ESRF	**Experiment title:** **Interface investigation in Cr/^{57}Fe periodical multilayer by means of the resonant standing waves created at Bragg conditions**	**Experiment number**: SI-553
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Report:

The main goal of the measurements was to show that the time spectra of nuclear resonance reflectivity from a multilayer containing periodically spaced ^{57}Fe layers at the Bragg angle is sensitive to the distribution of hyperfine fields across ^{57}Fe layer. Moreover that the change of the grazing angle in vicinity of the Bragg peak leads to the enhancement of the signal from different parts of ^{57}Fe layer («scan» across bilayer depth).

The time spectra of reflectivity at different grazing angles in vicinity of the Bragg peak (Fig.1) were measured at room temperature without external magnetic field for a microcrystalline (Fe/Cr)$_{26}$ multilayer (Fig.2).

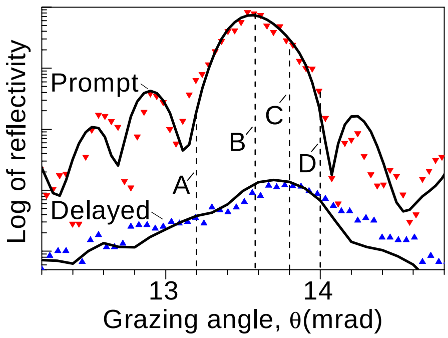

Fig.1. Prompt and delayed reflectivity for 0.086nm SR. Dots are the experiment, solid lines are the theoretical fit.

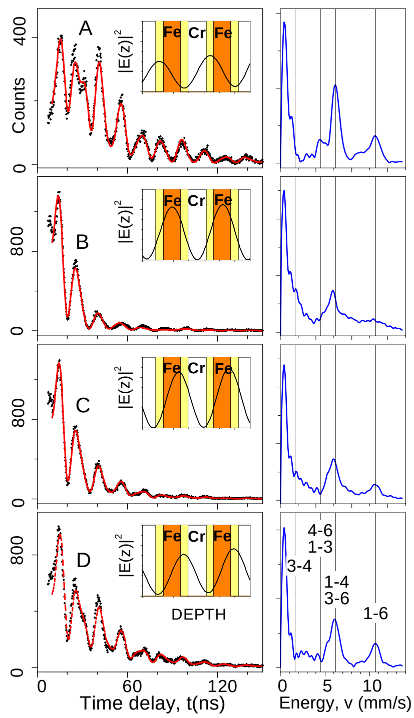

Fig.2. Experimental time spectra (left side) for four angles (A -13.2, B - 13.58, C - 13.8 and D - 14.0 mrad), marked by vertical dotted lines in Fig.2, and their Fourier transforms (right side). Inserts are the standing wave pattern for the chosen angles calculated at the delay time 11.8 ns. Vertical lines across the Fourier spectra show the quantum beat energies corresponding to the interference between Mössbauer lines in α-iron, numbered on the bottom. Theoretical (solid) curves are the result of the fit; the obtained model is in Fig.4.

A clear variation of the spectrum shape as a function of the angle has been seen. In order to distinguish the speed-up, dynamical and quantum beat effects the Fourier transforms of our spectra were done (Fig.2, right side). It immediately gives a qualitative picture of the hyperfine field distribution across the bilayer depth, because at each angle we have enhanced signal from a definite ^{57}Fe sublayer (according to the shift of the standing wave maximum, as presented in the inserts). At the Bragg angle we observe one dominant frequency while the spectra for off-Bragg angles are characterized by additional frequencies. So we conclude that the magnetic field orientation is different in the interfaces and in the central part of ^{57}Fe layers

Computer program was developed for the fit of the experimental spectrum set, calculation of the reflectivity takes into account the variations of the eigen polarizations of radiation field with depth as well as roughness of the interfaces. Direct fit of the experimental spectra confirms the noncollinear alignment of magnetic momemts in our sample [1,4]. In such a way we have proved that the shift of the angle in vicinity of the Bragg peak allows us to «scan» across bilayer depth. So we have developed a new method of «hyperfine reflectometry».

The same measurements of the time spectra of reflectivity in vicinity of the Bragg angle were performed with four additional monocrystalline samples: MgO/[^{57}Fe(7)/V(10)]$_{29}$/Pd, MgO/[^{57}Fe(10)/V(5)]$_{20}$/V, MgO/[^{57}Fe(5)/Co(5)]$_{25}$/V, MgO/[^{57}Fe(6)/Co(3)]$_{35}$/V (numbers in brackets mean the nominal number of monolayers). The unexpected thing was that all our samples had spontaneous magnetization. Model calculations confirm the high sensitivity of the shape of the time spectra to the hyperfine field distribution across bilayer depth. Simultaneous fit of the time spectra for several grazing angles gives the following results. For both ^{57}Fe/Co samples it occurs that the highest hyperfine field is not on the nuclei in the interfaces (as was predicted in the theory), but in the middle part of ^{57}Fe layers [3]. The interfaces of both ^{57}Fe/V samples are strongly asymmetric, and the larger hyperfine magnetic field is connected with V-on-Fe interface but not with Fe-on-V [2]. The obtained results are in contradiction with the previous interpretations of the hyperfine field structure in the samples, so we are going to check the results by new measurements.

The attempt was made to detect the time variation of the radiation field inside our multilayer by measuring the fluorescent radiation of non-Mössbauer atom (vanadium in the case of MgO/[^{57}Fe(7)/V(10)]$_{29}$/Pd sample). Unfortunately the background appeared to be too high in order to distinguish this signal. Because the behavior of the radiation field inside a periodical resonant medium in the time domain is quite interesting we shall try to find some other way for its detection.

The results of investigation has been submitted for publication in the following papers:

1. M.A. Andreeva, V.G. Semenov, L. Häggström, B. Kalska, B. Lindgren, A.I. Chumakov, O. Leupold and R. Rüffer, Standing wave effects in nuclear resonance Bragg reflectivity: comparison of the energy and time scales and first experimental results, Book of Abstracts of the 12th International Conference on Hyperfine Interactions (August 12-17, 2001, Park City, Utah, USA), P-119, paper has been submitted to «Hyperfine interactions».
2. B. Kalska[b], L. Häggström, B. Lindgren, P. Blomquist, R. Wäppling, M.A. Andreeva, Yu.V. Nikitenko, V.V. Proglyado, V.L. Aksenov, V.G. Semenov, A.I. Chumakov, O. Leupold and R. Rüffer, Magnetic properties of monocrystal ^{57}Fe/V multilayers investigated by CEMS, nuclear resonance reflectivity in time scale and polarized neutron scattering, ibid, O-14; paper has been submitted to «Hyperfine interactions».
3. B. Lindgren, M. A. Andreeva, L. Häggström, B. Kalska, V.G. Semenov, A.I.Chumakov, O.Leupold and R.Rüffer, ^{57}Fe/Co multilayers investigated by CEMS and nuclear resonance reflectivity time spectra using grazing incident SR, ibid, P-89,. paper has been submitted to «Hyperfine interactions»
4. M.A. Andreeva, V.G. Semenov, B. Lindgren, L. Häggström, B. Kalska, A.I. Chumakov, O. Leupold and R. Rüffer, Interface sensitive investigation of ^{57}Fe/Cr superstructure by means of nuclear resonance standing waves in time scale, Book of Abstracts of the International Conference on the Applications of the Mossbauer Effect (ICAME-2001), 2-7 September 2001, Oxford, UK; paper has been submitted to «Hyperfine interactions»
5. M.A.Andreeva, V.G.Semenov, L.Häggström, B.Lindgren, B.Kalska, A.I.Chumakov, O.Leupold, R.Rüffer, K,.A.Prokhorov and N.N.Salashchenko, Interface selective investigation of ^{57}Fe/Cr multilayer by nuclear resonance Bragg reflectivity in time scale, Euro-Asian symposium «Trends in Magnetism» (EASTMAG-2001, Ekaterinburg, Russia, February 27 - March 2, 2001), Ekaterinburg, 2001, p.257; paper accepted for publication in Fizika Metallov i Metallovedenie.
6. M.A.Andreeva, V.G.Semenov, L.Häggström, B.Lindgren, B.Kalska, A.I.Chumakov, O.Leupold, R.Rüffer, K,.A.Prokhorov and N.N.Salashchenko, Time-domain Mössbauer spectroscopy of magnetic maltilayers - the sensitivity of the Bragg reflectivity to the structure of separate bilayer, Proceedings of the Workshop «X-ray Optics -2001», Institute of Physics for Microstructures RAS, Nizhnii Novgorod (Russia), 19-22 February 2001, p.16-22.
7. M.A.Andreeva, V.G.Semenov, L.Häggström, B.Lindgren, B.Kalska, A.I.Chumakov, O.Leupold, R.Rüffer, K,.A.Prokhorov and N.N.Salashchenko, Time-domain Moessbauer reflectometry with synchrotroin radiation as a method of investigation of magnetic multilayers and intefaces, Book of Abstracts of the III national conference on the application of X-ray, synchrotron radiations and neutrons for material science (RSNE-2001, 21-25 May, 2001), Moscow, Institute of Crystallography RAS, 2001, p.203.
8. M.A. Andreeva, Mössbauer Standing Waves in Periodical Resonant Medium after Synchrotron Pulsed Excitation, Proceedings SPIE, 2001, in press.