

FOCAL CONE HIGH HARMONIC GENERATION



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OF ALBERTA

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Infraestructuras
Científicas y Técnicas
Singulares



Outline

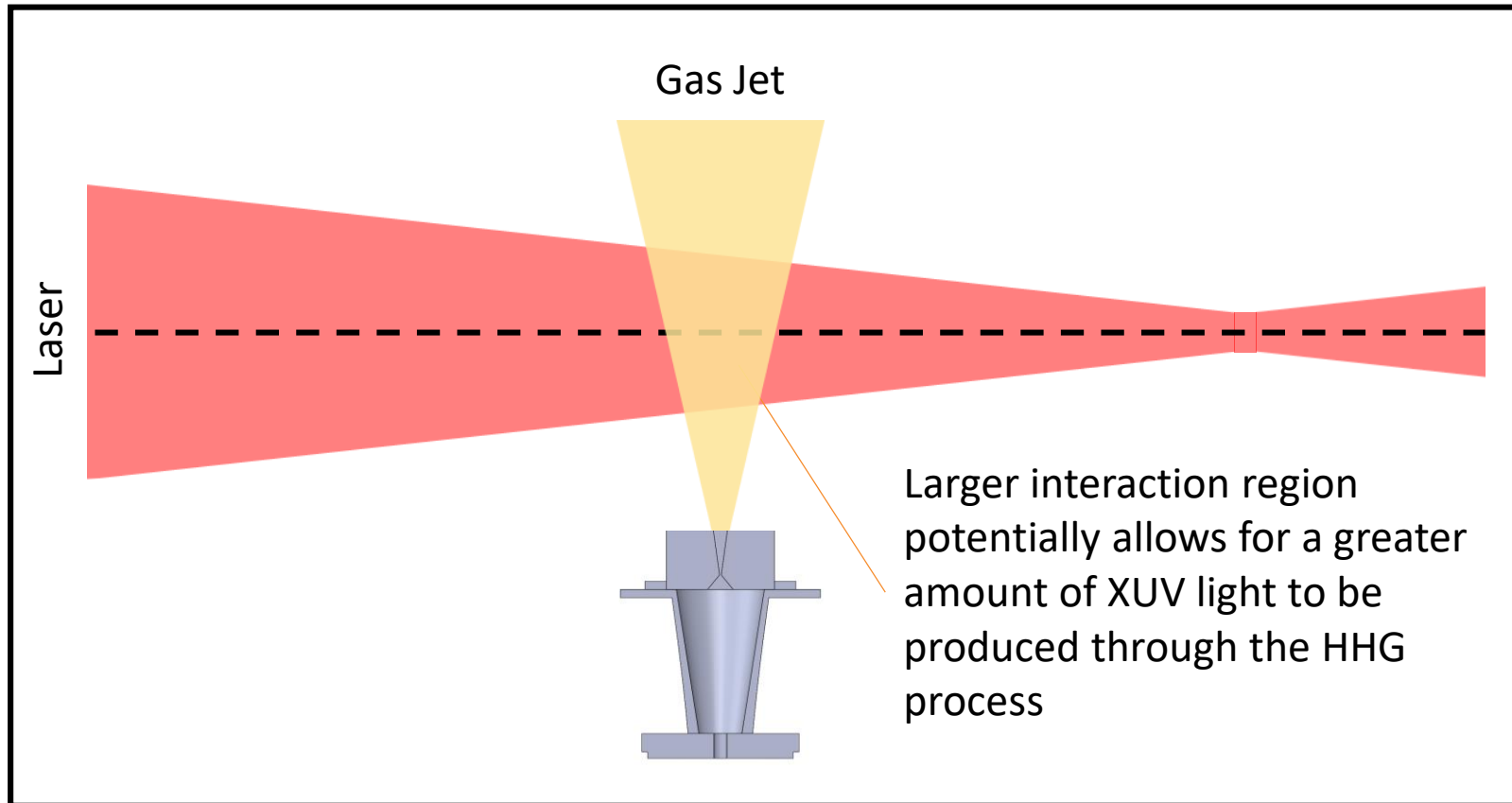
- Motivation for Experiment
- Experiment Layout
- Experimental Results
- Conclusions and Future Work

CENTRO DE LÁSERES PULSADOS – SALAMANCA, SPAIN

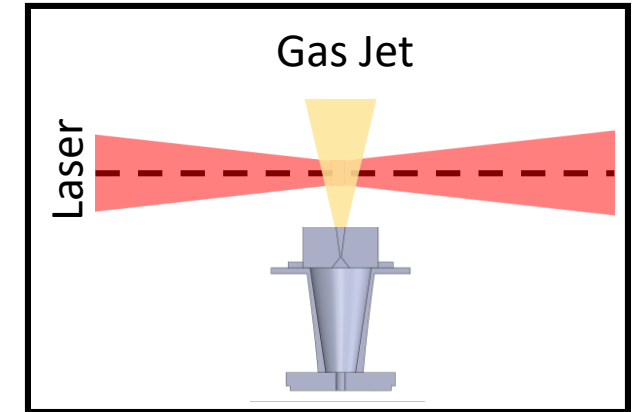


Focal Cone High Harmonic Generation

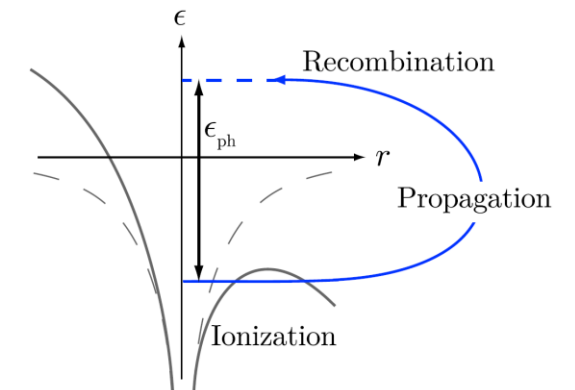
Focal Cone HHG



Traditional HHG

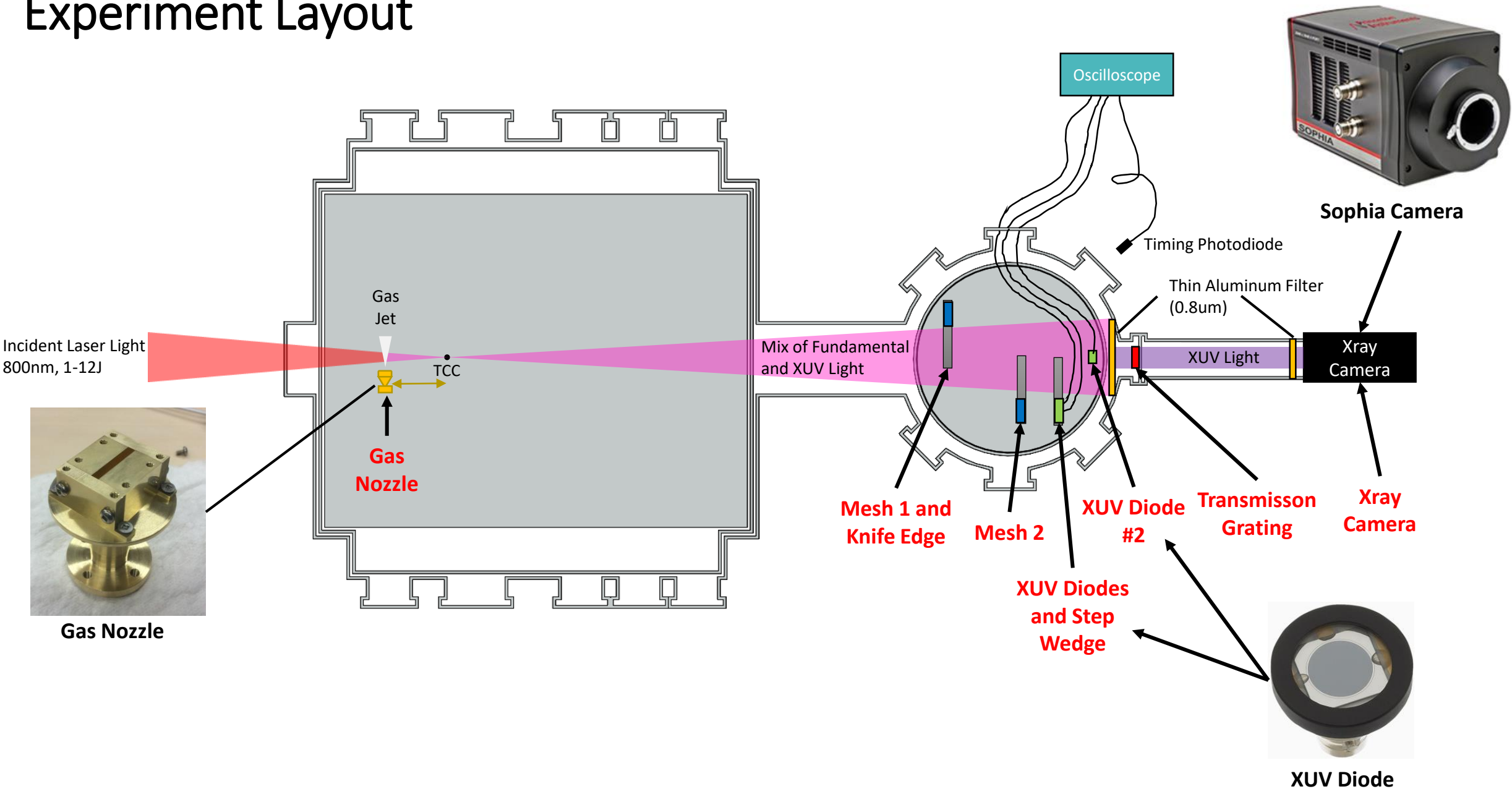


Recollisional Model

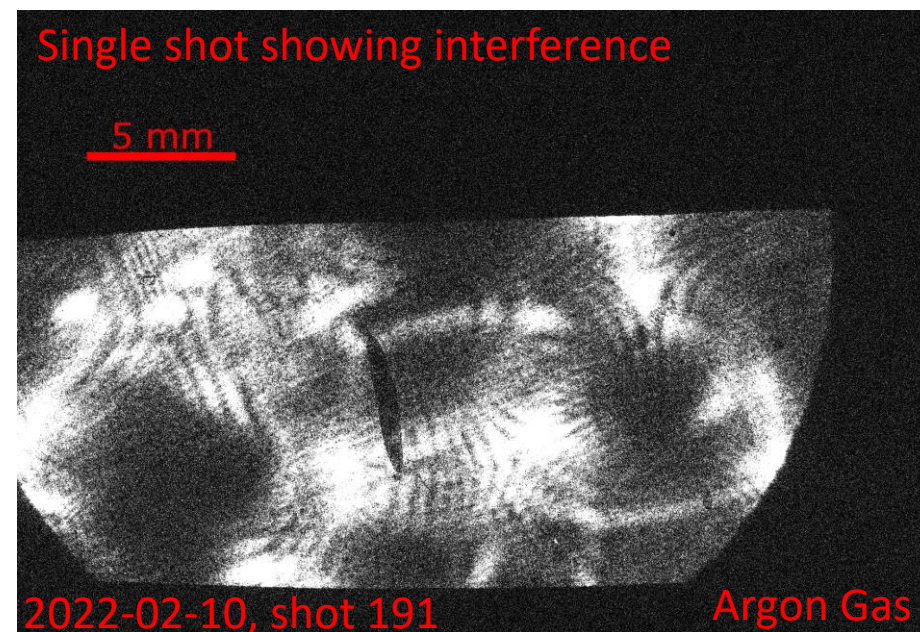
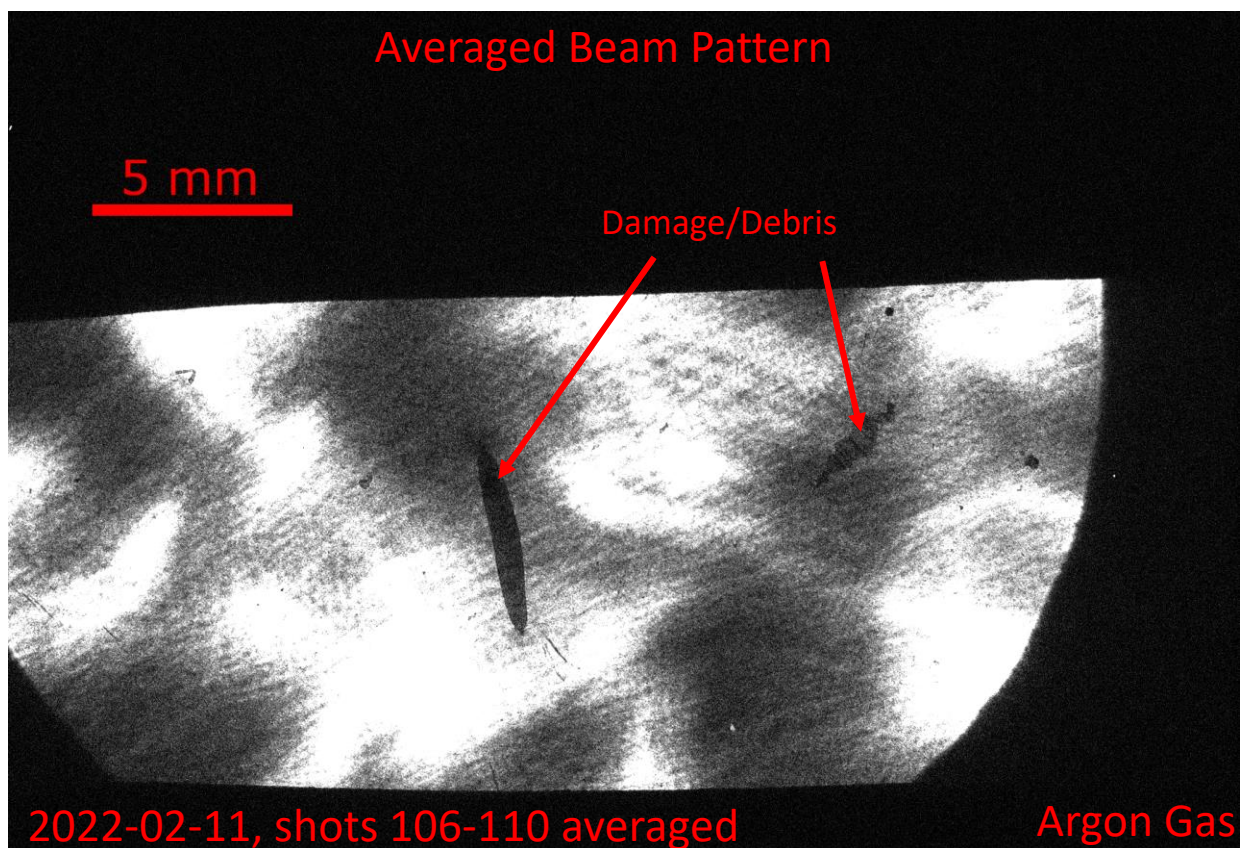


C. M. Heyl et al, "Introduction to macroscopic power scaling principles for high-order harmonic generation," *Journal of Physics B: Atomic, Molecular and Optical Physics*, vol 50, 2017.

Experiment Layout



Modulated Beam Profile

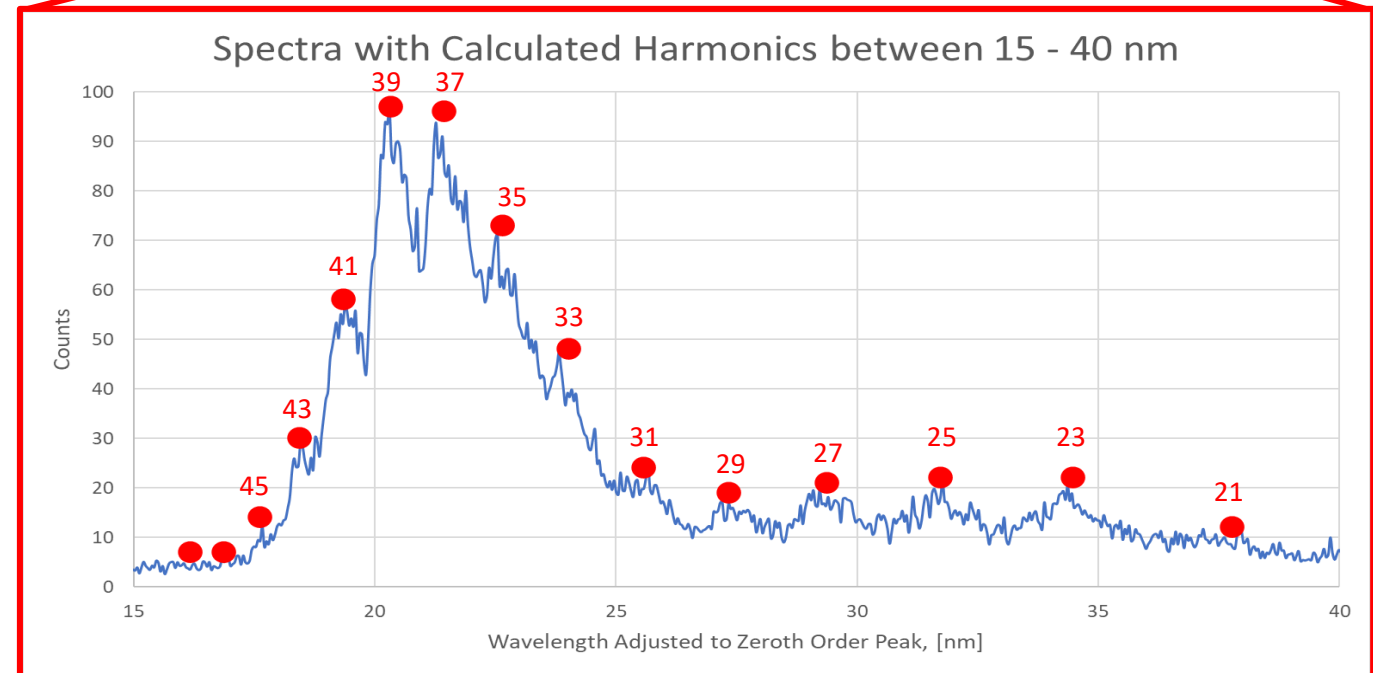
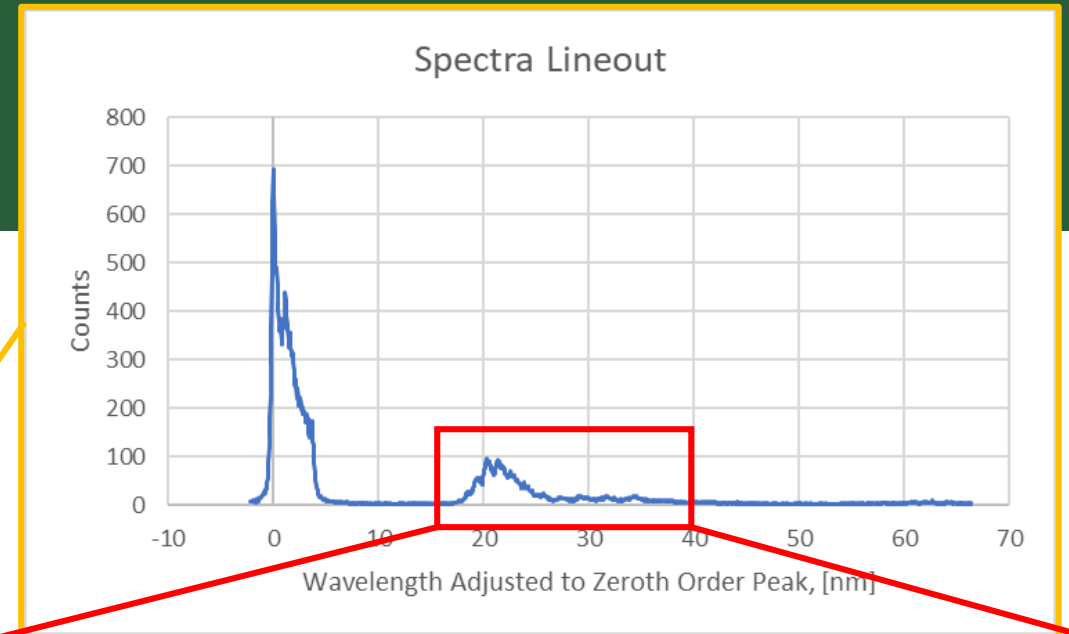
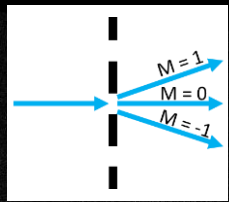
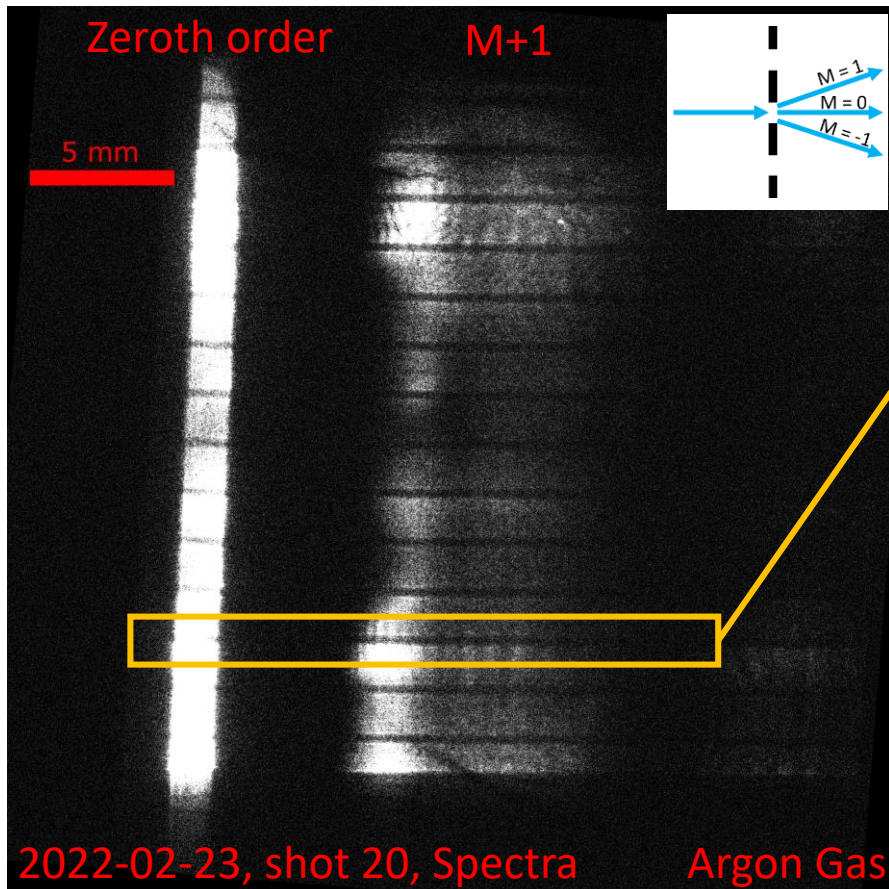


Spectral Characterization: 12 Joules – 130 mm from focus

Transmission Grating Spectra

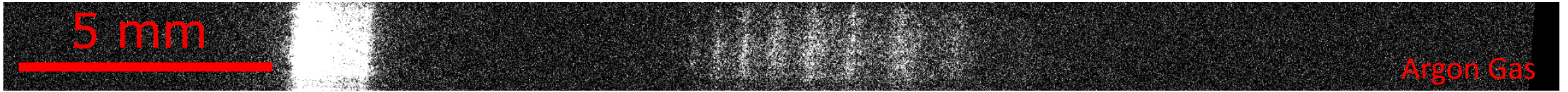
Grating : 500 lines/mm

Distance to camera : 69.25 cm \pm 1cm

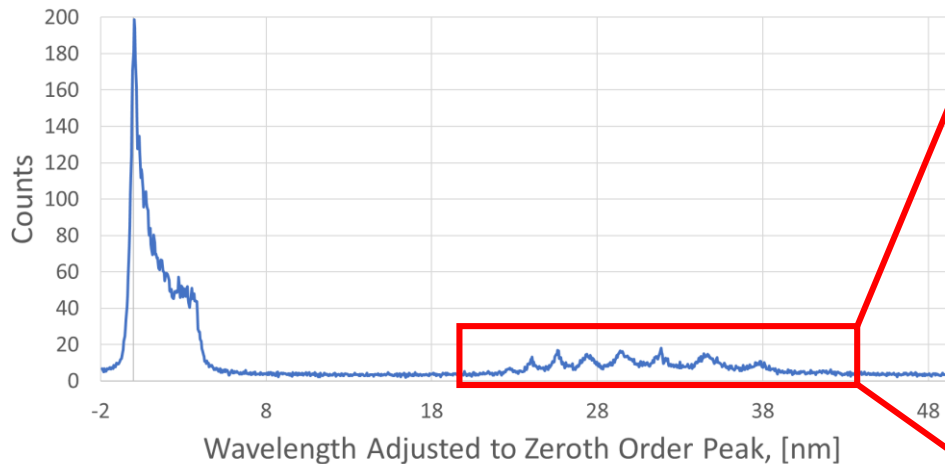


Harmonic Spectra: 8 Joules – 100 mm from focus

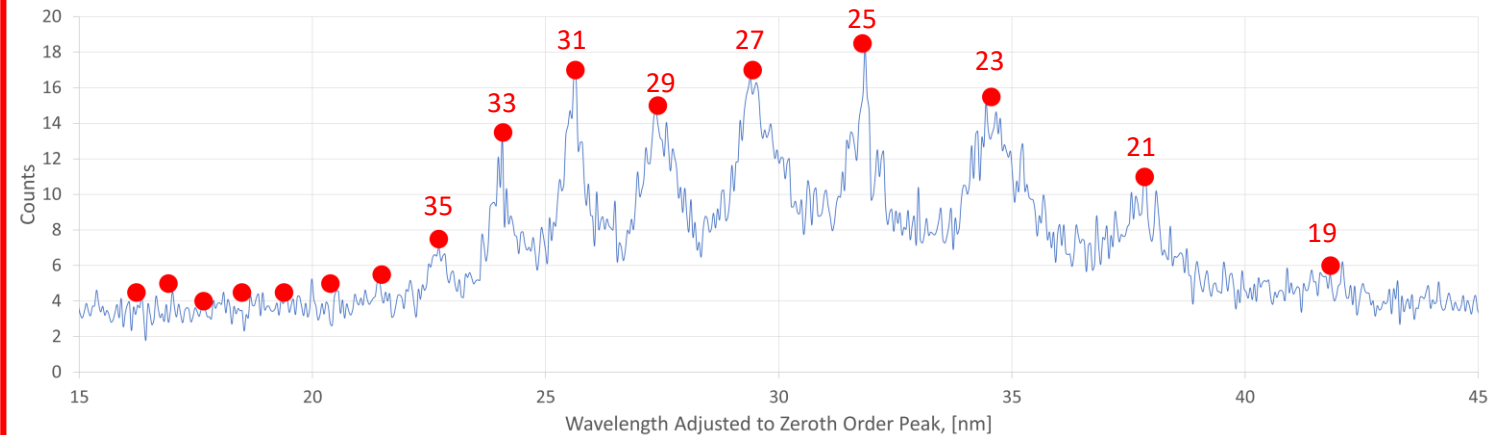
2022-02-22 Shot 27, Spectra



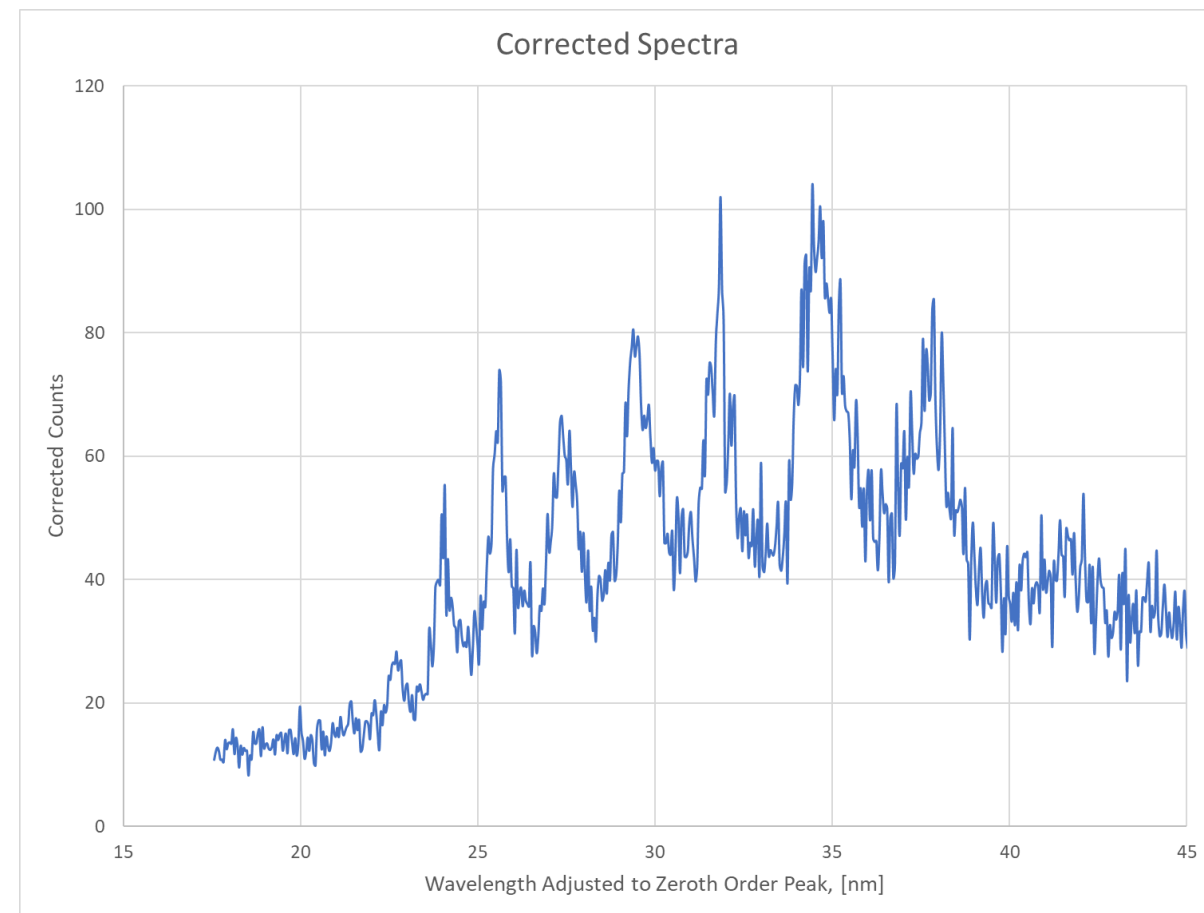
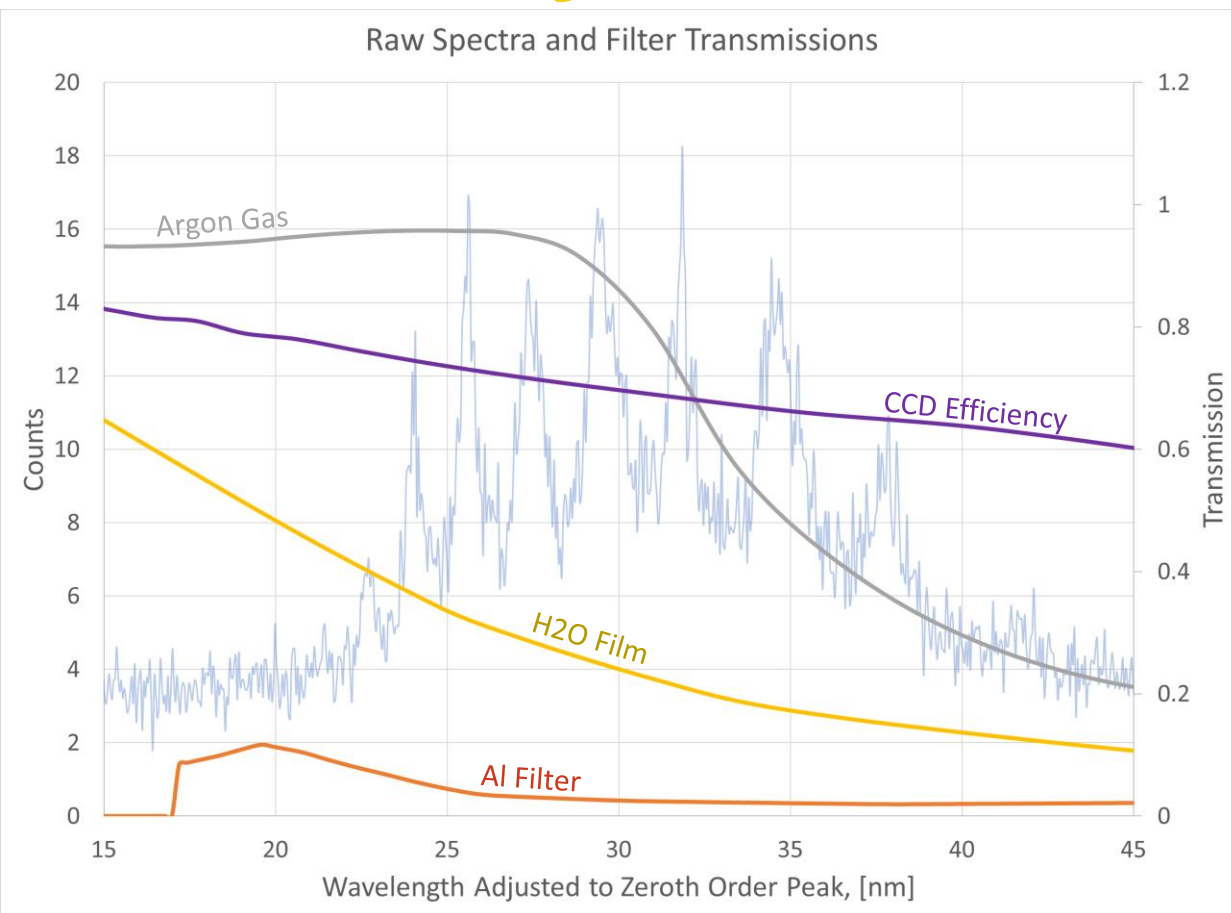
Spectra Lineout



Spectra with Calculated Harmonics between 15 - 40 nm

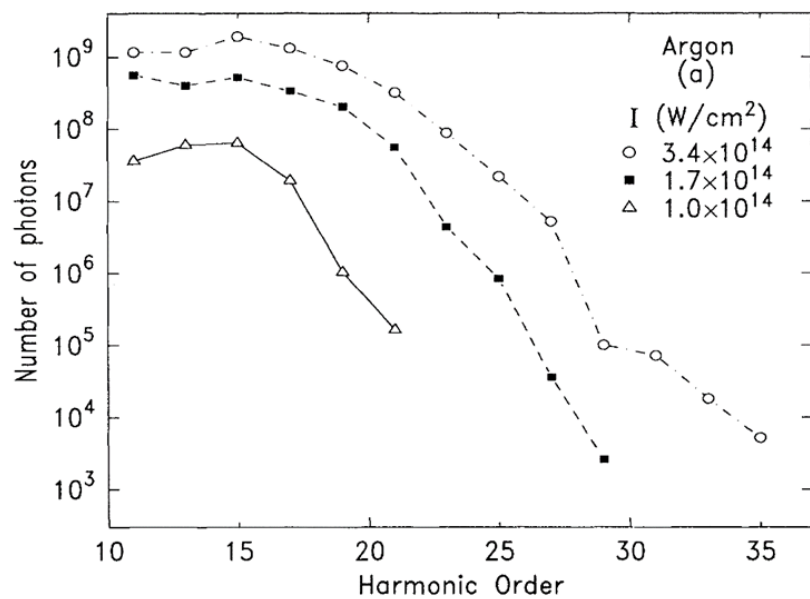


Absorption in Filters and Detector Efficiency

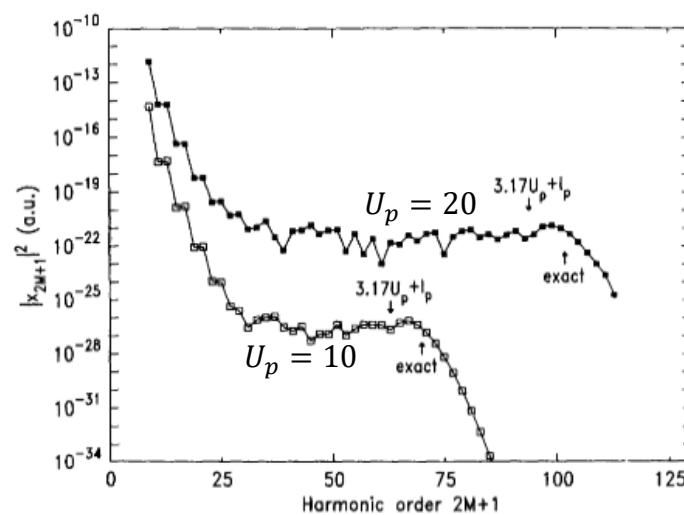


At longer wavelengths absorption in the argon gas and aluminum filters prevents light from reaching the CCD

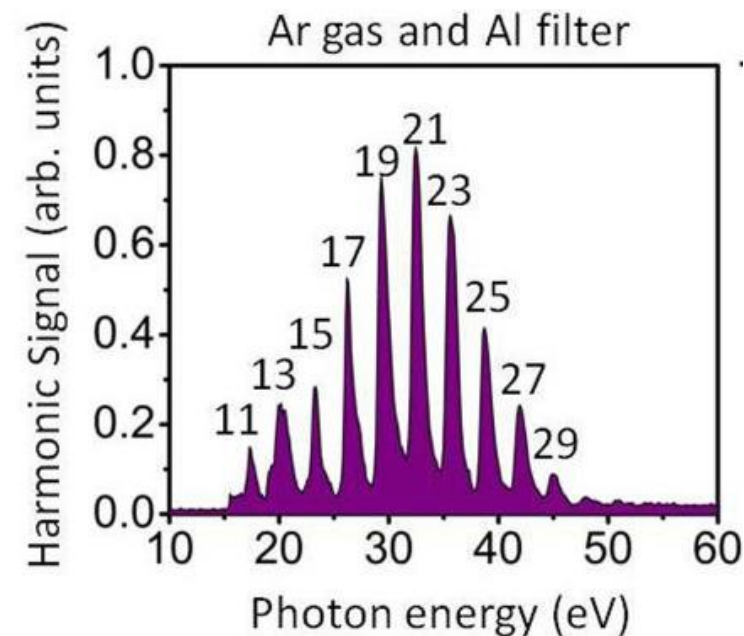
Previous Harmonic Results



J. L. Krause et al, "High-Order Harmonic Generation from Atoms and Ions in the High Intensity Regime," *Physical Review Letters*, vol 68, no 24, 1992.



M. Lewenstein, Ph. Balcou, M. Yu. Ivanov, Anne L'Huillier, and P.B. Corkum, "Theory of high-harmonic generation by low-frequency laser fields," *Physical Review A*, vol 49, no 3, 1994.

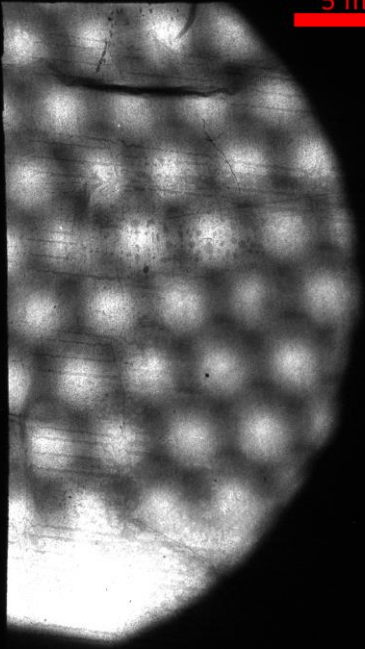


A. Nayak et al, "Multiple Ionization of argon via multi-XUV-photon absorption induced by 20-GW high-order harmonic laser pulses," *Physical Review A*, vol 98, 2018.

Shadowgraphic Imaging of Mesh

2022-02-18, shots 221-225, Mesh 1, Hot Plasma

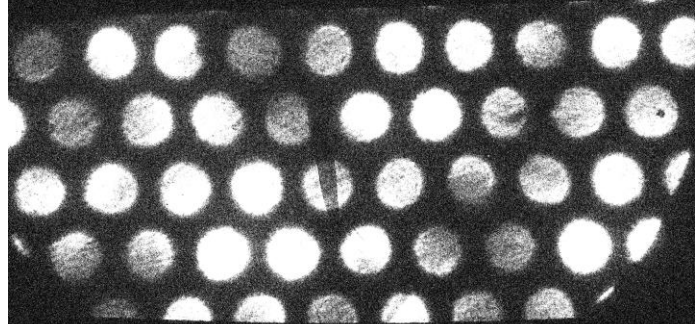
5 mm



Xenon Gas

2022-02-11, shots 207-210, Mesh 1, HHG

5 mm



Argon Gas

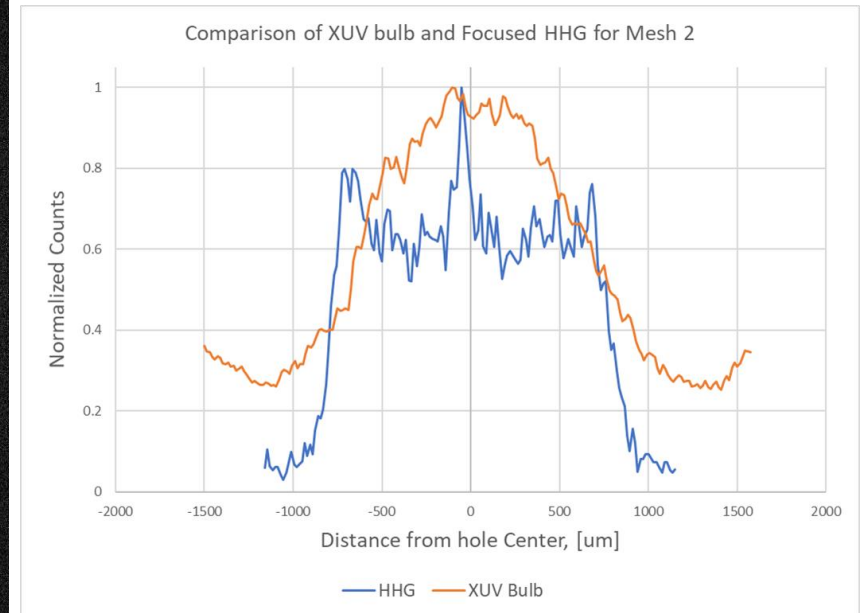
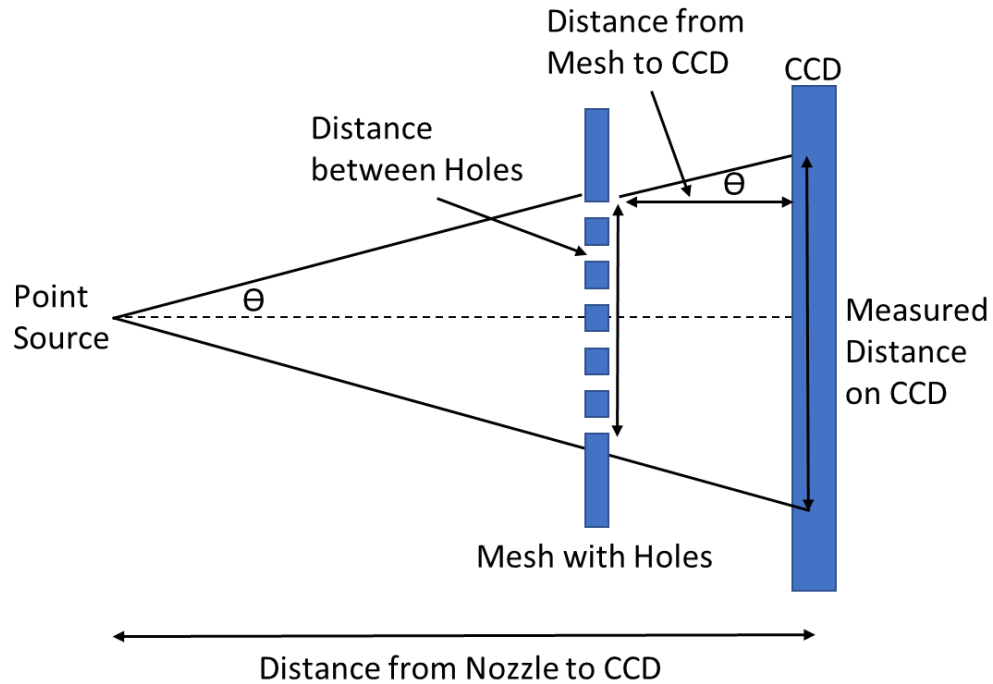
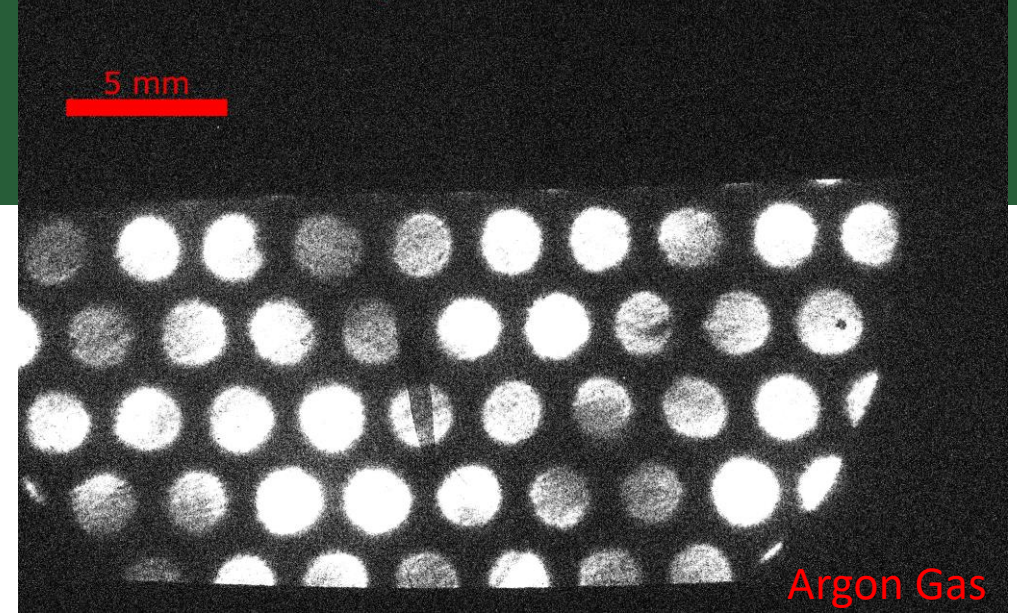


Image Projection Calculation of Point Source

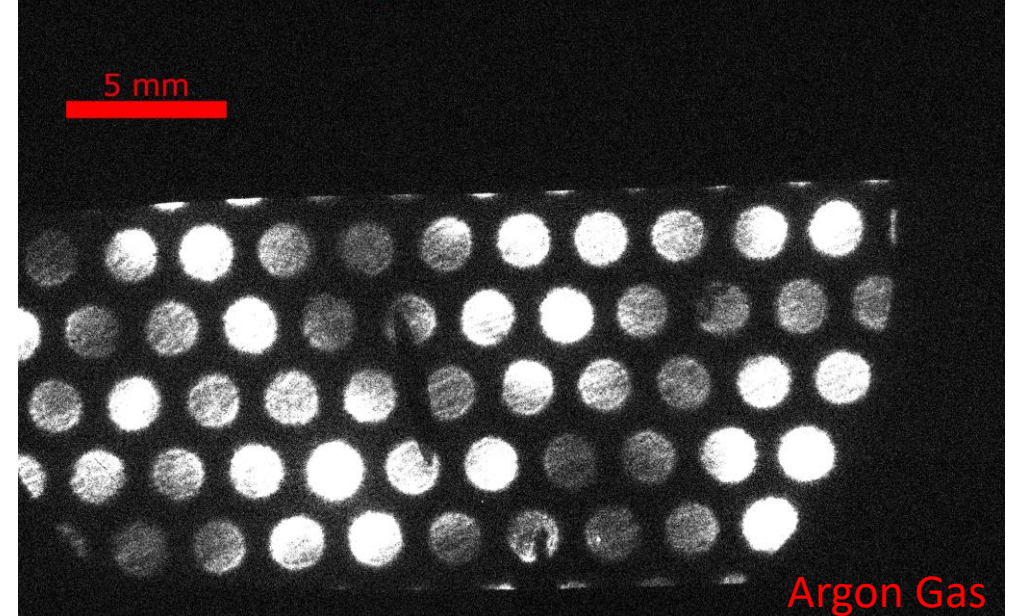


Distance from TCC to CCD : **3.00 ± 0.02 meters**
Distance based on Mesh 1 measurement: **2.96 ± 0.08 meters**
Distance based on Mesh 2 measurement: **2.86 ± 0.08 meters**

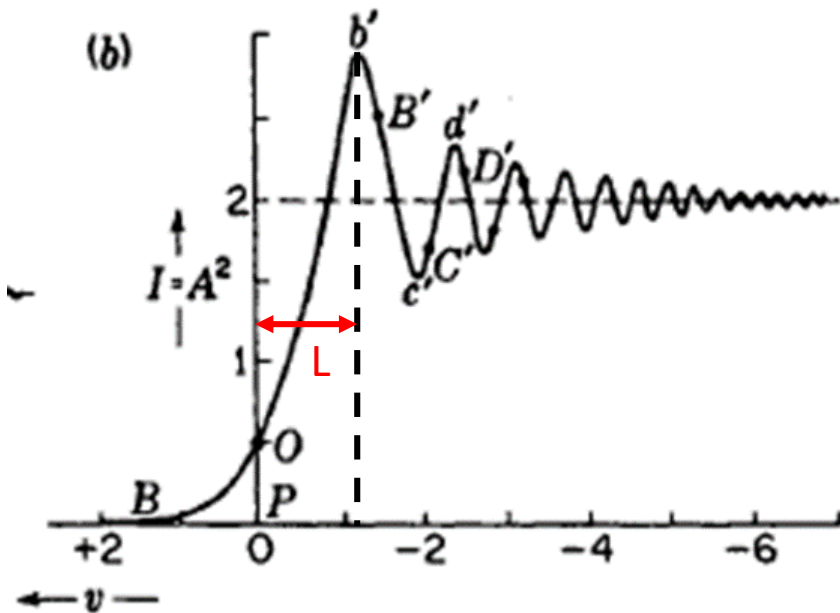
Mesh 1 - Shots 207-211, 2022-02-11



Mesh 2 - Shots 202-206, 2022-02-11

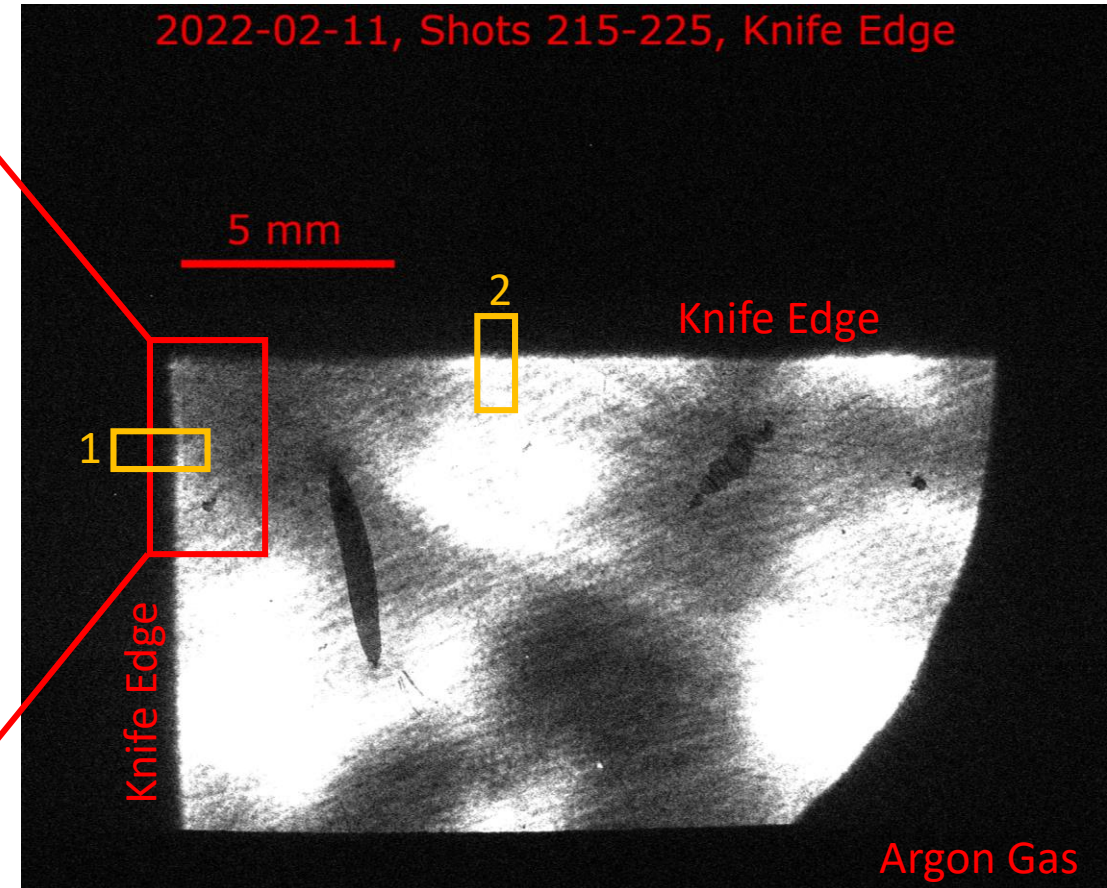
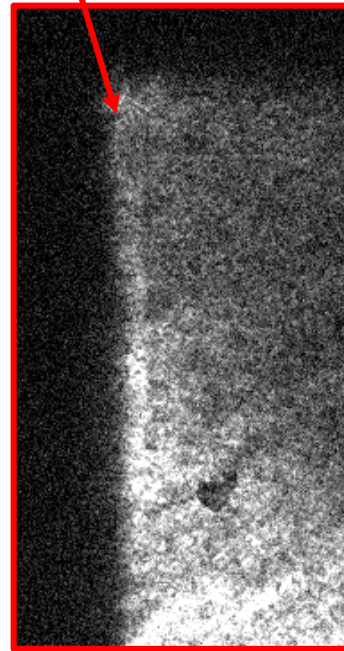


Spatial Coherence Using Knife Edge



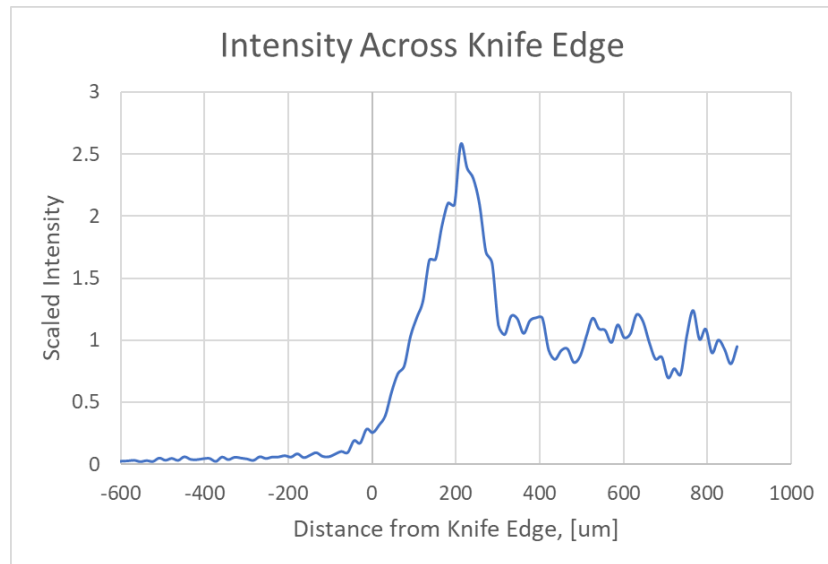
$$L = 1.2 * \sqrt{\frac{b\lambda*(a+b)}{2a}}$$

Fresnel Diffraction



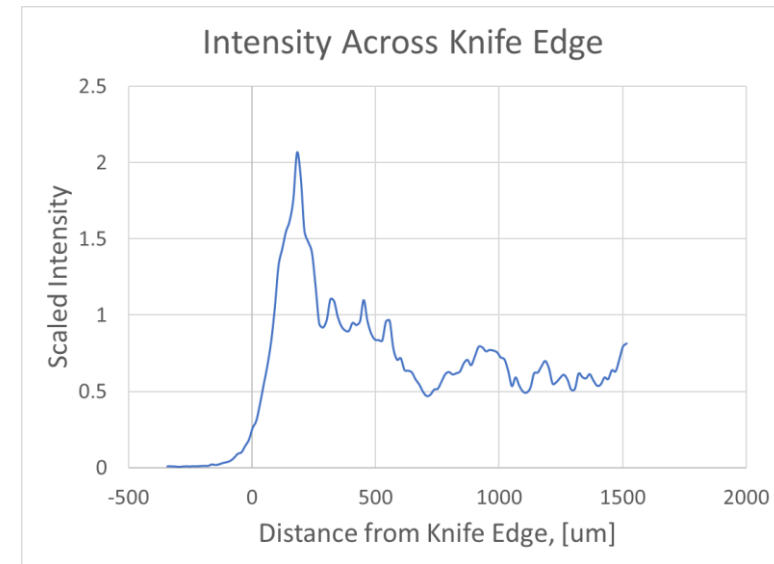
Spatial Coherence Using Knife Edge

Lineout 1



31.44 nm

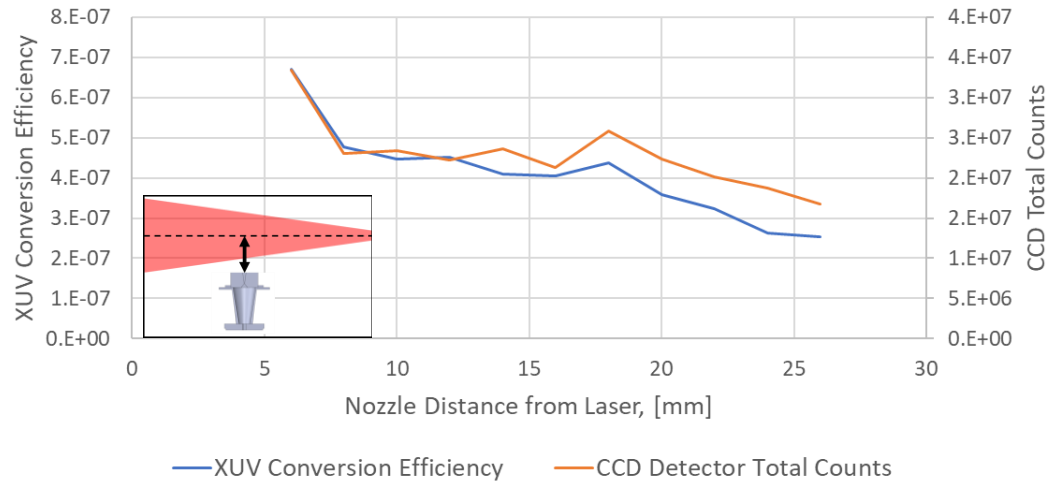
Lineout 2



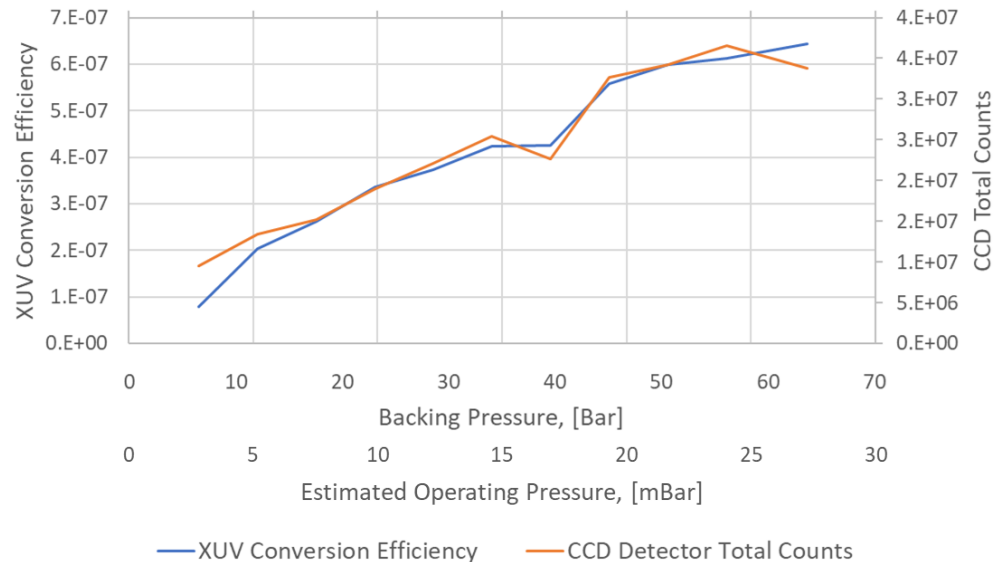
23.26 nm

Efficiency Scaling With Pressure and Nozzle Distance From Laser

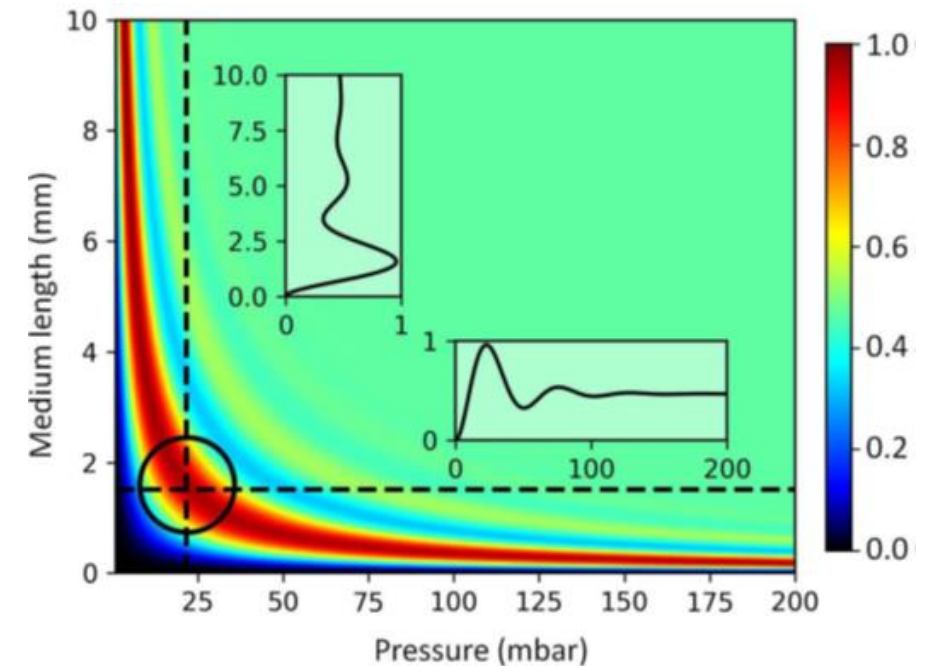
HHG Dependence on Nozzle Transverse Position at 4J backing pressure 31 bar, Argon Gas



HHG Dependence on Operating Pressure at 4J

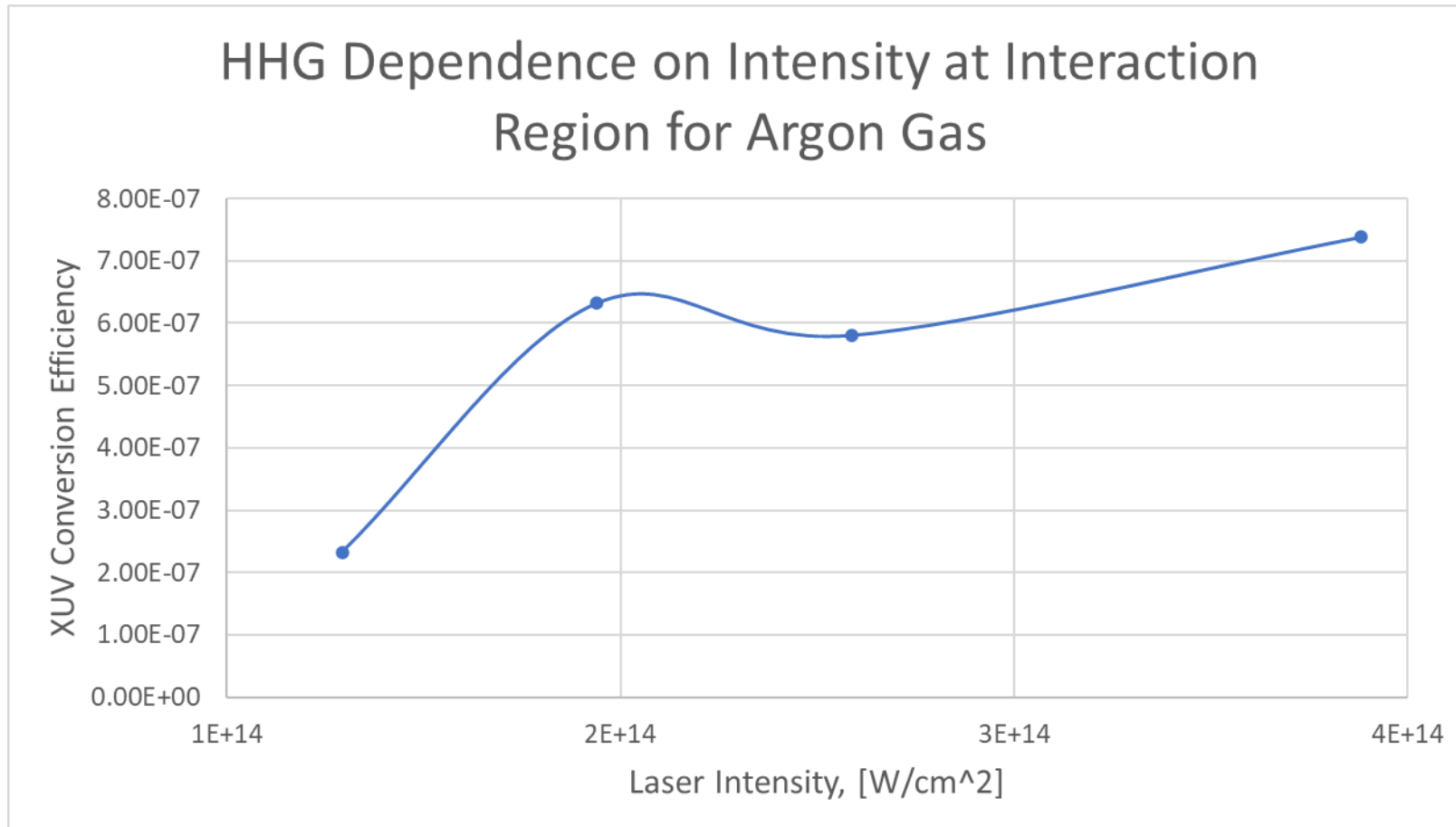


Optimum Pressure-Length Product: 40 mbar mm



A. Nayak et al, "Multiple Ionization of argon via multi-XUV-photon absorption induced by 20-GW high-order harmonic laser pulses," *Physical Review A*, vol 98, 2018.

Scaling with Laser Intensity



Conclusion and Future Work

Conclusions

- High Harmonic Generation has been obtained in the focal cone geometry
- Focusing harmonic spot has been generated
- Conversion efficiency on the order of 10^{-7} achieved
- Highly dependent on beam spatial properties leading to highly modulated patterns

Future work

- Improve beam quality to reduce modulation
- Carry out model calculations to identify best set up for high conversion efficiency
- Carry out more, higher precision, spectroscopic studies to improve efficiency

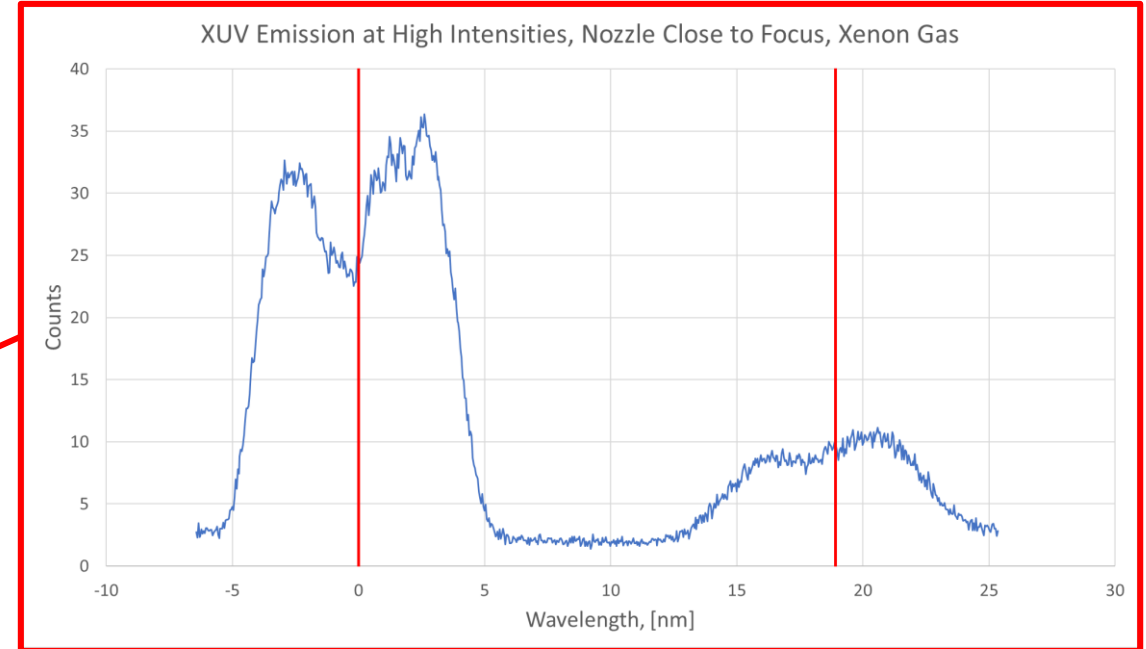
Spare Slides

Broadband XUV Emission at Higher Laser Intensities

2022-02-21, Shots 126-136, Averaged

5 mm

Xenon Gas

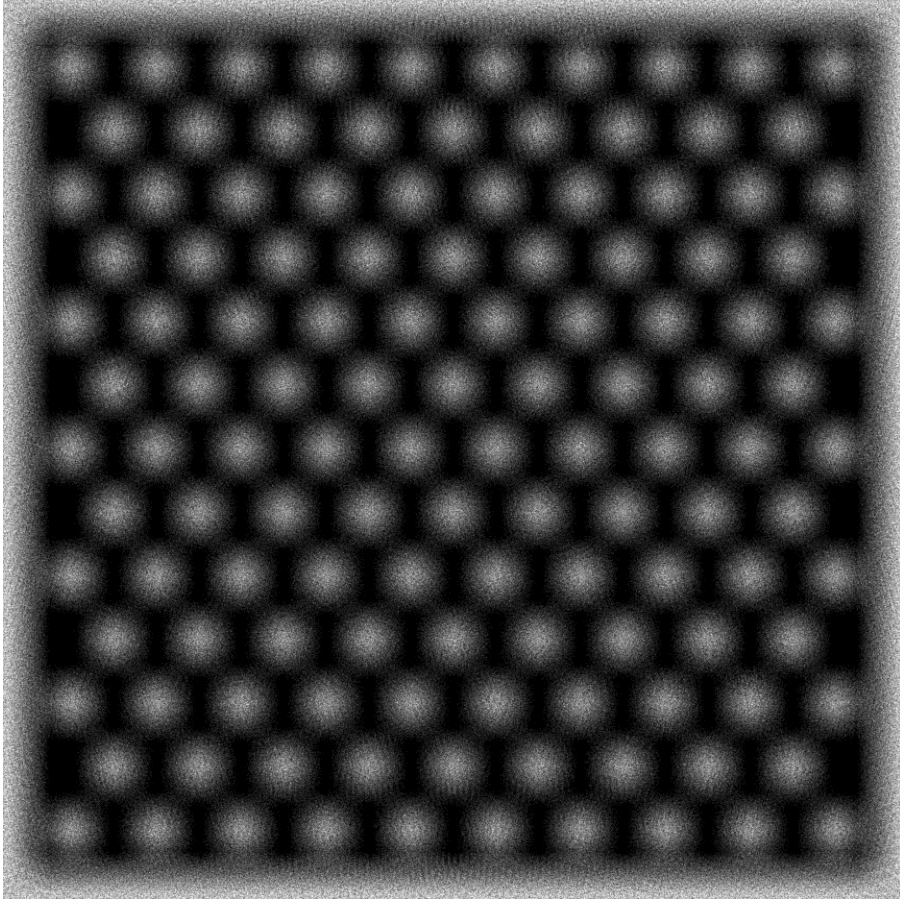


Xenon Spectral line at 18.9 nm

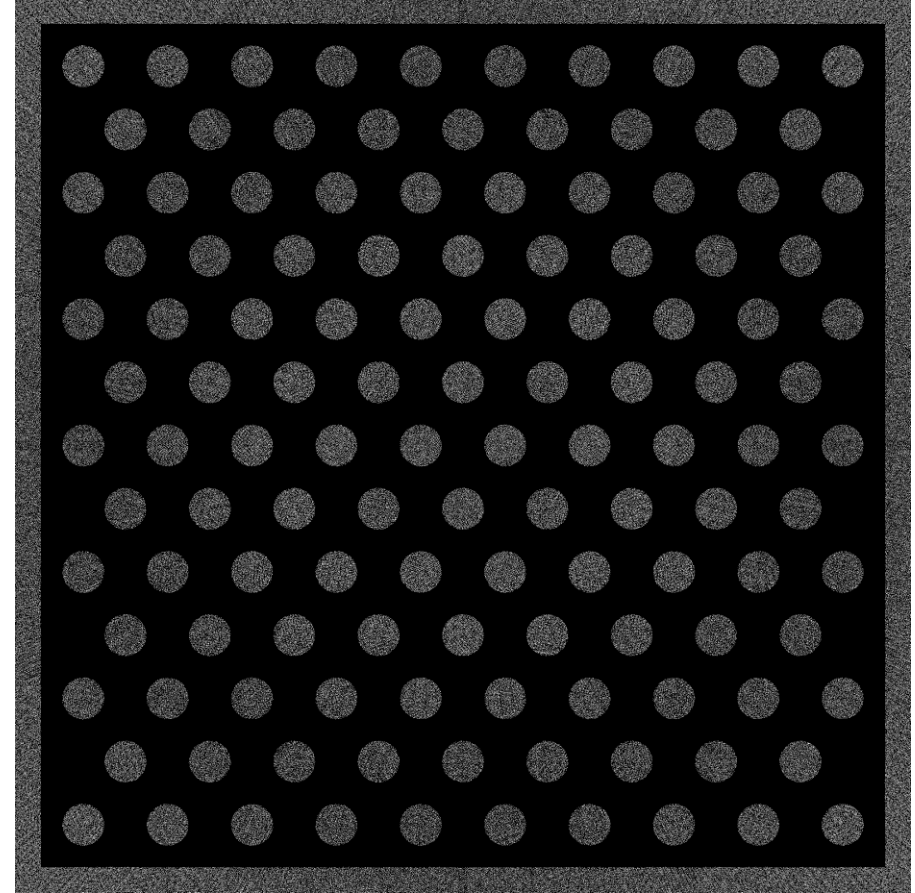
Laser Intensity at $1.8E15 \text{ W/cm}^2$

At higher intensities hot plasma is formed which emits recombination radiation

Optic Studio Simulations

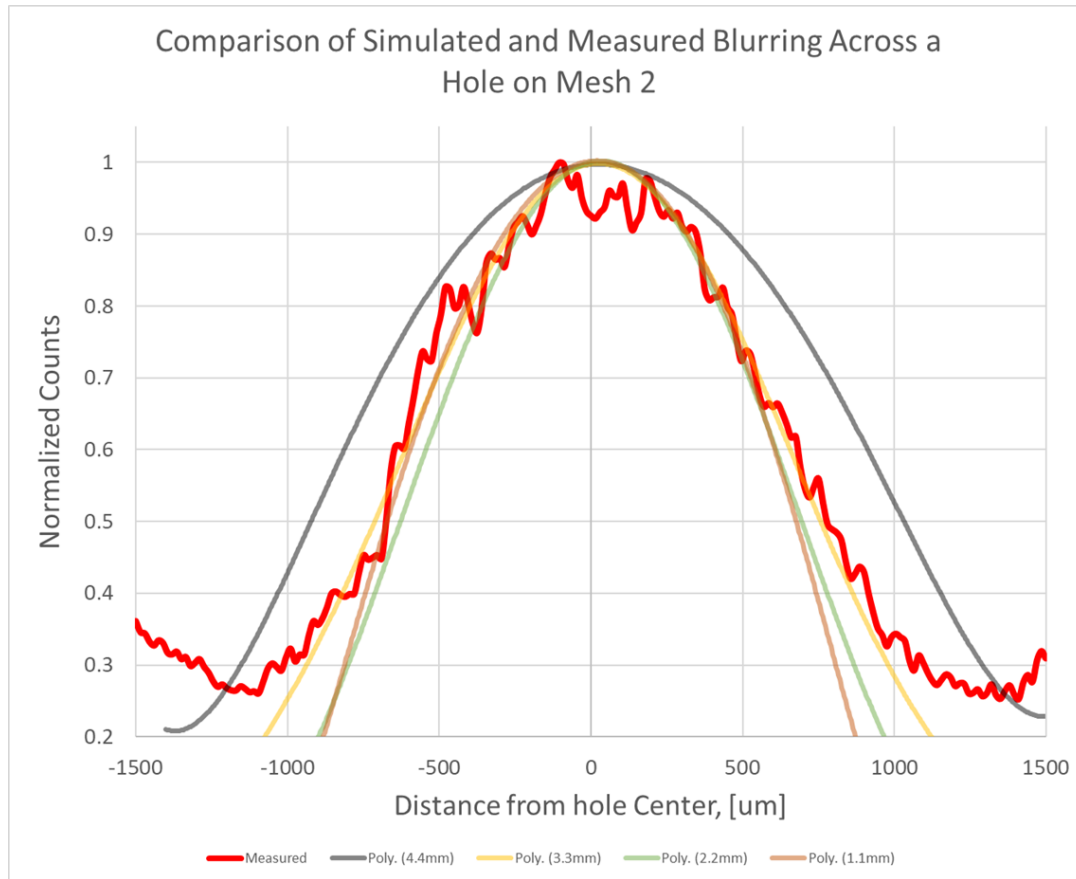


3.3 mm Bulb

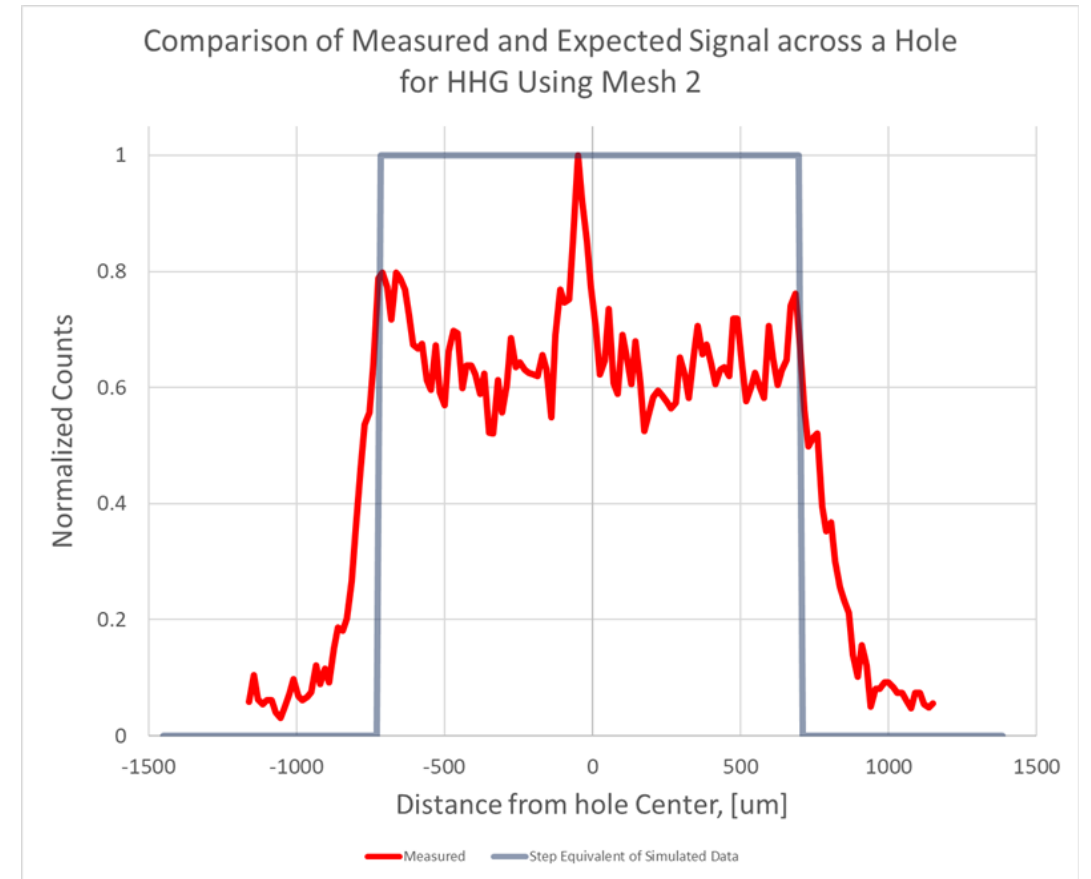


Focused Beam

Comparing Simulated and Measured Blurring

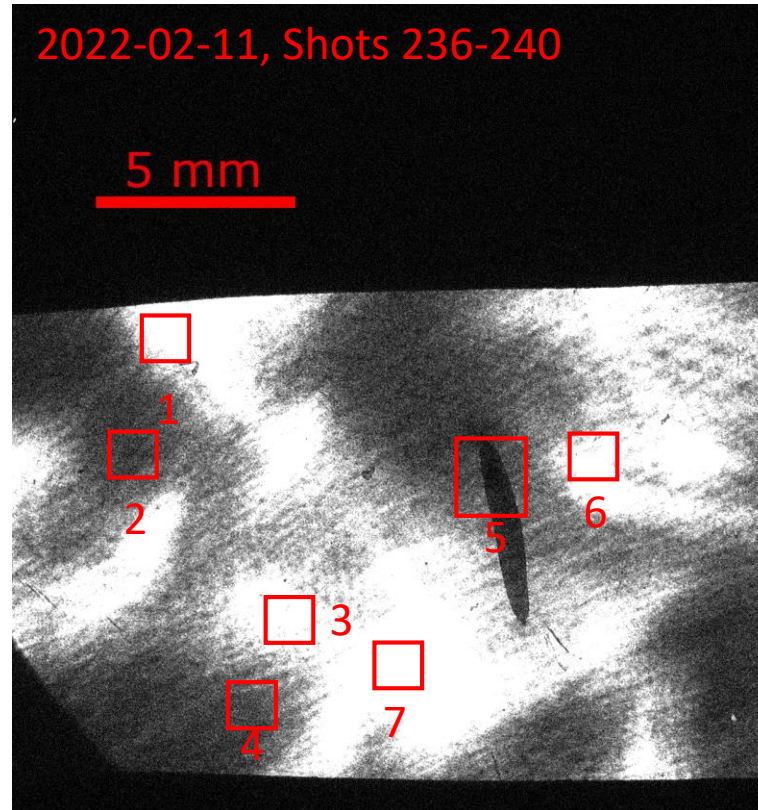
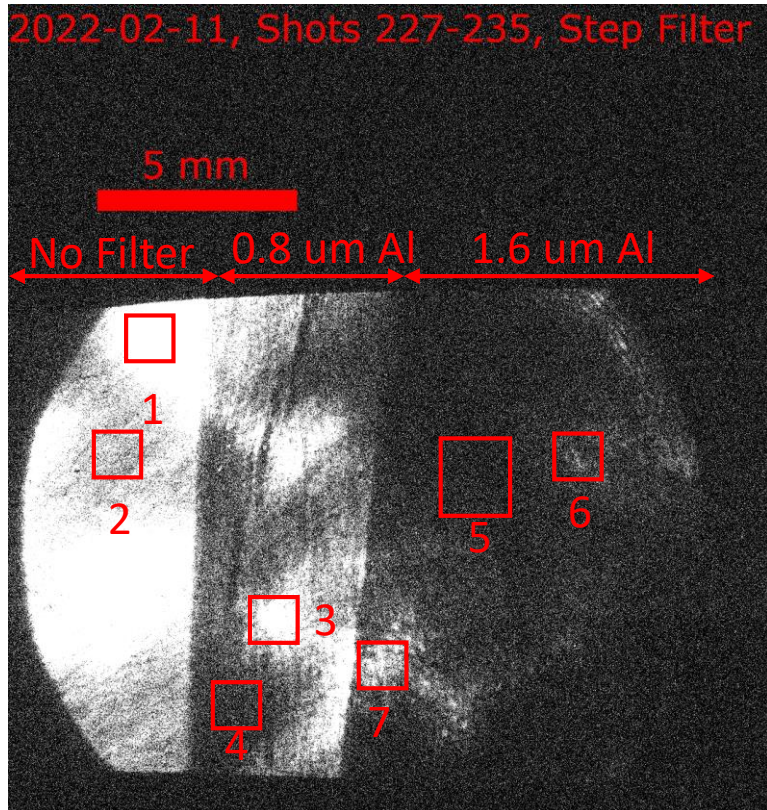


XUV Bulb



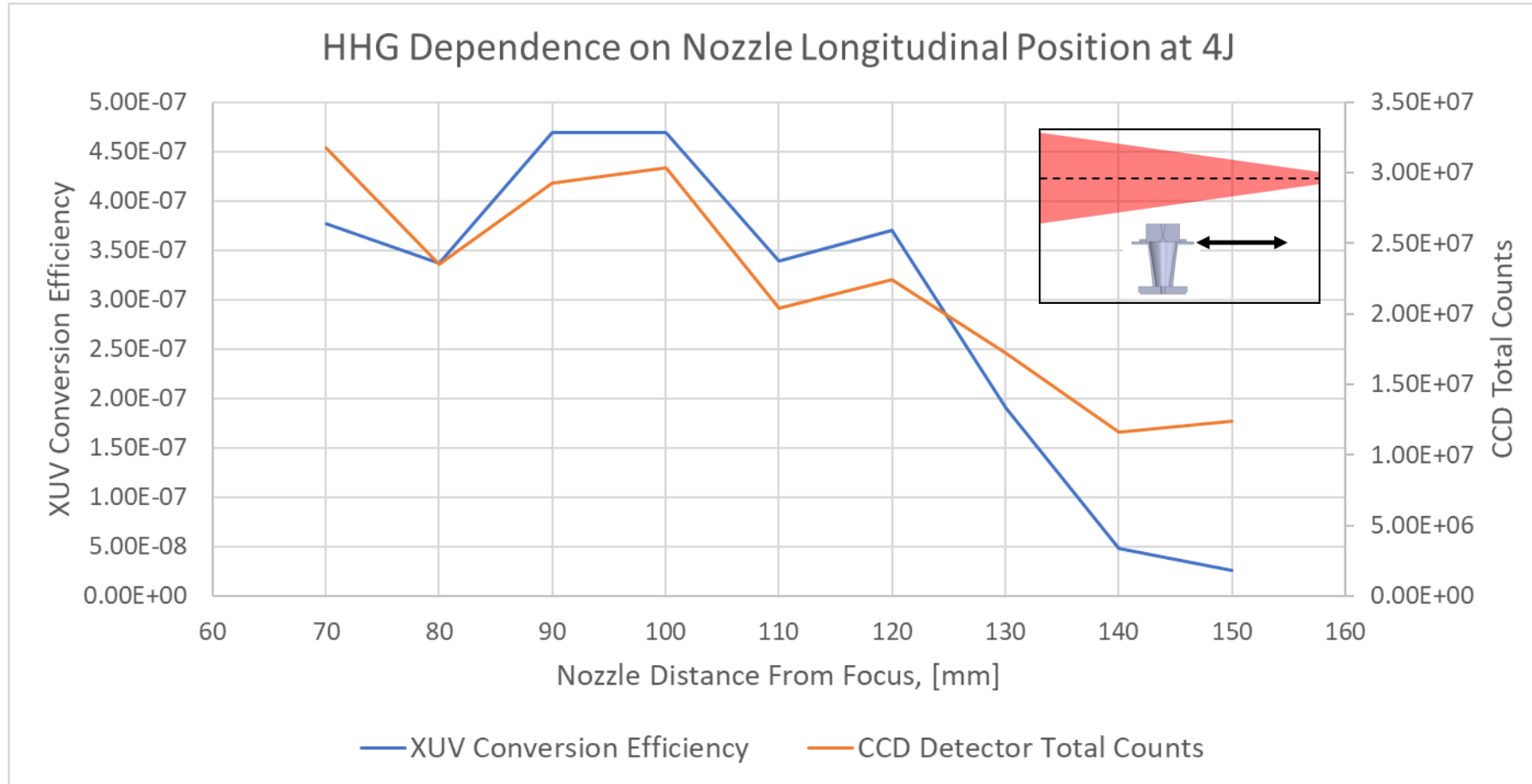
HHG

Step Wedge

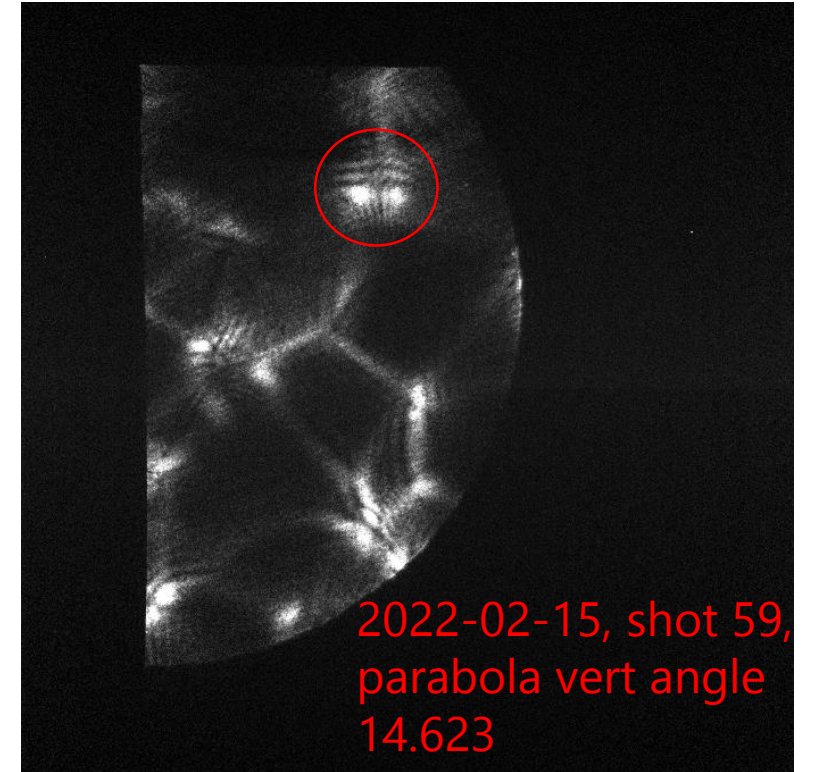
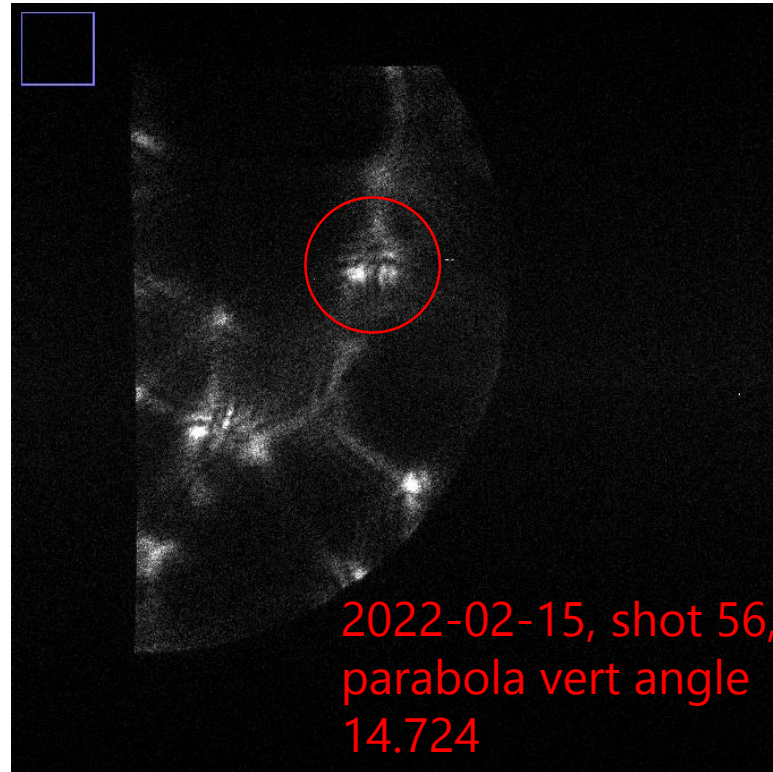
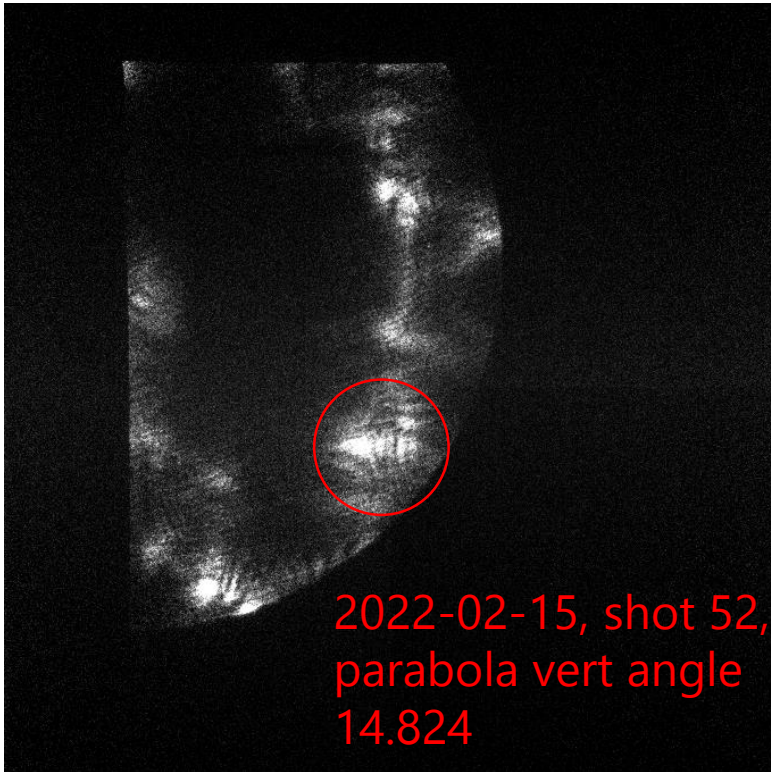


Attenuation	
Point 1	0.77
Point 2	0.92
Point 3	4.62
Point 4	3.62
Point 5	4.26
Point 6	19.43
Point 7	31.01

Scaling with Longitudinal Position



Changing Off Axis Parabola



Beam Spot Ablation Pattern

From Another Experiment



From Our Experiment

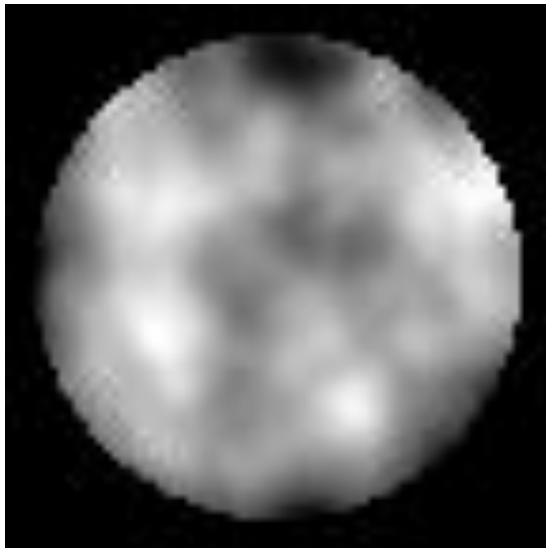


Beam Spot Ablation Pattern

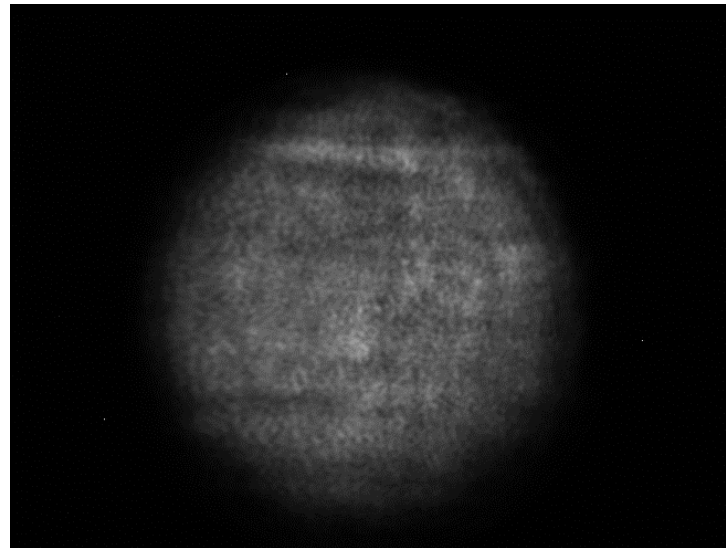


Beam Profiles for 2022-02-23

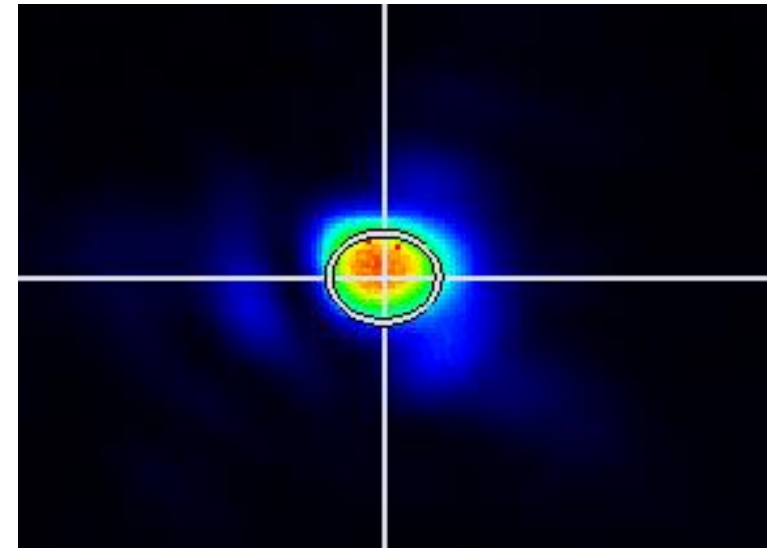
Wavefront



Near-Field

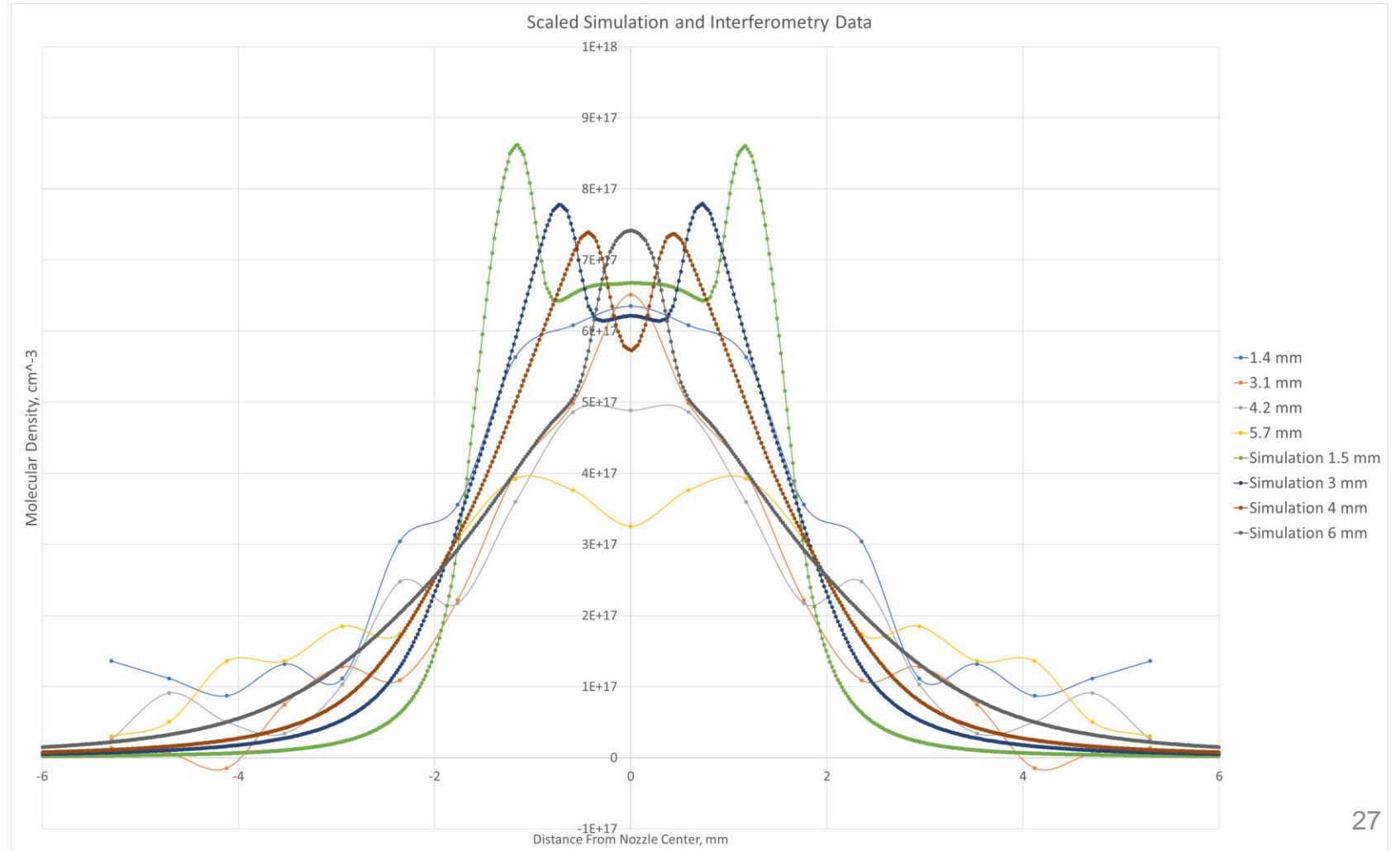


Far-Field



Interferometry/Simulation Results

- Data for the 3D Printed Nozzle
- Gas: Nitrogen
- Backing Pressure of 230-200 psi
- 15ms after opening
- Open for 20ms
- Opens at 0ms



Carlos Interferometry

- Data for the Brass Nozzle
- Gas: Argon
- Backing Pressure of 20 bar (290 psi)
- 0ms after opening
- Open for 7ms
- Opens at -4ms

