Experimental report

15/09/2023

Proposal: **3-14-433** **Council:** 10/2022

Title: Investigation of the diffraction properties of holographic optical elements for cold neutrons

Research area: Methods and instrumentation

This proposal is a new proposal

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Samples: commercial polymer films
organic nanoparticle in polymer matrix

Instrument	Requested days	Allocated days	From	To
PF2 VCN	17	17	11/04/2023	18/04/2023
			22/06/2023	05/07/2023

Abstract:

In order to proliferate science with cold and very cold neutrons (VCN), we work on holographic optical elements (HOE) with materials that have customized diffraction properties (tuned by thickness, period and grating strength) for the VCN wavelength range. We use photosensitive materials to record a light interference pattern acting as diffraction grating by optical holography. The light exposure of the material triggers chemical processes that result in a spatial modulation of its constituents, and hence, in a spatially modulated refractive index. The resulting HOE works as a diffraction grating also for neutrons. The HOE¿s performance for neutrons can be evaluated by measuring the angular dependence of its diffraction efficiency by SANS. In the proposed experiment, we aim to test holographic optical elements based on commercially available off-the-shelf Bayfol foils and, additionally, novel organic nanoparticle materials with VCN.

Investigation of the diffraction properties of holographic optical elements for cold neutrons

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In our experiment, we aimed to test holographic optical elements based on commercially available off-the-shelf Bayfol foils recorded in reflection geometry, so that the grating period was in the range of only 200 nm. A weak diffraction signal was found. Thus, we conclude that the approach is promising iff the right material can be used.

We use materials that are sensitive to light and apply holographic techniques to record diffraction gratings for long-wavelength neutron optics in such materials.
Recently, we have learnt about the commercially available material Bayfol HX 200 manufactured by the company Covestro (see Ref. [1]). Bayfol is a very robust, versatile and easy-to-use material which we consider as complementary to our high-end nanoparticle-polymer composite materials. Bayfol can be used for quick proof-of-principle tests prior to dedicated development of more involved nanodiamond (for instance) gratings.
Next to transmission geometry (both recording beams enter the recording material via the same surface), holographic gratings can be recorded in so-called reflection geometry. The latter can result in very small grating periods in the range of 200 nm and below. Such gratings cannot readily be tested by diffraction of visible light, as the Bragg condition cannot be fulfilled for the period/wavelength combination. Instead, VCN diffraction can be employed.
The experiment was carried out directly after commissioning of the freshly refurbished PF2 VCN instrument, using the beamtime also for detecting and documenting possible errors in the instrumentation for later corrections and repairs. In Fig. 1, a very-cold neutron (VCN) rocking curve of a close-to-sinusoidal hologram recorded in a 16-microns-thick piece of Bayfol foil in our lab in Vienna is shown. One can see that the distance between the diffraction spots is relatively large due to the small grating period, as expected. The corresponding large diffraction angles angles are advantageous for using the gratings in neutron interferometry, since it is easier to move a phase shifting object into only one of the beams at large beam separation. Moreover, for some experiments a larger area enclosed by the beam paths within the interferometer improves the resolution [2], as it is the case for the COW experiment, for example.
In summary, the experiment could successfully show that the principle works. However, it also became clear that the material we were using is not suitable or has to be optimized before further pursuing the approach.

[1] F.-K. Bruder, T. Fäcke, and T. Rölle, Polymers **9**, 472 (2017).

[2] H. Rauch and S. A. Werner, *Neutron Interferometry: Lessons in Experimental Quantum Mechanics, Wave-Particle Duality, and Entanglement* (Oxford University Press, Oxford, UK, 2015).

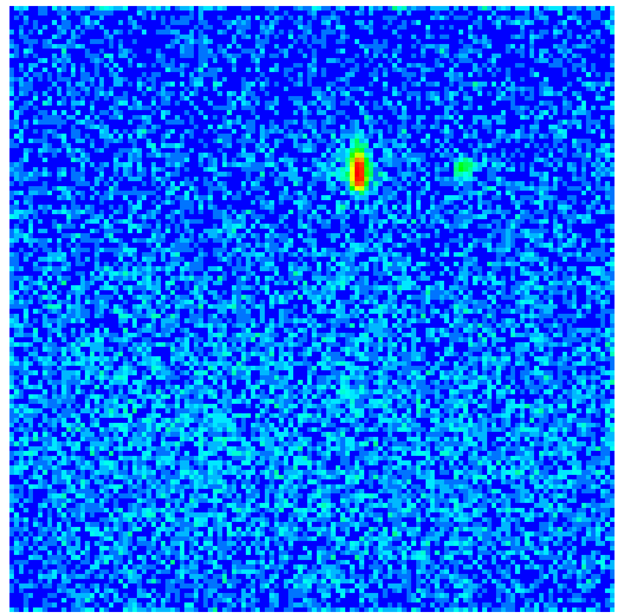

Figure 1: Detector image with the 0th and 1st order diffraction spots. From given sample-detector distance, wavelength (6.5 nm) and the pixel size, one can confirm the grating period of about 177 nm.

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