Single-order
Lamellar Multilayer Gratings

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A major challenge in the soft x-ray (SXR) and eXtreme UltraViolet (XUV) spectral ranges is the ability to manipulate radiation using appropriate optical elements. Multilayer mirrors for these spectral ranges do exist, but they act as plane, reflective elements only. By patterning conventional multilayer mirrors with nanoscale structures, a next group of optical elements with a variety of new optical properties can be obtained. An important example are Lamellar Multilayer Gratings (LMG), which can be used to improve the spectral resolution of x-ray fluorescence spectroscopy.

Although the LMG concept has long been known, the implementation of LMGs has been hampered by two critical challenges. The first being serious limitations in existing simulation methods, which provided limited insights in LMG operating principles and could only be used for idealized structures. The second challenge was the lack of a reproducible fabrication method with accurate dimension control for LMGs with grating periods well below 1 µm.

The author has addressed both topics in his thesis. He derived a Coupled Waves Analysis (CWA) to simulate reflection and diffraction from LMGs. From this CWA, an optimal operating regime was identified, referred to as the single-order regime. He also developed a reproducible fabrication process, based on UV-NanoImprint Lithography and Bosch Deep Reactive Ion Etching, for single-order LMGs with grating periods down to record values of 200 nm. These LMGs achieved spectral resolutions of up to 330, to be compared with values of only 70 for conventional multilayer mirrors.

This study can be considered as a pilot case for other optical elements that combine diffractive optics with Bragg reflection from multilayer mirrors. This opens up the route to many new short-wavelength optical applications, a topic that will be addressed in a new research group at the MESA$^+$ Institute for Nanotechnology, headed by thesis supervisor Prof. Fred Bijkerk.

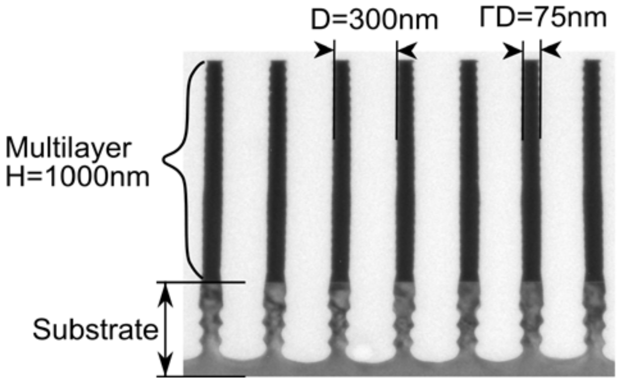

Figure 1 Transmission Electron Microscope image of a Lamellar Multilayer Grating. The grating was etched into a 400 bi-layer W/Si multilayer mirror with a total stack height *H* of 1 µm and tungsten layer thicknesses of only 3 atoms. The grating had a period *D* of 300 nm and a lamel width *ΓD* of 75 nm.