DEVELOPMENT OF REFLECTOMETRIC STUDIES IN OSCILLATING MAGNETIC FIELDS AT THE IBR-2 REACTOR

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Polarized neutron reflectometry (PNR) in an external static magnetic field is one of the principal techniques for investigating thin-film and multilayer magnetic structures. By measuring the four spin-dependent reflection channels, one can separate the nuclear and magnetic contributions to the effective optical potential and thereby reconstruct the depth profile of magnetization along the surface normal. Owing to this depth sensitivity, PNR has become a standard tool for the analysis of artificially structured magnetic materials and spintronic heterostructures [1–4].

Conceptually, RF-PNR retains the central element of magnetic resonance, namely spin reversal in the combined action of a static field and a transverse oscillating magnetic field. However, the physical nature of the measured observable differs fundamentally from that in conventional nuclear magnetic resonance (NMR). In NMR, one detects the collective macroscopic response of the spin subsystem, whereas in polarized neutron reflectometry one measures the reflection probability of an individual neutron in a given spin channel. This probability depends on the depth profile of the nuclear and magnetic potentials, interface-induced interference, the magnitude and orientation of the local magnetic field, and Zeeman corrections to the scattering kinematics. As a consequence, RF-PNR combines resonance selectivity with nanometer-scale depth sensitivity, a capability that is not accessible to conventional NMR techniques [1–6].

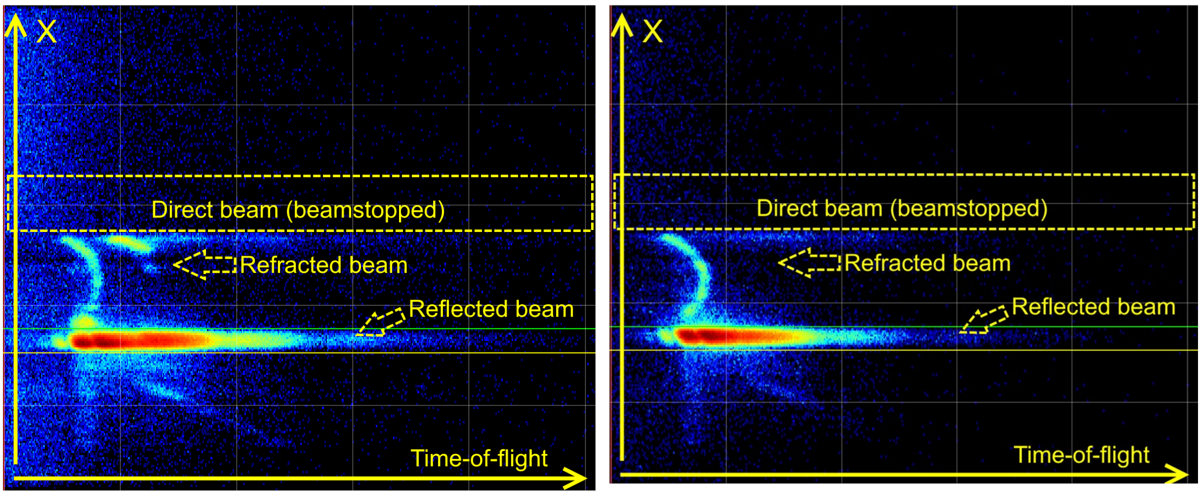

Fig.1: The PSD dependence of the intensity of the reflected neutron beam on the wavelength for the “+-” (left) and “++” (right) components in the oscillating field for sample CaTiO3 // Fe (50nm). H0 = 400 Oe, H1 = 5Oe, θ = 4.8 mrad, λ crit (Fe) = 3A. Larmor frequency ωL = 23.2 MHz

First proof-of-work results (Fig.1) were obtained using a model sample with a simple structure: CaTiO3 // Fe (50nm). A dedicated experimental module for neutron reflectometry in high-frequency oscillating magnetic fields was successfully developed and tested at the REMUR spectrometer. The measurements confirmed the influence of oscillating magnetic fields on polarized neutron reflection. The experiments demonstrated that the system operates reliably and is suitable for such measurements. A redistribution of the neutron beam intensity was observed as a function of the applied field frequency.

During this experiment we faced a few complications. Firstly, PSD is extremely vulnerable to electromagnetic interference. Therefore, enhanced shielding of the connecting cables and the detector itself is required, along with reliable RF grounding bus. Another limiting factor is sample heating during the experiment. The thermal power when generating an oscillating field of about 5 Oe reaches 140 W. At the same time, the power limit of the assembled module exceeds 2 kW.

The development of polarized neutron reflectometry in an oscillating magnetic field is therefore of considerable importance for the study of modern magnetic and spintronic systems. This approach makes it possible to investigate not only static magnetization profiles in thin films, but also dynamic magnetic processes, spin-flip transitions, resonant phenomena, and effects associated with spatially inhomogeneous internal fields. As a result, the method is particularly promising for the characterization of multilayer nanostructures in which both the depth distribution of magnetic parameters and their high-frequency dynamics are of fundamental importance [2–8].

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