New applications for nano-gratings

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Abstract

Nano-gratings offer several advantages for matter-wave optics [1]. For example, in Arizona we diffract electrons, molecules, and atoms. Because these particles pass within 25 nm of a nano-grating bar, we can study particle-surface interactions.

For electrons we used nano-gratings to build a Talbot interferometer [2] and a Lau interferometer [3]. We made these by adapting a scanning electron microscope and inserting two nano-gratings. Fringes from these interferometers were used to study electric fields around samples, wave-front radii of curvature for electron beams, transverse coherence lengths for electron beams, and electron-surface image-charge interactions. Surprisingly, a nominally 2 nm thick Au/Pd coating - not even enough to make a macroscopically measurable conductivity - mitigates charging enough so that silicon nitride nano-structures can serve as gratings for coherent electron optics.

For atoms, we use nano-gratings as beam-splitters for a Mach-Zehnder interferometer. We use beams of Li, Na, K, Rb, Sr, He*, or Ar* in the same apparatus. Recently we measured the ground state DC polarizability for Na, K, and Rb atoms, each with an uncertainty of 1.0%, and an uncertainty in the ratios (e.g. $\alpha_{\mathrm{Rb}}/\alpha_{\mathrm{Na}}$) of 0.3% [4].

Atom diffraction was used to measure atom-surface van der Waals C_3 coefficients for Li, Na, K, and Rb with 3% uncertainty in the ratios. These data support predictions that core electrons contribute 17% to C_3 for Rb atoms and a silicon-nitride surface. This compares to only 4% for Na atoms.

In collaboration with the Toulouse group we measured atomic de Broglie wave phase shifts that result from atoms passing through a nano-grating [5]. These phase shifts were measured precisely enough to test the power law for the atom-surface potential, to set new limits on non-Newtonian gravitational interactions between the atoms and the nano-grating, and to observe the predicted $v^{-0.49}$ velocity dependence.

Keywords: Nanostructures, electron holography, atom interferometry, polarizability, van der Waals

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