Experimental report

17/02/2020

Proposal: **3-14-392** **Council:** 10/2018

Title: Diamond nanoparticles in nanoparticle-polymer composite neutron diffraction gratings

Research area: Methods and instrumentation

This proposal is a new proposal

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Samples: Nanodiamonds in nanoparticle-polymer composite

Instrument	Requested days	Allocated days	From	To
PF2 VCN	15	15	09/01/2020	27/01/2020

Abstract:

We use materials that are sensitive to light combined with holographic techniques to develop diffraction gratings for long-wavelength neutron optics. The treated materials exhibit a periodic neutron refrac-tive-index pattern, arising from a light-induced redistribution of the con-stituents. Our goal is to find the most versatile and efficient material to produce neutron-optical elements, such as wavelength-standards and gratings for neutron phase-imaging or very-cold neutron interferometry. Various tests of nanoparticle-polymer composite gratings based on SiO2 nanoparticles have demonstrated that two- and three-port beam-splitters as well as free-standing film mirrors (diffraction efficiency ~90 %) for cold neutrons and VCN are feasible. The experiment described in this proposal aims at testing improved NPC gratings containing diamond nanoparticles.

Diamond nanoparticles in nanoparticle-polymer composite neutron diffraction gratings

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We measured diffraction on several holographic diamond nanoparticle gratings. Our aim is to produce gratings that beat our own old record diffraction efficiency (DE) achived with SiO_2 gratings, which was almost 90 %. So far, we could not beat this record but have, to our surprise, found that the nanodiamond gratings are much less durable than the SiO_2 gratings.

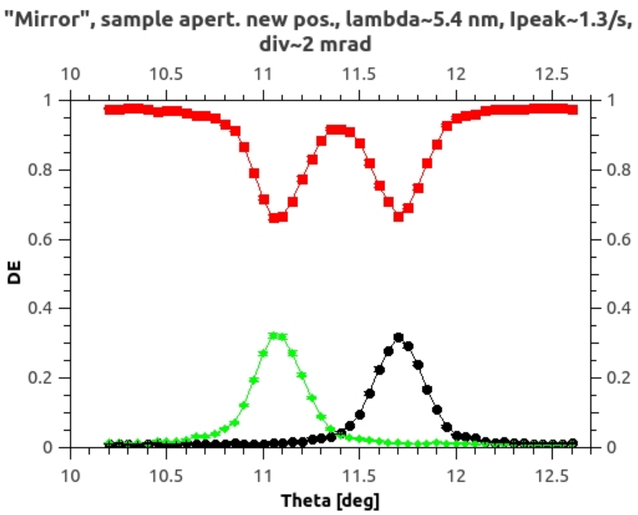

Figure 1: New rocking curve of the 9-year old free-standing-mirror sample (see [2] for the original data).

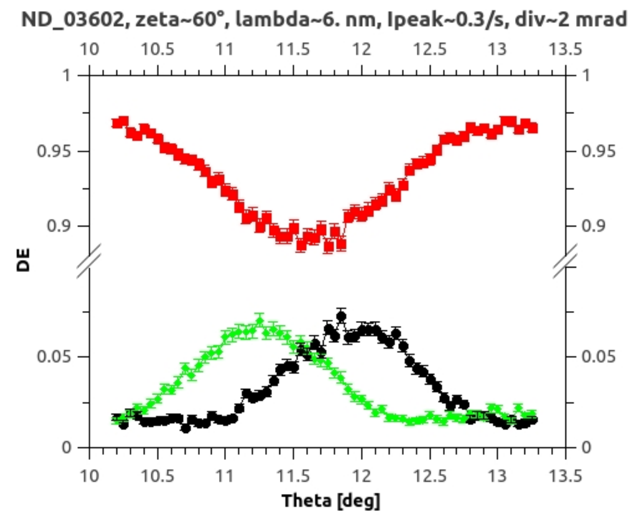

Figure 2: Rocking curve of holographic nanodiamond grating.

We use materials that are sensitive to light in addition to holographic techniques to produce relatively large area transmission gratings for neutron-optics [1]. The treated materials exhibit a periodic neutron refractive-index pattern, arising from a light-induced redistribution of the constituents, which results in a modulation of the scattering length density.

The width of the rocking curve (DE vs. angle of incidence) 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 (typically below $100\,\mu$m). The latter are decisive parameters also for reaching high DE. However, increasing DE by increasing the grating thickness leads to high DE at the cost of very narrow rocking curves, which makes gratings difficult to adjust as parts of optical systems (interferometers, for instance) and inefficient at badly collimated low-intensity beamlines. Therefore, novel materials should preferably reach high DE at low thickness via increasing their constituents' scattering length contrast. For the above reasons, we are trying to implement diamond nanoparticle gratings, which supposedly have the best neutron optical properties, instead of the already very well-working SiO_2 nanoparticle gratings. As one can see in Fig. 1, the SiO_2 sample (the results about which were published in 2012 [2]) is still exhibiting excellent neutron diffraction properties today.

After promising test measurements of our first nanodiamond gratings in 2018, in our beamtime in January 2020 we found *(1)* that, as expected, we still need to work on the contrast between the material matrix (polymer and rests of photoinitiator chemicals) and the nanodiamonds as the DE found is good (see Fig. 2), but still far from the one of the old SiO_2 sample, as shown in Fig. 1 and, *(2)*, that even the nanodiamond grating tested in 2018 had decayed and showed much less DE than one and a half years ago. The latter is somewhat surprising and relatively fast decay was confirmed also for our new nanodiamond samples, and also for light. We suspect unexpected interplay of photoinitiator and the monomers in use. While the finding is an important result, it definitely needs to be tackled, as diffraction properties changing on time scales of months prevent gratings to be used as diffractive optical elements.

[1] Y. Tomita, E. Hata, K. Momose, S. Takayama, X. Liu, K. Chikama, J. Klepp, C. Pruner, and M. Fally, J. Mod. Opt. **63**, S1 (2016), http://dx.doi.org/10.1080/09500340.2016.1143534
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[2] J. Klepp, C. Pruner, Y. Tomita, K. Mitsube, P. Geltenbort, and M. Fally, Appl. Phys. Lett. **100**, 214104 (2012).

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