Opening the road to custom astronomical UV gratings

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Historically, ultraviolet (UV) gratings used in astronomical spectrographs have been made using two different techniques.

Mechanically-ruled gratings have been produced for more than a hundred years. A diamond tool is used to create parallel grooves onto a fine metallic coating layer that has been previously deposited on a polished substrate. The edge-on profile of these grooves is a sawtooth tilted at a specific angle called the "blaze" angle. The blaze angle is the deciding factor that will allow for maximum efficiency at a specific wavelength called the "blaze" wavelength.

Holographic gratings are produced using interference lithography. A layer of photoresist deposited on a substrate is exposed to fringes usually formed by exposure to two coherent laser beams. After development, the resulting pattern is sinusoidal by nature. Blazing one side of the sinusoidal profile of holographic gratings is possible through ion etching, but is only commonly used for a limited subset of grating parameters.

Both types of gratings have different advantages:

- Ruled gratings have a sharp, blazed profile that ensures good efficiency. However, they suffer from groove spacing inconsistencies that lead to stray light and ghosting.

- Holographic gratings do not suffer from groove spacing errors which minimizes stray light. However, their sinusoidal profile (if not ion etched) leads to efficiency losses.

At Penn State University, we are studying new processes that allow to fabricate blazed, high efficiency and high spectral resolution UV gratings for astronomical purposes. These processes are derived from the ones we used in creating X-ray gratings and consist of:

1) writing an electron-beam pattern consisting of parallel grooves on a layer of positive resist that has been deposited on a Si substrate.

2) dry etching this profile into a hard mask made of silicon nitride.

3) wet etching with KOH that will create the sawtooth profile at a specific blaze angle thanks to the properties of the different crystallographic planes of silicon.

Gratings fabricated using these techniques show an excellent behavior all around, combining the best qualities from both ruled and holographic gratings. Indeed, they display a sharp sawtooth profile, they do not suffer from periodicity errors, and grating facets show low roughness. Recent testing done at UC Boulder shows efficiencies that are close to the maximum, theoretical limit. Combined with the possibility to create custom blaze angles through the use of custom cut Si wafers, this opens the way to new applications in the field of astronomical UV spectroscopy.

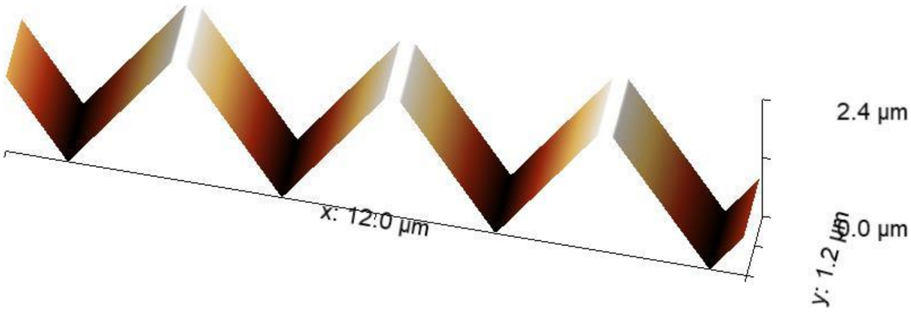

Figure 1: Atomic Force Microscopy imaging of a UV grating fabricated at Penn State University. The groove spacing is 3.4 um while the facets are blazed at an angle of ~55 deg.

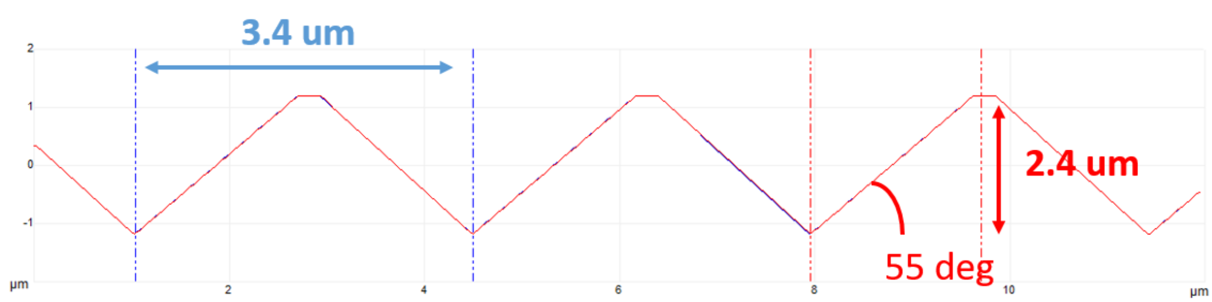

Figure 2: Profile of the grating imaged in Fig. 1