Project Acronym and Number: NoWaPhen 247556

Project Title: Novel Wave Phenomena in Magnetic Nanostructures

Start and End Dates: 3/5/2010 till 2/5/2014

EC Contribution: 333,000 €

Topic

Spin waves and electromagnetic waves in magnetic, superconducting, and hybrid nano-materials and devices

Summary of project goals

The academic exchange aims to establish and support multi-lateral transfer of knowledge and expertise among several European and international research teams striving to advance the research fields of magnonics and magneto-photonics.

Funded by the FP7 NMP programme, the beneficiaries (UNEXE, TUM, and AMU) have already formed an EU collaboration to explore novel nano-structured magnonic meta-materials of magnonics. The academic exchange aims to augment this activity by collaborations with leading groups in Ukraine (DONNU, DIPE, KKNU, and IMAG) and Russia (Kotel'nikov), and thereby to explore *new* opportunities in physics of magnetic nanostructures in areas where the existing knowledge is yet insufficient to set up a full-scale research programme. The ambition is to carry out adventurous proof-of-concept studies aiming to underpin future directions of science and technology of magnetic meta-materials.

Potential Applications

Spintronics, magnonics, electromagnetics, and microwave electronics, including magnonic and magneto-photonic crystals, spintronic, magnonic, and hybrid superconductor-magnetic devices interconnected with more conventional photonic, plasmonic, and electronic devices.

Coordinator: Volodymyr Kruglyak, University of Exeter, UK

V.V.Kruglyak@exeter.ac.uk

Relevant review articles:

V. V. Kruglyak, S. O. Demokritov, and D. Grundler, "*Magnonics*", J. Phys. D – Appl. Phys. **43**, 264001 (2010);

M. Krawczyk and D. Grundler, "*Review and prospects of magnonic crystals and devices with reprogrammable band structure*", J. Phys. Cond. Matter. **26**, 123202 (2014).

Summary of the key achievements

1. A composite fermion theory of the metal-insulator transition in a two-dimensional conductor with the long-range Coulomb interaction between electrons has been developed. [V. M. Gvozdikov, "*Composite fermions without a magnetic field: An application to the metal-insulator transition in a two-dimensional conductor with the long-range Coulomb interaction between electrons*", Phys. Rev. B **82**, 235110 (2010)]

2. A detailed theoretical understanding of the temperature- and thickness-dependence of the photonic band gap spectra of the one-dimensional photonic crystal with a superconducting defect layer has been developed. [N. N. Dadoenkova, A. E. Zabolotin, I. L. Lyubchanskii, Y. P. Lee, and Th. Rasing, "*One-dimensional photonic crystal with a complex defect containing an ultrathin superconducting sublayer*", J. Appl. Phys. **108**, 093117 (2010)]

3. Micromagnetic method of s-parameter characterization of magnonic devices has been developed and tested. The method allows numerical characterisation of magnonic devices in terms of their s-parameters. [M. Dvornik, A. N. Kuchko, and V. V. Kruglyak, "*Micromagnetic method of s-parameter characterization of magnonic devices*", J. Appl. Phys. **109**, 07D350 (2011)]

4. The magnonic counterpart of the Goos-Hanchen Effect (well-known in photonics) has been theoretically predicted to occur in thin magnetic films and nanostructures. [Y. S. Dadoenkova, N. N. Dadoenkova, I. L. Lyubchanskii, M. Sokolovskyy, J. W. Klos, J. Romero-Vivas, and M. Krawczyk, "*Huge Goos-Hanchen effect for spin waves: a promising tool for study magnetic properties at interfaces*", Appl. Phys. Lett. **101**, 042404 (2012)]

5. The enhanced spin-wave transmission in nanowires with a zigzag-like magnetization state in comparison with the states of more homogeneous magnetization has been discovered. As a result, spin waves propagate in narrow channels remotely positioned from the edges. Rotation of the magnetic field at a specific value is found to vary the propagation velocity opening the perspective of creation of the velocity modulation magnonic transistor. [G. Duerr, K. Thurner, J. Topp, R. Huber, and D. Grundler, "*Enhanced transmission through squeezed modes in a self-cladding magnonic waveguide*", Phys. Rev. Lett. **108**, 227202 (2012)]

6. A novel exchange-based magnetic anisotropy has been discovered. [V. S. Tkachenko, A. N. Kuchko, M. Dvornik, and V. V. Kruglyak, "*Propagation and scattering of spin waves in curved magnonic waveguides*", Appl. Phys. Lett. **101**, 152402 (2012)]

7. A new class of non-reciprocal spin-wave phenomena inherent to metallised magnonic crystals has been discovered. [M. Mruczkiewicz, M. Krawczyk, G. Gubbiotti, S. Tacchi, Y. A. Filimonov, D. V. Kalyabin, I. V. Lisenkov, S. A. Nikitov, "*Nonreciprocity of spin waves in metallized magnonic crystal*", New J. Phys. **15**, 113023 (2013)]

8. Criteria for occurrence of localised states in magnonic crystals with defects have been proposed. [J. W. Klos and V. Tkachenko, "*Symmetry-related criteria for the occurrence of defect states in magnonic superlattices*", J. Appl. Phys. 113, 133907 (2013)]

9. Periodically modulated metamaterials combining functional properties of both photonic and magnonic crystals have been invented. [J. W. Klos, M. Krawczyk, Yu. S. Dadoenkova, N. N. Dadoenkova, and I. L. Lyubchanskii, "*Photonic-magnonic crystals: multifunctional periodic structures for photonics and magnonics*", J. Appl. Phys. **115**, 174311 (2014)]

10. A detailed understanding of spin wave propagation in networks of magnonic waveguides biased by applied magnetic field has been achieved. [C. S. Davies, A. Francis, A. V. Sadovnikov, S. V. Chertopalov, M. T. Bryan, S. V. Grishin, D. A. Allwood, Y. P. Sharaevskii, S. A. Nikitov, and V. V. Kruglyak, (unpublished)]