

# Generation and Characterization of Femtosecond DUV Laser

## Pulses via Four Wave Mixing in Hollow Capillary Fibers

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### Introduction

#### ? Why Deep Ultraviolet (DUV) Pulses?

- Many fundamental physical processes occur on femtosecond timescales
- DUV photons can uniquely drive **electronic motion** in most atomic and molecular systems
- Femtosecond DUV pulses pump/probe ultrafast processes



**Goal:** generate femtosecond (fs,  $10^{-15}$ ) 206 nm pulses

#### ? How are femtosecond pulses usually generated?

Typically, we create UV fs pulses using non-linear crystals:



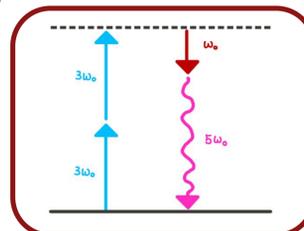
#### However, these crystals ...

- Absorb UV photons
- Get damaged by the intense light
- Experience phase matching issues

**Solution** → Use Hollow Capillary Fibers!

#### ? What are Hollow Capillary Fibers (HCFs)?

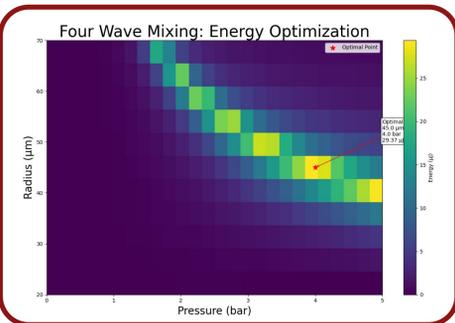
A thin hollow glass fiber filled with a rare gas, used to guide light



Using a process called **four wave mixing (FWM)**, DUV wavelengths with high pulse energies that are often inaccessible can be generated

### Simulations: Optimizing HCF Conditions for Maximum Pulse Energy

#### ? What HCF conditions should be changed?

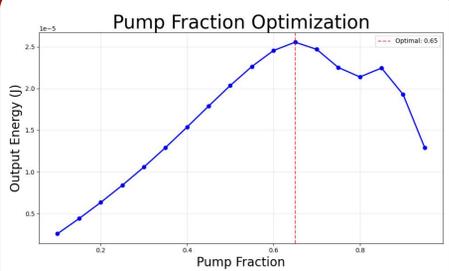


#### Pressure vs. Radius

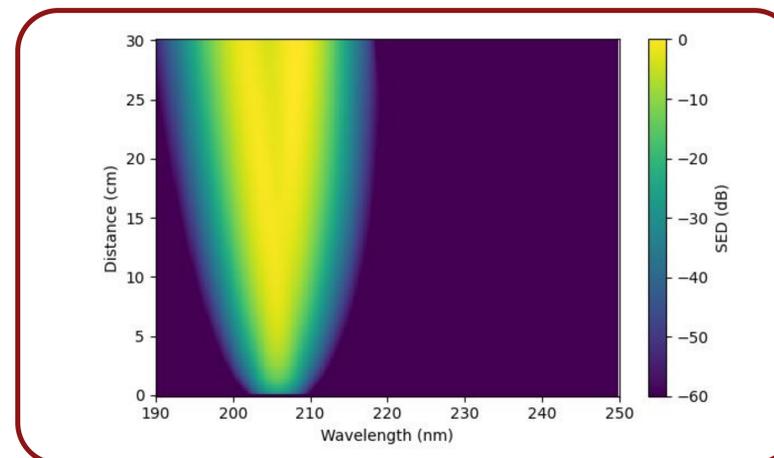
- Optimal region
  - ~4.0 bar
  - Radius of 45  $\mu\text{m}$
- We utilized 50  $\mu\text{m}$  HCF
  - 45  $\mu\text{m}$  were not being produced

#### Pump to Seed Ratio

- Pressure, radius, length, total energy held constant
- Tested ways to distribute energy between the pump (1030 nm) and seed (343 nm)
- Optimum conversion efficiency occurs when 65% of the energy goes to the pump pulse.

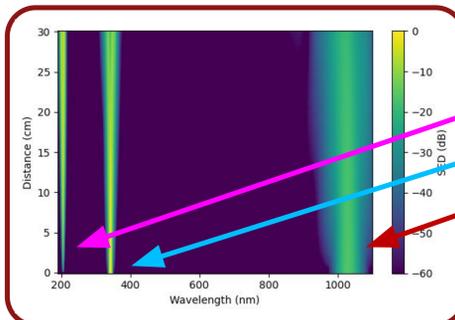


#### ? What other conditions should be considered for ultrafast DUV pulse generation?



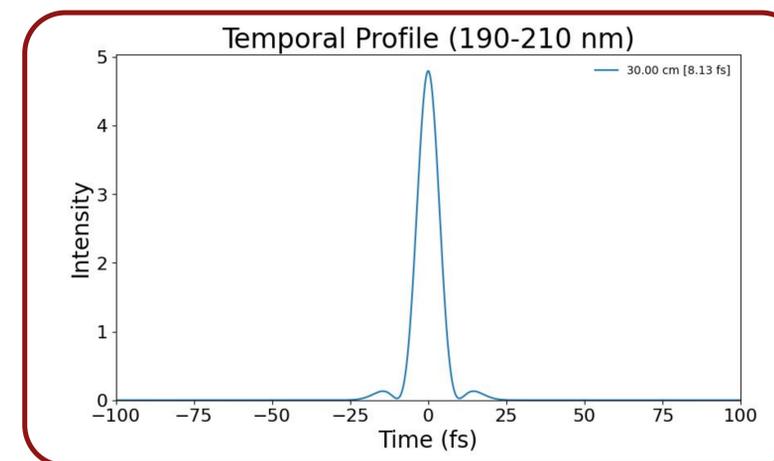
#### 5th Harmonic

- Spectral energy density (SED), pulse energy per unit wavelength
- Following **5th Harmonic** generation, the DUV pulse undergoes spectral broadening
- Results in sub 10 fs bandwidth



#### Propagation in HCF

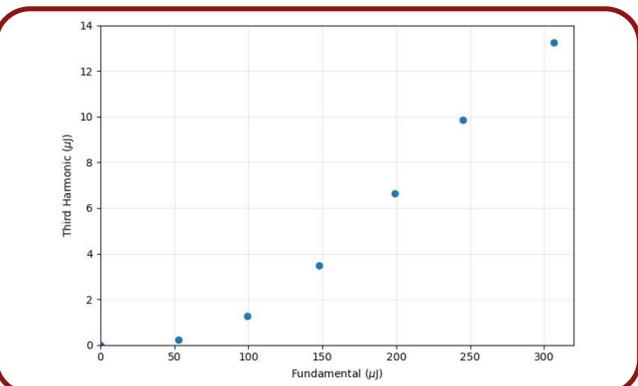
- 5th Harmonic - 206 nm
- 3rd Harmonic - 343 nm
- Fundamental - 1030 nm
- Generation of 5th harmonic as pulse propagates down the HCF



#### Fourier Transform Limit

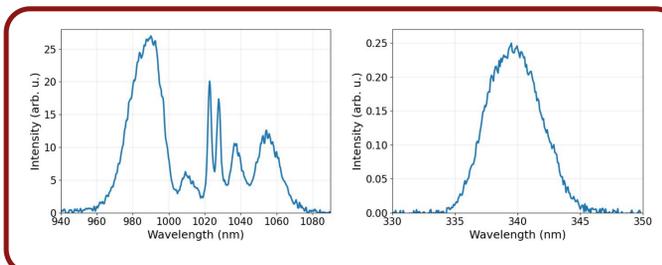
- Following spectral broadening, the generated bandwidth supports an 8 fs pulse
- Subsequent dispersion management (e.g. prism compressor) enables pulse compression

### Experiment Design: DUV Pulse Generation via FWM



#### Third Harmonic vs. Fundamental

The expected nonlinear scaling behavior observed between the **Fundamental** and **3rd Harmonic**

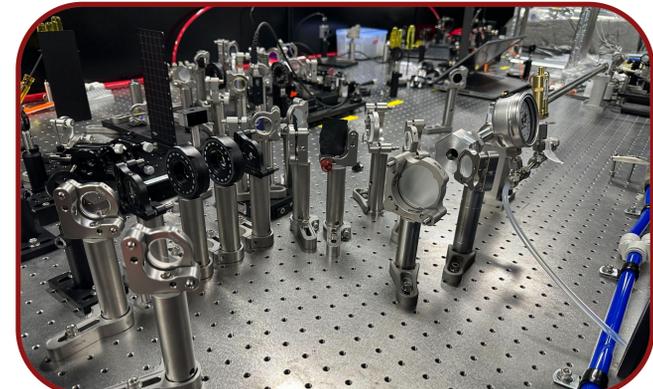


#### Left Plot

**Fundamental** spectrum of spectrally broadened Yb laser system

#### Right Plot

**3rd Harmonic** spectrum following up conversion in bulk crystals



- **3rd Harmonic** generation scheme with **Fundamental** recombination for the **four wave mixing** scheme
- HCF seen on the right

References:

