ANNOUNCEMENTS OF THE MATERIALS

of Dr. Pavlina Hristova Atanasova

Department of Applied Mathematics and Modeling at FMI

at the University of Plovdiv "Paisii Hilendarski"

FOR PARTICIPATION IN THE COMPETITION

for Academic Position 'Associate Professor'

A. SCIENCE PUBLICATIONS

1. **P. Atanassova**, Khr. Semerdzhiev, *Generalized Interpolating Polynomials in Newtonian Form*, Sci. works of the Univ. of Plovdiv "Paisii Hilendarski", vol 33, **2001**, Maths; **Zbl 1014.41001**, https://www.zbmath.org/?q=an%3A1014.41001

Divided differences with respect to trigonometric, exponential and Chebyshev systems of basic functions are introduced and the interpolating polynomials are presented in Newtonian form.

2. **P. Kh. Atanasova**, *Some presentations of generalized polynomials based on the theory of interpolation*, Sci. works of the Univ. of Plovdiv, Vol. 36, Book 3, **2009**, Math., 19-24, ISSN 0204-5249 (**MathSciNet,** MR3243473), https://mathscinet.ams.org/mathscinet-getitem?mr=3243473

In this short communication some presentations of polynomials based on algebraic, trigonometric, exponential and generalized fundamental polynomials using in the interpolation are given.

3. **P. Khr. Atanasova**, *On an approach for construction of I-V curves in LJJ*, Sci. works of the Univ. of Plovdiv, Vol. 37, Book 3, **2010**, Math., 13-22, ISSN 0204-5249 **(Zentralblatt, Zbl 1240.74008),** https://zbmath.org/?q=an%3A1240.74008

New approach for construction of current-voltage (I-V) curves which are significant in Physics of long Josephson junctions (LJJ) is presented in this paper. The bifurcational static solution and eigenfunctions of the corresponding Sturm-Liouville problem is used. After discretization an overdetermined nonlinear algebraic system is obtained which is solved by least square method. The properties of eigenfunctions lead to the possibility to solve the problem recursively using the continuous analog of Newton's method. An algorithm for successive finding of I-V curve points is described.

4. **P.Kh. Atanasova**, E. V. Zemlyanaya and Yu M Shukrinov. *Interconnection between static regimes in the LJJs described by the double sine-Gordon equation*. Journal of Physics: Conf. Ser. 393 (**2012**) 012023 (**SCOPUS, SJR=0.217**), https://doi.org/10.1088/1742-6596/393/1/012023

The second harmonic contribution to the current-phase relation changes the properties of the static magnetic flux distributions in the long Josephson junction (LJJ) and inspires new homogenious and fluxon static states. We study stability properties and bifurcations of these static regimes within the

frame of a model described by the double sine-Gordon equation. The critical curves behavior and the interconnection between different types of magnetic flux distributions are analyzed.

5. **P.Kh. Atanasova**, E.V.Zemlyanaya, Yu.M.Shukrinov, *Numerical Study of Fluxon Solutions of sine-Gordon Equation under the Influence of the Boundary Conditions*, G. Adam, J. Buˇsa, and M. Hnatiˇc (Eds.): MMCP 2011, LNCS 7125, pp. 201–206, Springer-Verlag Berlin Heidelberg **2012**; (**Scopus, SJR = 0.346**), https://link.springer.com/chapter/10.1007/978-3-642-28212-6_21

The fluxon solutions of a boundary problem for the sine-Gordon equation (SGE) are investigated numerically in dependence on the boundary conditions. Interconnection between fluxon and constant solutions is analyzed. Numerical results are discussed in context of the long Josephson junction model.

6. **P.Kh.Atanasova**, E.V.Zemlyanaya. *Bifurcations in long Josephson junctions with second harmonic in the current-phase relation: numerical study*. Lecture Notes in Computer Sciences, Springer, Vol. 8236, pp.190-197, **2012**. (**Scopus, SJR = 0.346**), https://doi.org/10.1007/978-3-642-41515-9_19

Critical regimes in the long Josephson junction (LJJ) are studied within the frame of a model accounting the second harmonic in the current-phase relation (CPR). Numerical approach is shown to provide a good agreement with analytic results. Numerical results are presented to demonstrate the availabilities and advantages of the numerical scheme for investigation of bifurcations and properties of the magnetic flux distributions in dependence on the sign and value of the second harmonic in CPR.

7. E.V.Zemlyanaya, E.V.Alexeeva**, P.Kh.Atanasova**. *Ac-driven nonlinear Schroedinger equation and double sine-Gordon equation: numerical study of complexes of localized states*. AIP Conference Proceedings 1629, 217 (**2014**); (**Web of Science, Scopus, SJR=0.171**), https://doi.org/10.1063/1.4902276

We investigate complexes of localized states in two dynamical systems: (i) directly driven nonlinear Schrödinger equation (NLS) and (ii) double sine-Gordon equation (2SG). Our numerical approach is based on the numerical continuation with respect to the control parameters of the stationary solutions and stability analysis by means of the linearized eigenvalue problem. We show that in the weak damping case the directly driven NLS equation holds stable and unstable multi-soliton complexes. We also show that the second harmonic changes properties and increases the complexity of coexisting static fluxons of 2SG equation.

8. **E. Zemlyanaya, N. Alexeeva, P. Atanasova,** *Complexes of localized states in ac-driven nonlinear Schrödinger equation and in double sine-Gordon equation*, Bulletin of PFUR. Series Mathematics. InformationSciences. Physics. No 2, **2014**. Pp. 363–368, https://cyberleninka.ru/article/n/complexes-of-localized-states-in-ac-driven-nonlinear-schrodinger-equation-and-in-double-sine-gordon-equation

Complexes of localized states are numerically analyzed in two dynamical systems: directly driven nonlinear Schrodinger equation (NLS) and double sine-Gordon equation (2SG). Both systems have a wide range of physical applications. Our numerical approach is based on the numerical continuation with respect to the control parameters of the quiescent (stationary) solutions and stability and bifurcation analysis of the linearized eigenvalue problem. Multisoliton complexes of the NLS equation

are studied in the undamped and the weak damping regimes. We show that in the weak damping case the directly driven NLS equation holds stable and unstable multi-soliton complexes. The results are confirmed by means of direct numerical simulations of the time-dependent NLS equation. Properties of the multi-fluxon solutions of 2SG equation are studied depending on the parameter of the second harmonic. We show that the second harmonic changes properties and increases the complexity of coexisting static fluxons of 2SG equation. Results are discussed within the frame of the long Josephson junction model.

9. E.V.Zemlyanaya, **P.Kh.Atanasova**, A.V.Volokhova, V.D.Lakhno, I.V.Amirkhanov, I.V.Puzynin, T.P.Puzynina, V.S.Rikhvitskiy. *Numerical Simulation of Photoexcited Polaron States in Water*. AIP Conference Proceedings 1684, 100006 (**2015**); **(Web of Science, Scopus, SJR=0.152),** doi: 10.1063/1.4934343, https://aip.scitation.org/doi/abs/10.1063/1.4934343

We consider the dynamic polaron model of the hydrated electron state on the basis of a system of three nonlinear partial differential equations with appropriate initial and boundary conditions. A parallel numerical algorithm for the numerical solution of this system has been developed. Its effectiveness has been tested on a few multi-processor systems. A numerical simulation of the polaron states formation in water under the action of the ultraviolet range laser irradiation has been performed. The numerical results are shown to be in a reasonable agreement with experimental data and theoretical predictions.

10. **P.Kh.Atanasova**, E.V.Zemlyanaya, *Numerical Investigation of Bifurcations in Long Josephson Junctions with Second Harmonic in the Current-Phase Relation*. Comptes rendus de l'Acad´emie bulgare des Sciences, MATHEMATIQUES, M´ethodes de calculs num´erique Tome 68, No 12, **2015, (Web of Science, IF = 0.233; Q4, SJR=0.205),** http://www.proceedings.bas.bg/cgi-bin/mitko/0DOC_abs.pl?2015_c_02

The second harmonic in the LJJ current-phase relation plays important role in the modeling of different JJs. It deforms the shape, changes the properties of standard static magnetic flux distributions and inspires new static states. We have described the numerical scheme for the bifurcation analysis of static magnetic flux distributions in long Josephson junctions described by double sine-Gordon equation. Instead of direct numerical simulation of partial differential equation we numerically solve the boundary problem for the system of nonlinear ordinary differential equations. We show that our numerical approach allows one to obtain new fluxon distributions, to investigate their stability and bifurcations and to construct the critical current dependence which is an important physical characteristic of LJJs. Our numerical technique has been conrmed to be effective way to obtain new information about complexity of static distributions in LJJs.

11. E.V. Zemlyanaya, M.V. Bashashin, I.R. Rahmonov, Yu.M. Shukrinov, **P.Kh. Atanasova**, and A.V. Volokhova. *Model of stacked long Josephson junctions: Parallel algorithm and numerical results in case of weak coupling*. AIP Conference Proceedings 1773, 110018(1-9), **2016**; (**Web of Science, Scopus, SJR=0.165**), https://doi.org/10.1063/1.4965022

We consider a model of system of long Josephson junctions (LJJ) with inductive and capacitive coupling. Corresponding system of nonlinear partial differential equations is solved by means of the standard three-point finite-difference approximation in the spatial coordinate and utilizing the Runge-Kutta method for solution of the resulting Cauchy problem. A parallel algorithm is developed and implemented on a basis of the MPI (Message Passing Interface) technology. Effect of the coupling

between the JJs on the properties of LJJ system is demonstrated. Numerical results are discussed from the viewpoint of effectiveness of parallel implementation.

12. **Pavlina Atanasova**, Atanaska Georgieva, Lozanka Trenkova, *Existence of Continuous Solutions of a Perturbed Linear Volterra Integral Equations*, Annular of the FMI, SU, Tome 103, **2016**, **(MathSciNet, MR3676978),** https://mathscinet.ams.org/mathscinet-getitem?mr=3676978

In this paper we study the existence of continuous solutions on compact interval of a perturbed linear Volterra integral equations. The existence of such a solution is based on well- known Leray-Schauder principle for fixed point in Banach space. A special interest is devoted to the study of uniqueness of continuous solution. A numerical approach is based on fixed point method and quadrature rules to approximate a solution for the perturbed linear Volterra integral equations. The convergence of the numerical scheme is proved. Some numerical examples are given to show applicability and accuracy of the numerical method and ensuring the theoretical results.

13. М.В.Башашин, Е.В.Земляная, И.Р.Рахмонов, Ю.М.Шукринов, **П.Х.Атанасова**, А.В.Волохова. *Вычислительная схема и параллельная реализация для моделирования системы длинных джозефсоновских переходов*. Компьютерные исследования и моделирование (Computer Research and Modeling), ISSN:2076-7633, eISSN:2077-6853, Изд: Изд-во технической литературы «Институт компьютерных исследований») Т.8, вып.4, 2016, с.593–604, http://crm.ics.org.ru/uploads/crmissues/crm_2016_4/16.08.01.pdf

We consider a model of stacked long Josephson junctions (LJJ), which consists of alternating superconducting and dielectric layers. The model takes into account the inductive and capacitive coupling between the neighbor junctions. The model is described by a system of nonlinear partial differential equations with respect to the phase differences and the voltage of LJJ, with appropriate initial and boundary conditions. The numerical solution of this system of equations is based on the use of standard three-point finite-difference formulae for discrete approximations in the space coordinate, and the applying the four-step Runge-Kutta method for solving the Cauchy problem obtained. Designed parallel algorithm is implemented by means of the MPI technology (Message Passing Interface). In the paper, the mathematical formulation of the problem is given, numerical scheme and a method of calculation of the current-voltage characteristics of the LJJ system are described. Two variants of parallel implementation are presented. The influence of inductive and capacitive coupling between junctions on the structure of the current-voltage characteristics is demonstrated. The results of methodical calculations with various parameters of length and number of Josephson junctions in the LJJ stack depending on the number of parallel computing nodes, are presented. The calculations have been performed on multiprocessor clusters HybriLIT and CICC of Multi-Functional Information and Computing Complex (Laboratory of Information Technologies, Joint Institute for Nuclear Research, Dubna). The numerical results are discussed from the viewpoint of the effectiveness of presented approaches of the LJJ system numerical simulation in parallel. It has been shown that one of parallel algorithms provides the 9 times speedup of calculations.

14. I.R.Rakhmonov, Yu.M.Shukrinov, **P.Kh.Atanasova**, E.V.Zemlyanaya, M.V.Bashashin. *Effect of Inductive and Capacitive Coupling on the Current–Voltage Characteristic and Electromagnetic Radiation from a System of Josephson Junctions*, Journal of Experimental and Theoretical Physics, ISSN 1063-7761, **2017**, Vol.124, No.1, pp.131-138 (Pleiades Publishing Inc.), (**Web of Science, Scopus, IF = 1.255; Q3 , SJR=0.437),**
https://link.springer.com/article/10.1134/S1063776116150139

We have studied the current–voltage characteristic of a system of long Josephson junctions taking into account the inductive and capacitive coupling. The dependence of the average time derivative of the phase difference on the bias current and spatiotemporal dependences of the phase difference and magnetic field in each junction are considered. The possibility of branching of the current–voltage characteristic in the region of zero field step, which is associated with different numbers of fluxons in individual Josephson junctions, is demonstrated. The current–voltage characteristic of the system of Josephson junctions is compared with the case of a single junction, and it is shown that the observed branching is due to coupling between the junctions. The intensity of electromagnetic radiation associated with motion of fluxons is calculated, and the effect of coupling between junctions on the radiation power is analyzed.

15. **Atanasova P**, Georgieva A, Konstantinov M. *Dichotomous solutions of linear impulsive differential equations*. Math Meth Appl Sci. **2018**; 1–8.**, (Web of Science, Scopus, IF = 1.533; Q2, SJR=0.666)** https://doi.org/10.1002/mma.4701

The notion of $L_p(h; k)$-solutions of linear impulsive differential equations in Banach spaces is introduced. Suficient conditions for existence of such solutions are derived. Possible applications to linear control systems with impulses are considered. An illustrative example is given.

16. I. R. Rahmonov, Yu. M. Shukrinov, **P. Atanasova**, E.V.Zemlyanaya, O.I. Streltsova, M. I. Zuev and M.V. Bashashin, *Simulation of collective excitations in the stack of long Josephson junctions*, EPJ 173, 06011, **2018**. (**Web of Science, SJR =0,197**), https://www.epj-conferences.org/articles/epjconf/abs/2018/08/epjconf_mmcp2018_06011/epjconf_mmcp2018_06011.html

The phase dynamics of a stack of long Josephson junctions has been studied. Both inductive and capacitive couplings between Josephson junctions have been taken into account in the calculations. The IV-curve, the dependence on the bias current of the radiation power and dynamics of each JJs of the stack have been investigated. The coexistence of the charge traveling wave and fluxon states has been observed. This state can be considered as a new collective excitation in the system of coupled Josephson junctions. We demonstrate that the observed collective excitation leads to the decrease of radiation power from the system.

17. E.V. Zemlyanaya, A.V.Volokhova, V.D.Lakhno, M.V.Bashashin, I.V.Amirkhanov, I.V.Puzynin, T.P.Puzynina and **P.Kh.Atanasova**. *Numerical Study of Formation of Hydrated Electron States*. AIP Conference Proceedings, **2018**; (**Web of Science, SCOPUS, SJR=0,152**), https://doi.org/10.1063/1.5064951

Formation of hydrated electron states in water is investigated within the polaron model which is described by a system of nonlinear partial differential equations. This framework is shown to provide an agreement of numerical results with experimental data on absorbtion of the light by the hydrated electron. Mathematical formulation of problem and the numerical approach are described, results of numerical simulation are presented in comparison with experimental data.

18. **Pavlina Atanasova**, Stefani Panayotova, Yury Shukrinov, Ilhom Rahmonov, and Elena Zemlyanaya, *User software for numerical study of Josephson junction with magnetic momenta*, EPJ 173, 05002, **2018**. (**Web of Science, SJR =0,197**), https://www.epj-

conferences.org/articles/epjconf/abs/2018/08/epjconf_mmcp2018_05002/epjconf_mmcp2018_05002.html

A user software for numerical study of a Josephson junction model with magnetic momenta is presented. Computer implementation has been done by means of Wolfram Mathematica using the extensive capabilities of this system to create interactive dynamic objects. Two methods for numerical solution of the respective system of ordinary differential equations are implemented: the four-step Runge-Kutta algorithm and the Runge-Kutta-Fehlberg method with predetermined accuracy. Results of numerical simulation are presented to confirm the correctness of the calculations done with the developed software.

19. **Atanasova P.K**., Panayotova S.A., Zemlyanaya E.V., Shukrinov Y.M., Rahmonov I.R. *Numerical Simulation of the Stiff System of Equations Within the Spintronic Model*. In: Nikolov G., Kolkovska N., Georgiev K. (eds) Numerical Methods and Applications. NMA 2018. Lecture Notes in Computer Science, vol 11189. Springer, Cham, pp 301-308 **(2019)**, (**Web of Science, SCOPUS, SJR =0.339**), https://link.springer.com/chapter/10.1007/978-3-030-10692-8_33

We consider a stiff system of ordinary diferential equations within a spintronic model of the superconductor-ferromagnetic-superconductor Josephson junction (SFS JJ). For some values of parameters, the explicit algorithms failed for numerical solution of this system and special numerical approaches like the implicit two-stage Gauss-Legendre method are required. In our study, we use both explicit and implicit numerical schemes which have been implemented in the respective interactive software on the basis of Wolfram Mathematica technique. In this software, we employ the 4-step explicit Runge-Kutta algorithm and the two-stage GaussLegendre method of the 4th accuracy order (also known as the implicit Runge-Kutta scheme), combined with the fixed point method. We analyze the effectiveness of two numerical approaches and demonstrate an advantage of implicit method over the explicit scheme. Results of numerical simulation of superconducting processes in the SFS JJ depending on parameters are presented.

B. TRAINING HANDBOOKS

20. Gocheva-Ilieva S., H. Kulina, **P. Atanasova**, D. Voynikova, A. Ivanov, Laboratory notebook of the course in Software Systems in Mathematics, ed. Fastumprint, 2015 r. ISBN: 978-619-7223-10-1, printed version

The "Mathematics Software Systems" laboratory notebook is designed for a student from the Faculty of Mathematics and Informatics of the University of Plovdiv "Paisii Hilendarski". Reporting of the curriculum of the students in Software Engineering and Design, education and education for Bachelor's degree at FMI at Paisii Hilendarski University. The bulk of the task presentation was appraised during the academic year 2014/2015. The notebook contains 7 laboratory exercises with 70 tasks. In each exercise are solved selected examples, as well as the rest of the independent work. A list of basic rules for working with Wolfram Mathematica is attached at the end of the abstract. The laboratory notebook can also serve as head of the new Wolfram Mathematica user. It can be used for self-study with a software system, as well as for preparation for the computer math Olympiad.

21. **P.Atanasova,** Electronic Materials for the discipline "Computer Numerical Methods" - presentations for training and self-preparation, videos and work files, Plovdiv University, Plovdiv, 2017; http://atanasova.fmi-plovdiv.org/obuchenie/18/

The aim of the course is to study the basic methods of numerical solving of mathematical problems and their computer realization. Lectures, besides theoretical knowledge, are also given concrete examples. For each basic method, the student compiles a computer program during class hours and / or as a homework that is endorsed by the supervisor. The course includes numerical methods for solving equations and systems of linear equations (exact and iterative methods), approximations of experimental data (interpolation, splines, least squares method), numerical differentiation and integration, approximation of nonlinear systems of algebraic equations, numerical integration of ordinary differential equations and models, initial and boundary problems for ordinary differential equations, etc. The course is fully computer oriented. The aim is to acquire the skills to solve problems with professional mathematical and statistical packages, to develop skills to understand correctly and interpret the results obtained with the software packages. The Wolfram Mathematica packages and the online WolframAlfa computing engine and/or other software programming environments preferred by students are used.

22. **P. Atanasova**, Electronic Materials for the discipline "Computational Mathematics 2" - presentations for training and self-preparation, videos and work files, Plovdiv University, Plovdiv, 2016; http://atanasova.fmi-plovdiv.org/obuchenie/13/

The course examines the stages and peculiarities of scientific calculations; mathematical models, numerical methods and computer calculations. The concepts of stability, correctness and convergence are presented. The numerical integration of Koshi problem for ordinary differential equations (ODE) and ODE-systems is represented by several types of methods: one-step methods (Euler's method and modifications); Runge-Kutta methods; multi-step methods of the Adams type - extrapolation and interpolation formulas. Numerical solving of boundary problems for ODEs is presented by network methods for solving linear boundary problems from the second order. The course includes elements of the theory of differential schemes (DS): meshes, template, mesh functions, approximation of the main differential operators; mesh norms, differential analogs of the main differential operations; construction and authorization of the DS; correctness and stability of the DS. With the solution of partial differential equations (PDE), a mesh method is displayed and demonstrated. Classification of the second-order linear PDEs is made and parabolic PDE-equations of the heat conduction for the hyperbolic PDE-wave equation are solved. For all the tasks, a detailed analysis of the theoretical rationale is given and examples of Wolfram Mathematica are presented.

Prepared:
Dr. PAVLINA ATANASOVA

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Plovdiv