



Blazed, Variable-Line-Space Reflection Gratings for 13.5-nm Optics Fabricated at Inprentus

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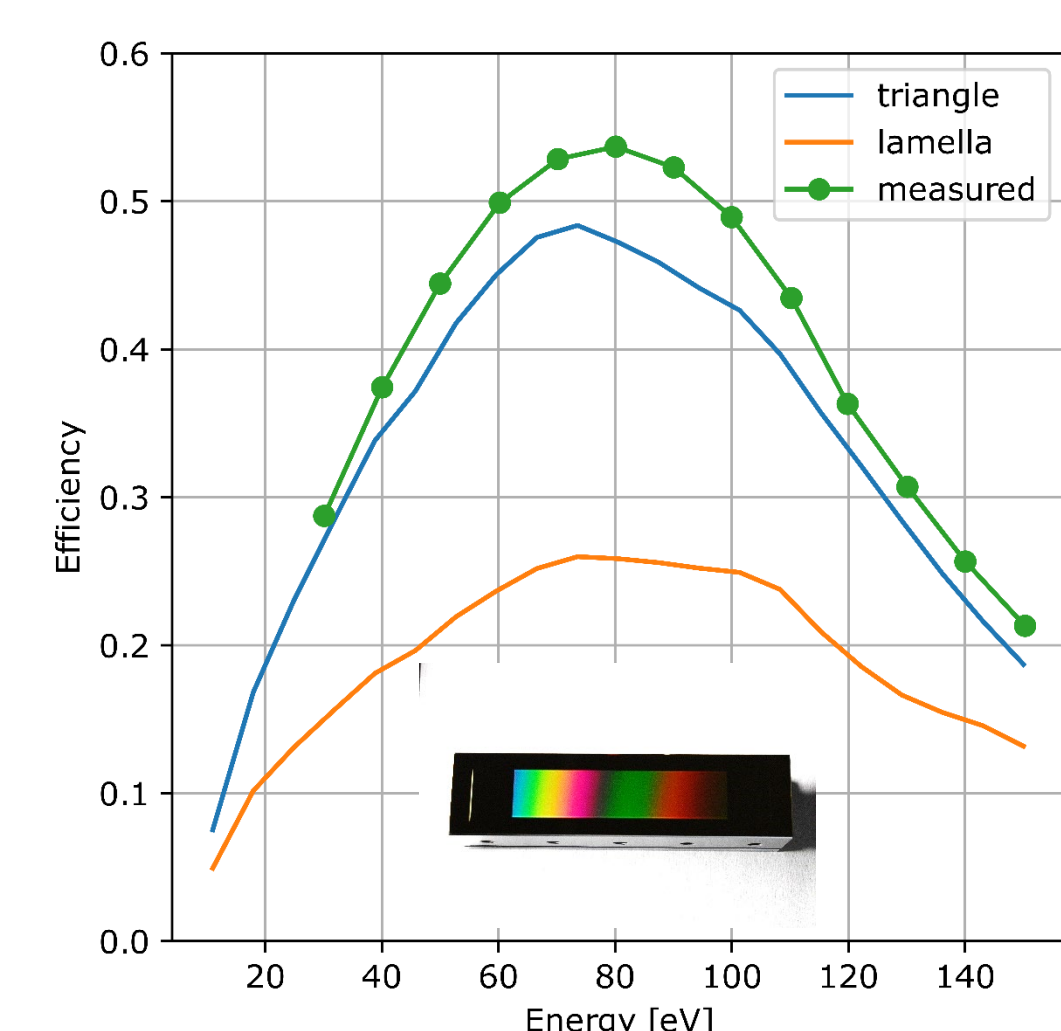
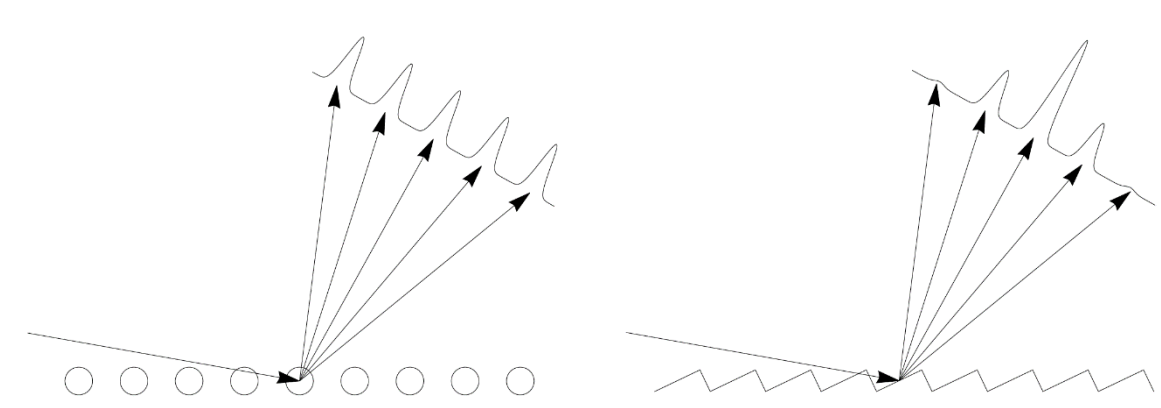
Introduction



Blazed reflection gratings manufactured by Inprentus for Soft X-ray, EUV, UV-VIS-IR and LRIR applications

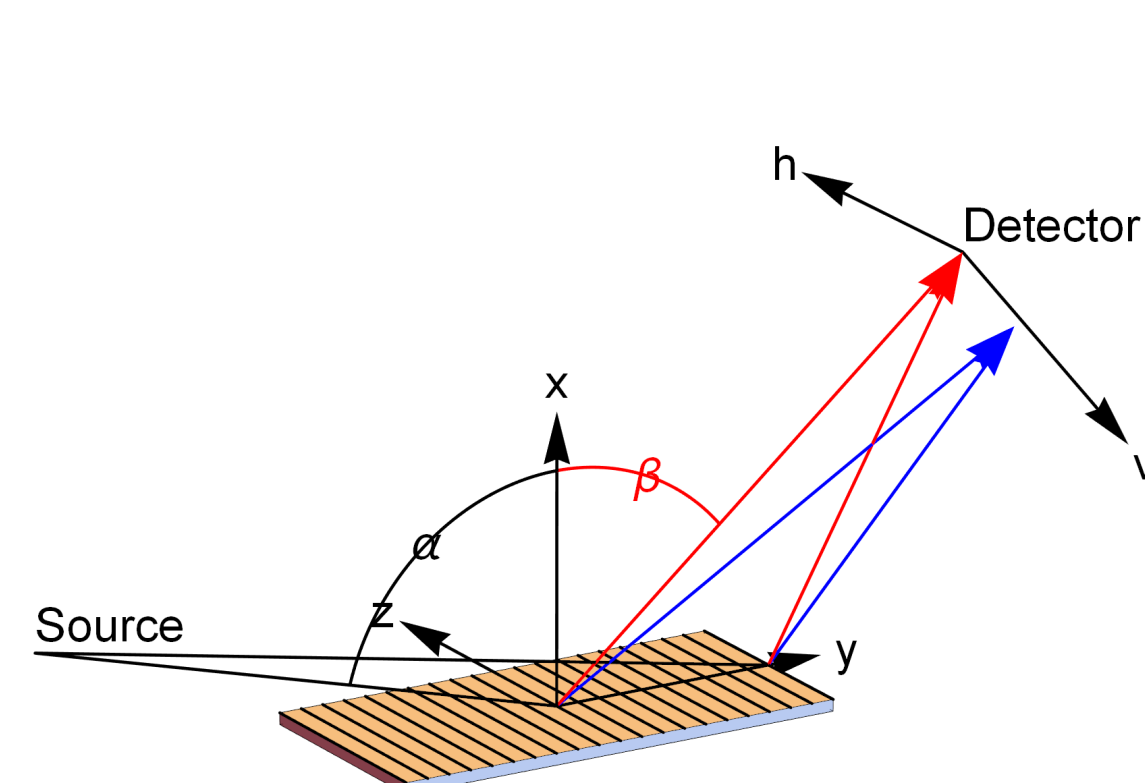
- Diffraction gratings have been employed as photon-wavelength discriminators for 150 years
- Inprentus manufactures ultra-high vacuum (UHV) compatible, reflective master gratings that are mechanically robust
- Inprentus blazing technology provides high efficiency solutions
- Inprentus mechanical ruling technology allows combining dispersion and imaging into a single optic and allows writing large, aberration-free gratings suitable for high NA applications

Blazing



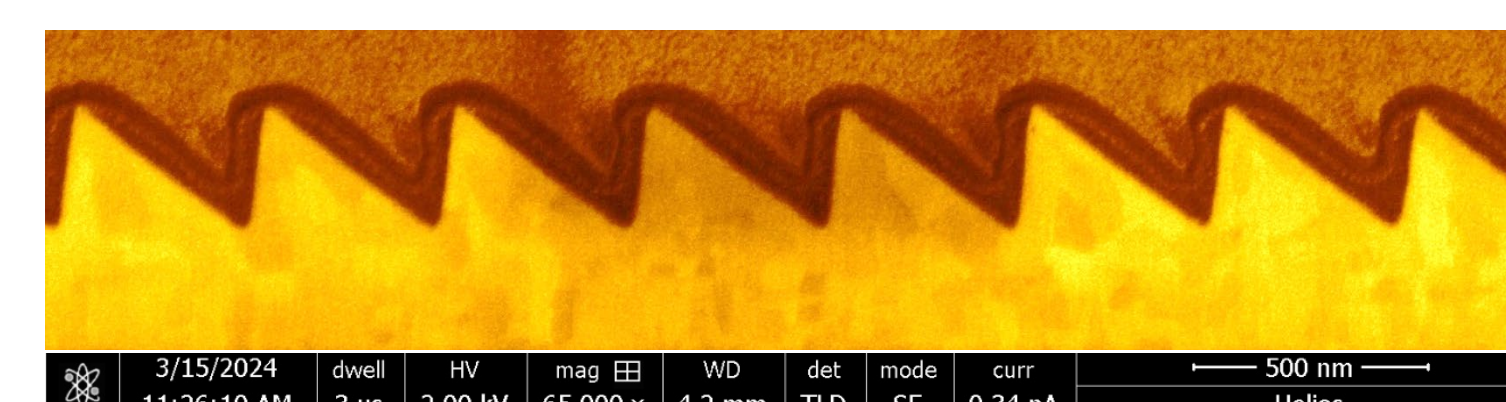
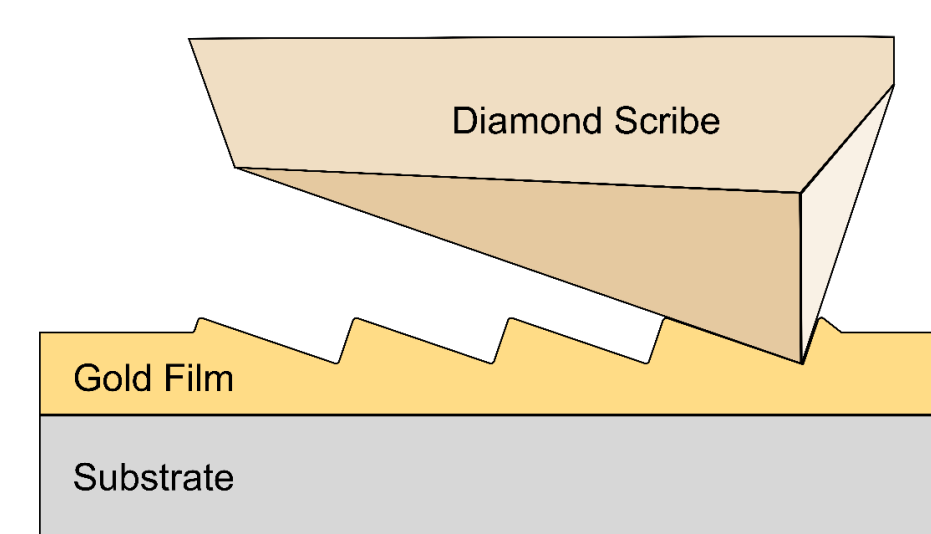
- Blazed surface profiles are advantageous for throughput as they concentrate reflected radiation into a single diffraction mode (Top figure)
- Inprentus blazed grating doubles the efficiency at the Advanced Light Source beamline 4.0.3 (MERLIN) at LBNL, Berkeley (green symbols vs. orange line, bottom figure)

Variable Line Spacing (VLS)



- An arbitrary phase profile can be added to diffracted waves by adjusting groove positions
- Variable line spacing (VLS) is used to focus dispersed light at a detector plane without a downstream mirror
- This allows for simpler optical systems with higher throughput

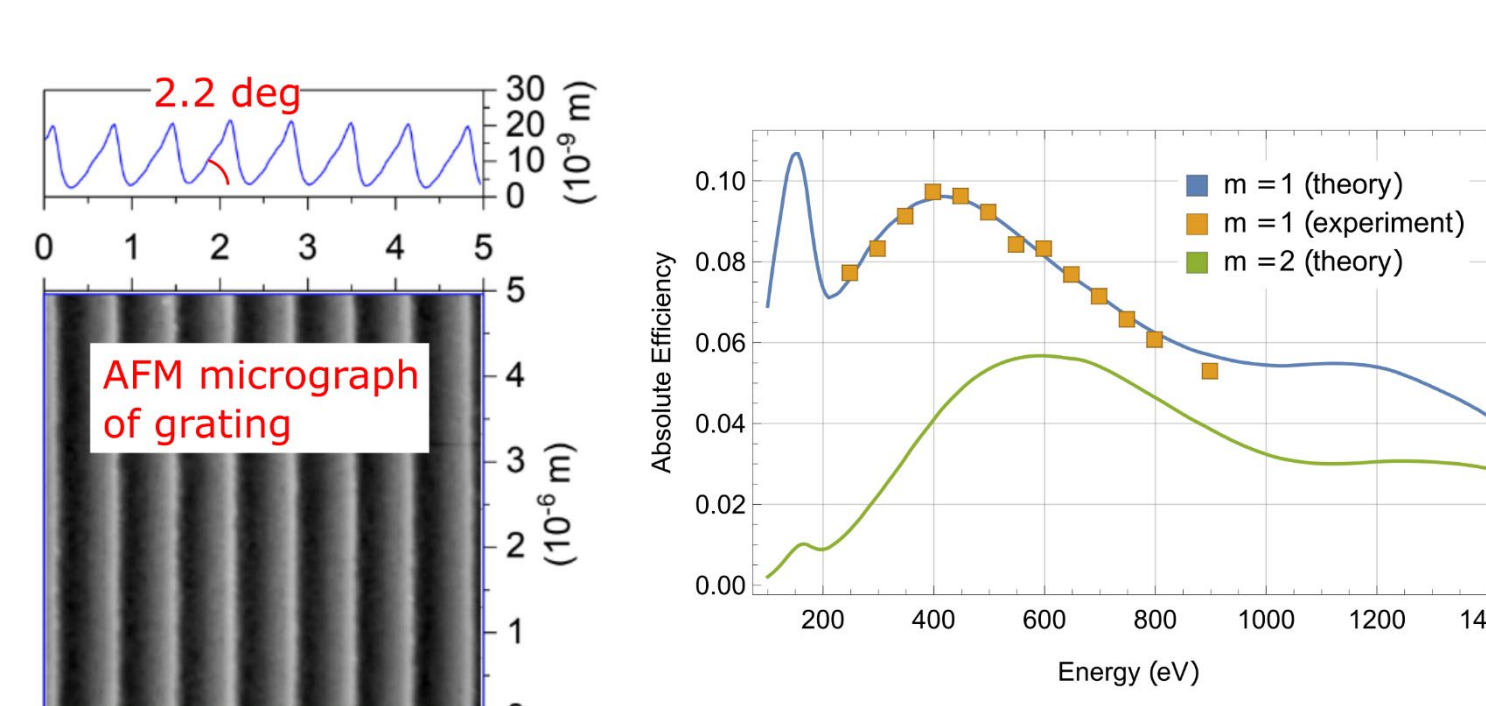
Grating Fabrication



Electron micrograph of Inprentus grating ruled at 400 nm pitch

- Inprentus has a 12000 sq. ft manufacturing facility and cleanroom in Champaign, Illinois
- Versatile substrate materials and geometries are metallized in-house using a custom deposition system
- Blazed grooves are serially inscribed into a metal (typically Au) film using a diamond tool
- Pitch and blaze can be modulated across the surface
- Wide range of manufactured pitch available: 160 nm – 20 μm ; line densities from 50 lpmm to 6000 lpmm
- Blaze angles down to 0.1 deg
- Specular-reflection-preserving profiles for, e.g., beam diagnostics are available

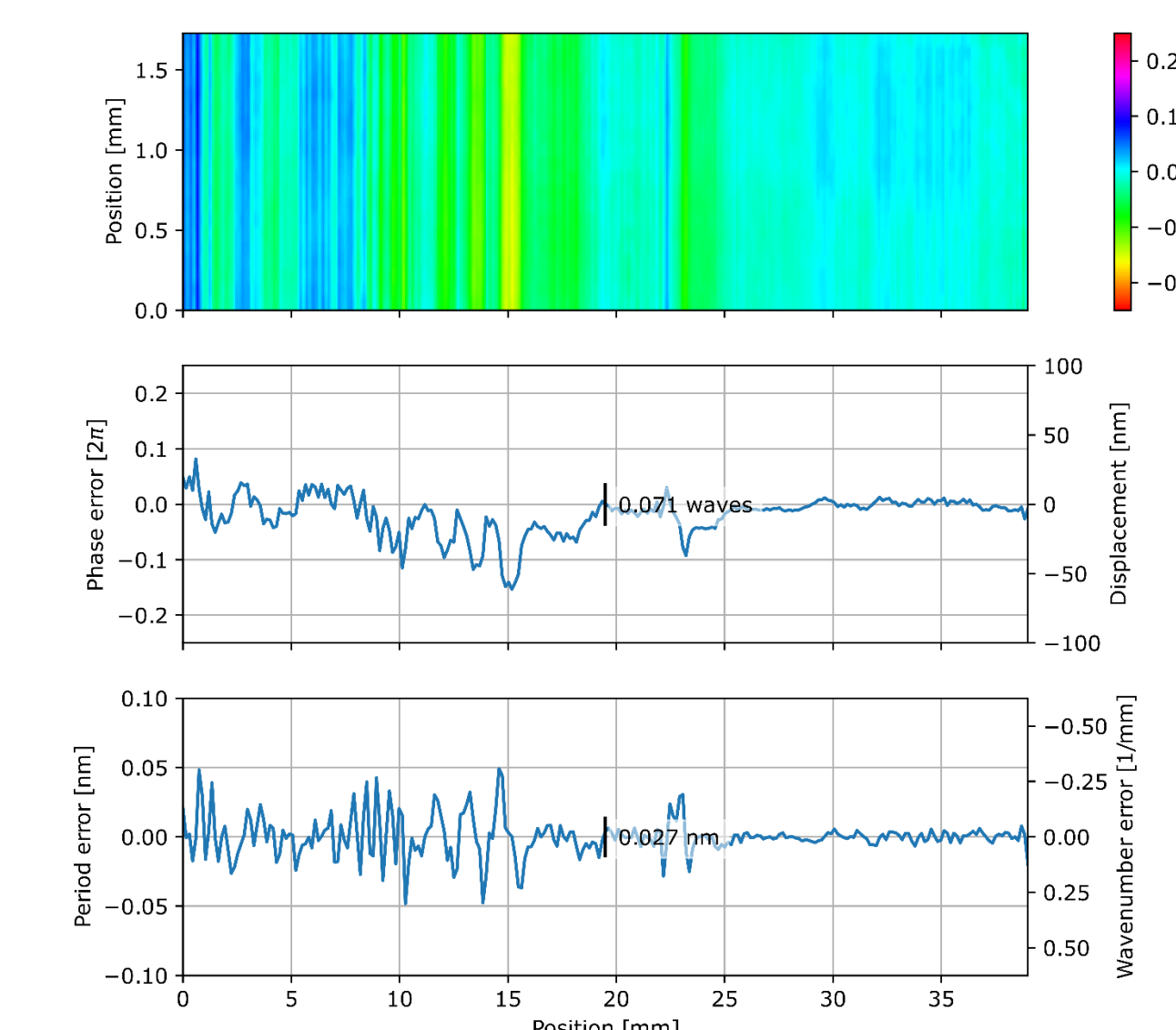
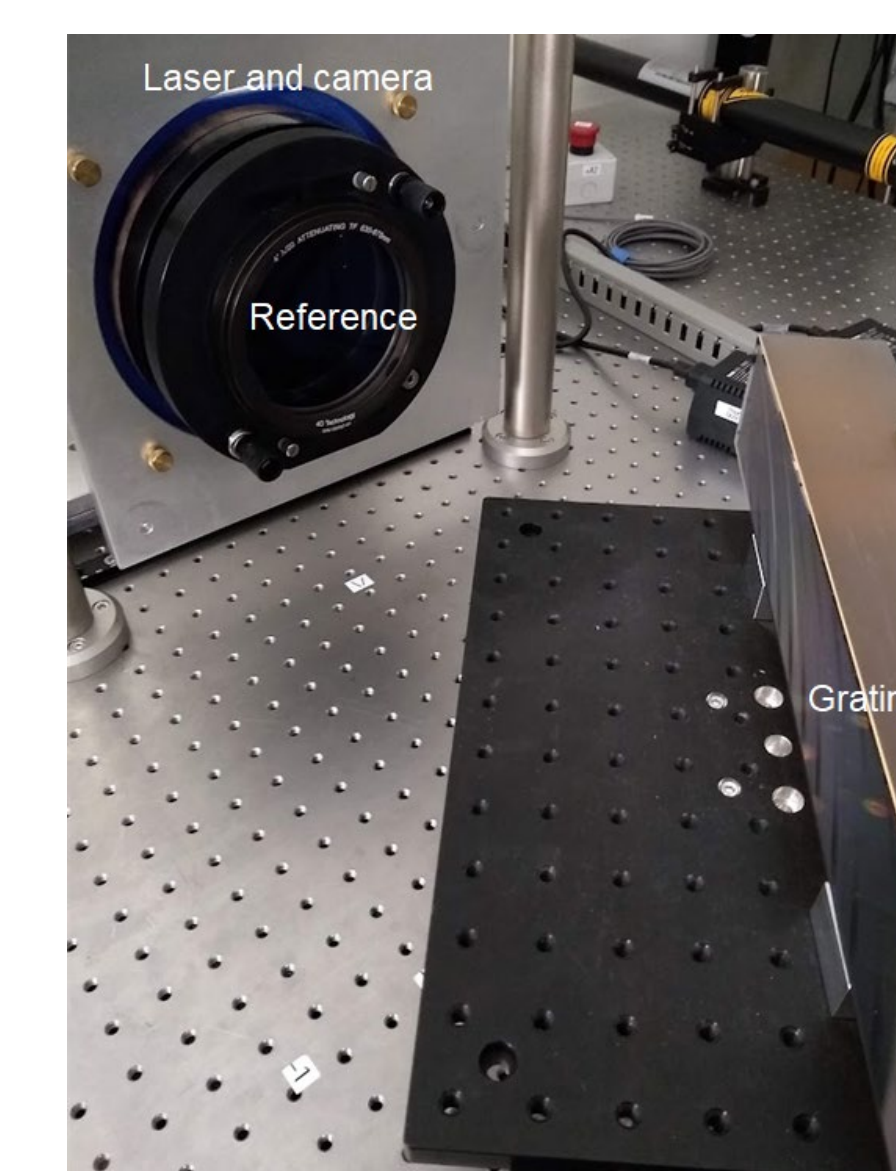
Custom Optical-Design Services



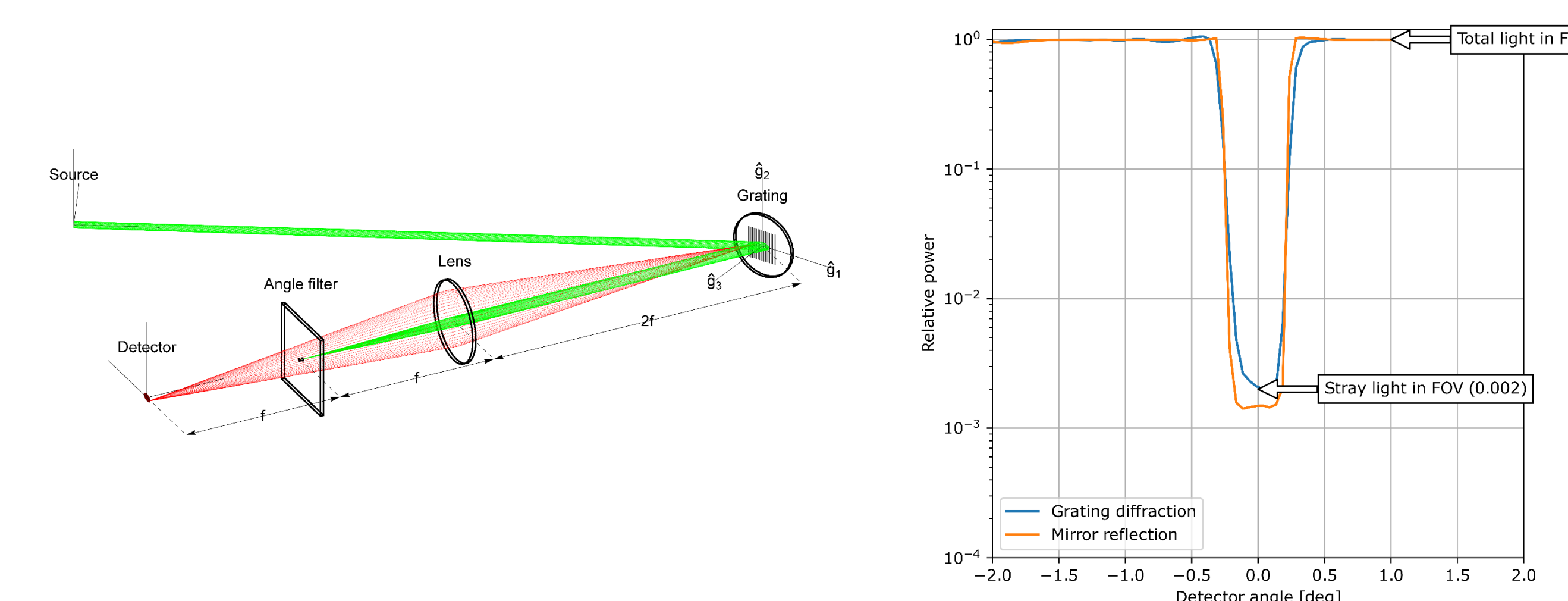
Inprentus simulations of as-manufactured grating efficiency agree with ALS measurements

- Dynamical simulations for groove profile optimization
- Ray traces for VLS optimization
- End-to-end monochromator and spectrometer optical design

Characterization



- High spectral resolution achieved with control over long-range, coherent errors in groove position
- Measured diffracted wavefronts using a Fizeau interferometer (top figure, left) are flatter than wave/10 at in-plane $q/(2\pi) = 2500 \text{ 1/mm}$ (top figure, right)
- Absolute groove-positioning error is less than 40 nm (Top figure, right)
- Diffraction-limited grating resolution is achieved



- Minimal diffuse scattering caused by short-range, random errors
- (Bottom figure) total power measured in integrated diffuse scatter is 0.2% of diffracted power at in-plane $q/(2\pi) = 2500/\text{mm}$

Conclusions

- Inprentus blazed reflection gratings offer spectral filtering and analysis at EUV wavelengths without sacrificing throughput
- VLS gratings reduce the number of required reflections
- Inprentus gratings achieve diffraction-limited dispersion with low stray-light background