Experimental report

20/09/2024

Proposal: 3-14-437 **Council:** 4/2023

Title: Tests of particular neutron diffraction grating configurations for a VCN interferometer

Research area: Methods and instrumentation

This proposal is a new proposal

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Samples: Holographic gratings (nanoparticle-polymer composite)
Bayfol photosensitive foils

Instrument	Requested days	Allocated days	From	To
PF2 VCN	18	23	07/09/2023	27/09/2023
			24/10/2023	26/10/2023
			26/10/2023	07/11/2023

Abstract:

We use light sensitive materials combined with holographic techniques to develop diffraction gratings for long-wavelength neutron optics and, in particular, interferometry. The experiment proposed here aims at testing two particular grating configurations feasible with holographically structured nanodiamond-polymer composites and commercially available light-sensitive photopolymer films, for the design of a new very-cold neutron (VCN) interferometer at PF2, which is part of the project NeqstPi (granted by the Austrian Research Promotion Agency FFG).

Tests of particular neutron diffraction grating configurations for a VCN interferometer

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The experiment aimed at testing holographically structured nanodiamond-polymer composites produced at University of Vienna, Austria, for the design of a new very-cold neutron (VCN) interferometer at PF2 (part of the project NextPi, Austrian Research Promotion Agency FFG, Quantum-Austria NextPi: grant number FO999896034, European Union: NextGenerationEU).

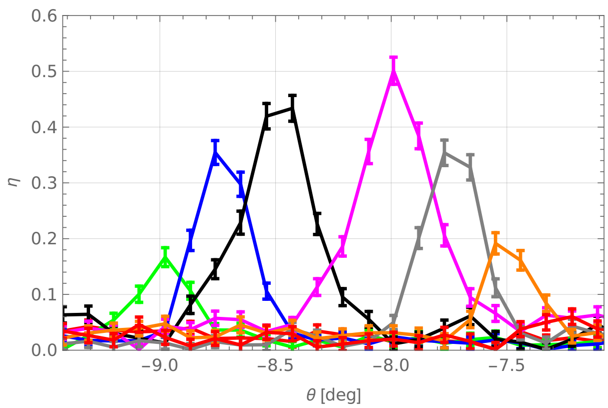

Figure 1: Diffraction efficiency η for 6 diffraction orders vs angle of incidence θ (arbitrary position) of a nanodiamond-polymer composite grating (sample ND 97, grating period $\approx$ 517 nm, grating thickness $\approx$ 53 μm, grating diameter $\approx$ 1 cm) measured at PF2 VCN at about 4.5 nm wavelength.

We use materials that are sensitive to light and apply holographic techniques to record diffraction gratings for light as well as for long-wavelength neutron optics in such materials [1, 2]. Installation of a new VCN interferometer [3] at PF2 VCN as part of new research infrastructure at the ILL has been granted via the project NextPi (partners: Technical University and University of Vienna, National Metrology Institute of Italy INRiM, and ILL) for neutron interferometry at all energy scales (Austrian Research Promotion Agency FFG, Quantum-Austria NextPi: grant number FO999896034, European Union: NextGenerationEU). Within the frame of the project, we have carried out considerable effort for knowledge transfer from Y. Tomita's group of University of Electro-Communication, Tokyo, Japan to University of Vienna, Austria. In the experiment reported here, holographic nanodiamond-polymer gratings [4, 5] produced in the lab in Vienna were successfully tested at PF2 VCN. In particular, very high diffraction efficiency was found in a preliminary analysis, without the need for increasing the effective thickness by tilting the grating (see Fig. 1). Increased effective thickness can lead to higher diffraction efficiency, but also makes the rocking curves narrower. For neutron interferometry, where adjustment requirements are very strict, wide rocking curves are preferable for ease of adjustment. Note also that, in Fig. 1, even if we see more than one diffraction order in the rocking curve, at two particular angular positions (the peak positions of the $\pm$1st orders, pink and black lines and data points in Fig. 1, respectively) all other orders but two (either $-$1st and 0th or $+$1st and 0th orders) are strongly suppressed, which helps economize on scarce incident VCN flux, which otherwise would be wasted to unwanted diffraction orders.
Our next step is to slightly increase the grating area of the gratings to about 15 cm^2 and proceed to the installation of a VCN interferometer at PF2 in 2025 in a forthcoming experiment.

[1] J. Klepp, C. Pruner, Y. Tomita, P. Geltenbort, I. Drevenšek-Olenik, S. Gyergyek, J. Kohlbrecher, and M. Fally, Materials **5**, 2788 (2012).

[2] 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).

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

[4] Y. Tomita, A. Kageyama, Y. Iso, K. Umemoto, A. Kume, M. Liu, C. Pruner, T. Jenke, S. Roccia, P. Geltenbort, M. Fally, and J. Klepp, Phys. Rev. Applied **14**, 044056 (2020).

[5] E. Hadden, M. Fally, Y. Iso, T. Jenke, J. Klepp, A. Kume, K. Umemoto, and Y. Tomita, Applied Physics Letters **124**, 071901 (2024).

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Instrument: PF2 VCN