Efficient Generation of UV Pulses Through Four-Wave Mixing in Hollow Core Fibers

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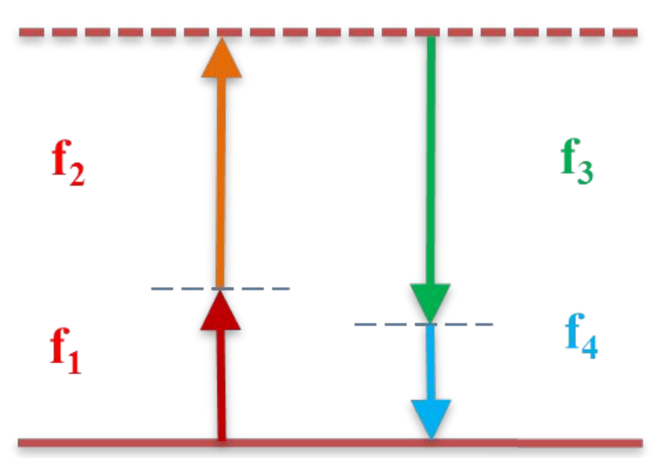
Introduction

Four Wave Mixing Process

- Nonlinear optical effect arising from at least two frequency components interacting in nonlinear medium
- Phase sensitive→ 4WM can only happen under proper phase matching conditions

UV pulse generation

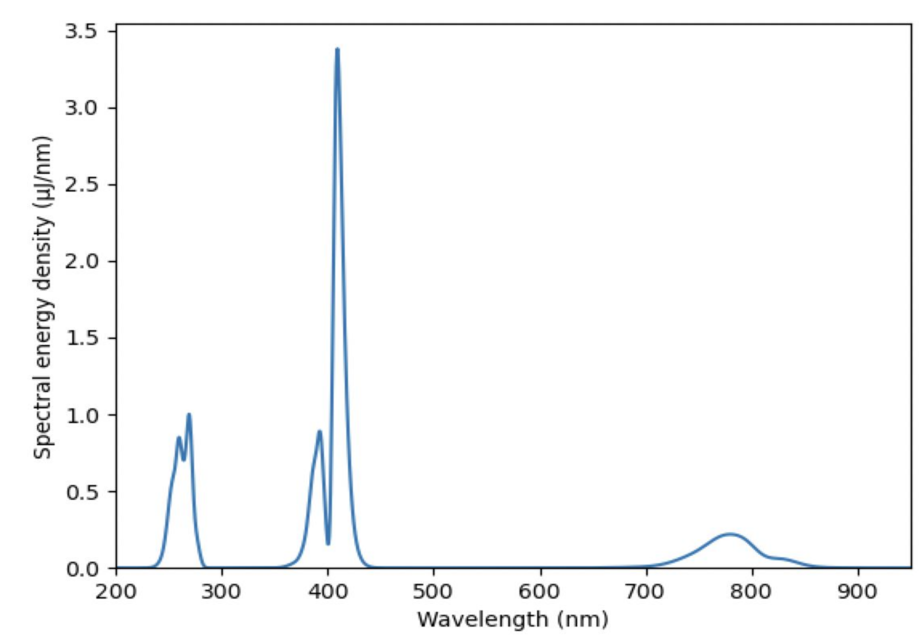
- The 4WM process can be applied to the generation of optical pulses in the UV spectrum with the use of gas-filled hollow core capillary fibers
- The properties of the signal pulse are dependent on the correct phase matching conditions, determined by both the fiber parameters and certain pump and seed pulse properties
- A cascaded 4WM process occurs where the first signal pulse is involved in the creation of a fourth frequency



Parameters and Phase Matching Conditions

Pump and **Seed:** wavelengths, pulse energies, pulse duration, polarization
Fiber: Gas type (He, Ne, Ar), Length, Radius, Pressure

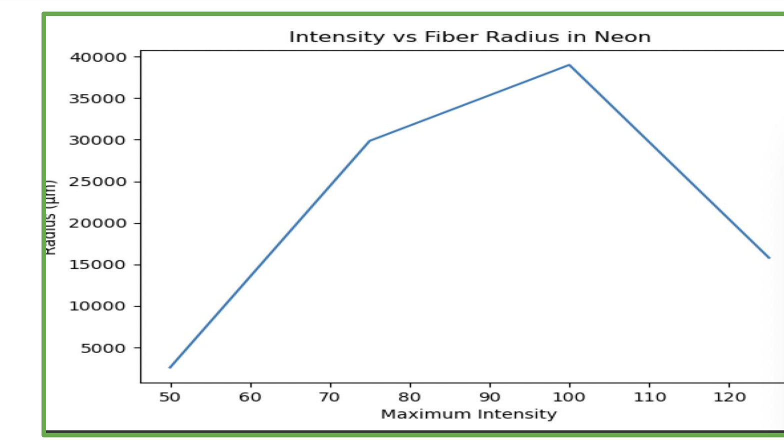
- Due to the large number of parameters affecting this process optimization via numerical simulations provides the ideal route to designing experimental systems in the lab



Ytterbium Laser Systems for LCLS II

- For the next generation of high repetition rate
- experiment at LCLS Yb lasers will be exploited instead of Ti-Sapphire.
- The longer pulse duration and wavelengths of these system require re-optimization of the phase matching parameters.

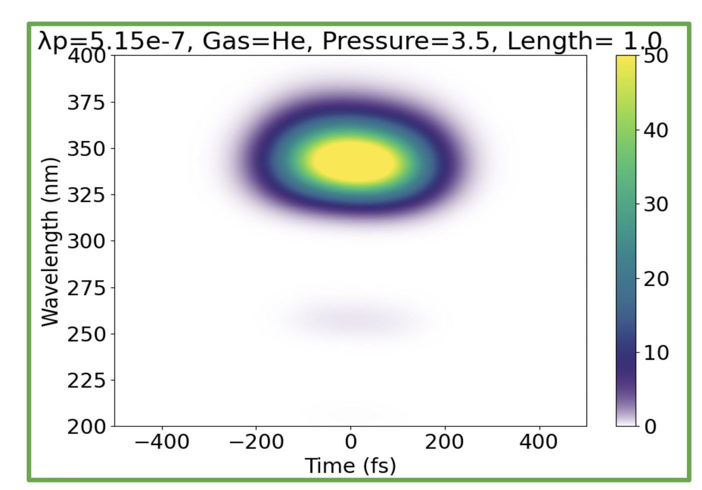
	125μm	100μm	75μm	50μm
Ne(3w)	1.0	1.5	2.75	NA
Ne(4w)	0.25	1.0	1.6	2.5
He(3w)	2.25	3.5	5.0	NA
He(4w)	1.25	2.0	3.6	NA

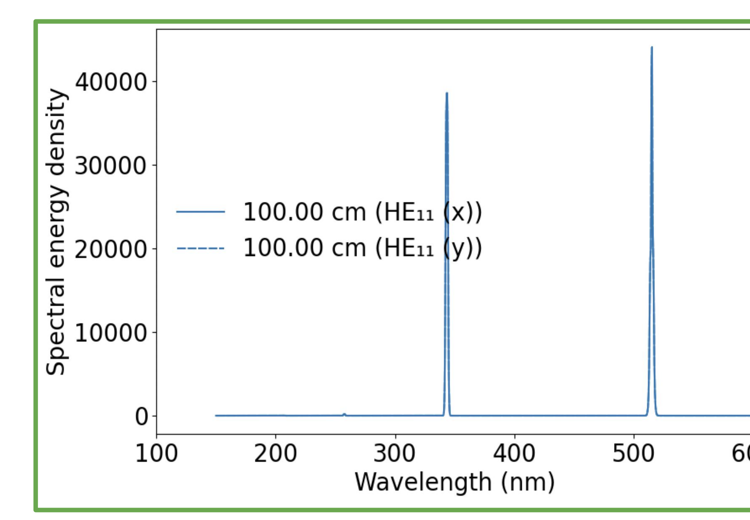


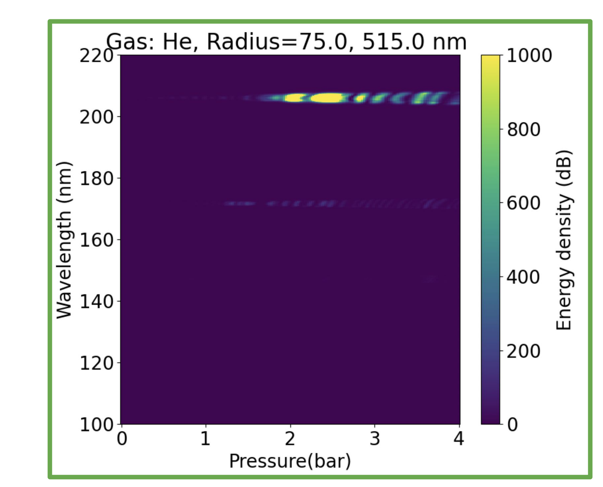
To simulate in Luna package

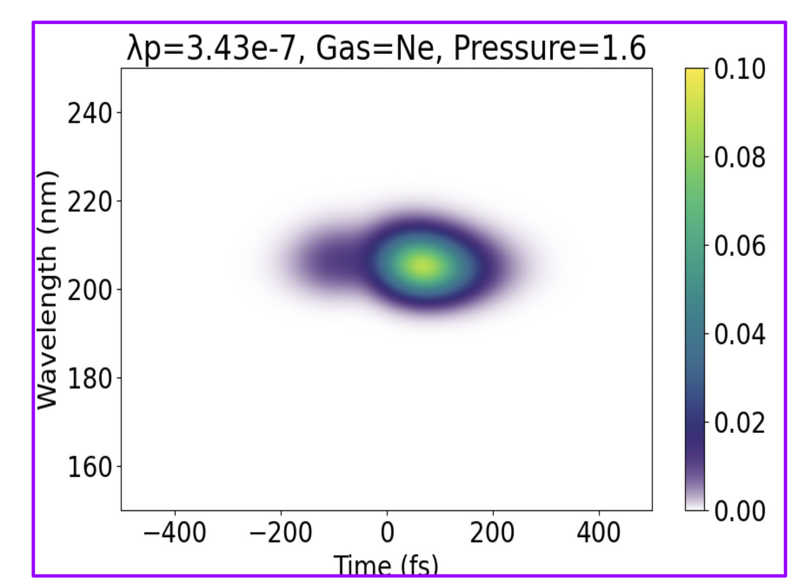
- Two different Pump pulses: 515 nm/500μJ and 343 nm/200μJ
- Seed Pulse: 1030 nm/500 μJ
- Long duration pulses (330 fts)

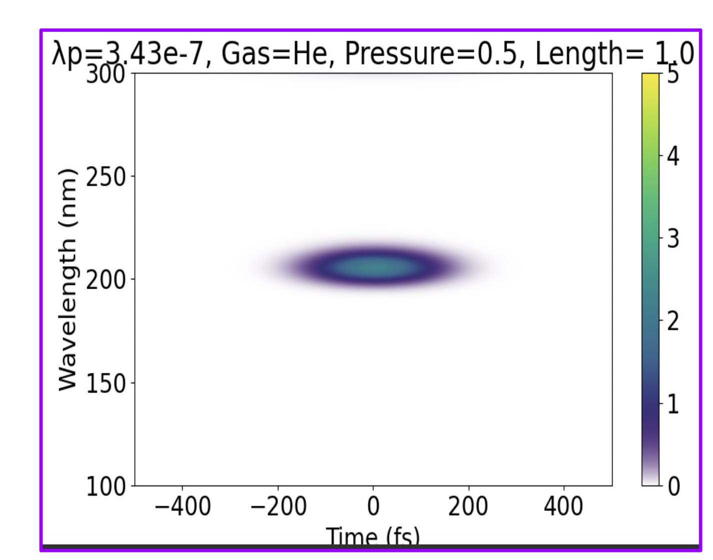
Utilizing prior simulations to find optimal conditions for UV generation

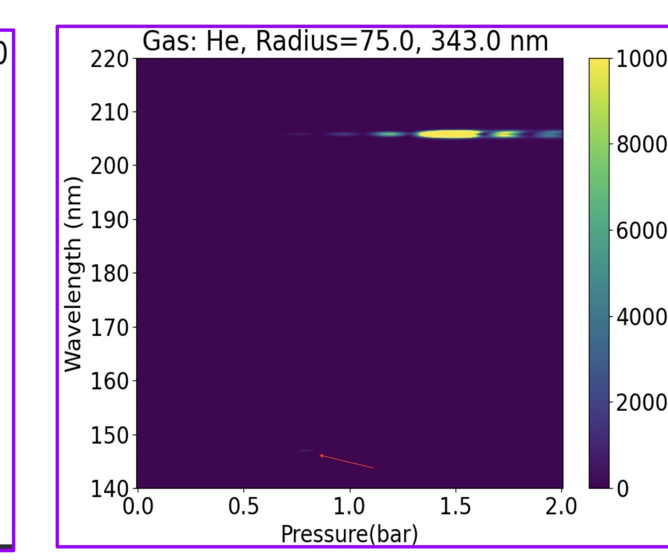




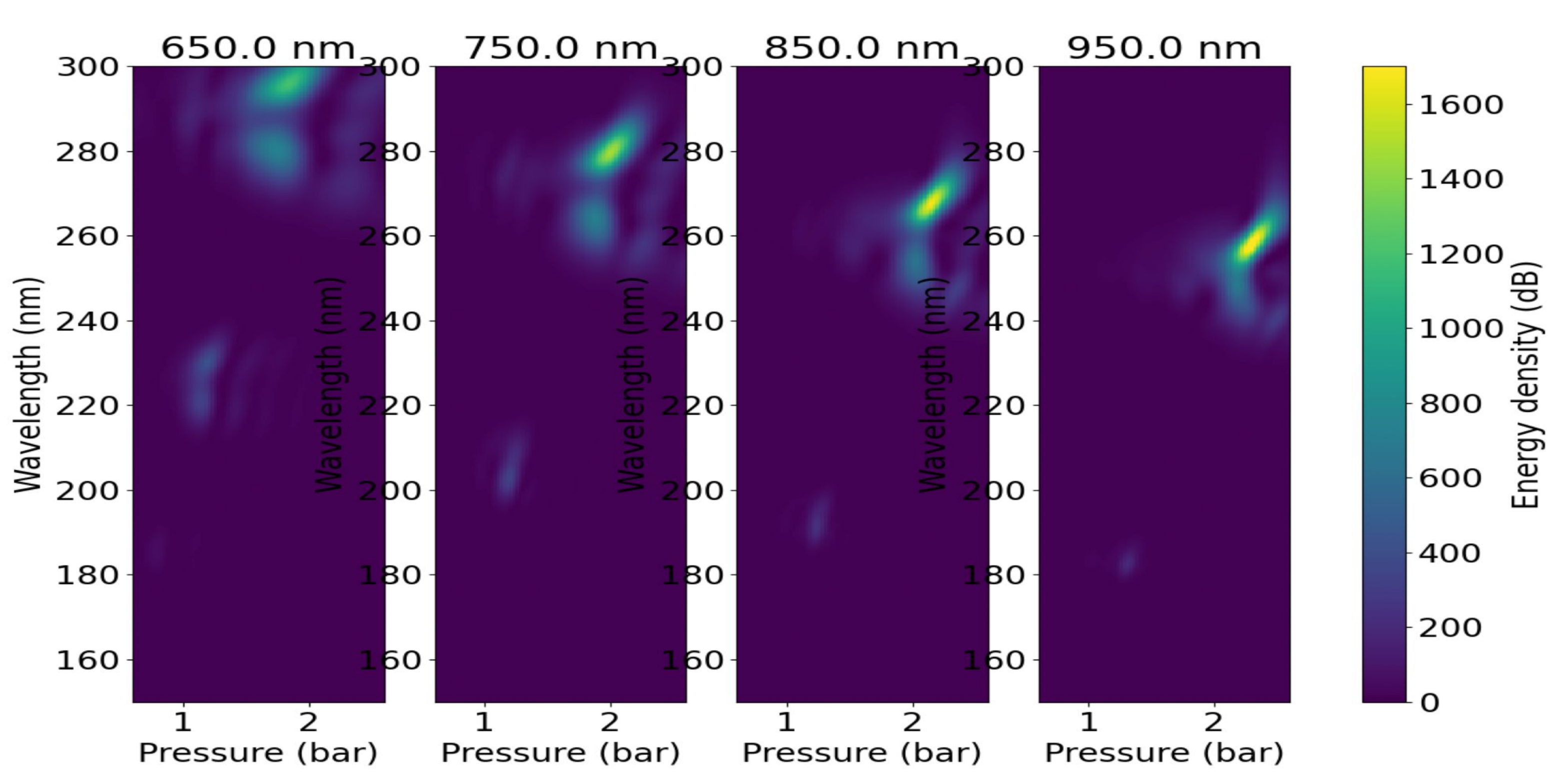




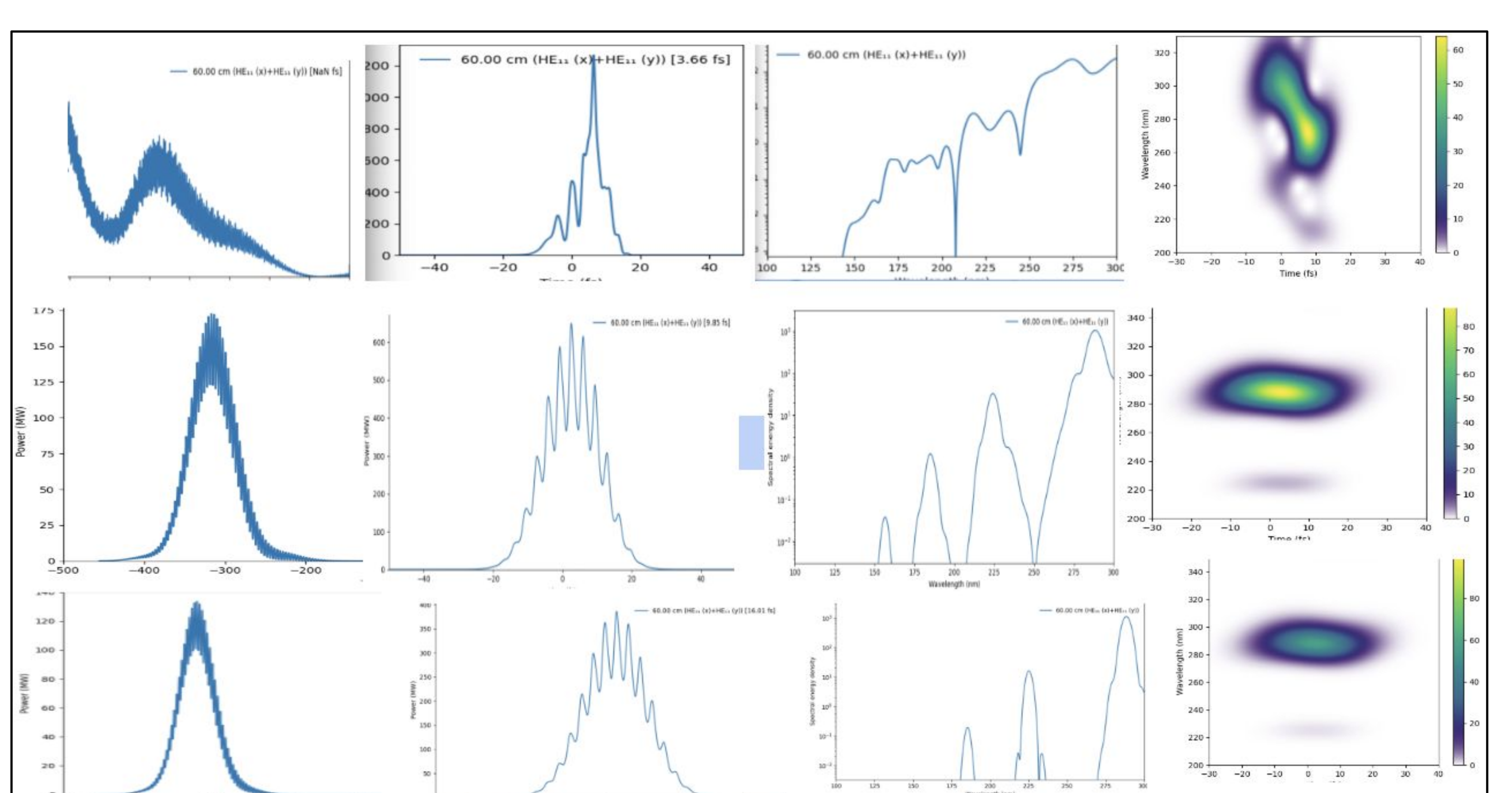


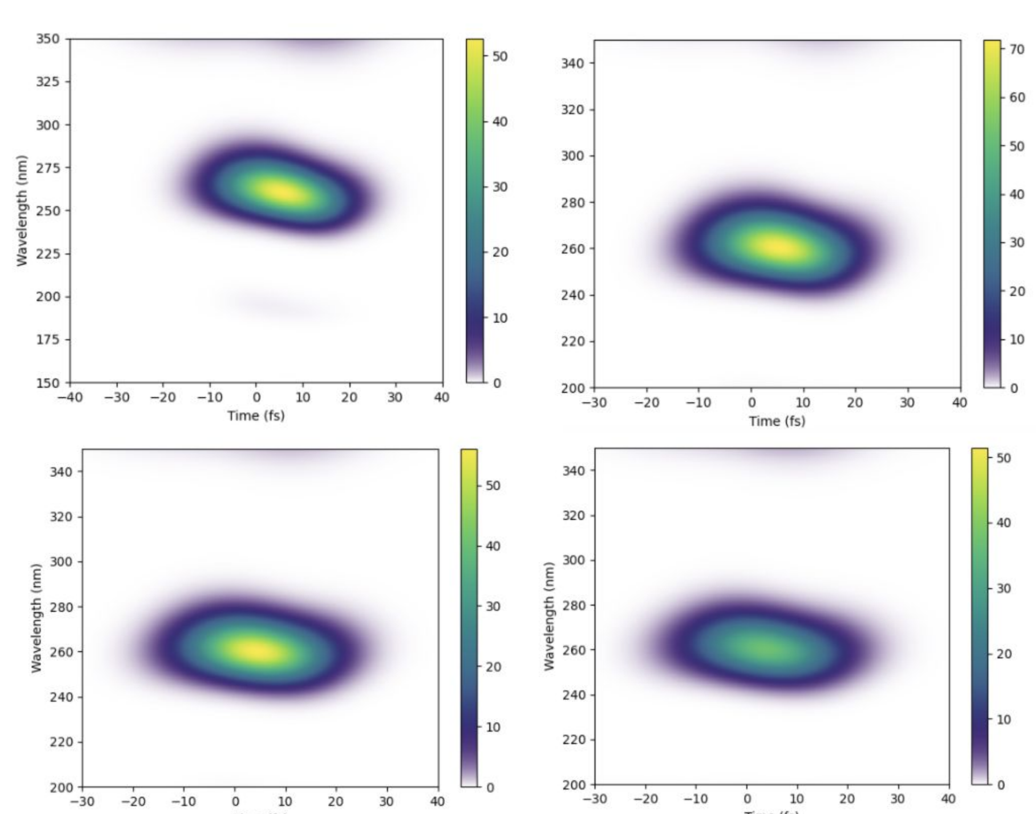


Ti-Sapphire Laser Systems for LCLS I



- Used Luna package in Julia to run simulations
- Initially used parameters of Ti-sapphire lasers to create streamlined process to collect data around optimization of 4WM
- Ideal pressure was found proportional to seed wavelength
- Phase control and Intensity (based on paper by Durfee Et al).
- Propagation through MgF_2 to document impact of dispersion on phase control (i.e. to simulate delivery to an experimental endstation)





Conclusions and Outlook

- Ultrafast pulses in the UV spectrum are critical to studying photochemical reactions, particularly for ultrafast dynamics involving the coupled motion of electrons and nuclei.
- UV generation in gas filled HCF's avoids the challenges posed by solarization of materials and thermal challenges in associated with nonlinear crystals
- These simulations provide a blueprint for designing the next generation of systems for the Ytterbium laser systems being exploited at LCLS-II

Next Steps

- Create a more robust set of simulations for the 343 nm pump case for extending into the vacuum ultraviolet .
- Fine tune to minimize double peaked structure of signal pulse due to spectral broadening
- Have more direct control over energy levels of signal pulse

Acknowledgements

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