Studying nanostructure magnetism with the use of polarized neutron reflectometry

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Introduction

Interest in multi-layer magnetic structures is motivated by their numerous applications – both realized and those being developed – in magnetic and spin electronics: for example, highly sensitive magnetic field sensors, magnetic recording and storage devices, etc. Much interest is shown to phase transitions, spin structure, scaling (qualitative change of properties), and proximity effects related to decreasing the material dimensions. Special attention is drawn by the following properties of such structures: exchange bias, giant magnetoresistance, induced and suppressed magnetism, artificial magnetic semiconductivity and superconductivity, etc.

Such structures are widely used in different areas. For example, car brake anti-blocking is based on detecting the magnetic field associated with wheel rotation. Another application of magnetic nanosystems is using them in magnetic carriers of information [1].

Thus one can see that studying magnetic nanosystems is an important task of modern science. Polarized neutron reflectometry (PNR) is irreplaceable for studying magnetic nanosystems. The method is based on the interaction between the neutron's magnetic momentum and magnetic moments within the structure. With grazing angles of 3 ё 30 mrad and neutron wavelength of several Angstroms – parameters typical for neutron reflectometry – the transmitted impulse is 10-3ё10-1 A-1, which provides spatial resolution of 1ё100 nm in determining magnetization.

The students performing this project will get the idea of the polarized neutron reflectometry, learn to handle spectra, and do data processing and analysis. The results of data processing are presented as quantitative information on magnetic structure: magnetic moment magnitude and direction, domain size, etc. For practical work, used will be spectra of scattering by real samples obtained at the REMUR facility (Fig. 2) [2,3].

Description of the project

Fig. 1 shows a classical reflectometry experiment.

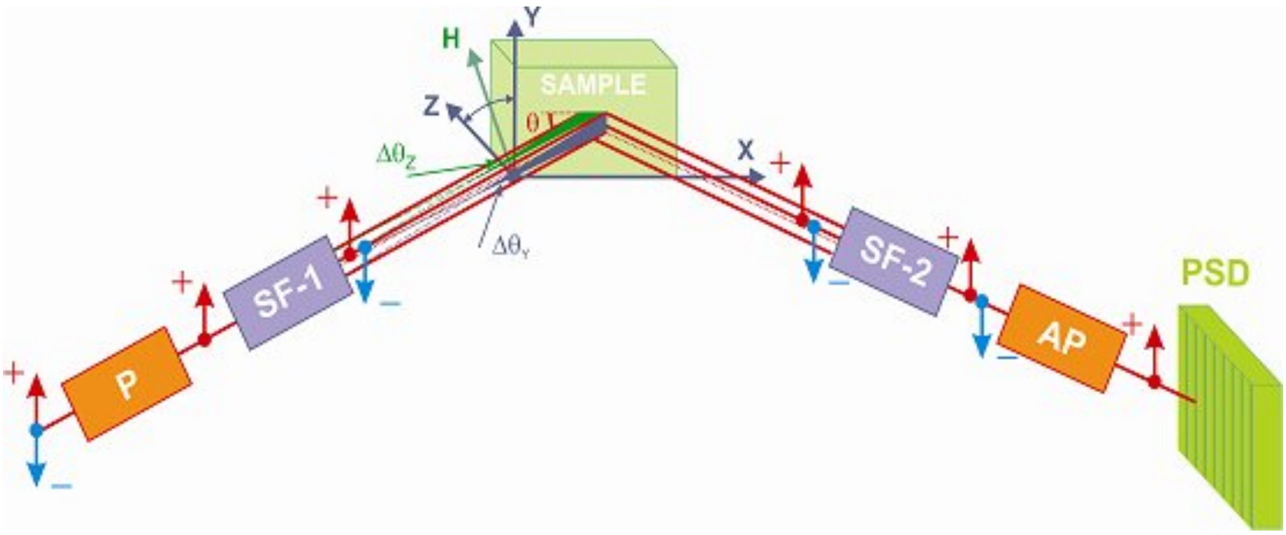

Fig.1. Layout of a polarized neutron reflectometer: polarizer P, spin-flippers SF-1 and SF-2, analyzer of polarization AP, position-sensitive detector PSD.

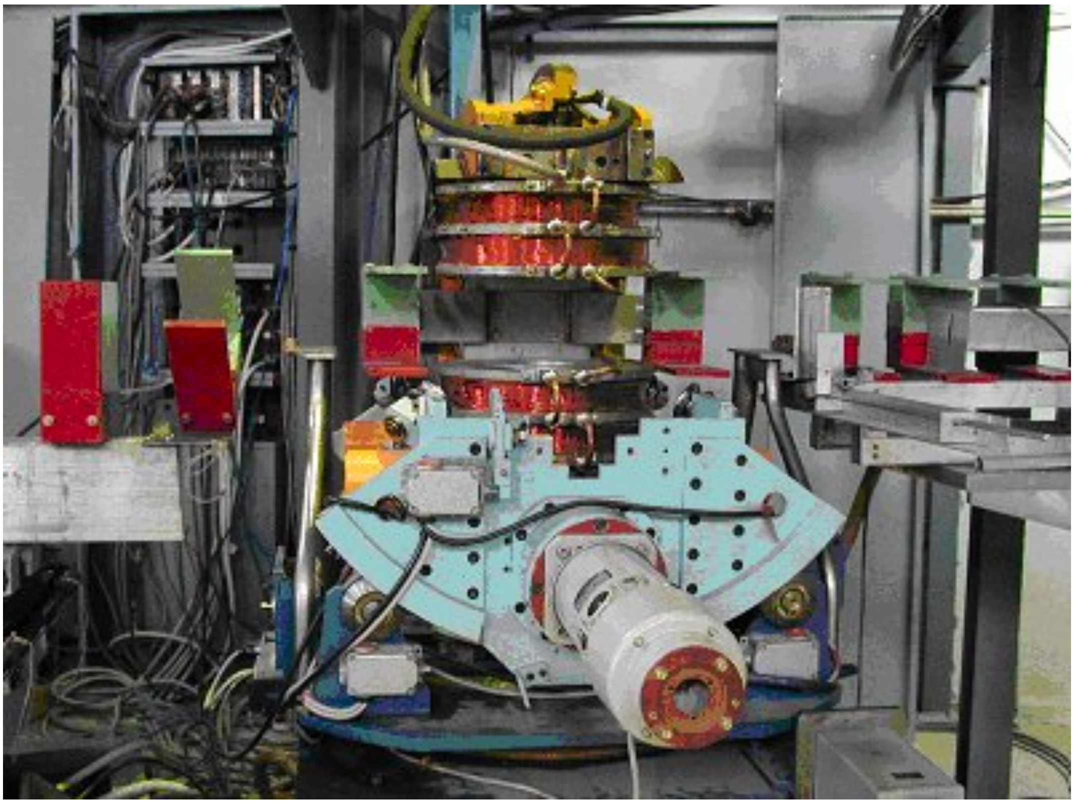
Fig.2. The main part of the REMUR spectrometer: a goniometer with a constant magnet.

The main parameters of the REMUR spectrometer
Sample plane: vertical
Scattering plane: horizontal
Neutron wavelength: 0.9 – 10 Å
Wavelength resolution: δλ = 0,011 Å
Scattering angle range: 1 – 100 mrad
Sample – detector distance: 4.9 m
Detector's spatial resolution: 1.5 mm

Neutron flux in two polarization modes:
· two polarizers (PR1+PR2): 104 neutron/(sec·cm2)
· the second polarizer (PR2): 3·104 neutron/(sec·cm2)

The **measurement procedure** consists of two stages:
1. Preliminary processing of the spectra. Two-dimensional intensity maps are processed, which results in one-dimensional spectra of the coefficients of mirror and diffuse scattering of polarized neutrons.
2. Mirror and/or diffuse scattering data are analyzed, and magnetic parameters of the samples are evaluated.

The project participants will choose from several nanosystems from different fields: for example, Fe/Cr and Fe/V nanoystems. The first one is an artificial antiferromagnet with the giant magnetoresistance effect. The latter consists of superconductor and ferromagnetic layers and is actively used in studying the proximity effects.

The results are presented as a report containing –
1. Introduction to the physics of a chosen phenomenon.
2. Description of the facility and measurement procedure.
3. Obtained raw data and description of the processing procedure.
4. Evaluated magnetic parameters of the sample, magnetic momentum magnitude and direction, domain size, etc.

To perform the project successfully, its participants have to know condensed matter physics in the amount of a university course. Experience in using ORIGIN software package for data processing and basic knowledge about mirror reflection spectra fitting (SimulReflec [4], EFFI2 [5]) would be an advantage.
Performing the project will take place in the conditions close to those of a real experiment. The number of its participants should also correspond to an optimal team of experimenters (two or a maximum of three).

The project supervisor

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Field of research:
Low-dimensional magnetism, proximity effects, polarized neutron techniques.
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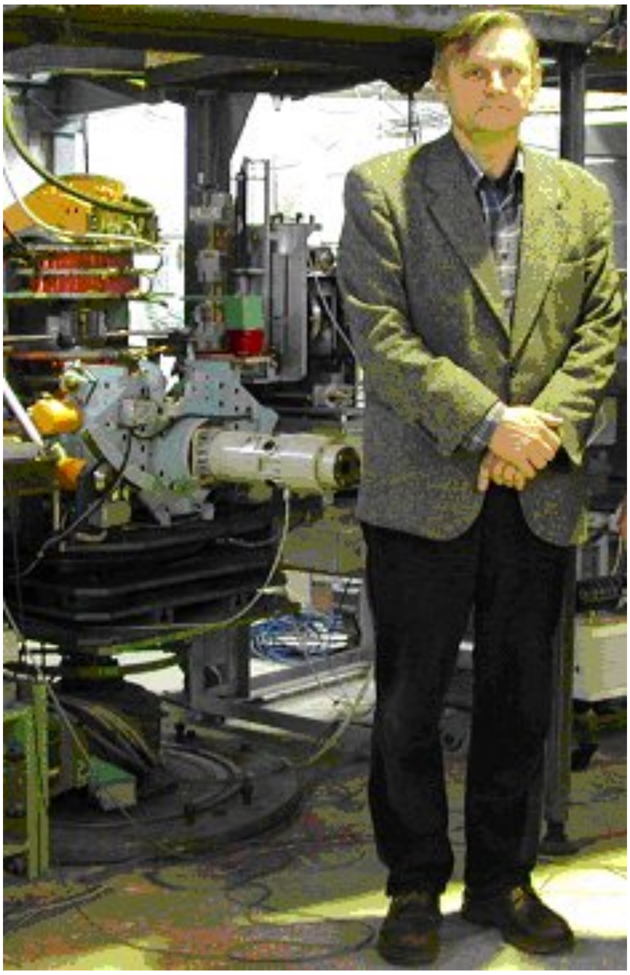

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