Fully-calibrated Sn LPP EUV Source Spectrum from 5.5 – 265 nm

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Contents

1. **What is the problem we are trying to solve?**
    - How to determine continuous, fully calibrated spectrum of Sn microdroplet laser-produced plasma from EUV to DUV range

2. **What is our solution?**
    - Use a 1000 line/mm transmission grating spectrometer (TGS) with a suite of filters with different passbands to remove shorter wavelength emission, removing their higher order contributions which contaminates and dominates longer wavelengths

3. **Conclusion**
    - Fully calibrated spectrum in the 5.5 - 265.5nm range from a microdroplet-tin 1µm Nd:YAG laser-produced plasma
    - This calibration technique can be used to better understand EUV light sources of all types, highly useful for EUV lithography

Raw Emission Spectrum

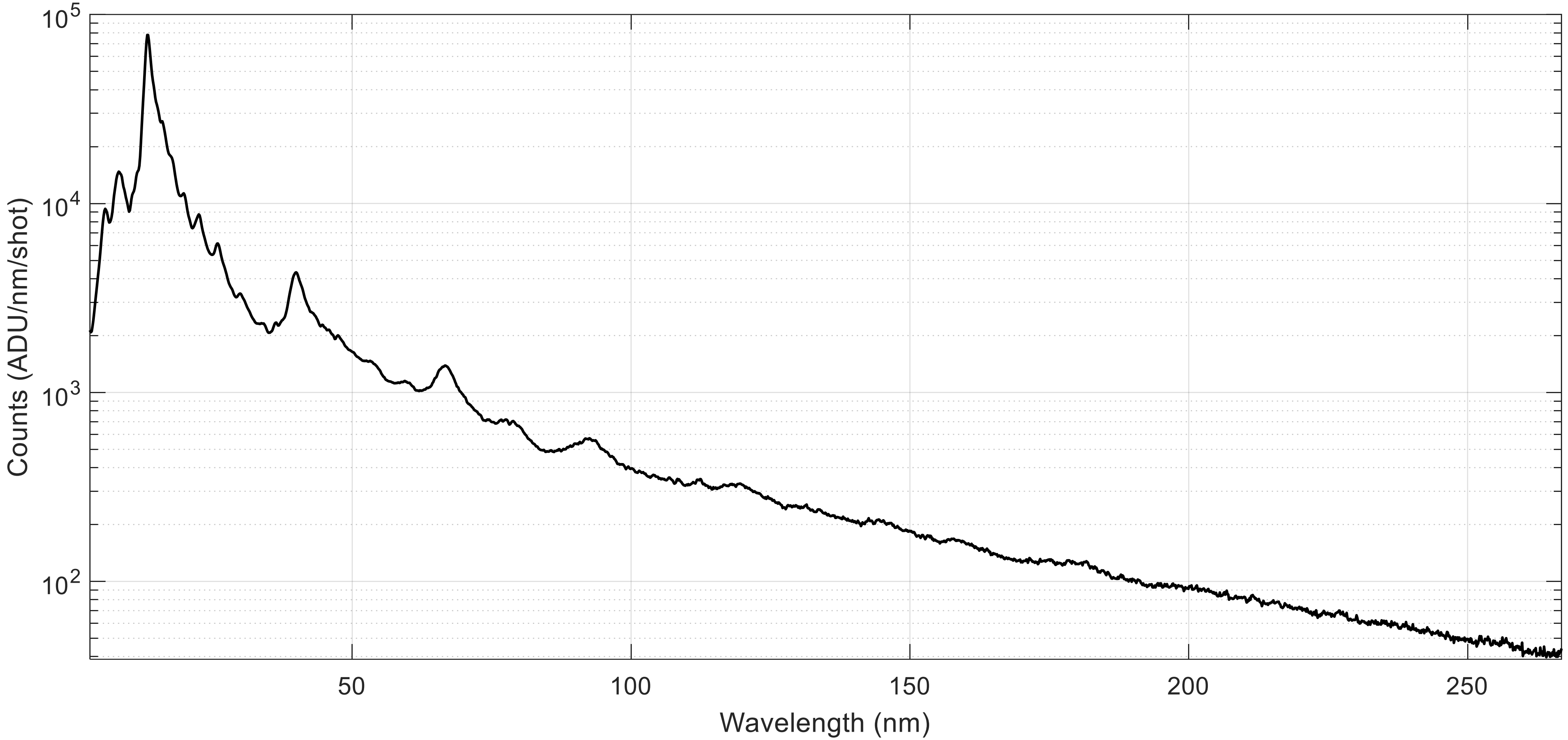

Figure 1 – Unfiltered, raw emission spectrum for 1 µm Nd:YAG driven Sn LPP

Raw Emission Spectrum

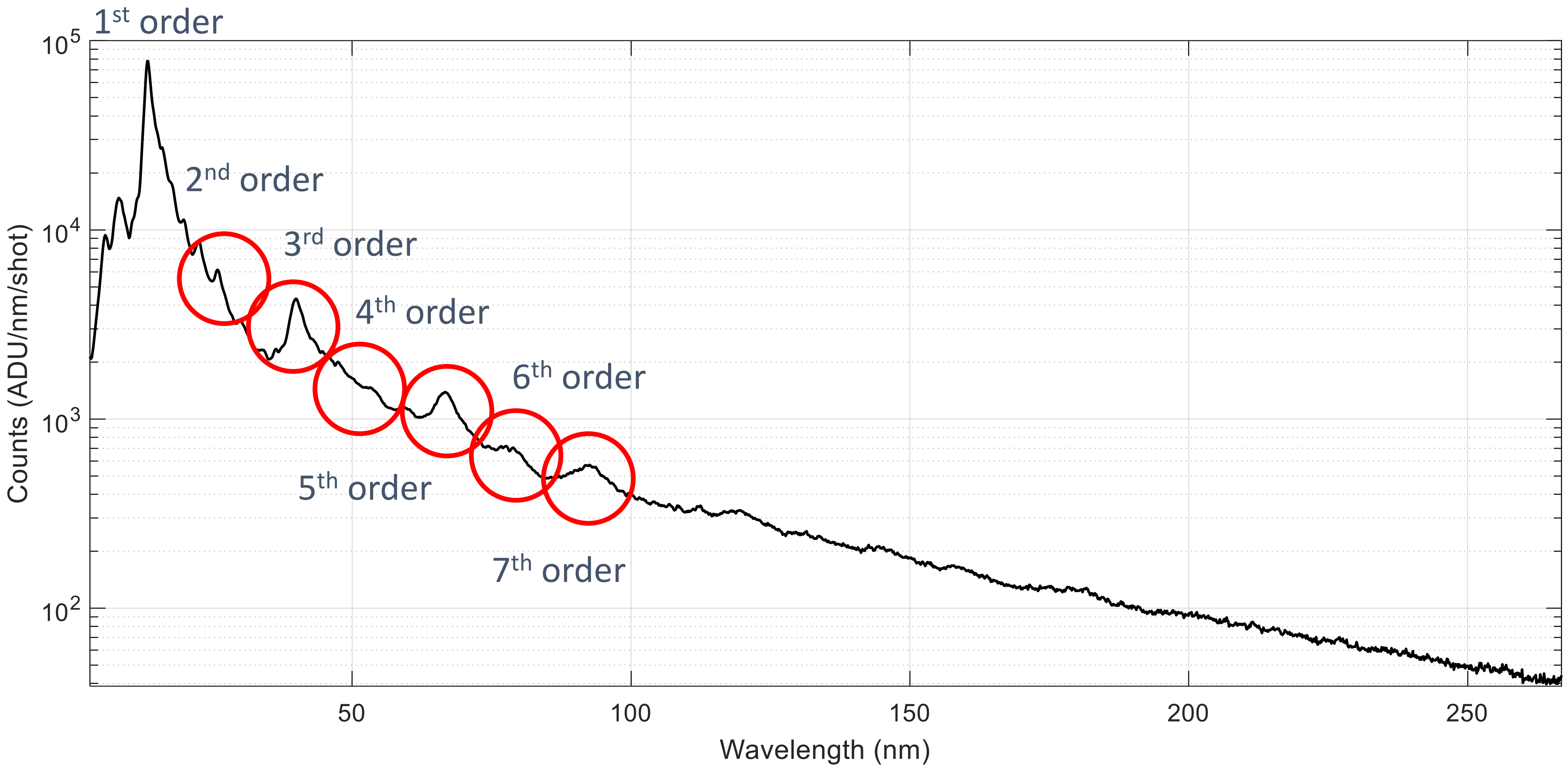

Figure 1 – Unfiltered, raw emission spectrum for 1 µm Nd:YAG driven Sn LPP , including position of higher diffraction orders

Transmission Grating Spectrometer (TGS)

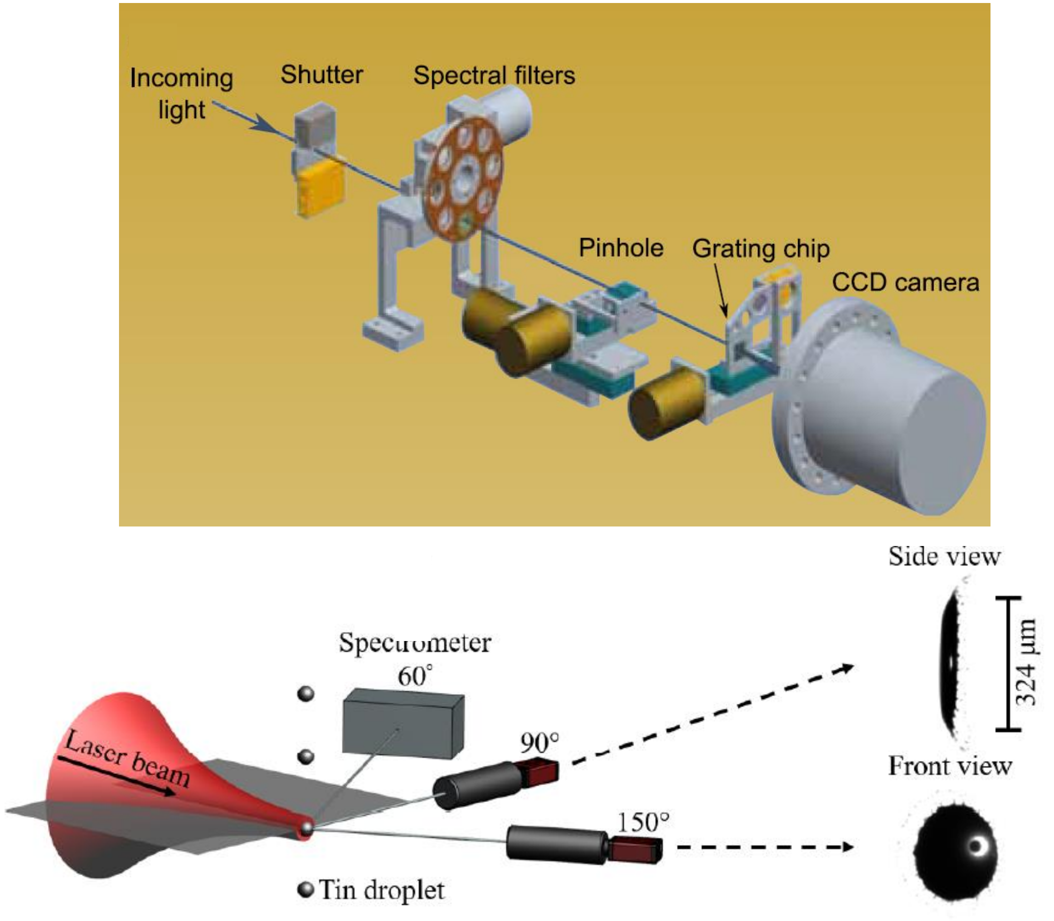

Figure 2 – Top: Spectrometer optical components; Bottom: Experimental setup showing side and front-view shadowgraph of the Sn target captured by differently oriented cameras

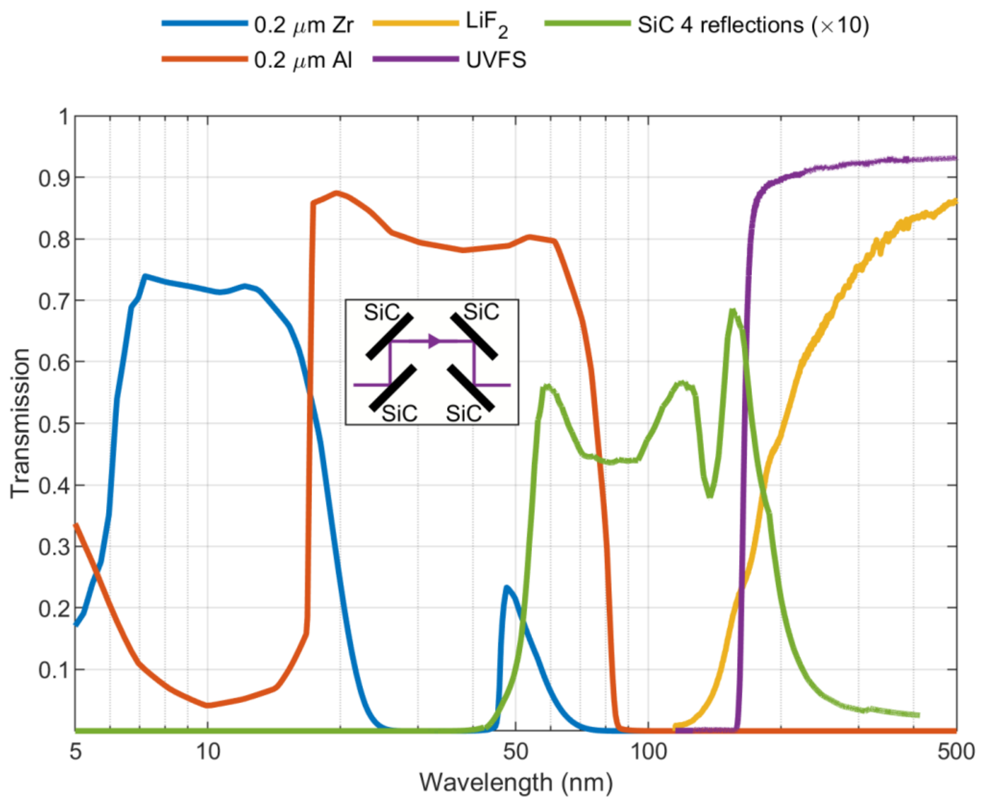

Figure 3 –Filter transmission spectra, showing how full, uninterrupted range can be covered using full suite

Low-Wavelength Spectrum Cleanup: 5.5 – 41 nm

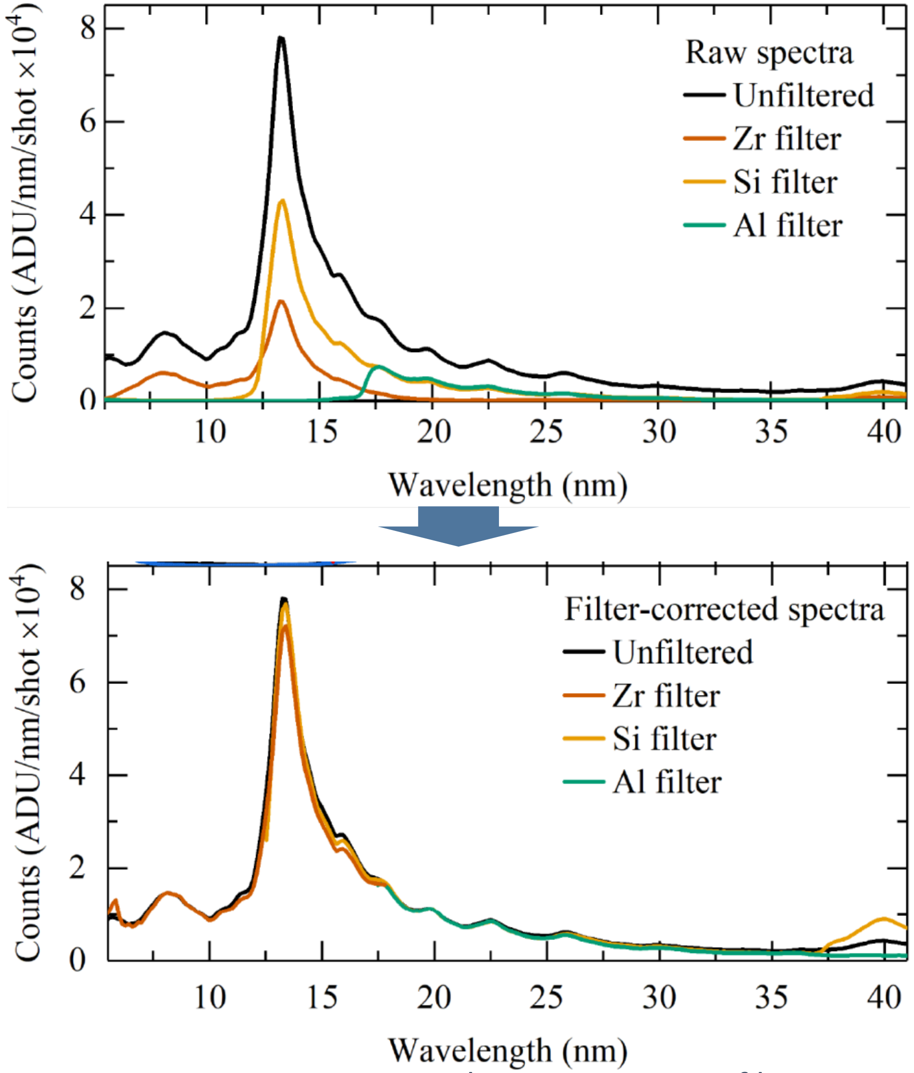

Figure 4 – Top: Spectra taken using various filters.
Bottom: Filter-corrected spectra

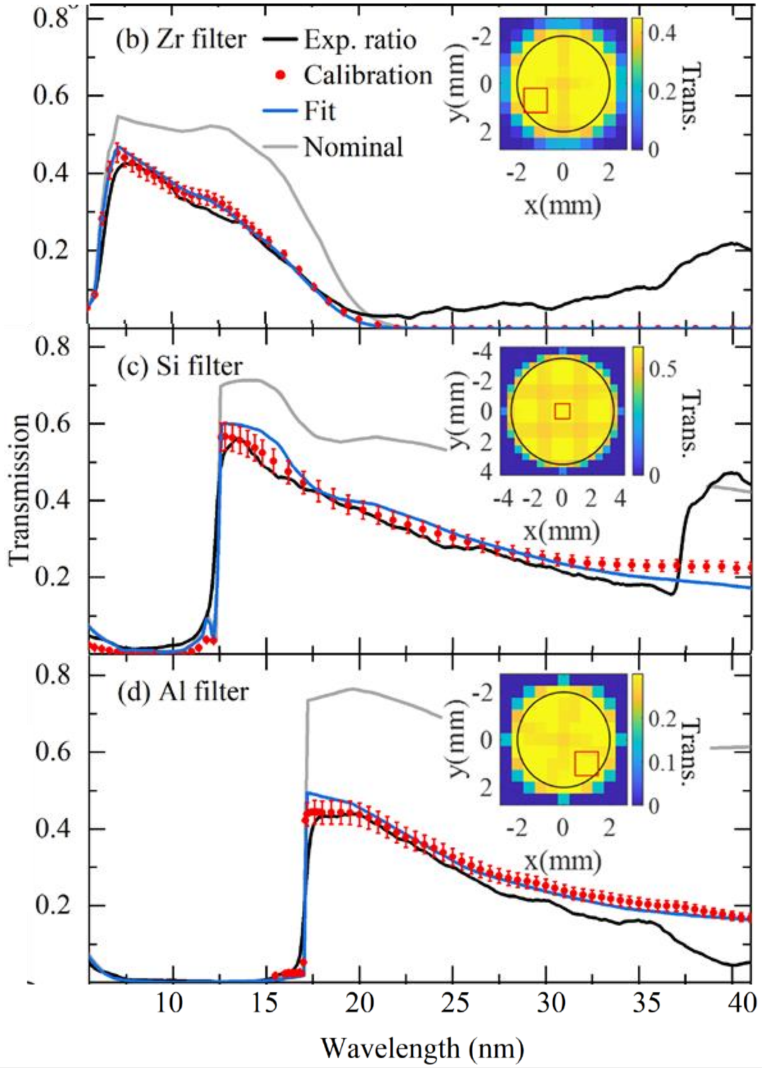

Figure 5 – Zr, Si and Al filters showing transmission as a function of filter position at specific wavelength (insets)

SiC 4-Bounce Mirror Filter

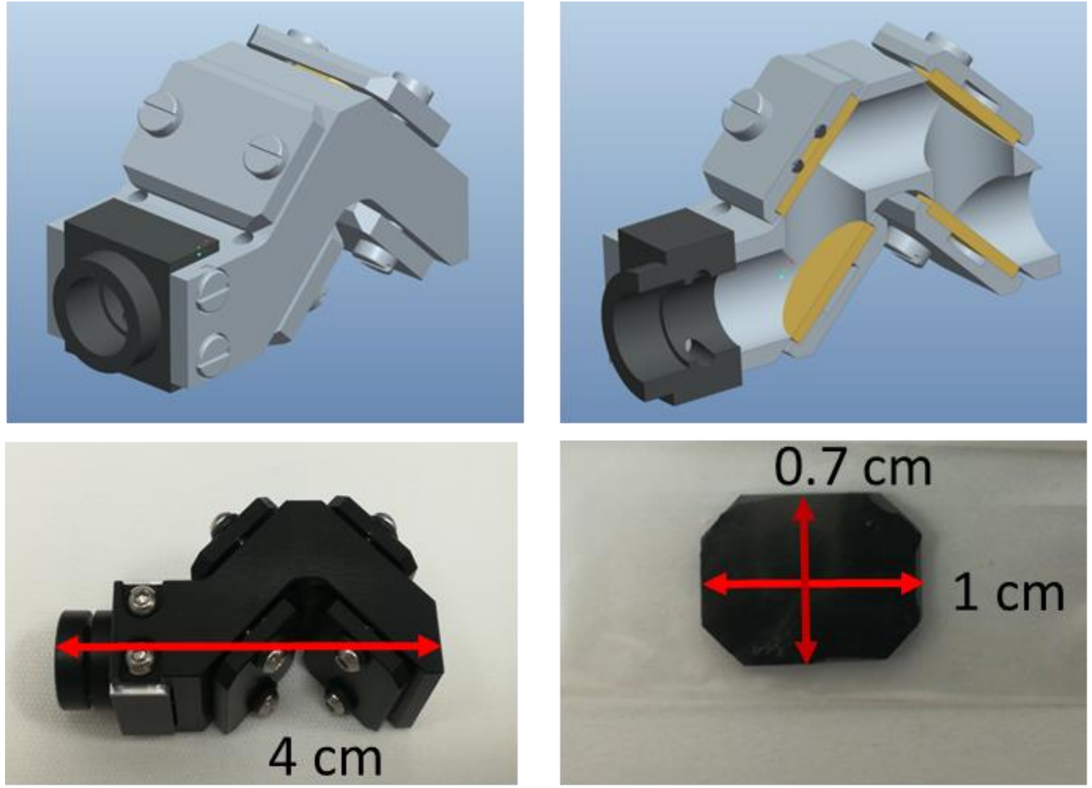

Figure 6 – SiC mirror system filter. Top: CAD drawings. Bottom: Images of actual device

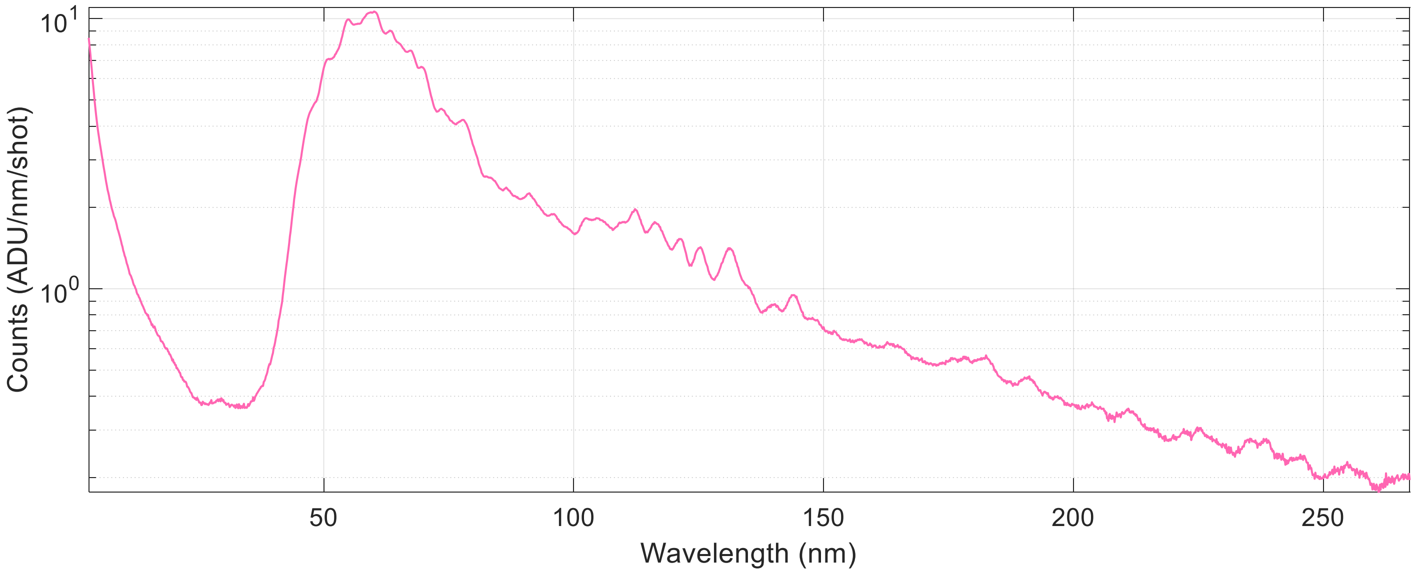

Figure 7 – Sn LPP spectrum using SiC mirror system filter, showing clear pass-band edge at 50 nm

Mid-Wavelength Spectrum Cleanup: 41 - 115 nm

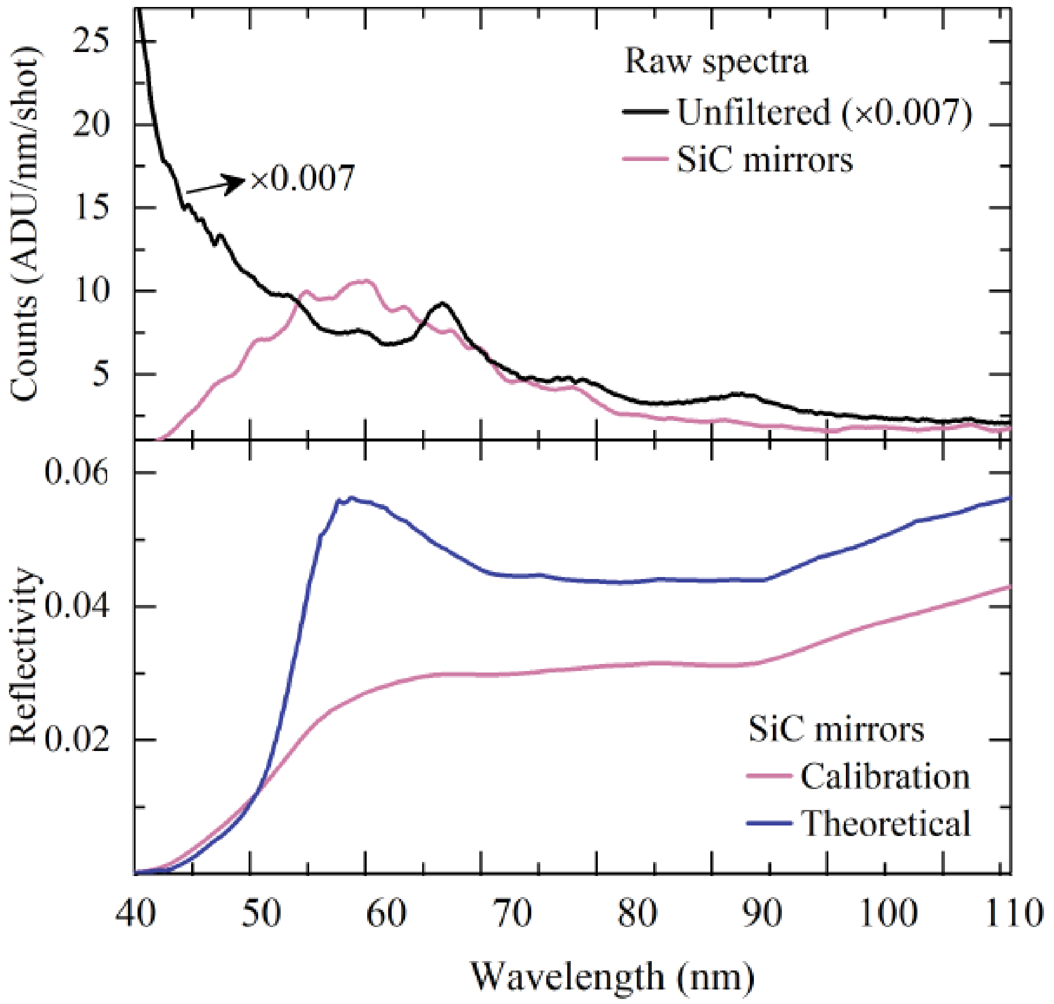

Figure 8 – Top: Unfiltered spectra and SiC mirror system filtered spectra. Bottom: Theoretical and PTB calibrated SiC reflectivity spectra

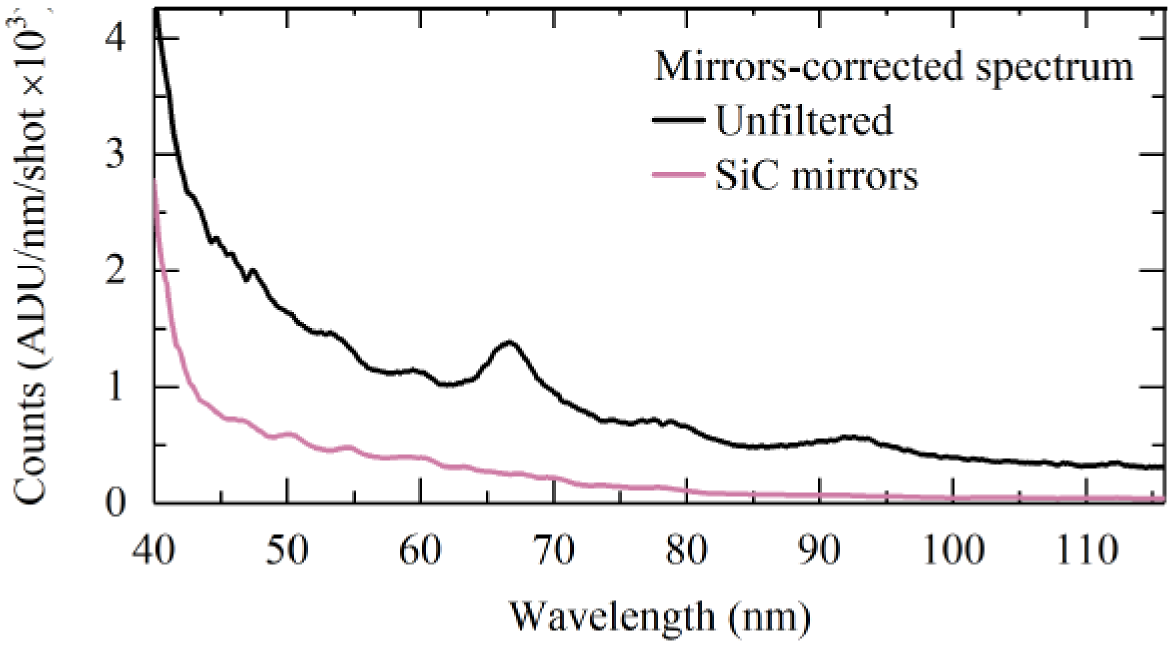

Figure 9 – Unfiltered spectra showing significant higher order contributions, and filtered spectra clear of higher order contributions

High-Wavelength Spectrum Cleanup: 115 – 265.5 nm

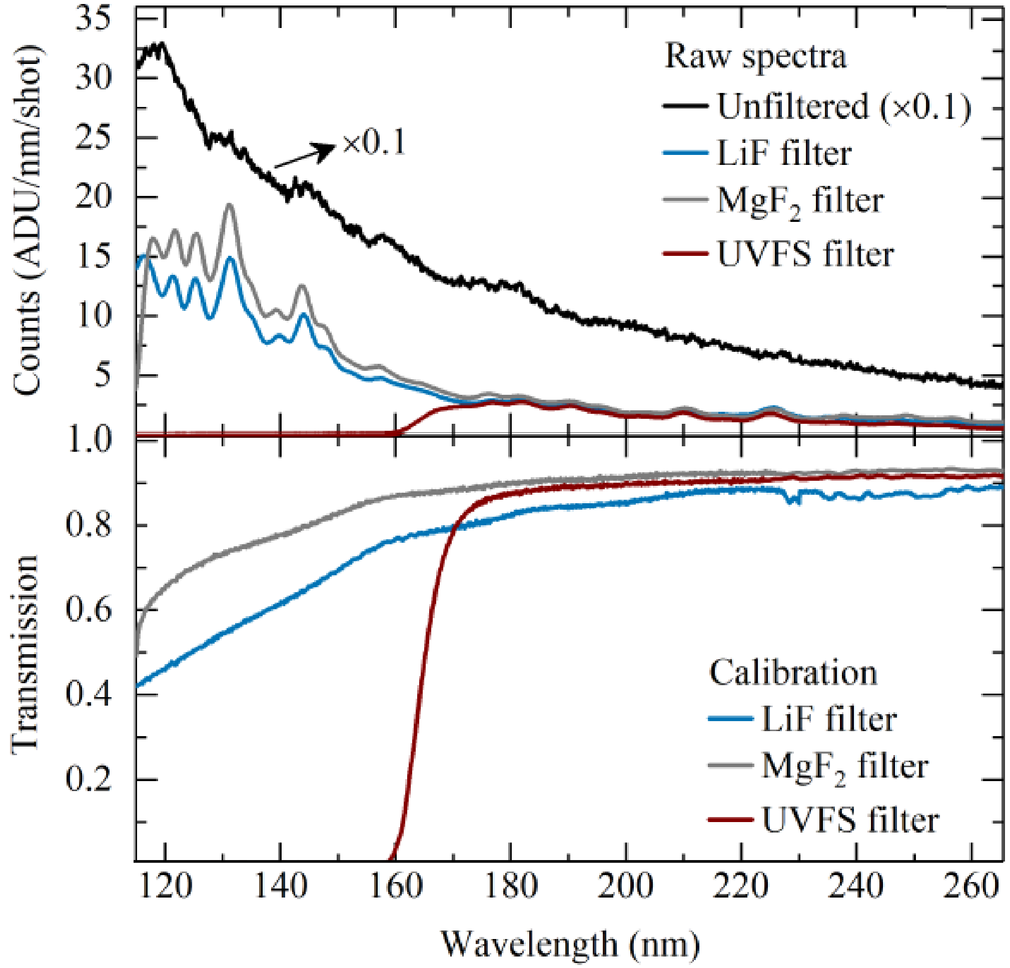

Figure 10 – Top: Emission spectra taken using various filters. Bottom: Theoretical and calibrated transmission spectra. Those filters calibrated using a vacuum-ultraviolet spectrograph equipped with a deuterium lamp.

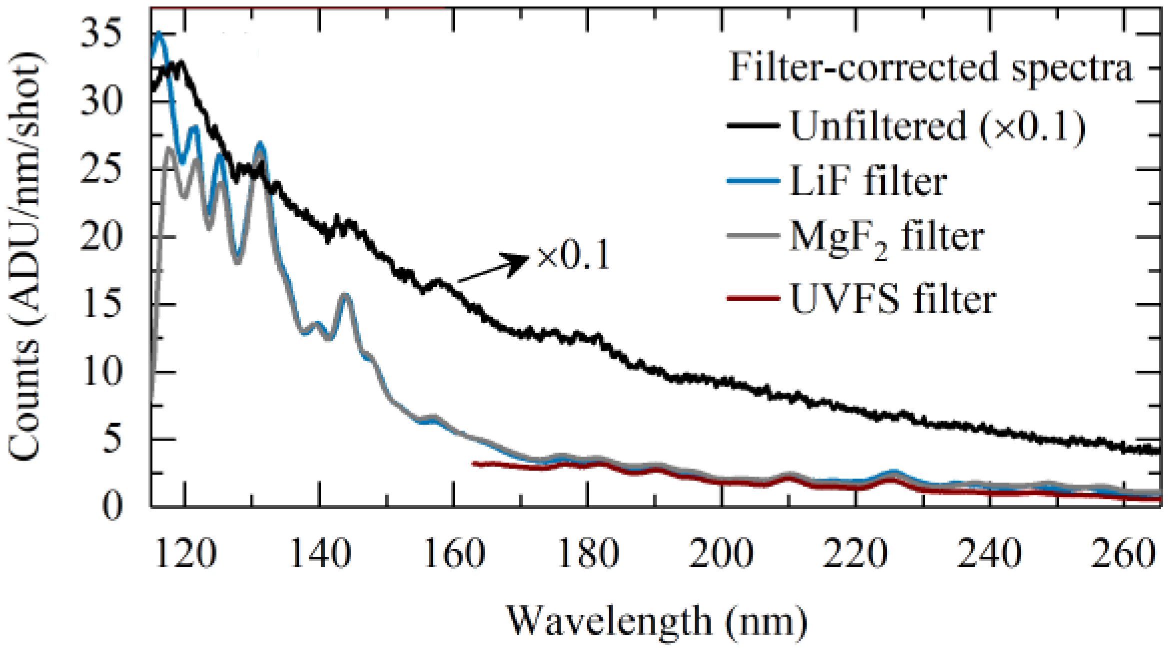

Figure 11 – Unfiltered spectra showing significant higher order contributions, and filtered spectra clear of higher order contributions

Full Corrected Spectra: 5.5 - 265 nm

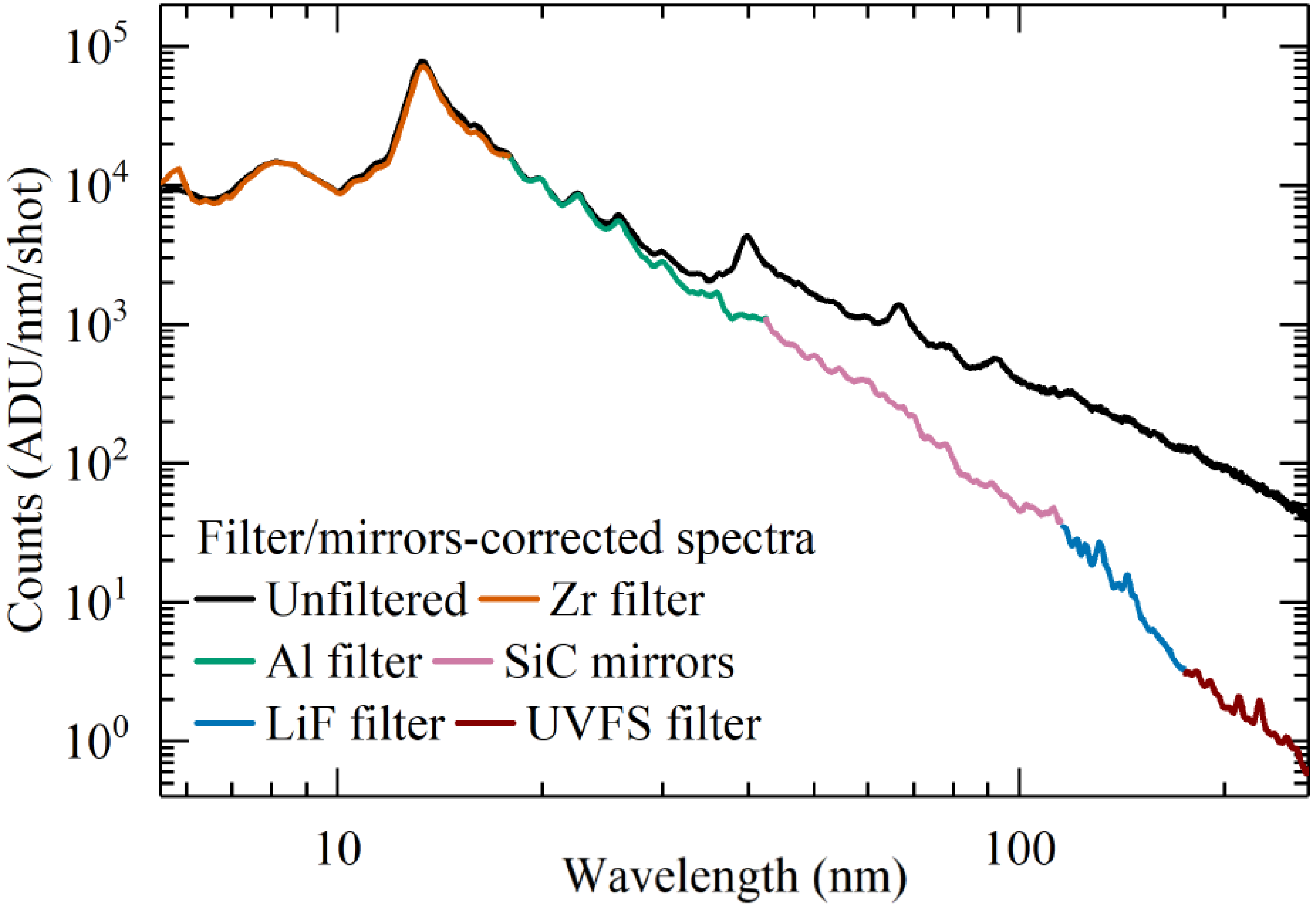

Figure 12 – Unfiltered spectra showing significant higher order contributions above ~20 nm, especially above 30 nm, and the complete filter corrected spectra with higher order contributions removed

Conclusion

- Technique for calibrating full soft-X-ray to DUV spectra of EUV sources, using filters to **remove spectrum contaminating higher contributions**
- SiC mirror system filter can be used to see the otherwise inaccessible 40 - 115 nm region
- This technique enables optimization of EUV light sources for lithography

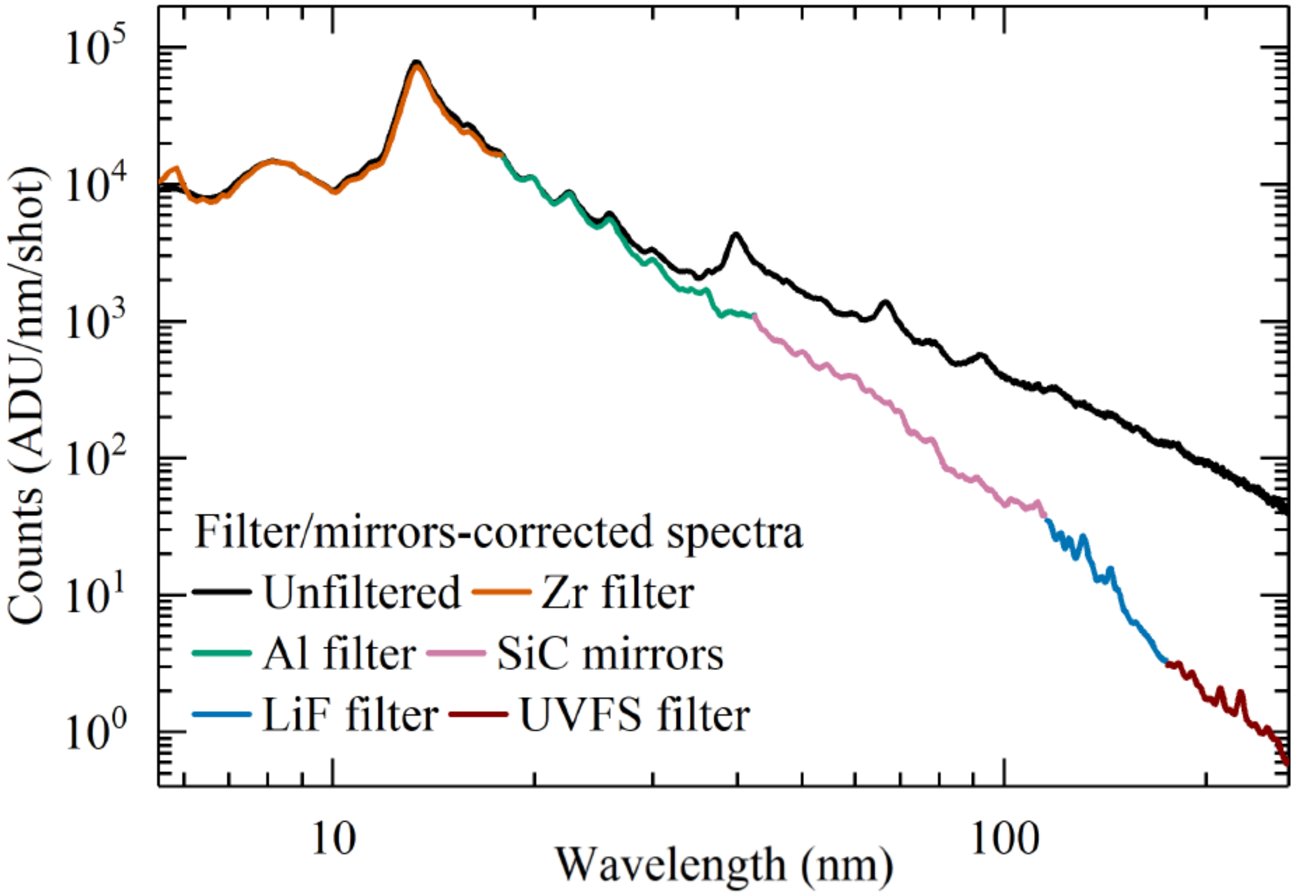

Figure 12 – Unfiltered spectra showing significant higher order contributions, and the complete filter corrected spectra with higher order contributions removed

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