Experimental report

13/02/2019

Proposal: **3-14-390** **Council:** 4/2018

Title: Photothermal refractive glasses for holographic-grating neutron-optical elements

Research area: Methods and instrumentation

This proposal is a new proposal

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Samples: photothermal refractive glass

Instrument	Requested days	Allocated days	From	To
PF2 VCN	12	12	05/09/2018	17/09/2018

Abstract:

We use materials that are sensitive to light, combined with holographic techniques to produce transmission gratings for neutron-optics. The treated materi-als exhibit a periodic neutron refrac-tive-index pattern, arising from a light-induced redistribution of the con-stituents. To keep rocking curves wide for adjustment and collimation reasons, novel materials should reach high reflectivity via increasing their con-stituents' contrast in coherent scattering length. One candidate material new to the field are photothermal refractive glasses (PTR glasses) that could enable diffraction at much larger Bragg angles than obtained with materials investigated previously. We intend to measure neutron diffraction from holographic gratings recorded in PTR glasses.

Photothermal refractive glasses for holographic-grating neutron-optical elements

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Photothermal refractive (PTR) silicate glasses are materials in the glass state on which patterns of nanocrystals are grown undergoing holographic illumination. They do not exhibit limitations when it comes to decreasing the grating period for enlarging the Bragg angles of gratings to be used for interferometry, for instance.

All neutron-optical phenomena arising from coherent elastic scattering, are governed just by the neutron-optical potential or, equivalently, the neutron refractive-index. We use materials that are sensitive to light and holographic techniques to produce transmission gratings for neutron-optics. The treated materials exhibit a periodic neutron refractive-index pattern, arising from a light-induced redistribution of the constituents.

The width of the rocking curve of diffraction gratings (the distance in angle of incidence between the minima adjacent to the central maximum) is approximately given by 2 times the grating period (typically $0.5\,\mu$m) divided by the grating thickness d (typically about $100\,\mu$m). The latter are decisive parameters also for reaching high diffraction efficiency (DE). However, increasing DE by increasing d leads to high DE at the cost of very narrow rocking curves, which makes gratings difficult to adjust as parts of optical systems (interferometer, for instance) and inefficient at badly collimated low-intensity beams. Therefore, novel materials should preferably reach high DE via increasing their constituents' scattering length contrast. Moreover, composite materials investigated so far (all based on polymers) often suffer from fundamental lower limits of the grating period due to the dimensions of polymer molecules and networks formed. Mostly, polymer-based materials work well down to periods of 500 nm, resulting in Bragg angles in the range of only about 0.1 deg, even for VCN. PTR silicate glasses however do not exhibit such limitations so that, in principle, the full capabilities of optical holography can be harnessed to record much smaller grating structures than previously in polymers.

Due to technical problems, our collaborators could not finish the samples as scheduled, so that we were forced to switch to some alternatives which are always plentiful in our field of research. We chose a novel nanoparticle-polymer composite grating incorporating superparamagnetic nanoparticles (magnetite) as sample. The problem with holographic structuring with magnetic particles is that they absorb too much of the incident light for hologram recording at sufficiently high nanoparticle concentration [1]. Slowly, that limitation is tackled by careful choice of the material components. Nanoparticle concentrations are increased. The result of a VCN diffraction experiment of a nanoparticle-polymer composite grating (period $1\,\mu$m, thickness $\approx 26\,\mu$m, nanoparticle concentration $\approx$ 9.3 vol.%) loaded with magnetite nanoparticles is shown in Fig. 1. It can be seen that diffraction is clearly observable. The diffraction efficiency is relatively high, taking into acount the still low concentration of not even 10 vol.%. The peaks overlap as is expected for relatively thin diffraction gratings. To observe a difference in the peak height when applying a magnetic field, we arranged an electromagnet so that the maximum field at the sample position was about 0.32 T. No significant difference was observed and we have – in the meanwhile – successfully applied for beamtime at an ILL SANS instrument for clarifying with polarized neutrons and a stronger magnet why we cannot see a difference at supposedly sufficient field strength and concentration. The diffraction measurements with PTR glasses must be postponed until the sample production issues have been solved.

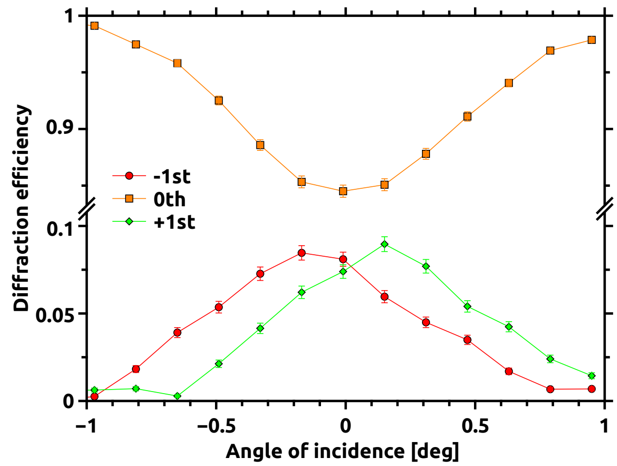

Figure 1: Rocking curve of a magnetite nanoparticle-polymer composite grating measured with VCN.

[1] J. Klepp, I. Drevenšek-Olenik, S. Gyergyek, C. Pruner, R. A. Rupp, and M. Fally, J. Phys.: Conf. Ser. **340**, 012031 (2012).

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