NEW MONOCHROMATOR AND FOCUSING GUIDE ON THE POLARISED NEUTRON REFLECTOMETER PRISM : A POLARISED REFLECTOMETER FOR THE INVESTIGATION OF SURFACE MAGNETISM.

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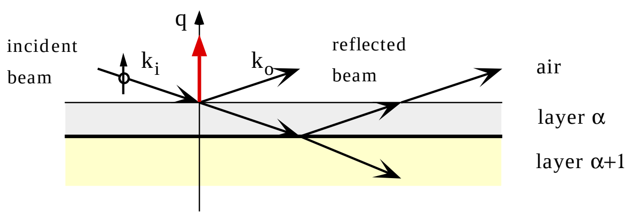
The neutron reflectivity technique has emerged less than 15 years ago. It appeared as a key technique in the study of polymers and magnetic thin films. Topics such as polymer interdiffusion, di-block copolymers ordering have been addressed. Besides, especially after the discovery of the giant magnetoresistance (GMR) effect, neutron reflectivity has been successfully applied to the study of magnetic multilayers and ultrathin films. Problems such as the magnetic ordering in rare-earth multilayers, surface magnetism and anisotropy in ultrathin magnetic layers have been solved. However, in order to extend the possibilities of the neutron reflectivity, an increase of the flux was necessary. In that aim, we have recently rebuilt a polarised reflectometer with polarisation analysis, dedicated to the study of magnetic thin films.

Neutron reflectivity principle

The neutron reflectivity technique consists in measuring the reflection of a neutron beam on a thin film (liquid, polymer or solid) at grazing incidence. The measured reflectivity as a function of the scattering wave vector **q** gives information on the chemical composition, the thickness of the layers and the roughness of a multilayer system. Neutron reflectometry is especially interesting to study polymers because of the large scattering length of hydrogen, and of the possible labelling of polymer chains by selective deuteration.

Moreover, the neutron is a ½ spin particle and the magnetic interaction with unpaired electrons is very large (as large as the nuclear scattering). By using polarised neutron reflectivity with polarisation analysis, it is possible to obtain information on magnetic systems: the type of magnetic ordering in multilayers systems (ferro, anti-ferro or helicoidal) or more generally the magnetisation profiles throughout the depth of magnetic thin films (along the scattering vector **q**).



Reflectivity geometry on a multilayer system.

To increase the available neutron flux, three different solutions are or will be put in place :

- increase of the wavelength spectrum width dl/l by using a multilayer monochromator,
- focussing of a 100 mm high neutron beam onto a 15 mm high region at the sample position,
- use of a position sensitive detector.

The previous PADA reflectometer was a two axis spectrometer using a graphite monochromator which had an excellent wavelength resolution $\delta\lambda/\lambda$ (~0.6%). The new PRISM spectrometer is still located on the guide G2 of the reactor Orphée. Here is the description of this instrument, schematically represented in figure 2.

The incident beam is deviated and monochromatised by a 3 m guide (M) made of nickel-titanium multilayers. The direction of the monochromatised beam makes an angle of 2.4° with the direction of the main guide. This part of the guide has been built and mounted by the CILAS company. The angular deviation of 2.4° is however not enough to move away the output beam from the main guide at the sample position. Thus, we have mounted two 1.80 m long $2\theta_c$-supermirror neutron guides (B) after the monochromator. The total beam deviation, from the main guide at the sample position is of 900 mm. This is enough for the shielding around the main guide (50mm lead, 250mm concrete) and the sample environment (cryostat, magnetic field). Since most of the studies on magnetic samples are realised on samples less than 20mm wide, we have focussed the beam vertically on the sample position. This vertical focussing is realised by a 8 m conical neutron guide (C) made of $2\theta_c$-supermirrors, which is interrupted twice. These two interruptions allow the introduction of the polarising (P) and flipping systems. The transmission polariser is made of Fe/Si multilayers deposited on 50 mm high silicon substrates (these mirrors were provided by Th. Christ from the HMI in Berlin). The incidence angle on the polarisers is small, 0.3°, in order to reject long wavelength neutrons generated by the monochromator system. The polarisation efficiency is 0.97 and the transmission of this polariser is 70%. At the sample position, a 50 mT field allows to maintain a good polarisation efficiency. The analysis system (A) is similar to the polariser except that the height of the device is 80 mm. It enables a full analysis of the reflected beam, which is highly divergent in the vertical direction.

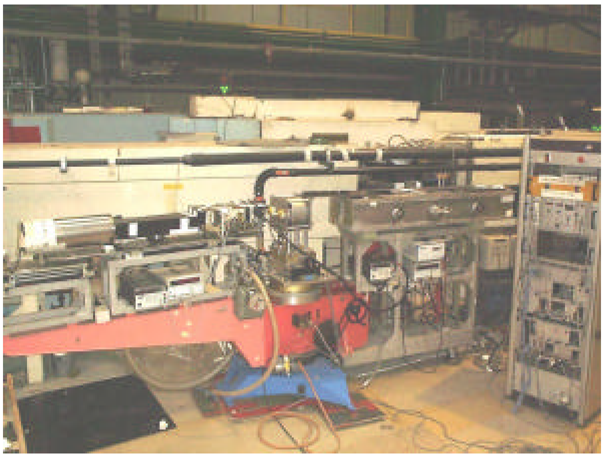


Figure 1. The Polarized reflectometer PRISM

With these two improvements (new monochromator and focussed beam), the available flux has been multiplied by a factor 15 and is presently of $5x10^5$ neutrons/cm².s after analysis on the detector with a resolution $\delta\theta = 0.03°$.

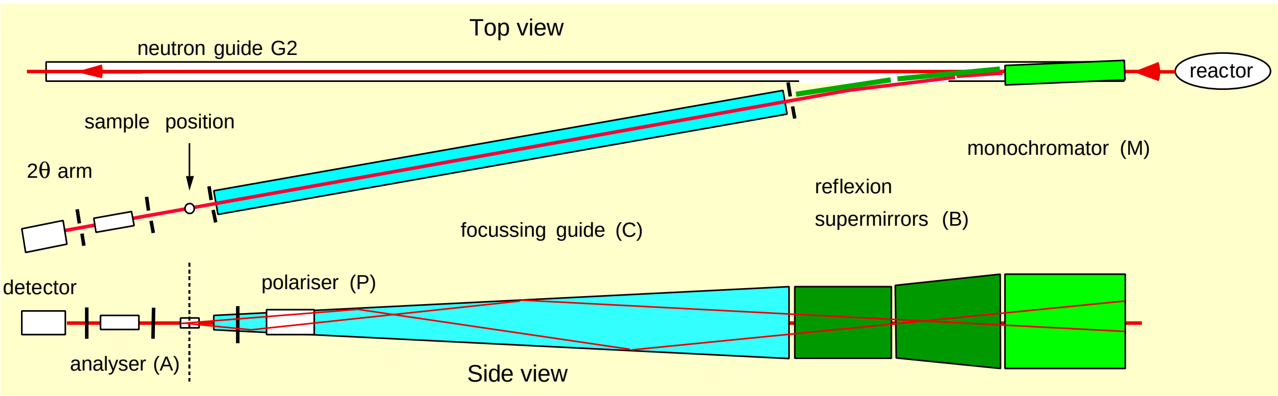


Figure 2. Scheme of the PRISM spectrometer and of its focussing guide, top view and side view

This high neutron flux will allow two main progresses in the reflectivity experiments. It will drastically reduce the measuring times of the reflectivity curves, and will permit measurements in various conditions of magnetic field and temperature. The second gain is the scattering vector range, twice as large as before. ($1.10^{-2} < q(Å^{-1}) < 0.25$). The wavelength is now 4 Å with a resolution $\delta\lambda/\lambda$ of 4%. The angular resolution $\delta\theta$ can be varied from 0.01 to 0.06°. The intensity dynamic range of measurement is now typically between 10^5 to 10^6 neutrons/s on a 1 cm² sample for an 8 hours full analysis scan and a resolution $\delta\lambda/\lambda = 4\%$ and $\delta\theta = 0.05°$ (see figure 3).
During 1999, a position sensitive detector, based on the micro strip technology (currently developed in the frame of the European XENNI program) will be installed. It will allow off-specular studies on magnetic systems.

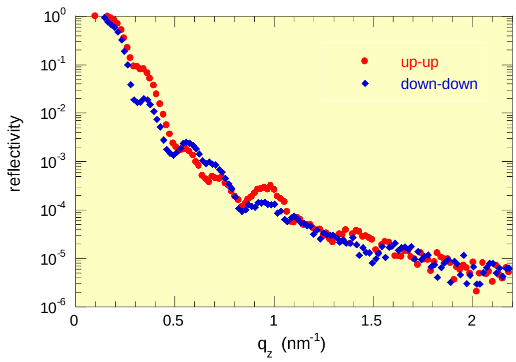


Figure 3. Reflectivity of a spin-valve system (Mn/Fe/Co/Ru /Co/NiFe) under a 0.3T field. The measurement time was 3 minutes per point on a 1 cm² sample