Generation and Control of Multimode Structured Neutron Beams via Phase-Grating Arrays

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We present recent advances in the generation and manipulation of structured neutron beams using nanofabricated silicon phase-grating arrays. These holographic elements enable precise wavefront engineering, producing neutrons carrying well-defined orbital angular momentum (OAM) states through fork-dislocation gratings, as well as tailored Airy beams that exhibit unique propagation and auto-focusing properties.

By arranging multiple phase gratings at controlled separations along the beam path, we demonstrate multimode structured neutron beams that simultaneously populate several orthogonal OAM modes and hybrid OAM–Airy combinations in a single measurement. This multiplexed approach efficiently harnesses the incident flux, overcomes single-grating efficiency limitations, and provides a flexible, scalable platform for complex wavefront control without requiring stringent alignment. Our most recent work further extends these capabilities by realizing multimode structured beams that open new possibilities for neutron wavefunction engineering, enabling extended spatial and angular-momentum measurements in scattering experiments and probing of topological materials.

The same phase-grating technology underpins broadband phase-grating moiré interferometers (PG-MIs), supporting high-flux applications in precision metrology (*e.g.* measurements of the Newtonian gravitational constant) and materials characterization, including enhanced interferometric small-angle neutron scattering for phase-sensitive studies of topological and complex samples. This work significantly expands the structured neutron toolbox, bridging optical wavefront shaping techniques with neutron-based quantum optics, sensing, and fundamental physics investigations.