Contributed papers

Poster session - Tuesday

Perturbative solution of optical Bloch equations for analysis of electromagnetically induced absorption

Jelena Dimitrijević, Dušan Arsenović and Branislav M. Jelenković

Institute of Physics,
University of Belgrade, Serbia
e-mail: jelena.dimitrijevic@phy.bg.ac.rs

We study phenomenon of electromagnetically induced absorption (EIA) in the Hanle configuration by solving time-dependent optical Bloch equations (OBEs) for the case of closed multilevel $Fg = 1 \rightarrow Fe = 2$ transition. Our model gives OBEs as a non-homogenous system of ordinary linear differential equations. For weak laser fields ($\Omega << \Gamma$ i.e. Rabi frequency small compared to spontaneous emission rate), a perturbative method to solve linear differential equations can be applied. Perturbative method is realized by solving (in the time-domain) higher-order correc-tions to the density matrix which in sum converge to the exact solution of OBEs. By its form, each successive correction is also system of ordinary linear differential equations which depends on the solution of previous ones.

Corrections are partitioned so that odd give corrections to optical coherences, while even give corrections to populations and Zeeman coherences. We present numerical results for the behavior of density matrix elements with successive corrections, and compare them with exact solution of OBEs. EIA is observed as a 4^{th} and higher (even) correction to populations, where behavior in respect of both time and magnetic field is viewed. Since in our method each correctiondepends on the solution of previous ones, we can analyze how (through mechanism of transfer of coherences and transfer of populations between Zeeman sublevels) EIA is formed. We also discuss qualitative differences in the behavior (with respect to time) of certain density matrix elements for magnetic fields "inside" and "outside" EIA.

Photon's Structure of Motion

N.V. Delić[1], B.S. Tošić[2], J.P. Šetrajčić[1,♣], B.Markoski[3], S.S. Pelemiš[4]

[1]*Department of Physics, Faculty of Sciences, University of Novi Sad, Vojvodina – Serbia*
[2]*Vojvodina Academy of Sciences and Arts, Novi Sad, Vojvodina – Serbia*
[3]*Technical Faculty in Zrenjanin, University of Novi Sad, Vojvodina – Serbia*
[4]*Faculty of Tecnology in Zvornik, University of East Sarajevo, Republic of Srpska, BiH*
[♣]*Academy of Sciences and Arts in Banja Luka, Republic of Srpska, BiH*
e-mail: alannica@gmail.com

A free photon Hamiltonian [1]

$$\hat{H} = \pm c\sqrt{\hat{p}_x^2 + \hat{p}_y^2 + \hat{p}_z^2}\,, \tag{1}$$

where $\hat{p}_j = -i\hbar\dfrac{\partial}{\partial x_j}$; $j = (x, y, z)$, are the operators of photon momentum components and c is velocities of light, is linearized using Pauli's matrices [2] – photon Hamiltonian becomes a linear operator but given in the form of $2x2$ matrix, i.e.:

$$\hat{H} = \pm c\begin{pmatrix} \hat{p}_z & \hat{p}_x - i\hat{p}_y \\ \hat{p}_x + i\hat{p}_y & \hat{p}_z \end{pmatrix}. \tag{2}$$

Linearized Hamiltonian represents a bilinear form of products of spin and momentum operators, and commutators components of total momentum with him are:

$$\left[\hat{J}_j, \hat{H}(\vec{r})\right] = \left[(\hat{L}_j + \hat{S}_j), \hat{H}(\vec{r})\right] = 0\,;\; j = (x, y, z) \tag{3}$$

which leads to following: total momentum $\hat{\vec{L}} + \hat{\vec{S}}$ is integral of motion for photon. Up to now we have the proof that total momentum $\hat{\vec{L}} + \hat{\vec{S}}$ is free photon integral of motion, for arbitrary spin.

Unitary transformation of this form results in an equivalent Hamiltonian:

$$\hat{H}_{\text{eq}} = E_0 + \hat{H} + \hat{H}_{\text{s}}, \tag{4}$$

where $\hat{H}$ is starting Hamiltonian, $E_0 = \hbar c(k_x \sin 2\rho + k_z \cos 2\rho)$ and $\hat{H}_{\text{s}} = -g\left(P + P^{+}\right) + 2aP^{+}P$, with $g = \hbar c\sqrt{k_y^2 + k_x^2\cos^2 2\rho + k_z^2 \sin^2 2\rho - k_x k_z \sin 4\rho}$ and $a = \hbar c(k_x \sin 2\rho + k_z \cos 2\rho)$, which has been analyzed by the method of Green's functions [3]. The evaluated Green's function has given possibility for interpretation of photon reflection as a transformation of photon to anti-photon [4] with energy change equal to double energy of photon and for spin change equal to Dirac's constant.

Since photon is relativistic quantum object the exact determining of its characteristics is impossible. It is the reason for series of experimental works in which photon orbital momentum [5–7], which is not integral of motion, was investigated. The exposed theory was compared to the mentioned experiments and in some elements the satisfactory agreement was found.

References:

[1] A.Messiah, Quantum Mechanics, *North-Holland*, Amsterdam 1970.
[2] P.A.M.Dirac, Principles of Quantum Mechanics, 4 Ed., *Univ.Press*, Oxford 1958.
[3] M.Sapaznjikov, Anti-World – a Reality, *Znanie*, Moscow 1983 (in Russian), pp.33, 34.
[4] G.Rickayzen, Green's Functions and Condensed Matter, *Academic Press*, London 1980.
[5] J.Leach, M.J.Padgett, S.M.Barnett, S.Franke-Arnold, J.Courtial, *Phys.Rev.Lett*. **25**, 257901 (2002).
[6] A.T.O'Neil, I.Mac Vicar, L.Allen, M.J.Padgett, *Phys.Rev.Lett.* **88**, 053601 (2002).
[7] K.Volke-Sepulveda, V.Garc´es-Ch´avez, S.Ch´avez-Cerda, J.Arlt, K.Dholakia, *J.Opt.*B **4**, S82 (2002).

Analysis of shot noise correlations and entanglement in a double quantum dot system coupled to a quantized bosonic field

M. Živković[1], I. Djurić[1] and C. P. Search[1]

[1]*Department of Physics and Engineering Physics,*
Stevens Institute of Technology, Hoboken, NJ 07030, USA
e-mail: mzivkovi@stevens.edu

Quantum entanglement is the essential resource for quantum information. In typical quantum systems the correlation always decay as a result of noisy environments, leading to the degradation of the entanglement between two particles. Some suggested ideas for preserving quantum information during the transfer and processing is the usage of photon entanglement for the transfer and entanglement among electron spins in storage/processing phase. This naturally raises the question of appropriate transfer of entanglement from photon-photon pairs to electron-electron pairs.

We examine a double quantum dot system coupled to a quantized mode of an optical microcavity. The quantum dots are connected to normal leads at zero bias voltage across them. A dot is modeled as a two level spin system with one of the spin states lying below the Fermi level of the leads and the other above. Spin ips followed by subsequent tunneling out/into the leads generate a pure spin current in the absence of any charge current. In our previous work presented in Phys. Rev. B, 74, 115327, we found, for a single dot coupled to the cavity, nonclassical correlations indicative of entanglement between the cavity field (photons) and electron spin in the photon and spin current shot noise. Here we investigate spin current and photon current shot noise cross-correlations for the two dots as an indicator of electron-photon and electron-electron entanglement. We relate these shot noise correlations to a quantitative measure of the entanglement in this system and analyze the possibility of a transfer of entanglement between photons to entanglement between the spins of the electrons in the two dots.

Nuclear quantum optics: DC, AC Stark effect in atoms and nuclei and dynamics with intense laser pulses

A.V. Glushkov[1,2]

[1]*Odessa University, P.O.Box 24a, Odessa-9, 65009, SE, Ukraine*
[2]*Russian Academy of Sciences, Troitsk, 142090, Russia*
e-mail: glushkov@paco.net

QED theory is developed for studying interaction of atoms and nuclei with an intense and superintense laser field. Method bases on a description of system in the field by the k- photon emission and absorption lines. The lines are described by their QED moments of different orders, which are calculated within Gell-Mann & Low adiabatic formalism [1,2]. The analogous S-matrix approach is developed for consistent description of the laser-nucleus interaction. We have studied the cases of single-, multi-mode, coherent, stochastic laser pulse shape. Results of the calculation for the multi-photon resonance and ionization profile in Cs, Yb, Gd atoms are presented. It is also studied the phenomenon of the above threshold ionization. Efficiency of method is demonstrated by QED perturbation theory calculations for the two-photon ionization cross-sections for extended photon energy range (including above-threshold ionization) in Mg. Comparison with the R-matrix calculation of Luc-Koenig et al is given. Strong field (DC, AC) Stark effect for nuclei, atoms, including Rydberg atoms, is studied within new quantum approach, based on the operator PT [1]. We present here the calculation results of the Stark resonances energies and widths for a number of atoms (H, Li, Tm, U etc.) and for a whole number of low-lying and also Rydberg states. We discovered and analyzed the weak field effect of drastic broadening of widths of the Letokhov-Ivanov re-orientation decay autoionization resonances in Gd, Tm, U atoms and the corresponding nuclei.

Atomic dynamics with the rectangular and non-rectangular laser pulses is studied and the results of numerical calculation of population kinetics of the resonant levels for atoms in the non-rectangular pulse field on the basis of the modified Bloch equations are presented. The equations describe an interaction between two-level atoms ensemble and resonant radiation with an account of the atomic dipole-dipole interaction [2]. A new idea of this work is discovery of strengthen possibility of manifestation for the internal optical bi-stability effect special features in the temporary dynamics of populations for the atomic resonant levels under adiabatic slow changing the field intensity. Modelling nuclear ensembles in a super strong laser field provides opening the field of nuclear quantum optics [3].

References

[1] A. Glushkov and L. Ivanov, Phys. Lett. A 170, 33 (1992); Preprint ISAN N AS3 (1992); J.Phys.B: Atom. Mol. Opt. Phys. 26, L379 (1993); A. Glushkov et al, Int. J. Quant. Chem. 99, 889 (2004); 99, 936 (2004); 105, 512 (2005); 105, 562 (2005).
[2] A. Glushkov et al, Frontiers in Quantum Systems in Chemistry and Physics (Berlin, Springer) 18, 541 (2008); Molec. Phys. 106, 1257 (2008); Europ.Phys.Journ. 160, 195 (2008); Physica Scripta, N135, 305001 (2009).
[3] A.V. Glushkov et al, In: Advances in the Theory of Atoms, Molecular Systems and Condensed Matter, Vol.19, Eds. P. Piecuch, J.Maruani, G. Delgado- Barrio, S. Wilson (Springer, Berlin, 2009), P.301-327.

On treating atomic parity non-conservation in heavy atoms and observing P and PT violation using NMR shift in a laser beam

O.Yu. Khetselius[1,2]

[1]*Odessa University, P.O.Box 24a, Odessa-9, 65009, SE, Ukraine*
[2]*Russian Academy of Sciences, Troitsk, 142090, Russia*
e-mail: nuclei08@mail.ru

During the past decade, first of all the optical experiments to detect atomic parity on-conservation (PNC) have progressed to the point where PNC amplitudes can be measured with accuracy on the level of a few percents in certain heavy atoms [1]. Promising idea (Forston) is to apply the techniques of laser cooling and ion trapping to measurement of the PNC in $6s^2S_{1/2}$-$5d^2D_{3/2}$ transition of the singly ionized barium. To provide an adequate treating these experiments in terms of the standard model for a electro-weak interaction, comparison of the measured amplitudes with theoretically defined ones is required. Nowdays the PNC in atomic systems has a potential to probe a new physics beyond the standard model. In our paper we systematically apply the formalism of the QED many-body perturbation theory [2] to precise studying PNC effect in heavy atoms with account for the relativistic, nuclear and radiation QED corrections. Earlier an efficiency of this approach has been demonstrated in the precise calculation of the hyperfine structure constants, E1, M1 transition probabilities for heavy atoms and heavy ions [3]. We present the preliminary calculation results for energy levels, hyperfine structure intervals, E1-, M1-transitions amplitudes in heavy atoms of ^{133}Cs, $^{137}Ba^{+}$, ^{207}Pb, ^{119}Sn.

As example, let us present below the calculation result for the parity non-conserving 6s-7p dipole amplitude in Cs. Our calculation gives the value: $D=<6s|Dz|7s>= -0.903\cdot10^{-11}$ i|e|a($-Q_w/N$). For comparison let us present other known results (c.f.[1]): $D=-0.91\cdot10^{-11}$ i|e|a($-Q_w/N$) by Dzuba etal (Novosibirsk); $D=-0.908\cdot10^{-11}$ i|e|a($-Q_w/N$) by Bouchiat etal (Paris); $D=-0.935\cdot10^{-11}$ i|e|a($-Q_w/N$) by Johnson etal (Indiana), $D=-0.902\cdot10^{-11}$ i|e|a($-Q_w/N$) and $D=-0.905\cdot10^{-11}$ i|e|a($-Q_w/N$) by Johnson-Sapirstein-Blundell (Notre Dame).

Comparison of calculated D value with the measurement by Noeker et al gives the following data of weak nuclear charge Q_w and the Weinberg angle ϑ_W. We also discuss a new improved possibility for observing P and PT violation using a nuclear magnetic resonance (NMR) frequency shift in a laser beam [4]. The cited shift is provided by a correlation of the a nuclear spin with the momentum of the photon (***Ik***).

References

[1] W. Johnson, J. Sapirstein, S. Blundell, Phys. Scripta T46, 184 (1993); N. Forston, Phys. Rev. Lett. 70 ,2382 (1993); V. Dzuba, V.Flambaum, M. Safronova, Phys. Rev. A 73, 022112 (2006); B.Sahoo, B. Das, et al, Phys. Rev.A 75, 032507 (2007)
[2] A. Glushkov, O. Khetselius, etal, Nucl. Phys.A734, 21 (2004); Frontiers in Quant. Systems in Chem. and Phys. (Berlin, Springer) 18, 521 (2008); Recent Adv. in Theory of Phys. and Chem. Systems (Berlin, Springer), 15, 285 (2006).
[3] O. Khetselius, Phys. Scripta, N135, 305090 (2009); Int. J. Quant.Chem. 109, N13, (2009).
[4] O. Sushkov, Phys. Scripta T46, 193 (1993).

Transient Dynamics of Atoms in rectangular cylindric guides

Smail Bougouffa and Saud Al-Awfi

Department of Physics, Faculty of Science,
Taibah University, P.O.Box 30002, Madina, Saudi Arabia
e-mail: sbougouffa@hotmail.com

The study of radiation forces on atoms is at the present time one of the most important developing fields of physics, and it is the basis for some of the most important applications of lasers.In order to investigate concretely the limits of the recent expanding research field, called laser cooling and trapping, several theoretical treatments have been proposed. The review of some of these approaches and the comparison of their advantages, diffculties and domains of validity, can be found in the literatures [1].

In general the physical mechanisms of the atomic motion in light are governed by the optical Bloch equations and they are solved in the steady-state [2], to illustrate the mean radiative forces for a two- and three-level atom. In this case the range of the validity of these solutions is assumed to be in the same order of the characteristic time required by the internal state of the atom to reach its steady state. It therefore seems appropriate to seek for an enlargement of the range of investigations in order to include more general types of problems, which are frequently met in practice [3-6]. However, the dynamical aspects of the Bloch equations will be considered here. We consider in this work a two level atom in a particular cavity, namely a cylindric waveguide with rectangular cross-section [2].

The motivation for such a structure reside essentially in the fact that the quantization of the modes and the spontaneous emission rate in this structure have been calculated [2]. On the other hand, the rectangular cross section is a natural extension for the parallel plates case [2].

The principal interest in such investigation arises from the theoretical diffculty in resolving the system of coupled differential equations, which is related to the Bloch equations. This diffculty can be overcome using a new separation approach of coupled differential equations [7,8]. Using this new technique, the Bloch equations can be solved exactly for two-level atoms. The emphasis is given to the case of the atomic motion in this structure. The essential features of the forces have been reported and discussed for the Eu^{3+} ion.

References

[1] C. Cohen-Tannoudji, Atomic motion in laser light. In: Fundamental Systems in Quantum Optics, Dalibard, J., Raimond, J. M., and Zinn-Justin, J. (Eds.), North-Holland, Amesterdam, 1992.
[2] S. Al-Awfi and M. Babiker, Phys Rev. A 58, 1998, 2274.
[3] J. P. Dowling and J. Gea-Banacloche, Adv. Atom. Mol. and Opt. Phys. 37, 1996, 1.
[4] V. Sandoghdar, C. I. Sukenick, S. Haroche and E. A. Hinds, Phys. Rev. A 53, 1996, 1919.
[5] S. Haroche, In Fundamental Systems in Quantum Optics, Les Houches Summar School Session 53, eds. Dalibar J, Raymond J M, and Zinn-Justin J, Elsevier Science,1992.
[6] E. A. Hinds, Adv. Atom. Mol. and Opt. Phys. Supp. 2, 1993, 1.
[7] Smail Bougouffa, Saud Al-Awfi, J. Mod. Opt., 55, No. 3, 2008, 473.
[8] Smail Bougouffa, Saud Al-Awfi, Eur. Phys. J. Special Topics 160, 2008, 43-50.

Stark-chirped rapid adiabatic passage in a multilevel atom

M. Radonjić, D. Arsenović and B. M. Jelenković

Institute of Physics,
Belgrade, Serbia
e-mail: milanr@phy.bg.ac.rs

We generalize Stark-chirped rapid adiabatic passage [1] to the case of a multilevel atom. The atom is assumed to have two ground state levels g and f and an excited level e. The adiabatic passage is carried out by resonantly driving the $g - e$ and $f - e$ transitions with time-dependent pump and Stokes fields in the presence of strong far-off-resonant Stark field. Our formalism determines the states that participate in population transfer and is applicable to systems with arbitrary numbers of degenerate states in each level and arbitrary couplings of the $g - e$ and $f - e$ transitions. We give an illustration of the formalism by application to adiabatic passage in real atom.

References

[1] A. A. Rangelov, N. V. Vitanov, L. P. Yatsenko, B. W. Shore, T. Halfmann, and K. Bergmann, Phys. Rev. A 72, 053403 (2005).

Coherent beam splitting by thin gratings and crystal plates

M. Božić[1], D. Dimić[2] and M. Davidović[3]

[1]*Institute of Physics, University of Belgrade, Belgrade, Serbia*
[3]*Faculty of Mathematics and Natural Sciences, Niš, Serbia*
[3]*Faculty of Civil Engineering, University of Belgrade, Serbia*
e-mail:bozic@phy.bg.ac.yu

The wide use of beam splitters in quantum interferometry [1], attosecond metrology [2], modern quantum information processing has been based on coherence of beams emerging from a beam splitter. Here we further develop the approach [3, 4, 5] in which a beam splitter is regarded as a generator of a wave field (photon field or matter wave field), which has narrow maxima at the points along and in close vicinity of two (or more) particular lines, and negligible values at all other points. Such a field is generated from an initial narrow beam.

This description was derived by considering a thin grating as a model of a beam splitter for photons [4] and atoms [5]. Here we present in the analogous form the results of a dynamic theory of diffraction [6, 1], on which and a neutron beam splitter is based. A time dependent wave function of a single particle, behind a beam splitter, describes the wholeness of a wave and its evolution [4, 5]. The possible paths of a particle are the lines along which its wave function has maxima [4, 5]. This explains the intriguing finding of quantum interferometry, that a single quanton moving along one of the paths has the information about the existence of other paths [1, 7]: this information is due to the wholeness of particle's wave function along and in between these paths.

References

[1] H. Rauch and S.A. Werner, *Neutron Interferometry: Lessons in Experimental Quantum Mechanics* (Clarendon Press, Oxford, 2000) p. 350-365.
[2] E. Goulielmakis et al., Appl. Phys. B **74** (2002) 74.
[3] W. P. Schleich, *Quantum Optics in Phase Space* (Wiley-VCH, Berlin, 2001), Chapter 9.
[4] M Davidović, A. S. Sanz, D- Arsenović, M. Božić and S. M. Artes, Phys. Scr. **T134** (2009) to appear
[5] D Arsenović, M Božić, A S Sanz and M Davidović, Phys. Scr. **T134** (2009) to appear
[6] H. Rauch and D. Petrascheck, in *Neutron diffraction* (ed. H. Dachs), Top. Curr. Phys. **6** (1978) 303, Springer-Verlag. Heidelberg.
[7] M. Božić and Z. Marić, Phys. Lett. A **158** (1991) 33.

Geometric phase of an open quantum system

N. Burić[1], and M. Radonjić[1]

[1]*Institute of Physics,*
Belgrade, Serbia
e-mail: milanr@phy.bg.ac.rs

Quantum state diffusion (QSD) unraveling of the Linblad master equation is utilized to define a geometric phase of an open quantum system. It is then shown that such geometric phase is invariant on unitary symmetry transformations of the Linblad equation and moreover could be defined such that it is invariant on decomposition of the initial density matrix into convex combination of pure state projectors. These are important properties not shared by the geometric phases based on other types of unraveling. The QSD geometric phase is computed for a qubit in different types of environments.

Interplays between Josephson-junctions and the driven damped pendulum

E. Papp[1], C. Micu[2] and I. Bica[1]

[1] *Depatment of Theoretical Physics,*
West University of Timisoara, Timisoara, Romania
[2]*Department of Physics,*
North University of Baia Mare, Romania
e-mail: erhardt_papp_2005@yahoo.com

The phase difference across a Josephson junction as well as the phase characterizing a driven pendulum evolves according to the same second-order nonlinear equation. This equation is analyzed in some detail by resorting to the asymptotic theory of nonlinear oscillations. Relationships with the Harper equation are also presented.

References

[1] D. H. Dunlap, V. Kovanis, R. V. Duncan and J. Simmons, Phys. Rev. B 48, 7975(1993).
[2] R. L. Kautz, J. Appl. Phys. 62, 198 (1987).
[3] D. E. McCumber, J. Appl. Phys. 39, 113 (1968).
[4] E. Papp and C. Micu, *Low-dimensional nanoscale systems on discrete spaces* (World Scientific, Singapore, 2007).

Analysis of high efficiency Electromagnetically Induced Transparency in Potassium vapor

S. Gozzini[1], D. Slavov[2], S. Cartaleva[2], L. Marmugi[1], A. Lucchesini[1]

[1]*IPCF-CNR, Area della Ricerca, via Moruzzi 1, 56124 Pisa, Italy*
[2]*Institute of Electronics, BAS, boul. Tzarigradsko shosse 72, 1784 Sofia, Bulgaria*
e-mail: slavov_d_g@yahoo.com

Electromagnetically Induced Transparency (EIT) resonances have been studied mainly in Rb and Cs vapors, due to the availability of conventional diode lasers matching their resonance lines. Recently strong enhancement of EIT resonance contrast and amplitude have been demonstrated experimentally, for EIT prepared in Hanle configuration and K atoms contained in anti-relaxation coated and buffered cells [1]. Such relevant improvement is a consequence of the reduced optical pumping in K due to the significant overlapping of the hyperfine-level Doppler profiles, which does not occur in the case of Rb and Cs vapor. Provided by the velocity changing collisions of K with buffer gas atoms or coated-cell walls, efficient repumping is realized of the ground level directly excited by the light.

We reported in Ref. [2] that EIT resonances in K created with kHz intensity modulated laser light showed high contrast and good width parameters. A similar modulation approach has been used for coherent resonance study in Rb, registered as non-linear magneto-optical rotation of the light polarization [3].

In this communication we present a theoretical modeling of the optical pumping on the Potassium D_1 line, its influence on the EIT resonance parameters and a comparison with the experimental results.

The EIT preparation by monochromatic or intensity-modulated light is concerned. Two types of cells are compared: (i) one containing pure K, where the collisions with the cell walls result in the atomic spin randomization and the subsequent destruction of the ground-state coherence introduced by the light and (ii) one buffered by noble gas, which preserves atomic spin orientation and, at the same time, provides complete Maxwellisation of atomic velocity distribution due to the velocity changing collisions. In both configurations, population rate equations are solved, describing the interaction of Doppler broadened three-level system with monochromatic light. The most important feature of the system is that the profiles of the optical transitions starting from the two ground states strongly overlap.

In the evacuated cell it is not possible to profit significantly of the Doppler profiles overlapping: both transition excitations by the mono-mode laser light can be considered independent and the atomic collisions with the cell walls destroy the coherence. In the case of the buffered cell, the situation is different: the collisions of the alkali atoms with the buffer gas atoms are spin preserving and result in strong enhancement of the ground-level coherence lifetime. Due to the longer coherence lifetime and velocity-changing collisions of K atoms with buffer gas, a Maxwellian reshaping of the population distribution takes place, providing with the possibility of optical pumping compensation.

The advantages of using K as a medium for EIT preparation are analyzed and new possibilities for future applications are studied, thanks to the very narrow and high-amplitude resonance observed in the K buffered cell.

The work was partially supported by the Italian National Research Council (bilateral cooperation program CNR/BAS and STM) and partially supported by the Bulgarian NCSR (grant No: DO 02-108/22.05.2009) and Indian-Bulgarian bilateral contract № BIn-2/075**.**

References

[1] S. Gozzini, S. Cartaleva, A. Lucchesini, C. Marinelli, L. Marmugi, D. Slavov, T. Karaulanov, Eur. Phys. J. D 53, 153 (2009).
[2] S. Gozzini, S. Cartaleva, D. Slavov, L. Marmugi, A. Lucchesini, Proc. SPIE, vol. 7027, 70270K, (2008).
[3] S. Pustelny, A. Wojciechowski, M. Gring, M. Kotyrba, J. Zachorowski, W. Gawlik, Journ. Appl. Phys., 103, 063108 (2008).

Coherent Population Trapping on the second resonance line of potassium

S. Gozzini[1], S. Cartaleva[2], T. Karaulanov[2], A. Lucchesini[1], D. Slavov[2]

[1]*IPCF-CNR, Area della Ricerca, via Moruzzi 1, 56124 Pisa, Italy*
[2]*Institute of Electronics, BAS, boul. Tzarigradsko shosse 72, 1784 Sofia, Bulgaria*
e-mail: stefka-c@ie.bas.bg

Coherent Population Trapping (CPT) phenomenon has mainly been studied on the D_1 and D_2 lines of alkali atoms due to the widely available single-mode near-infrared laser diodes. The promising to many applications CPT spectroscopy can now be extended to the violet/blue spectral region due to the progresses in the development of semiconductor lasers emitting at these spectral regions. Potassium is a very promising candidate for efficient preparation of CPT resonances due to the fact that the optical transitions between its hyperfine (hf) levels on the D_1 and D_2 lines exhibit significant overlapping that helps in overcoming of hf optical pumping [1].

In this communication we present our results of CPT resonance study on the second resonance line of Potassium: $4s^2S_{1/2} \rightarrow 5p^2P_{3/2}$ transition with wavelength of 404.5nm. Moreover, due to cascade transitions, a transfer of this CPT resonance to the $4p^2P_{1/2}$ state occurs. The transfer is evidenced by the observation of a narrow CPT resonance in the fluorescence from the $4p^2P_{1/2,}$ level (770.1nm) when the alkali excitation is performed at 404.5nm. It should be pointed out that the resonance observed on the infrared line has more favorable parameters compared to that on the 404.5nm transition. The superiority is provided by the fact that when observing the CPT resonance on the 770.1nm line, the exciting laser light at 404.5nm can be completely filtered thus avoiding the noise in the laser light. It is well known that when the CPT resonance has much less amplitude than the exciting laser light, the laser noise is one of the main drawbacks for applications of coherent resonances for precise measurements.

Potassium atoms are excited by single-frequency laser light at 404.5nm and the CPT resonances are registered in Hanle configuration, monitoring atomic fluorescence dependence on an orthogonal to the laser beam magnetic field B varied around B=0. Potassium vapor is irradiated by circularly-polarized 404.5nm light. The 404.5nm or 770.1nm fluorescence is measured versus magnetic field. Appropriate filters are used to distinguish and perform measurements with the violet or infrared line separately. The CPT resonance contrast and width are measured in dependence on the cell temperature.

Measuring the 404.5nm fluorescence, a dark CPT resonance is observed in the entire examined cell temperature interval (100^oC-180^oC). Significant narrowing of the CPT resonance is demonstrated as the cell temperature increases, which is attributed to the enhancement of the density of Potassium atoms. As the atomic density rises, collisions between atoms increase, which leads to some destruction of the CPT resonance. It has been shown [2] that the resonance destruction is more effective at its wings, while at its center the resonance is more resistant. Thus, the resonance destruction can result in its narrowing.

In case of 770.1nm fluorescence measurement, the CPT resonance is of similar width and contrast. However, the resonance is dark only till cell temperature about 150^oC and after that it reverses its sign. The reasons of the resonance sign reversal are not yet clarified.

The resonance transfer by cascade transitions is of importance for the study of processes in atomic vapour as well as for practical applications, due to the possibility to avoid the laser intensity noise.

The work was done under collaboration program between the Italian National Research Council and the Bulgarian Academy of Sciences and partially supported by the Bulgarian NCSR (grant No: DO 02-108/22.05.2009) and Indian-Bulgarian bilateral contract № BIn-2/075**.**

References

[1] S. Gozzini, S. Cartaleva, A. Lucchesini, C. Marinelli, L. Marmugi, D. Slavov, T. Karaulanov, Eur. Phys. J. D 53, 153 (2009).
[2] F. Renzoni, E. Arimondo, Europhys. Lett. 46, 716 (1999); F. Renzoni, A. Lindner, E. Arimondo, Phys. Rev. A60, 450 (1999); F. Renzoni, E. Arimondo, Phys. Rev. A58, 4717 (1998).

Population loss in closed optical transitions of alkali atoms confined in micrometric thin cells

V. Biancalana[1], S. Cartaleva[2], Y. Dancheva[1], P. Gosh[3], E. Mariotti[1], L. Moi[1], N. Petrov[2], B. Ray[3], D. Sarkisyan[4], D. Slavov[2]

[1]*CNISM- Unità di Siena, Dipartimento di Fisica Università di Siena, via Roma 56, 53100 Siena, Italy*
[2]*Institute of Electronics, BAS, boul. Tzarigradsko shosse 72, 1784 Sofia, Bulgaria*
[3]*Department of Physics, UC, 92 APC Road, Calcutta 700009, India*
[4]*Institute for Physical Research, NAS of Armenia, Ashtarak-2, 378410, Armenia*

e-mail: stefka-c@ie.bas.bg

Single light beam transmission through a 10 ÷ 1000 μm thin cell reveals weak sub-Doppler features centered at the resonance frequency of the hyperfine transitions of alkali atoms [1]. In an Extremely Thin Cell (ETC, thickness < 1 μm) these resonances can easily be observed [2].

We report here an experimental observation of high-amplitude narrow dips in the fluorescence profiles of hyperfine optical transitions, on the D_2 line of Rb. Experiment was performed using cell with thickness L = 700 μm, which is irradiated by linearly polarized laser light tuned around the D_2 line of Rb. The light beam propagates in direction orthogonal to cell windows. The cell is filled with Cs but, due to the existing small portion of Rb, it was possible to study Rb spectrum in the presence of much larger Cs vapor pressure (serving as "buffer gas" with precisely varied pressure with temperature). Changing the alkali source temperature in an interval of (120-300)^{o}C, different behavior is demonstrated for sub-Doppler resonances centered at $F_g \rightarrow F_e \leq F_g$ and $F_g \rightarrow F_e > F_g$ optical transitions. Here, F_g is the hyperfine structure quantum number of the ground state and F_e is that of the excited state.

Two sets of hyperfine optical transitions were studied: (i) the first one involves transitions starting from $F_g = 2$ level of ^{87}Rb and (ii) the second one - $F_g = 3$ level of ^{85}Rb. Each set forms a single fluorescence line, due to the strong overlapping of the hyperfine optical transitions. At relatively low (120^{o}C) alkali source temperature, very well pronounced and resolved dips in the fluorescence were observed centered at the $F_g \rightarrow F_e \leq F_g$ transitions only: namely $F_g = 2 \rightarrow F_e = 1,2$ transitions for ^{87}Rb and $F_g = 3 \rightarrow F_e = 2,3$ transitions in case of ^{85}Rb. When increasing the temperature, two more dips in the fluorescence appear centered at the $F_g \rightarrow F_e > F_g$ transitions - $F_g = 2 \rightarrow F_e = 3$ (^{87}Rb) and $F_g = 3 \rightarrow F_e = 4$ (^{85}Rb). For the ETC, tiny narrow dips in the fluorescence profiles have been reported [3] and attributed to the atomic population loss in a narrow frequency interval, which occur for very slow atoms. There, such dips in the fluorescence were observed only for the open $F_g \rightarrow F_e \leq F_g$ transitions suffering velocity selective population loss due to hyperfine and Zeeman optical pumping.

In case of $F_g \rightarrow F_e > F_g$ transitions, the dips in the fluorescence profiles, observed in the presented experiment for the first time, increase their amplitude with temperature. The appearance and amplitude enhancement of these dips with temperature are attributed to the depolarization of the F_e state by collisions between Rb and Cs atoms. Note that without the depolarizing collisions the $F_g \rightarrow F_e > F_g$ transition can be considered as completely closed: the light drives it in the most absorbing state. However, the F_e level depolarization leads to atomic population accumulation to the ground level with the lowest probability of excitation [4]. Thus, some effective "population loss" (for very slow atoms) occurs when the excited level is depolarized by atomic collisions.

Presented results contribute to the further development of high resolution spectroscopy in thin vapor layers, which is promising not only for fundamental studies, but also for technological applications, for example like the one of building precise frequency references and photonic sensors.

This work was supported by the Bulgarian NCSR (grant No: DO-02-108/22.05.2009) and Indian-Bulgarian bilateral collaboration (№ БИн-2/075).

References

[1] S. Briaudeau, D. Bloch, M. Ducloy, Phys. Rev. A 59, 3723 (1999).
[2] D. Sarkisyan, D. Bloch, A. Papoyan, M. Ducloy, Opt. Commun. 200, 201 (2001).
[3] C. Andreeva, S. Cartaleva, L. Petrov, S. M. Saltiel, D. Sarkisyan, T. Varzhapetyan, M. Ducloy, Phys. Rev. A 76, 013837 (2007).
[4] Andreeva C., Cartaleva S., Dancheva Y., Biancalana V., Burchianti A., Marinelli C., Mariotti E., Moi L., Nasirov K., Phys. Rev. A 66, 012502, (2002).

All-optical polarization switch – Competition of to quantum-coherence phenomena

S. Pustelny[1], R. Drampyan[2], W. Gawlik[1]

[1]*Center for Magneto-Optical Research, Institute of Physics, Jagiellonian University, Krakow, Poland*
[2]*Institute for Physical Research, National Academy of Sciences of Armenia, Ashtarak, Armenia*
e-mail: pustelny@uj.edu.pl

Three or more-level atomic systems allow observation of several interesting and widely studied quantum-interference phenomena, e.g. coherent population trapping, electromagnetically induced transparency, electromagnetically induced absorption, "slow and fast light", etc. A specific example of such phenomena is nonlinear Faraday effect (NFE) which is light-intensity dependent rotation of a polarization plane of linearly polarized light upon its propagation through a medium placed in a longitudinal magnetic field [1]. The rotation is caused by light-generated quantum superpositions of atomic states. Particularly large rotations (up to 10 rad) can be observed when the coherences are established between magnetic sublevels of the long-lived ground state in the so-called Λ scheme. Another quantum interference phenomenon is electromagnetically induced transparency (EIT) [2]. The effect consists in reduction of absorption of a weak, resonant probe light propagating through a medium in which a probe and a strong coupling beam jointly establish two-photon coherence in a three-level system. A specific atomic scheme in which EIT may be studied is ladder structure.

In this contribution we report on experimental and theoretical study of NFE under conditions of EIT at the $5S_{1/2}\rightarrow5P_{3/2}\rightarrow5D_{5/2}$ two-photon transition in rubidium vapor [3]. These transitions realize the so-called inverted Y model which combines Λ and ladder systems. Strong nonlinearity allowing for large rotation angles of a probe beam tuned to the S→P transition was obtained by creation of quantum superpositions of magnetic sublevels (Zeeman coherences) in the rubidium ground state (Λ scheme). Additionally, EIT was accomplished in a ladder scheme by acting with an extra strong coupling laser on the P→D transition. Under conditions of a two-photon resonance the rotation was strongly suppressed, which is interpreted as a competition between the two processes. The effect was observed in sub-Gauss magnetic fields and could be used for efficient coherent control of generation of the ground-state coherences, e.g. for controlling the polarization state of the probe light. Ability of controlling light polarization state may have interesting applications in telecommunication as all-optical switch.

References

[1] D. Budker, W. Gawlik, K. F. Kimball, S. M. Rochester, V. V. Yashchuk, and A. Weis, Rev. Mod. Phys. 74, 1153 (2002).
[2] M. Fleischhauer, A. Imamoglu, J. P. Marangos, Rev. Mod. Phys. 77, 633 (2005).
[3] R. Drampyan, S. Pustelny, W. Gawlik – accepted for publication in Phys. Rev. A.

Invisibility in low dimensional systems: a theoretical framework

V. Čelebonović

Institute of Physics,
Belgrade, Serbia
e-mail: vladan@phy.bg.ac.rs

At the PHOTONICA07 meeting this author has presented a derivation of a theoretical expression linking the reectivity R and electrical conductivity, and applied it to the Q1D Bechgaard salts [1]. As a byproduct of this calculation, the frequency for which the reflectivity becomes approximately equal to 0 was also determined. The point $R \cong 0$ physically corresponds to the object becoming invisible. Since the PHOTONICA07 meeting, the number of experimental attempts aimed at achieving invisibility of objects has been steadily growing. Among the latest examples of such work are [2] and [3]. Work reported in [2] has, for example, achieved invisibility in the wavelength range 1400 to 1800 nm. Both these papers reffer to three dimensional systems and analyze the possibilities of cloaking them and thus rendering them invisible.

In the present contribution the reectivity of 1D and to some extent 2D systems will be considered, from the point of view of material science. Starting from the expression for reflectivity derived in [1], it will be shown how does R of Q1D systems depend on various material parameters and the temperature. Any application of the expression for R demands the knowledge of the electrical conductivity, and this has been calculated for the Bechgaard salts in [4] within the Hubbard model. The material parameters on which R depends are the hopping integral t, the doping n, the Hubbard repulsion U. External parameters which can influence R are the temperature T and the external pressure. Theoretical expressions showing the dependence of R on these parameters will be presented.

The conductivity and relectivity of the 2D case are interesting because of their applicability in high Tc studies. The conductivity of 1D systems has been calculated within the memory function method, recently reviewed in [5]. Applying this method to the 2D case would be even more complex. However, in the particular case of a square lattice, a way has been found to reduce the 2D problem to the 1D problem. Some details, which ultimately lead to the conductivity and reflectivity, will be presented.

References

[1] V. Čelebonović, Acta Phys.Polonica A 112, 949 (2007).
[2] http://arxiv.org/pdf/0904.3602v1
[3] http://arxiv.org/pdf/0904.3508v1
[4] V. Čelebonović in: Trends in Materials Science Research, Editor B. M. Caruta, Nova Science Publishers Inc., New York, pp. 245-260 (2006).
[5] U. Balucani, M. H. Lee and V. Tognetti, Phys. Rep., 373, 409 (2003).

Parametric amplifcation of light waves at low-frequency pumping in aperiodical nonlinear photonic crystals

I.V. Shutov and A.S.Chirkin

Physics Faculty, M.V.Lomonosov Moscow State University, Moscow, Russia
e-mail: iv.shutov@physics.msu.ru

The process of nondegenerate optical parametric amplification at low-frequency pump field, which includes traditional parametric amplification process at high-frequency pumping

$$\omega_p \rightarrow \omega_1 + \omega_2$$

and two processes of up-frequency conversion

$$\omega_p + \omega_1 \rightarrow \omega_3, \quad \omega_p + \omega_2 \rightarrow \omega_4$$

is investigated in detail. In order to realize consecutively several three-frequency nonlinear optical processes in a nonlinear optical crystal one have to provide phase matching conditions for several nonlinear optical processes. It is impossible to realize in a homogenous nonlinear crystal. Such wave interactions can be implemented in aperiodical nonlinear photonic crystals (ANPC) where the sign $g(z)$ of the quadratic nonlinearity changes aperiodically in space. APNC can be designed by rather simple method of modulation superposition [1].

The basic idea of designing such crystals is the following. The formula for N simultaneous quasi-phase matched processes can be presented in the form

$$g(z) = sign\left(\sum_{j=1}^{N} a_j \sin\left(\frac{2\pi z}{\Lambda_j} + \varphi_j\right)\right),$$

where a_j , φ_j are amplitudes and phases of the harmonic modulations, $\Lambda_j = 2\pi/|\Delta k_j|$ is the period of the nonlinear lattice necessary for the realization of the j-process with the phase mismatch Δk_j.

This method allows to control the effective nonlinear coupling coefficients of the involved wave interactions by choosing the a_j. Due to this circumstance the parametric amplification at low-frequency pumping can be implemented [2].

The theoretical approach was developed for analytical calculation of nonlinear coupling coefficients. It allows to greatly simplify them calculations. Results of the direct numerical investigations were compared with the suggested approach results and we have obtained good agreement.

We have calculated frequency tuning of the process, the spatial dynamics and the band width of parametric amplification for the real APNC LiNbO3. The influence of the structure creation inaccuracy on the process efficiency was also analyzed.

The process under examine can be interested for creation of multifrequency coherent light sources and for generation of multimode entangled quantum states.

References

[1] A. A. Novikov, A.S. Chirkin, JETP, 106, 415 (2008).
[2] A. S. Chirkin, I.V. Shutov, JETP Lett. 86, 693 (2007).

Asymmetric Second Harmonic Generation from Gold Nanostructures of Ancient Greek Design

V. K. Valev[1,*], A. V. Silhanek[2], W. Gillijns[2], O. A. Aktsipetrov[3], V. V. Moshchalkov[2]
T. Verbiest[1]

1) Molecular Electronics and Photonics, INPAC, Katholieke Universiteit Leuven, Celestijnenlaan 200 D, B-3001 Leuven, Belgium.
2) Nanoscale Superconductivity and Magnetism & Pulsed Fields Group, INPAC, Katholieke Universiteit Leuven, Celestijnenlaan 200 D, B-3001 Leuven, Belgium.
3)Department of Physics, Moscow State University, 11992 Moscow, Russia
E-mail: v.k.valev@fys.kuleuven.be

Recently, the research on metamaterials has revealed several new electromagnetic phenomena, such as artificial magnetism and negative refraction, [1] extraordinary transmission, [2] cloaking [3] and asymmetric transmission [4]. Here we report on another new electromagnetic phenomenon – the asymmetric second harmonic generation (ASHG) from planar chiral structures, i.e. structures that exhibits chirality (the handedness of nature) in two dimensions, whereupon turning the object around yields the opposite handedness. ASHG is due to the homodyne interference of anisotropic and chiral electric and/or magnetic multipoles, which were observed within the surface plasmon resonance of chiral gold nanostructures arranged in an Ancient Greek ornamental pattern.

Since the discovery of optical activity in 1811 by Arago, in optics, the handedness of chiral materials has always been revealed through separate polarization states of the light. The case of ASHG is fundamentally different in the sense that the handedness becomes apparent through a variation in the sample rotation angle. Furthermore, up to now, every optical effect in chiral systems resulted from an interference between electric dipole and magnetic dipole (or quadrupole) contributions. In the present case, the effect originates in an interference between higher order multipoles only.

References

[1] R. D. Smith, J. B. Pendry and M. C. K. Wiltshire, Science **305**, 788 (2004).
[2] W. L. Barnes, A. Dereux and T. W. Ebbesen, Nature (London) **424**, 824 (2003).
[3] D. Schurig, J. J. Mock, B. J. Justice, S. A. Cummer, J. B. Pendry, A. F. Starr and D. R. Smith, Science **314**, 977 (2006).
[4] V. A. Fedotov, P. L. Mladyonov, S. L. Prosvirnin, A. V. Rogacheva, Y. Chen, and N. I. Zheludev, "Asymmetric Propagation of Electromagnetic Waves through a Planar Chiral Structure", Phys. Rev. Lett. **97**, 167401 (2006).

Super intense laser field action on surface with forming atto-second laser plasma and new laser technology for cleaning the materials

A.V. Glushkov[1,2], A.P.Fedchuk[1], A.V. Loboda[1], A.A. Svinarenko[1]

[1]*Odessa University, P.O.Box 24a, Odessa-9, 65009, SE, Ukraine*
[2]*Russian Academy of Sciences, Troitsk, 142090, Russia*
e-mail: glushkov@paco.net

An action of the super short light pulses changes principally a character of interaction of a laser radiation with substance [1]. For laser intensities more than 10^{15} Wt/cm^2 electrons get energy of 100-1000eV and it is realized a process of forming the femto-second laser plasma.(FLP). We study possibilities of governing by processes, which are taken a place in the FLP in nano-structured porous materials (NSPM; Si). NSPM consist of the separated clusters set with the fractal structure. The key mechanism of the hot electrons generation in plasma is provided by oscillation of electron on the border "plasma-vacuum" or resonant absorption of laser radiation. One may wait for the sharp increasing the hot electrons generation and X-ray radiation. For large laser intensity it is observed a new type of the hydrodynamic ablation. Experimental estimates show that a velocity of the plasma flying of the strongly porous samples Si (I~3x10^{16}W/cm^2) is ~10^{8}cm·s^{-1}, that is ~ to energy 2±1 MeV [2]. We carried out the modeling of FLP forming in the porous materials on the basis of the energy balance equations, the Greens function method and S-matrix formalism [2, 3]. Special attention is devoted to the modeling the system: NSPM with clusters, on surface of which there is a great number of bonds with H and OH groups. In a case of D-and OD group's one can wait for realization of cluster explosion process and reaction D+D→α+n (3,8MeV).

Laser photo-ionization and photo-dissociation of molecules method is supposed to be very much perspective method for cleaning the semiconductor materials from molecular admixtures. Laser cleaning of mono-silan represents a great interest for technology of obtaining a poor Si in the semiconductor industry. We propose new optimal schemes of laser photo ionization nano-technologies for control and cleaning the semiconducting substances. Here at first we construct the optimal scheme of the laser photoionization technology for preparing the films of pure composition on example of creation of the 3-D hetero structural super lattices (layers of Ga(1-x)Al(x)As with width 10Å and GaAs of 60Å). The scheme of preparing the films of the especially pure composition is based on using the multi-stepped laser photoionization scheme. It includes at first step an excitation of atoms by laser field and their transition into Rydberg states and then ionization by electric field [2]. A creation of the films of pure composition (our problem is creation of the 3-D layers of Ga(1-x)Al(x)As with width 10Å and GaAs of 60Å) is directly connected with using the photo ion pencils of Ga, Al, As. Similar pencils can be created by means of the selective photoionization method with ionization by electric field [3].

References

[1] Superstrong Fields in Plasmas. Eds. M.Lontano etal, AIP. V.426, (1998).
[2] A.V. Glushkov, A. Loboda, et al, J.Phys.CS. 178, 188 (2005); IJQC 105, 562 (2005).
[3] V.S. Letokhov, Non-linear selective photoprocesses in atoms and molecules, Moscow (1983).

Mechanoluminescence Due to Fracture Produced during Slow Deformation of solids

R. K. Kuraria[1] S. R. Kuraria[1] Neha Chourasia[1] and B. P. Chandra[2]

1. Govt. Model Science College , Jabalpur - 482001 (M.P.) India
2. Shankaracharya Engineering College, Durg – 4920020 (C.G.) INDIA
e-mail: rkkuraria@rediffmail.com

The present paper reports the mechanoluminescence (ML) induced by the movement of cracks produced during slow deformation of solids. The ML may be induced by fracture of crystals due to several processes involved in charging of newly- created surfaces. In fracto ML, the number of ML pulses emitted indicate the number of cracks moved in a crystal. Thus, there is one-to-one correspondence between the number of cracks formed and the number of ML flashes emitted during the deformation of a crystal. An expression derived for the dependence of the number of ML flashes, Np on the strain ε of crystals may be expressed as, $Np = [\{\exp \alpha(\varepsilon - \varepsilon_f)\}-1]$, where ε_f is the fracture strain and α is a constant. The total ML intensity indicates the total area of the newly created surfaces created during the deformation of a crystal. As the decay time of ML is constant and of the order of microseconds, in the case of slow deformation, the peak of ML intensity induced by a single crack indicates the area of newly created surfaces. The studies on fracto ML give important information that the number of cracks increases exponentially with the deformation of crystal and the area of newly created surfaces increases linearly with the deformation of crystal. The ML may be useful in the study of crack dynamics in microsecond ranges, where by important information related to the initiation, propagation and interaction of cracks in solids may be obtained. The rapid photographic method and CCD cameras can be used effectively to map the ML emission from fracture of solids. A good agreement is found between the theoretical and experimental results.

Bleaching and darkening effect in photochromic glasses under irradiation with femtosecond laser pulses

Kazem Jamshidi-Ghaleh

Department of Physics, Azarbaijan University of Tarbiat Moallem, Tabriz, Iran
email: k-jamshidi@azaruniv.edu

Optical properties modification of transparent materials by using of ultra-short powerful laser pulses (femtosecond and in some cases even picosecond laser pulses) has attracted much attention theoretically and experimentally [1-3]. In this paper, the interaction of 200 fs laser pulses at 800 nm wavelengths with photochromic oxide glass sample is studied. Two types of laser-induced modifications, bleaching and darkening, are observed. The induced darkening is observed inside the bleached volume. The effect of incident laser shot number and pulse energy on the bleached and darkened area are investigated. The pulse energy accumulation model [4] is applied for both of bleached and darkened area sizes. The bleaching and darkening modification fluence threshold are determined for single and multi-shot laser pulses.

Keywords: Ultra-Short laser Pulses, Darkening effect, Bleaching effect, Photochromic glass

References

[1] D. Ashkenasi, K. Jamshidi-Ghaleh and H.J. Hoffmann, Photonicswest, San Jose, SPIE, V. 5339, July (2004)
[2] K. Jamshidi-Ghaleh, D. Abdolahpour and N. Mansour, Laser Phys. Lett. 3, No. 12, 573-577 (2006)
[3] J.T. Dickinson, S. Orlando, S.M. Avavesyan, and S.C. Langford, Appl. Phys. A 79, 859–864 (2004).
[4] J. Jandeleit, G. Urbasch, H. Hoffmann, H.G. Treusch, and E. Kreutz, Appl. Phys. A 63, 117–121 (1996).

Numerical solution of nonlinear Helmholtz equations for counterpropagating wide beams in saturable photorefractive crystals

A. Piper[1], N.B. Aleksic[2], M.R. Belic[1] and D.V. Timotijevic[2]

[1]*Texas A&M University at Qatar*
Doha, Qatar
[2]*Institute of Physics,*
Belgrade, Serbia
e-mail: dvtimotijevic@phy.bg.ac.yu

We have investigated influence of paraxial approximation [1] in describing near collinear counterpropagating linearly polarized beams in isotropic, saturable, photorefractive Kerr-like media [2], by numerically solving system of coupled Helmholtz equations for the scalar electric fields and temporal equation for the space-charge field. Limits of applicability of paraxial approximation are discussed by taking into account wide and bent beams, and backscattered waves. Stationary solutions and spatio-temporal dynamics are observed.

References
[1] M. Lax, W.H. Louisell, W.B. McKnight, Phys. Rev. A 11, 1365 (1975).
[2] M. Belic, Ph. Jander, K. Motzek, A. Desyatnikov, D. Jovic, A. Strinic, M. Petrovic, C. Denz, and F. Kaiser, J. Opt. B 6, S190 (2004)

Numerical method for solving scalar nonlinear Schrödinger equation with periodically varying coefficients

A. Piper[1], N.B. Aleksic[2], M.R. Belic[1] and D.V. Timotijevic[2]

[1]*Texas A&M University at Qatar*
Doha, Qatar
[2]*Institute of Physics,*
Belgrade, Serbia
e-mail: dvtimotijevic@phy.bg.ac.yu

Propagation of linearly polarized beams in nonhomogeneous, photorefractive Kerr-like media in paraxial approximation, such as optical meta-materials, is modeled [1] with scalar nonlinear Schrödinger equation (NLS) with periodically varying coefficients. While inhomogeneity along the axis of propagation is easily dealt with split-step fast Fourier method (SSFFT), transverse variations involve dealing with convolutions. In this paper, we present modified SSFFT method for solving NLS with varying coefficients and discuss relative merit of using explicit convolutions as opposed to treating inhomogeneity as media correction.

References:
[1] M. Lax, W.H. Louisell, W.B. McKnight, Phys. Rev. A 11, 1365 (1975).

Gap solitons in binary waveguide arrays with saturable nonlinearity

P. P. Beličev[1], M. Stepić[1] and A. Maluckov[2]

[1] *Vinča Institute of Nuclear Sciences,Belgrade, Serbia*
[2] *Faculty of Sciences and Mathematics, Niš, Serbia*
e-mail: petrab@vinca.rs

Binary arrays composed of alternating thick and thin optical waveguides are characterized by the periodic modulation of the refractive index, which breaks the translational invariance and gives an effective discreteness in a continuous system. This opens up many possibilities for manipulating light propagation, including light localization in the form of discrete optical solitons [1, 2].

In this paper, we consider one-dimensional model that presumes binary waveguide array with saturable nonlinearity [3]. We derive the corresponding dispersion relation and band structure. In addition, we investigate the dependence of the binary waveguide band structure on the system parameters. The main aim of our work is to study the characteristics and dynamics of the localized structures created in the opened spectral gaps, so called gap solitons. They can be considered as fundamental modes that are strongly confined in narrow waveguides. The properties of the obtained discrete optical gap solitons resemble nonlinear localized gap modes in diatomic lattices [4].

References

[1] A. A. Sukhorukov and Yu. S. Kivshar, Opt. Lett. 27, 2112 (2002).
[2] R. Morandotti et al., Opt. Lett. 29, 2890 (2004).
[3] Y. Tan et al., Appl. Phys. B 95, 531 (2009).
[4] Yu. S. Kivshar and N. Flytzanis, Phys. Rev. A 46, 7972 (1992).

Strongly localized bright-dark structures in nonlinear fiber arrays with alternating dispersion

A. Daničić[1], A. Maluckov[2] and M. Stepić[1]

[1]*Vinča Institute of Nuclear Sciences, Belgrade, Serbia*
[2]*Faculty of Sciences and Mathematics, University of Niš, Niš, Serbia*
e-mail: mstepic@vinca.rs

Uniform fiber array represents a system of parallel, weakly coupled optical fibers. Low-intensity light beams (wave packets) inevitably spread during propagation in such arrays due to combined effects of dispersion and discrete diffraction. This spreading can be balanced by nonlinear response of optical media at higher beam intensities. Newly formed solitary structures, also known as optical bullets, are stable in both spatial and time domain [1]. Optical bullets represent a natural candidate for information carrier in all-optical networks [2, 3].

In this contribution we reveal a novel possibility to form stable one-dimensional spatio-temporal solitons. We study a fiber array with cubic self-focusing nonlinearity, normal discrete diffraction, and dispersion management in transverse direction. We investigate in detail both existence and linear stability of various stationary solutions. In some cases explicit analytical expressions are given. Soliton stability is confirmed by the energy principle method [4].

References:
[1] Y. Silberberg, Opt. Lett. 15, 1282 (1990).
[2] A. B. Aceves, G. G. Luther, C. De Angelis, A. M. Rubenchik, and S. K. Turitsyn, Phys. Rev. Lett. 75, 73 (1995).
[3] H. C. Gurgov and O. Cohen, Opt. Exp. 17, 7052 (2009).
[4] M. Stepić, Lj. Hadžievski and M. M. Škorić, Phys. Rev. E 65, 026604 (2002).

Calculating ionization transition rate for circularly polarized fields, including non-zero initial momenta, in the case of ADK-theory

V. M. Ristić, T. B. Miladinović and M. M. Radulović

Department of Physics, Faculty of Science,
Kragujevac University,
Kragujevac, Serbia
e-mail: ristic@kg.ac.yu

In describing ionization of complex atoms by low frequency laser fields the Keldysh theory, improved by many corrections has been now accepted widely. One of the most renowed theories that upgraded Keldysh's approach was ADK-theory. Yet in the most cases described in literature, using ADK-theory, the laser beam was considered linearly polarized, though there are papers which are working with circularly polarized laser fields. So we decided to check the behaviour of the transition rate when non-zero initial momentum of electrons ejected by a circularly polarized field is included into calculations.

Potassium atoms in circularly polarized laser field whose intensity (I) varies from $2\cdot10^{12}\,\mathrm{W/cm^2}$ to $2.5\cdot10^{14}\,\mathrm{W/cm^2}$ were studied. In the case when there is zero initial momentum, transition rate (that depends only on I) exhibits standard behaviour: as I increases, so thus the rate, until it reaches its maximum value at $1.1\cdot10^{14}\,\mathrm{W/cm^2}$; after that, rate diminishes as I increases.

In the case of non-zero initial momentum, transition rate (that now depends on I but also on initial momentum) exhibits following behaviour: dependence of rate on I follows standard pattern, it rises with increasing of I until it reaches its maximum, and than diminishes. But, with increasing of momentum, ionization rate gradually diminishes.

Maximum of ionization rate in both cases is found at approximately the same value: $1.1\cdot10^{14}\,\mathrm{W/cm^2}$. Also, those maximums differ slightly – when the momentum is zero, rate has greater value of maximum then in the case when momentum is different from zero.

References

[1] V. M. Ammosov, N. B. Delone,V.P. Krainov, Sov. Phys. JETP 64, 1191 (1986).
[2] L. V. Keldysh, Sov. Phys. JETP 20, 1307 (1965).
[3] V. M. Ristić, T. S. Premović, Kragujevac J. Sci. 25, 41 (2003).
[4] V. P. Krainov, V.M. Ristić, Sov. Phys. JETP 101, 1479 (1992).
[5] D. Bauer, Phys. Rev. A 55 (3), 55 (1997).
[6] D. Bauer, Theory of Laser–Matter Interaction, Max–Planck Institute, Heidelberg (2002).
[7] N. B. Delone, V.P. Krainov, Physics-Uspekhi 41 (5), 469 (1998).
[8] E. Gubbini, Multiple Ionization of Heavy Atoms in Super Strong Laser Fields, PhD dissertation (2004).
[9] V. M. Ristić, T.B. Miladinović, M.M. Radulović, Laser Phys. 18, 10, 1, (2008).
[10] L. D. Landau, E. M. Lifshitz, Quantum Mechanics: Non-Relativistic Theory, 3rd ed. Butterworth-Heinemann, London, (1991).

Counterpropagating matter waves in optical lattices

S. Prvanovic[1], D. Jović[1,2], R. Jovanovic[1,2], A. Strinic[1,2] and M. Belić[2]

[1] *Institute of Physics, P.O. Box 57, 11001 Belgrade, Serbia*
[2]*Texas A&M University at Qatar, P.O. Box 23874 Doha, Qatar*
e-mail: strinic@phy.bg.ac.yu

The investigation of Bose-Einstein condensate (BEC) in two dimensional potential, formed by laser beams, have attracted much attention in the past years. Here, we are interested in dynamics of BEC in cubic optical lattice since the periodic potential can lead to the stabilization of an otherwise unstable BEC. As is well known, it is not difficult to realize experimentally BEC which is the object of theoretical studies, i.e., dynamics of BEC can be easily experimentally controlled, so our results can be tested experimentally. Behavior of BEC in optical lattice is well described by the nonlinear or Gross-Pitaevskii equation which we solve numerically. By applying the Petviashvili iteration method, we investigated the existence of solitonic solutions in the case of counter-propagating matter waves, and analyzed their stability.

Beam propagation in nematics liquid crystals

A. Strinic[1,2], M. Petrović[1,2] and M. Belić[2]

[1] *Institute of Physics, P.O. Box 57, 11001 Belgrade, Serbia*
[2]*Texas A&M University at Qatar, P.O. Box 23874 Doha, Qatar*
e-mail: strinic@phy.bg.ac.yu

We studied a model for the laser light propagation in a cell containing a liquid crystal in the nematic phase. We investigated the behavior of beams in time and in three spatial dimensions, using an appropriately developed theoretical model and a numerical procedure based on the fast Fourier transform. We demonstrated the formation of stable solitons in a narrow threshold region of beam intensities for fixed parameters and display soliton breathing.

Spin precession of quasi-bound states in heterostructures with spin-orbit interaction

G. Isić[1;2], D. Indjin[1], Z. Ikonić[1], V. Milanović[3], J. Radovanović[3] and P. Harrison[1]

[1]*School of Electronic and Electrical Engineering, University of Leeds, United Kingdom*
[2]*Institute of Physics, Belgrade, Serbia*
[3]*School of Electrical Engineering, University of Belgrade, Serbia*
e-mail: isicg@phy.bg.ac.rs

The spin-orbit interaction in noncentrosymmetric semiconductors provides means for non-magnetic control of spin phenomena. The carrier spin responds to its electrostatic environment as moving electrons see an effective magnetic field B_{eff} in their reference frame. If a nonzero average momentum of the carrier ensemble is accomplished, B_{eff} may be manifested through spin precession of coherently excited carriers allowing its direct measurement [1].

We study the spin precession of an electron injected into the well region of a double-barrier AlGaAs system. States within the GaAs well are quasi-bound due to the coupling to the reservoirs behind AlGaAs barriers. In a finite-difference model, the finite lifetime due to tunneling out is described by a self-energy matrix Σ_{bc} which enforces the correct boundary conditions at boundaries between the system of interest and the reservoirs [2].

A self-energy Σ_{scatt} due to interface roughness and alloy disorder scattering is derived within the random phase approximation [3]. The dominant part is due to in-plane momentum relaxation while a smaller part describes spin-flip scattering. The former only decreases the state lifetime while the latter can also affect the spin precession frequency.

References

[1] L. Meier, G. Salis, I. Shorubalko, E. Gini, S. Schön and K. Ensslin, Nat. Phys. 3, 650 (2007).
[2] S. Datta, *Quantum transport: atom to transistor*, Cambridge University Press (2005).
[3] S. Datta, *Electronic transport in mesoscopic systems*, Cambridge University Press (1995).

About the origin of enhancements in high-order above-threshold ionization of atoms and negative ions

S. Vučić[1] and R. M. Potvliege[2]

[1] *Institute of Physics, Pregrevica 118, 11080 Belgrade, Serbia*
[2] *Physics Department, Durham University,Durham DH1 3LE, UK*
e-mail: vucic@phy.bg.ac.rs

We discuss the origin of enhancements of high-order above-threshold ionization (ATI) and above-threshold detachment (ATD) from atoms or negative ions exposed to a strong laser field. To this end, we calculate the ATI spectrum for several model potentials within the Sturmian-Floquet approach [1]. For all the models, the calculations are performed using essentially the same method in which the interaction of the outgoing electron with the residual ion is short-range. The initial bound system is represented by a single electron moving in a superposition of a Coulomb potential (of zero strength for model negative ions) and two short-range Yukawa potentials representing the interaction with the core [1]. When a strong laser field is added, the active electron moves in an effective oscillating time-dependent potential barrier created by the field and the atomic potentials. For optical frequencies, the barrier oscillates rapidly compared to the characteristic response time of the electrons in excited states preventing fast photoionization from these states. The part of the electronic population which is over the potential barrier but is located at smaller distances from the nucleus than the amplitude of quiver oscillations rescatters elastically or inelastically with it when the field approaches its maxima, thereby producing bursts of fast electrons.

In order to study the influence of atomic potentials to the photoelectron spectrum, we vary the parameters which determine both the strength and the asymptotic fall-off of the potentials. This is done in such a way that the binding energy of the initial ground state remains constant. At the same time the spectrum of highly excited states is altered. We compare the qualitative behavior of ATI spectra of Argon with the available theoretical ATD spectra for H^- and F^- ions [2]. Our results for ATI spectra show that when the long-range Coulomb potential is switched-off, several successive high-order peaks in ATI spectrum become significantly enhanced for intensities which approach ionization thresholds from below. Very similar enhancements are also found in ATD spectra of negative ions [2], where only the short range potentials are involved in the description of the photodetachement. This leads us to conclude that the threshold effects play the crucial roles when the strong-laser-field-assisted processes are governed by short-range potentials. On the other hand, when the long-range Coulomb potential controls photoionization as in the case of neutrals, the resonant coupling of the ground with higher excited states is of greater importance for the high-order ATI spectra behavior. This can be inferred from the fact that the intensities at which the strong enhancements occur follow the positions of resonances with higher states as parameters of the potentials vary.

Our results indicate that the threshold enhancements found in the detachment of negative ions are suppressed in the ionization of neutrals by the long-range Coulomb potential between the photoelectron and the core. They also confirm that the enhancements dominating the high-order ATI spectrum of rare gases are due to multiphoton resonances. Although the same recollisional mechanism is at the basis of the emission of the fast electrons in both cases, it thus appears that the enhancements of ATI and the enhancements of ATD have different origins

References

[1] R. M. Potvliege and S. Vučic, Phys. Rev. A **74** 023412 (2006).
[2] K. Krajewska, I. I. Fabrikant and A. F. Starace, Phys. Rev. A **78** 023407 (2008).

Atoms and molecules in a strong laser field

M. Busuladžić[1], A. Gazibegović-Busuladžić[2], E. Hasović[2], D. B. Miloševic[2,3] and W. Becker[3]

[1]*Medical Faculty, University of Sarajevo, Čekaluša 90, 71000 Sarajevo, Bosnia and Herzegovina*
[2]*Faculty of Science, University of Sarajevo, Zmaja od Bosne 35, 71000 Sarajevo, Bosnia and Herzegovina*
3*Max-Born-Institut, Max-Born-Str. 2a, 12489 Berlin, Germany*
E-mail: mustafabusuladzic@bih.net.ba

Atomic and molecular processes in intense laser fields have received much attention in the last few years [1, 2]. When an atom or molecule is exposed to an intense laser field, a series of nonperturbative phenomena may occur. In particular, two of those phenomena, high-order above-threshold ionization (HATI) and high-order harmonic generation (HHG), are of great interest for a deeper understanding of the laser-matter interaction. In this paper we are interested in the HATI process.

During interaction irradiated systems absorb more photons then is necessary for ionization: this is the so-called above-threshold ionization (ATI). If the ionized electron directly goes to the detector without any significant interaction with the binding potential, we call this process direct ATI. The ionized electron may also be driven back to its parent ion and rescatter elastically off the former, before reaching the detector. In this process the electron can absorb many more photons from the laser field than in the direct ATI. The above-mentioned process was named high-order above-threshold ionization, HATI.

We have developed a theory of ionization of diatomic molecules by a strong laser field within the modified molecular strong field approximation [3]. A diatomic molecule was considered as a three-particle system, which consists of two heavy atomic (ionic) centers and an electron. After separation of the center-of-mass, the dynamics of this system is reduced to the relative electronic and nuclear coordinates. In order to describe high-energy electrons contributing to the plateau region of the spectrum we have generalized the above-mentioned theory so that it includes rescattering [4]. As molecules are multicenter systems, ionization as well as rescattering can happen at different centers, causing interference structures in the electron spectrum. As a consequence the most noticeable feature of the molecular spectra is the existence of interference minima that are absent in the atomic case [5]. This novel two-source two-rescattering-centers interference survives focal averaging. Remarkably, it has been observed in experiments with *randomly oriented* O_2 molecules, but not for N_2 [6, 7].

References

[1] W. Becker F. Grasbon, R. Kopold, D. B. Milošević, G. G. Paulus, and H. Walther, Adv. At.,Mol., Opt. Phys. 48, 35 (2002).
[2] M. Lein, J. Phys. B 40, R135 (2007).
[3] D. B. Milošević, Phys. Rev. A 74, 063404 (2006).
[4] M. Busuladžić, A. Gazibegović-Busuladžić, D. B. Milošević, and W. Becker, Phys. Rev. Lett. 100, 203003 (2008); Phys. Rev. A 78, 033412 (2008).
[5] E. Hasović, M. Busuladžić, A. Gazibegović-Busuladžić, D. B. Milošević, and W. Becker, Laser Phys. 17, 376 (2007).
[6] M. Okunishi, R. Itaya, K. Shimada, G. Prümper, K. Ueda, M. Busuladžić, A. Gazibegović-Busuladžić, D. B. Milošević, and W. Becker, J. Phys. B 41, 201004 (F) (2008).
[7] M. Okunishi, R. Itaya, K. Shimada, G. Prümper, K. Ueda, M. Busuladžić, A. Gazibegović-Busuladžić, D. B. Milošević, and W. Becker, Phys. Rev. Lett. 103, accepted, (2009).

Analytic methods for approximating the quantum dynamics of cavity-assisted photoassociation of atom-molecule Bose-Einstein condensates

J. Mauricio Campuzano[1], Marko Zivkovic[1] and Christopher P. Search[1]

[1]*Stevens Institute of Technology*
Hoboken, NJ, USA
E-mail: christopher.search@gmail.com

We explore the quantum dynamics of photoassociation of Bose-Einstein condensed atoms into molecules using an optical cavity field. Inside of an optical resonator, photoassociation of quantum degenerate atoms involves the interaction of three coupled quantum fields for the atoms, molecules, and the photons. The feedback created by a high-Q optical cavity causes the cavity field to become a dynamical quantity whose behavior is linked in a nonlinear manner to the atoms inside and where vacuum fluctuations have a more important role than in free space. We develop and compare several methods for calculating the dynamics of the atom-molecule conversion process with a coherently driven cavity field. We first introduce an alternate operator representation for the Hamiltonian from which we derive an improved form of mean field theory and an approximate solution of the Heisenberg-Langevin (HL) equations that properly accounts for quantum noise in the cavity field. It is shown that our improved mean field theory corrects several deficiencies in traditional mean field theory based on expectation values of annihilation/creation operators. Also, we show by direct comparison to numerical solutions of the density matrix equations that our approximate quantum solution of HL equations gives an accurate description of weakly or undriven cavities where mean field theories break down.

The affect of Sagnac rotational phase shifts on matter wave transmission in a chain of periodic and aperiodic mesoscopic quantum rings

J. Toland, D. Dayon and C. Search

Department of Physics and Engineering Physics,
Stevens Institute of Technology, Hoboken, NJ 07030
e-mail:jtoland@stevens.edu

The ability to interferometrically detect inertial rotations via the Sagnac effect has been a strong stimulus for the development of atom interferometry because of the potential 10^{10} enhancement of the rotational phase shift in comparison to optical Sagnac gyroscopes. Here we analyze ballistic transport of atomic matter waves in a one dimensional chain of N coherently coupled quantum rings in the presence of a rotation of angular frequency, Ω. We show that the transmission probability, T, exhibits zero transmission stop gaps as a function of the rotation rate interspersed with regions of rapidly oscillating finite transmission. With increasing N, the transition from zero transmission to the oscillatory regime becomes an increasingly sharp function of Ω with a slope $\partial T / \partial \Omega N^2$. The steepness of this slope dramatically enhances the response to rotations in comparison to conventional single ring interferometers such as the Mach-Zehnder and leads to a phase sensitivity well below the shot noise limit. We additionally consider the roles that inhomogeneous broadening of the atomic velocities and imperfections in the sizes and shapes of rings have on the phase sensitivity. In particular, we numerically study the transmission properties through such chains for increasing amounts of disorder in the size and shapes of the constituent rings.

Two-dimensional discrete fundamental bright solitons in dipolar Bose-Einstein condensates

G. Gligorić[1], A. Maluckov[2], M. Stepić[1], B. A. Malomed[3] and Lj. Hadžievski[1]

[1] *Institute of Nuclear Sciences Vinča, Belgrade, Serbia*
[2] *Faculty of Sciences and Mathematics, University of Niš, Serbia*
[3] *School of Electrical Engineering, University of Tel Aviv, Israel*
e-mail: goran79@vinca.rs

The disk-morphed dipolar Bose-Einstein condensates (BEC) subject to strong confinement along the axial direction inside an optical lattice is studied in the framework of two twodimensional (2D) discrete models described by discrete Gross-Pitaevskii equation (DGPE) [1] and discrete nonpolynomial Schrödinger equation (DNPSE). Both models are derived by dimensional reduction and discretization procedures from three-dimensional (3D) Gross-Pitaevskii equation (GPE) and include description of the local contact interaction and the nonlocal dipoledipole (DD) interactions. Both attractive and repulsive contact interactions are considered for dipoles oriented parallel to the disk plane (anisotropic DD interaction) and for dipoles oriented perpendicular to the plane (isotropic DD interaction).

The aim of our investigation is to study the existence and dynamical stability of fundamental unstaggered bright localized BEC modes in 2D lattice with respect to the interplay between the local and nonlocal interactions. The special effort is done to consider the quasi-collapse of 2D solitons under the influence of nonlocality.

Our investigations show the similar behavior of the fundamental unstaggered bright localized modes in both DGPE and DNPSE models with respect to the local-nonlocal interactions effect in dipolar BECs. The existence region of fundamental modes in BEC with the attractive contact interaction is enabled by the nonlocal repulsive interactions among bosons. This regions corresponds with the region close to the boundary of the semi-infinite gap in the corresponding continuous 2D system [2] The most significant effect of the nonlocal interactions is generation of the solitons on the finite background when the background excitations start to play an active role in formation of localized structures. In the BEC with repulsive contact interaction new existence region is opened in the presence of the enough strong attractive isotropic DD interaction. This reminds on the 1D BEC counterpart [3, 4].

The stability properties of the solitons are investigated adopting the slope (Vakhitov-Kolokolov) and spectral criterion [3, 4]. It is shown that 2D fundamental solitons are unstable in the whole existence region independently on the character of the bosons' interaction. Direct numerical simulations confirm these results, showing that solitons evolve into on-site breathers accompanied with oscillations of the background. Namely, all types of unstaggered solitons evolve into breathers, while the rest of their energy is transfered into background oscillations. Moreover, the collapse instability of the attractive BECs is indicated by appearance of the 'frozen' highly pinned 2D soliton which is declared as the quasi-collapse in 2D BEC. Nonlocal interactions introduces only some quantitative changes in the threshold for such phenomenon.

References

[1] P. G. Kevrekidis, K. O. Rasmussen, and A. R. Bishop, Phys. Rev. E 61, 2006 (2000).
[2] Z. Shi, J. Wang, Z. Chen, J. Yang, Phys. Rev. A 78, 063812 (2008).
[3] G. Gligorić, A. Maluckov, Lj. Hadžievski, B. A. Malomed, Phys. Rev. A 78, 063615 (2008).
[4] G. Gligorić, A. Maluckov, Lj. Hadžievski, B. A. Malomed, Phys. Rev. A 79, 053609 (2009).

Modulation instability of two-dimensional dipolar BEC in a deep optical lattice

A. Wöllert[1], G. Gligorić[2], M. Škorić[3], A. Maluckov[4] and Lj. Hadžievski[2]

[1]*Faculty of Physics, University of Göttingen, Germany*
[2]*Institute of Nuclear Sciences Vinča, Belgrade, Serbia*
[3]*National Institute for Fusion Science, Toki, Japan*
[4]*Faculty of Sciences and Mathematics, University of Ni_s, Serbia*
e-mail:goran79@vinca.rs

The Bose-Einstein condensates (BEC) with different atomic species and various trapping geometries are nowadays in the focus of the researches of many experimental groups all over the world. As an interesting theoretical problem appears the modeling of the disk-shaped condensates of dipolar atoms in a very deep optical lattice. At zero temperature the disk-shaped BEC system is described by the two-dimensional Gross-Pitaevskii equation (2D GPE) [1]. Description of the dipolar condensates includes the dipole-dipole interaction term (DD) in the GPE model. In the case of a very deep optical trap the resulting 2D GPE with DD term can be transferred to the corresponding discrete-difference form. In such system the localized structures can be created via modulational instability which is a generic phenomenon in various physical settings [2].

We consider BEC with the attractive and repulsive contact interaction and isotropic and anisotropic dipole-dipole interaction. In this paper we study the stability of the plane wave solutions (CW) with purpose to connect the parameter region with the modulationaly unstable CWs to the region where discrete localized structures could be expected. The special attempt was to observe is this region affected by the presence of the DD interaction of both isotropic and anisotropic type.

References

[1] P. G. Kevrekidis, K. O. Rasmussen, and A. R. Bishop, Phys. Rev. E 61, 2006 (2000).
[2] Y. S. Kivshar, G. P. Agrawal, Optical Solitons, Academic Press, USA, (2003).

Ultraslow light phenomenon in a BEC: temperature effects and the dependence on the magnetic field intensity

A. Sotnikov and Yu. Slyusarenko

Akhiezer Institute for Theoretical Physics, NSC KIPT, Kharkiv, Ukraine
e-mail: *a_sotnikov@kipt.kharkov.ua*

We propose a microscopic approach for a description of processes of interaction of the ideal gas of alkali-metal atoms with a weak electromagnetic radiation. The description is constructed in the framework of the Green-function formalism that is based on a new formulation of the second quantization method in case of the presence of bound states of particles (atoms). For a gas with the Bose-Einstein condensate (BEC) the dependencies of the propagation velocity and damping rate on the microscopic characteristics of the system are studied [1].

The approach is generalized on the case on nonzero temperatures. The Green functions corresponding to the response of the condensate and non-condensate atoms are found. We analyze the inuence of the temperature effects on the slowing and absorption parameters of a BEC. It is shown that in the present experimental conditions the group velocity of pulses practically do not depend on the temperature in the region from the absolute zero to the critical temperature. We find the cases when the temperature effects in a BEC can play a significant role.

On the basis of the proposed approach the influence of the external homogeneous and static magnetic field on the slowing of electromagnetic waves in the condensate is studied. The description is based on the analysis of the Zeeman splitting of the ground and excited state levels with account of the hyperfine interaction in alkali-metal atoms. It is shown that the velocity of the pulses can be effectively controlled by the bias field [2].

References

[1] Y. Slyusarenko and A. Sotnikov, Phys. Rev. A 78, 053622 (2008).
[2] Y. Slyusarenko and A. Sotnikov, Phys. Lett. A 373, 1392 (2009).

Two-Dimensional magneto-optical trap as source of cold Rb atomic beam

D.V. Lukić[1], B. Panić[1], M.Radonjić[1], S. Ćuk[1] and B. Jelenković[1]
[1]*Institute of Physics, Belgrade, Serbia*
e-mail: lukic@phy.bg.ac.rs

Cold atomic beams are of incrising significance in a variety of applications. The applications include precision spectroscopy, atomic optics [1], atomic frequency standards, atom lasers [2], the production of Bose-Einstain condesation, etc. Our design of a source of slow Rb atoms is based on two-dimensional magneto-optical traping complemented with a pair of laser beams in axial directon for optical molasses cooling ($2D^+$ MOT)[3,4]. The experimetal setup consists of a two-chamber vacuum system within which the chambers are conected through a diferential pumping hole. In first chamber $2D^+$ MOT is produced. In the other chamber atomic beam will be manipulated with stimulated Raman adiabatic passage[5] and Stark-chirped rapid adiabatic passage [6].

[1] C.S. Adams, M. Seigel, and J. Mlynek, Phys. Rep. **240**, 143 (1994)
[2] T. Lahaye, et al., Phys. Rev. Lett. **93**, 0930030 (2004)
[3] K. Dieckmann et al., Phys. Rev. A **58**, 3891 (1998)
[4] R. S. Conroy et al., Opt. Commun. **226**, 259 (2003)
[5] A. D. Boozer, Phys. Rev. A **77**, 023411 (2008)
[6] A. A. Rangelov et al., Phys. Rev. A **72**, 053403 (2005)

A strongly end-pumped Yb-doped double-clad fiber lasers: the improvement of the analytical solutions of rate equations and the analytical investigation of thermal effects during operation

P. Elahi[1] and N. Zare[2]

[1]*Department of Physics, College of Science, Shiraz University of Technology, Shiraz, Iran.*
[2]*Department of Physics, Payame Noor University, Shiraz, Iran.*
E-mail: elahi@sutech.ac.ir

High-power fiber lasers have many applications due to their advantages. They have high beam quality and high efficiency, with respect to conventional solid-state lasers. In high-power regime, thermal effects influence the laser operation and can not be neglected [1]. The thermal effects often decrease the beam quality and knowledge of them will be important in laser design.

In this paper, at the first, we obtained an approximate analytic solution of the rate equations in single end-pumped Yb-doped fiber laser. To solve the equations, we consider both the upper-level population density of fiber, and the absorption cross section, often neglected in the literature [2]. In this way, we improved the analytical rate equation solutions and found the dependence of the output laser power on the input parameters. By using the output power of the laser, we solved the heat conduction equation inside the laser during operation. In this way we consider heat deposited in the fiber due to pump and laser power and solved the heat equation. The temperature distribution during the operation has been obtained and compared with temperature distribution in off operation.

References

[1] H Nadgaran and P Elahi, Pramana-J. Phys. **vol 66**, Issue 3, p 513 (2006).
[2] L. Xiao, P. Yan, M. Gong, W. Wei, and P. Ou, Opt. Commun. **230**, p 401 (2004).

The analytical investigation of thermal effects on the propagation parameters of fiber lasers

Parviz Elahi[1] and Ali Niakowsari[2]

[1]*Department of Physics, College of science, Shiraz University of Technology, Shiraz, Iran.*
[2]*Department of Physics, Payame Noor University, Shiraz, Iran.*
e-mail: elahi@sutech.ac.ir

Fiber lasers are under considerable attention due to their high efficiency and good beam qualitiy. In high-power regime, the heat generation due to pump beam [1] can influence the laser operation as well as the beam propagation characteristics. The heat deposition in end pumped fiber lasers changes the step-index fiber to grade-index, thus varying the propagation parameters, like V-numbers, propagation constant and dispersion. In this paper, after solving the heat conductive equation in the fiber lasers, the variation of such parameters have been studied for various pump profiles like Gaussian, super Gaussian and top-hat

Reference

[1] Yong Wang, Chang-Qing Xu, Hong Po, IEEE Photonic. Tech. L., **Volume 16**, Issue 1, p.63, (2004).

Blackbody-radiation-induced decay and excitation of Rydberg states in sodium

V. D. Ovsiannikov and I. L. Glukhov

Department of Physics, Voronezh State University, Voronezh, Russia
e-mail: GlukhovOfficial@mail.ru

Induced by BBR (blackbody radiation) bound-bound transitions from s-, p-, d-series of Na constitute an essential depopulation mechanism for Rydberg states. We used the modified Fues model potential [1] for calculating both decay and excitation rates for n=5-120.

It was demonstrated that the rates of BBR induced decays and excitations of a state with an effective principal quantum number $\nu = 1/\sqrt{-2E}$ may be presented as a polynomial in powers of a dimensionless parameter $x = 100/(\nu T^{1/3})$, multiplied by the number of thermal photons at ambient temperature *T*. This conclusion and previous results for spontaneous decays [2] allowed to make an approximation equation for ratios between stimulated by BBR decays (excitations) rates $P_{nl}^{d(e)}$ and spontaneous decay rates P_{nl}^{sp} for a Rydberg $|nl\rangle$-state:

$$R_{nl}^{d(e)} = \frac{P_{nl}^{d(e)}}{P_{nl}^{sp}} = \frac{a_0^{d(e)} + a_1^{d(e)} x + a_2^{d(e)} x^2}{\nu^2 \left\{\exp(0.31579\Delta_\mu x^3 - 1)\right\}},$$

where Δ_μ=1 for p- and d-states, and $\Delta_\mu = \mu_s - \mu_p$ for the excitation of s-states, $\Delta_\mu = \mu_s - \mu_p + 1$ for the decay of s-states (μ_l - the quantum defect for *l*-series); $a_i^{d(e)}$ are fitted coefficients, which slightly depend on temperature.

It turned out that for s-states $a_i^{d(e)}$ -coefficients are temperature-independent constants:

$$a_0^d = 8.5833, \quad a_1^d = -2.8473, \quad a_2^d = 0.29657;$$
$$a_0^e = 7.1104, \quad a_1^e = -1.4804, \quad a_2^e = 0.42966.$$

These coefficients provide a good agreement with direct calculation results. For example, in decay case at *T* = 50K the deviation between exact and approximation data doesn't exceed 1% for n> 20 and at *T* = 1000K for n=20 deviation is 1.7% and becomes less than 1% for n> 25.

For p- and d-states we propose the next temperature parametrization for a_i-coefficients:

$$a_i^{d(e)} = \sum_{k=0}^{2} b_{ik}^{d(e)} \left(\frac{T}{100}\right)^{-k}, \qquad i = 0, 1, 2.$$

At large T (> 1000K) $a_i \to b_{i0}$. As an example, b_{ik}-cofficients are presented for d-series:

$$b^d = \begin{pmatrix} 11.546 & 0.30930 & -0.10148 \\ -11.085 & 1.9480 & -0.57132 \\ 4.3113 & -1.8507 & 0.55707 \end{pmatrix} \qquad b^d = \begin{pmatrix} 5.2323 & -002667 & 0.45067 \\ 0.15739 & -0.17128 & -1.2770 \\ 0.23335 & -3.5013 & 3.0608 \end{pmatrix}$$

These bik-matrices provide accuracy to within 3% for n > 11 at T=300K and for n > 8 at T=1000K in case of excitations.

References

[1] A. A. Kamenski and V. D. Ovsiannikov, J. Phys. B 39, 2247 (2006).
[2] V. D. Ovsiannikov and I. L. Glukhov, Proc. Voronezh State Univ. Ser.: Physics. Math. 2, 99 (2006).

Excitations and decays of rubidium Rydberg states induced by blackbody radiation

I. L. Glukhov and V. V. Chernushkin

Department of Physics, Voronezh State University, Voronezh, Russia
e-mail: GlukhovOfficial@mail.ru

Interaction of blackbody radiation (BBR) with Rydberg states of rubidium at T=50-1000 K are investigated as a ubiquitous depopulation mechanism for highly excited states. The modified Fues model potential [1] was used for calculation of stimulated by BBR excitation and decay rates in s-, p-, d-series of rubidium.

The calculations demonstrate that both decay and excitation rates have a distinct maximum. An effective quantum number $\nu = 1/\sqrt{(-2E)}$ of a state with the maximum of a decay (excitation) rate at the temperature T in a series follows the next condition:

$$\nu^3 T = C$$

where *C* is a constant for a given series. The constants for rubidium are cited in the next table:

C constants in Rb			
series	s	p	d
decays	1.70	1.4	1.4
excitations	2.4	2.5	2.1

The approximation formula similar to the ionization case [2] may be proposed for excitation and decay rates of Rydberg states at temperature *T*

$R_{nl}^{d(e)} = \dfrac{a_0^{d(e)}(1 + a_1^{d(e)} x + a_2^{d(e)} x^2 + a_3^{d(e)} x^3}{\widetilde{\nu}^5 \left\{\exp(0.315792 x^3) - 1\right\}}$, where $x = \dfrac{100}{\nu T^{1/3}}$, $\quad \widetilde{\nu} = \dfrac{\nu}{100}$,

and $a_i^{d(e)}$ are fitted coefficients. It was found that $a_0^{d(e)}$ are temperature independent constants, which provide an asymptotic (n> 50) behaviour of decay (excitation) rates; they are fixed for each series. Coefficients $a_1^{d(e)}$, $a_2^{d(e)}$, $a_3^{d(e)}$ depend on temperature slightly and give a right behaviour of the approximation near the maximum of a decay (excitation) rate.

$$a_i^{d(e)} = b_{i0}^{d(e)} + b_{i1}^{d(e)} \left(\frac{T}{100}\right)^{-1} + b_{i2}^{d(e)} \left(\frac{T}{100}\right)^{-2}, \text{ where } i = 1,2,3.$$

As an example, coefficients a_0 and b_{ik}-matrices for s-series are presented:
ad

$$a_0^d = 1.104, \; a_0^e = 0.9342,$$

$$b_{ik}{}^d = \begin{pmatrix} -0.2391 & 0.05953 & 0.03137 \\ -0.1705 & 0.1821 & -0.08441 \\ 0.1262 & -0.03315 & 0.02248 \end{pmatrix} \qquad b_{ik}{}^e = \begin{pmatrix} 0.1310 & 0.1185 & -0.04425 \\ -0.7012 & 0.00280 & 0.01929 \\ 0.4646 & -0.07513 & 0.01269 \end{pmatrix}$$

:
They provide a good accuracy in presentation of direct calculations for both decay and excitation rates of Rydberg states at T > 50K.

References

[1] A.A. Kamenski and V.D. Ovsiannikov, J. Phys. B 39, 2247 (2006).
[2] I.L. Glukhov and V.D. Ovsiannikov, J. Phys. B 42, 075001 (2009)

Photothermal spectra of inhomogeneous coatings

M. Popovic[1], S. Galovic[1], and Z. Stojanovic[1]

[1]*The "Vinca" Institute of Nuclear Sciences*
Belgrade, Serbia
e-mail: bobagal@vinca.rs

We present a theoretical study for photothermal measurement on inhomogeneous coatings [1-4]. First we present a general photothermal mathematical model for thermal gradient materials [5]. Then, we discuss the effects of inhomogeneous thermal properties of photothermal amplitude and phase spectra of coatings. Finally, we demonstrate a method for quantitative depth profiling that makes use of prior knowledge about the type of profile existing in a sample to reduce the instabilities associated with the mathematically ill conditioned task [6].

References

[1] J. Fivez and J. Thoen,, J. Appl. Phys. 75, 7696 (1994).
[2] S. Galovic and M.D. Dramicanin, J. Phys. D: Appl. Phys. 32, 1511 (1999)
[3] P. Xiao, Y. Cui, and R. E. Imhof, Nondestructive Testing and Evaluation, 21, 141 (2006)
[4] F. Macedo, A. Goren, F. Vaz, J. L. Nzodoum Fotsing, J. Gibkes, B. K. Bein, Vacuum, 82, 1461 (2008)
[5] S. Galovic and D. Kostoski, J. Appl. Phys. 93, 3063 (2003)
[6] R. W. Jones and J. F. McClelland, Applied Spectroscopy, 56, 409 (2002)

Comparative study between energy levels of Co^{2+} and Cr^{3+} ions doped in MgF_2 crystal

Ramona Nistora[1], Laura Andreici[1] and N.M. Avram[1,2]

[1]*Department of Physics, West University of Timisoara, 300223 Timisoara, Romania.*
[2]*Academy of Romanian Scientists ,Independentei 54, 050094 Bucharest,Romania*
e-mail: nistora_ramona@yahoo.com

The optical properties of 3d ions in MgF_2 crystals have been confirmed that Co^{2+} and Cr^{3+} ions are substitution in Mg^{2+} sites. The unit cell of MgF_2 is tetragonal and the Mg^{2+} ion is surrounded by six fluorine occupying a distorted octahedra.

In this paper we present a comparison of the energy level structure of Co^{2+} ($3d^7$ electrons) and Cr^{3+} ($3d^3$ electrons), each of ions doped in MgF_2 crystal [1,2]. We report, following the paper [3], on the detailed and consistent crystal field analysis of Co^{2+} and Cr^{3+} spectra in MgF_2 crystal. The calculations have been performed in the framework of the exchange charge model of crystal field [4]. Overlap integrals between Co^{2+}, $Cr^{3+}$and F^- ions were calculated numerically and approximated by the exponential function. To ensure reasonable convergence of lattice sums needed for calculations of the crystal field parameters (CFPs), large clusters of Mg^{2+} and F^- ions were considered. After calculating CFPs, based on the structure of the host matrix, the crystal field Hamiltonians were diagonalized in the space spanned by wave functions of all 50 LS terms of $3d^7$ / $3d^3$ electron configuration. The obtained energy levels and estimated Racah parameters B, C and G parameter of the exchange charge model were compared with results of experimental data and discussed. The fine structure of the energy levels for Co^{2+} doped in MgF_2 due the spin-orbit interaction is also analyzed and possible Jahn-Teller effect is predicted (in the case of Cr^{3+}doped in MgF_2 the experimental data on fine structure are absent).The results, for both ions, are in satisfactory agreement with the experimental data [1,2].

References

[1] S.A. Payne, L. L. Chase, W.F. Krupte, J. Chem. Phys.,86 (6), 1987.
[2] H. Manaa, Y. Guyot, R. Moncorge, *Phys. Rev.* B1, 48, 3633-3645, (1993).
[3] M.G.Brik, N.M.Avram, C.N.Avram, J.Mater.Sci: Mater Electron, 20,S30-S32 (2009).
[4] B.Z. Malkin, in: A.A. Kaplyanskii, B.M. Macfarlane (Eds.), Spectroscopy of solids containing rare-earth ions, North-Holland, Amsterdam, pp. 33–50, 1987.

Exchange Charge Model for Fe^{3+}: $LiAl_5O_8$

Vaida Mirela[1], C.N. Avram[1]

[1]*Departments of Physics, West University of Timisoara, 300223, Timisoara, Romania*
e-mail: vaida.mirela@yahoo.com

$LiAl_5O_8$ used as a host for luminescent materials doped with transition metal ions, has received much attention and significant efforts have been devoted to the study its optical properties. $LiAl_5O_8$ belongs to compounds of type $(Li_xAl_{2-x})^A (Li_{1-x}Al_{3+x})^B O_8$, where *x* indicates the fraction of improperly coordinated Li ions in tetrahedral sites, and the superscripts *A* and *B* refer to the site designation [1].

A trivalent impurity, such as Fe^{3+}, which has the $3d^5$ electronic configuration, may occupy either a tetrahedral site or an octahedral site, depending on the oxygen coordination. In the ordered phase of the $LiAl_5O_8$, the Fe^{3+} center occupies preferentially the *A* sites (tetrahedral site), and a cluster of the type $[FeO_4]^{5-}$ is formed. The emission from this cluster is due to the $4T_1$ (G) $\rightarrow$ $6A_1$ (S) electronic transition [2].

The present work is devoted to calculate the energy levels scheme of Fe^{3+}: $LiAl_5O_8$ using the Exchange Charge Model (ECM) [3] of crystal field and geometrical structure of $LiAl_5O_8$. The structure of the doped crystal is based on the shell model and pair potential approximation. Our approach enables modeling the crystal field parameters (CFP) and thus calculates the energy levels scheme of Fe^{3+} ions in $LiAl_5O_8$. In ECM the crystal field parameters have taking into account the point charge of ligands and the effects of the covalent bond formation between the Fe^{3+} and O^{2-} ions. With these parameters, neglecting the spin-orbit interaction, we have diagonalized the Fe^{3+}: $LiAl_5O_8$ Hamiltonian in a complete basis set of the 100 LS terms of the $3d^5$ electronic configuration. Comparison of the theoretical obtained results for energy levels with the experimental data and those obtained in another model [1], yields satisfactory agreement and confirm the validity of the ECM.

References

[1] J. Maria Neto, T. Abritta, F. De S. Barros, N. T. Melamed, Journal of Luminescence, 22, 109, (1981);
[2] P. A. Bingham, J. M. Parker, T. M. Searle, I. Smith, Journal of Non-Crysstaline Solids, 353, 2479, (2007);
[3] B.Z. Malkin, in: A.A. Kaplyanskii, B.M. Macfarlane (Eds), Spectroscopy of solids containing rare-earth ions, North-Holland, Amsterdam, 33, (1987).

Crystal field analysis of Cr^{3+} doped $SrAl_2O_4$ spinel

M.L. Stanciu[1], M.G. Ciresan[1], N. M. Avram[1, 2]

[1]*Department of Physics, West University of Timisoara, 3200223 Timisoara, Romania*
[2]*Academy of Romanian Scientist, Independentei 54, 050094 Bucharest, Romania*
e-mail: stanciumarialetitia@yahoo.com

The spinel $SrAl_2O_4$ is generally regarded as versatile material of great technological importance and physical behavior [1]. The crystal structure is related to AB_2O_4 -spinel structure and belongs to the cubic space group $P2_1$ monoclinic, with eight formula units per cell. The A site has tetrahedral coordination, while the B site has distorted octahedral coordination [2]. The Cr^{3+} ion may occupy either a octahedral site or an tetrahedral site in the $SrAl_2O_4$ spinel.

The present work is devoted to crystal field analysis of trivalent chromium doped in $SrAl_2O_4$ spinel using the Exchange Charge Model (ECM) of crystal field [3]. Based on the crystal structure data ,modeled by shell model and pair approximation, our approach enables modeling the crystal field parameters (CFP) and thus calculates the energy level scheme of Cr^{3+} ions in spinel $SrAl_2O_4$. In ECM model, the calculation of the crystal field parameters have taking into account the point charge of ligands and the effects of the covalent bond formation between the Cr^{3+} and O^{2-} ions.

Using the B,C Racah parameters and the G exchange charge parameter, we have calculated the crystal-field parameters and the energy levels. With these parameters, we diagonalized the Cr^{3+} Hamiltonian, in a complete basis set spanned by all 50 wave functions of the LS terms of $3d^3$ electron configurations. Comparison of the obtained results for different site symmetry of Cr^{3+} ion, with the experimental one, we have established actually site symmetry of Cr^{3+} ion in $SrAl_2O_4$. The results are compared with experimental data [4] and discussed.

References

[1] H. Richter, T. Posch, M.N. Taran, H. Mutschke, Mineral. Petrol. 85, 53, (2005);
[2] B. Henderson, G.F. Imbush, *Optical Spectroscopy of Inorganic Solids*, Clarendon, Oxford, 2006; [3] B.Z. Malkin, in: A.A. Kaplyanskii, B.M. Macfarlane (Eds), *Spectroscopy of solids containing rare-earth ions*, North-Holland, Amsterdam, 33, 1987;
[4] Ada López, Mariana G. da Silva, Elisa Baggio-Saitovitch, Alexandre R. Camara, Raimundo N. Silveira Jr., Raul José Mauricio da Fonseca, *Luminiscence of $SrAl_2O_4$: Cr^{3+},* J. Mater Sci 43, 464 – 468, (2008).

Calculation of optical and spin-Hamiltonian parameters for Mn^{4+} doped in $LiGa_5O_8$

M.G. Ciresan[1], M.L. Stanciu[1], N.M. Avram[1, 2]

[1]*Department of Physics, West University of Timisoara, Bd. V. Parvan 4, Timisoara 300223, Romania*
[2]*Academy of Romanian Scientists,Splaiul Independentei 54, 050094-Bucharest, Romania*
e-mail: marcel_ciresan@yahoo.com

$LiGa_5O_8$ adopts an inverse spinel structure with space group $P4_332$ (constant lattice a= 8.203 Å), with four formula units in the cubic cell [1]. Significant efforts have been devoted by different research groups, in the past and till recently, to the study of the optical properties of impurity-doped $LiGa_5O_8$. It has reported several lithium gallium oxides such as $LiGa_5O_8$:Co, $LiGa_5O_8$:Ni, $LiGa_5O_8$:Cr, $LiGa_5O_8$:Mn, $LiGa_5O_8$:Fe, [2], etc. However, for the Mn-doped $LiGa_5O_8$, the studies are much fewer. In our case Mn^{4+} ions replace the Ga^{3+} ions in the $LiGa_5O_8$ and forms the complex $[MnO_6]^{-8}$. The site symmetry group for Mn^{4+} doped in $LiGa_5O_8$ is not trigonal, unlike that in normal spinels, it is orthorhombic and belongs to the C_2 point group [3].

In this work, we theoretically investigate the optical spectra and EPR (D-zero field splitting and g-factors) parameters for Mn^{4+}:$LiGa_5O_8$. The optical energy levels scheme has obtained by diagonalization of the Hamiltonian of the system, using all 50 wave functions of the LS terms of $3d^3$ electron configuration. The crystal field parameters have been obtained in exchange charge model of crystal field [4], taking into account the structure of the host matrix and effects of the covalent bond formation between the Mn^{4+} with O^{2-} ions. The spin-Hamiltonian zero field splitting D and g-factors have been calculated using the perturbation theory of Macfarlane. Obtained energy levels are compared with experimental data and satisfactory agreement is obtained.

References

[1] T. Abritta, F. H. Blak, J. Lumin. 48/49, 558 (1991)
[2] V.Singh, R.P.S. Chakradhar, J.L.Rao, D.K.Kim, Journal of Luminescence 129, 755-759 (2009)
[3] R.J.M. Da Fonseca and T. Abritta, Physica B 190 (1993) 327-332
[4] B.Z. Malkin, in: A.A. Kaplyanskii, B.M. Macfarlane (Eds), *Spectroscopy of solids containing rare-earth ions*, North-Holland, Amsterdam, 33, 1987.

Thermal issue management in rare-earth doped Near Infrared lasers

B. Viana, P. O. Petit, Ph. Goldner, F. Balembois, F. Druon, P. Georges

LCMCP-ENSCP 11 Rue P&M Curie 75231 Paris Cedex 05 France
Lab. Charles Fabry de l'Institut d'Optique, Campus Polytechnique, RD 128, 91127 Palaiseau
e-mail:

In the field of solid state lasers, thermal management has always been an important issue. Numerous works have been carried out to reduce the thermal load or to find crystals with very good thermal properties. We are working in these two directions.

1) when the difference between the excitation and laser emission is quite important, as that occurs in the case of Nd^{3+} and Er^{3+} emission, we have investigated composite systems. Composite crystals are bonded by a silicate interlayer realized by sol-gel process [1] to sapphire to extract thermal load. The interlayer thickness has been estimated to be around 150 nanometers. In the case of Er/Yb glass||sapphire composite, laser action at about 1.5µm has been achieved and low optical losses have been measured. Output power is increased by 40% and the maximum pumping power is two times higher. In the case of Nd:YVO_4||sapphire (for 1 µm emission), thermal mappings exhibit a reduced thermal load on the vanadate crystal thanks to this bonding technique. Output power has been increased by 50%, laser mode is not altered even for high pumping powers and finally, thermal lensing is reduced by 30% for high pumping power.

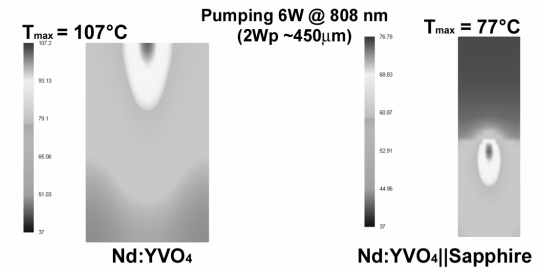


Fig. 1 Thermal mapping of unbonded and bonded laser material under laser action

2) With Yb^{3+} in solid state laser hosts, leading to an emission at about 1 µm under diode pumping at 0.98 µm, thermal problem occurs when the pumping power strongly increases. Yb^{3+}:$CaGdAlO_4$ has a very high thermal conductivity of about 6.5 W $K^{-1}m^{-1}$ [2] allowing high-power diode pumping power. Laser operation of Yb:$CaGdAlO_4$ pumped with up to 100W has been demonstrated. Thermal lens measurement has been carried out and revealed favourable behaviour. Under 86W of incident power, thermal lenses measured are f=37cm without laser and f=25cm with laser action. For 86W pumping power, the global temperature elevation reaches 105°C but the temperature gradient in the crystal is only 20°C. This relatively small increase of temperature clearly confirms the excellent thermal conductivity of this crystal and contributes to the small thermal lensing. In addition, this material has demonstrated interesting generation of ultrashort laser pulses (<100fs)[3].

References

[1] J. Petit, B. Viana, P. Goldner, C. Boissière, J.E. Montagne, "sol-gel de qualité optique", french patent FR2894249, (2007)
[2] P.O. Petit, J. Petit, P. Goldner, B. Viana; Opt. Mat. 30 (7), 1093, (2008)
[3] D. N. Papadopoulos, F. Druon, J. Boudeile, I. Martial, M. Hanna, P. Georges, P. O. Petit, P. Goldner, B. Viana, Opt. Lett. 34, (2)193, (2009).

Microstructure changes of iron-base superalloys induced by interaction with femtosecond laser beam

S. Petronic[1], S. Drecun-Nesic[1], A. Milosavljevic[1], A. Sedmak[1], M. Popovic[2] and A. Kovacevic[2]

[1]*School of Mechanical Engineering, University of Belgrade, Belgrade, Serbia*
[2]*Institute of Physics, University of Belgrade, Belgrade, Serbia*
e-mail: sanjapetronic@yahoo.com

The investigation was performed on nickel-base superalloy, with nickel being the most influential alloying ingredient. After thermo-mechanical preparation and corresponding processing, femtosecond laser beam machining has been performed. The laser wavelength was 800 nm. The exposition time, during which the samples have been exposed to the pulses of femtosecond laser beam, was changed, as well as the average output power. The changes of both the output power and the exposition time enabled the samples to be irradiated with different total energy during each exposition.

The changes in samples microstructure were observed with scanning electron microscopy and energy-dispersive spectrometry, and analyzed as well. The structure microconstituents were identified and both beneficial and disadvantageous influences of microstructure changes to mechanical and physical characteristics of the samples have been determined.

Keywords: superalloys, femtosecond laser, microstructure, SEM, EDS

Fine-scale structure investigation of Nimonic 263 superalloy surface damaged by femtosecond laser beam

A. Milosavljevic[1], S. Petronic[1], M. Sreckovic[2], A. Kovacevic[3], A. Krmpot[3] and K. Kovacevic[4]

[1]*School of Mechanical Engineering, University of Belgrade, Belgrade, Serbia*
[2]*School of Electrical Engineering, University of Belgrade, Belgrade, Serbia*
[3]*Institute of Physics, University of Belgrade, Belgrade, Serbia*
[4]*Institute for ferrous metallurgy, Niksic, Montenegro*
e-mail: sanjapetronic@yahoo.com

Due to the specific conditions of manufacturing, processing and utilization of nickel-base superalloys, the implementation of contemporary precision techniques is necessary in the research of the alloys features. Multi-component nickel-base superalloys, with about of 50% of nickel content, are commonly exploited in the conditions of high temperatures and pressures as well as in various aggressive operating environments. For successful quality control, which includes the monitoring of the changes in the alloy microstructure, fine-scale structure investigations are necessary.

The exposition of superalloys to pulsed beams of femtosecond lasers is a contemporary field of research [1, 2]. In this work, the samples of nickel-base superalloys have been exposed to 800 nm femtosecond laser in various operating regimes. Each sample was irradiated by different total energy. The energy of each exposition was altered by changing both the average output laser power, from 1.234 to 1.822 W, and the exposition time, from 10 to 180 s. The interaction with some samples produced the occurrence of plasma plume formation.

Surface damages and dents caused by femtosecond laser pulses have been observed by optical and scanning microscopy. The identification of desired and undesired emerging microstructures improved usual considerations of surface stability – the resistance to oxidation and corrosion.

Keywords: nickel-base superalloys, femtosecond laser, surface processing, SEM, EDS

References

[1] N. G. Semaltianos, W. Perrie, P. French, M. Sharp, G. Dearden, K. G. Watkins, Appl. Surf. Sci. 255, 2796 (2008) [http://dx.doi.org/10.1016/j.apsusc.2008.08.043].
[2] N.G. Semaltianos, W. Perrie, P. French, M. Sharp, G. Dearden, S. Logothetidis, K. G. Watkins, Appl Phys A 94, 999 (2009)
[http://springerlink.com/content/h5w47j0th3845801/fulltext.pdf].

Diffraction of Laguerre-Gaussian beam by a helical axicon

S. Topuzoski, Lj. Janicijevic

Institute of physics, Faculty of natural sciences and mathematics, University "Ss Cyril and Methodius", 1000 Skopje, Republic of Macedonia
e-mail: suzana_topuzoski@yahoo.com

We propose a new method for transformation of a Laguerre-Gaussian beam into a vortex, diverging or nondiverging Bessel beam, which can have increased or decreased phase singularity order, or can be a zero-th order Bessel beam, by means of a helical axicon. The Bessel beam divergence or nondivergence depends upon the waist position of the input Laguerre-Gaussian beam, regarding the plane where the helical axicon is situated.

The expressions for the amplitude and the intensity distribution of the diffracted wave field, in the process of Fresnel diffraction, are deduced using the stationary phase method. The theoretical analysis for the vortex radius and the maximum propagation distance of the Bessel beams obtained is presented.

Analysis of temperature and density of Ar I for 4S'→4P' in a Facing Target Sputtering System

Y. Yasuda, N. Nishimiya, Y. Hoshi and M. Suzuki
Department of Electronics and Information Technology, Tokyo Polytechnic University, 1583 Iiyama, Atsugi, Kanagawa, Japan
e-mail: yyasuda@seit.t-kougei.ac.jp

Recently, facing target sputtering (FTS) [1] has attracted considerable attention because the deposition rate of this process is high, the damage caused is less, and sputtering can be carried out even at low temperatures. Organic light emitting devices (OLEDs) have attracted much attention as promising next-generation flat panel displays. In the study of Uchida et al., transparent flexible OLEDs were fabricated on a plastic film substrate [2]. In order to deposit transparent electrode on such flexible substrates, a sputtering process that can be carried out at low temperatures and that causes minimum damage is required. It is essential to suppress the high-energy particles for low-temperature sputtering. Hoshi et al. have reported that the bombardment of high-energy particles and secondary electrons to the substrate can be suppressed completely by using FTS [3, 4].

The determination of the most suitable temperature and density of the sputtering gas for FTS is an important research topic. However, it is difficult to measure the thermodynamic temperature of the gas—which plays an important role in the sputter-deposition of the film—in the sputtering chamber. The Zeeman effect and the limitation of the resolving power of the spectrometer change the shape of the absorption lines in the sputtering chamber. To the best of our knowledge, the temperature and density of the gas in an FTS system have not been investigated in detail. These two parameters of the gas are generally estimated from the spectrum intensity and the line width [6, 7]. Absorption spectroscopy using tunable laser is a useful technique for determining the temperature and density of the sputtering gas. The static magnetic field between the two sputtering targets makes it easy to analyze the Zeeman-split lines.

In this study, we have demonstrated that high-resolution laser spectroscopy is extremely useful for analyzing the line profile of the absorption spectrum in the FTS process. We estimated the gas temperature and the density of the Ar I for the $4S'[1/2]0 \rightarrow 4P'[3/2]1$ transition (794.8nm) from the line width and the line intensity. For the analysis, we used a Voigt function [8] with the Doppler width and line intensity as the fitting parameters. A good agreement was obtained between the observed line and the calculated values.

References

[1] M. Naoe, S. Yamanaka, Y. Hoshi, IEEE Trans. Magn. MAG-16, 646 (1980).
[2] T. Uchida, S. Kaneta, M. Ichihara, M. Ohtsuka, T. Otomo, D. Marx, Jpn J. Appl. Phys. 44(9), 282 (2005).
[3] Y. Hoshi, H. Kato, K. Funatsu, Thin Solid Films 445, 245 (2003).
[4] R. Ohki, T. Hoshi, Trans. IEICE, J.83-C8, 715 (2000) (In Japanese).
[5] Y. Ralchenko, A. E. Kramida, J. Reader, NIST ASD Team (2008). NIST Atomic Spectra Database (version3.1.5), [Online].
[6] M. F. Dony, J. P. Dauchot, M. Wautelet, M. Hecq, A. Ricard, J. Vac. Sci. Technol. A 18(3), 809 (2000).
[7] N. Britun, M. Gaillard, Y. M. Kim, K. S. Kim, J. G. Han, METALS AND MATERIALS International13(6), 483 (2007)
[8] W. Demtröder, Laser spectroscopy Basic Concepts and Instrumentation, Springer, 2002, third edn.
[9] A. Mitchell and M. Zemansky, Resonance Radiation and Excited Atoms, 1971.

Quantum efficiency and UV performances of nanostructured Mg thin films on Cu substrates for photocathode applications

C. Ristoscu[1], F. Sima[1], I. N. Mihailescu[1], L. Cultrera[2], A. Perrone[3]

[1] *Laser Department, National Institute for Lasers, Plasma and Radiation Physics, PO Box MG-36, Bucharest-Magurele, RO-77125, Romania*

[2] *Istituto Nazionale di Fisica Nucleare (INFN), Laboratori Nazionali di Frascati, Via E Fermi 40, 00044 Frascati, Italy*

[3] *Physics Department and INFN, University of Salento, via Arnesano, 73100-Lecce, Italy*

e-mail: carmen.ristoscu@inflpr.ro

Pulsed laser ablation of pure Mg targets (99.99%) with an XeCl* excimer laser source (λ = 308 nm, τ = 30 ns) was used to grow nanostructured Mg coatings on Cu substrates. A thin layer of Mg (100–200 nm) was deposited in UHV of 5 x 10^{-6} Pa to ensure high purity. A second ultra-thin layer of MgO of 10–20 nm was deposited in oxygen at 10^{-2} Pa pressure to protect the first layer from atmospheric contamination. In separate experiments, the Mg coatings were protected with a thin layer of graphite.

Measurements for determining the electron yield of the deposited samples under UV irradiation were performed on a diode structure with another UHV apparatus evacuated down to 10^{-6} Pa. We report a detailed description of the laser cleaning procedure and emission performance measurements on a nanostructured Mg film. During the tests performed after the end of each cleaning operation, we have evidenced an increase of Quantum Efficiency (QE) in time. The QE stabilizes at a remarkably higher value. The study of this phenomenon is important because it determines both the working QE value and the lifetime of the cathode. Moreover, the stability of the QE has been revealed for a time scale of several days after each laser cleaning process, in our vacuum conditions.

Keywords: quantum efficiency, photocathode, free electron laser, magnesium, PLD

Effect of doping with carbon and nitrogen on photocatalytic activity of TiO_2 thin films synthesized by pulsed laser deposition

G. Socol[1], N. Stefan[1], I. N. Mihailescu[1], V. Djokic[2], D. Janackovic[2], C. Sutan[3], V. Malinovski[3], A. Moldovan[1]

[1] *National Institute for Lasers, Plasma and Radiation Physics, Magurele, Ilfov, Romania*
[2] *Faculty of Technology and Metallurgy, Karnegijeva 4, 11000 Belgrade, Serbia*
[3] *University of Pitesti, Research Centre for Advanced Materials, Targul din Vale Street, No 1, 110040, Pitesti, Arges, Romania*
e-mail: gabriel.socol@inflpr.ro

Titanium dioxide was intensively studied during the past few decades as a promising material for environmental protection, self-cleaning, deodorizing and sterilizing applications due to its excellent photocatalytic activity. The large bandgap of anatase TiO_2 (3.2 eV) restricts however its photocatalytic application to the UV range only. To ensure therefore visible-light photocatalytic activity of titania, it is important to generate active visible-light absorption centers. Anions have shown a great potential in introducing such absorption, and intensive efforts have been paid to develop methods for synthesizing anion-doped titania photocatalysts with a visible-light response.

In this work we report on the synthesis of C and N doped TiO_2 thin films on fused silica substrates by PLD or RPLD techniques using a KrF* laser source (λ=248 nm, $\tau_{FWHM} \sim 25$ ns). The doping of TiO_2 films was achieved by either ablation of undoped TiO_2 targets in a N_2 or CH_4 atmosphere or by controlled oxidation of Ti and TiN during the deposition. The influence of the deposition parameters (i.e. ambient gas nature and pressure, substrate temperature and composition of ablated material) was studied in respect with the catalytic activity of the obtained TiO_2 nanostructured films.

Information on composition and crystalline phases in the films was obtained by X-ray diffraction studies. The analysis of the XRD patterns revealed the presence of the anatase phase in most of the films but also the existence of the rutile phase under certain deposition conditions. The topography analyses by atomic force microscopy showed that the films roughness was in the range of several nm. The energy dispersive X-ray spectroscopy and X-ray photoelectron spectroscopy confirmed the incorporation of N and C in the TiO_2 matrix. The optical spectra showed a significant shift of the optical absorption edge due to nitrogen and carbon incorporation. The enhancement of the photocatalytic degradation efficiency in UV A and in a broad visible-light range was confirmed by the degradation of methylene orange and methylene blue.

We concluded that the films structure and photocatalytic activity strongly depend on target material, gas ambient pressure and substrate temperature.

Carbon dioxide monitoring system by measuring area intensity of absorption spectrum

N. Nishimiya, Y. Yasuda, and M. Suzuki

Department of Electronics and Information Technology,
Tokyo Polytechnic University, Japan
e-mail: nisimiya@seit.t-kougei.ac.jp

In order to measure the concentration of greenhouse gases in the atmosphere, we have developed a highly sensitive and accurate measuring system.

The concentration can be determined by measuring the intensity of the absorption spectrum of the gas. As spectral line width and intensity depend on the gas pressure, the calibration curve has to be changed with variations in pressure. The area intensity of the spectrum does not depend on the pressure but depend only on the concentration. We have measured the area intensity of CO_2 spectrum and determined the calibration curve.

Although there are strong basic bands of CO_2 in the infrared region, infrared laser source could not be easily obtained. In the near infrared region, overtone bands of CO_2 can be obtained [1-5]. We used diode lasers manufactured for optical communication in 1.5 μm. In this study, we have measured the rovibrational spectrum of $2\nu_1 + 2\ \nu_2 + \nu_3$ band by using the optical feedback-type diode laser (Suntec TSL-210) and determined the calibration curve. The optical path length of the CO_2 cell is 20 m. The dependency of Lorentzian and Doppler width on the concentration can be measured by fitting the Voigt function to the measured spectrum.

References

[1] J. P. Maillard, M. Cuisenier, Ph. Arcas, E. Arie, and C. Amiot, CAN. J. Phys. 58, 1560 (1980).
[2] L. Wallace and W. Livingston, J. Geophys. Res. D95, 9823 (1990)
[3] L. P. Giver, C. Chackerian Jr., M. N. Spencer, L. R. Brown, and R. B. Wattson, J. Mol. Spectrosc. 175, 104 (1996)
[4] C. E. Miller and L. R. Brown, J. Mol. Spectrosc. 228, 329 (2004)
[5] C. E. Miller, M. A. Montogomery, R. M. Onorato, C. Johnstone, T. P. McNicholas, B. Kovaric, and L. R. Brown, J. Mol. Spectrosc. 228, 355 (2004)

Laser beam profile influence on Hanle CPT resonances in Rb vapour

A. J. Krmpot, S. Ćuk, S. N. Nikolić, M. Radonjić, Z. D. Grujić, and B. M. Jelenković

Institute of Physics,
Belgrade, Serbia
e-mail: krmpot@phy.bg.ac.yu

Influence of two different laser beam profiles, the Gaussian and the Π (top hat) profile on the line-widths and contrast of the Hanle electromagnetically induced transparency (EIT) was studied. The laser beam propagates through the vacuum Rb glass cell, shielded from the laboratory stray magnetic fields with a triple layer of the μ-metal. Pure Gaussian profile was generated by the single mode optical fiber. Expanding the Gaussian beam and extracting its central part by circular iris, the Π laser beam profile was obtained.

Hanle EIT was measured for the two beam profiles and results were compared with theoretical predictions [1, 2] that Gaussian and the Π profile give different line-widths of the Hanle resonance. Studies were done at D1 line, for two open transitions in ^{85}Rb: $F_g=3\rightarrow F_e=2$ and in ^{87}Rb: $F_g=2\rightarrow F_e=1$. Distinct differences were observed, both in the experiment and in the model, similar to one in [1], on the laser intensity dependence of the Hanle EIT line-widths and contrast, when the same total beam laser power and the laser beam diameter were used for two laser beam profiles. Π profile beam have significantly faster increase of light intensity at its edge, so that an atom that enters the laser beam will be promoted faster to the dark state in comparison with Gaussian profile. Variations of the Hanle EIT line-shapes were also observed, for the same beam profile but using different parts of the laser beam, i.e., by detecting the light behind the small aperture, placed at different radial positions along the laser beam. Such variations can not be explained only by the effect of the laser power broadening.

This study has shown that the both laser beam profiles and different parts of the same beam considerably influence the EIT line profiles. Such findings are of importance for various applications of this phenomenon.

References

[1] M. Radonjić, D. Arsenović, Z. Grujić and B. M. Jelenković: „*Coherent population trapping linewidths for open transitions: Cases of different transverse laser intensity distribution*“, Phys. Rev. A **79**, 023805 (2009).

[2] M A. V. Taichenachev, A. M. Tumaikin, V. I. Yudin, M. Stahler, R. Wynands, J. Kitching, and L. Hollberg: „*Nonlinear-resonance line shapes: Dependence on the transverse intensity distributionof a light beam* “, Phys. Rev. A **69**, 024501 (2004).

Simulation and computation of laser cavity using modern software tools

B. Djokic[1], M. Sreckovic[2], S. Ostojic and A. Kovacevic[2]

[1]*School of Informatics Educon, Belgrade, Serbia*
[2]*School of Electrical Engineering, University of Belgrade, Serbia*
[3]*Institute of Physics, Belgrade, Serbia*
e-mail: djokic.bilja@gmail.com

Modern laser technology demands powerful numerical tools to analyze complex laser systems. Since the laser was invented, its development has been supported continuously by theoretical models, which have been able to describe the physics of the laser to a high degree. But there are still open problems, and modern laser technology demands powerful numerical tools, for instance to model thermal lensing and gain guiding effects in laser cavities, or to predict the efficiency of laser configurations.

In this paper, we simulated stress propagation of Q-switch laser beam. We also modelled cases of various pumping methods and temperature distribution in active materials by various engineering software.

The beam is propagating through spherical dielectric interfaces, gaussian ducts, i.e. parabolic distributions of refractive index and gain, or is reflected on spherical mirrors, analytical solutions of the paraxial wave equation are available in the form of the well known Hermite-gaussian polynomials. In real situations, the gaussian mode algorithm can successfully be applied, if the distributions of refractive index and gain in laser crystals can be approximated by parabolic. This approach for instance is used in the laser cavity code. LASCAD (Laser Cavity Analysis and Design tool), besides its other capabilities, can evaluate temperature, deformation and stress distributions. Effects of thermal lensing are included for different configuration of pumping and cooling. Simulation is defined with automatic meshing algorithm, to generate semi-unstructured grid. Laser crystals, thin disk lasers and side-pumped sandwiched slabs can be included in design. Elements for choosing are mirrors, dielectrical interface, lenses, adjustable number of elements, parameters of refraction etc. are included in gain calculation. Non-linear interactions concerning thermal and optical effects are also incorporated. Some results for active material in the shape of side-pumped rod are presented. Simulation of temperature distributions transversally and laterally, configuration of pumping diodes around the active material, cross-section.

References

[1] A. E. Siegman and H. Y. Miller, "Unstable optical resonator loss calculation using the Prony method", Appl.Opt. 9(10), 2729-2736 (1970).
[2] M. D. Feit and J. A. Fleck, "Spectral approach to optical resonator theory", Appl. Opt. 20(16**)**, 2843-2851 (1981),
[3] A. E. Siegman, *Lasers* (University Science Books, Mill Valley, 1986),
[4] http://www.las-cad.com.

Derivation of temperature distribution function in fibers laser with eccentric multi-end-pumping by using Green's function method

A. Gharaati[1] and M. Jafari[1]

1-Department of Physics, Payame Noor University, Shiraz Center
e-mail: agharaati@pnu.ac.ir

In this paper, we investigate temperature distribution function of an eccentric fiber lasers with a multi-end-pumping by using Green's function method in a cylindrical coordinate system. We drive analytically Green's function for an end pumped fiber laser by method of image. Then we consider heat deposited in the core region in which they are eccentric with respect to its clad. The effects of the inhomogeneous heat deposition on thermo optics properties such as temperature dependent of refractive index and stress have been studied. Finally, we have obtained the temperature distribution function for a typical fiber laser, and draw their variations as a function of radius and angle.

PACS No: 42.44
Keyword: Multi-end-pumping, Eccentric fiber lasers, Green's function method.

References:
[1] J. D. Jackson, *Classical electrodynamics,* John Wiley & Sons, Inc, 3rd edition, (1999).
[2] D. G. Duffy, *Green's Functions with Applications,* CHAPMAN & HALL/CRC, (2001).
[3] P. Elahi, A. Taghavi and A. Gharaati, *The analytical investigation of temperature distribution in off-central diode-pumped lasers,* Pramana-J. Phys., **70(4)**, 649-656, (2008).
[4] W. Koechner*, Solid state laser engineering*, 5th edition, Springer-Verlag, New York, (1999).

Measurement of betanin fluorescence using TR-LIF technique

M. S. Rabasovic[1], D. Sevic[1], M. Terzic[2], S. Savic-Sevic[1], B. Muric[1], D. Pantelic[1], B. P. Marinkovic[1]

[1] *Institute of Physics, Belgrade, Serbia*
[2] *Faculty of Science, University of Novi Sad, Serbia*
e-mail: sevic@phy.bg.ac.yu

Laser induced fluorescence (LIF) is a powerful spectroscopic technique commonly used to study the structure and internal state distributions in molecules of biological interest. Betanin ($C_{24}H_{26}N_2O_{13}$) is a specific violet betacyanin and the most prominent pigment in the red beet root where it contributes between 75% - 90% of the total visible color. When used properly, beets can serve as a natural organic food coloring, giving foods a magenta hue [1, 2, 3].

Our method of excitation of the betanin (1% water solution) in optical cell is based on the tunable (320 nm to 475 nm) Nd: YAG laser system. The streak camera used for detection of the fluorescence signal enables simultaneous measurements of the spectrum and lifetime of fluorescence [4]. The calibration of the time-resolved laser-induced fluorescence (TR-LIF) detection system is performed with standard fluorescent solution dyes, such as Rhodamine B and fluorescein [5].

Fluorescence images of betanin (1% water solution) excited at 320, 340, 360 and 400 nm were obtained. The fluorescence is observed in domain from 580 nm to 660 nm.

References

[1] F. G. Herrero, F. G. Carmona, J. Escribano, Nature, Vol.437, 7057 (2005).
[2] F. G. Herrero, F. G. Carmona, J. Escribano, Food Res. Int. 38, 879 (2005).
[3] F. G. Herrero, J Escribano, F. G. Carmona, Planta 222, 586 (2005).
[4] Terzić, B. P. Marinković, D. Šević, J. Jureta and A. R. Milosavljević, Facta Universitatis, Series Phys. Chem. Technol. 6, p.105 (2008).
[5] R. Sjöback, J. Nygren, M. Kubista, Spectrochimica Acta Part A 51, L7-L21(1995).

Investigation of the fluorescence spectra of Cs-vapor layers with nano-metric thickness

K. Vaseva[1], P.Todorov[1], S. Cartaleva[1], D. Slavov[1],
S. Saltiel[2]

[1]*Institute of Electronics, Bulgarian Academy of Sciences, 72 Tzarigradsko Shosse bld, 1784 Sofia, Bulgaria*
[2]*Sofia University, Faculty of Physics, 5 J. Bourchier boulevard, 1164 Sofia, Bulgaria*
e-mail: slavov_d_g@yahoo.com

High resolution laser spectroscopy of alkali-vapor layers has been made possible through the development of Extremely Thin Cell (ETC) (of thickness $\leq$ 1 μm) [1]. The vapor-layer thickness can be precisely controlled in an interval around the wavelength of the irradiating laser light λ = 852 nm. It has been reported that the width of the fluorescence profiles increases monotonously with the cell thickness [2].

Here we present a detailed investigation of experimental and theoretical profiles of the fluorescence on the D_2 line of Cs-atomic-layers with thickness L = mλ (where m = 0.5, 0.75, 1, 1.25). Fluorescence spectra are investigated at $6S_{1/2}$ ($F_g = 4$) $\rightarrow$ $6P_{3/2}$ ($F_e = 3,\ 4,\ 5$) hyperfine transitions, for different irradiating powers. Very well resolved resonances are registered with the single beam spectroscopy due to the fact that in the ETC the fluorescence signal comes mainly from slow atoms, whose velocity is small enough to allow time for absorption of a photon and subsequent spontaneous emission before collisions with the cell wall. The developed in Ref. [3] model is used, which is based on the Optical Bloch Equations. The simulation results are in very good agreement with the experimental observations. The calculations are made for two-level system involving closed or open transitions as well as with parameters applicable to the performed experiments. For the open transitions suffering population loss due to the hyperfine/Zeeman optical pumping, well pronounced narrow dips in the fluorescence profiles are observed on the contrary to the case of the closed transitions where a tiny feature is seen, in the case of L = 1. 25 λ only [4].

Detailed comparison is made for the fluorescence profiles amplitude and width, obtained theoretically and experimentally. The amplitude of the fluorescence profiles increases with laser power, for all transitions and all cell thicknesses. Also the width of the transition profiles is growing with L, strongly depending on the layer thickness (with such a small variations as 213 nm). We report about a new peculiarity related to the enhancement rate of the transition width. It is not growing monotonously, but it is larger for L varying in the interval $0.75\ \lambda \leq L \leq \lambda$ than that varying in the interval $\lambda \leq L \leq 1.25\ \lambda$.

Presented results are of importance for spectral investigations of atoms confined in nano volumes, as well as for spectroscopy of miniature gas discharges.

Authors are grateful for the support by Bulgarian Fund of Scientific research (grant: DO-02-108/22.05.2009) and Indian-Bulgarian bilateral collaboration (project: BIn-2/07).

References

[1] D. Sarkisyan, D. Bloch, A. Papoyan, M. Ducloy, Opt. Commun. 200, 201 (2001).
[2] D. Sarkisyan, T. Varzhapetyan, A. Sarkisyan, Yu. Malakyan, A. Papoyan, A. Lezama, D. Bloch, M. Ducloy, Phys. Rev. A69, 065802(2004).
[3] C. Andreeva, S. Cartaleva, L. Petrov, S. M. Saltiel, D. Sarkisyan, T. Varzhapetyan, D. Bloch, M. Ducloy, Phys. Rev. A **76**, 013837 (2007).
[4] P. Todorov, K. Vaseva, S. Cartaleva, D. Slavov, I. Maurin and S. Saltiel, Proc. SPIE, vol. **7027**, 70270R (2008).

Lensless ghost imaging with pseudo-thermal light

Nandan S. Bisht[1], Enakshi K. Sharma[2] and H. C. Kandpal[1]

[1]*Optical Radiatoin Standard's, National Physical Laboratory, New Delhi, India*
[2]*Department of Electronic Science,University of Delhi South Campus, New Delhi, India*
e-mail: bishtns1@mail.nplindia.ernet.in

The first two-photon imaging experiment was demonstrated by Pittman et al. in 1995 [1]. Due to its non-local features the experiment was named as ghost imaging. Initially ghost imaging [2] was performed with entangled photon [3]. Basically, the ghost imaging configuration is based on splitting of the light beam into two spatially separated optical arms where an object is placed in one of the arms (object arm) other one called reference arm. Recently, ghost imaging, a quantum effect was simulated by classical light called pseudo-thermal light [4-7].In these studies the dependence of the visibility and the quality of ghost interference has been shown to depend on source parameters [7]. However, in the ghost imaging studies the dependence of the visibility and quality of the image on the source parameters i) transverse size of source, ii) the transverse coherence length of the source and iii) object characteristics has been studied theoretically [6].

We demonstrate classical correlated lensless ghost imaging experiment using pseudo-thermal light source. The effect of source properties and the number of transparent feature of object on the resultant ghost image is studied. The ghost image is reconstructed in the coincidence measurement of object and reference arms photons. It is observed that the larger the transverse size of the source, better the quality and the smaller the visibility of the image. The larger coherence in the source is less the quality and higher the visibility. The visibility and quality of the image decrease by increasing the number of transparent feature and size of the object. The ghost image is reconstructed by measuring the coincidence counts between spatially separated object and reference beams which is resultant of the superposition among the indistinguishable two-photon amplitudes.

References

[1] T. B. Pittman, Y. H. Shih, D. V. Strekalov, A. V. Sergienko, Phys. Rev. A 52, R3429 (1995).
[2] A. F. Abouraddy, B.E.A. Saleh, A.V. Sergienko, M.C. Teich, Phys. Rev. Lett. 87, 123602 (2001); J. Opt. Soc. Am. B 19, 1174 (2002).
[3] A. Zeilinger**,** Rev. Mod. Phys. 71, S288 (1999).
[4] A. Gatti, E. Brambilla, M. Bache, L. A. Lugiato, Phys.Rev. A 70, 013802 (2004).
[5] K. Wang, D. Cao, Phys. Rev. A 70, 041801 (2004); D. Cao, J. Xiong, K. Wang, Phys. Rev. A 71, 013801 (2005).
[6] Y. J. Cai, S. Y. Zhu, Phys. Rev. E 71, 056607 (2005).
[7] I. Vidal, D. P. Caetano, E. J. S. Fonseca, J. M. Hickmann, Opt. Lett. 34, 1450 (2009).

Contributed papers

Poster session - Thursday

Study on formation and nonlinear optical properties of noble metal nanoparticles embedded in silica glass investigated by Z-scan technique

K. Dzierzega[1], M. Grabiec[1]

[1]*Institute of Physics, Jagiellonian University, Cracow, Poland*
e-mail: michal.grabiec@uj.edu.pl

Nonlinear optical properties of silver nanoclusters have attracted wide attention, owing to their potential use as non-linear optical devices. In the surface plasmon resonance (SPR) absorption region, the material exhibits large optical nonlinearities and ultrafast time response.

We present formation of silver nanoclusters and measurements of the third order nonlinear refraction and absorption coefficients for ion implanted samples. Silver nanocluster formation in soda-lime glass was observed after irradiation and annealing by measuring light absorption in wide spectrum. The peak position and the bandwidth of the plasmon transition depend on the size and the form of the nanoparticles.

The Z-scan technique was used with ns laser pulses at wavelength of 532 nm to characterize the optical properties of the materials. It turns out that nonlinear absorption and refraction indices magnify significantly after nanocluster creation due to SPR. Among the mechanisms involved in the case of different samples, the Kerr-induced self-interaction, excited state saturation and multiphoton absorption play crucial roles in the variation of refractive indices and absorption of these media. Because determination of these parameters can be dependent on method of calculation proper fitting procedure and parameter initialization is also presented.

Future plans cover studies on interaction between laser light and nanoclusters in external electric field.

References

[1] K. L. Kelly et al., J. Phys. Chem. B 2003, 107, 668-677
[2] P. B. Chapple et al., J. Nonlinear Opt. Phys. Mat, Vol. 6, No. 3 (1997) 251-293
[3] H. C. van de Hulst, Light Scattering by Small Particles (Dover Publications, 1981)
[4] R. A. Ganeev, Appl. Phys. B 84, 295–302 (2006)

High Power UV and VUV excilamps and they applications

V. Tarasenko, S. Avdeev, M. Erofeev, M. Lomaev, E. Sosnin, V. Skakun, D. Shitz

High Current Electronics Institute, Tomsk, Russia
e-mail: VFT@loi.hcei.tsc.ru

In the present paper, the review of the basic results obtained at the Laboratory of Optical Radiation at High Current Electronics Institute SB RAS during 2007-2009 years is presented. Efficient radiation of Ar_2, Kr_2, Xe_2, KrBr*, KrCl*, XeI*, XeBr*, XeCl*, Cl_2* molecules and I atoms was obtained in rare gas or in rare gas - Br_2 (Cl_2, I_2) mixtures.

Study of radiation parameters and lifetime period of the manufactured barrier discharge excilamp has been performed. Average power of radiation for the just sealed off KrCl ($\lambda \sim 222$ nm) excilamp exceeded 100 W was obtained. UV output power of ~75 W and efficiency of 10 %, respectively, at $\lambda \sim 308$ nm (XeCl* excilamp) were obtained under excitation by pulses with frequency of 100 kHz. The lifetime of gas mixture in small XeCl* barrier discharge excilamps over 5000 hours was demonstrated. VUV output power of ~120 W at $\lambda \sim 172$ nm was obtained under excitation by pulses with frequency of ~100 kHz. Dynamics of discharge formation in KrCl excilamp has been studied. It has been shown that transition to stationary stage of discharge (in the form of separate microdischarges consisting from two cones with connected tops) takes place within one second as four stages with different discharge forms. Before formation of the stationary fourth stage of discharge, which has the highest efficiency of radiation, the spark stage of discharge is registered during which the bright branchy channels (sparks) are observed. It is supposed that discharge transition from spark to diffuse discharge is determined by formation of runaway electrons in the gap.

An efficient low-pressure sealed-off cylindrical excilamp with capacitive discharge excitation is under discussion. Investigation was carried out on the characteristics of XeCl ($\lambda \sim 308$ nm), XeBr ($\lambda \sim 282$ nm), KrCl ($\lambda \sim 222$ nm) and XeI ($\lambda \sim 253$ nm) capacitive discharge excilamps. High efficiency of exciplex molecules and simple design were obtained under capacitive HF discharge excitation. The lifetime of gas mixture in KrCl*, XeBr*, XeCl*, XeI* capacitive discharge excilamps over 3000 hours was demonstrated.

Investigations of radiation of inert gases with haloids excited by high voltage pulses was carried out in the operating mixtures pressure range of 60–750 Torr at various inert gas/halogen. The highest pulsed power densities of $KrCl^*$, $XeCl^*$, $XeBr^*$, and $KrBr^*$ molecules radiation were 3.7 kW/cm^2, 3.1 kW/cm^2, 4.5 kW/cm^2, and 2.1 kW/cm^2 at the efficiencies 5%, 4.8%, 5.5%, and 4%, respectively.

Work was supported by ISTC, project #3583p.

Spectra of Cr^{3+} eightfold coordinated in MeF_2 (Me=Ca, Cd, Sr, Ba)

N.M. Avram [1,2], A.E.Nikiforov[3] ,V.A.Chernyshev[3], C.N.Avram[1], M.Vaida[1], R.Nistora[1]

[1] *Department of Physics, West University of Timisoara, Bd. V. Parvan 4, Timisoara 300223, Romania*
[2] *Academy of Romanian Scientists ,Splaiul Independentei 54,Bucharest 050094,Romania*
[3] *Ural State University, Lenin Av 5, Yekaterinburg 620083,Russia*
e-mail: avram@physics.uvt.ro

Crystals with fluorite structure provide the possibility of investigating impurity ions in eightfold cubic coordination, when the ions are substituted on cation sites. In the present work we investigate, from theoretically point of view, the optical energy levels scheme of Cr^{3+} eightfold coordinated in fluorite-structure hosts MeF_2, with Me=Ca, Cd, Sr, Ba. We report on the detailed and consistent crystal field analysis of Cr^{3+} spectra in all crystals, which was performed in the framework of the exchange charge model [1] of crystal field (CF). Calculations of crystal field parameters (CFP) were performed, for all cases, using crystal structure data, after geometry optimization. Overlap integrals between wave functions of Cr^{3+} and Me^{2+}, were calculated like in [2] Diagonalization of the CF Hamiltonian resulted in getting complete energy level schemes of C^{r3+} ions in all crystals. The obtained energy levels and estimated Racah parameters *B* and *C,* during diagonalization, were compared with experimental data.[3].Interpretation of these spectra has been done assuming octahedrally coordinated Cr^{3+} centres $[CrF6]^{3-}$, with a small trigonal distortion, rather eightfold cubically coordinates.

The effective spin-Hamiltonian parameters (g-factors and D zero field splitting of ground state) have been calculated using the perturbation theory of Macfarlane. The results of the calculation agree with experimentally data and suggest a strong trigonally distortion of normally eightfold cubic coordination of the cation site in these crystals.

References

[1] B.Z. Malkin, in: A.A. Kaplianskii, B.F. Macfarlane (Eds), Spectroscopy of Solids Containing Rare-Earth Ions, North Holland, Amsterdam, 1987, pp.133.
[2] C. Rudowicz, M. G. Brik, N. M. Avram, Y. Y. Yeung and P. Gantek, J.Phys.: Condens. Matter. **18**, 5221 (2006).
[3] S. A. Payne, L .L. Chase, W.F. Krupke , J. Chem. Phys.,86,3455 (1987).

Lithium niobate crystals doped with iron by thermal diffusion: relation between lattice deformation and reduction degree

M.V. Ciampolillo, A.M. Zaltron, N. Argiolas, M. Bazzan, C. Sada

[1]*Department of Physics and CNISM, University of Padova, Italy*
e-mail:ciampolillo@padova.infm.it

Iron doped lithium niobate (Fe:LN) is a promising material for the realization of photorefractive devices of great interest for all – optical signal processing and optical memories [1]. The aim to integrate a photorefractive stage into a miniaturized optical circuit on the surface of a monolithic substrate addresses the doping by thermal diffusion from thin films as a way to locally increase the photorefractive effect. Since the Fe^{2+}/Fe^{3+} ratio plays a key role in determining the photorefractive response of the system, a study of the effect of a reduction treatment *at the surface* of the sample is of great importance. In this work we therefore report on the correlation between the compositional and structural properties of the iron doped $LiNbO_3$ crystals depending on the ratio Fe^{2+}/Fe^{3+} promoted within doped region by means of suitable annealing processes. In particular the Secondary Ion Mass Spectrometry (SIMS) technique and the high resolution X-ray diffraction (HR-XRD) are exploited to get the iron in-depth profiles and the strain within the doped region while the optical absorption measurements were used to estimate the Fe^{2+}/Fe^{3+} ratio.

Several samples of X-cut commercial congruent LN were covered with a thin iron film (10-15 nm) and thermally annealed at 900 – 1000°C for durations ranging between 8 – 10 h under a continuous oxygen flow. The thermal diffusion resulted in a doped region with semi-gaussian concentration profile of Fe extending for several micrometers from the surface. The reduction degree of those samples was subsequently modified by annealings at 500°C under Ar + H_2 flow with different durations in order to get different Fe^{2+}/Fe^{3+} ratios depending on the annealing time. The amount of Fe^{2+} was estimated by means of optical absorption [2], while the SIMS analysis allowed a quantitative measure of the Fe in-depth distribution. In particular the structural characterization, performed by HR-XRD, revealed the onset of a pseudomorphic layer with a negative normal strain i.e. a reduction of the interplanar spacing for the planes parallel to the surface. The strain at the surface depends linearly on the reduction degree and a quantitative relation linking the strain with the absolute concentration of Fe^{2+} and Fe^{3+} was consequently derived.

The present approach is indicated as a characterization technique for the measure of the Fe^{2+}/Fe^{3+} ratio in photorefractive Fe – doped surface layers in lithium niobate.

References

[1] G. C. Valley, M. B. Klein, R. A. Mullen, D. Rytz, B. Wechsler, Ann. Rev. Mater. Sci. 18, 165 (1988).
[2] D. Berben, K. Buse, S. Wevering, P. Herth, M. Imlau, Th. Woike, J. Appl. Phys. 87, 1034 (2000).

IC Resonant Absorption in Molecular Nanofilms

S.S. Pelemiš [1] , J.P. Šetrajčić [2,*], B.Markoski [3], N.V. Delić [2], S.M. Vučenović [4], D.Lj. Mirjanić [4,*]

[1]*Faculty of Technology Zvornik, University of East Sarajevo, Republic of Srpska – BiH*
[2]*Department of Physics, Faculty of Sciences, University of Novi Sad, Vojvodina – Serbia*
[3]*Technical Faculty Zrenjanin, University of Novi Sad, Vojvodina – Serbia*
[4]*Faculty of Medicine Banja Luka, University of Banja Luka, Republic of Srpska – BiH*
[*]*Academy of Sciences and Arts in Banja Luka, Republic of Srpska, BiH*
e-mail: alannica@gmail.com

The optical properties changes in consequence of boundary existence in nanofilm molecular crystals were theoretically investigated in the paper. Starting exciton Hamiltonian is in the boson harmonic approximation [1, 2]:

$$H = \sum_{\vec{n}} \Delta_{\vec{n}} B_{\vec{n}}^{+} B_{\vec{n}} + \sum_{\vec{n},\vec{m}} X_{\vec{n}\vec{m}} B_{\vec{n}}^{+} B_{\vec{m}} \quad , \qquad (1)$$

with boundary conditions:

$$\Delta_{\vec{n}} \equiv \Delta \left[1 + d\left(\delta_{n_z,0} + \delta_{n_z,N}\right)\right];$$
$$X_{\vec{n},\vec{n}+\vec{\lambda}} \equiv X \left[1 + x\left(\delta_{n_z,0} + \delta_{n_z,N-1}\right)\right]; \quad X_{\vec{n},\vec{n}-\vec{\lambda}} \equiv X \left[1 + x\left(\delta_{n_z,1} + \delta_{n_z,N}\right)\right], \qquad (2)$$

Energy spectra (Fig.1, for example) and possible states of excitons and their space distribution through direction perpendicular to boundary surfaces were founded by analytical and numerical calculations, using Green's function method [3].
The relative permittivity (Fig.2, for example) of these ultrathin dielectric films is determined [2–4] and influence of boundary parameters on appearance of discrete (by frequencies) and selective (by layers) absorption was analyzed.
It is seen the selective resonant peaks on strictly defined frequencies appear in separated layers.

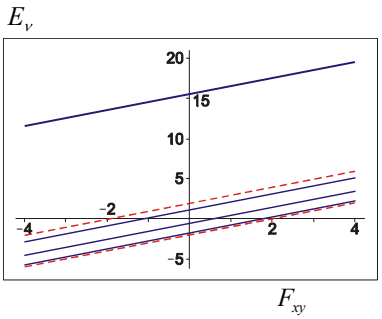
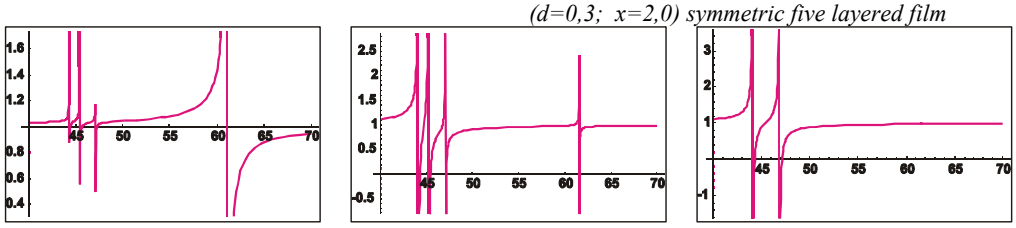


Fig.1 – Exciton dispersion law of strong perturbed (d=0,3; x=2,0) symmetric five layered film



n_z= 0 i 4; d = 0,3; x = 2,0 n_z= 1 i 3; d = 0,3; x = 2,0 n_z= 2; d = 0,3; x = 2,0

Fig.2- Relative permittivity of strong perturbed symmetric five layered film

References:
[1] V.M.Agranovich and V.L.Ginzburg: Crystaloptics with Space Dispersion and Theory of Excitons, *Nauka*, Moskwa 1979.
[2] S.M.Vučenović, J.P.Šetrajčić, S.S.Pelemiš, B.S.Tošić and D.Lj.Mirjanić: Dielectric Properties of Molecular Crystalline Films, *Proceedings of 24th Conference on Microelectronics* (Niš, May 16-19, 2004) **1**, 279 (2004).
[3] J.P.Šetrajčić, D.I.Ilić, B.Markoski, A.J.Šetrajčić, S.M.Vučenović, D.Lj.Mirjanić, B.Škipina, and S.S.Pelemiš: Adapting and Application of the Green's Functions Method onto Research of the Molecular Ultrathin Film Optical Properties, *Physica Scripta* – accepted (2009).
[4] I.E.Dzialoshinski and L.P.Pitaevski, *Zh.eksper.teor.Fiz.* **36**, 1977 (1959).

Dispersion properties of optical polymers

N. Sultanova[1], S. Kasarova[1] and I. Nikolov[2]

[1]*Department of Physics,*
University "Assen Zlatarov" – Bourgas, Bulgaria
[2]*Department of Optics and Spectroscopy, Faculty of Physics,*
University of Sofia, Bulgaria
e-mail: kasarova_st@yahoo.com

Refractive indices of different types of optical polymers (OPs) including more than twenty sample materials have been measured in the visible (VIS) and near infrared spectral (NIR) regions. We have used the Pulfrich refractometer with the V-type prism at its standard spectral lines and a goniometric set-up [1] for selected wavelengths in the region between 400 and 1060 nm. A He-Ne laser has been also applied [2]. The estimated accuracy of measuring results was better than ±0.001, though a nonlinear dependence of the refractive index deviation with the wavelength was registered.

Dispersion coefficients of the examined OPs have been calculated by means of our developed OptiColor program based on the Cauchy – Schott dispersive equation. A comparison with Sellmeier's approximation has been also accomplished [3]. Dispersion charts of various OPs were generated in the considered spectral region.

In this report dispersion properties of the examined polymers are discussed. A number of comparative dispersion curves are presented. A comparison with some optical glasses with similar refraction at the d- and e-lines is performed. Schott glasses [4] have been selected as test materials such as N-BK10 for PMMA and Polyacrilate, N-SK5 for PC and PS plastics, N-BAK4 for SAN and NAS copolymers, etc. The nonlinear dependence of $dn/d\lambda$ of OPs and test glasses with the wavelength is calculated and analyzed. Normalized dispersion curves at 550 nm and 880 nm are presented to illustrate better the dispersion properties of the examined OPs in the VIS and NIR spectral regions, separately. Abbe numbers are calculated to exhibit the mean and partial dispersion.

The presented refractive and dispersive characteristics of the examined OPs could be useful for optical manufacturers and designers.

References

[1] N. Sultanova, I. Nikolov, C. Ivanov, Opt. and Quant. Electron. 35, 21 (2003).
[2] I. Nikolov, N. Sultanova, S. Kasarova, Proc. SPIE 5830, 511 (2005).
[3] S. Kasarova, N. Sultanova, C. Ivanov, I. Nikolov, Opt. Mat. 29, 1481 (2007).
[4] http://www.us.schott.com/.

Nonlinear Responses and Optical Properties Modification of SK3 under Irradiation of Femtosecond Laser Pulses

Kazem Jamshidi-Ghaleh [1], Hosain Masalehdan [2]

[1,2] *Department of Physics Engineering (Optics-Laser), Bonab Islamic Azad Universict*

[1] *Departmant of Physics, Azarbaijan University of Tarbiat Moallem*

e-mail: k-jamshidi@azaruniv.edu

ABSTRACT

In this paper, the nonlinear responses and optical properties modification of SK3 glass sample are investigated. The nonlinear responses measurement were performed by using of the z-scan and nonlinear transmission monitoring of 200-femtosecond at 800 nm laser pulses. The optical power limiting threshold is measured to be 35 mJ/cm^2. The decrease of transmitted intensity is about 65% compared to the theoretical linear transmission for incident pulse energies of 300 mJ/cm^2.

For prediction of the experimental nonlinear behavior results, a theoretical model based on three-photon absorption and absorption of free-carriers is presented. By fitting of experimental results with theoretical model, three-photon absorption coefficient and free-carrier absorption cross-section are reported.

The photo-induced modifications of optical properties are observed blow breaking threshold intensity and as a darkening. To investigation of modification sizes, the laser pulse energy accumulation model is applied.

Aberrations of betanin sensitized gelatin microlenses

D. Vasiljević[1], B. Murić[1], D. Pantelić[1], B. Panić[1]

[1]*Laboratory for optics and lasers, Institute of Physics*
University of Belgrade, Serbia
e-mail:darko@phy.bg.ac.rs

Micro optics is fast expanding field [1, 2]. In our previous papers we have been producing microlenses on various types of sensitized gelatin [3 – 5]. There is an increasing interest in the use of natural food pigments instead of synthetics. Betanin as natural, water soluble pigment, from red beet roots (as a commercially available food dye -E 162), was applied to sensitize gelatin. It has a maximum absorption at 535 nm. The betanin-sensitized gelatin film deposited on microscope glass plate, was used as material for microlens fabrication. The material is cheap, nonpoisonous and photosensitive in the green part of spectrum. Microlenses (individual or array) were produced by direct laser writing. The second harmonic Nd:YAG laser (532 nm) was used as a light source. Produced microlenses stay stable without additional chemical processing.

Aspheric concave microlenses were created. For the purpose of ray tracing and analysis microlens are approximated by one even asphere surface and one flat surface [3]. The microlens imaging properties are analyzed by the RMS wave aberration and the spot diagram.

Produced microlenses had the effective focal length from 0.08 mm to 0.17 mm and the numerical aperture from 0.53 to 0.28. All produced microlenses had good imaging characteristics.

References

[1] Ph. Nussbaum, R. Völkely, H. P. Herzig, M. Eisner and S. Haselbeck, Pure Appl. Opt. **6,** 617–636 (1997).
[2] T.R.M. Sales, S. Chakmakjian, G. M. Morris and D. J. Schertler, Photonics Spectra **38,** 58-65 (2004).
[3] D. Vasiljević, B. Murić, D. Pantelić, B. Panić, *ACTA PHYSICA POLONICA A,* Vol. 112 (2007), No. 5, p. 993 – 999.
[4] B. Murić, D. Pantelić, D. Vasiljević, B. Panić, *APPLIED OPTICS,* Vol. 46 (2007), No. 35, p. 8527 – 8532.
[5] B. Murić, D. Pantelić, D. Vasiljević, B. Panić, *OPTICAL MATERIALS*, Vol. 30 (2008), pp.1217 – 1220.

Field induced singlet exciton dissociation and exciton-exciton annihilation in MEH-PPV films studied by photocurrent spectra

J. Petrović[1], P. Matavulj[1] L. Pinto[2] and S. Živanović Šelmić[2]

[1]*School of Electrical Engineering,*
University of Belgrade, Serbia
[2]*Institute for Micromanufacturing, Louisiana Tech University, Ruston, LA 71272, USA*
e-mail: jovana@etf.rs

In this paper we investigate different processes which lead to charge carrier generation in ITO/PEDOT:PSS/MEH-PPV/Al photodetector. Primary photogenerated singlet excitons contribute the photocurrent directly through dissociation on the electrodes. Singlet exciton distribution in the active area of the photodetector is calculated on the base of continuity equation including exciton generation, diffusion and recombination. Depending on the applied electric field and incident photon flux secondary charge carrier generation processes appear in the active MEH-PPV film. Two balk charge generation mechanisms are considered. Nonlinear recombination of excitons through exciton-exciton annihilation leads to electron and hole polaron generation. Exciton states are depopulated, also, by exciton dissociation in the presence of high electric field. We assume hole polarons to be majority carriers. Polaron contribution to photocurrent is calculated by solving the continuity and drift-diffusion equations for these carriers. Photocurrent spectra are measured for different bias voltages and different incident photon flux intensities. Good agreement between experimental and simulated data confirms our theoretical approach.

References

[1] A. J. Levis, A. Ruseckas, O. P. M. Gaudin, G. R. Webster, P. L. Burn, I. D. W. Samuel, Organic Electronics, 7, 452 (2006),
[2] B. Kraabel, V. I. Klimov, R. Kohlman, S. Xu, H-L. Wang, and D. W. McBranch, Physical Review B, 61, 8501 (2000),
[3] V. I. Arkhipov, H. Bassler, M. Deussen, E. O. Gobel, R. Kersting, H. Kurz, U. Lemmer, R. F. Mahrt, Physical Review B, 52, 4932 (1995),
[4] J. Petrović, P. Matavulj, D. Qi, D. K. Chambers, S. Šelmić, IEEE Photonics Technology Letters, 20, 348 (2008)..

Multi-color emission in quantum-dot-quantum-well semiconductor heteronanocrystals

R. Kostić and D. Stojanović

University of Belgrade, Institute of Physics, Center for Solid State Physics and New Materials, P. O. Box 68, 11080 Belgrade, Serbia
E-mail: rkostic@phy.bg.ac.yu

We present our calculation results of multi-color spontaneous emission from quantum-dot-quantum-well semiconductor heteronanoctystals. Our theoretical results explaine experimental results of onion like spherical system similar to: CdSe (core), ZnS (shell), CdSe (shell) spherical quantum dots surrounded by ZnS. By alternating of the shells thickness and composition (shells are not of pure ZnS and CdSe composition) we demonstrate influence of the shell composition, beside shell thickness, to exciton localization in distinct layers of heteronanoctystals. Multi-color emission of such heterosystem is determinated by n=1 states in CdSe core and n=2 states in CdSe shell.

References
[1] D Battaglia, B. Blackman, X. Peng, J. Am. Chem. Soc. 127, 10889 (2005).
[2] S. Nizamoglu, H. V. Demir, Optics express 16, 3515 (2008).

Optical characterization of laser-synthesized anatase TiO_2 nanopowders by spectroscopic ellipsometry and photoluminescence measurements

M. Šćepanović, M. Mirić, M. Grujić-Brojčin, Z. Dohčević-Mitrović, and Z. V. Popović

Center for Solid State Physics and New Materials, Institute of Physics, Belgrade, Serbia
e-mail: maja@phy.bg.ac.rs

Nanosized titania (TiO_2) is synthesized by laser-induced pyrolysis using $TiCl_4$ as a liquid precursor. The specific surface area of as-produced nanopowders is measured by the BET method. The X-ray diffraction and Raman scattering confirmed the anatase structure of TiO_2 nanocrystals [1].

The ellipsometric data were recorded in the energy range from 1.5 to 6 eV at room temperature in air. To interpret the experimental results, a model based on a generalized Bruggeman effective medium approximation of a dielectric function has been proposed. It is based on the polycrystalline character of TiO_2 nanoparticles including island-structure and porosity of the nanopowders [2], along with the anatase single crystal dielectric functions [3]. Thus, by comparing the calculated and experimental results, the values of microscopic parameters of nanocrystalline powders can be deduced.

Photoluminescence (PL) measurements have been carried out at temperatures between 20 and 300 K in vacuum. Under laser irradiation with photon energy of 2.71 eV anatase nanocrystals displayed strong visible light emission, even at excitation power as low as 0.05 W/cm^2. The PL spectra of anatase nanopowders are attributed to 3 kinds of physical origins: self-trapped excitons (STE), surface states and oxygen vacancies. The supremacy among these effects mainly depends on the synthesis condition [4], and reflects on the variation of the line shape and position of broad PL band with the temperature. The domination of STE luminescence in PL spectra of anatase nanopowder leads to significant PL shift towards lower energies as the temperature decreases. However, in nanopowder with dominant influence of recombination via intrinsic surface states, PL shift with temperature decrease is less pronounced.

This study represents an attempt to understand optical properties of anatase nanocrystals, related to band-to-band transitions, as well as the electronic transitions mediated by defect levels within the band gap.

References

[1] M. J. Šćepanović, M. U. Grujić-Brojčin, Z. D. Dohčević-Mitrović, and Z. V. Popović, Materials Science Forum 518, 101 (2006).
[2] M. Grujić-Brojčin, M. J. Šćepanović, Z. D. Dohčević-Mitrović, I. Hinić, B. Matović, G. Stanišić and Z. V. Popović, J. Phys. D: Appl. Phys. 38, 1415 (2005).
[3] N. Hosaka, T. Sekiya, C. Satoko, and S. Kurita, J. Phys. Soc. Jpn. 66(3), 877 (1997).
[4] M. Šćepanović, Z. D. Dohčević-Mitrović, I. Hinić, M. Grujić-Brojčin, G. Stanišić, and Z. V. Popović, Mat. Sci. Forum 494, 265 (2005).

The patterns of the optical excitonic effect in type-I nanorings

M. Tadić,[1] V. Arsoski,[1] N. Čukarić,[1] and F. M. Peeters[2]

[1]*Faculty of Electrical Engineering,*
University of Belgrade, P.O. Box 35-54, Belgrade 11120, Serbia
[2]*Department of Physics, University of Antwerp, Groenenborgerlaan 171, B-2020 Antwerp, Belgium*
e-mail: tadic@etf.bg.ac.rs

We investigate the dependence of the oscillator strength for the exciton recombination in the type-I (In,Ga)As/GaAs nanorings. The effective mass model is employed to compute the electron states, while the strain distribution, which modifies the confinement potentials for the electron and the hole, is extracted from the continuum mechanical model. The appearance of the optical excitonic Aharanov-Bohm oscillations is found in both nanorings. The oscillator strength is found to exhibit sharp deeps, which correspond to crossings between different exciton states of the $L = 0$ orbital momentum. No full transitions from bright to dark exciton states is found. The dependence of the oscillator strength on the magnetic field is strongly size dependent. For small rings, the oscillator strength increases linearly with the magnetic field, with the deeps evenly distributed. On the other hand, the deeps of the oscillator strength in large rings appear at crossings of the parabolas corresponding to different exciton states of the zero orbital momentum.

References

[1] M. Tadić and F. M. Peeters, Phys. Rev. B **79**, 153305 (2009).
[2] A. O. Govorov, S. E. Ulloa, K. Karrai, and R. J. Warburton, Phys. Rev. B **66**, 081309 (2002).

Engineering and advanced digitalization of photonic structures with bound field in the continuum

N. Prodanović, V. Milanović and J. Radovanović

School of Electrical Engineering, University of Belgrade, Serbia
e-mail: *radovanovic@etf.bg.ac.rs*

We describe a method for generation of complex optical potentials which support a bound state of the electric field in continuous part of the spectrum. It is based on deep analogy between quantum mechanical and electromagnetic phenomena [1,2] and relies on the application of supersymmetric (SUSY) quantum mechanics [3,4] to generate a smoothly varying complex optical potential, together with the corresponding electric field function for the (singular) localized state. However, the obtained potential profile is generally a strongly oscillating function which requires additional processing to make it suitable for practical realization. With this goal in mind, i.e. the construction of a realizable photonic crystal with complex permittivity which supports one bound state in continuum, we have developed an original scheme of digital grading [5,6]. It approximates the values of the complex relative permittivity in such manner that the final structure may be realized by assembling the layers of homogeneous materials.

References

[1] E. N. Bulgakov, A. F. Sadreev, Phys. Rev. B 78, 075105 (2008).
[2] D. C. Marinica, A. G. Borisov, S. V. Shabanov Phys. Rev. Lett. 100, 183902 (2008).
[3] J. Pappademos, U. Sukhatme, A. Pagnamenta, Phys. Rev. A 48, 352535 (1993).
[4] J. S. Petrovic, V. Milanovic, Z. Ikonic, Phys. Lett. A 300, 595 (2002).
[5] S .Vlaev, F . Garcia-Moliner, V. R. Velasco, Phys. Rev. B 52, 13784 (1995).
[6] J. H. Lee, S. S. Li, M. Z. Tidrow, W. K. Liu, K. Bacher, Appl. Phys. Lett. 75, 3207, (1999).

Surface modification of metallic targets with ultrashort laser pulses

B. Gakovic[1], J. Stasic[1], S. Petrovic[1], B. Radak[1], A. Krmpot[2], B. Jelenkovic[2], M. Trtica[1]

[1]*Institute of Nuclear Sciences "Vinca"*
Belgrade, Serbia
[2]*Institute of Physics*
Belgrade, Serbia
e-mail: jelsta@vinca.rs

Interaction of pulsed Ti:sapphire laser, operating at high repetition rate, with nickel-based superalloy Inconel 600 and WTi thin film (deposited in silicon) was studied. Laser was emitting ultrashort pulses of 160 fs duration at 800 nm, while the repetition rate was 75 MHz. Low laser fluence regime of maximum 50 mJ/cm^2, for short (10 seconds) and long irradiation times (minutes), was used for the surface modifications studied. The radiation absorbed from the laser beam, under these conditions, generates at the surface a series of effects, such as direct material vaporization, plasma creation, formation of clusters, etc. Morphological modifications of the targets can be summarized as: (a) intensive removal of surface material and appearance of crater like forms; (b) creation of nano-structures, especially clusters, at the outer periphery; (c) sporadic occurence of microcracking and; (d) plasma appearance in front of the target. Ablation of Inconel 600 target surface is effective, resulting in formation of holes with small diameter ($\leq$ 10 μm) and relatively large depth ($\leq$ 150 μm). In case of WTi thin film, the surrounding rim is not so expressed, and crater depths are lower. Generally, it can be concluded that the average laser power of the order of watts (pulse energies of the order of nJ and high repetition rates in MHz range), as in our case, can successfully modify metallic materials.

References

[1] B. Tan, S. Panchatsharam, K. Venkatakrishnan, J. Phys. D: Appl. Phys. 42, 065102-1 (2009).
[2] E. G. Gamaly, A. V. Rode, B. Luther-Davies, V. T. Tikhonchuk, Phys. Plasm. 9, 949 (2002).

Hydrothermal synthesis of CeO_2 and $Ce_{0.9}Fe_{0.1}O_2$ nanocrystals

M. Radović[1], Z. D. Dohčević-Mitrović[1], A. Golubović[1], B. Matović[2], M. Šćepanović[1] and Z. V. Popović[1]

[1]*Institute of Physics, Center for Solid State Physics and new Materials*
Belgrade, Serbia
[2]*Institute of Nuclear Sciences Vinca*
Belgrade, Serbia
e-mail:marrad@phy.bg.ac.rs

Ceria as a material with relatively high dielectric constant attracted renewed interest as a capacitor dielectric in dynamic random access memories (DRAMs) and as resistive oxygen sensor [1]. It is a potential electrolyte for intermediate temperature solid oxide fuel cells (ITSOFCs) and recently it becomes a promising material for the second generation of spintronics due to the observed room- temperature ferromagnetism [2, 3].

Pure and 10 mol% Fe^{3+} doped CeO_2 nanopowders were synthesized by hydrothermal method in two different alkali solutions (NH_4OH and NaOH). Samples were calcinated at 140 and 200°C. The characterization of crystalline structure, vibrational and optical properties was performed using X-ray diffraction, Raman spectroscopy and spectroscopic ellipsometry. Obtained results showed that the Fe-doped samples are solid solutions with different size of nanocrystals, very dependent on the synthesis temperature and type of alkali solution. Raman measurements demonstrated electron molecular vibrational coupling and increase of oxygen vacancy concentration whereas doping provokes a small decrease of optical absorption edge in comparison with pure ceria.

References

[1] N. Izu, W. Shin, I. Matsubara, N. Murayama, Sens. Actuators B 94, 222 (2003)
[2] T. Matsui, M. Inaba, A. Mineshige, Z. Ogumi, Solid State Ion. 176, 647 (2005)
[3] Q. Y. Wen, H. W. Zhang, Y. Q. Song, Q. H. Yang, H. Zhu and J. Q. Xiao, J. Phys.: Condens. Matter 19, 246205 (2007)

Laser interaction with material – theory, experiments and discrepancies

M. Sreckovic[1], J. Ilic[2], M. Davidovic[3], B. Djokic[4], Z. Tomic[5], Z. Latinovic[1], D. Druzijanic[1]
[1]*Faculty of Electrical Engineering,* [2]*Faculty of Mechanical Engineering,* [3]*Faculty of Civil Engineering, University of Belgrade, Serbia,* [4]*Educon, Nova Varos, Serbia,* [5]*Iritel, Belgrade, Serbia*
e-mail: milena@grf.bg.ac.yu

Numerous approaches to interaction of laser beams with a material should be constantly updated, due to the development of new types of lasers ranging from cw lasers to atto-second pulse lasers, which used to be considered as pulses beyond the theoretical frontier. Apart from the models developed directly for the particular ranges of pulse durations, various laser dynamics, power densities and materials required new approaches. The possibility that with the highest power densities, regardless the treated material, lasers produce explosive and total disintegration processes, should not be discarded. At lower power densities, of greater importance are other factors not expressed by the crucial optical and thermodynamic properties of treated materials (thermal conductivity, density, specific heat, coefficients of reflection and absorption).

Detailed analyses of laser – mater interaction require application of numerical methods. Specific approach is modeling of general statistics that involve fluctuations of a beam (polarization, power, pulse energy) and appropriate mathematical functions that express specific fluctuations.

There were attempts to explain the discrepancies between the experimental and theoretical LIDT (laser induced damage threshold) values by the prehistory of a material and its impurities. That led to the parallel development of models based on damage threshold, dielectric breakdown, Brillouin threshold, self-focusing, thermal lenses, thermal breakdown, etc.

The field of pulse compression concerning refraction indices and their increments (partial derivatives) is important for nonlinear electro-optic and electromagnetic processes, and it is developed separately.

The tendencies to explain the discrepancies between the theory and experiments by general approaches, involving the statistics of the phenomena, appeared recently. These theories include in the same model pure materials as well as the influence of impurities. The right choice of the statistical function proved to be the solution. Thus, using the statistics of binomial and Poisson type seem to give good explanation of the causes of the discrepancies.

In this paper, for the chosen materials, including pure metals and composites, the performed experiments and results of the exposures of materials to the laser beams of various regimes are analyzed. For the specific cases, numerical estimations of the distributions of temperatures and provoked stresses will be performed. The programs typically used in electric circuit analysis - here applied in analysis of mechanical disturbances caused by laser-mater interaction, will be implemented. Some available programs for the study of the provoked damages on the optical components and accessories along the pulse propagation path will be analyzed.

The estimations of the nonlinear constants of the materials and expected dependencies to be taken into account in general thermal and other equations involving linear and nonlinear parts of the used parameters will be given. The attention will be paid to the new categories of the discrepancies i.e. the gap between the theory and the results obtained on bulk material (exposed to the laser beam) and the analysis of ejected material. Some novel problems include the interpretation of the relation between the regime of the pulses and damages (single or cumulative effects). Apart from “standard” techniques such as microscopy, micro-hardness etc. results obtained by image processing will be analyzed. This way, the energy distribution of the laser beam and its multimode structure will be obtained or confirmed.

References

[1] M.Sreckovic et al, Acta Phys. Polonica A 112, 935 (2007).
[2] M. Srećković et al. Proceedings LASERS 2001, 201 (2002).

Optical properties of Y_2O_3: Eu^{3+} red emitting phosphor obtained via spray pyrolysis

Ž. Antić,* R. Krsmanović, V. Đorđević, T. Dramićanin and Miroslav. D. Dramićanin

Vinča Institute of Nuclear Sciences, P.O.Box 522, Belgrade, Serbia
*e-mail: zeljkaa@gmail.com

Spray pyrolysis is an aerosol process commonly used as a synthesis technique providing a wide variety of materials in powder form including metals, metal oxides, ceramics, superconductors and fullerenes [1, 2].

Europium-doped yttrium oxide (Y_2O_3:Eu^{3+}) is considered to be one of the best red emitting inorganic phosphors, due to the sharp emission (λ_{ems} = 611 nm) of the europium ions, excellent luminescence efficiency, color purity and stability [3]. Among various synthesis procedures, spray pyrolysis is a promising alternative process for its large-scale production in a form of micron and sub-micron size spherical particles [4].

In the present work we explored the possibility of obtaining Y_2O_3: Eu^{3+} micron-size particles by an ultrasonic spray pyrolysis method, starting from yttrium and europium nitrate solutions. Morphology and crystallinity of the as-prepared and thermally processed samples were investigated using scanning electron microscopy and x-ray diffraction analysis. As-prepared sample constitutes of spherical, hollow particles with an average size of 1 to 2 μm but yet the pure cubic Y_2O_3 is not formed. Therefore sample was additionally thermally treated for 2 hours at 800°C resulting in a pure phase and well crystalline, cubic Y_2O_3 powder. Detail optical investigation has been done by photoluminescence spectroscopy measurements in the energy and time domains. In particular we analyzed $^5D_0 \rightarrow {}^7F_J$ spin forbidden f-f transitions and emission kinetics. Also we analyzed the asymmetry ratio of the integrated intensity of the $^5D_0 \rightarrow {}^7F_2$ and $^5D_0 \rightarrow {}^7F_1$ transitions to find asymmetry of the coordination environment around the Eu^{3+} ion. For the same purpose we measured the splitting of Stark components of the $^7F_1$ manifold induced by crystal field.

References

[1] A. Gurav, T. Kodas, T. Pluym, Y. Xiong, Aerosol Sci. Technol. 19, 411 (1993).
[2] S.E. Pratsinis, S. Vemury, Powder Technol. 88, 267 (1996).
[3] C.R. Ronda, J. Lumin. 72–74, 49 (1997).
[4] Y.C. Kang, S.B. Park, I.W. Lenggoro, K. Okuyama, J. Mater. Res. 14-6, 2611 (1999).

High pressure optical studies of α–$ZnAl_2S_4:Cr^{3+}$

B. R. Jovanić[1], I. Broussell[2], B. Panić[1], B. Radenković[3], M. Despotović[3]

[1]*Institute of Physics, Belgrade, P.O.Box 68, 11080 Zemun, Serbia.*
[2]*Department of Physics, University of Ottawa, Ottawa, ON KIN 6N5, Canada.*
[3]*Faculty of Organization Science,University of Belgrade, Jove Ilića 154, 11000 Belgrade, Serbia.*
e-mail: brana@phy.bg.ac.rs

The effect of hydrostatic pressure at room temperature on the emission spectra and fluorescence lifetime τ of the R1 line in tiospinel (α-$ZnAl_2S_4$) crystal has been studied. Research was carried out in the interval between 0 and 91 kbar. On the basis of the position of the R1 line ($^2E \rightarrow {}^4A_2$ transition) in the emission spectrum, we have concluded that pressure induces red-shift. The significance change in τ with pressure has also been noticed. The change of λ and τ induced by pressure was explained by a simple model. A good correlation between theoretical and experimental values of λ and τ within the pressure interval in question has been achieved.

References

[1] I. Bruoussell, E. Fortin, L. Kulyuk, S. Popov, Sol. Stat. Comm. 99, 921 (1996).
[2] B. R. Jovanić, B. Viana, M. Dramićanin, B. M. Panić, B. Radenković, Opt. Materials 30, 1070 (2008).

Fishnet-based metamaterials: spectral tuning through adsorption mechanism

Z. Jakšić[1], D. Tanasković[1] and J. Matovic[2]

[1]*Institute Microelectronic Technologies and Single Crystals,*
IHTM – Institute of Chemistry, Technology and Metallurgy, Belgrade, Serbia
[2] *Institute for Sensor and Actuator Systems ISAS, Vienna University of Technology, Vienna, Austria*
e-mail:jaksa@nanosys.ihtm.bg.ac.rs

Since their practical introduction, metamaterials with negative effective refractive index (NRM), also known as left-handed metamaterials, have attracted large attention [1]. They may be described as artificial metal-dielectric (nano)composites with electromagnetic properties not readily found in nature. Among the various designs proposed for such materials in the optical range, probably the best performance to date has been achieved utilizing the fishnet structure [2].

A unit cell of a fishnet metamaterial consists of two square metal sheets in the xy plane divided by a dielectric layer along the z direction. The sheets are discontinued at each edge of the square. Each metal sheet is thus basically a superposition of a thin wire along the y direction and a short slab along the x direction. If a large number of such unit cells is observed simultaneously, the structure has an appearance of a fishnet, where the discontinuities at the edges are the fishnet holes. These holes may be rectangular, but also circular or ellipsoidal.

The main advantage of the fishnet structure is its ability to generate left-handed response for a light beam incident perpendicularly to the xy plane. In this manner one obtains a strong left-handed response using a single metal-dielectric-metal structure.

In this work we analyzed the behavior of fishnet NRM in presence of various dielectric analytes adsorbed to their surfaces. It is known that most of the NRM are strongly resonant and their properties are thus very sensitive to even small variations of their geometrical and structural parameters. The tunability of their spectral transmission and reflection due to adsorption of nm-thin dielectric layer has been described in [3]. This property has a direct practical interest in the use of NRM for all-optical sensors of various chemical or biological analytes. In addition to that, any resonant metal-dielectric nanocomposite will have its properties strongly modified by adsorption and it is thus of general interest to know the extent of such changes for NRM in a given environment.

We simulated the electromagnetic response of the fishnet NRM for the optical range utilizing the finite element method. We analyzed the influence of the adsorption of various fluids, including some known pollutants. Our considerations include laminated structures (metal-dielectric-metal sandwiches with nanometric thickness). The basic building block of such structures are metallic or metal-composite freestanding nanomembranes with large aspect ratio, the structures experimentally fabricated by our team [4]. The fishnet patterning of the structures can be done by the focused-ion-beam method [5]. Strong modification of the spectral reflectance of the NRM is a consequence of its resonant nature and of the fact that effective change of dielectric parameters due to surface adsorption increases for such ultrathin structures. We believe our analysis is useful for label-free, high sensitivity all-optical sensing but also for the investigation of general behavior of optical metamaterials in real environments.

References

[1] C. M. Soukoulis, M. Kafesaki, E. N. Economou, Adv. Mat. 18 (15), pp. 1941-1952, 2006
[2] M. Kafesaki, I. Tsiapa, N. Katsarakis, Th. Koschny, C. M. Soukoulis, E. N. Economou, Phys. Rev. B 75, 235114 (2007).
[3] Z. Jakšić, O. Jakšić, Z. Djurić, C. Kment, *J. Opt. A: Pure Appl. Opt.* **9**, S377 (2007).
[4] J. Matović, Z. Jakšić, Microel. Eng., in press, [doi:10.1016/j.mee.2008.12.009], 2009.
[5] J. Matović, J. Kettle, E. Brousseau, N Adamovic, Proc. 26th IEEE Conf. on Microelectronics MIEL, vol. 1, 104 (2008).

Vacuum fluctuations in optical metamaterials containing nonlinear dielectrics

Z. Jakšić[1], S. Ostojić[2], D. Tanasković[2] and J. Matović[3]

[1]*Institute Microelectronic Technologies and Single Crystals, IHTM – Institute of Chemistry, Technology and Metallurgy, University of Belgrade, Serbia*
[2]*Faculty of Technology and Metallurgy, Belgrade, Serbia*
[3]*Institute for Sensor and Actuator Systems ISAS, Vienna University of Technology, Vienna, Austria*
e-mail:jaksa@nanosys.ihtm.bg.ac.rs

We investigated the influence of zero-point fluctuations (vacuum fluctuations, optical quantum noise) to the optical response of electromagnetic metamaterials containing dielectrics with third order Kerr-like nonlinearity.

Optical metamaterials may be described as artificial metal-dielectric nanocomposites with optical response not readily found in nature (whence the prefix "meta-"), typically based on the propagation of plasmon modes. The presence of plasmons in such structures results in extreme electromagnetic field localizations and enhancements, which promotes nonlinear optical effects.

Smolyaninov [1] described the modification of the properties of the nonlinear dielectrics near the metal interface by the zero-point fluctuations in the vacuum state [2] of the surface plasmons. The spatial locations of the peaks of the evanescent plasmon field and of the vacuum fluctuations coincide, both being largest at the metal-dielectric interface and exponentially decreasing away from the interface. This has been denoted as an optical analogue of the "heated highway effect" [1].

The effect is especially important for the surface plasmon polariton-based chemical, biochemical and biological sensors, where analyte molecules are very often strongly nonlinear, thus contributing an additional intrinsic noise component in device readout. Such sensors are already among the most sensitive devices for label-free biosensing. On the other hand, metamaterial-based devices represent a generalization of such devices and offer further performance enhancements and additional design freedoms [3, 4]. Due to their strongly resonant character and extreme field localizations, the properties of such systems will be especially sensitive to any fluctuations of their properties [5].

In our work we determined the zero-point noise and calculated it for different analytes, including those used in forensic analysis and organic pollutants. The zero-point noise level is highest for shortest-wavelength plasmons and decreases towards long-range plasmons. It may be tailored through a convenient design of the metamaterial structure. Since noise spectral power is proportional to the nonlinearity of the analyte species present, we considered the possibility to use zero-point noise as an auxiliary tool for identification of targeted nonlinear samples. We believe our investigation could be of importance in homeland defence, forensics, biomedical characterization, etc.

References

[1] I. I. Smolyaninov, *Phys. Rev. Lett*. 94, 057403 (2005).
[2] P. W. Milloni, *The Quantum Vacuum*, Academic Press (1994).
[3] Z. Jakšić, O. Jakšić, Z. Djurić, C. Kment, *J. Opt. A: Pure Appl. Opt.* **9**, S377 (2007).
[4] C. M. Bingham, H. Tao, X. Liu, R. D. Averitt, X. Zhang, W. J. Padilla, Opt. Expr. 16, 18565 (2008).
[5] Z. Jakšić, O. Jakšić, J. Matović, J. Nanophot. 3, 031770 (2009).

Modelling the variable angle reection and transmission from metamaterial slabs

G. Isić[1,2], B. Vasić[1], M. Mirić[1], B. Jokanović[3], I. Bergmair[4], R. Gajić[1] and K. Hingerl[5]

[1]*Institute of Physics, Belgrade, Serbia*
[2]*School of Electronic and Electrical Engineering, University of Leeds, United Kingdom*
[3]*IMTEL Communications A.D., Belgrade, Serbia*
[4]*Profactor GmbH, Functional Surfaces and Nanostructures, Steyr-Gleink, Austria*
[5]*Zentrum fur Oberachen- und Nanoanalytik, Universitat Linz, Austria*
e-mail:isicg@phy.bg.ac.rs

The established method for extracting effective metamaterial parameters is by the use of S-parameters calculated or measured for perpendicular incidence. It is suited for RF and microwave frequencies where both the transmission/reection amplitude and phase are readily measured and inverted to give the refractive index and wave impedance or the effective permittivity ε_{eff} and permeability μ_{eff}.

At higher frequencies, where it is hard to measure the phase, variable angle ellipsometric measurements are a promising tool for metamaterial characterization. So far, little work has been done in interpreting oblique angle reection and transmission measurements of metamaterial slabs [1]. For oblique incident angles the effective parameter retrieval is complicated by anisotropy and spatial dispersion [2].

We consider structures composed of periodically arranged unit cells assumed infinite in $\hat{z}$ direction. The cells consist of a metallic strip pair [3] or a split-ring resonator. Only waves propagating in the $x - y$ plane are considered so the problem formulation is two-dimensional. By calculating the Bloch modes for the structure periodic in the $x - y$ plane and using a finite difference scheme for the averaged fields [4], we obtain effective parameters ε_{eff} and μ_{eff} that can be used to describe reflection and transmission from structures finite in the $\hat{x}$ direction. This works for frequencies where propagating modes exist. To obtain ε_{eff} and μ_{eff} for all the frequencies (including the bandgaps), we use the idea described in Ref. [5] which consists of modifying a Drude-Lorentz model to take into account the phase advance across a unit cell. The results are verified by comparing the values of r_{p} and r_{s} (complex reflection coefficients for p- and s-polarization) obtained analytically using expressions for the slab with effective parameters to those obtained by numerically simulating the reflection from the metamaterial slab.

References

[1] T. Driscoll, D. N. Basov, W. J. Padilla, J. J. Mock, D. R. Smith, Phys. Rev. B 75, 115114 (2007)
[2] C. R. Simovski, S. A. Tretyakov, Phys. Rev. B 75, 195111 (2007)
[3] G. Shvets, Y. A. Urzhumov, J. Opt. A: Pure Appl. Opt. 8, S122 (2006)
[4] D. R. Smith, J. B. Pendry, J. Opt. Soc. Am. B 23, 391 (2006)
[5] R. Liu, T. J. Cui, D. Huang, B. Zhao, D. R. Smith, Phys. Rev. E 76, 026606 (2007)

Breather induction by modulational instability in binary metamaterials

N. Lazarides[1], M. I. Molina[2] and G. P. Tsironis[1]

[1]*Department of Physics, University of Crete, and FORTH, P. O. Box 2208, 71003 Heraklion, Greece*
[2]*Departamento de Física, Facultad de Ciencias, Universidad de Chile, Casilla 653, Santiago, Chile*
e-mail:nl@physics.uoc.gr

Metamaterials, typically comprised of discrete resonant elements, exhibit electromagnetic properties not available in naturally occuring materials. Particularly, the magnetic metamaterials (MMs) exhibit significant magnetic properties up to Terahertz and optical frequencies [1]. The most common realization of a MM is comprised of periodically arranged split-ring resonators (SRRs), which are just metallic rings with a slit. The SRRs can become nonlinear either by the insertion of a nonlinear dielectric or a nonlinear electronic component in their slits, resulting in a nonlinear MM [2]. The combination of nonlinearity and discreteness makes possible the generation of nonlinear excitations in these materials in the form of discrete breathers (DBs) [3]. Recently, a novel MM comprised of two types of SRRs was investigated theoretically and it was demonstrated that in the nonlinear regime such binary MMs are suited for the observation of phase-matched parametric interaction and enhanced second harmonic generation [4].

The binary structure of the lattice allows for generation of breathers through direct external induction [5, 6]. The dispersion curves for a binary MM do not contain any acoustic-like branch; the two curves are of the 'optical' type, and they are separated by a gap [7]. For a frequency gapped linear spectrum, some of the modes become unstable at large amplitude. If the curvature of the dispersion curve in the region of that mode is negative and the lattice potential is hard then, the large amplitude mode becomes unstable with respect to formation of a DB in the gap above the linear spectrum. In order to generate DBs with frequency chirping for a dissipative-driven MM we initiate the driver with a frequency just below the top of the upper linear band, which is then chirped with time to produce enough vibrational amplitude to induce modulational instability, which then leads to spontaneous DB generation. At the end of the frequency chirping phase, the driver frequency is well above the top of the upper linear band, and only supplies energy into the DB(s) that are locked to the driver and they are trapped at particular SRRs. After that, the driver frequency is kept constant and the DBs continue to receive energy falling into a stationary state.

MMs are driven by alternating fields and thus it is expected that dissipative DBs are relevant to these type of experiments when nonlinearity is present. We have generated numerically dissipative DBs in a model nonlinear MM with frequency chirping of the driver [8]. Since SRR-based MMs with approximatelly cubic capacitive nonlinearities have been already constructed, at least in the microwave frequency range, the realization of a binary array is in principle possible. We propose that an experiment with frequency chirped applied field can lead to dissipative DB generation in a fashion very similar to that described above.

References

[1] S. Linden et al., IEEE J. Selec. Top. Quant. Electron. 12, 1097 (2006).
[2] I. V. Shadrivov, A. B. Kozyrev, D. vander Weide, Yu. S. Kivshar, Appl. Phys. Lett. 93, 161903 (2008).
[3] N. Lazarides, M. Eleftheriou, G. P. Tsironis, Phys. Rev. Lett. 97, 157406 (2006).
[4] M. V. Gorkunov, I. V. Shadrivov, Yu. S. Kivshar, Appl. Phys. Lett. 88, 071912 (2006).
[5] M. Sato et al., Phys. Rev. Lett. 90, 044102 (2003).
[6] M. E. Manley et al., Phys. Rev. B 79, 134304 (2009).
[7] M. I. Molina, N. Lazarides, G. P. Tsironis, subm. to Phys. Rev. E (2009).

Influence of Goos-Hänchen shift on tunneling times in dispersive nonlinear media

I. Ilić[1], P.P. Beličev[1], V. Milanović[2], J. Radovanović[2] and Lj. Hadžievski[1]

[1] *Vinča Institute of Nuclear Sciences, Belgrade, Serbia*
[2] *Faculty of Electrical Engineering, University of Belgrade, Serbia*
e-mail: igori@vinca.rs

The Goos-Hänchen effect is an optical phenomenon in which linearly polarized light undergoes a small shift, when totally internally reflected. Due to this effect, when an optical wave propagates through a slab, its tunneling times may change accordingly. This influence of Goos-Hänchen shift on tunneling times, i.e. group delay and dwell time, has been previously investigated for a slab made of linear nondispersive material [1].

In this paper, we consider the impact of Goos-Hänchen effect on group delay and dwell time for electromagnetic wave propagating through a nonlinear dispersive slab placed inside a linear dispersive surrounding. As a special case, these effects are calculated for a double negative index metamaterial (DN-NIM) embedded into a material with saturable (Kerr) nonlinearity, when a background medium is vacuum. Tunneling times have already been obtained for these types of materials [2,3], but Goos-Hänchen effect has been neglected in these calculations. Results for tunneling times in this paper are compared to the ones obtained for media with omitted Goos-Hänchen effect. It is shown that approach described in this paper gives more accurate expressions for tunneling times when angle of incidence has a non-zero value.

References

[1] A. M. Steinberg, R. Y. Chiao, Phys. Rev. A 49, 3283 (1993)
[2] I. Ilić, P.P. Beličev, V. Milanović, J. Radovanović, J. Opt. Soc. Am. B 25, 1800 (2008)
[3] P. P. Beličev, I. Ilić, J. Radovanović, V. Milanović, Lj. Hadžievski, Acta Phys. Pol. A 115, 834 (2009)

Light scaterring by a finite spherical particle

Igor Ilić and Nevena Raičević

Institute of Nuclear Sciences Vinca, Serbia
e-mail: nevenar@vinca.rs

Light scattering by small spherical particles with weak dissipation rates, so called Lorentz-Mie (LM) scattering, is one of the fundamental problems of electrodynamics. Nowadays this problem attracts special attention in the fields of the subwavelength optics, information processing, nanotechnologies etc. The main intriguing characteristics of the resonance LM scattering are the inverse hierarchy of optical resonances, complex near-field structure, unusual frequency and size dependence [1]. This can be correlated with the well known phenomenon of Fano resonances in quantum physics [1].

In this paper we study the properties of the LM scattering by the spherical obstacle made of materials with different types of nonlinearity and both signs of the index of refraction [2]. The spherical obstacle is considered to be embedded into different surrounding media: vacuum and dispersive media. Our main interest is to find and discuss favorable conditions for observing Fano resonances.

By numerical simulation based on the finite difference time domain (FDTD) method we confirmed the anomalous properties of the LM scattering. In addition, our results show that the LM scattering properties significantly depend on the obstacle characteristics: type of nonlinearity and sign of the index of refraction.

References

[1] M. I. Trybelsky et al., Phys. Rev. Lett. **100,** 043903 (2008).
[2] http://arxiv.org/PS_cache/arxiv/pdf/0904/0904.0153v1.pdf

Surface roughness in 1D photonic crystals: theoretical and experimental study

O. Glushko, R. Meisels, F. Kuchar

Institute of Physics, University of Leoben, A-8700 Leoben, Austria

Photonic crystals (PhC) have been intensively investigated since the end of the 1980s when the possibility of the existence of photonic band gaps in periodic dielectric lattices was predicted [1] and then demonstrated first by numerical simulation [2] and experimentally [3]. During the last years the development of this area is characterized by the tendency to miniaturization of photonic crystals with the main aim to scale down the working range to the near IR and visible regions. It is evident that more and more precise fabrication techniques are required for the realization of this task. Thus, the problem of the influence of disorder on the properties of photonic crystals has attracted a great deal of attention. Since defects and inaccuracies in the determination of the geometrical parameters of real structures are inevitable phenomena in sub-micrometer fabrication, the disorder-induced modifications of photonic crystal properties must be taken into account. Since the existence of photonic band gaps in a photonic crystal is a consequence of the periodicity of the refractive index, disturbing that periodicity should result in a modification of the photonic band structure and finally in the disappearance of the band gaps.

In this contribution we present numerical simulations as well as experimental investigations of 1D photonic crystals with intentionally introduced surface roughness. Experimental structures consist of five mm-size alumina plates separated by air. The surface roughness is created by gluing alumina powder on the both surfaces of each layer. The transmission spectra in the GHz region are measured first for "perfect" (without powder) structures and then compared to the structure with roughness.

The simulations of 1D PhCs with roughness are performed using the 2D FDTD method. We describe the surface roughness by introducing the roughness parameter δ which defines the maximal height of surface roughness features with respect to the thickness of an alumina layer. In order to exclude the effect of a particular roughness profile on the transmittance an ensemble of different profiles with the same roughness parameter are generated. The coincidence between simulation and experiment can be regarded as very good.

The results of the simulations and the comparison with the experimental data give rise to the following conclusions [4]:

- The effect of surface roughness on the position and width of *the lowest band gap* is negligible if an average thickness equal to the thickness of a structurally perfect PhC is used.
- For the second and third gap the depth of the transmission minimum and the width are reduced with increasing roughness but the gaps are still clearly seen even for a roughness parameter as large as $\delta=0.4$
- For the higher bands the effect of disorder gets stronger at shorter wavelengths and becomes significant when $\lambda/n \sim l_h\delta$, where n and l_h are the refractive index and thickness of the high-index layers, respectively.

Due to the scalability of Maxwell's equations one can extend our results to submicron-sized 1D photonic crystals and state that the lowest band and gap remain unchanged for any reasonable amount of fabrication imperfections during growth or structurization.

References

[1] Yablonovich E 1987 *Phys Rev. Lett.* **58** 2059; John S 1987 *Phys. Rev. B* **58** 2486
[2] Ho K M, Chan C T, Soukoulis C M, 1990 *Phys. Rev. Lett.* **65**, 3152; Shang Z, Satpathy S, 1990 *Phys Rev. Lett.* **65** 2650; Leung K M and Liu Y F, 1990 *Phys Rev. Lett.* **65** 2646
[3] McCall S L and Platzman P M 1991, *Phys. Rev. Lett.* **67** 2017;Yablonovich E, Gmitter T J and Leung K M, 1991 *Phys. Rev. Lett.* **67** 2295
[4] Glushko O, Meisels R, Kuchar F, 2008 *J. Phys. Cond. Matt.* **45** , 454220

Optimization of quantum well infrared photodetectors with embedded photonic crystals

O. Glushko, R. Meisels
Institute of Physics, University of Leoben, Leoben, Austria
S. Schartner, S. Kalchmair, G. Strasser
Center for Micro- and Nanostructures, TU Vienna, Austria

The detection mechanism of quantum well infrared photodetectors (QWIPs) is based on intersubband transitions within a single energy band of the material. Thus, by controlling the thickness and composition of quantum well layers it is possible to alter the detection region in the range 3- 20 μm.

QWIPs are only sensitive to photons which are polarized in the direction perpendicular to the interfaces of the quantum well stack (in our calculations the E_y component of the electric field corresponds to this polarization). The problem of the effective coupling of the light into the required polarization can be solved by a reflective diffraction grating on top of the contact layer. Another way is to couple light into a photonic crystal which is produced by etching holes through the active region of a QWIP. QWIPs with an embedded photonic crystal structure can be used as narrow bandwidth photodetectors [1,2] and we believe that signal-to-noise ratio can be improved with respect to conventional QWIPs due to resonance nature of the light coupling mechanism. In our work we are trying to find optimal parameters for the design of such QWIPs by means of full 3D FDTD calculations.

In our case the modeled QWIP structure starts with the experimental parameters used in [2]. The 2D triangular photonic crystal is formed by creating an array of air holes in the top gold contact layer and the active GaAs/$Al_xGa_{1-x}As$ quantum well active region. The typical parameters of investigated samples are the following: the thickness of quantum well active region is about 2.8 μm, the period of the photonic crystal is 3 μm, the radius of the pores is 1.1 μm, depth of the pores is about 4 μm. The light is incident normal to the surface (so E_y component is absent initially). The plane wave is diffracted at the edges of air holes in gold layer and penetrates into the quantum well region. Together with transmission and reflection we are recording the field distributions as well as the amount of electromagnetic energy transformed into E_y component within the active region of a QWIP.

The calculations show that resonant coupling of the incident light occurs for some narrow spectral region. This resonant coupling is indicated by a drop in the reflection spectrum; at the same time the integrated value of E_y^2 within the active region reaches its maximum. The field distribution patterns show that a photonic crystal dipole mode is excited which is confirmed also by photonic band structure calculations [1]. For the parameters mentioned above the resonant coupling occurs at a free-space wavelength of 5.8 μm.

Our simulations also show that the excited photonic crystal mode is localized in a layer of thickness of approximately 2.5 - 3 μm below the contact gold layer and does not penetrate deeper.

Point defect cavity structures made by removing a hole from the photonic crystal and changing the radii of the surrounding holes are also examined.

As a result of our simulations, some improvements of existing QWIPs with embedded photonic crystal are proposed, particularly: (i) placing the active region of a QWIP as close as possible to the top gold contact should increase quantum efficiency of the device; (ii) etching pores deeper than 2-3 μm is not necessary; (iii) filling the pores with some higher-index material may increase the quantum efficiency of the device.

This work was supported by the Austrian Nanoinitiative RPC PLATON.

References

[1] S. Schartner, S. Golka, C. Pfluegl, et. al Appl. Phys. Lett. **89** 15107 (2006)
[2] S. Schartner, M. Nobile, W. Schrenk, et.al. Opt. Express **16** 4797 (2008).

Optical properties of Archimedean photonic crystals

Đ. Jovanović[1]*, R. Gajić[1] and K. Hingerl[2]

[1]*Institute of Physics, Belgrade, Serbia*
[2]*Zentrum für Oberächen- und Nanoanalytik und Universität Linz, Altenbergerstr. 69, A-4040 Linz, Austria*
e-mail:djordje@phy.bg.ac.yu

Abstract: We presented theoretical research of the optical properties in the square and hexagonal 2D Archimedean photonic crystals. The structures are GaAs dielectric rods in air. Research is mainly focused on analyzing band structures, equifrequency contours and electromagnetic propagation through the structures and waveguides. We study negative refraction and self-collimation for the purpose of posible aplications in optics and optoelectronic industry.

References
[1] Đ. Jovanović, R. Gajić and K. Hingerl, Opt. Exp. **16,** 4048 (2008).
[2] J. D. Joannopoulos, R. D. Meade, J. N. Winn, *Photonic Crystals – Molding the Flow of Light*, 2nd ed., Princeton University Press, New Jersey (2008).

Influence of the heat treatment duration on the band gaps in biopolymer photonic crystals

S. Savic Sevic, D. Pantelic and B. Jelenkovic

Institute of Physics,
Belgrade, Serbia
e-mail:savic@phy.bg.ac.yu

The results of our study of the influence of the heat treatment duration on the band gap position in photonic crystals are reported. One-dimensional photonic crystals are recorded in pullulan (biopolymer with linear polysaccharide structure) sensitized with ammonium dichromate (DCP) as volume holograms. The hologram was obtained by interference of two oppositely directed beams inside the emulsion [1, 2]. The interference pattern consists of planes parallel to the substrate surface with spacing $d = \lambda/2n$, where λ is the wavelength of the laser source and n is the refractive index. For DCP n=1.44 and the space between the two adjacent constructive planes was calculated to be 184 nm.

A single-frequency, diode pumped Nd-YAG laser, at 532 nm, is used for exposure. After exposure, plates were chemically processed. Processing involves washing the plates in a mixture of water and isopropyl alcohol, and drying in pure isopropyl alcohol.

Band gaps in the visible range are observed. We found that the band gap positions are tuned by heat treatment. The spectral measurements show that the band gap centre shifts towards the short wave region with increasing time of heating.

References

[1] 1. R. Ma, J. Xu, W. Y. Tam, Applied Physics Letters 89, 081116 (2008).
[2] 2. J.Hung, M. H. Kok, W. Y. Tam, Applied Physics Letters 94, 014102 (2009).

Application of Fourier-Pade approximation in analysis of holographic photonic crystal structures

D. Sevic, S. Savic-Sevic, D. Pantelic, B. Jelenkovic and B. P. Marinkovic

Institute of Physics,
Belgrade, Serbia
e-mail:sevic@phy.bg.ac.yu

Photonic crystal structures are fabricated in Laboratory for Photonics, Institute of Physics, Belgrade, by the holographic technique [1]. Fast Pade approximation is used as a numerical aid in studies of photonic crystals, see recent publication [2] and some of references therein.

In this paper a method based on Fourier transform and Pade approximants is investigated for analysis of holographic photonic crystal structures. Pade approximants are numerical tool that can be used to accelerate the convergence of a slowly converging sequence. For a power series defined as:

$$F_n(z) = \sum_{n=0}^{N} c_k z^k \qquad (1)$$

of order N in the variable z (real or complex) with coefficients c_k, Pade approximant is a rational fraction $P_m(z)/Q_n(z)$, which approximates the fully converged values of the function $F_n(z)$. If we let $z=e^{-jkn}$, then equation (1) corresponds to Discrete Fourier Transform (DFT), so Pade method is used to improve spectral resolution of FFT, the most popular tool in spectral analysis. This method is usually called Fourier-Pade (FP) approximation.

We applied Fourier-Pade approximation to analyze photonics crystal structures fabricated in Laboratory for Photonics, enhancing the FFT analysis of investigated samples.

References

[1] S. Savic-Sevic, D. Pantelic, R. Gajic, G. Isic, Acta Physica Polonica A, vol.112, nr. 5 1079-1082 (2007)
[2] Y. Zhang, W. Zheng, M. Xing, G. Ren, H. Wang, L. Chen, Optics Communications 281, 2774 (2008).

Spatial Frequency Combs and Supercontinuum Generation in 1D Photonic Lattices

R. Dong[1], C. E. Rüter[1], D. Kip[1], O. Manela[2], M. Segev[2], C. L. Yang[3], and J. J. Xu[3]

1) Institute of Physics and Physical Technologies, Clausthal University of Technology, 38678 Clausthal-Zellerfeld, Germany

2) Department of Physics, Solid State Institute, Technion, Haifa 32000, Israel

3) Key Laboratory of Weak-Light Nonlinear Photonics, Nankai University, Tianjin 300457, P.R. China

e-mail: d.kip@pe.tu-clausthal.de

In a one-dimensional (1D) nonlinear waveguide array, which is periodically modulated in the transverse direction x but invariant along the propagation direction z, under the nonlinear effect, the Floquet-Bloch (FB) modes couple power with each other. We find that, by solving the nonlinear Schrödinger equation, when two FB modes with quasi-momentum $k_{x1} - n\Delta k_{12}$ and $k_{x2} + n\Delta k_{12}$ (n = 1, 2, … , $\Delta k_{12} = k_{x2} - k_{x1}$) are initially excited at z = 0, after a sufficient long propagation distance, a cascaded excitation of modes occurs by four-wave mixing of the newly generated FB modes with the modes which have excited them. This scenario continues until these modes reach the edge of the first Brillouin zone (BZ). The dynamics is sensitively dependent on the commensurability of the momentum difference between the two initial FB modes Δk_{12} and the lattice momentum G (width of the BZ, $G = 2\pi/\Lambda$, Λ is the period of WA). If Δk_{12} is commensurable with G (i.e., $\Delta k_{12} = \alpha G$ with a rational $\alpha = m/l$, m and l being coprime integers), the nonlinear interaction leads to the appearance of a comb of FB modes, comprising only l modes in each band. If Δk_{12} is incommensurable with G (for which α is irrational), the nonlinear interaction excites an infinitely dense set of modes.

Experimentally, we use the 1D waveguide array fabricated by in-diffusion of Ti on a Fe-doped $LiNbO_3$ wafer with the ferroelectric axis along the x-direction. The array consists of approximately 250 stripes with a width of 6 μm and a grating period Λ = 10 μm. With the prism-coupling scheme, we adjust two input beams to excite simultaneously two different FB modes on the first band. The Bloch momentum difference of the excited modes is adjusted by superimposing the two input beams at the prism base with a small angle difference in the xz-plane.

For the commensurate case, we adjust Δk_{12} to be $G/5$. The propagation distance is 6 mm. Under low input optical power (25 nW per channel), no nonlinear interactions appear in the array. When the input power is increased to 0.9 μW per channel, the increasing nonlinearity triggers the formation of a comb of spatial frequencies. The spectrum eventually develops into a comb containing 5 FB modes in the first BZ, in agreement with the theoretical anticipation of the number of modes in each band. For the incommensurate case, $\Delta k_{12} = G/8.24$. All other conditions remain the same. No energy exchange between the two FB modes occurs under low input power. As soon as the excitation starts under the power of 0.9 μW per channel, the system becomes highly nonlinear, giving rise to coupling between FB modes and to energy spreading, and after 20 minutes, a broad spectrum of FB modes covering almost the full BZ has finally formed.

We also find, both theoretically and experimentally, that an additional weak wave accelerates the formation of spatial supercontinuum (SC) and frequency combs (FC) as well. We emphasize that both SC and FC are universal, and apply to all nonlinear periodic structures where waves propagate. In this vein, SC and FC should be observable in Bose-Einstein condensates (BEC) in optical lattices, with both attractive and repulsive interactions.

References

[1] D. N. Christodoulides, F. Lederer, and Y. Silberberg, Nature **424**, 817 (2003).
[2] E. Fermi, J. Pasta, and S. Ulam, Los Alamos Report LA-**1940** (1955).
[3] G. Bartal, O. Manela, and M. Segev, Phys. Rev. Lett. **97**, 073906 (2006).
[4] O. Manela G. Bartal, M. Segev, and H. Buljan, Opt. Lett. **31**, 2320 (2006).
[5] C. E. Rüter, J. Wisniewski, and D. Kip, Opt. Lett. **31**, 2768 (2006).

Optical Soliton Formation in one - dimensional Photonic Crystal with Cubic Nonlinear Response

V. Trofimov[1], T. Lysak[1], O. Matysevich[1], S. Lan[2]

[1]*Lomonosov Moscow State University, Moscow 119992, Russia*
[2]*South China Normal University, Guangzhou, Guangdong 51063, P.R.China*
e-mail: vatro@cs.msu.ru

Optical soliton formation in photonic crystals is one of important problems of modern laser optics. Successful solution of this problem will result in constructing of a number of optical devices such as optical switches and data storages. In our preceding papers [1]–[3] the optical soliton formation was found out both for self-action of laser pulse in layered photonic crystal with cubic nonlinear response and for dual-waves interaction in layered photonic crystal with combined nonlinearity. It should be stressed that the soliton appeared in some layers of photonic crystal and they were separate in space. In these papers we investigated their formation from initial Gaussian pulse under its propagation in photonic crystal.

In this report we develop a method for finding the soliton, which forms in several layers of nonlinear photonic crystal. The number of layers can be chosen. We also investigate a stability of found spatial soliton and show that they are stables both to fluctuation of their profile and to fluctuation of value of nonlinear response (it means, for example, the stability to peak intensity fluctuation or to value of cubic susceptibility of layers).

To investigate the problem we used computer simulation, based on conservative differential schemes for this equation. Finding of soliton was made on the base of an eigenfunction problem for nonlinear Schrodinger equation with periodic coefficients. Such solitons are stable under the propagation along the layers. Fluctuation of soliton profile or maximum intensity leads to oscillation of its radius and peak intensity. Nevertheless, the profile of soliton does not change. It is very important for application.

Formulated criteria on spatial size of soliton location allow us to find soliton which cover the requiring number of layers. We found out that for stability of such soliton it is necessary a sufficient number of free (from soliton) layers before lateral boundaries of photonic crystal.

We discuss the influence of parameters of photonic crystal on formation of soliton and on soliton profile and on its stability. As our photonic crystal is a limited in space as well in direction of propagation, the important question is an influence of these boundaries on soliton propagation.

The report was supported partly by Russian Foundation for Basic Research.

References

[1] V. A. Trofimov, E. B. Tereshin, M. V. Fedotov, Optics and Spectroscopy. 95(1). 106 (2003).
[2] V. A. Trofimov, E. B. Tereshin, M. V. Fedotov, Technical Physics. 49(5). 587 (2004).
[3] V.A. Trofimov, E.B. Tereshin, M.V. Fedotov, Optics and Spectroscopy. 97 (5), 773 (2004).

Temperature dependence analysis of mode dispersion in step-index polymer optical fibers

M.S. Kovacevic[1, 2] and A. Djordjevich[2]

[1]*Faculty of Science, Department of Physics, University of Kragujevac, Serbia*
[2]*City University of Hong Kong, Tat Chee Avenue, Kowloon, Hong Kong*
e-mail: kovac@kg.ac.rs

In this paper, temperature dependence of the mode dispersion was investigated for commercially available polymethyl methacrylate (PMMA) based step-index polymer optical fibers (SI POF). An analytical expression has been proposed to describe thermal variation of refractive index of PMMA based SI POF. Refractive index decreases with increasing temperature because of the decline in the density of the polymer material. Behavior of mode dispersion with temperature have been studied over a wide temperature range, from -100 ^{0}C to 100 ^{0}C. The results show that the modal dispersion decrease as temperature increases, consequently the bandwidth increase as temperature increases.

Keywords: modal dispersion, bandwidth, step-index polymer optical fibers.
PACS: 42.81.-i, 42.81.Ht, 42.81.Dp.

References

[1] J. Zubia, and J. Arrue, Opt. Fiber Technol. **7**, 101 (2001).
[2] W. Daum, J. Krauser, E. P. Zamzow, and O. Zeimann, *POF-Polymer Optical Fibers for Data Communication*, Springer-Verlag (2002).
[3] C. A. Bunge, and Poisel H. (Ed.), *POF Modelling Theory, Measurement and Application*, Herstellung und Verlag: Books on Demand GmbH, Norderstedt (2007).
[4] M. S. Kovacevic, D. Nikezic, and A. Djordjevich, Appl. Opt. **44**, 3898 (2005).
[5] A. F. Garito, J. Wnag , and R. Gao, Science **281**, 962 (1998).
[6] G. Aldabaldetreku, G. Durana, J. Zubia, and J. Arrue, J. Light. Technol. **24** (10), 3770 (2006).
[7] G. Durana, G. Aldabaldetreku, J. Zubia, J. Arrue, and C. Tanaka, Opt. Express **16** (11) 7929 (2008).
[8] A. Priyadarashi, L. Shimin, E. H. Wong, R. Rajoo, S. G. Mihaisalkar, and V. Kirpesh, J. Elec. Mat. **34**, (11), 1378 (2005).
[9] L.W. Chen, W.H. Lu, Y. C., Chen, Opt. Comm. (Article in press) (2009).
[10] P. Michel, J. Dugas, J. M. Cariou, and L. Martin, J. Macromol. Sci. Phys. B**25** (4), 379 (1986).
[11] A. Snyder, and J. D. Love, *Optical Waveguide Theory*, Champan and Hill, London (1983).
[12] J. M. Cariou, J. Dugas, L. Martin, and P. Michel, Appl. Opt. **25** (3) 334 (1986).

Comparison of methods for calculating coupling length in step-index optical fibers

Svetislav Savović[1,2], Alexandar Djordjevich[1], Branko Drljača and Milan S. Kovačević[2]

[1]*City University of Hong Kong, 83 Tat Chee Avenue, Kowloon, Hong Kong, China*
[2]*Faculty of Science, R. Domanovića 12, 34000 Kragujevac, Serbia*
e-mail: savovic@kg.ac.rs

A recently reported function for calculation of the coupling length at which the equilibrium mode distribution is achieved in step-index plastic optical fibers is compared to a long established calculation method and to experimental findings. The recent function, while simpler to apply as it eliminates the need to numerically solve the power flow equation repeatedly for every case, is also more accurate for high-NA (0.45 to 0.5) plastic optical fibers.

Equilibrium Mode Distribution and Steady State Distribution in Step-Index Glass Optical Fibers

S. Savović[1,2] A. Djordjevich[1], B. Drljača[2] and A. Simović[2]

[1] *City University of Hong Kong, 83 Tat Chee Avenue, Kowloon, Hong Kong, China*
[2] *Faculty of Science, R. Domanovića 12, 34000 Kragujevac, Serbia*
e-mail:savovic@kg.ac.rs

Using the power flow equation, we have examined mode coupling in a step-index multimode glass optical fiber. As a result, the coupling length at which the equilibrium mode distribution is achieved and the length of fiber required for achieving the steady-state mode distribution are obtained. These lengths are much longer for glass fiber than they are for plastic optical fibers. Our results are in good agreement with experimental results reported earlier.

Calculation of the Impulse Response of Step-Index Plastic Optical Fibers Using the Time-Dependent Power Flow Equation

B. Drljača[1], S. Savović[1,2] and A. Djordjevich[2]

[1]*Faculty of Science, R. Domanovića 12,*
34000 Kragujevac, Serbia
[2]*City University of Hong Kong, 83 Tat Chee Avenue, Kowloon,*
Hong Kong, China
e-mail:savovic@kg.ac.rs

The analytical solution of the time-dependent power flow equation is employed to calculate impulse response in a step-index plastic optical fiber. Results are given at different fiber lengths and are shown to agree with those reported in the literature. Mode-dependent attenuation, modal dispersion and mode coupling in plastic optical fibers are known to affect fiber-optic power delivery, data transmission, and sensing systems.

Optical mini-disk resonator integrated into a compact optoelectronic oscillator

P. Salzenstein[1], H. Tavernier[1], K. Volyanskiy[1], N. N. T. Kim[1], P. Féron[2], L. Larger[1] and E. Rubiola[1]

[1]*FEMTO-ST Institute, CNRS UMR 6174, Besançon, France*
[2]*ENSSAT-FOTON, CNRS UMR 6082, Lannion, France*
e-mail:patrice.salzenstein@femto-st.fr

First optoelectronic oscillators were built using optical delay lines [1]. Their phase noise of 140 dB.rad²/Hz at 10 kHz offset frequency can be achieved with km-size optical fiber. But the fiber suffers from curvature-dependent loss, which imposes liter-size spool. Despite recent advances in optical fiber technology which decreased the size, it still remains of order of several centimeters. Using optical resonators in optoelectronic oscillators allows to achieve more compact assembly since they potentially bring very high quality factors with their sizes range from several millimeters to several micrometers. In this work we present our experiments concerning an optical disk resonator fabrication and preliminary results of its integration into an optoelectronic oscillator.

Resonator material is MgF_2, which is available as a highly pure crystal, harder than very popular CaF_2 with its 6 Mohs hardness, and easier to manipulate without damaging the surface. It has the required optical and mechanical properties for building high Q resonator. We designed and built a machine for shaping and polishing small disk resonators. The resonator surface is polished with Si powder and then with CeO_2 powder of decreasing grain size, as it is usually done with optical surfaces. At the end of the process, local measurements show that rugosity is of 1-5 nm (3-12 atoms) rms. Unfortunately, the available instrument permits only the measurement of a small area, while a smooth defect-free surface is required in the whole equatorial region of the resonator.

The first MgF_2 resonator prototypes are disks of 5 mm diameter and 100 µm thickness, with spherically shaped edges. This geometry provides the free spectral range of about 15 GHz. The very first measured Q is of 3.10^8. Though still modest compared to record of 6.10^{10} [2], it goes with some achievements, first of which a sharp and stable modal selectivity with 1 µm tapered fiber. Coupling with a tapered fiber is still a critical step for integration and requires additional development. We have done a computer simulation of RF response of a photonic channel containing a 1550 nm DFB laser, an electro-optical phase modulator, the mini-resonator and a photo-detector. First experimental results show workability of such architecture, with a potentially small size format. Additionally, preliminary phase noise measurements are expected on dedicated instruments developed at the laboratory [3, 4].

The authors thank the French space agency (CNES) for its support with contract number CNES/60281/00.

References

[1] X. S. Yao, L. Maleki, J. Opt. Soc. Am. B 13(8), 1725-1735 (1996)
[2] I. S. Grudinin, A. B. Matsko, A. A. Savchenkov, D. Strekalov, V. S. Ilchenko, L. Maleki, Optics Comm., 265, 33-38 (2006)
[3] P. Salzenstein, J. Cussey, X. Jouvenceau, H. Tavernier, L. larger, E. Rubiola, G. Sauvage, Acta Phys. Pol. A, 112 (5), 1107-1111 (2007)
[4] K. Volyanskiy, J. Cussey, H. Tavernier, P. Salzenstein, G. Sauvage, L. Larger, E. Rubiola, J. Opt. Soc. Am. B 25(12), 2140-2150 (2008)

Design and Modeling of Silicon-on-Insulator Strip Waveguides

P. Matavulj[1], D. Bradić[2], M. Milošević[3], and G. Z. Mashanovich[3]

[1]*Faculty of Electrical Engineering,*
University of Belgrade, Serbia
[2]*Faculty of Electrical Engineering,*
University of Banja Luka, Bosnia and Herzegovina
[3]*Advanced Technology Institute*
University of Surrey, Guildford, UK
e-mail: danijela@etfbl.net

In the last few years there has been an increased interest in silicon photonic devices due to performance and cost reasons. An optical waveguide, built in the most promising silicon-on-insulator (SOI) platform represents the basic building component in many optical systems, such as arrayed waveguide gratings (AWGs), resonators, modulators, optical filters, wavelength converters, lasers and tunable systems [1,2].

In this paper we investigate a silicon-on-insulator (SOI) waveguide structure in the form of a strip waveguide – silicon wire structure. Single mode and birefringence free conditions for small cross sectional rib waveguides have been discussed in [3]. This paper reports the simulation results for both single mode and polarisation independence conditions for shallow and deeply etched silicon-on-insulator (SOI) strip waveguides.

The influence of waveguide width on single mode condition for a given value of waveguide height and top oxide cover thickness are presented. Both TE and TM polarisations are considered at an operating wavelength of λ=1.55 μm. Birefringence free conditions are also investigated over a range of waveguide dimensions. Design rules that satisfy both single mode and polarisation independent requirements for this type of SOI strip waveguides are presented and compared with the results obtained in [4,5] for similar rib structures.

References

[1] M. M. Milosevic, P. S. Matavulj, G. Z. Mashanovich, "Polarization independent strained optical waveguides for near- and mid- infrared applications", ETRAN, Palic, Serbia (2008).
[2] K. Yamada, H. Fukuda, T. Watanabe, T. Tsuchizawa, T. Shoji, S. Itabashi, "Functional photonic devices based on silicon wire waveguide", 2nd IEEE International Conference on Group IV Photonics, Antwerp, Belgium (2005)
[3] S. P. Chan, C. E. Png, S. T. Lim, G. T. Reed, V. M. N. Passaro, "Single-mode and polarization-independent silicon-on-insulator waveguides with small cross section", Journal of Lightwave Technololgy, vol. 23, no. 6, pp. 2103-2111 (2005).
[4] M. M. Milosevic, P. S. Matavulj, B. D. Timotijevic, G. T. Reed, G. Z. Mashanovich, "Desing rules for single mode and polarization-independent silicon-on-insulator rib waveguides using stress engineering", Journal of Lightwave Technology, vol. 26, no. 13, pp. 1840-1846 (2008).
[5] M. M. Milosevic, P. S. Matavulj, G. Z. Mashanovich, "Single mode and polarization independence in the strained silicon-on-insulator rib waveguides", 6th Seminar of Young Researchers, Belgrade, Serbia (2007).

Side-mode suppression ratio in injection-locked Fabry-Perot lasers

M. Krstić and D.M.Gvozdić

School of Electrical Engineering, University of Belgrade, Serbia
e-mail: marko.krstic@etf.rs

Recent progress in high-speed optical transmission systems has enabled fast development of access passive optical networks (PONs). The next-generation passive optical networks require the use of cost-effective technologies in order to increase the scalability of these networks to more end users, longer spans and higher bit rates. A key solution for this realization of the extended reach high-capacity PONs is the combination of wavelength division multiplexing (WDM) with advanced electronic processing schemes and simple optical solutions. One of the crucial subsystems in these networks is optical network unit (ONU), which is responsible for upstream transmission from ONU to optical line terminal (OLT) or central office (CO). One possible solution for ONU based on WDM technologies uses injection locked transmitters [1]. In the injection locking technique, the light of the master laser (tunable laser in the central office - CO) is injected into the Fabry-Perot (FP) slave laser in ONU [2]. In this way, the slave laser is locked to the wavelength of the master laser, and every ONU needs only one FP laser instead of much more expensive tunable laser.

In this paper we investigate the influence of light injection on transient properties of directly modulated FP laser diode. Mode spectra with and without light injection are calculated. We study dependence of side-mode suppression ratio (SMSR) on injected power and on mode number. An important correlation between spontaneous emission coupling factor and required injection power for reaching monomode output is analyzed. Finally, we investigate modulation responses of free running and injection locked lasers.

We base our model on multimode rate equation system, which comprises extra terms describing the light injection and phase locking with the light of the master laser. We take into account considerably large number of modes (from 30 to 60), which seems to be sufficient for the problem in the work. The gain spectrum is approximated by parabolic profile, including nonlinear gain suppression and spontaneous emission coupling. The system consists of large number of nonlinear differential equations which number depends on number of included modes. The system is solved by using the Runge-Kutta adaptive method of the fourth order. Stable locking range is calculated, and detuning of the master laser is chosen to be within the stable locking range.

One of the important results of our simulation is dependence of required injection power for different modes necessary to achieve SMSR > 30 dB. It is shown that required injection power increases with mode number and spontaneous emission coupling. Our calculation shows that number of modes which satisfy SMSR > 30 dB increases with injection power and reduction of spontaneous emission. Other improvements of the injection locking technique are also demonstrated: reduction of relaxation oscillations, more linear modulation responses, higher modulation bandwidth, etc. Comparison with the model which comprises only 3 modes (one central and two side modes) [2], shows that an accurate model is necessary for proper calculation of SMSR.

By applying injection locking technique, one can simplify ONU and achieve cost effective WDM PON. We base our analysis on nonlinear and complex model of equations, which comprises significant number of modes. In addition to this, spontaneous emission coupling factor is proven to be very important, since input optical power of the master laser and number of modes satisfying adequate SMSR (>30dB), strongly depend on its value.

References

[1] N.Kashima, M. Watanabe, J. Lightw. Technol, vol.24, no. 3, pp. 1523-1533, 2006.
[2] N.Kashima, J. Lightw. Technol, vol.24, no. 8, pp. 3045-3058, 2006.

Intersubband absorption in quantum dash nanostructures

J. V. Crnjanski and D. M. Gvozdić

School of Electrical Engineering, University of Belgrade, Serbia
e-mail:jasna.crnjanski@etf.rs

Self-assembled quantum nanostructures have already attracted considerable interest for application in photonics and optical communications, due to their new and advanced electronic and optical properties and their self-assembling process of growth, which doesn't require any additional lithographic steps. The most interesting application of these structures is usually related to semiconductor lasers and optical amplifiers, where self-assembled quantum dots are used as an active region, providing for low threshold current, low chirp and small linewidth enhancement factor. However, studies of quantum dot lasers are limited on GaAs substrates with emission wavelength smaller than 1.3 μm. The growth of self-assembled nanostructures on InP substrates led to the discovery of quantum dash structures (QDH), with emission wavelength around 1.5 μm, which have high potential for applications in optical communications.

Quantum dashes are wirelike semiconductor nanostructures which self-assemble during the growth process. One of the prominent features of quantum dashes is significant size fluctuation in respect of widths, heights and lengths. This feature results in broadening of sharp peaks in the density of states, as usually found in ideal quantum wires, and broadening of gain spectrum, when quantum dashes are used as an active medium of lasers [1].

However, the application of quantum dashes so far has been related to interband optical transitions, which occur among the subbands of the conduction and the valence band. In our work, we investigate intersubband transitions in the conduction band of quantum dashes, taking into account fluctuation of their size, described by a Gaussian distribution [1]. In order to determine optical intersubband properties, we calculate intersubband absorption of a single wire for various widths and heights and carry out ensemble average by summation of the intersubband absorption of single dash weighted by the probability of the dash dimension (width and height). In our consideration we assume that the length of dashes is much larger than their width and height, so that the quantization in the longitudinal dash direction leads to continuous subband structure. The calculation of the single quantum dash absorption is based on the dipole approximation and subband structure of the conduction band. The subband structure is self-consistently calculated in the parabolic approximation. It is shown in [2] that nonparabolicity may affect intersubband absorption spectra, but in our work, we focus on the effect of the Hartree potential, which is much more prominent. In our calculation we assume that electrons necessary for optical transitions are provided from two doped layer, which are equally separated by spacer layers from the layer comprising quantum dashes. The spacer layers width is used to control the carrier concentration in the dashes. Calculation is performed for InAs well material, which is grown on and surrounded by GaAs. The width of the structure is varied from 8 nm to 20 nm, while their height goes from 2 nm to 4 nm. The calculation of intersubband absorption of quantum dash nanostructures shows that statistical nature of the dash size leads to very broad intersubband spectra with more or less Gaussian profile. For the structure and material system considered in this work the absorption spectrum lies in the range from 150 meV ($\lambda \approx 8$ μm) to 320 meV ($\lambda \approx 4$ μm). It is also observed that further increase of Gaussian distribution width, for a fixed average size of dashes, will not follow Gaussian shape of absorption spectra, although it will become broader. Such a broad absorption spectra can find application in detection or modulation of far- or mid-infrared radiation, terabit optical data communications or ultra-precision metrology and spectroscopy [3].

References:
[1] J. H. Wei, K.S. Chan, J. Appl. Phys. 97, 123524 (2005).
[2] J. Crnjanski, D. Gvozdić, J. Appl. Phys. 101, 013104 (2007).
[3] C. Gmachl, D.L. Sivco, R. Colombelli, F. Capasso, A. Y. Cho, Nature 415, 883 (2002).

Mode analysis of optical waveguides using electromagnetic energy flow lines

Miloš Davidović[1] and Milena Davidović[2]

[1]*School of Electrical Engineering,*
University of Belgrade, Serbia
[2]*Faculty of Civil Engineering,*
University of Belgrade, Serbia
e-mail:milos84@gmail.com

In this work we present the results of a mode analysis, obtained by construction of electromagnetic energy flow lines for different types of optical waveguides.

The density of energy flow lines depicts energy distribution along the waveguide. The undulation of constructed lines along the boundary surface is imposed by the boundary conditions.

We observe patterns of undulation for various modes and get an elucidating physical picture of source energy distribution for propagatating and non-propagationg modes.

This method has been previously used by R. D. Prosser [1] in a different context, namely to complement Hygens principle of secondary wavelets and to supply a new insight in the interpretation of two slit diffraction of planar EM wave.

Energy flow lines were introduced for the first time by the authors of [2] as a possible analogon of description of paths for massive particles in Bohmian quantum mechnanics.

References

[1] R. D. Prosser International Journal of Theoretical Physics, vol. 15, no.3 pp. 169-180 (1976)
[2] M. Davidovic, A S Sanz, D Arsenovic, M Bozic and S Miret-Artés, Phys. Scr. T134 (2009)

Time-frequency analysis of non-stationary optical signals using Husimi type function

Miloš Davidović[1] and Milena Davidović[2]

[1]*School of Electrical Engineering, University of Belgrade, Serbia*
[2]*Faculty of Civil Engineering, University of Belgrade, Serbia*
e-mail:milos84@gmail.com

Time-frequency analysis is important to identify the localized information of a non-stationary signal in the time and the frequency domains simultaneously. There are few different time-frequency analysis methods available with their own specialty and suitability [1].

In quantum mechanics Husimi function of any quantum mechanical state arises naturally whenever the simultaneous measurement of coordinate and momentum is performed on this state with maximal accuracy allowed by the Heisenberg uncertainly relations. Husimi function is a probability distribution for the statistics of simultaneous unsharp measurement of coordinate and momentum.

In general, like the Wigner function, Husimi function can be defined in space of any pair of conjugate variables. In particular, in studies of signal processing, this space is time-frequency space. In the present work we consider Husimi function in this space, and apply it to analyse multicomponent optical signals. The time-frequency representations of the simulated signals by using Husimi distribution (HD) clearly show the frequency features along the time axis. The results are encouraging and indicate that, like in corresponding analogous problems in quantum mechanics, HD approach in time-frequency analysis for non-stationary multicomponent optical signals, may provide some insights which are not so easily obtained in other, more spread approaches.

References

[1] L. Cohen, "Time-frequency distributions - a review," Proceedings of the IEEE, vol. 77, no. 7, pp. 941- 981, July 1989.

Plasmonic Bragg Reflector and Tamm Plasmon Polaritons in Metal-dielectric Superlattices

S. Vukovic

Institute of Physics, University of Belgrade, Pregrevica 118, 11080 Zemun, Belgrade, Serbia
e-mail:svukovic@phy.bg.ac.rs

We investigate the properties of electromagnetic waves in two-dimensional periodic structures created by alternating metal and dielectric layers. The structure is assumed to be finite in the direction normal to the layers and infinite in other directions. We derive and analyze the dispersion relations for both TE- and TM-polarized eigenmodes of the structures that reveal typical plasmonic Bragg reflector properties [1].

Recently, it has been demonstrated that the surface states within the light cone, called Tamm plasmon polaritons, can be formed in both TE- and TM-polarization at the interface between a semi-infinite metal and a conventional dielectric Bragg reflector [2]. This is in contrast to the dispersion of surface plasmon polaritons that can propagate along the boundary of metallic and dielectric media. Those are strictly TM polarized and their dispersion lies outside the light cone. Here, we show that eigenstates of a plasmonic Bragg mirror that can be excited by almost normally incident light, posses the dispersion properties of Tamm plasmon polaritons, and their in-plane dispersion is parabolic, and the splitting between TE- and TM-polarized modes increases quadratically with the in-plane wavevector [2, 3]. We reveal that the group velocity of TE-polarized modes is always positive or zero, while the group velocity of TM-modes can be either positive, zero or negative. This leads to slow and spatially localized light with possible positive (both TE- and TM-polarized modes) or negative refraction (TM-polarization only).

References

[1] J. Elser, and V. A. Podolsky, Phys. Rev. Lett. 100, 066402 (2008).
[2] M. E. Sasin, *et.al.*, Appl. Phys. Lett. 92, 251112 (2008).
[3] X. Kang, W. Tan, Z. Wang, and H. Chen, Phys. Rev. A 79, 043832 (2009).

Measurement of small variations in optical properties of turbid ingredients with respect to surrounded turbid medium

I. Bliznakova, O. Vankov, T. Dreischuh and D. Stoyanov

Institute of Electronics, Bulgarian Academy of Sciences
72 Tzarigradsko Chaussee Blvd. Sofia 1784, Bulgaria
e-mail: irbliznakova@abv.bg

Earlier detection and diagnosis of different pathological formations such as carcinoma, cyst, fibroadenoma lesions, etc., in breast tissues lead to less invasive treatments and increase the chances of complete cure of the patient. Optical tomography methods that use near-infrared light to probe biological tissues could be effectively used for the detection and characterization of different benign and malignant breast lesions due to the difference in their optical properties (absorption and scattering). The literature data display some differences in reduced scattering coefficients of normal and abnormal tissues (for carcinoma lesions they are slightly higher ~ 10-25% than the normal tissue; for cyst lesions they are lower down to 10% to 50%, for fibroadenoma lesions ~ 30-80% higher than the normal tissue). So, the development of reliable methods for non-invasive optical identifying and distinguishing of such formations (as turbid ingredients) surrounded by normal tissues (turbid media) will allow earlier detection and offer new opportunities for earlier intervention.

In this work we develop a method and experimental set-up for determination of small variations in optical properties of turbid ingredients posed into large turbid medium. A CW-laser diode emitting collimated sensing beam in the near-infrared (λ=850nm, P_{out}=27mW) is used to illuminate a transparent cubic container filled with a liquid that simulates a turbid medium. A cylindrical object filled with a liquid with some different optical properties represents a small ingredient embedded in the medium. As a phantom to simulate the optical properties of turbid tissue-like medium the 20% Intralipid emulsion is used. To obtain phantoms and ingredients with different optical parameters the concentration of the Intralipid solutions is varied. In such schematics (similar to real measurement schematics) the useful signal depending on the difference of the optical properties of the medium and the small ingredient is very weak. Therefore, it requires high sensitivity and stability of the entire system. The optical receiver comprises a scanning optical fiber of large numerical aperture posed in the medium, an optical radiometer (Laser precision corp., USA) with RqP-546 silicon probe in external locking regime, a 14bits analog-to-digital converter and a computer for data acquisition and additional software averaging and precise statistical processing.

The variation in the optical properties of the embedded small ingredients is measured when varying the concentration of the Intralipid solutions in the range up to 60% with respect to the surrounding medium. Five phantom concentrations are analyzed covering the typical turbidity of the breast tissues. The output signals depend not only on the magnitude but also on the sign of the difference in optical properties of both media. This would be useful for distinguishing of different kinds of abnormal formations. A near-linear dependence of the output magnitude on the variations of the Intralipid concentrations in the ingredient is measured. The minimum detectable changes in the ingredient optical properties are estimated to be below 5% with respect to the medium.

As a whole, the method offers good opportunities for laboratory analysis as well as for further development of some non-invasive techniques for direct determination of the changes in optical properties of small abnormal formations inside the breast tissues and a specification of their origin.

Long-range correlation in atomic vibrations of chicken lysozyme backbone

D. Crăciun,[1] A. Isvoran,[2,3] and N. M. Avram[4,5]

[1]*West University of Timisoara, Teacher Training Department, 4 Blvd. V. Parvan, Timisoara, 300223, Romania*
[2]*West University of Timisoara, Department of Chemistry, 16 Pestalozzi, Timisoara, 300115, Romania*
[3]*Nicholas Georgescu-Roegen Interdisciplinary Research and Formation Platform, 16 Pestalozzi, Timisoara, 300115, Romania*
[4]*West University of Timisoara, Department of Physics, 4 Blvd. V. Parvan, Timisoara, 300223, Romania*
[5]*Academy of Romanian Scientists, 54 Independentei Street, Bucharest, 050094, Romania*

e-mail:craciundana@gmail.com

Abstract. Within this study we use methods such as spectral analysis (SA) that gives the spectral coefficient β [1], detrended fluctuations analysis (DFA) that gives the scaling exponent α [2] and the determination of Hurst exponent (H) [3] to analyze the spatial series corresponding to the changes in the temperature factors [4] of N, C-alpha (CA) and C atoms of lysozymes backbone when it forms 15 complexes with other macromolecules. Temperature factors are reported in experimental atomic-resolution structures and provide information about local mobility [4]. The mean values of the investigated parameters obtained for the 15 complexes are $\beta = 1.798 \pm 0.086$, $\alpha = 1.284 \pm 0.011$ and respective $H = 0.965 \pm 0.029$ and they reveal long-range correlation in atomic vibrations corresponding to the chicken lysozyme backbone [5].

References

[1] P. Szendro, G. Vincze, A. Szasz, Pink – noise behavior of biosystems, Eur. Biophys. J. 30, 227 – 231, (2001).

[2] C. K. Peng, S. Havlin, H. E. Stanley, A. L. Goldberger, Detrended fluctuation analysis, Chaos 5, 82 – 87 (1995).

[3] P. B. DePetrillo, D. Speers, U. E. Ruttimann, Determining the Hurst exponent of fractal time series and its application to electrocardiographic analysis, Comput. Bio. Med. 29, 393 – 406 (1999).

[4] M. Vihinen, E. Torkkila, P. Riikonen, Accuracy of protein flexibility predictions, Proteins 19, 141-149 (1994).

[5] V. V. Morariu, A. Coza, Nonlinear properties of the atomic vibrations in protein backbones, Physica A 320, 461 – 474 (2003).

Challenges in imaging skin using optical coherence tomography

N. Krstajić[1], L. E. Smith[2], S. J. Matcher[2], D. T. D. Childs[3], M. Bonesi[4], P.D.L. Greenwood [3], M. Hugues[3], K. Kennedy[3], M. Hopkinson[3], K.M. Groom[3], S. Macneil[2], R. A. Hogg[3], R. Smallwood[1]

[1]*Department of Computer Science, University of Sheffield, Sheffield, UK,*
[2]*Department of Engineering Materials, University of Sheffield, Sheffield, UK,*
[3]*Department of Electronic Engineering, University of Sheffield, Sheffield, UK,*
[4]*Department of Medical Physics, University of Vienna, Vienna, Austria*

e-mail:n.krstajic@sheffield.ac.uk

Optical coherence tomography (OCT) is an infrared imaging technique that gates interferometrically the backscattered light [1, 2]. OCT has had an excellent track record in imaging the eye [3], but its application in other fields such as dermatology has been slower [4]. We present our attempts to image *in vivo* skin, *ex vivo* skin and tissue engineered skin using our time-domain (TD-OCT) system.

The crucial part of any OCT system is the light source. We use a quantum dot (QD) based superluminescent diode (QD-SLED) designed and grown in the EPSRC National Centre for III-V technologies, Sheffield, UK. The centre wavelength is 1280nm, bandwidth 85nm and power 20mW. Prior work showed significant promise in using QD structures in SLED design [5]. The properties we explore are QD-SLED power, bandwidth and noise. Higher power and low noise SLEDs increase the signal-to-noise ratio, while broad bandwidth optimizes the spatial resolution along optical axis. Furthermore, we explore optical feedback properties of QD-SLEDs. A commercial device would benefit greatly from optical-feedback immunity as this would obviate the need for a dedicated optical isolator.

We applied the QD-SLED from the III-V centre to TD-OCT and we present our results in skin imaging. The initial goals in applying OCT to dermatology have been to: 1) delineate epidermis from dermis in all skin specimens; 2) distinguish cancerous formations. We have had some success in terms of goal 1, but goal 2 is still being pursued. Thick stratum corneum (top layer of epidermis) is clearly visible with *in vivo* skin and tissue engineered skin, but *ex vivo* skin shows no contrast at all. Body locations with thinner stratum corneum do not show much contrast either. For *in vivo* imaging, applying hyperosmotic agents such as glycerol improves depth penetration of infrared light [6]. Overall, skin is a very difficult specimen where multiple scattering starts to dominate the signal at shallow imaging depths (200-300 μm). We discuss our results in the light of recent developments in OCT.

References:

[1] Brezinski, M. E., *Optical coherence tomography: principles and applications*. 2006, Amsterdam; Boston: Academic Press.

[2] Drexler, W. and J. G. Fujimoto, *Optical coherence tomography: technology and applications*. 2008, Berlin; New York: Springer.

[3] Drexler, W. and J. G. Fujimoto, *State-of-the-art retinal optical coherence tomography.* Progress in Retinal and Eye Research, 2008. **27**(1): p. 45-88.

[4] Welzel, J., *Optical coherence tomography in dermatology: a review.* Skin Research and Technology, 2001. **7**(1): p. 1-9.

[5] Ray, S. K., T. L. Choi, K. M. Groom, H. Y. Liu, M. Hopkinson, and R. A. Hogg, *High-power 1.3-mu m quantum-dot superluminescent light-emitting diode grown by molecular beam epitaxy.* IEEE Photonics Technology Letters, 2007. **19**(2-4): p. 109-111.

[6] Vargas, O., E. K. Chan, J. K. Barton, H. G. Rylander, and A. J. Welch, *Use of an agent to reduce scattering in skin.* Lasers in Surgery and Medicine, 1999. **24**(2): p. 133-141.

An ellipsometrical and AFM study of ferritin adsorption kinetics on a gold surface

L. Vladimirova[a], A. Andreeva[b], V. Savov[a], A. Gritzkow[c], M. Burova[b]

[a] *Sofia University "St. Kliment Ohridski", Faculty of Physics, Department of Atomic Physics, 5 James Boucher Blvd. 1164 Sofia, Bulgaria; phone: +359 2 81 61 317, fax: +359 2 96 25 276*
[b] *Sofia University "St. Kliment Ohridski", Faculty of Physics, Department of Semiconductors, 5 James Boucher Blvd. 1164 Sofia, Bulgaria; phone: +359 2 81 61 610, fax: +359 2 96 25 276*
[c] *Sofia University "St. Kliment Ohridski", Faculty of Physics, Department of Optics, 5 James Boucher Blvd. 1164 Sofia, Bulgaria; phone: +359 2 81 61 317, fax: +359 2 96 25 276*
e-mail:vladimirova@phys.uni-sofia.bg

Abstract:

The kinetics of ferritin adsorption on gold (Au) surface was studied with ellipsometry and atomic force microscopy (AFM).

The thickness and the refraction index of the adsorbed layer were determined using a theoretical model system: air-interface layer-solution-adsorbed layer-gold surface. The relations between the parameters of the adsorbed layer and pH and the protein concentration are obtained. It seems that the ferritin adsorption is a relatively slow multi-stage process.

The obtained results enable modelling of the protein adsorption on blood vessels and tissues in pathological processes. The kinetics of protein adsorption could be implemented in medical applications and in development of new biosensor systems.

Biopolymer-calcium phosphate composites synthesized by pulsed laser technologies for medical applications

F. Sima[1], E. Axente[1], N. Serban[1], C. Ristoscu[1], I. N. Mihailescu[1], K. Anselme[2], E. Pauthe[3], O. Gallet[3]

[1]*National Institute for Lasers, Plasma and Radiation Physics, Bucharest, Romania*
[2]*IS2M, CNRS LRC7228, Haute-Alsace University, 68057 Mulhouse Cedex, France*
[3]*ERRMECE, Cergy-Pontoise University, 95302 Cergy-Pontoise Cedex, France*
e-mail: felix.sima@inflpr.ro

Although many biomaterials have been used in regeneration and substitution of injured or lost bone, no synthetic material offered till now characteristics close enough to the natural tissue, in terms of either biological or mechanical aspects.

Composites have been recently proposed as a prospective alternative for performant thin coatings. They combine the bioactive performance with improved mechanical properties characteristic to hard tissues.

Organic-inorganic nanocomposites obtained from soluble salts of calcium, phosphorus, and biopolymers were deposited by matrix assisted pulsed laser evaporation (MAPLE) on Ti substrates of biomedical interest. Human plasma proteins were applied by MAPLE in view of biomaterial activation by increasing both protein adsorption and cells adhesion at biointerface.

The biocompatibility and bioactivity were evaluated by in vitro tests. We demonstrated that human osteoblast precursor cells proliferate faster, reach a normal morphology and remain viable when cultured on MAPLE deposited coatings as compared to bare titanium or reference cover slips.

Interpretation of fluorescence decay kinetics in oligonucleotides using a heterogeneity model of lifetime distribution based on long-range photoinduced electron transfer

Borys Kierdaszuk

Department of Biophysics, Institute of Experimental Physics, University of Warsaw, 93 Zwirki i Wigury St., 02-089 Warsaw, Poland;
e-mail: borys@biogeo.uw.edu.pl

Fluorescence intensity decays of 3-methylbenzimidazole (m^3B) in di-, tri- and tetra-phosphate analogues of 3-methylbenzimidazolyl(5′-5′)guanosine (m^3Bp_nG, n = 2, 3, 4) can not be satisfactory fitted with single-exponential function [1]. Although an increase of a number of exponents led to better fits, interpretation of the individual exponential terms, i.e. preexponential amplitudes and fluorescence lifetimes, can not be adequately characterized. We show that these fluorescence decays are best fitted by power-like function $I(t)=[(2-q)/\tau_0][1-(1-q)t/\tau_0]^{(1/(1-q))}$ derived from physically justified distribution of the fluorescence lifetimes given by gamma function [2]. Fluorescence intensity decays are characterized by the mean value of lifetime distribution (τ_0), and one new parameter of heterogeneity (q) objectively reflecting physical heterogeneity of the system. Heterogeneity parameter is related $q=\omega+1$ to the relative variance $\omega=\langle(\gamma-\langle\gamma\rangle)^2\rangle/\langle\gamma\rangle^2$ of fluctuations of the decay rates $\gamma=1/\tau$ around their mean value $\langle\gamma\rangle=1/\tau_0$. The factor $(2-q)/\tau_o$ results from normalization, and the mean decay time $\langle t_p\rangle$ is given by $\langle t_p\rangle=\tau_0/(3-2q)$. The normalization of power-like decay function and existence of the mean value of decay time imply that $1<q<3/2$. In the classical limit, when $q \rightarrow 1$, the gamma distribution becomes the Dirac delta function, and decay function converges from power-like form to the single-exponential form. When the q value increases stepwise from 1 to 3/2, deviation from single-exponential form increases, and it is more pronounced for the tail part of each decay.

The power-like function well fits complex (heterogeneous) as well as simple mono-exponential fluorescence intensity decays in biological systems. For instance, the number of phosphate groups in the 5′,5′-polyphosphate bridge of 5′,5′-dinucleotide analogues affects kinetics of long-range electron transfer (ET) responsible for 3-methylbenzimidazole (m^3B) fluorescence quenching in model dinucleotides [3]. The di-, tri- and tetra-phosphate analogues of 3-methylbenzimidazolyl(5′-5′)guanosine dinucleotides (m^3Bp_nG, n = 2, 3 and 4) having m^3B donor, 5′-5′ polyphosphate bridge, and guanine (G) acceptor, exhibit exponential-dependence of the ET rate on the number of phosphates, i.e. donor-acceptor distance. Involvement of the 5′-5′ polyphosphate bridge in the ET is also strongly supported by lack of m^3B-G stacking effect on the exponential factor, which is the same at 20 °C, where m^3B-G intramolecular stacking dominates, as that at 75 °C where stacking-unstacking equilibrium is shifted in favour of the unstacked structure. The latter is of great importance for the studies of the mechanism of fluorescence quenching in nucleic acids.

Acknowledgements: Support of the Polish Ministry of Scientific Research and Higher Education (MNiSW), grant No. N202105536.

References

[1] B. Kierdaszuk, J. Wlodarczyk, Eur. Biophys. J. 2006, 35, 424.
[2] J. Wlodarczyk, B. Kierdaszuk, Biophys J. 2003, 85, 589.
[3] B. Kierdaszuk, J. Wlodarczyk, Eur. Biophys. J. 2007, 36, 253.

Optical and mass-spectrometric study of the slow electrons interaction with nucleic acid components

M. I. Shafranyosh, M. I. Sukhoviya, I. I. Shafranyosh

Department of Physics, Uzhgorod National University, Uzhgorod, 88000, Ukraine
e-mail: lshafr@rambler.ru

Interest in experimental studies of the processes in the molecules of biological relevance by electron-impact is related, first of all, to the significance of the problem of intracellular irradiation of biological structures by secondary electrons produced in the substance in quite considerable amounts under the influence of different-type radiation. It has been shown in our preliminary experiments carried out with the heterocyclic components of the above molecules [1–3] that under electron impact different physical processes occur: i.e. molecules excitation, ionization, dissociative excitation and dissociative ionization. Physical modeling of these processes and estimation of their radiobiological consequences require knowledge of their basic characteristics – absolute ionization and excitation cross sections. Reliable data on the cross sections could be obtained only in the precise experiment, in which the role of environment is minimized. Such approach was applied in this work.

Production of positive and negative ions of nucleic acid base molecules has been studied using a crossed electron and molecular beam technique. The method developed by the authors enabled the molecular beam intensity to be measured and the electron dependences and the absolute values of the total cross sections of production of both positive and negative ions to be determined**.** A five-electrode electron gun with a tungsten cathode was used as an electron beam source. Measurements were carried out at the 10^{-7}–10^{-6} A electron beam current and the $\Delta E_{1/2}$~0.3 eV (FWHM) energy spread. An electron energy scale was calibrated with respect to the resonance peak of the SF_6^- ion production, the position of which determined the zero point of the energy scale.

The emission (luminescence) spectra of nucleic acid bases were obtained in the wavelength range 200-600 nm, as well as the electron energy dependences of the effective excitation cross sections (excitation functions) of the molecular bands at their peaks.

Using the technique developed by the authors, the absolute cross sections of the positive and negative uracil ions formation have been determined within the 0–200 eV (positive ions) and 0.4–5.0 eV (negative ions) incident electron energy ranges. It has been found that the maximal positive ion production cross section is observed at 78 eV and reaches $7.8 \cdot 10^{-16}$ cm^2. Value of the ionization cross section obtained by us has a sense of the total cross section, i.e. it includes ion production cross sections for both initial molecules and its fragments. Formation of the primary molecular positive ion dominates. It has been found that the maximal negative-ion formation cross section is observed at 1.5 eV and is $4.2 \cdot 10^{-18}$ cm^2. Main contribution to the cross section was shown to result from the dissociative ionization cross section. It has been noted that due to the resonance mechanism of the negative uracil ions formation just at low incident electron energies considerable disorders in the nucleic acid macromolecules are probable.

References

[1] Sukhoviya M. I., Slavik V. N., Shafranyosh I. I., Biopolym. Cell. **7,** 77 (1991) (in Russian).
[2] Sukhoviya M. I., Shafranyosh M. I., Shafranyosh I. I., Spectroscopy of Biological Molecules: New Directions (Kluwer Acad. Publ.-Dordrecht /Boston /London) p.281 (1999).
[3] Shafranyosh I .I., Sukhoviya M. I., Shafranyosh M. I., J.Phys.B: At.Mol.Opt.Phys., **39**, 4155 (2006).

Optical biopsy method for breast cancer diagnosis based on artificial neural network classification of fluorescence landscape data

T. Dramićanin[1], I. Zeković[1], B. Dimitrijević[1], S. Ribar[2] and M.D. Dramićanin[1]

[1]*Institute of Nuclear Sciences "Vinča", University of Belgrade,11001 Belgrade, Serbia*
[2]*Faculty of Mechanical Engineering, University of Belgrade, Kraljice Marije 16, 11120 Belgrade, Serbia*
e-mail: tatjana@vinca.rs

Tissue diagnosis using optical spectroscopy has been considered as an alternative technique for the conventional diagnostic methods because of its advantages, such as minimal invasiveness, less time consumption and reproducibility. For more than two decades, various optical spectroscopic techniques including fluorescence spectroscopy have been widely explored as diagnostic tools in the discrimination of normal from abnormal tissues in various organ sites such as breast [1,2], colon [3], oral [4], and skin [5]. The endogenous fluorophores, such as NADH, FAD, collagen, elastin, amino acids, vitamins, lipids and porphyrins, have a significant variation in the concentration in different tissue types. These differences, together with alternations in the local environment within the tissue, are the basis for the discrimination between tumor and normal tissue by fluorescence spectroscopy. To observe majority of fluorescence changes a more sophisticated method of fluorescence diagnosis is developed, called fluorescence landscape spectroscopy (also known as excitation–emission matrix spectroscopy), utilizing multiple-color illumination, with the full fluorescence spectrum recorded for each excitation wavelength. The different excitation wavelengths might be expected to variously excite different fluorophores, resulting in more complex emission patterns with more information relevant to biochemical changes than for single-color excitation, and with presumed greater likelihood of distinguishing malignancy from normal conditions. However, observed data are subtly related in ways that are often difficult to express in the form of diagnostic rules and must be processed for tissue classification purposes.

Artificial neural networks are very useful for handling complex decision tasks such as those involved in medical diagnosis. The networks can capture such relationships between the input findings to generate robust outputs. In addition, networks are always consistent, for they are not prone to human fatigue or bias. In this work, an attempt was made to apply supervised self-organizing maps [6,7] for classification of human breast tissue samples utilizing data obtained from fluorescence landscape measurements. Female breast tissue samples were taken soon after the surgical resection, identified and stored at -80 ^{0}C until fluorescence measurements. From fluorescence landscapes obtained in UV-VIS region spectral features showing statistically significant differences between malignant and normal samples are identified and further quantified to serve as a training input to neural network. Additional set of 33 measurements was used as a test group input to trained network to evaluate sensitivity and specificity of proposed optical biopsy method.

References

[1] R. R. Alfano, G. C. Tang, A. Pradhan, W. Lam, D. S. J. Choy and E. Opher, IEEE J. Quantum Electron. 23, 1806 (1987).
[2] T. Dramićanin, M. D. Dramićanin, V. Jokanović, D. Nikolić-Vukosavljević, B. Dimitrijević, *Photochem. Photobiol.* 81, 1554 (2005).
[3] K. T. Schomacker, J. K. Frisoli, C. C. Compton, T. J. Flotte, J. M. Richter, N. S. Nishioka and T. F. Deutsch, *Lasers Surg. Med.* 12, 63 (1992).
[4] S. D. Kamath and K. K. Mahato, *J. Biomed. Opt.* 12, 14028-1 (2007).
[5] H. J. C. M. Sterenborg, M. Motamedi, R. F. Wagner, M. Duvic, S. Thomsen and S. L. Jacques, *Lasers Med. Sci.* 9, 191 (1994).
[6] T. Kohonen, Self-organizing maps, third ed., Springer, Berlin, 2001.
[7] T. Kohonen, Computer 21, 11 (1988).

Optical Properties of Acupunctural Points as diagnostic method

B. R. Jovanić[1,*], D. Nikolovski[2], B. Radenković[3] and M. Despotović[3]

[1]*Institute of Physics, CEP, Belgrade University, P.O.Box 68, 11080 Zemun, Serbia, Phon:(381) 11 3160-260; Fax: (381) 11 3160-190;*

[2]*Institute for Helth, Pasterova 2, 26000 Pančevo, Serbia.*
[3]*FON, Lab. Simulation, Belgrade University, Jove Ilića 180, 11001 Belgrade, Serbia.*
e-mail: brana@phy.bg.ac.rs

The goal of this work was to establish a connection between the optical parameters of the skin in which the acupuncture points have been settled and the pathological state of the organism. For the first time a connection between the optical characteristics of the specific skin parts (acupuncture points) and the state of the organism has been demonstrated. The optical parameter of the acupuncture point optical parameter (APOP/ surface of the reflectance curve between 470nm-660nm) conduct in accordance with the traditional Chinese medicine theories (balance disturbance within the organism, time change). Acquired results point to the possibility of using APOP measuring as a method to determine the number of therapeutically treatments during the traditional Chinese medical treatments.

References

[1] Y.Omura, "Marked Beneficial Effects Obtained After Acupuncture at True St. 36 Compared With Very Little Effects Obtained From Acupuncture on Traditional St. 36 –Location of True St. 36 & Traditional St. 36 and their Acupuncture Effects Clarified Using Bi-Diagital O-Ring Test, Jap. Acupuncture Journal., Japanese Medicine, 692, 129 (2001).

Correlation between physical and anthropometric characteristics of junior football players

A. Ciorsac[1], D. Craciun[2], A. Isvoran[3], V. Ostafe[3]

[1] Politehnica University of Timisoara, Department of Physical Education and Sport, 2 P-ta Victoriei, 300006, Timisoara, Romania
[2] West University of Timisoara, Teacher Training Department, 4 Blvd. V. Parvan, Timisoara, 300223, Romania
[3] West University of Timisoara, Department of Chemistry, 16 Pestalozzi, Timisoara, 300115, Romania
e-mail: craciundana@gmail.com

Within this study we compare and correlate the physical characteristics to anthropometric ones for junior football players by age categories. There are two groups: the group A consists of 21 footballers of age 15-16 years and the group B consists of 27 footballers of age 18-19 years. There is a significant effect ($p < 0.05$) of age and playing level on the muscular power of legs, speed and agility, these physical characteristics increase with increasing age and playing level. We also notice a good correlation between the physical characteristics and the anthropometric ones. These kinds of tests may be used as a predictive tool for football player selection, respectively for the rationalization and standardization of the training techniques.

References

[1] M. Morh, P. Krustrup, J. Bangsbo, J Sports Sci 23, 593 (2005).
[2] J. Bangsbo, M. Morh, P. Krustrup, J Sports Sci 24, 665 (2006).
[3] R. M. Malina, J. C. Eisenmann, S. P. Cumming, B. Ribeiro, J. Aroso, European J App Phys 91, (2004).
[4] R. M. Malina, J. C. Eisenmann, S. P. Cumming, B. Ribeiro, J. Aroso, J. Sports Sci 23, 515 (2005).
[5] R. M. Malina, B. Ribeiro, S. P. Cumming, British J Sports Med 41, 290 (2007).
[6] S. Gil, F. Ruiz, A. Irazusta, J. Gil, J. Irazusta, J Sports Med Phys Fit 47, 25 (2007).
[7] A. Ciorsac, Sci Bull UPT 6, 64 (2008).
[8] A. J. Figueiredo, C. E. Gonçalves, E. Coelho, M.J. Silva, R. M. Malina, Annals Hum Biol, 36, 60 (2009).
[9] J. Hoff, J Sports Sci 23, 573 (2005).
[10] T. Metaxas, T.; Sendelides, N. Koutlianos, K. Mandroukas, J Sports Med Phys Fit 46, 520 (2006).
[11] R. Silvestre, W. J. Kraemer, C. West et al, J Str Cond Res 20, 962 (2006).
[12] V. I. Kalapotharakos, N. Strimpakos, I. I. Vithoulka, C. Karvounidis, K. Diamantopoulos, E. Kapreli, J Sports Med Phys Fit 46, 515 (2006).
[13] M. Venturelli, F. Trentin, M. Bucci, J Sports Med Phys Fit 10, 80 (2007).