Experimental report

19/09/2024

Proposal: 3-14-445 **Council:** 10/2023

Title: Neutron diffraction from cyclic allylic sulfide based photopolymer film gratings

Research area: Methods and instrumentation

This proposal is a new proposal

Main proposer: Juergen KLEPP

Experimental team: Juergen KLEPP
Martin FALLY
Christian PRUNER

Local contacts: Hanno FILTER
Tobias JENKE

Samples: Cyclic allylic sulfide based photopolymer film

Instrument	Requested days	Allocated days	From	To
PF2 VCN	16	16	20/06/2024	06/07/2024

Abstract:

We use materials that are sensitive to light combined with holographic techniques to develop diffraction gratings for long-wavelength neutron optics, for which crystals are not an option due to their small lattice constants. The experiment proposed here aims at testing diffraction gratings based on cyclic allylic sulfide based photopolymer films used in high performance spectrographs applied for astronomical investigations. The advantage of the material are potentially strong diffraction of relatively thin gratings (ease of adjustment due to wide rocking curve) and large, extremely homogeneous area.

Neutron diffraction from cyclic allylic sulfide based photopolymer film gratings

J. Klepp [1], *M. Fally* [1], *H. Filter* [2], *T. Jenke* [2], *C. Pruner* [3]
[1] *Faculty of Physics, University of Vienna, A-1090 Vienna, Austria*
[2] *Institut Laue Langevin, Boîte Postale 156, F-38042 Grenoble Cedex 9, France*
[3] *Department of Materials Science and Physics, University of Salzburg, A-5020 Salzburg, Austria*

The diffraction efficiency of holographic gratings recorded in cyclic allylic sulfide based polymers was measured for very cold neutrons. While they are designed for light optical astronomical purposes they showed a very good neutron optical characteristic due to density changes initiated by a thermal post process. Such gratings are among the best candidates to serve as beam-splitters in a VCN interferometer.

Successfully setting up an interferometer for cold or very cold neutrons (VCN) based on artificial gratings in triple Laue-geometry requires two decisive steps: 1) the preparation of gratings with desired properties (beam-splitter, mirror), and 2) the accurate mutual alignment of these gratings with respect to their grating vectors and distance. Concepts are around since the 1980ies [1], realizations were accomplished for VCN [2–4] and cold neutrons [5, 6]. To further enhance the sensitivity, large-size interferometers are to be built. In this experiment we probe the applicability of gratings in novel polymeric materials, cyclic allylic sulfide (CAS) based, as neutron optical gratings.

Gratings designed originally for light optical spectroscopy in astronomical instruments are provided by A. Bianco, INAF—Osservatorio Astronomico di Brera, Merate, Italy. CAS gratings exhibit an additional considerable density modulation upon a thermal post process [7] which make them so interesting for neutron optics. The grating period of $\Lambda \approx 830\,\mathrm{nm}$ and the thickness $d_0 \approx 17 \ldots 20\,\mu\mathrm{m}$ are optimized for light optics, however, are expected to demonstrate their ability to diffract VCN efficiently, too.

In this experiment the angular dependence of the diffraction efficiency $\eta(\Theta)$, the rocking curve, was measured for several gratings. We made use of a beam with a rather narrow wavelength distribution (adopted from the preceding experiment *TEST-3253*; spectra by T. Neulinger) with an average wavelength of $\lambda = 4.5\,\mathrm{nm}$ and a width $\Delta\lambda/\lambda \approx 10\%$. The angular divergence was about $\Delta\theta < 2$ mrad. To increase the effective thickness d and thus to enhance η the grating was tilted by 60° around an axis parallel to the grating vector resulting in $d = 2d_0$. The rocking curve is shown in Fig. 1, highlighting that two-port beamsplitters ($\eta_{\max} \approx 42\%$) can be obtained with CAS at moderate thicknesses of less than $50\,\mu\mathrm{m}$. The latter is important to release the utmost strict requirements during aligning such gratings to form a VCN interferometer. A reduction of the grating period will separate the contributions of +1 und −1 orders while the low angular selectivity will retain.

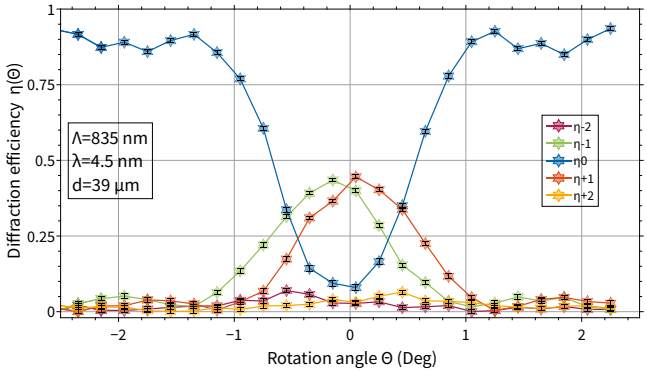

Figure 1: Rocking curve for a holographic grating in CAS. Maximum diffraction to the first orders yields reflectivities of 42%.

[1] A. Ioffe, G. M. Drabkin, and Y. Turkevich. *Diffraction-grating neutron interferometer*. JETP Lett. **33**, 374 (1981).

[2] M. Gruber, K. Eder, A. Zeilinger, R. Gähler, and W. Mampe. *A phase-grating interferometer for very cold neutrons*. Phys. Lett. A **140**, 363 (1989). doi:10.1016/0375-9601(89)90068-6.

[3] G. van der Zouw, M. Weber, J. Felber, R. Gähler, P. Geltenbort, and A. Zeilinger. *Aharonov-Bohm and gravity experiments with the very-cold-neutron interferometer*. Nucl. Instrum. Meth. A **440**, 568 (2000). doi:10.1016/s0168-9002(99)01038-4.

[4] G. van der Zouw. *Gravitational and Aharonov-Bohm phases in neutron interferometry*. Ph.D. thesis, Universität Wien, Austria (2000). https://ubdata.univie.ac.at/AC03029673

[5] U. Schellhorn, R. A. Rupp, S. Breer, and R. P. May. *The first neutron interferometer built of holographic gratings*. Physica B **234-236**, 1068 (1997). doi:10.1016/S0921-4526(97)00015-X.

[6] C. Pruner, M. Fally, R. A. Rupp, R. P. May, and J. Vollbrandt. *Interferometer for cold neutrons*. Nucl. Instrum. Meth. A **560**, 598 (2006). doi:10.1016/j.nima.2005.12.240.

[7] P. Galli, R. A. Evans, C. Bertarelli, and A. Bianco. *Cyclic allylic sulfide based photopolymer for holographic recording showing high refractive index modulation*. J. Polym. Sci. **59**, 1399 (2021). doi:10.1002/pol.20210192.

Proposal-number: 3-14-445
Instrument: PF2 VCN