Neutron mirrors from nanoparticle-polymer composites

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The reported SANS experiment demonstrates the implementation of a holographic grating recorded in a nanoparticle-polymer composite as a beam-splitter for cold neutrons.

All neutron-optical phenomena, i.e., those arising from coherent elastic scattering, are governed just by the neutron optical potential or, equivalently, the neutron refractive-index. Thus, an important task in the design of neutron-optical elements is structuring the neutron refractive-index of materials in an efficient way. For this purpose we utilize materials that are sensitive to light, combined with holographic techniques to produce diffraction gratings for neutron-optics. Due to the photo (neutron)- refractive effect [1], the treated materials exhibit a periodic neutron refractive-index pattern, arising from a light-induced redistribution of SiO2 nanoparticles in a polymer matrix. Experiments with holographically produced gratings containing polymer-dispersed liquid-crystals (H-PDLC) [2] or deuterated poly(methylmethacrylate) culminated in the successful test of a triple-Laue interferometer for cold neutrons [3]. Nanoparticle-polymer composites [4] offer advantages for efficient tuning of the refractive-index modulation by suitable choice of the species among an abundance of possible nanoparticles, their size and volume-ratio (polymer matrix/nanoparticles). Thus, beam-splitters and mirrors for neutron interferometry seemed within reach. The experimental demonstration of this behavior of a holographically produced nanoparticle-polymer grating was the aim of the proposed experiment.

Two glass microscope slides were glued together enclosing a fixed gap provided by a roughly $100\,\mu m$ thick spacer-foil. The liquid monomer-nanoparticle mixture is sucked into the gap by capillary force. A sinusoidal hologram with grating spacing of $\Lambda = 0.5\,\mu$m was recorded in the material by laser interferometry (see e.g. [3, 5]). SANS measurements of various such gratings with different volume ratio have been carried out.

The Pendellösungs length of nanoparticle-polymer composite gratings is of the order of mm [5]. Therefore, for given wavelength the diffraction efficiency at the Bragg angle can be adjusted by changing the effective thickness of the grating by tilting the sample as it was done with thin crystals in [6].

The main result of the present experiment is shown in Fig. 1. Beam-splitter behavior for $\lambda = 2$ nm neutrons is exhibited by a holographic SiO_2 nanoparticle-polymer grating at a tilt angle of about 60 °. Clearly, diffraction occurs essentially in the Bragg-regime (two-beam coupling) as desired for use of the gratings in Mach-Zehnder interferometers for cold neutrons. The main problem in the experiment was the small sample diameter (roughly 1 cm), that strongly limited the transmitted flux at larger tilt angles, so that it was impossible to observe mirror-like behavior. This can easily be overcome for future experiments by slightly modifying the recording laser setup.

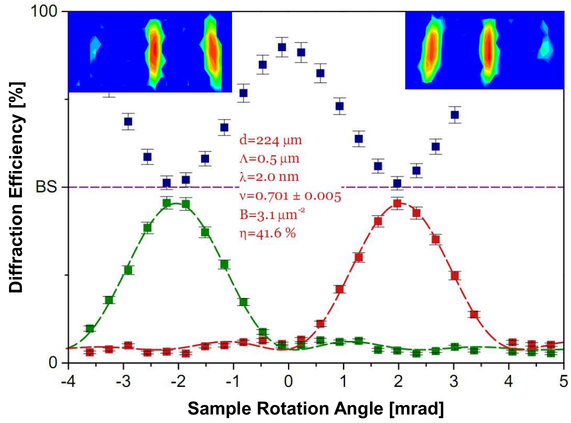

Figure 1: Rocking curve in Laue geometry: -1^{st} (green), $+1^{\text{st}}$ (red) and 0^{th} (dark blue) order diffraction efficiencies at neutron wavelength of $\lambda = 2$ nm of a holographic grating recorded in SiO_2 nanoparticle-polymer composite. The insets show the detector pictures at peak positions of -1^{st} (left) and $+1^{\text{st}}$ (right) diffraction orders.

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