Experiment title:	Experiment number:
Russian Grant Proposal: Study of exchange interactions between chiral-ordered magnetic layers in rare earth superlattices	HC-2901

Beamline:	Date of experiment:	Date of report:
ID18	from: 6 Dec 2016 to: 10 Dec 2016 from: 9 Mar 2017 to: 13 Mar 2017	27.02.2018
Shifts: 18	**Local contact(s):** Aleksandr Chumakov, Rudolf Rüffer	*Received at ESRF:*

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Report:

The main goal of our work was to study magnetic ordering in Al_2O_3/Nb(100nm)/Y(10nm)/[Dy(6nm)/Gd(6nm)]$_{20}$Al(10nm) multilayers using nuclear resonant (Mössbauer) reflectometry technique. We want to determine of magnetic structure Dy/Gd superlattices as a function of layer's thicknesses, temperature and magnetic field, and establish correlation between macroscopic magnetic properties of the superlattices and their microscopic magnetic structure.

It was the first experiment for ^{161}Dy isotope (25.6515 keV E1 transition) in reflection geometry in time domain.

Before the measurements sample was cooled down to 4 K in a cryo-magnetic system in 4 T field applied perpendicular to the sample surface, after that external field was turned off.

The nuclear resonant reflectivity (NRR) curve (Fig. 1.) from [Dy(6nm)/Gd(6nm)]$_{20}$ multilayer was measured as an integral over delayed signal at each angle. At 4 K the NRR curve from sample clearly shows the additional magnetic maximum, which is not presented in the X-ray reflectivity curve (Fig. 1), indicating the mismatch between the magnetic ($D^{magn} \approx$ 8.7 nm) and chemical ($D^{chem} \approx 11.4$ nm) period which could be the evidence of magnetic helix structure existence in Dy layers.

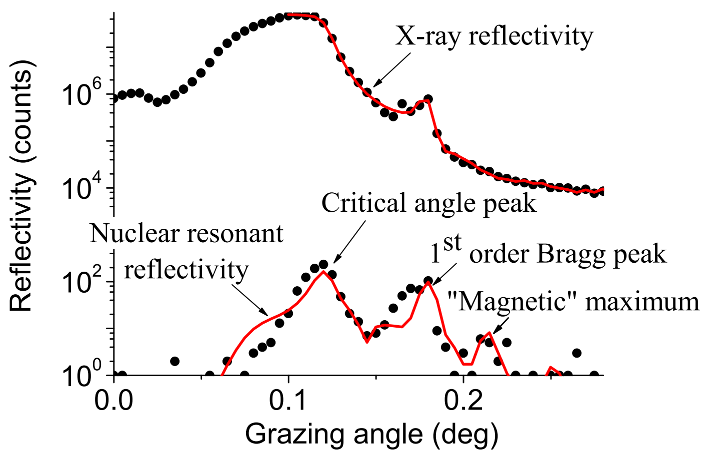

Fig. 1. X-Ray (prompt response) and nuclear resonance (integrated delayed signal) reflectivity curves measured at 4 K after removing the external field.

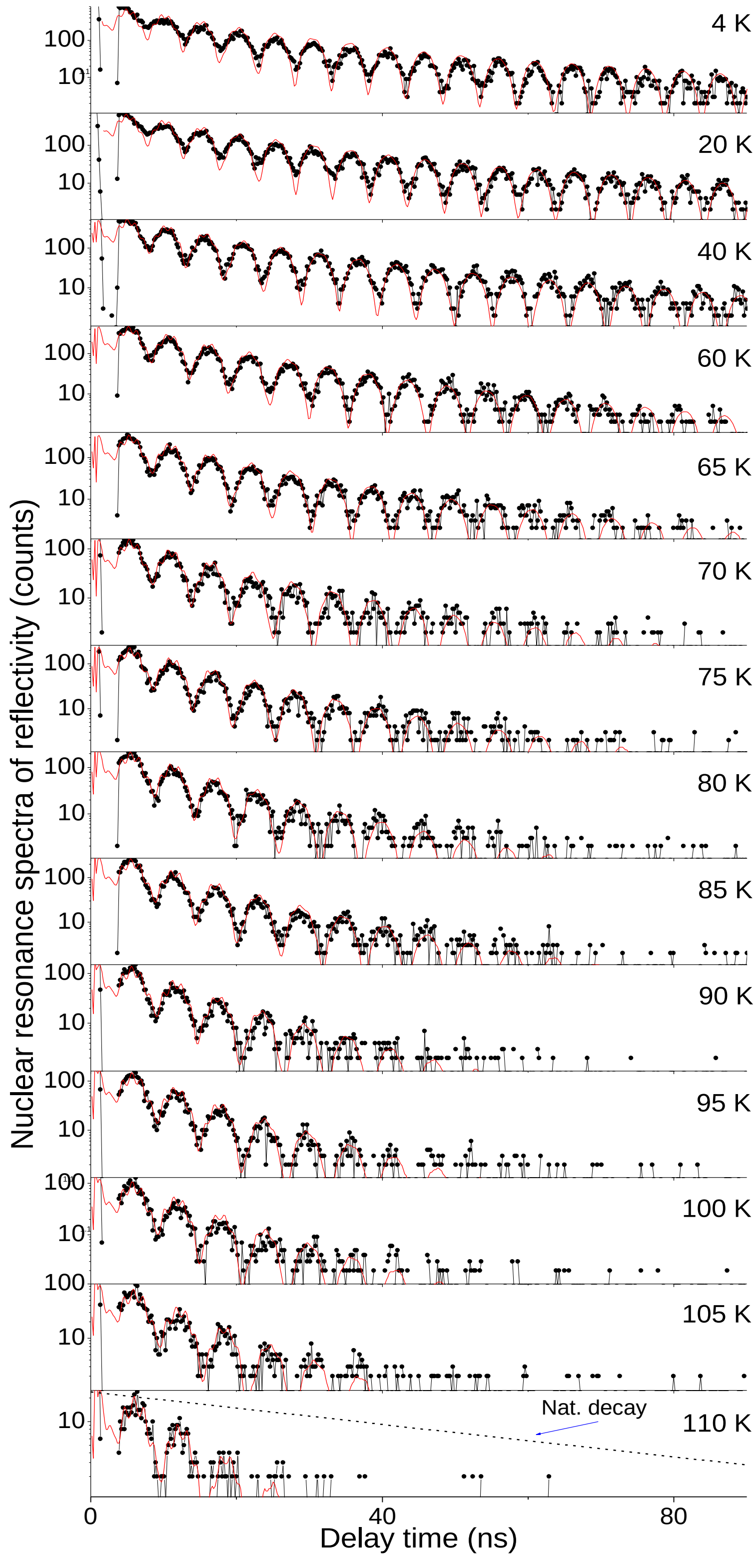

Fig.2 Nuclear resonant reflectivity time spectra measured at critical angle in temperature range between 4 and 110 K

We have measured a set of time spectra at critical angle at the temperature range 4-110 K with out magnetic field (Fig.2). It was taken about 3 hours to measure each spectrum The temperature stabilization after each step of heating was 30 min. Also nuclear resonance reflectivity (in short angular range) measurements was needed at each temperature to find the maximum critical angle to increase nuclear resonant signal (about 10 min).

Above 110 K nuclear resonant signal was fully suppressed by relaxation and the count rate was about 0.1 count per second.

Time spectra have only one frequency of quantum beats which is correspond to interference between two middle lines of Dy Mössbauer spectrum. Detection of high frequency quantum beats was impossible due to the time-resolution of the detector.

Frequency of quantum beats is decreasing with sample heating. Despite the fact that we have only one oscillation on time spectrum it is enough to restore values of magnetic hyperfine fields even at spectra with bad statistics (see spectra at 105 and 110 K). The Hyperfine field B_{hf} decreases from 569.7 T at 4 K to 462.2 T at 110 K. The enhanced relaxation at 110 K indicates the onset of the magnetic phase transition. Also we have measured one spectrum at Bragg maximum, and on spectrum at external field (4T).

During the experiment we have faced two problems. First one, temperature stabilization during the heating was too long. Second one, that regular adjustment of high resolution monohromator (HRM) was needed to increase resonance signal. When the count rate of reflected beam is too low it was impossible to adjust HRM during the measurements. So we have to set up reference Dy foil particular before each time spectrum to check resonance.

In summery:

We have performed the nuclear resonance reflectivity measurements on the [Dy/Gd]$_{20}$ multilayer in the time domain for the first time. Nuclear resonance reflectivity curve indicates the existence of nonlinear helix magnetic structure at 4 K in Dy layers. Nuclear resonant reflectivity spectra were measured at temperature range 4-110 K. Frequency of quantum beats allows to restore values of magnetic hyperfine field at each temperature.