ESF ACTIVITY:Arrays of Quantum Dots and Josephson Junctions (AQDJJ)
HOST INSTITUTE: Professor Feodor Kusmartsev, Loughborough Uni, United Kingdom

# Intrinsic Josephson effect and plasmon-polariton excitations in the stack-array of Josephson Junctions made in multilayer high-$T_c$ superconductors probed by infrared and Raman Spectroscopy

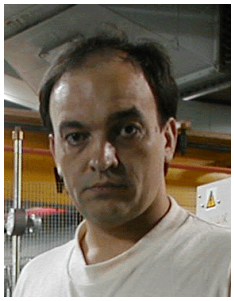
For multilayer high-$T_c$ superconducting (HTSC) cuprates, which contain more than one $CuO_2$ plane per unit cell, it has already been shown that a sizeable absorption peak develops below $T_c$ in the far-IR range [1-3, and Refs. therein]. Evidence has been presented that its spectral weight (SW) is mostly electronic in origin and that it belongs to the SC condensate. This can be understood in terms of the interlayer-tunneling model, which assumes that the $CuO_2$ planes are weakly coupled by the Josephson-currents in the SC state. For bilayer and trilayer compounds (Y123, Bi2212, and Bi2223) this results in two kinds of Josephson-junctions with different longitudinal plasma frequencies. Their out-of-phase oscillation gives rise to a transverse Josephson-plasma resonance (t-JPR), which has been assigned to the absorption peak that develops below $T_c$. The Josephson-superlattice model successfully describes the anomalous far-IR *c*-axis response of Y123, Bi2212, and Bi2223 [1,3], and the changes of the $A_{1g}$-polarized Raman spectra of trilayer and fourlayer HTSC [2]. Nevertheless, it is not commonly accepted, and it is disputed whether the SW of the absorption band belongs to the SC condensate [4].

The aim of the project is systematic and correlated investigations of the SC-induced $A_{1g}$-poalrized Raman- and c-axis-IR- active modes in trilayer and fourlayer compounds with different doping levels. A more elaborated theoretical approach in the framework of formalism of charge-density fluctuations between the superconducting planes is expected to be explored. The Department of Physics, Loughborough University has the modern HR LabRam Raman spectrometer (the latest technology, 2004) and perfectly suitable for the proposed project. It is supposed that during the visit the setup of the first experiments will be established and preliminary results will be obtained.

[1] A.V. Boris *et al.* , Phys. Rev. Lett. **89**, 277001 (2002).
[2] D. Munzar and M. Cardona , Phys. Rev. Lett. **90**, 077001 (2003).
[3] N.N. Kovaleva *et al.* , Phys. Rev. B **69**, 054511 (2004).
[4] S.V. Dordevic *et al.* , Phys. Rev. B **69**, 094511 (2004).

**CURRICULUM VITAE** ***Alexander V. BORIS, Ph. D.***

## 1.Personalia




**Born :** 13th of March, 1965, Brest distr., Baranovichy, USSR
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## 2. Education

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|---|---|
| **Ph.D.: (Solid State Physics)** ***September 1992*** | Institute of Solid State Physics, Russian Academy of Sciences & Moscow Institute of Physics and Technology (State University) |
| **M.Sc. : (Physics )** ***June 1988*** | ***Diploma with Honor*** from Moscow Institute of Physics and Technology (State University), Faculty of General and Applied Physics, Moscow, Russia |

## 3.Employment

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|---|---|
| **March 2001 – present:** | ***Research Scientist / Max-Planck Society fellowship***, Max-Planck Institute for Solid State Physics, Stuttgart, D-70569 Germany |
| **Jan. 1994 – Sep. 2003:** | *Also* ***Research Scientist*** *at* Institute of Solid State Physics, Russian Academy of Sciences, Chernogolovka, Moscow distr., 142432 Russia |
| **(June 2000 – Feb. 2001)** | *Research Scientist* of Department of Exp.Physics V/ Electronic Correlations and Magnetism, Institute of Physics, University of Augsburg, Germany |
| ***(Oct. 1999 – Jan. 2000)*** | *Research Visitor* of Optical Solid State Physics Group, Solid State Physics Laboratory, University of Groningen, Groningen, The Netherlands |
| ***(Feb. - Apr. 1998 Feb. – Apr. 1997)*** | *Research Visitor* of Research Institute for Materials and High Field Magnet Laboratory, University of Nijmegen, 6525 ED Nijmegen, The Netherlands |
| **Nov. 1992 - Jan. 1994 :** | ***Research Associate*****,** Research Institute for Scientific Measurements, Tohoku University 2~1~1 Katahira, Aoba-ku, Sendai, 980-77, Japan |
| **Sept. 1988 - Oct. 1992 :** | ***Junior Researcher and Post-Graduate*****,** Institute of Solid State Physics, Russian Academy of Sciences, Chernogolovka, Moscow distr., 142432 Russia |

## 4. Current research activity

The work is now concentrated on the optical and magneto-optical properties of strongly correlated electron systems exhibiting unconventional electronic transport and magnetic phenomena. In particular, the main part of the recent experimental work was done on cuprate high-$T_c$ superconductors, on perovskits manganites which reveal a magnetoresistance effect, on cobaltites $Na_{1-x}CoO2$ with strong charge-spin-lattice coupling, and on rutheno-cuprates $RuSr_2GdCu_2O_8$ in which a long range magnetic order and superconductivity compete and coexist. Polarized angle resolved optical (from IR to UV) probes such as ellipsometry, reflectance and transmittance spectroscopy are used.

## 5. Working experience, references

### A. Optical properties of strongly correlated electron systems (1996 – present)

*The respective works were done [1-17] and are being carried in collaboration with:*
Prof. B. Keimer, Prof. C. Bernhard, *Max-Planck Institute for Solid State Physics, Stuttgart, Germany;*
Prof. A. Loidl, *Department of Experimental physics V/ EKM, University of Augsburg, Germany;*
Prof. Th. Rasing, *Nijmegen Science Research Institute for Molecules and Materials, University of Nijmegen, The Netherlands*
Prof. N.-C. Yeh, *Department of Physics, California Institute of Technology, Pasadena, USA.*

### B. Solid State Ionics (1988 – 1997)

*The **M.Sc.(1988)** and **Ph.D.(1992)** include the results of the investigations of optical, photoelectrical, electron transport properties of disordered solids. In particular, the effect of disordered ionic subsystem on the electron properties of the systems with fast ion transport has been studied .*

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## 6. List of recent publications


1. A.V. Pimenov, *A. V. Boris*, L. Yu, V. Hinkov, Th. Wolf, B. Keimer, and C. Bernhard, "Ni impurity induced enhancement of the pseudogap in cuprate high $T_C$ superconductors"- submitted to Physical Review Letters.

2. C. Bernhard, *A. V. Boris*, N.N. Kovaleva, G. Khaliullin, A. Pimenov, L. Yu, D.P. Chen, C.T. Lin, and B. Keimer - "Charge Ordering and Magneto-Polarons in $Na_{0.82}CoO_2$", Phys. Rev. Lett**. 93** 167003 (2004).

3. N.N. Kovaleva, *A. V. Boris*, C. Bernhard, A. Kulakov, A. Pimenov, A.M. Balbashov, G. Khaliullin, B. Keimer - "Spin-Controlled Mott-Hubbard Bands in $LaMnO_3$ Probed by Optical Ellipsometry", Phys. Rev. Lett. **93** 147204 (2004).

4. *A. V. Boris*, N.N. Kovaleva, O.V. Dolgov, T. Holden, C.T. Lin, B. Keimer, C. Bernhard – "In-Plane Spectral Weight Shift of Charge Carriers in $YBa_2Cu_3O_{6.9}$", Science **304** 708-710 (2004).

5. T. Holden T., H-U. Habermeier, G. Cristiani, A. Golnik, *A. V. Boris* , A. Pimenov, J. Humlícek, O. Lebedev, G. van Tendeloo, B. Keimer, and C. Bernhard – "Proximity induced metal/insulator transition in $YBa_2Cu_3O_7/La_{2/3}Ca_{1/3}MnO_3$ superlattices", Phys. Rev. B **69** 064505 (2004)

6. N.N. Kovaleva, *A. V. Boris*, T. Holden, C. Ulrich, B. Liang, C.T. Lin, B. Keimer, C. Bernhard, J.L. Tallon, D. Munzar, A.M. Stoneham – "*c*-axis lattice dynamics in Bi-based cuprate superconductors", Phys. Rev. B **69** 054511 (2004).

7. C. Bernhard C., T. Holden, *A. V. Boris*, N.N. Kovaleva, A.V. Pimenov, J. Humlicek, C. Ulrich, C.T. Lin, and J.L. Tallon – "Anomalous oxygen isotope effect on the in-plane FIR conductivity of detwinned $YBa_2Cu_3{}^{16,18}O_{6.9}$", Phys. Rev. B **69** 052502 (2004).

8. A. Lebon, P. Adler, C. Bernhard, *A. V. Boris*, A. Pimenov, A. Maljuk, C. T. Lin, C. Ulrich, B. Keimer – "Magnetism, Charge Order and Giant Magnetoresistance in $SrFeO_{3-d}$ Single Crystals", Phys. Rev. Lett. **92** 037202 (2004).

9. *A. V. Boris*, D. Munzar, N.N. Kovaleva, B. Liang, C.T. Lin, A. Dubroka, A.V. Pimenov, T. Holden, B. Keimer, Y.-L. Mathis, and C. Bernhard – "Superconductivity Induced Electronic Excitation and Phonon Anomalies in Trilayer $Bi_2Sr_2Ca_2Cu_3O_{10}$", NSLS Science Highlights, http://www.nsls.bnl.gov/newsroom/science/2003/05-Boris.htm (2003)

10. *A. V. Boris*, D. Munzar, N.N. Kovaleva, B. Liang, C.T. Lin, A. Dubroka, A.V. Pimenov, T. Holden, B. Keimer, Y.-L. Mathis, and C. Bernhard – "Josephson plasma resonance and phonon anomalies in trilayer $Bi_2Sr_2Ca_2Cu_3O_{10}$", Phys. Rev. Letters **89**, 277001 (2002).

11. *A. V. Boris*, C. Bernhard, N.N. Kovaleva, P. Mandal, and A. Loidl – "Phonon anomalies in the infrared conductivity of the $RuSr_2GdCu_2O_8$ ferromagnetic superconductor", Physica B **312–313**, 797 (2002).

12. N.N. Kovaleva, J.L. Gavartin, A.L. Shluger, *A. V. Boris*, and A.M. Stoneham – "Lattice relaxation and charge-transfer optical transitions due to self-trapped holes in nonstoichiometric $LaMnO_3$ crystal", Journal of Experimental and Theoretical Physics **94**, 178 (2002).

13. N.N. Kovaleva, J.L. Gavartin, A.L. Shluger, *A. V. Boris*, and A.M. Stoneham – "Formation and relaxation energies of electronic holes in $LaMnO_3$ crystal", Physica B **312–313**, 734 (2002).

14. N.N. Kovaleva, J.L. Gavartin, *A. V. Boris*, and A.M. Stoneham – "Optical transitions in non-stoichiometric $LaMnO_3$ identifying the charge-transfer transitions", Physica B **312–313**, 739 (2002).

15. *A. V. Boris*, P. Mandal, C. Bernhard, N.N. Kovaleva, K. Pucher, J. Hemberger, and A. Loidl – "Phonon anomalies and electron-phonon interaction in the $RuSr_2GdCu_2O_8$ ferromagnetic superconductor: Evidence from infrared conductivity", Phys. Rev. B **63**, 184505 (2001).

16. *A.V. Boris*, N.N. Kovaleva, A.V. Bazhenov, P.J.M. van Bentum, Th. Rasing, S- W. Cheong, A.V. Samoilov, N.-C. Yeh, - "Infrared studies of a $La_{0.7}Ca_{0.3}MnO_3$ single crystal: optical magnetoconductivity in a half-metallic ferromagnet", Phys. Rev. B **59**, R697 (1999).

17. *A. V. Boris*, N.N. Kovaleva, A.V. Bazhenov, A.V. Samoilov, N.-C. Yeh, R.P. Vasquez, - "Infrared optical properties of $La_{0.7}Ca_{0.3}MnO_3$ epitaxial films", J. Appl. Phys. **81**, 5756 (1997).


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