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Guest Editors:

Stanko Vl. Shtrakov
Mariana N. Georgieva-Grosse
Georgi N. Georgiev

Trans Black Sea Region Union of Applied Electromagnetism
BSUAE

Institute of Communication and Computer Systems

Athens - GREECE

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TRANS BLACK SEA REGION UNION OF APPLIED ELECTROMAGNETISM (BSUAE)

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PROPAGATION OF LASER PULSES IN MEDIA WITH NON-STATIONARY OPTICAL AND MAGNETIC RESPONSE

K. L. Kovachev, L. M. Ivanov, V. N. Serkin, and L. M. Kovachev 1

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nonlinear Slowly Varying Equation of Amplitudes (SVEA) in a second approximation of the linear dispersion. It is important to point out that the SVEA obtained in media with non-stationary optical and magnetic response is similar to the SVEA equation with stationary magnetic response. The only difference is in the expressions for the group velocity and for the dispersion parameters. In particular, in paramagnetic media near to the magnetic resonances and also in experiments with a strong DC longitudinal magnetic field, it is possible to attain negative group velocity and group velocity, higher than the velocity of light in vacuum.

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INTERACTIONS OF ^{8}B AND ^{9}C NUCLEI WITH EMULSION NUCLEI

R. Zh. Stanoeva, D. O. Krivenkov, G. I.Orlova, J. N. Stamenov, and P. I. Zarubin 22

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EDITORIAL

This Special Issue of the Journal of Applied Electromagnetism is dedicated to the Third International Scientific Conference FMNS 2009, organized by the Faculty of Mathematics and Natural Sciences at the South-West University "Neofit Rilski" in Blagoevgrad, Bulgaria in June 2009. This is an event which assembled researchers, working in different branches of the mathematics, physics, chemistry, informatics, computer technologies, geography, ecology and methodology of education. In view of the scope of the Journal we focussed our attention on the studies in the field of physics only. All papers from this area, presented at the Conference and published in the Proceedings, have been reviewed by us. Five of them which in our opinion are the most representative, have been selected and included in this Special Issue. Our ambition was to cover various directions of the contemporary physics: laser technology, nuclear physics, fiber optics, viscosimetry of aerosol systems and energy analysis of wind. It is worthwhile to characterize briefly the contributions of each of the investigations.

K. L. Kovachev, L. M. Ivanov, Vl. N. Serkin and L. M. Kovachev deal with the possibility to use in experiments new laser sources with pulse duration of about 50-100 fs, the dynamic of propagation of which is not fully explained by now. This problem is solved by the authors, taking into account the non-stationary magnetic response in some nonlinear media, together with an optical one.

St. Vl. Shtrakov reports a circumstantial review of the suitable mathematical methods to assess the parameters of the Weibull distribution functions to study the wind energy potential of Bulgaria. Engineering compliance software, tailored for use by professionals to perform calculations, aimed at achieving economical and energy efficiency in wind projects, is demonstrated. Preliminary outcomes of the search are portrayed on the geographical map of the country.

R. Zh. Stanoeva, D. O. Krivenkov, G. I. Orlova, J. N. Stamenov and P. I. Zarubin present results on the dissociation of ^{8}B and ^{9}C in very peripheral interactions with emulsion nuclei. They afford a framework for further accumulation of statistics and for a detailed analysis of the ^{9}C interactions. The observations given serve as an illustration of the prospects for utilization of relativistic nuclear beams in the nuclear astrophysics.

K. S. Damov and A. S. Antonov investigate the lowering of the upper limit of an aerosol of high concentration ("quasi-liquid"), formed in a vertical glass cylinder, during its flowing out through a calibrated tube above the bottom of the vessel. The process is free, subject to the natural hydrostatic pressure of the substance examined. Different evolution times are considered. Assuming that the flowing out is laminar and follows the Poiseuille's law, an analogy with the Boltzmann's law is made (the concentration of a system of particles is expressed in the earth gravitational field as a function of the height). An original formula for experimental determination of the mass of the most refined fraction of the aerosol particles (resp. of their radius) is suggested. A conclusion is drawn that the latter are identical with the condensational (Aitken's) nuclei in the atmosphere.

L. M. Ivanov, Vl. N. Serkin, L. M. Kovachev and M. L. Ivanov propose for the first time a method, harnessing the nonlinear optical four-photon mixing process. It allows by measuring the frequencies shifts between the new spectral components, generated as a consequence of it and the pump wave, to determine simultaneously the basic fiber parameters.

It is our duty to express our gratitude to *The Honorary Editor and Founder Prof. Nikolaos Uzunoglu*, *The Editor-in-Chief Prof. Panayiotis Frangos* and *The Editorial Board* of The Journal of Applied Electromagnetism for providing us the opportunity to prepare this Special Issue.

We would like to thank *The South-West University "Neofit Rilski"* in Blagoevgrad and its Faculty of Mathematics and Natural Sciences for inviting us as Guest Editors of this Special Issue.

We appreciate very much the co-operation and patience of *the authors* in editing the text of the manuscripts to attain the high standard of the Journal.

We are indebted to *all the members of our families*, especially to *Trifonka Romanova Popnikolova* and to *Kalina Georgieva Shtrakova*, as well, for their support and understanding during the time of our work on this Special Issue.

ASSOC. PROF. STANKO VL. SHTRAKOV, PHD

MARIANA N. GEORGIEVA-GROSSE, PHD

ASSOC. PROF. GEORGI N. GEORGIEV, PHD

GUEST EDITORS

The biography of **Associate Professor Stanko Vl. Shtrakov** is published on page 21 of this Issue.

Mariana Nikolova Georgieva-Grosse was born in Polikraishte, Bulgaria. In 1982 she graduated from First Gymnasium "St. St. Cyril and Methodius" in Veliko Tirnovo, Bulgaria, with complete honours and a Golden medal. During 1981 and 1982 she was awarded with G. Dimitrov's stipendium for her extraordinary achievements in the education. She received a diploma in Radiophysics and Electronics (honours) in 1987 from the Faculty of Physics, University of Sofia, "St. Clement Okhridski", Sofia, Bulgaria, equivalent to MS degree in Physics and a second diploma for a High-school teacher in Physics. During 1986 she was awarded with G. Dimitrov's stipendium for exceptional attainments in the studies. In 1995 she received a PhD degree in Physics from the University of Sofia for a thesis on the theory of nonlinear plasma waveguides.

In 1992-1993 she was a Honorary Assistant Professor in Informatics at the Faculty of Mathematics and Informatics, University of Veliko Tirnovo "St. St. Cyril and Methodius", Veliko Tirnovo, Bulgaria. In 1995-1997 she was with the Faculty of Physics, University of Sofia as an Assistant Professor in Physics. Besides, in 1995-1997 she was on part-time with the Bochum University, Germany, as a Research Assistant, as well. In 1997 she was elected as a Young scientist of the year of the Faculty of Physics, University of Sofia. In 1997 she received a Professional Certificate in Management from the Open University, UK. Since 2000 she is a Microsoft Certified System Engineer (MCSE). In 2000-2001 she was with the Duerr Systems GmbH, Stuttgart, Germany. In 2001 she was with Duerr Systems GmbH, at the VW plant in Puebla, Mexico. Since 2001 she is an Engineer and a Project Manager, engaged in the elaboration of advanced automotive electronic applications at Robert Bosch GmbH, Stuttgart, Germany. In 2003-2005 she was a Program Manager, responsible for the software development of a driver assistant system "Night Vision". In 2006 this system was nominated for the "Award of the Future" of the Federal President of the Federal Republic of Germany as one of the four most sophisticated technological achievements in the country. Simultaneously, she is Consulting in physics and computer sciences, as well. She was an Invited Lecturer at the University of Veliko Tirnovo "St. St. Cyril and Methodius", (2009).

She was Co-editor of the Bulgarian-German Summerschool and Symposium on Waveguide Discharges, Faculty of Physics, University of Sofia "St. Clement Okhridski", Bulgaria, (1996). She is Member of the Editorial Board and Head of the Publishing Department of the *Journal of Applied Electromagnetism*, Athens, Greece since 2009. She is a reviewer of *IEEE Antennas and Wireless Propagation Letters* and of the *Journal of Applied Electromagnetism*. Her area of interests includes analytical and computational electromagnetics, mathematical physics, plasma physics, guided wave propagation through anisotropic media and ferrite control components. She is an author and co-author of over 90 publications in those fields. The most significant of them are published in: NATO ASI Series: Series B: Physics, (Plenum Press, NewYork, USA, 1993); Series C: Mathematical and Physical Sciences, (Kluwer Academic Publishers, Dordrecht, The Netherlands, 1998 and 1999); *Journal of Plasma Physics* (1994); *Physics D: Applied Physics* (1995); *Contributions in Plasma Physics* (1996); *Journal of Electromagnetic Waves and Applications* (1997); *IEEE Antennas and Wireless Propagation Letters* (2003); *Journal of Telecommunications and Information Technologies* (2005); *PIERS Online* (2010); *XXIX URSI General Assembly*, (Chicago, IL, USA, 2008); *Progress in Electromagnetics Research Symposium PIERS*, (Moscow, Russia, 2009; Xi'an, China 2010; Cambridge, MA, USA, 2010; Marrakesh, Morocco, 2011); *2010 IEEE AP-S International Symposium on Antennas and Propagation and CNC-USNC/URSI Radio Science Meeting*, (Toronto, ON, Canada, 2010); *European Conferences on Antennas and Propagation EuCAP Series*, (Nice, France, 2006; Berlin, Germany, 2009; Bacelona, Spain, 2010); *International Conference on Electromagnetics in Advanced Applications ICEAA*, (Turin, Italy, 2009; Sydney, Australia, 2010); *Asia-Pacific Microwave Conference APMC*, (Adelaide, Australia, 1992; Singapore, 2009); *ESA Antenna Workshops on Satellite Antenna Technology Series*, European Space Agency (Noordwijk, The Netherlands, 2002-2010). Her main scientific activities and research results consist in: 1. Development of analytical and numerical methods, based on the perturbation theory for investigation of nonlinear and nonhomogeneous behaviour of surface waves in layered plasma waveguides and a study of the effects of self-focusing and self-modulation (with A. Shivarova, S. Grosse, Yu. M. Aliev, H. Schlueter); 2. Introduction of the *A*, *B*, *C* classes of real numbers, tabulation of their values and substantiation of formulae for computation of the differential phase shift, provided by the azimuthally magnetized circular ferrite waveguides which support normal TE_{0n} modes, using these numbers. 3. Introduction of the class of real *L* numbers as the limits of certain infinite sequences of positive real

numbers, connected with the zeros of the Kummer confluent hypergeometric function or with the roots of some equations, involving confluent hypergeometric functions and eventually cylindrical ones of specially chosen parameters, and its application in the theory of the circular waveguides with azimuthally magnetized ferrite, (items 2., 3. with G. N. Georgiev).

Dr. Georgieva-Grosse is Senior Member of the Chinese Institute of Electronics (CIE), Beijing, China, since 1996, Member of the Trans Black Sea Region Union of Applied Electromagnetism (BSUAE), since 1996, Member of the European Association on Antennas and Propagation (EurAAP), since 2009 and Member of the Electromagnetic Academy since 2011. Her biography was cited in the 2011 Edition of the *2000 Outstanding Intellectuals of the 21th Century*, Cambridge, UK. Languages spoken: English, German, Slovak, Russian and Czech, beside the native Bulgarian.

Georgi Nikolov Georgiev was born on January 17, 1957 in Polikraishte, Bulgaria. In 1974 he graduated from First Gymnasium "St. St. Cyril and Methodius" in Veliko Tirnovo, Bulgaria, with complete honours and a Golden medal. During 1974 he was awarded with G. Dimitrov's stipendium. In the same year he won the National Olympiade in Physics and the right to represent the country as Member of the Bulgarian National Olympic Team at the 7th International Olympiade in Physics in Warsaw, Poland. For his exceptional achievements he was awarded by the Minister of Education of Republic of Bulgaria. Moreover, he won the privilege to be admitted as a student without competitive entrance examinations and to study in any University in Eastern Europe and the former Soviet Union he wishes, of his own choice. He chose the University of Sofia "St. Clement Okhridski", Bulgaria and in 1974 he became a student at its Faculty of Physics. In 1979 he received a diploma for Engineer-Physisist in Radiophysics and Electronics from the University of Sofia with honours, equivalent to MS degree in Physics and a second diploma for a High-school teacher in Physics. He studied Rhetoric and received also a diploma for a lecturer from the same University. In 1983 he became a postgraduate student at the Institute of Electronics, Bulgarian Academy of Sciences, Sofia and received a PhD degree in Physics in 1987 from it for a thesis on the theory of anisotropic waveguides. Its main part was published as the Book chapter "Azimuthally magnetized circular ferrite waveguides" (with K.P. Ivanov) in *Ferrite Phase Shifters and Control Devices*, by J. Helszajn, (McGraw-Hill, London, UK, 1989).

In 1988 he joined in founding the Faculty of Mathematics and Informatics, University of Veliko Tirnovo "St. St. Cyril and Methodius", Veliko Tirnovo, Bulgaria, as an Asisstant Professor in Physics. Since 1994 he is an Associate Professor in Physics (Classical Electromagnetic Theory) at the same University. He teaches courses in General Physics, Analytical Mechanics and Numerical Methods for students in Mathematics and Computer Sciences. In 1991-1995 he was a Deputy Dean of the Faculty. In 1996 he was on a specialization at the National Technical University of Athens, Athens, Greece. In 2002 he was Member of an International Scientific Jury in Kiev, Ukraine and in 2006-2008 – of Bulgarian National Scientific Juries. In 2004 he was a Visiting Professor at the Democritus University of Thrace, Xanthi, Greece. Besides, he was Member of an International research team, working on a project of the General Secretariat for Research and Technology of Greece, aiming at developing new antennas, based on ferrite and plasma media. During the same year he was an INTAS supervisor, as well, of the postdoctoral specialization of a young scientist from the Ivane Javakhishvili Tbilisi State University, Tbilisi, Georgia and of a personal communication systems research project of the Tbilisi State University, of the Swiss Federal Institute of Technology, ETH-Zürich, Switzerland and of the University of Veliko Tirnovo. Since 2007 he is Chairman of the General Assembly of the Faculty of Pedagogy of the University of Veliko Tirnovo. Since 2008 he is on the list of reviewers of the Romanian National University Research Council. He was an Invited Lecturer at the South-West Institute of Applied Magnetics of China, Mianyang, Sichuan Province, People's Republic of China (1994), National Technical University of Athens, Athens, Greece (1995, 1996, 2005, 2006), Belarussian State University, Minsk, Belarus (1995), Dokuz Eylül University, Izmir, Turkey (2001), Democritus University of Thrace, Xanthi, Greece (2001), Hellenic Air Force Academy, Athens, Greece (2006), Ivane Javakhishvili Tbilisi State University, Tbilisi, Georgia (2009, 2010), Georgian Technical University, Tbilisi, Georgia (2009, 2010), The Institute of Structures, Special Systems and Engineering Maintenance, Tbilisi, Georgia (2009, 2010), I. Vekua Institute of Applied Mathematics, Tbilisi, Georgia (2009), EM Consulting and Software, EMCoS Ltd., Tbilisi, Georgia (2009, 2010), Technical University of Sofia, Sofia, Bulgaria (2010). He was a SPIE Visiting Invited Plenary Lecturer at the *IX Kharkov Young Scientists Conference "Radiophysics, Photonics, Electronics and Biophysics"*, (Kharkov, Ukraine, 2009).

He is Associate Editor since 2009 (Member of the Editorial Board since 1997) of the *Journal of Applied Electromagnetism*, Athens, Greece. He was Member of the International Organizing Committees of the First and Second Trans Black Sea Region Symposia on Applied Electromagnetism (BSUAE) (Metsovo and Xanthi, Greece, 1996, 2000, resp.), Member of the Technical Programme Committees of the European Conferences on Antennas and Propagation Series (EuCAP 2007, Edinburg, Scotland; EuCAP 2009, Berlin, Germany, EuCAP 2010; Barcelona, Spain and EuCAP 2011, Rome, Italy) and Member of the Technical Committee of the International Scientific Conference "Advanced Lightweight Structures and Reflector Antennas", organized by The Institute of Structures, Special Systems and Engineering Maintenance of The Georgian Technical University, held under the aegis of The European Space Agency (ESA), Tbilisi, Georgia, 2009. He is reviewer of *IEEE Transactions on Microwave Theory and Techniques*, *IEEE Microwave and Wireless Components Letters*, *International Journal of Electronics*, *Journal of Applied Electromagnetism*, *Journal of Electromagnetic Waves and Applications* (*JEMWA*) and *Progress In Electromagnetic Research* Journals (*PIER*, *PIER B*, *C*, *M* and *PIER Letters*), as well as of scientific conferences in the USA, Greece, Georgia and Malaysia. His field of interests includes mathematical physics (application of the special functions in the electromagnetic theory, in particular application of the confluent hypergeometric functions), analytical and computational electromagnetics, microwave physics, ferrite control components and guided wave propagation in anisotropic structures. He is an author and co-author of over 100 publications. The most significant of them are published in: *IEEE Transactions on Microwave Theory and Techniques* (1986); *Proceedings of the Institute of Electrical Engineers, Pt. H* (*Microwaves, Antennas and Propagation*) (1985, 1988); *Electronics Letters* (1986); *Journal of Applied Physics* (1990); *European Transactions on Telecommunications and Related Technologies* (1991); *Chinese Journal of Radio Science* (1995); *IEEE Antennas and Wireless Propagation Letters* (2003); *Journal of Telecommunications and Information Technologies* (2005); *PIERS Online* (2010); *XXIX URSI General Assembly*, (Chicago, IL, USA, 2008); *Progress in Electromagnetics Research Symposium PIERS*, (Moscow, Russia, 2009; Xi'an, China 2010; Cambridge, MA, USA, 2010; Marrakesh, Morocco, 2011); *2010 IEEE AP-S International Symposium on Antennas and Propagation and CNC-USNC/URSI Radio Science Meeting*, (Toronto, ON, Canada, 2010); *European Conferences on Antennas and Propagation EuCAP Series*, (Nice, France, 2006; Berlin, Germany, 2009; Bacelona, Spain, 2010); *Millennium Conference on Antennas and Propagation*, (Davos, Switzerland, 2000); *International Conference on Electromagnetics in Advanced Applications ICEAA*, (Turin, Italy, 2009; Sydney, Australia, 2010); *Asia-Pacific Microwave Conference APMC*, (Adelaide, Australia, 1992; Singapore, 2009); *ESA Antenna Workshops on Satellite Antenna Technology Series*, European Space Agency (Noordwijk, The Netherlands, 2002-2010). His main scientific contributions consist in: 1. Development of methods for computation of the phase and differential phase shift characteristics of the azimuthally magnetized circular ferrite-dielectric waveguides for normal TE_{0n} modes, based on the confluent hypergeometric and cylindrical functions, and using iterative techniques. 2. Numerical analysis of the complex Kummer and Tricomi confluent hypergeometric functions and development of methods for numerical solution of some transcendental equations, involving them. 3. Introduction of the *A*, *B*, *C* classes of real numbers, calculation of their values and substantiation of formulae for computation of the differential phase shift, provided by the structures mentioned, using these numbers. 4. Introduction of the class of real *L* numbers as the limits of certain infinite sequences of positive real numbers, connected with the zeros of the Kummer function or with the roots of some equations, involving confluent functions and possibly cylindrical ones of specially chosen parameters. Computation of the numbers, investigation of some of their properties and their application of the theory of aforesaid configurations, (all with M. N. Georgieva-Grosse).

Assoc. Prof. Dr. Georgiev is an IEEE Member (MTT-S, AP-S, ED-S and Communications Society) since 1995 and an Advisor of the IEEE Student Branches which he created in 1998 at the University of Veliko Tirnovo and at the National Military University "Vasil Levski" in Veliko Tirnovo. Since 1996 he is Senior Member (Member since 1995) of the Chinese Institute of Electronics (CIE), Beijing, China. He is co-founder of the Trans Black Sea Region Union of Applied Electromagnetism (BSUAE), founded in Metsovo, Greece in 1996 and Member of the Co-ordination Committee of BSUAE. He is Member of the Society of Photo-Optical Instrumentation Engineers (SPIE) since 2009, Member of the Electromagnetic Academy since 2011, Member of the American Chemical Society since 2011. In 2006 he was awarded with the Golden medal of the University of Veliko Tirnovo "St. St. Cyril and Methodius" for his contribution in science and for the strengthening and the affirmation of the name of the University. His biography was cited in the 2010 and 2011 27th and 28th Editions of the Marquis *Who's Who in the World* and in the 2010 Edition of the *2000 Outstanding Intellectuals of the 21th Century*, Cambridge, UK. Languages spoken: English, Slovak, Russian, German, Czech, French, Polish and Italian, beside the native Bulgarian.

THIRD INTERNATIONAL SCIENTIFIC CONFERENCE OF THE FACULTY OF MATHEMATICS & NATURAL SCIENCES, FMNS 2009, SOUTH-WEST UNIVERSITY "NEOFIT RILSKI", BLAGOEVGRAD, BULGARIA

The Third International Scientific Conference of The Faculty of Mathematics & Natural Sciences (FMNS 2009) at the South-West University "Neofit Rilski" took place in Blagoevgrad, Bulgaria in June 3-7, 2009. This is the third issue of the Conference, organized by the Faculty of Mathematics & Natural Sciences and it is already its traditional scientific and educational activity.

Honorary Chairman of the Conference was Prof. Ivan Mirchev, PhD, Rector of the South-West University and Chairman – Assoc. Prof. Borislav Yurukov, PhD, Dean of the Faculty of Mathematics & Natural Sciences.

Works in eight Sections were presented. The reports were directed in the fields of Physics, Mathematics, Informatics and Computer Sciences, Chemistry, Ecological problems of certain regions in Europe, Geography and Methodology in the Education. The Conference provided a very good opportunity, specialists in diverse branches to meet and exchange ideas and results. During it many contacts were established and groups for scientific co-operation were formed between researchers from different institutions and countries.

Prof. Ivan Mirchev, PhD, Rector of the South-West University opens the Conference.

The main topics of the Conference were:

- PHYSICS,
- MATHEMATICS,
- INFORMATICS AND COMPUTER TECHNOLOGIES,
- CHEMISTRY,
- GEOGRAPHY AND ECOLOGY,
- METHODOLOGY IN EDUCATION,
- WORKSHOP - RENEWABLE ENERGY TECHNOLOGIES.

The Conference was attended by over 120 scientists, lecturers and visitors from Bulgaria, Romania, Germany, Greece, Slovenia, The Czech Republic, Poland, Russia, Albania, Macedonia and the USA. More than 80 works in various scientific areas of study were presented. Four plenary lectures were given by the Members of the Bulgarian Academy of Sciences (BAS): Acad. Petar Kenderov, Acad. Petar Nikolov, Acad. Evgeny Golovinsky and Corr. Member of the BAS Yordan Stamenov. All submissions were reviewed and Proceedings in two volumes were printed. They were published also on the web site (http://www.fmns.swu.bg).

The Conference Centre ”Bachinovo“.

The Plenary session of the Conference.

Exhibition of a collection of minerals.

The welcome party.

The Conference was held in Blagoevgrad at the Educational Centre of the South-West University – ”Bachinovo“ (3 km away from the town of Blagoevgrad). An excursion to the Rozhen Monastery, Melnik (the Kordopoulov’s house) and Petrich (Rupite – The she-prophet Vanga Museum) was organized for the participants.

Assoc. Prof. Stanko Vl. Shtrakov, PhD

BLAGOEVGRAD, BULGARIA

Blagoevgrad is located in the southwestern part of Bulgaria. Its municipality covers an area of 628 square kilometers. It is close to Greece and Macedonia and has an easy access to the Bulgarian capital, Sofia which is 100 kilometers to the north. The E79 international highway and a railway system which connects Central Europe with Greece, run through the town. The population of Blagoevgrad and the region totals up to 82 415 people. About 76 000 of them live in the town and the remaining ones are scattered throughout the 25 regional villages. Blagoevgrad lies in the neighbourhood of the extremely beautiful Rila and Pirin mountains.

Administrative map of Bulgaria: Blagoevgrad – located in the southwestern part of the country.

The centre of Blagoevgrad.

Assoc. Prof. Stanko Vl. Shtrakov, PhD

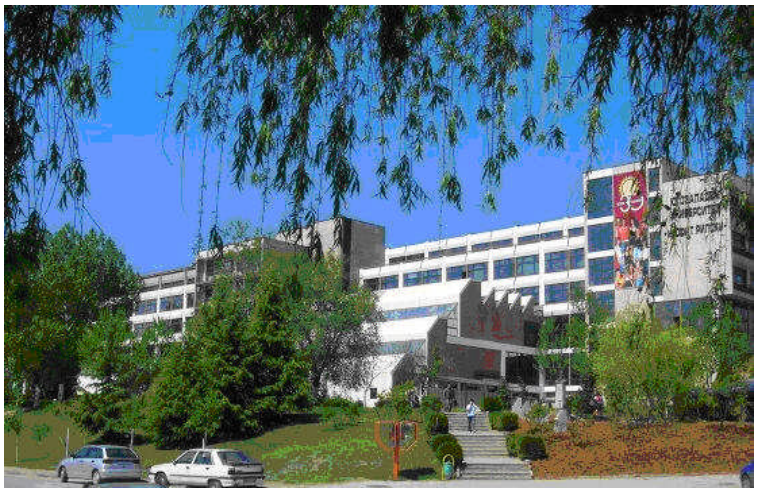
SOUTH-WEST UNIVERSITY "NEOFIT RILSKI", BLAGOEVGRAD, BULGARIA

Patron of the University in Blagoevgrad is the Patriarch of the new Bulgarian education – Neofit Rilski. The University was first founded as a Branch of the University of Sofia "St. Clement Okhridski" with Order No. 323, dated August 9, 1975 of the Bureau of the Council of Ministers (State Newspaper No. 65/1975). The first 200 students were admitted in 1976/77 in two specialties – Pedagogy for preparation of teachers for the kindergardens and Pedagogy for preparation of teachers for the primary schools. In this way, for the first time preparation of teachers with a University degree for kindergardens and primary schools started in Bulgaria. The tutorials were realized by three Professors, two Assoc. Professors and thirteen Assistant Professors.

With Act No. 2296, dated August 4, 1983 of the State Council of the Republic of Bulgaria (State Newspaper No. 62/1983), the Branch was transformed into a separate Higher Pedagogical Institute. The Institute was looking for its own image and own way in the preparation of teachers. Two years later in 1985 a Scientific Council began functioning in it. It had the right to elect Associate Professors in Pedagogy, Psychology, Defectology and Methodology of Teaching. Many new specialties like Mathematics, Physics, Bulgarian Language and Literature, Bulgarian Language and History found place in the educational programmes. In 1990 already education of full and part time students in five faculties and in ten specialties was realized. The Institute more and more confirmed itself as a Higher school of a university type. Admission of foreign students started.

In the period after 1990, under the influence of the processes of democratization in all spheres of the social life and in accordance with the Law for the Academic Autonomy, the Higher School in Blagoevgrad developed with accelerated rate. New specialties and faculties were created. Alongside with the education, financed by the state, paid education was introduced, too.

With regards to the level of development attained and the high demand of specialists with a university degree, especially in the fields of Economics, Law and



The main building of the South-West University "Neofit Rilski".

the social activities, with a decision of the People's Assembly, dated July 1995 (State Newspaper No. 68/1995), the Higher Pedagogical Institute, Blagoevgrad became South-West University "Neofit Rilski", Blagoevgrad. At present 7590 students are taught in the University in the Bachelor, 266 in the Professional Bachelor (College) and 1910 in the Master programmes by 54 Professors, 223 Associate Professors, 262 Assistant Professors, 119 Honorary Professors and Associate Professors, and 162 Honorary Assistant Professors.

The Rector of the South-West University "Neofit Rilski": Prof. Ivan Mirchev, PhD.

Faculties and colleges

- Faculty of Law and History
- Faculty of Mathematics and Natural Sciences
- Faculty of Economics
- Faculty of Public Health and Sports
- Faculty of Pedagogy
- Faculty of Philology
- Faculty of Philosophy
- Faculty of Arts
- Technical College

Faculty of Mathematics and Natural Sciences

The Faculty of Mathematics and Natural Sciences was founded in 1989 by a decree of the Council of Ministers of Republic of Bulgaria. It was organized to pursue higher education and research in different fields of the natural sciences.

The enormous development and differentiation of the natural sciences and their rapidly growing importance in the life of the globalizing world put the institutions, providing education and research in this field in a very important position. In order to best serve the needs of the modern society, the Faculty went through various organizational adjustments during the years.

The Faculty of Mathematics and Natural Sciences currently offers Bachelor, Master and PhD degree programmes, as well as specialized courses for a continuing study. It also offers a programme for obtaining a qualification as Secondary School Teachers. It involves a collateral study, including also pedagogical and didactical subjects.

The Faculty members, carrying out teaching and research, are highly qualified. They participate in many international projects and events and their works often appear in recognized international journals. Much emphasis is placed on the experimental work and students are invited to join research with their tutors, as soon as possible. They are encouraged to participate in many extracurricular activities and projects. The Faculty provides a lot of information and communication services through its server and web site, maintained by the students. Free access to computer labs and internet is available. The Faculty has also enthusiastically embraced multimedia innovations. These new developments are incorporated into working out of the sophisticated skills, required to navigate in an increasingly computerized world.

As a whole, the Faculty of Mathematics and Natural Sciences provides an attractive learning, research and working environment for the students and the staff

and offers a global outlook, professional skills and adaptability for the students to succeed in today's rapidly changing international workforce.

The Faculty develops successful international co-operation with many European Universities and Institutes. Some of them are: the Carlov University, Prague, The Czech Republic; the Higher Technical Institute, Patras, Greece; the VSB Technical University in Ostrava, The Czech Republic; the University "St. Cyril and Metodius", Scopie, Macedonia; the Uludag University, Bursa, Turkey; the Higher Technical Institute, Nicosia, Cyprus, etc.

The Faculty of Mathematics and Natural Sciences has the following Departments:

- Physics,
- Mathematics,
- Computer Sciences,
- Computer Systems and Technologies,
- Chemistry,
- Geography, Ecology and Environment Protection.

Its Dean is Assoc.Prof. Borislav Yurukov, PhD.

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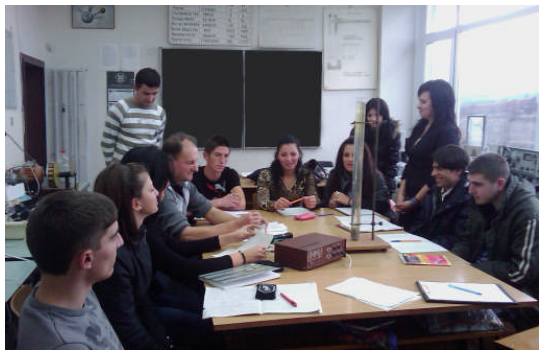

A class in Physics.

During the Winter (Summer) Semester of the 2008/2009 school year 96 (88) students were taught in the Bachelor programmes of the Faculty of Mathematics and Natural Sciences in the Specialty Mathematics and Informatics, 50 (42) in Physics and Mathematics, 67 (62) in Chemistry and Physics, 202 (191) in Informatics, 78 (70) in Physics, 77 (77) in Chemistry, 109 (111) in Geography, 122 (122) in Ecology and Environment Protection, and 269 (265) in Computer Systems and Technologies or total 1102 (1056). The Master Programmes of the Faculty were attended by 19 (8) students in Informatics, 2 (2) in Physics, 10 (10) in Chemistry, 10 (10) in Geography, 3 (3) in Ecology and Environment Protection or total by 44 (33) students. In the Postgraduate Courses 78 students were instructed in the following subjects: 10 in Informatics, 22 in Chemistry, 8 in Geography, 14 in Ecology and Environment Protection, and 24 in the discipline Man and Nature.

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PROPAGATION OF LASER PULSES IN MEDIA WITH NON-STATIONARY OPTICAL AND MAGNETIC RESPONSE

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Abstract

We investigate the propagation of laser pulses in media with non-stationary optical and magnetic response. A new amplitude integro-differential equation, governing the evolution of wave packets with one and few cycles under the envelope, is derived. The application of slowly varying amplitude approximation to this equation reduces it to a nonlinear Slowly Varying Equation of Amplitudes (SVEA) in a second approximation of the linear dispersion. It is important to point out that the SVEA obtained in media with non-stationary optical and magnetic response is similar to the SVEA equation with stationary magnetic response. The only difference is in the expressions for the group velocity and for the dispersion parameters. In particular, in paramagnetic media near to the magnetic resonances and also in experiments with a strong DC longitudinal magnetic field, it is possible to attain negative group velocity and group velocity, higher than the velocity of light in vacuum.

1. INTRODUCTION

An important trend in the contemporary laser physics is the generation and spreading of ultra short femtosecond (fs) laser pulses. The significant decrease of the time scales leads to the appearance of new linear and nonlinear processes and methods for investigation. On the other hand, the fs pulses provide new challenges for experiments on magneto-optical effects with ultra-fast magnetic response. The first experimental observations revealed demagnetization times of 260 fsec [1,2], while the theoretical studies based on spin-orbit relaxation mechanisms give relaxation times up to 10 fsec [3,4]. The experimental values of demagnetization time were determined from the magneto-optical response, using a pump-probe technique with fsec pulses

and measuring explicitly the time resolved Kerr ellipticity and rotation of some ferromagnets as Ni, and also in semiconductors [5,6]. The considerable growth of μ_{st} and of the short relaxation times in the ferromagnets, mentioned above and in semiconductors, requires a new treatment of the ultra-short pulse propagation dynamics and using both, non-stationeries, due to dipole transition and ones which are a consequence of the magnetic (quantum current's) transition.

In this paper we investigate the propagation of optical pulses in media with non-stationary optical $\varepsilon(t-\tau)$ and magnetic $\mu(t-\xi)$ response, as well as with time durations of the order of the optical period (large spectral bandwidth) and pulses with many cycles under the envelop (slowly-varying amplitude approximation). The magnetization was calculated by the standard Bloch equations, since the ferromagnets are transformed to standard paramagnetic structures, when their temperature is higher than the Curie's point.

2. ULTRA-FAST MAGNETIC RELAXATION PROCESSES IN FERROMAGNETIC AND SEMICONDUCTOR STRUCTURES

Typically, the static part μ_{st} of the magnetic permeability for paramagnetic materials has a very small magnitude – of the order of $10^{-5}\div10^{-6}$. On the other hand, we know that the spin lattice relaxation times in such materials are of the order of $\Delta t \cong 100\,\text{ps}$. For this reason, the magnetic permeability dispersion $\mu(\omega)$ is of 4-5 orders less than the electric susceptibility dispersion $\varepsilon(\omega)$ and could be neglected in the dynamics of the electromagnetic pulses propagation. The situation changed significantly in the last few years, after longitudinal relaxation time of magneto-optical transitions of the order of $T_1 \approx 50\div100$ fsec [5,6] was observed. The experiments were provided with ultra short femtosecond optical pulses on the basis of the Kerr's magneto-optical effect. The change of the polarization angle is important for pulses with energies, exceeding the ones of the Curie's point in case of ferromagnetic and over the Fermi's level in case of semiconductor-metal based structures [5,6]. It is necessary to notice that for such structures the static magnetic permeability μ_{st} obeys the Curie – Weiss law with respect to the temperature:

$$\mu_{st}(T) = C/(T-\theta), \tag{1}$$

where C is the Curie's constant and θ is the Curie paramagnetic temperature. In these cases the static linear magnetic permeability can increase up to $\mu_{st} \sim 10^{-2}$, with

relaxation times $T_1 \approx 50 \div 100$ fs and the magnetic permeability dispersion $\mu(\omega)$ can be only of one order less than the electric susceptibility dispersion $\varepsilon(\omega)$.

Another physical mechanism which leads to such a fast response, is the spin-orbit interaction or the *magnetic-dipole transitions* at optical frequencies [4,7]. These transitions are between different orbit levels and spins. The well-known magnetic resonance transition [7] on one orbital level between states with opposite spins gives resonances in the microwave and radio regions. Both processes: the *magnetic dipole transition* and the *magnetic resonance transitions* are non-stationary and are obtained as a result of the oscillation between different orbital levels or between sublevels respectively, with nonzero quantum current. A classical description of such processes is achieved, solving the Bloch equation. Let the latter be written for the longitudinal magnetic field (for the H_z-part of the electromagnetic pulse in waveguide structures) $\vec{H} = \vec{z}H_1 \cos\omega t$. In consideration of the magnetization, μ_z relaxes to the momentary value of the magnetic field $\mu_z^0 = \mu_{st} H \cos\omega t$ and we can write the Bloch equation in the form:

$$\frac{d\mu_z}{dt} = \gamma(\vec{M} \times \vec{H})_z + \frac{\mu_{st} H_1 \cos\omega t - \mu_z}{T_1} \tag{2}$$

where ω is the carrying frequency of the localized electromagnetic wave. The cross product in Eq. (2) is zero, since the vectors $\vec{M}$ and $\vec{H}$ are collinear. The solution for its real and imaginary parts, is [8]:

$$\mu_z^{'}(\omega) = \frac{\mu_{st}}{1+\omega^2 T_1^2}, \qquad \mu_z^{''}(\omega) = \frac{\mu_{st}\omega T_1}{1+\omega^2 T_1^2}. \tag{3}$$

The real part of the longitudinal component of the magnetic permeability $\mu_z^{'}(\omega)$ is an even function with respect to the frequency, in distinction from the electric susceptibility which is an odd function. The maximum values of the magnetic permeability are of four-five orders less than those of the dielectric ones $\mu_{st} << |\varepsilon(\omega_0)|^{\max}$ and for this reason the dispersion of magnetic response is negligible. An experimental set-up for increasing the magnetic response in such materials is by using in addition strong longitudinal DC magnetic field. Thus, the levels, connected with the magnetic dipole transitions can be separated considerably and one giant magnetic response of the order of the electric ones $\mu_{st} \sim |\varepsilon(\omega_0)|^{\max}$ can be obtained. In case of a single pulse propagation which we examine, the polarization rotation in a

linear regime is not observed in the experiments [5,6] and further we will assume $\mu(\omega)$ and $\varepsilon(\omega)$ as scalar functions with respect to the frequency. The theory, developed below, could be generalized for media with broken symmetry, as well when the magnetic permeability and the electric susceptibilities are tensor functions.

3. FROM THE MAXWELL'S EQUATIONS OF A MEDIUM WITH NON-STATIONARY OPTICAL AND MAGNETIC RESPONSE TO THE AMPLITUDE WAVE EQUATION

In case of short femtosecond optical pulses propagation with duration more or of the order of the optical and magnetic relaxation times in an isotropic medium, the linear electric polarization $\vec{P}_{lin}$ can be represented, as follows:

$$\vec{P}_{lin} = \int_{-\infty}^{t} (\delta(t-\tau) + 4\pi\chi^{(1)}(t-\tau)\vec{E}(\tau,r)d\tau = \int_{-\infty}^{t} \varepsilon(t-\tau)\vec{E}(\tau,r)d\tau \,. \tag{4}$$

Besides, the magnetic induction with respect of the magnetic field $\vec{H}$, is:

$$\vec{B}_{lin} = \int_{-\infty}^{t} (\delta(t-\zeta) + 4\pi\mu^{(1)}(t-\zeta)\vec{H}(\zeta,r)d\zeta = \int_{-\infty}^{t} \mu(t-\zeta)\vec{H}(\zeta,r)d\zeta \tag{5}$$

where $\vec{B}_{lin}$ is the magnetic induction and $r = (x, y, z)$ denotes the 3D spatial dimensions. The susceptibilities of different orders $\chi^{(n)}$ are related to the optical-dipole transitions of the atoms and molecules, whereas the magnetic permeability μ is connected with the magneto-dipole and the magneto-resonance transitions. In Eqs. (4) and (5), different relaxation times τ and ζ are used, because the optical-dipole and magneto-dipole transitions constitute different physical processes. The first are linked with the variation of the spatial distribution of the dipole charges density and the second ones – with the spatial distribution of the current density for quantum transitions in the atoms and molecules. In this case the Maxwell's equations become:

$$\nabla \times \vec{E}(r,t) = -\frac{1}{c}\frac{\partial}{\partial t}\int_{-\infty}^{t} \mu(t-\zeta)\vec{H}(r,\zeta)d\zeta \,, \tag{6}$$

$$\nabla \times \vec{H}(r,t) = \frac{1}{c}\frac{\partial}{\partial t}\int_{-\infty}^{t} \varepsilon(t-\tau)\vec{E}(\tau,r)d\tau \,, \tag{7}$$

$$\nabla \cdot \vec{H} = \nabla \cdot \vec{B} = 0 \,, \tag{8}$$

$$\nabla \cdot \vec{P}_{lin} = 0 . \tag{9}$$

The structures of the linear responses are conformed to the causality principle: the induction at any fixed point in the time-space depends only on the previous moments in the time. In Eq. (6) the magnetic field $\vec{H}$ is a function of the time variable ζ and for synchronization of these variables, it is necessary to write the magnetic field in Eq. (7) to be depended on the same one:

$$\nabla \times \vec{H}(r,\zeta) = \frac{1}{c}\frac{\partial}{\partial \zeta}\left(\int_{-\infty}^{\zeta} \varepsilon(\zeta - \tau)\vec{E}(\tau,r)d\tau \right). \tag{10}$$

Applying the ***curl*** operator to Eq. (7) and using Eq. (10), we obtain:

$$\nabla \times \nabla \times \vec{E}(r,t) = -\frac{1}{c^2}\frac{\partial}{\partial t}\int_{-\infty}^{t} \mu(t-\zeta)\frac{\partial}{\partial \zeta}\left(\int_{-\infty}^{\zeta} \varepsilon(\zeta - \tau)\vec{E}(\tau,r)d\tau \right)d\zeta . \tag{11}$$

In the left part of the latter we represent the electric field with its Fourier integral:

$$\vec{E}(r,\tau) = \int_{-\infty}^{\infty} \hat{\vec{E}}(r,\omega)e^{-i\omega\tau}d\omega \quad \text{and} \quad \vec{E}(r,\tau_i) = \int_{-\infty}^{\infty} \hat{\vec{E}}(r,\omega)e^{-i\omega\tau_i}d\omega , \tag{12}$$

and as a result we get:

$$\nabla \times \nabla \times \vec{E}(r,t) = -\frac{1}{c^2}\frac{\partial}{\partial t}\int_{-\infty}^{t} \mu(t-\zeta)\frac{\partial}{\partial \zeta}\left(\int_{-\infty}^{\zeta} \varepsilon(\zeta - \tau)\int_{-\infty}^{\infty} \hat{\vec{E}}(r,\omega)e^{-\omega\tau}d\omega d\tau \right)d\zeta \tag{13a}$$

or

$$\nabla \times \nabla \times \vec{E}(r,t) = -\frac{1}{c^2}\frac{\partial}{\partial t}\int_{-\infty}^{t} \mu(t-\zeta)\frac{\partial}{\partial \zeta}\left(\int_{-\infty}^{\zeta} \hat{\vec{E}}(r,\omega)\int_{-\infty}^{\infty} \varepsilon(\zeta - \tau)e^{-\omega\tau}d\tau d\omega \right)d\zeta . \tag{13b}$$

The causality principle implies the following conditions on the response functions: $\varepsilon(\zeta - \tau_i) = 0$ when $\zeta < \tau_i$ and $\mu(t-\zeta) = 0$ when $t < \zeta$.

They allow to extend the upper limit of integration to infinity and to arrive at the next expressions for the linear response functions:

$$\int_{-\infty}^{\zeta} \varepsilon(\zeta - \tau)e^{-i\omega\tau}d\tau = \int_{-\infty}^{\infty} \varepsilon(\zeta - \tau)e^{-i\omega\tau}d\tau = -\varepsilon(\omega)e^{-i\omega\zeta} , \tag{14}$$

$$\int_{-\infty}^{t} \mu(t-\zeta)e^{-i\omega\zeta}d\zeta = \int_{-\infty}^{\infty} \mu(t-\zeta)e^{-i\omega\zeta}d\zeta = -\mu(\omega)e^{-i\omega t} . \tag{15}$$

After brief calculations, Eq. (13b) takes the form:

$$\nabla \times \nabla \times \vec{E}(r,t) = \int_{-\infty}^{\infty} \left(\frac{\omega^2 \varepsilon(\omega)\mu(\omega)}{c^2} \hat{\vec{E}}(r,\omega) \right) e^{-i\omega t} d\omega \,. \tag{16}$$

We denote the square of the linear k^2 wave-vector with the expression:

$$k^2(\omega) = \omega^2 \varepsilon(\omega)\mu(\omega)/c^2 \,. \tag{17}$$

Thereby, it is true:

$$\nabla\left(\nabla \cdot \vec{E}(r,t)\right) - \Delta\vec{E}(r,t) = \int_{-\infty}^{\infty} k^2(\omega)\hat{\vec{E}}(r,\omega)e^{-i\omega t} d\omega \,. \tag{18}$$

Let us introduce here the amplitude function $\vec{A}(r,t)$ for the electric field $\vec{E}(r,t)$:

$$\vec{E}(r,t) = \vec{A}(r,t)e^{i(k_0 z - \omega_0 t)} \tag{19}$$

where ω_0 and k_0 are the carrier frequency and the carrier wave number of the wave packet, and also the Fourier transform of the amplitude function $\hat{\vec{A}}(r,\omega-\omega_0)$:

$$\vec{A}(r,t) = \int_{-\infty}^{\infty} \hat{\vec{A}}(r,\omega-\omega_0)e^{-i(\omega-\omega_0)t} d\omega \,. \tag{20}$$

The following relation between the Fourier presentation of the electrical field $\hat{\vec{E}}(r,\omega)$ and the Fourier presentation of the amplitude function $\hat{\vec{A}}(r,\omega-\omega_0)$ holds:

$$\hat{\vec{E}}(r,\omega)e^{-i\omega t} = e^{i(k_0 z - \omega_0 t)}\hat{\vec{A}}(r,\omega-\omega_0)e^{-i(\omega-\omega_0)t} \tag{21}$$

where $\vec{A}(r,t)$ и $\hat{\vec{A}}(r,\omega-\omega_0)$ are the amplitude function and its Fourier image, respectively. Writing the function mentioned in this form means that we consider propagation in $+z$ $-$direction only and neglect the transmission in the opposite one. Substituting Eqs. (20) and (21) in Eq. (18) and bearing in mind the fact that $\nabla\left(\nabla \cdot \vec{E}\right) \approx 0$, we derive the following integro-differential amplitude equation:

$$\Delta\vec{A}(r,t) + 2ik_0 \frac{\partial \vec{A}(r,t)}{\partial z} - k_0^2 \vec{A}(r,t) = -\int_{-\infty}^{\infty} k^2(\omega)\hat{\vec{A}}(r,\omega-\omega_0)e^{-i(\omega-\omega_0)t} d\omega \,. \tag{22}$$

No restrictions are imposed here on the amplitude function. When the analytical expression for $k^2(\omega)$ and $\hat{k}_{nl}^2(\omega)$ are known for a specific spectral region, the integral in the right-hand side of Eq. (22) is bounded, since the Fourier transform of the localized function (pulse) of the electric field is a localized one. This is why we can investigate optical pulses with duration of the order of the optical oscillation. Generally, with Eq. (22) we can describe wave-packets with duration of the order of

the optical oscillation, as well as such, with higher number of cycles under the pulse in media with polarization and magnetization. In this way we can transform Eq. (22) to a linear one which governs the evolution of pulses with duration of the order of the optical oscillation in a medium with non-stationary optical and non-stationary magnetic response. The linear integro-differential Eq. (22) could be written as differential equations, if in their left-hand side we do the Fourier transform with respect to time (20). The differential operators in the left are spatial. Therefore, we can shift them after the integral and thus we obtain the following linear equation:

$$\Delta\hat{\vec{A}}(r,\omega-\omega_0)+2ik_0\frac{\partial\hat{\vec{A}}(r,\omega-\omega_0)}{\partial z}+\left(k^2(\omega)-k_0^2(\omega_0)\right)\hat{\vec{A}}(r,\omega-\omega_0)=0\,. \qquad (23)$$

Thus, we transformed Eq. (22) to the Helmholtz's type Eq. (23) for the amplitude function with respect of the spectral component. These equations express the well-known fact that natural basis for the spectral component of the amplitude function is the spectral deviation $\Delta\omega=\omega-\omega_0$ and not the frequency itself. In the special case of pulses with at least of a few cycles in a pulse, on expanding the linear wave vector's square up to the second degree of dispersion, in the next Section we will obtain a form of the integro-differential Eq. (22), valid for slowly varying amplitudes.

4. SLOWLY-VARYING EQUATION OF AMPLITUDES (SVEA) IN MEDIA WITH OPTICAL AND MAGNETIC RESPONSE

To obtain the SVEA in a second approximation to the linear dispersion, we develop k^2 in Taylor series around the wave-packets carrying frequency ω_0:

$$k^2=\frac{\omega^2\varepsilon(\omega)\mu(\omega)}{c^2}=k_0^2(\omega_0)+\frac{\partial\left(k^2(\omega)\right)}{\partial\omega_{\omega=\omega_0}}(\omega-\omega_0)+\frac{1}{2}\frac{\partial\left(k^2(\omega)\right)}{\partial\omega_{\omega=\omega_0}}(\omega-\omega_0)^2+\ldots\,. \qquad (24)$$

The first term of the Taylor's series of the linear wave vector cancels with the last term in the left-hand side of Eq. (22). The second and the third terms in the Taylor's development of the linear wave vector (24) (dispersion of the first and second order) give the main contribution in the Fourier's integral in the right-hand side of Eq. (22). As shown in Ref. [9], the convergence of the series (24) for gases and dielectric materials depends on the harmonics under the wave-packet envelopes. For wave-packets with more than 5-10 cycles under the envelope on the level "half-max" of the pulse, the Taylor's series (24) is strongly convergent and the third term is 3-4 times

smaller than the second one. For that reason we can interrupt the Taylor series to examine the dynamics of the wave-packets in an approximation up to the second order of the dispersion. In case of wave-packets with only two, one or less than one periods of the optical oscillations under the envelope curve, the series (24) is non-convergent. Therefore, the equations for the slowly varying amplitudes which will be worked-out below, cannot describe the propagation dynamics of the wave-packets with duration of the order of the optic oscillation. Introducing the series (24) into Eq. (22) and after some calculations, we obtain the next SVEA up to the second approximation of the linear dispersion:

$$\Delta\vec{A} + 2ik_0\frac{\partial\vec{A}}{\partial z} = -2ik_0k'\frac{\partial\vec{A}}{\partial t} + \left(k_0k'' + k'^2\right)\frac{\partial^2\vec{A}}{\partial t^2}... \tag{25}$$

Eq. (25) seems identical with the SVEA equations for media with stationary magnetic response $\mu = const$. The most important result here is that the inclusion also of the dispersion of the magnetic response $\mu(\omega)$ in Eq. (25) gives us significant new dynamics of the localized optical waves. We now define the next constants of the wave packets: wave number $k_0(\omega_0)$, linear refractive index $n(\omega_0)$, group velocity v, and dispersion of the group velocity $k''(\omega_0)$:

$$k_0 \equiv k(\omega_0) = \frac{\omega_0}{c}\sqrt{\varepsilon(\omega_0)\mu(\omega_0)}, \tag{26}$$

$$n(\omega_0) = \sqrt{\varepsilon(\omega_0)\mu(\omega_0)}, \tag{27}$$

$$v = \left.\frac{1}{k'}\right|_{\omega=\omega_0} = c\Big/\left(\sqrt{\varepsilon(\omega_0)\mu(\omega_0)} + \frac{\omega_0}{2}\left(\sqrt{\frac{\mu}{\varepsilon}}\left.\frac{\partial\varepsilon}{\partial\omega}\right|_{\omega=\omega_0} + \sqrt{\frac{\varepsilon}{\mu}}\left.\frac{\partial\mu}{\partial\omega}\right|_{\omega=\omega_0}\right)\right), \tag{28}$$

$$k''(\omega_0) = \left.\frac{\partial^2 k}{\partial\omega^2}\right|_{\omega=\omega_0}. \tag{29}$$

All these quantities allow a direct physical interpretation and we will rewrite Eq. (25) in a form, consistent with these constants:

$$-i\left[\frac{\partial\vec{A}}{\partial t} + v\frac{\partial\vec{A}}{\partial z}\right] = \frac{v}{2k_0}\Delta\vec{A} - \frac{v}{2}\left(k'' + \frac{1}{k_0v^2}\right)\frac{\partial^2\vec{A}}{\partial t^2}. \tag{30}$$

Eq. (30) can be assumed to be a SVEA of the second approximation with respect to the linear dispersion in media with non-stationary linear optical and magnetic response. It includes the effects of transition in z direction with group velocity v,

diffraction and dispersion of the second order. Similar expressions for the group velocity and the dispersion of the group velocity have recently been deduced in one-dimensional SVEA approximation [10]. We use only the linear magnetic response, that is why, as it can be seen from the expression, the linear effects as linear refractive index, group velocity and the dispersion of the group velocity, are substantially different, than the expressions for these constants when $\mu = const$ (standard dielectric media). New possibilities for spreading of wave packets in media with non-stationary optical and magnetic response appear. Particularly when $\mu(\omega)$ is an even function, near to the magnetic resonance, we can obtain the magnetic permeability to be of the order of the optical one ($\varepsilon(\omega) \propto \mu(\omega)$) and with opposite sign of their derivatives:

$$\frac{\partial \varepsilon}{\partial \omega_{\omega=\omega_0}} > 0\,, \qquad \frac{\partial \mu}{\partial \omega_{\omega=\omega_0}} < 0\,. \tag{31}$$

This gives the unique opportunity to get group velocity, larger than the phase velocity and the velocity of light in vacuum, if the denominator in the expression of the group velocity (28) is smaller, than the expression:

$$\sqrt{\varepsilon(\omega_0)\mu(\omega_0)} + \frac{\omega_0}{2}\left(\sqrt{\frac{\mu}{\varepsilon}}\frac{\partial \varepsilon}{\partial \omega_{\omega=\omega_0}} + \sqrt{\frac{\varepsilon}{\mu}}\frac{\partial \mu}{\partial \omega_{\omega=\omega_0}}\right) < 1 \tag{32}$$

or negative group velocity when the denominator in (28) is negative:

$$\sqrt{\varepsilon(\omega_0)\mu(\omega_0)} + \frac{\omega_0}{2}\left(\sqrt{\frac{\mu}{\varepsilon}}\frac{\partial \varepsilon}{\partial \omega_{\omega=\omega_0}} + \sqrt{\frac{\varepsilon}{\mu}}\frac{\partial \mu}{\partial \omega_{\omega=\omega_0}}\right) < 0\,. \tag{33}$$

As the static and correspondingly the non-stationary magnetic susceptibility is of three orders smaller, than the optical-dielectric one, the conditions (32) and (33) are practically unfulfilled for optical pulses propagation in standard paramagnetic structures. In spite of this, for the discussed above ferromagnetic with temperature slightly higher than the Curie paramagnetic one near paramagnetic resonances or by using a strong longitudinal DC magnetic field in semiconductors and paramagnetic structures, the conditions (32) or (33) can be satisfied.

We therefore make the following conclusion: The SVEA (30) derived for media with dispersion of the optical susceptibility and magnet permeability, practically admit equal structures and terms as the equation with stationary magnetic and non-stationary optical response. On the other hand, the dynamics of the localized waves is quite

different from that in media with $\mu = const$, as the expressions for linear refractive index (27), the group velocity (28) and the dispersion of the group velocity (29) are different from these of the standard dielectrics.

5. CONCLUSION

In the last few years several experiments have been made, demonstrating ultra-short relaxation times of the linear magnetic response of the order of 50-100 fsec [5,6]. It is important to point out here also the significant increase of the static magnetic response in such materials as nickel for temperatures up to the Curie paramagnetic temperature and also in some semiconductors. The higher values of the static permeability and ultra-short relaxation times of the magnetic response requires the non-stationary magnetic response together with optical one in Maxwell's equations for such media also to be taken into account. In this paper these non-stationary processes are investigated and an amplitude integro-differential Eq. (22), governing the dynamics of the optical pulses with duration of the order of the optical period, is obtained. For pulses with many optical harmonics under the envelopes, the Taylor series of the square of the linear and nonlinear wave vectors, are strongly convergent. This is the reason the nonlinear integro-differential Eq. (22) to be reduced to a nonlinear differential SVEA (30). We mention, too that the SVEA (30), derived here for media with dispersion of the optical susceptibility and magnet permeability, practically admits equal structures and terms as the equation with stationary magnetic and non-stationary optical response, while the dynamics of the localized waves, determined from the expression for the group velocity (28) and the dispersion of the group velocity (29), are quite different than the corresponding dynamics for media with $\mu = const$. Particularly, near to the paramagnetic resonances or in a paramagnetic, pumped by additional longitudinal strong DC magnetic field, it is possible to obtain negative group velocity and group velocity higher than the phase velocity and the velocity of light in vacuum.

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PROBABILITY METHODS FOR WIND ENERGY ASSESSMENT

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Abstract

The wind characteristics and wind energy potential are analyzed in this study, using a monthly and yearly average wind speed data. The wind energy potential of several sites in Bulgaria is investigated by compiling data from different sources. Wind speed distribution curves are generated, employing the Weibull and Rayleigh probability density functions. The results, relating to the wind energy potential, are presented in terms of the monthly average wind speed, wind speed probability density function (PDF), wind speed cumulative density function (CDF) and wind speed duration curve. A technical assessment is made for electricity generation from two wind turbines, having capacity of 60 and 600 kW. The yearly energy output, produced by the two different turbines, is calculated. On the basis of these results, wind energy potential map of Bulgaria, is created.

1. INTRODUCTION

The wind is an energy source with accelerating penetration in the energy market. However, the development of new wind projects continues to be hampered by the lack of reliable and accurate wind resource data in many parts of the world. Such data are needed to determine the priority which should be given to wind energy utilization and to identify potential areas that might be suitable for the development of wind farms. The time distribution of wind speeds is important for the design of wind farms and power generators.

Bulgaria has a large potential of renewable energies. The wind energy is economically valuable and over the last few years wind projects with approximately 300 MW installed capacity have been developed. Particularly, some parts of the coastal region of the Black Sea and locations with rugged mountains are especially promising regions for wind energy utilization.

In the last decade, a lot of studies, related to the wind characteristics and wind power potential have been made in many countries worldwide [1-5]. For a proper and

beneficial development of the wind power at any location, the wind data analysis and the accurate wind energy potential assessment are the key requirements. The energy assessment of wind resources needs suitable and accurate source data. In Bulgaria there are different types of statistically prepared data that require special mathematical treatment. The main wind data which could be used for an energy evaluation are the monthly average and standard deviation of the wind speed data and the probability for the wind speed to be within determined intervals. These two data sources could be employing to appraise the wind speed distribution and the wind energy.

2. PROBABILITY ESTIMATION

Before the installation of a wind turbine, it is necessary to estimate the expected power output in order to assess the economic viability of the project. In order to calculate the power output from a given wind turbine, it is indispensable to know the wind speed distribution at the planned turbine location. It is very easy to find the average wind speed at a certain location, but this is not sufficient for the energy estimation. This is due to the fact that the power potential of the wind is related to the cube of the wind speed. However, the power production performance of a practical wind turbine is rather proportional to the square of the average wind speed. The difference is accounted for by the aerodynamic, mechanical and electrical conversion characteristics and efficiencies of the wind turbines.

The human sensory perception of the wind is usually based on short-term observations of climatic extremes, such as wind storms and wind chill impressions, but these "wind speeds" might be wrongly interpreted as representatives of a windy site. The proper wind resource assessment is a standard and important component of the wind energy project developments.

For the wind industry it is very important to be able to describe the variation of wind speeds. The turbine designers need the information to optimize the design of their turbines. The turbine investors need the information to evaluate their income from the electricity generation. A simple knowledge of the mean wind speed is not sufficient to estimate the available regional wind potential. Additionally, thorough information is needed to determine the probability distribution of the appearance of several wind speed values in the course of time, with an emphasis on recording the stillness intervals and the intervals of the appearance of very strong winds [4].

Wind power density (*wpd*, Wm^{-2}) can be calculated, according to the relation [4,7]:

$$wpd = \frac{1}{2}(\rho C_{PR} C_T)V^3 \tag{1}$$

where ρ is the air density (kg/m^3) and V is the wind speed (m/s). Pressure and temperature correction terms (C_{PR} and C_T, respectively) are applied to account for the deviations from the standard atmospheric density (1.225 kg/m^3), due to differences from the standard sea level pressure (1013.25 hPa) and temperature (288.15 K). The correction factors are computed from the expression [5]:

$$C_{PR} = \frac{P_a}{1013.25}; \quad C_T = \frac{288.15}{T_a} \tag{2}$$

where P_a is the sea level pressure (hPa) and T_a is the air temperature (K) at the site.

Eq. (1) shows that it is very important to know the number of hours per month or per year, during which the given wind speeds occurred, i.e. the frequency distribution of the wind speeds. The average wind speed is not suitable for the wind power density determination.

The wind speed probability distributions are the main tools, used in the wind-related investigations and project calculations. Their mathematical functions propose a wide range of techniques, utilized to identify the parameters of the distribution functions [5]. The employment of such functions for analyzing the wind speed data and wind energy economics is verified very carefully [6,7]. The wind speeds in the largest part of the world can be modeled, applying the Weibull distribution [6]. This statistical tool tells us how often winds of different speeds will be seen at a location with a certain average (mean) wind speed. The distribution mentioned is widely used in reliability and life data analysis, due to its versatility. Depending on the values of the parameters, it can be harnessed to model also a variety of life behaviors.

Advantage can be taken of the two-parameter Weibull probability model, the lognormal, gamma and Rayleigh ones [3,5,6]. The practice and investigations show that the Weibull probability distribution function should be found to fit the monthly frequency distribution of wind speed measurements very accurately. This means that the most of the wind speed distribution characteristics at any site can be described by two parameters: the shape parameter K and the scale one C. The fraction of time duration in which the wind blows at speed V, is thus determined therefore by [3,5,6]:

$$f(V)=\frac{K}{C}\cdot\left[\frac{V}{C}\right]^{K-1}\exp\left(-\left[\frac{V}{C}\right]^{K}\right). \tag{3}$$

This expression is valid for $K>1$, $V\geq 0$ and $C>0$. The shape factor typically ranges from 1 to 3. For a given average wind speed, the smaller shape factor indicates a relatively wide distribution of the wind speeds around its average value, while the larger one points out a relatively narrow distribution of the wind speeds (see, Fig. 1). The smaller shape factor normally leads to a higher energy production for a given average wind speed. C is the scale factor which is calculated from the following equation [5,6]:

$$C=\frac{\overline{V}}{\Gamma\left(1+\frac{1}{K}\right)} \tag{4}$$

where $\overline{V}$ is the average wind speed value and Γ is the gamma function.

The duration curve may be found from the total probability function [5], i.e.:

$$F(V\leq V_0)=1-\exp\left[-\frac{V_0^k}{C}\right]. \tag{5}$$

Here ''F'' represents the probability for the speed ''V'' to be lower than a certain value ''V_0''.

A key problem for the wind speed analysis is the estimation of the Weibul parameters K and C. They depend on the geographical characteristics of the region, on the wind regime and on the type of wind data, collected for a given location. Numerous methods have been proposed over the last few years for the Weibul parameter estimation [6,8]. In this study, the two parameters of the Weibull distribution are determined, by using the mean wind speed-standard deviation method and an approach, based on the data of the wind speed duration in speed intervals. The first of them uses the monthly-mean wind speed and standard deviations, calculated for the available time-series data.

The value that fits best for K is found to be [6]:

$$K=\left(\frac{\sigma}{\overline{U}}\right)^{-1.086} \tag{6}$$

where, $\overline{U}$ ($\overline{U}\equiv\overline{V}$) is the mean wind speed and σ is the standard deviation.

Table 1. Probability distribution data for wind speed – region Kaliakra.

Wind speed	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
0 – 2	10.5	13.7	14.8	23.2	25.9	26.0	23.0	18.5	14.4	15.9	13.0	11.6
2 – 6	34.2	33.1	36.2	26.6	44.0	45.0	45.4	48.0	48.8	46.2	43.4	38.8
6 – 10	26.2	21.1	18.4	10.1	13.4	14.8	14.9	13.4	17.1	17.4	20.5	19.7
10 – 14	9.5	7.6	6.2	2.9	3.6	3.1	4.1	3.2	3.8	5.6	7.4	4.9
14 – 18	3.3	3.7	3.1	0.7	0.3	0.8	0.9	0.8	1.7	2.1	2.7	3.1
18 – 20	4.3	3.0	2.5	0.7	0.4	0.2	0.1	0.3	0.2	1.5	1.5	2.9
> 20	1.2	0.4	1.3	0.3	0.2	0.1	0.1	0.4	0.3	0.2	0.0	1.6

The second method employs the data of the observations for wind speed in intervals with preliminary defined boundaries. The same can be utilized to construct a rough approximation to the duration curve. The latter represents the probability of the wind speed V to be lower than a certain value. Data, available in a specific region of Bulgaria, are given in Table 1, showing the ranges in which the monthly probability value (in percentages) for the wind speed varies.

These results can be used to create the duration curve for the wind speed distribution and by means of Eq. (4) – to find the parameters K and C.

The equation referred to can be written also, as follows [10]:

$$\ln(-\ln(1-F(V \le V_0))) = K \ln\left(\frac{V_b}{C}\right) = K \ln(V_b) - K \ln(C) . \tag{7}$$

The numerical equivalent of the quantities K and C can be calculated through the least squares fitting of the duration curve that describes the above data.

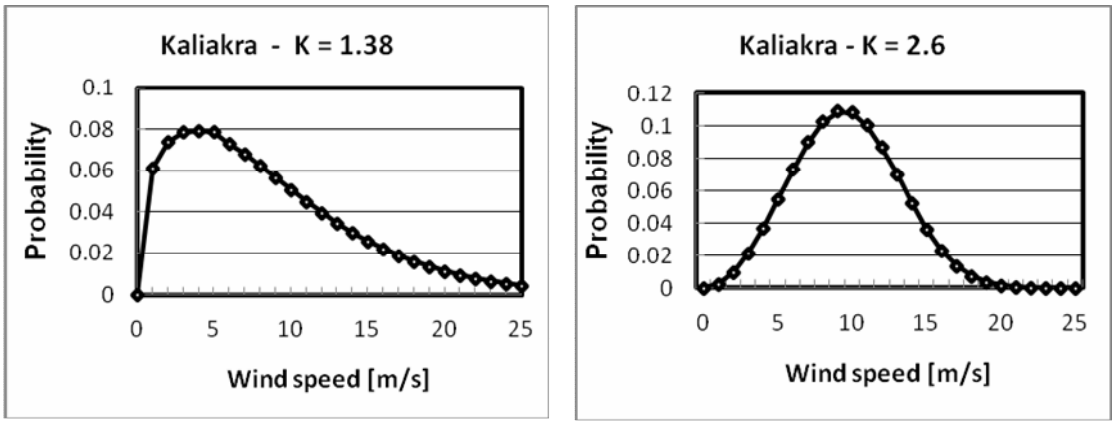

Figure 1. Weibull probability distribution function.

The calculations made, using the two methods, give different results for the most of the locations in Bulgaria. The probability curves of the wind speed, counted with the parameters, assessed by the two schemes, are presented in Fig. 1. The probability curves are from the Kaliakra region, near the Black Sea. The first of them is reckoned with a shape factor $K = 2.6$. It is estimated, employing the mean wind speed and the standard deviations. The second line depicts the wind speed distribution with a shape factor $K = 1.38$. It is figured, taking advantage of the least squares fitting the duration curve. It gives a more accurate approximation of the data from Table 1. This ascertainment acts for the most of the locations in Bulgaria. Because of that, the second method is applied predominantly for assessing the wind speed distribution in this work.

3. ENERGY CURVE

The energy curve is the total amount of energy, a wind turbine produces over a range of annual or monthly average wind speeds. In Fig. 2, the curves for the Atlantic Orient Corporation AOC 15/50 – 60 kW wind turbine (rotor diameter – 15 m) and Vestas V47 – 600kW (rotor diameter – 47 m) are computed over the range from 3 to 25 m/s average wind speed and are displayed graphically.

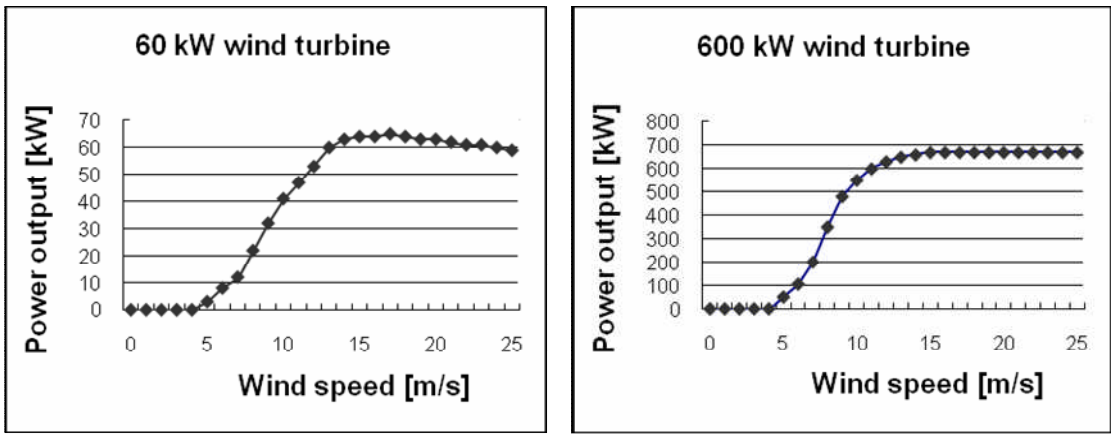

Figure 2. Energy curves for 60 KW and 600 kW wind turbines.

The user determines the wind turbine power curve as a function of the wind speed in increments of 1 m/s, from 0 m/s to 25 m/s. As for the power curve model of a wind turbine, it can be done for four specific parameters: the cut-in speed V_c, the rated speed V_r, the cut-off speed V_f and the nominal power P_r. The power curve of a wind turbine can be approximated well by the parabolic law [9]:

$$P = \begin{cases} P_r \dfrac{V^2 - V_c^2}{V_r^2 - V_c^2}, & if \;\; V_c \le V < V_r \\ P_r, & if \;\; V_r \le V < V_f \\ 0, & otherwise \end{cases} \tag{8}$$

where V is the wind speed considered. Gross energy production E_V is the total annual energy, produced by the wind energy equipment, before any losses, at the wind speed, atmospheric pressure and temperature conditions at the site. E_V is then figured out from the formula [9]:

$$E_V = T \sum_{i=1}^{25} P_i \; p(i) \tag{9}$$

in which P_i is the turbine power at wind speed i and $p(i)$ is the Weibull probability density function for wind speed i, calculated for an average wind speed V.

4. WIND ENERGY POTENTIAL ON THE TERRITORY OF BULGARIA

A software program (*Wind_Energy*) for evaluating the energy efficiency in wind projects is elaborated. Calculations, related to many places in Bulgaria are made with its help for two wind turbines. The result for the gross energy production is presented

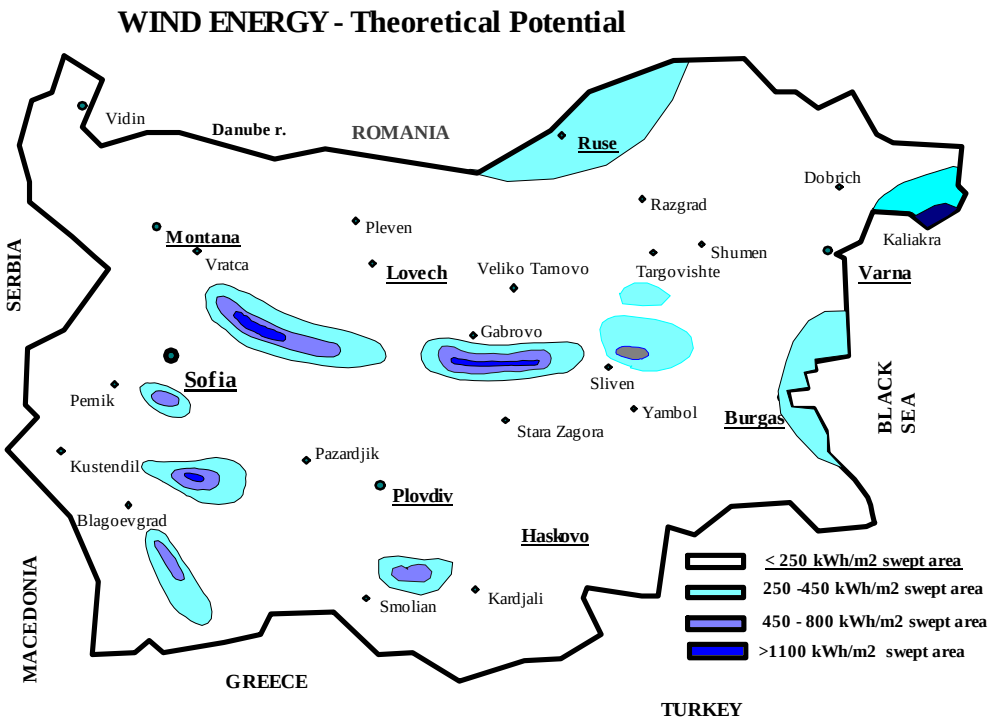

Figure 3. Wind energy potential of Bulgaria.

as the energy for an unit 'swept' area by wind turbine rotor – kWh/m^2. This information is summarized and depicted graphically by the geographical map of the wind energy potential in Bulgaria (cf. Fig. 3). It is seen that there are some places with a very good energy potential, but a very large part of the territory of the country is not suitable for wind energy utilization.

5. CONCLUSION

Detailed analysis of the suitable mathematical methods is conducted to asses the parameters of the Weibull distribution functions. For the available wind speed data in Bulgaria the least squares fitting the duration curve method is chosen.

New technologies in planning, design and operation for wind energy utilization often need the employment of computers. Mathematical models of wind speed distribution require computer programs for detailed energy calculations. An engineering software is developed (*Wind_Energy*) for use by professionals to perform calculations aimed at achieving energy efficiency in wind projects.

Calculations related to many places in Bulgaria are made with the software program mentioned. The information is summarized and presented graphically by a geographical map of wind energy potential in Bulgaria.

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INTERACTIONS OF ^{8}B AND ^{9}C NUCLEI WITH EMULSION NUCLEI

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Abstract

Results on the dissociation of ^{8}B and ^{9}C nuclei in very peripheral interactions with emulsion nuclei are presented. The paper is illustrated with characteristic images, obtained by means of a microscope, equipped with a CCD camera.

1. INTRODUCTION

The BECQUEREL Project is devoted to a systematic exploration of the clustering features of light stable and radioactive nuclei in beams from the Nuclotron at the Joint Institute for Nuclear Research (JINR, Dubna), by employing the emulsion technique. The method of nuclear track emulsions is the most appropriate for studying the relativistic fragmentation of neutron-deficient light nuclei, because it ensures the most detailed observation of the interaction pattern. Examples, illustrating the application of this approach, can be found in Refs. [1-3]. The traditional task of the nuclear-track-emulsion method is to outline the nuclear-interaction pattern on the basis of a limited statistical data sample in order to plan better future complicated experiments, featuring various detectors. Limitations on the statistics, subjected to the analysis, are compensated to a certain extent by the impossibility to observe completely the composition of fragments within other procedures.

The presence of rather heavy nuclei of silver and bromine and a group of light nuclei of carbon, nitrogen, oxygen and hydrogen in similar concentrations in nuclear track emulsions is of use in comparing peripheral interactions of different types.

Under identical conditions, one can observe the break-up of a nucleus both in the electromagnetic field of a heavy target nucleus and in collisions with target protons. Events of the fragmentation of track-emulsion nuclei contain strongly ionizing target fragments, including alpha particles, protons of energy below 26 MeV and light recoil nuclei (b particles whose multiplicity is denoted by n_b), as well as nonrelativistic protons of energy in excess of 26 MeV (g particles whose multiplicity is denoted by n_g). Relevant reactions are also characterized by the multiplicity n_s of product mesons (s particles). Using these parameters, one can draw preliminary conclusions on the character of the interaction. An example of the interaction of projectile nuclei in a nuclear track emulsion is shown in Fig. 1.

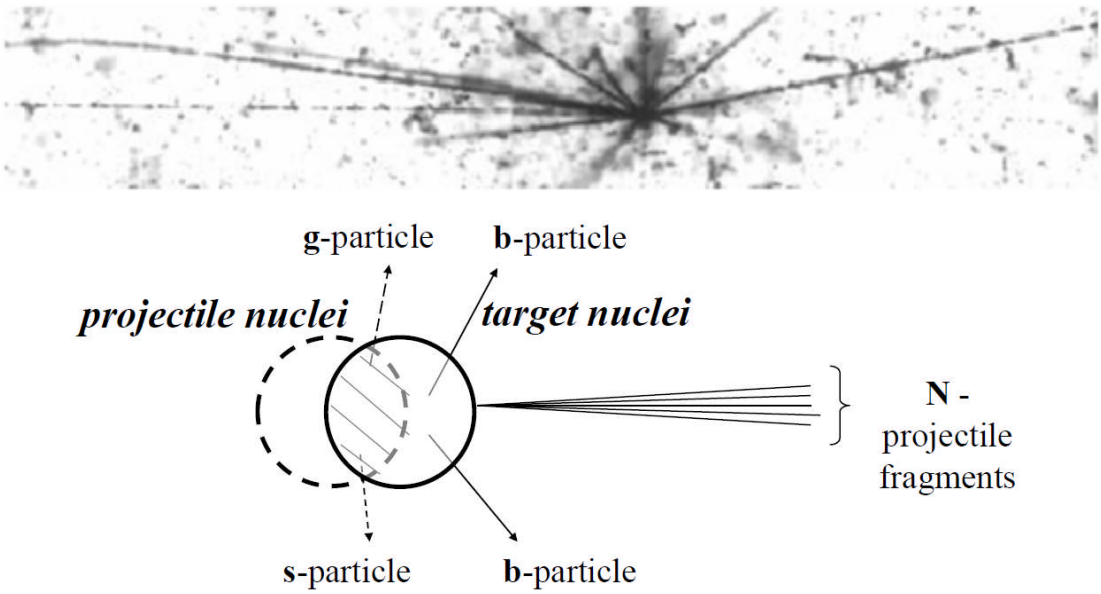

Figure 1. Example of the interaction of projectile nuclei in a nuclear track emulsion. The upper microphotograph represents the image of the event in emulsion.

The fragmentation of the relativistic ^{8}B and ^{9}C nuclei is the aim of the research. The nuclei in question are studied first by the method of the nuclear track emulsion. This enables to deduce information both about the dissociation channels $^8\mathrm{B} \to {}^7\mathrm{Be} + p$, $^9\mathrm{C} \to {}^8\mathrm{B} + p$, $^9\mathrm{C} \to {}^7\mathrm{Be} + p + p$ and about dissociation into extremely light nuclei He and H. Of particular interest are events that do not contain target-nucleus fragments or charged mesons ($n_b = 0$, $n_g = 0$, $n_s = 0$) – the so-called "white" stars (examples are given in Figs. 2 and 3). They form an observational basis in the search for electromagnetic dissociation events. (Micro-photographs and movies of typical events can be found at the address http://becquerel.lhe.jinr.ru/movies/movies.html.)

Figure 2. Example of the peripheral interaction of ^{7}Be→2He in a nuclear track emulsion ("white" star). Following the direction of the fragment jet, it is possible to distinguish 2 doubly charged fragments.

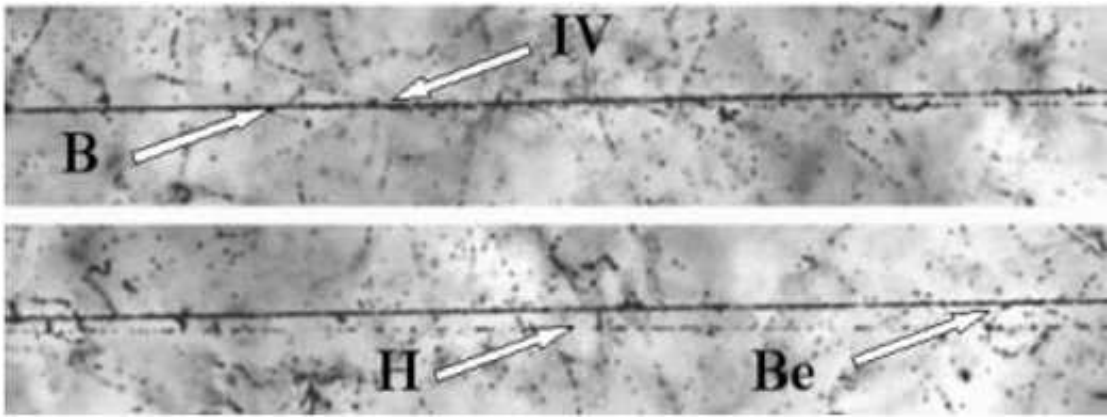

Figure 3. Example of the peripheral interaction of a 1.2 A GeV ^{8}B→^{7}Be+p in a nuclear track emulsion ("white" star). The interaction vertex (indicated as IV) and the nuclear fragment tracks (H and Be) in a narrow angular cone are seen in the upper and bottom parts of the microphotograph.

2. ^{8}B DISSOCIATION

Nuclear emulsions were exposed to relativistic ^{8}B nuclei at the JINR Nuclotron. The beam of relativistic ^{8}B nuclei was obtained in the $^{10}\mathrm{B} \rightarrow {}^{8}\mathrm{B}$ fragmentation reaction, using a polyethylene target [4]. Data were obtained at a beam energy of 1.2 A GeV. Events were sought by a microscope scanning over the emulsion plates. 1070 interactions of $Z_{pr} \geq 3$ (Z_{pr} – the charge of primary nuclei) nuclei over the total track length of $L = 144$ m were found. The mean free path before interaction was $\lambda = 13.5 \pm 0.4$ cm (see Fig. 4) which corresponds to the expectation, based on the data for the closest cluster nuclei. In this sample, 434 peripheral-fragmentation stars were selected in which the total charge of the relativistic fragments in the fragmentation cone of critical angle 8° satisfies the condition $\sum Z_{fr} > 2$.

About 5% of all inelastic interactions or about 12% of all peripheral interactions are events of the type "white" stars (52 events) which contain only the charged fragments of a relativistic nucleus. They do not contain any other secondary charged particles and the total charge of the fragments is equal to the primary-nucleus one $Z_{pr} = 5$. A leading contribution of the "white" stars $^{8}\mathrm{B} \rightarrow {}^{7}\mathrm{Be} + p$ (50% or 25

events), having the lowest energy threshold was revealed. Owing to an extremely small binding energy of the outer proton, the ^{8}B nucleus is the most sensitive indicator of electromagnetic interaction with heavy nuclei. 14 electromagnetic events, characterized by a mean value of the total transverse momentum $\langle P_T(^{8}\mathrm{B}^{*})\rangle = 50 \pm 8$ MeV/c at RMS = 30 MeV/c were selected. Precisely they are the ones that correspond to the presumed criteria for the electromagnetic character of their formation and underlie the estimation of the cross section for electromagnetic dissociation through the ^{7}Be + p channel. Because of the very strong dependence of the electromagnetic cross section on the target-nucleus charge in the form Z^2, it is natural to assume a proportional contribution of Ag and Br nuclei from the composition of the nuclear track emulsion and to disregard the contribution of the light nuclei. The obtained values of the electromagnetic cross section were $\sigma_{\mathrm{Ag}} = 81 \pm 21$ mb and $\sigma_{\mathrm{Br}} = 44 \pm 12$ mb. For electromagnetic dissociation on a Pb nucleus, an extrapolation of σ_{Ag} leads to a value of $\sigma_{\mathrm{Pb}} = 230 \pm 60$ mb which is close to the theoretical value of about 210 mb [5] and which is consistent with the assumption of the electromagnetic nature of the selected events.

Information about the relative probability of the ^{8}B dissociation modes with larger multiplicity has been obtained, too. The (2He + H) and (He + 3H) channels saturate about 50% for events of the type "white" stars. The ^{7}Be core dissociation in ^{8}B is found to be similar to that of the free ^{7}Be nucleus [6].

3. ^{9}C DISSOCIATION

The fragmentation of 1.2 A GeV ^{12}C nuclei, accelerated at the JINR Nuclotron, was used to form a secondary beam with low magnetic rigidity for the best selection of ^{9}C nuclei [4]. The exposed stack consisted of 19 layers of BR-2 nuclear track emulsion with a relativistic sensitivity. The layer thickness and dimensions were 0.5 μm and 10x20 cm^2. Stack exposure was performed in a beam, directed in parallel to the plane of the stack, along its long side. The presented analysis is based on a complete scanning of 13 layers along the primary tracks with charges, visually assessed as $Z_{pr} > 2$. ^{3}He nuclei were rejected at the primary stage of the selection. The ratio of intensities $Z_{pr} > 2$ and $Z_{pr} = 2$ was about 1:10. The presence of particles $Z_{pr} = 1$ in the ratio $Z_{pr} > 2$ 1:1 was also detected. The $Z_{fr} = 1$ fragments were separated visually from the $Z_{fr} = 2$ fragments, because their ionization was four times

smaller. Over the viewed length of 167.1 m traces, one finds 1217 interactions, mostly produced by C nuclei. Thus, it was obtained that the mean free path was equal to $\lambda_C = 13.7 \pm 0.4$ cm (see Fig. 4). This value corresponds to the estimate, based on the data for the neighbouring cluster nuclei.

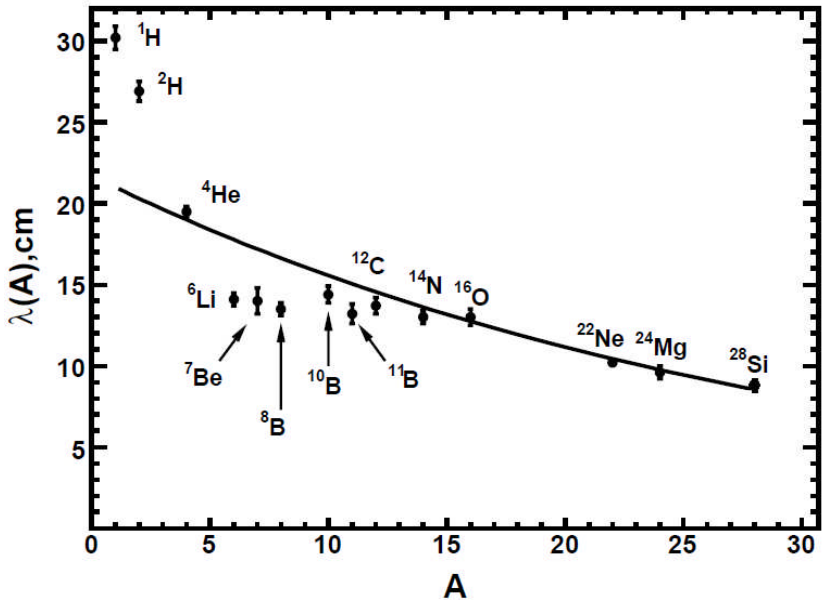

Figure 4. Mean range λ(A) of a projectile with respect to the inelastic interactions in the photo-emulsion as a function of the projectile mass number. The curve represents a fit, obtained within the geometric model.

Information about the charge composition of charged fragments and about the channels of ^{9}C nucleus fragmentation in peripheral collisions has been obtained. The number of the found events, having the primary-nucleus charge $Z_{pr} = 6$ in which the total charge of fragments is equal to six and in which charged mesons or target-nucleus fragments are not observed, is equal to 90 (about 7% of all the events). Events with fragments $Z_{fr} = 5$ and 4 and identified charges $Z_{pr} = 6$, accompanied by protons, are interpreted as channels $^9\mathrm{C} \rightarrow {}^8\mathrm{B} + p$ and $^7\mathrm{Be} + 2p$. These two channels are relative to the most low-threshold dissociation of the nucleus ^{9}C and constitute about 30% of the events of $\sum Z_{fr} = 6$. The main conclusion is that the contribution of the dissociation channel $^9\mathrm{C} \rightarrow {}^8\mathrm{B} + p$ and $^9\mathrm{C} \rightarrow {}^7\mathrm{Be} + 2p$ is most important in events that do not involve the production of target-nucleus fragments or mesons ("white" stars). It can be concluded that in the peripheral ^{9}C dissociation the picture hitherto obtained for ^{8}B and ^{7}Be with the addition of one or two protons, respectively, is reproduced.

The distribution of "white" stars, produced by ^{7}Be, ^{8}B and C nuclei of the charge configurations $\sum Z_{fr}$ which consist only of the nuclei H and He, is presented in Table 1. From the sum $\sum Z_{fr}$ one H nucleus is excluded for the ^{8}B cases and 2H – for the C cases. There are similar fractions of the channels 2He and (He + 2H) which correspond to the appearance of ^{7}Be as a core of ^{9}C.

Table 1. Distribution of the numbers and fractions of "white" stars of ^{7}Be, ^{8}B and C nuclei, over H and He configurations.

Channel	**^{7}Be**	**Fraction, %**	**^{8}B (+ H)**	**Fraction, %**	**^{9}C (+ 2·H)**	**Fraction, %**
2He	41	43	12	40	24	42
He + 2H	42	45	19	47	28	44
4H	2	2	4	13	6	10
Li + H	9	10	3	0	2	4

This paper provides a framework for further accumulation of statistics and for a detailed analysis of the ^{9}C interactions.

4. CONCLUSION

The presented observations serve as an illustration of the prospects of the relativistic nuclear beams for the nuclear astrophysics. The results of an exclusive study of the interactions of relativistic ^{8}B and ^{9}C nuclei in nuclear emulsion lead to the conclusion that the known features of their structure are clearly manifested in very peripheral dissociations. In spite of an extraordinarily large distinction from the nuclear excitation energy, the relativistic scale does not impede investigations of nuclear interactions in energy scale, typical for nuclear astrophysics, but on the contrary – gives also new methodical advantages.

Due to a record space resolution, the emulsion technique affords a unique entirety in studying of light nuclei, especially, neutron-deficient ones. Providing the 3D-observation of narrow dissociation vertices, these classical technique provides novel possibilities for moving toward more and more complicated nuclear systems. Therefore, this technique deserves an upgrade, without changes in its detection basis, with the aim at speeding up the microscope scanning for rather rare events of peripheral dissociation of relativistic nuclei.

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At the time of publication the biographies of the other authors were not presented.

VISCOSIMETRIC METHOD FOR ASSESSMENT OF THE MOST REFINED FRACTION IN AN AEROSOL SYSTEM WITH A LIMITED VOLUME

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Abstract

The mass and the size of the particles of the most refined fraction in an aerosol system with a limited volume are determined via measuring the cinematic viscosity. The measurements of the latter are performed when the system is left to stay after forming for a period of time, called a delay time. The results for different aerosol volumes are extrapolated at a delay time, tending to infinity when only the finest in size particles of the aerosol remain. They are interpreted as Aitken's nuclei of condensation in the atmosphere.

1. INTRODUCTION

In some previous papers of ours [1,2] we discussed a method for measuring the cinematic viscosity of aerosol systems with a limited volume, possessing properties, analogous to those of the liquids. The method is based on the investigation of the decrease of the aerosol boundary in case of outflow, resulting in the action of its own hydrostatic pressure. In Ref. [3] we specified that this is due to the extra pressure, created by the aerosol phase.

The method mentioned is applied to the measurement of the cinematic viscosity of an aerosol system (tobacco smoke) which is left undisturbed after forming for a certain time. Extrapolating the results for the case in that the time tends to infinity, yields information for the mass and size of the finest aerosol particles.

2. METHODS

The aerosol is formed in a cylindrical vessel with a cross section S and flows out through a horizontal tube of length L and radius R, near the bottom of the vessel.

Assuming that the outflow is laminar and follows the Poiseuille's law [1,4], we deduce the expression below for the cinematic viscosity:

$$\nu = \eta \,/\, \rho = B \left[\frac{d(\ln H)}{dt} \right]^{-1} \tag{1}$$

where η is the dynamic viscosity, ρ is the density of the aerosol phase $B = \pi R^4 g \,/\, 8 L S$, g is the gravity acceleration and H is the height of the free aerosol boundary above the outflow tube. The changes in H – the height of the aerosol boundary, are registered by photo detectors which receive a signal from the dispersed light of a laser beam, scanning the aerosol in a direction, perpendicular to its horizontal free boundary. In Refs. [2,3] expression (1) has been presented, as follows:

$$\nu = (\eta \,/\, \rho) = B \left(\overline{H} \,/\, \Delta H \right) \Delta t \tag{2}$$

where Δt is the time, needed to decrease the free aerosol boundary by a discrete step ΔH around the height $\overline{H}$. ρ is the mean density of the aerosol phase in the aerosol volume $V = S\,\overline{H}$.

If after the aerosol formation and before measuring its cinematic viscosity it is left to stay for a period of time τ, called in [1] evolution time (delay time), then in the aerosol system which is typically an unbalanced one, a decrease in the density ρ and a respective increase in the viscosity ν occurs, as a result of the processes of sedimentation and precipitation on the walls of the vessel. This leads to a change in the time Δt of the outflow between two successive photo detectors, corresponding to the height $\overline{H}$. From (2) we obtain an expression for the outflow time Δt of an aerosol with a volume $\Delta V = S\ \Delta H$:

$$\Delta t = -c\nu \,/\, \overline{H} \tag{3}$$

where $c = 8\, S\, \Delta H\ L \,/\, \pi\ R^4 g$. The time Δt can be treated as a new characteristic of the aerodispersion systems with a limited volume. It depends on the cinematic viscosity ν, on the height of the aerosol boundary $\overline{H}$ and on the evolution time τ, via ν.

We defined experimentally the quantity Δt for 7 different heights of the aerosol boundary (aerosol volumes) in case of 11 evolution times. The experiments were conducted with an aerodispersion system model, namely smoke from 3 cigarette brands, the aerosol, being formed in a cylindrical measurement chamber with a diameter of 0.030 m and a height of 0.450 m. The outflow tube was with diameter of

0.008 m and length of 0.030 m. The results indicate that the time Δt depends approximately linearly on the evolution time τ, as the angular coefficient of the obtained straight lines increases with the decrease of the aerosol boundary, i.e.:

$$\Delta t = \alpha(\overline{H})\,\tau + \beta(\overline{H}). \tag{4}$$

The linearized dependences of Δt as a function of τ are illustrated in Fig. 1.

Let us divide the two sides of Eq. (4) by τ. We obtain:

$$\Delta t/\tau = \alpha(\overline{H}) + \beta(\overline{H})/\tau\,. \tag{5}$$

The quantities in the right-hand side of the above equation depend, as seen from Fig. 1, on the height $\overline{H}$. In Eq. (5) we can perform the approximation $\tau \to \infty$ when the most refined fraction of the aerosol remains only. Then $(\Delta t/\tau) \to \alpha$, i.e. the quantity $\alpha(\overline{H})$ appears as a characteristic of the fraction mentioned. Fig. 2 represents

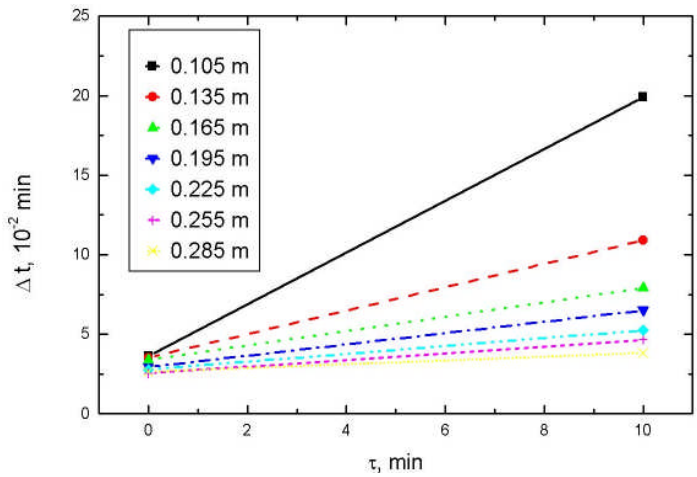

Figure 1. Linearized dependence of the outflow time of aerosol Δt on the evolution time τ at seven different heights $\overline{H}$ (aerosol volumes). The aerosol is smoke from Arda cigarettes.

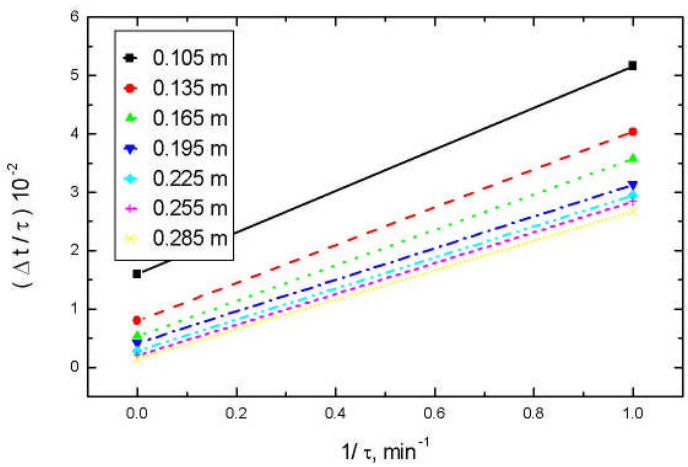

Figure 2. Dependence of $\Delta t/\tau$ on $1/\tau$ in case of seven different heights $\overline{H}$.

the ratio $\Delta t/\tau$ vs. $1/\tau$ for different heights of the same aerosol. The values of $\alpha(\overline{H})$ are defined by the cross points of the straight lines with the ordinate axis (for convenience the zero abscissa axis when $1/\tau = 0$, is moved a little to the right).

Fig. 3 depicts the dependence of $\alpha(\overline{H})$ on $\overline{H}$. The points designate the values of $\alpha(\overline{H})$, defined by Fig. 2 and the solid line yields an approximation with a fit exponential function (received by the software package Origin), specified by the formula:

$$y = y_0 + A_1 \exp[-(x - x_0)/t_1] \tag{6}$$

in which $y_0 = 0.175 \pm 0.043$, $x_0 = 0.105$, $A_1 = 1.395 \pm 0.063$, $t_1 = 0.042 \pm 0.005$.

As seen from Fig. 3, $\alpha(\overline{H})$ can be expressed well enough via an exponent. We obtained analogous results for other aerosols, too, smoke from different cigarette brands. Fig. 4 shows the experimentally obtained dependences of $\ln\alpha(\overline{H})$ on $\overline{H}$ for three kinds of aerosols (tobacco smokes from three tips of cigarettes, presented by triangles points and squares, resp.) and their approximations with straight lines. The results from Fig. 3 and Fig. 4 give us the right to formulate the following relation:

$$\alpha = \alpha_0 \exp(-b\overline{H}). \tag{7}$$

The above dependence resembles the one of the concentration n of a system of particles with mass m on the height H in the earth gravity field (the well known Boltzmann's law):

$$n = n_0 \exp(-mgH/kT) \tag{8}$$

where g is the gravity acceleration, k is the Boltzmann's constant and T is the abso-

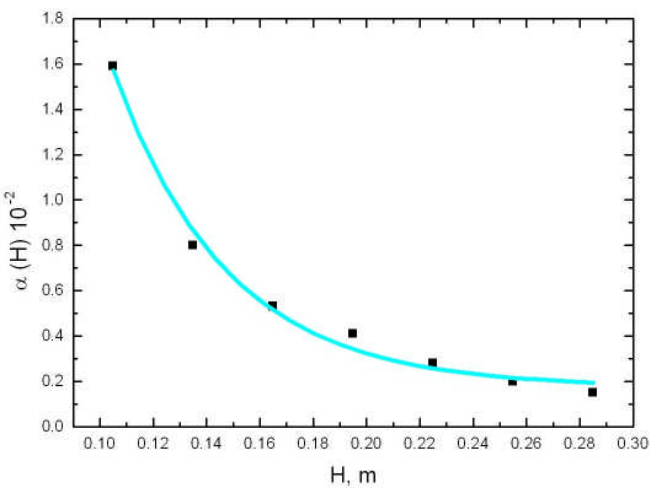

Figure 3. Dependence of $\alpha(\overline{H})$ on $\overline{H}$ for the investigated aerosol (with points) and approximation with exponential function (the solid line).

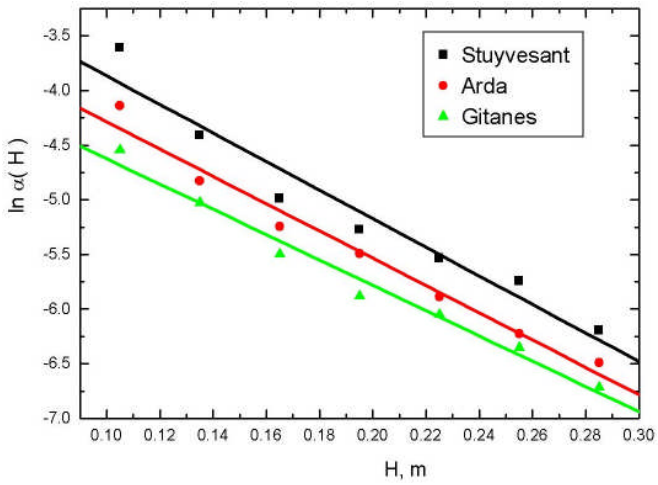

Figure 4. Dependence of $\ln\alpha(\overline{H})$ on $\overline{H}$ for tree kinds of aerosols (tobacco smokes from three types of cigarettes).

lute temperature. On the basis of this analogy, we can deduce that the dimensionless quantity α is proportional to the concentration of the most refined fraction of the investigated aerosols. If we take a natural logarithm from (7) and differentiate it afterwards with respect to $\overline{H}$, we obtain:

$$b = \frac{d\ \ln(\alpha)}{d\overline{H}}. \tag{9}$$

On analogy with (8), we can deduce:

$$b = m_a\, g/(kT) \tag{10}$$

where m_a is the mass of the most refined particles of the aerosol (we assume that the aerosol is monodispersive).

From formula (10), using an experimental definition of the quantity b (from Fig. 4 and Eq. (9)), we can calculate the mass m_a of the particles of the most refined fraction:

$$m_a = b\,k\,T/g\,. \tag{11}$$

On the assumption that the particles are spherical with radius r, their mass, expressed via the volume V and the density ρ_a of the substance of the aerosol particles, will be:

$$m_a = (4/3)\pi\, r^3 \rho_a\,. \tag{12}$$

Replacing m_a from (11) in (12), we obtain for the radius of the particles:

$$r = \sqrt[3]{\frac{3\,b\,k\,T}{4\,\pi\ g\ \rho_a}}\,. \tag{13}$$

3. RESULTS

Assuming an approximate value for $\rho_a = 4 \times 10^3$, kg/m^3 (about the mean density of the earth crust), $T = 293$K, $k = 1.381$x10^{-23} J/K, then for the mass and the size of the particles of the most refined fraction of the aerosol phase, for three kinds of aerosols – smoke from cigarettes, we obtain the following values, listed in Table 1.

Table 1. The mass and the size of the particles of the most refined fraction of the aerosol phase, for three kinds of aerosols (tobacco smokes).

Aerosol	Stuyvesant	Arda	Gitanes
m_a, 10^{-21} kg	5.4±0.6	5.1±0.3	4.8±0.3
r, 10^{-9} m	6.8±0.2	6.8±0.2	6.6±0.1

As seen, the numerical equivalents of m and r of the particles of the three kinds of aerosols are close to each other. Because of this fact and because of the physical sense of $\alpha(H)$ which characterizes the most refined particles that remain during the aerosol evolution, we assume that these particles appear as centers of condensation in the atmosphere. In Ref. [5] such centers are designated as Aitken's nuclei. They have inorganic origin which gives us a ground to deduce that ρ_a equals the mean density of the Earth's crust.

4 CONCLUSION

The results presented by the authors demonstrate a possibility to receive microscopic parameters such as mass and dimension of aerosol particles via a macroscopic measurement of the cinematic viscosity of aerosol system with a limited volume.

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Due to his active work, Prof. Antonov was awarded in Bern Switzerland by the "Association for investigation of bio-psycho phenomena" in 2003. He is a long-standing Member of the Union of Scientists and of the Union of Physicists in Bulgaria. He is Member of the National list of Committees on the scientific fields in Bulgaria.

DETERMINATION OF FIBER PARAMETERS BY NON-LINEAR OPTICAL METHOD

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Abstract

A non-linear optical method for determination of the optical fiber parameters is developed. It is based on the stimulated four-wave mixing process. This is the first similar method for fiber parameters control. It is very useful, allowing to obtain simultaneously the most important parameters, such as core radius a_{cor}*, core cladding refractive index difference* Δn*, cut-off wavelength* λ_c *and fiber* V *parameter.*

1. INTRODUCTION

At present, most of the developed methods for control of the optical fiber parameters determine them one by one separately [1]. All of these approaches can be associated with the linear optical ones. For the first time we propose a method, based on a non-linear optical process. We use the four-photon mixing process which occurs in the optical fibers. The frequencies of the new spectral components, generated as a result of it, depend on the fiber parameters. This allows by measuring the frequencies shifts between the new components and the pump wave to determine simultaneously the basic fiber parameters such as: core radius a_{cor}, core cladding refractive index difference Δn, cut-off wavelength λ_c and fiber V parameter.

2. METHOD

The stimulated Four-Wave Mixing (FWM) is a non-linear process in which two pump photons of frequency ν_p are transformed into Stokes and anti-Stokes pair of

frequencies ν_s and ν_a, resp., obeying the energy balance $\nu_p - \nu_s = \nu_a - \nu_p$. The process is efficient, if the phase matching condition $\Delta k = k(\nu_s) + k(\nu_a) - 2k(\nu_p) \cong 0$, is fulfilled. A perfect phase-matching cannot be achieved in optical glasses, because Δk is always different from zero. An exact phase-matching is possible in optical fibers with a suitable combination of the modes in which the group velocities difference can be compensated by the modal dispersion. In the negative dispersion region of multimode fibers, this is a necessary condition for the existence of parametric solitons, as well [2]. The frequencies ν_s and ν_a, generated by a FWM process can accurately be predicted for a fixed modal combination, if the parameters of the fiber, including the refractive index profile, are precisely known.

At the same time, the solution of the inverse problem – the finding of the fiber parameters from the given FWM frequencies – has to deal with difficulties, connected mainly with the influence of the refractive index profile. Most of the fibers, produced by the Modified Chemical Vapor Deposition (MCVD) technique, have a central dip in the profile. Its shape and depth substantially modify the dispersion properties of the fiber and the frequency shifts of the various modal combinations.

In this work we demonstrate the possibility for a substantial reduction of the error, associated with the FWM method. Usually four-photon mixing is observed in the case of weakly guided fibers [3] and at a divided pump process. This is a process in which the Stokes and one of the pump waves propagate in one fiber mode, while the anti-Stokes and the other pump wave propagate in another fiber mode. In this case the frequency shift $\Delta\nu$ depends on Δn, V, $2a$ and n_{cor}, as follows [4,5]:

$$\Delta\nu\lambda_p D(\lambda_p) = \Delta n\left[\frac{d(B_s V)}{dV} - \frac{d(B_a V)}{dV}\right] \tag{1}$$

where

$$V = \frac{2\pi a}{\lambda}\sqrt{2n_{cor}\Delta n}, \tag{2}$$

is the normalized frequency, λ_p is the pump wavelength, $D(\lambda) = \lambda^2\left(\frac{d^2 n}{d\lambda^2}\right)$ is the core material dispersion and $\frac{d(BV)}{dV}$ are differential mode delays of the propagating Stokes and anti-Stokes waves. These modal delays depend only on the V parameter

and on the real profile of the refractive index of the waveguide core. For distinct combinations of modes, the following characteristic equation for the parameter V can be written [6]:

$$\frac{\Delta\nu^{(1)}}{\Delta\nu^{(2)}} = \frac{\dfrac{d(B_s^{(1)}V)}{dV} - \dfrac{d(B_a^{(1)}V)}{dV}}{\dfrac{d(B_s^{(2)}V)}{dV} - \dfrac{d(B_a^{(2)}V)}{dV}} = R(V). \tag{3}$$

In Eq. (3) the superscripts (1) and (2) denote the first and the second modal combination, respectively. If the refractive index profile is already known, the right-hand side of this equation depends on the V parameter only. This fact expresses the possibility to obtain the V parameter, and after that – the other fiber parameters. However, the various refractive index profiles yield a different value for the normalized group delays [7], and therefore a substantially different function $R(V)$. As a result, the error of the V parameter obtained, can be too large. In order to find the conditions for minimizing this error, we investigated the $R(V)$ function for various refractive index profiles and modal combinations.

The main concept of our approach is straightforward. The central dip of the refractive index profile influences substantially the normalized group delays of the axially symmetric mode only (the LP_{lp} modes with first index $l = 0$) [8]. The latter is a consequence of the fact that the intensity maximum of these modes for the fiber without a dip must lay in its center. Hence, the presence of the dip changes the radial field distribution and the group velocity of the wave. The influence of the refractive index profile on the axially anti-symmetrical modes (the first index $l > 0$) is much less pronounced, because their intensity at the center of the fiber is zero.

Fig. 1 shows the dependencies $R(V)$ for the rectangular refractive index profile in the rather extreme case when the radius of the rectangular central dip is 15% of the core radius and the refractive index in the center of the fiber equals the refractive index of the cladding. The dependencies $R(V)$ are shown for three different combinations of the pump wave modes, including respectively 0, 1 and 2 axially symmetric modes. Curve 1 corresponds to $\Delta\nu^{(1)}$, obtained with the pair $LP_{31} - LP_{21}$ and to $\Delta\nu^{(2)}$, obtained with $LP_{21} - LP_{11}$, curve 2 to $\Delta\nu^{(1)}$, obtained with $LP_{21} - LP_{11}$ and $\Delta\nu^{(2)}$, obtained with $LP_{11} - LP_{01}$, curve 3 to $\Delta\nu^{(1)}$, obtained with $LP_{02} - LP_{11}$ and $\Delta\nu^{(2)}$, obtained with $LP_{11} - LP_{01}$. It is interesting to mention that these are

combinations of the lowest order modes. It is seen from Fig. 1 that $R(V)$ has zeros for certain values of V. Consequently, for them the normalized group delays, participating in the numerator of Eq. (3), are equal. The negative value of $R(V)$ corresponds to the case when the anti-Stokes wave in the modal combination in the numerator of Eq. (3) propagates in a higher mode, than the Stokes wave. The positive values answer respectively to the case when the Stokes wave is in the higher mode.

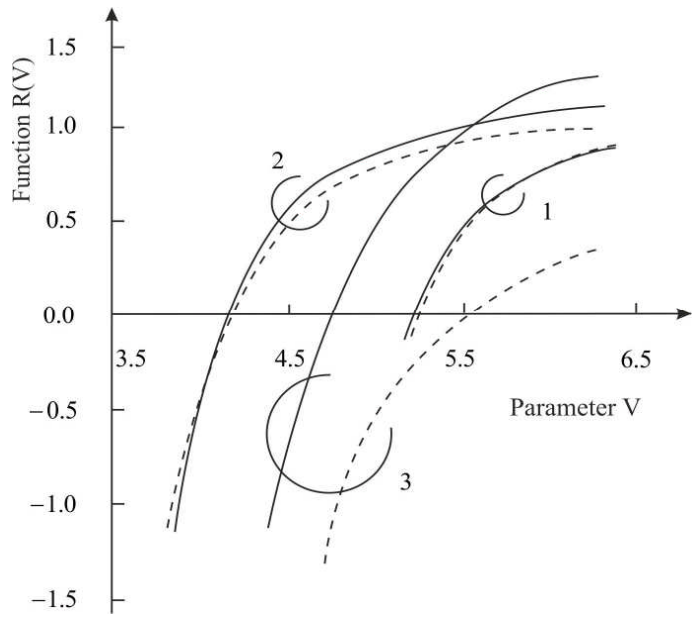

Figure 1. The dependence $R(V)$ of different modal combinations and for rectangular index profile (continuous line) and for a profile with a central dip (dotted line).

As seen from the curves presented, if only axially anti-symmetric modes are used, the function $R(V)$ for the cases of a rectangular refractive index profile and a profile with a central dip, almost completely coincide. Hence, using such modal contribution, the value of the V parameter can be determined with a remarkable precision, without considering the type of profile. In the case of only one symmetric mode, participating in the process, an interval of the V value where the two curves coincide precisely enough, can be found, too. This is the interval, around the point where the function $R(V)$ becomes zero. For the concrete case when the first frequency is obtained for the LP_{21} and LP_{11} fiber modes, while the other – for the LP_{11} and LP_{01} ones in the interval $3.9 < V < 4.3$, the error of the value of V found, is less than 1%. However, for larger values of V, the error becomes considerable. Suitable interval of the V values does not exist in the case of two axially symmetric modes, so such a modal combination is not preferable to be used in specifying the V parameter.

If the latter is already known, the determination of the other parameters (core radius a_{cor} and the core cladding refractive index difference Δn) requires information about the doping composition of the fiber, or equivalently, about the refractive index $n(\lambda)$ and the dispersion $D(\lambda)$. We will show below that in the case of optical waveguide, doped by only one element, we can determine its concentration ($n(\lambda)$ and $D(\lambda)$, respectively), using a recurrent procedure. If the core is doped by more than one element, the later is not applicable. Using the data for the pure fused quartz now we can get a good accuracy for such an approximation [8]. The error, due to this exchange, is especially negligible, if λ_p is far from the point of a zero material dispersion of the fused silica. After that, the derivation of Δn and a_{cor}, is straightforward.

3. EXPERIMENTAL RESULTS

In order to prove experimentally the feasibility of determining the fiber parameter, applying the FWM process with one axially symmetric mode, we studied a fiber with a known V parameter which was approximately 3.9 for $\lambda_p = 532\text{nm}$. An experimental set-up which is widely used for studying non-linear phenomena in optical fibers, was employed for obtaining the stimulated FWM spectra. The fiber was pumped by the second harmonic of a Q-switched and mode-locked CW Nd: YAG

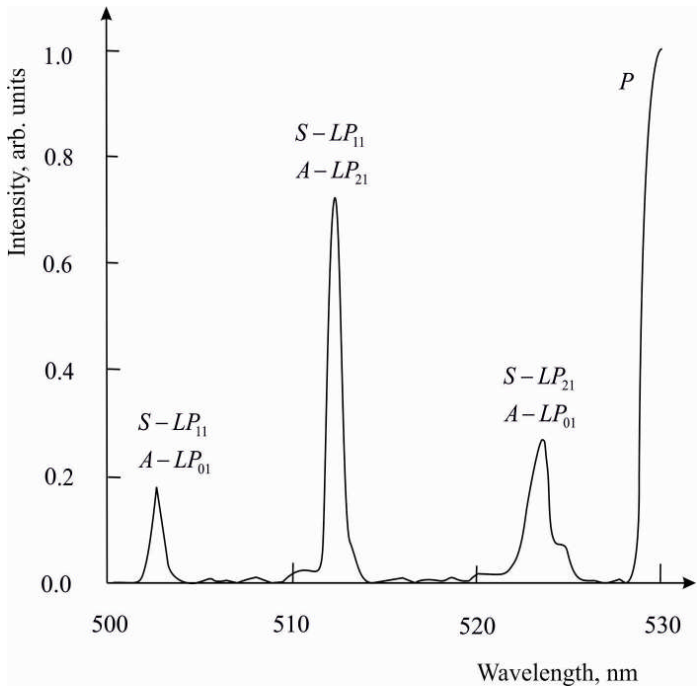

Figure 2. Anti-Stokes components of the FWM spectrum.

laser. The fiber had been produced by the MCVD technique and had pure silica cladding and Ge-doped cores with different molar concentration.

In the experiments the excitation of the different groups of modes was accomplished by varying the launching conditions for the pump beam. The modal structure of the generated radiation was identified visually, after splitting a fraction of the fiber output with a grating. FWM were recorded by optical multichannel analyzer.

The anti-Stokes parts of the FWM spectra are shown in Fig. 2. For this fiber the refractive index profile differs substantially from the rectangular one. Fig. 2 shows also the modal combination of the Stokes and anti-Stokes components for the respective frequency. The Stokes sector of the spectra is more complicated. Beside the Stokes frequencies, due to the FWM, it contains also a wide line, due to the stimulated Raman scattering. It increases the uncertainty of the adjacent FWM frequencies. For this sample we used $\Delta\nu^{(1)} = 722\,\mathrm{cm}^{1}$, obtained with $LP_{21} - LP_{11}$ and $\Delta\nu^{(2)} = 1089\,\mathrm{cm}^{-1}$ – with $LP_{11} - LP_{01}$. The frequency shift $\Delta\nu^{(1)} = 722\,\mathrm{cm}^{1}$ was obtained when the anti-Stokes component was in the higher mode. That's why we take this value as negative. Via Eq. (3) we found that the V value of the pump wavelength is 3.96.

Using it, the parameters of the fiber were easily calculated. The standard optical fibers are made of SiO_2 with a Ge-doped core. But the doping concentration weakly effects the core refractive index n_{cor}, the core material dispersion $D(\lambda) = \lambda^2\left(\frac{d^2n}{d\lambda^2}\right)$ and the differential mode delays $\frac{d(BV)}{dV}$ [8]. Then, if we use the data for pure silica, the error will be negligible. Solving Eq. (2), we get for the core-cladding refractive index difference $\Delta n = 3{,}04.10^{-2}$. From Eq. (2) we find out for the core diameter $2a = 2.25\,\mu\mathrm{m}$. We have to mention that the passport data are correspondingly $\Delta n = 3.2.10^{-2}$ and $2a = 2.2\,\mu\mathrm{m}$.

4. CONCLUSION

In conclusion, a non-linear optical frequency-resolved method is proposed to determine simultaneously most of the important fiber parameter, without accounting for the specific refractive index profile which was experimentally demonstrated. The accuracy of the obtained data is satisfactory. The largest deviation from the certificate

parameters is 5% and in addition, it is a sum of the errors, associated with the standard methods and with our measurements.

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The biography of **Associate Professor Lubomir Milchev Kovachev** is published on page 12 of this Issue.

At the time of publication the biography of **Mr. Mihail Lyubenov Ivanov** was not presented.

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