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Precision Measurements in neutron optics

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Neutrons have a long history at the forefront of precision metrology, from the first experiment demonstrating the effect of gravity on a quantum particle (the C.O.W. experiment), to demonstrations of the spinor' s 4\pi -periodicity, on to recent searches for chameleon dark energy fields. Compared to photons, electrons, and other wave-particle probes, neutrons offer a unique penetrating ability. Following in the footsteps of the C.O.W. experiment, we aim to generate structured neutron momentum profiles and apply these states to tackle difficult problems. One such problem is to measure the gravitational constant, G, currently the least precisely measured fundamental constant of nature. The significant discrepancy between G experimental results underscores the need for new experiments whose systematic uncertainties can be decoupled from existing techniques. Previously, perfect-crystal neutron interferometers were used to measure local gravitational acceleration, g, unfortunately, the low neutron flux (a few neutrons per second) of these devices makes them impractical for precision measurements of G. The recently demonstrated Phase-Grating Moiré Interferometer (PGMI) offers an increase in neutron flux of several orders of magnitude while preserving the large interferometer area, and thus the sensitivity, of a perfect-crystal interferometer. This device possesses a set of systematic uncertainties that are independent from existing techniques which measure G. In this talk, I will demonstrate how one can structure a neutron wave, show examples of the interference seen in a 3-grating PGMI, and discuss the feasibility of measuring G using a similar apparatus with a test mass on the order of 1 tonne. Further, I will address how we can optimize this setup to maximize the phase shift from a 1-tonne mass and consider some of the systematic effects.

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