Low-temperature and extra low-temperature microwave ESR-radiospectroscopy of low-dimensional magnetic structures

• radiospectroscopy of artificial magnetic and non-magnetic materials;
• the interaction of microwaves with the magnetic low-dimensional structures;
• physics and techniques of electron spin/magnetic resonance (ESR/EMR) radiospectroscopy for the millimeter range;
• physics and techniques of low temperature radiospectroscopy;
• planar photonic crystals for ESR radiospectroscopy

Responsible persons: S. Nedukh (Ph.D.), A. Vakula (Junior Researcher), S. Tarapov (corr. member of NASU)

Main results

- the effect of a giant magnetoimpedance in magnetic multilayer nanostructure $Fe(Co/Cu)_n$ in mm waveband is discovered and investigated. It is shown that in the frequency range 30-150 GHz and magnetic field H=±1000 Oe, the effect of a giant magnetoimpedance is caused by the spin-dependent scattering of the conduction electrons in nanostructures;
- the effect of tunneling magnetoimpedance in magnetic granular structures *Co-TiO*, *Co-AlO* in the mm waveband discovered and investigated. It is shown that the effect of tunneling magnetoimpedance exhibits the maximum in the metallic phase state of the percolation transition "metal-insulator". It is found that in the range of magnetic field H=±2000 Oe, the effect of tunneling magnetoimpedance is caused by the spin-dependent scattering of the conduction electrons in nanostructures.

Experimental equipment

1. Millimeter wavelengths cryomagnetic radiospectroscopy complex (National Scientific-Related Patrimony of Ukraine): Its main function elements are:

1.1.BURAN spectrometer of electron spin resonance, with the following main parameters

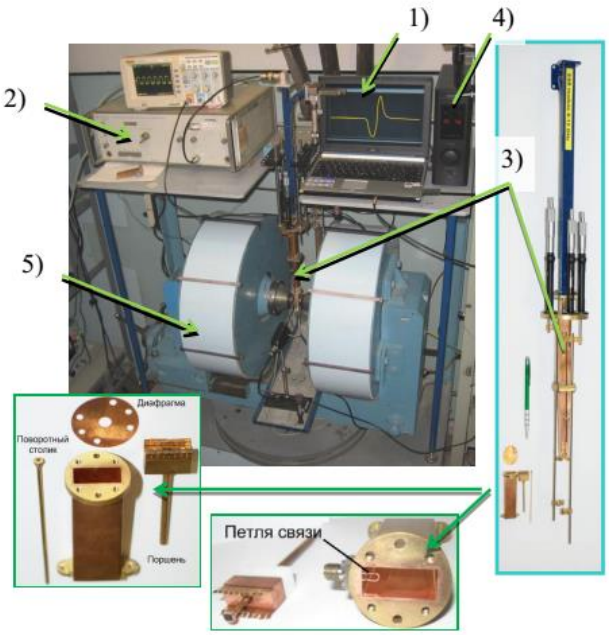
Frequency band - 75GHz -150GHz
Temperature band - 0.3K-150K
Magnetic field - up to 7T
Cooling system - Top-loading closed-cycle ^{3}He refrigerator with the working chamber volume - 200cm^3.

1.2. Radiospectrometer "Quark"; the techniques of registration of ferromagnetic resonance and the magnetization. (Responsible persons S.V. Nedukh, A.S. Vakula)

The radiospectrometer "Quark" intended for research of ferromagnetic resonance in nanocomposite materials.

2. The Extra High Frequency (EHF) unit of the spectrometer is under permanent modernizing /upgrading and consist from:

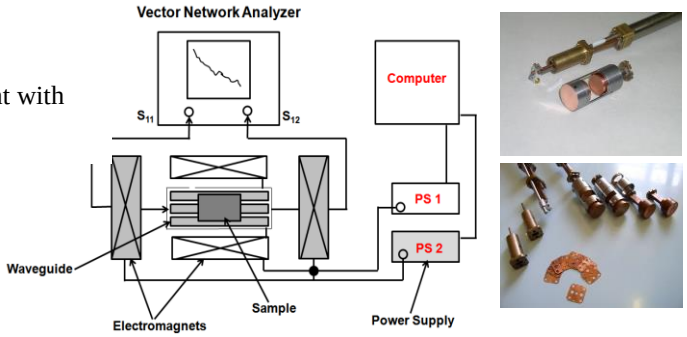
1. The registration system on the base of the specially designed high-speed analog-to-digital and digital-to-analog converter, which acts as a signal amplifier and synchrodetector (the original design - A.S. Vakula);
2. The set of the microwave generators at frequency ranges 7-12, 25-35, 37-50 GHz;
3. The set of the microwave modules for a magnetic resonance experiment, based on the original set of open resonators and cavity (7-12, 25-35, 37-50 GHz);
4. The low-noise low-frequency amplifier for amplification of weak signals;
5. The electromagnet H=0-2 T, included the modulation coils;
6. The set of the specialized softwares for complex control and processing of the experimental results

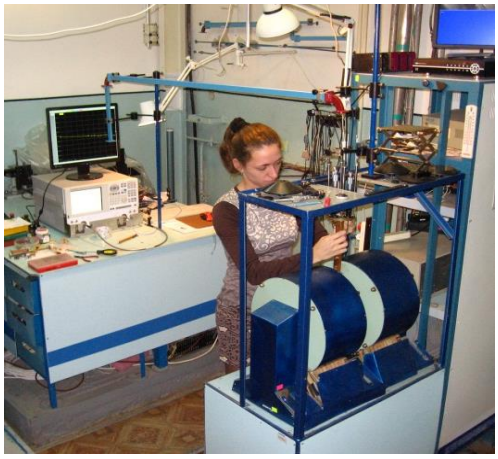


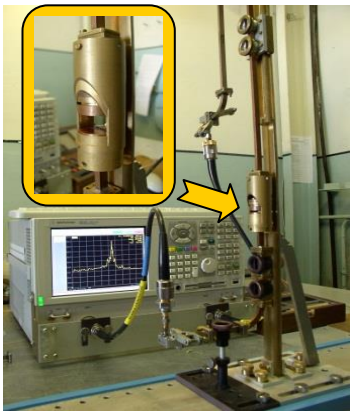
3. VNA ESR– spectrometer of electron spin resonance – with simultaneously scanning of a constant magnetic field and a frequency.

3.1. The spectrometer is based on a set of microwave modules, Vector Analyzer Agilent PNA-L NA5230A, and a family of specialized computer software for data management and experiment control:

ESR experiment with microstrip line

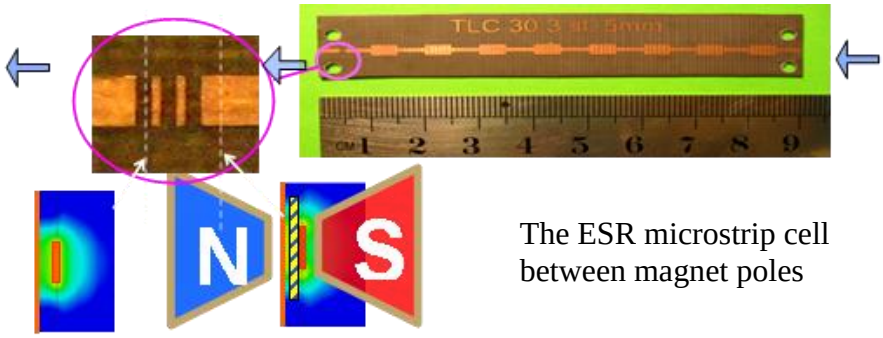




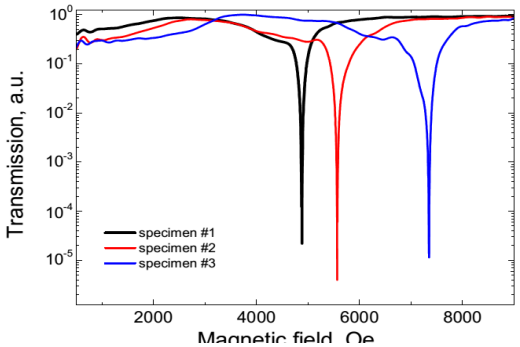


3.2. Electron spin resonance cell based on a planar photonic crystal [5]- for investigation of quasi 2D magnetics:

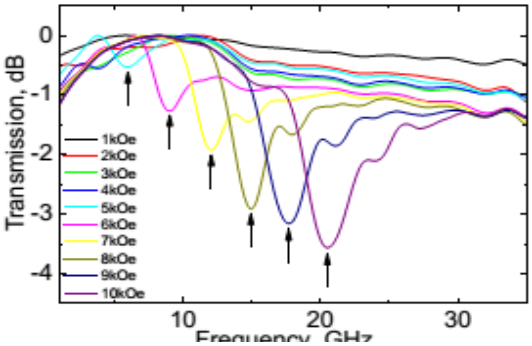
The ESR microstrip cell and a permanent magnet



The ESR microstrip cell between magnet poles



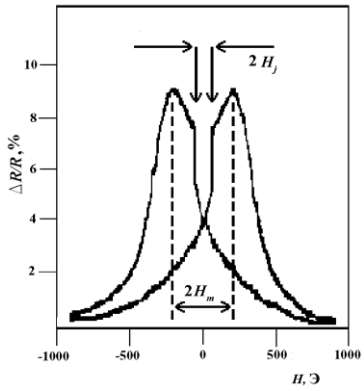
FMR –peak: magnetic field scanning

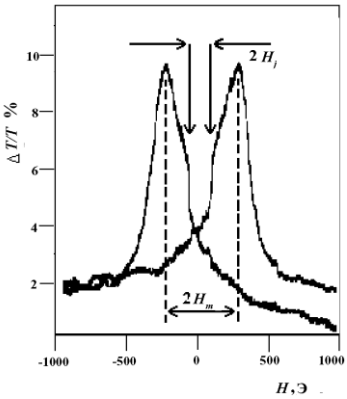


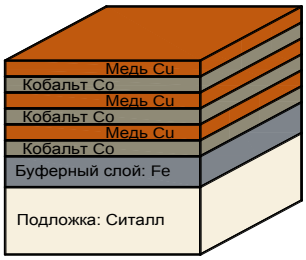
FMR –peak: frequency scanning

Main results:

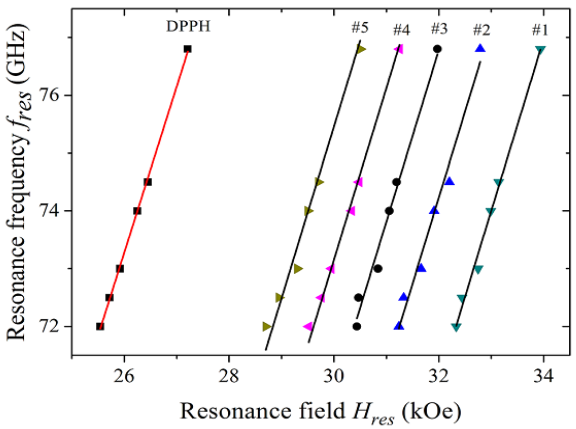
1. The effect of the spin-dependent scattering of conduction electrons at permanent current, at a frequency of 44 GHz (the giant magnetoresistance (GMR) and giant magnetoimpedance (GMI) in a magnetic multilayer structure [4] is founded:

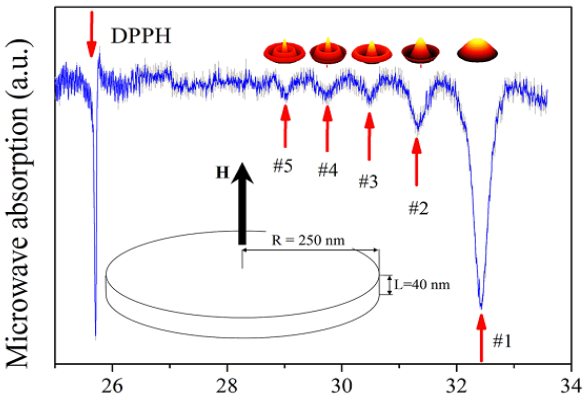




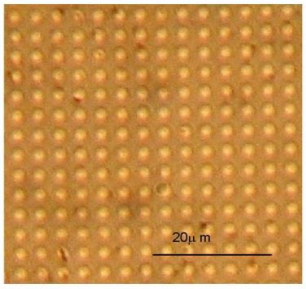


2. The excitation of homogeneous and the first 4-th inhomogeneous spin modes in a patterned array of magnetic nanodisks in the millimeter waveband [1-3] is revealed





nanodisk specimen



More detail results are presented in

References:

1. A.Moskaltsova, S.Nedukh, M.P. Proenca, C.T. Sousa, A. Vakula, G.N. Kakazei, S.I. Tarapov, J.P. Araujo Study of magnetoelastic and magnetocrystalline anisotropies in Co_xNi_{1-x} nanowire arrays Journal of Magnetism and Magnetic Materials 374 (2015) 663–668

2. D.P. Belozorov, A.A. Girich, A.N. Moskaltsova, S.I. Tarapov, S.V. Nedukh Microwave Analogue of Tamm states in periodic chain-like structures PIER Letters, Vol. 46, pp 7-12 (2014)

3. S.I. Tarapov, D.P. Belozorov, A.A. Kharchenko, S.V. Nedukh, V.O. Golub, I.V. Kilimchuk, O.Y. Salyuk, E.V. Tartakovskaya, S.A. Bunyaev, G.N. Kakazei Standing spin waves in perpendicularly magnetized circular dots at millimeter waves JOURNAL OF APPLIED PHYSICS 113, 17B521 (2013)

4. D.P. Belozorov, V.N. Derkach, S.V. Nedukh, A.G. Ravlik, S.T. Roschenko, I.G. Shipkova, S.I. Tarapov, F. Yildiz, B. Aktas Magnetization and impedance measurement of multilayer Co/Cu structure in millimeter waveband Journal of Magnetism and Magnetic Materials, 263, 2003, pp. 315-323.

5. A Planar Photonic Crystal-Based Resonance Cell for Ferromagnetic Resonance Spectrometer, A.A. Girich, M.A. Miliaiev, S.V. Nedukh, A. Shuba, S.I. Tarapov, Telecommunications and Radio Engineering, 2014, v. 73, N8, p.749-755.