Advanced Strategies for Sub-Picometer Line Placement Accuracy in Variable Line Spacing Gratings Using Electron Beam Lithography

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Variable Line Spacing (VLS) gratings are indispensable for quantum technologies due to their ability to deliver high spectral resolution and correct optical aberrations. They play a pivotal role in instruments like monochromators and spectrometers, enabling precise filtering and analysis of light for applications such as resonant inelastic X-ray scattering (RIXS) and single-photon sources. These capabilities are critical for exploring quantum states and interactions with exceptional precision. Achieving sub-picometer line placement accuracy in VLS gratings is essential to meet the stringent demands of next-generation gratings.

This work explores strategies to minimize groove displacement errors and optimize pattern fidelity in VLS gratings, leveraging the latest enhancements in electron beam lithography (EBL) systems. By integrating multi-pass exposures, mainfield field scaling, and dose modulation strategies using the Raith EBPG Plus system, we demonstrate the ability to achieve sub-picometer groove density placement precision. Atomic force microscopy (AFM) and laser measurements validate the groove density and improved control up to the quadratic term in VLS grating profiles.

Our findings reveal that precise dose gradient control and our workflow significantly enhance pattern placement and speed up writing, all while reducing environmental instabilities during long writing processes. These advancements enable the production of high-quality VLS gratings tailored for quantum device applications and synchrotron beamline instrumentation.