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Precision neutron scattering lengths using neutron interferometry[1]

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Historically, neutron interferometry (NI) has been the preferred method for measuring neutron scattering lengths due to its incredible phase sensitivity and negligible systematic effects. Although scattering lengths are widely used in neutron science and nuclear engineering, the scattering lengths of many isotopes are known only to a few percent relative uncertainty. Since 2001, the NI facility at NIST has been engaged in sub 0.1 % measurements of light nuclei that include hydrogen, deuterium, helium-3 and helium-4. A significant motivation for more precise measurements of neutron scattering lengths is to provide high-quality "set-point" data for effective range expansions that can be used to assist construction of improved phenomenological nuclear models. Further, they help constrain low-energy constants used in high order nuclear chiral effective field theory calculations. In either case it is hoped that such new models will bring few nucleon theory and experiment into better agreement. A NI spatially separates the wavefunction of a single neutron, via Bragg diffraction, into two spatially separated coherent paths. The relative phase shift between the two paths causes a modulation in the neutron intensity measured after the interferometer. For gaseous samples, an aluminum cell filled with a target gas was placed in one path of the interferometer. The phase shift due to the neutron-gas interaction is proportional to the gas density and scattering length. The gas density was determined from the known temperature and pressure of the sample gas. Our most recent result [Haun et al., PRL **124** (2020)] for n-^{4}He represented a factor of 10 improvement over previous efforts and a 2 % shift in the world average. Further, the measurement of helium-4 provided insight into systematics not previously considered in weakly scattering gas targets.

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