1.5.3 JRA3 - NO-PST

Coordinator: 11 - FRM-II
Partners: 5 – PSI, 9 - CEA LLB, 10 - CNR INFM, 13 – HMI, 23 - BNC-RISP
Observers: ILL, ATI

Project objectives

The most efficient means for increasing the flux at beam lines for neutrons is the use of advanced focusing techniques based either on diffractive optics or the reflection of neutrons from surfaces that are coated with artificial multilayer structures termed “supermirror”. In addition, the flux can be increased by actively changing the phase space of the radiation, for example by cooling the spectrum of the neutrons and/or by moving monochromators. The goal of the JRA3-collaboration was the development and exploration of new focusing techniques and phase space transformations that allow for the investigation of small samples as they occur often in the fields of soft condensed matter and in materials research as well as materials exposed to extreme conditions, for example high magnetic fields and/or high pressure.

In order to increase the neutron flux for small angle neutron scattering (SANS), a multi-beam collimator has been developed, featuring 7 masks with 51 pinholes each. First test experiments using a suspension of Latex spheres with a diameter of 225 nm prove that the principle is working leading to the expected flux gains while maintaining the resolution. An alternative design, using a multiplexing of highly collimated beams makes measurements on objects with 20 microns diameter feasible (Fig. J3). For inelastic neutron scattering experiments, the *Q*-resolution can often be relaxed. Therefore, concepts of focusing devices concentrating the neutron beams by reflection from supermirror-coated glass tubes that are elliptically curved or solid state Si-lenses have been developed. A flux gain of approximately 25 has been measured using neutrons with a wavelength in the range 3 Å < λ <6 Å.
In order to increase the efficiency further, improved coating techniques using magnetron sputtering have been developed thus increasing the number of diffracting layers from 500 to several thousand layers. In addition, laterally graded multilayers with improved reflectivity increase the performance further. The systematic studies have led to an improvement of the coatings with respect to the critical angle of reflection and reflectivity.

Elliptic guides have been developed for the transport of the neutrons from the moderator to the spectrometer. First prototypes show that the expected flux gains of more than a factor of five compared to regular neutron guides can be realised. It is gratifying to see that the new techniques are already being incorporated at the new Target Station 2 at ISIS that is presently in the construction phase.

Using the concept of moving monochromators it was proven that the high phase space density of ultra cold neutrons could be transformed to high neutron energies using the Doppler shift. The simulations demonstrate that the concept works. Moreover, first experiments at the ILL confirm the results of the simulations. This new concept of a phase space transformer shall be installed at the new UCN-source being presently built at PSI.

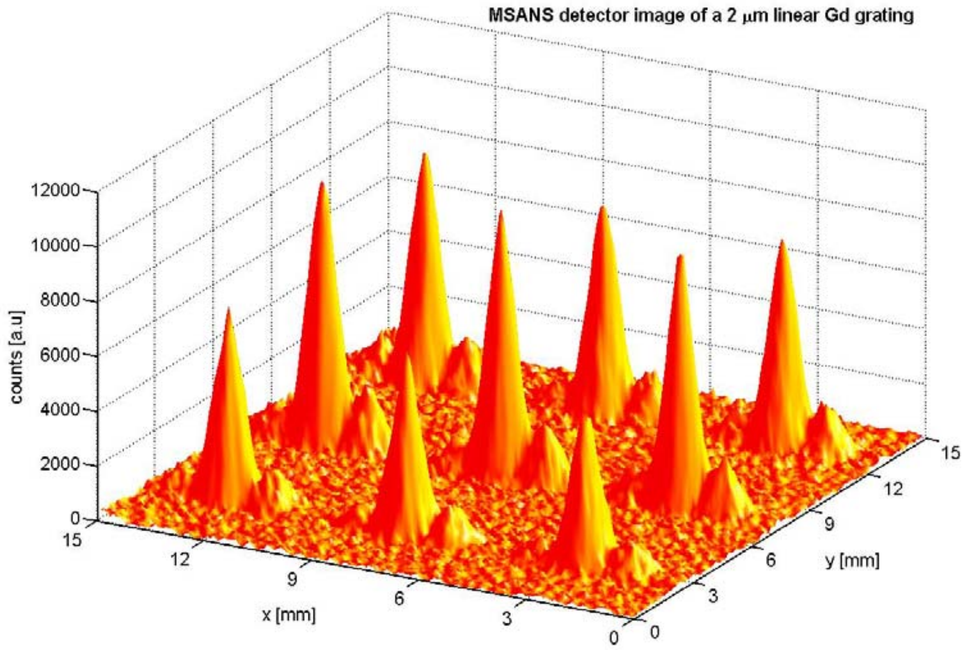

Figure J3: MSANS detector image of a 2 m linear Gd grating

Methods

Several key technologies had to be improved for achieving the anticipated goals. Highly efficient absorbing and reflecting coatings had to be developed using magnetron sputtering in order to define well-collimated beams and to provide a highly efficient transport and focusing of the neutron beams, respectively. Atomically smooth coatings exceeding 2000 layers had to be optimised. Laterally as well as vertically graded interfaces were produced for parabolic focusing and as higher order filters, respectively. For the production of Fresnel lenses, reliable high resolution etching techniques had to be provided. For the solid state Si-lens detailed simulations were performed and a precise holding and bending system was developed.

Impact

Regular small angle neutron scattering (SANS) allows the investigation of inhomogeneities up to length scales of the order of 400 nm. Within JRA3 we have developed two new SANS techniques, which allow us to decrease the momentum transfer by one to two orders of magnitude while maintaining a high intensity, thus challenging the presently used ultra-SANS techniques based on perfect crystal optics. Several neutron scattering centres, such as TU Delft and JCNS are now also proposing similar instruments though not using the same technology. These instruments are likely to play a significant role in the study of composite materials and hybrid materials. This field of studies has direct connections with industrial materials.

The newly developed focusing techniques are going to have a significant impact in the field of new materials that are usually only available in small quantities as well as for investigation of materials under extreme environment. Many such beam lines are presently being installed worldwide. The use of elliptic guides for the transport of neutrons shall soon become a standard technique. It allows reducing the reflection losses thus increasing the neutron flux at the beam lines significantly and delivering a neutron beam with a rather homogeneous phase space.