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# Corrected Off-axis Diffraction Holograms for Electrons

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The transverse wavefunction of a free electron can be structured with the use of off-axis diffraction holograms [1, 2]. Uses for structured electron wavefronts require exceedingly precise control of over this degree of freedom [3, 4]. Algorithms for the generation off-axis hologram patterns designed to produce an exact desired phase and amplitude in a specific diffraction order exists for phase only type holograms [5], which is useful for spatial light modulators in light optics. Implementations of these algorithms have been shown for material holograms for electrons [6], but the non-zero amplitude loss due to high angle scattering through the material give non-exact outputs. Here we present an exact solution to this problem allowing for production of precisely shaped electron wavefronts from amplitude and phase shifting material off-axis holograms for electrons. This is done by casting the transfer function in the thin hologram approximation as the sum of diffraction orders and inverting the thickness and phase profile of the hologram to be written as a function of the desired output.

We use gas-assisted focused ion beam milling to create these corrected holograms; it has the ability to very precisely control the spatial mill depth [7]. An iterative transport of intensity phase reconstruction is applied to focal series images to estimate the spatial phase of corrected probes in the back focal of the hologram. These reconstructed phases are compared to expected result for two different superpositions of Laguerre Gaussian modes. The first of two mode superpositions is a balanced superposition of with azimuthal and radial indices $l=-8$ and $p=2$, and $l=8$ and $p=2$. The second mode superposition has the indices $l=5$ and $p=3$, and $l=10$ and $p=1$.

Although we are presenting this for as a method for creating corrected holograms, this method is completely general for any complex scalar field. It can be used to create corrected off-axis material holograms for x-rays, neutrons, atom beams provided the phase shift and amplitude loss through the material is linear with the thickness of the material.

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