GENERATION AND APPLICATION OF STRUCTURED NEUTRONS

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Neutrons are invaluable tools for non-destructive material analysis and experiments in fundamental physics. As charge-less, magnetically sensitive particles with nanometer wavelengths, they interact directly with atomic nuclei, providing high material penetrability and isotope sensitivity [1, 2, 3]. To refine the neutron as a high-precision quantum probe, it is possible to endow the neutron with additional quantum degrees of freedom by structuring the neutron wavefunction. While it is straightforward to shape light and electrons [4, 5], neutrons are challenging due to their refractive index being extremely close to unity, making conventional neutron lenses impractical. However, recent advances in nano-fabrication have opened new opportunities for a holographic approach to neutron shaping. By fabricating microscopic silicon diffraction gratings, we can imprint specific phase profiles onto the wavefunctions to map the spatial profiles in the far field. In this presentation, we demonstrate how we utilize the neutron's degrees of freedom using these holographic techniques. We demonstrate neutron Orbital Angular Momentum (OAM), which has potential applications in quantum information processing, and magnetic material characterization [6, 7]. Furthermore, we explore the generation of neutron Airy beams, which have properties of self-acceleration, non-diffraction, and self-healing. These beams have applications ranging from neutron imaging to defining quantum gravitational energy states in the search for dark energy and dark matter [8]. Finally, we present the development of modified Fresnel Zone Plates (FZPs) as a pragmatic alternative to conventional lenses. The modified FZPs could enhance neutron shaping techniques by increasing efficiency and resolution, thus advancing neutron diffractive optics.

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