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GRAY LASER & EMIR OPA

Non-linear optics and harmonic generation in ZnS using femtosecond mid-IR near zero dispersion wavelength

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Overview

- High harmonic generation (HHG) with high efficiency is promising for new light sources, laser gain media, long wavelength detectors, and few-cycle pulse generation[1].
- Likely mechanism for harmonic generation in polycrystalline materials is random quasi-phase matching (RQPM)[2]:
  - Random grain orientation → random-walk in phase space
  - Robust, less expensive, and versatile with decent thickness scaling
- Expansion of previous work done with polycrystalline zinc selenide (ZnSe)[3].
- We study HHG and MIR pulse broadening in polycrystalline ZnS (Cleartran™) with ~3.6 μm pump (the measured zero group velocity dispersion[4]).

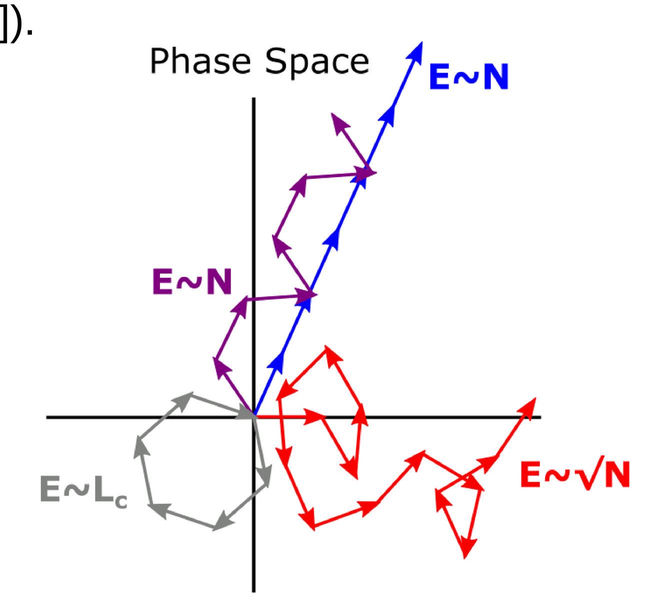
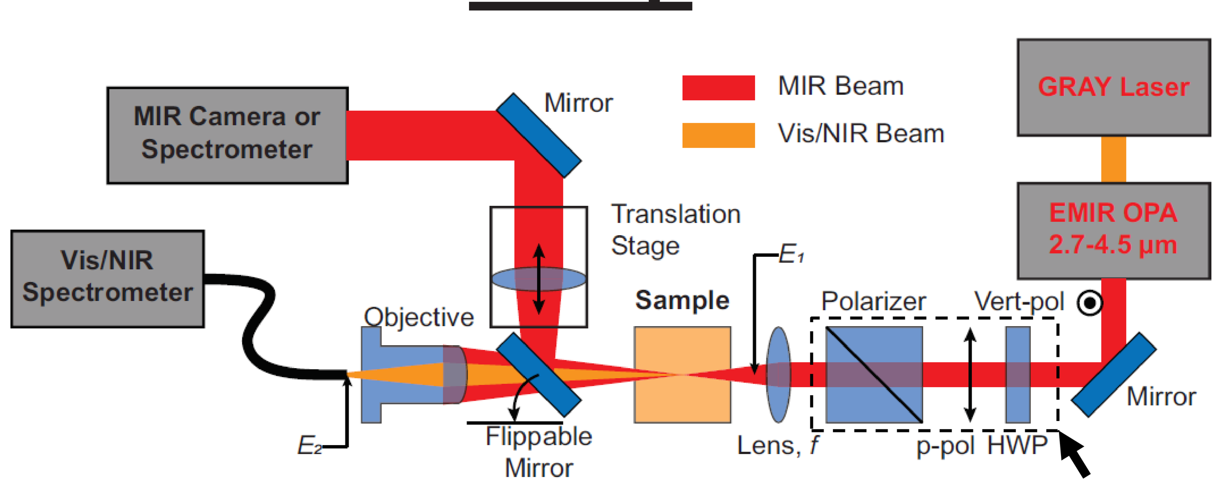


FIG 1: Phasor addition between pump and harmonics for various methods.
N: number of grains that the beam propagates through
L_c: coherence length of the material.
Inspired by M. Baudrier-Raybaut et al. [2].

Setup



CLEARTRAN™ SPECS:

- 3, 10, 20, and 40 mm thick
- Hot isostatically pressed poly-ZnS
- Most grains are zincblende [5]

PUMP BEAM SPECS:

- Central wavelength: 3.5-3.7 μm
- Pulse Duration: ~200 fs
- Rep Rate: 500 Hz
- Max Pulse Energy: 12 μJ

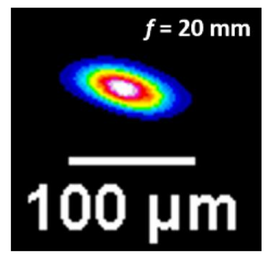
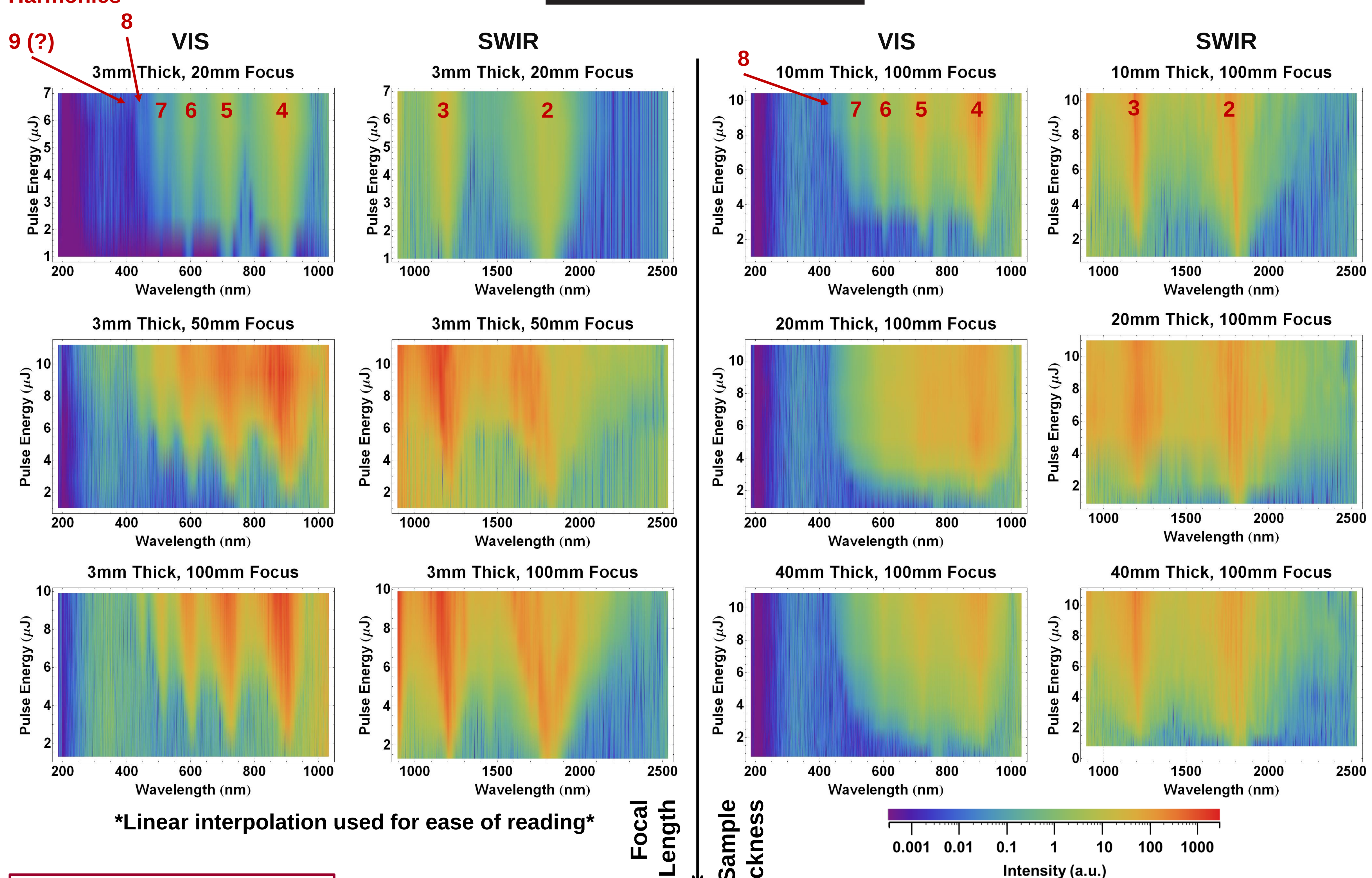


FIG 2: Focal spot profile at 20 mm focusing.

Lens focal length (mm)	100	50	20
Max pulse intensity (TW/cm²)	0.040	0.22	1.6

Harmonic Data



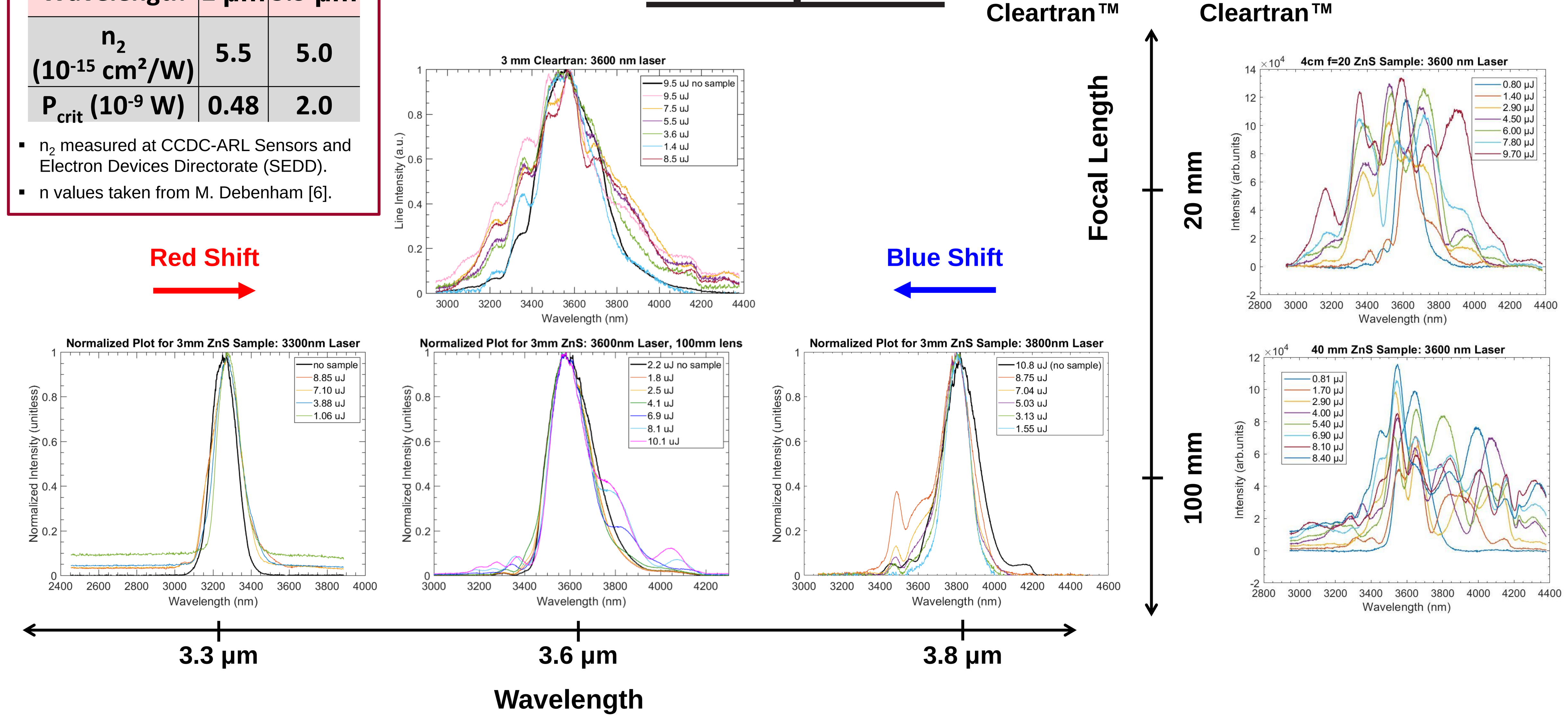
Linear interpolation used for ease of reading

n_2 Z-scan

Wavelength	2 μm	3.9 μm
n_2 (10^{-15} cm²/W)	5.5	5.0
P_{crit} (10^{-9} W)	0.48	2.0

- n_2 measured at CCDC-ARL Sensors and Electron Devices Directorate (SEDD).
- n values taken from M. Debenham [6].

MIR Spectra



Results

HARMONICS:

- **Measured 28% harmonic conversion**
- Continuum generation and filamentation in Cleartran™
- Harmonics become sharper with thinner samples/ more continuum generation for thicker samples
- Stronger harmonics and continuum at 50mm focal length than 20mm or 100mm
- 2nd harmonic weaker and broader than the 3rd harmonic for all power scans, possibly due to depletion
- Blue shift in harmonics when stronger than continuum

MIR SPECTRUM:

- More dispersion with shorter focal length
- Red shift for fundamental less than zero GVD wavelength, and vice versa

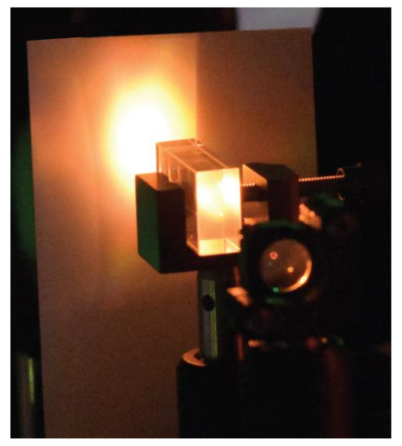


FIG 3: Picture of continuum generation and filamentation for 40 cm of propagation through Cleartran™.

Further Work

- Analyze power scaling for each harmonic and compare with sample thicknesses
- Thorough study of pump polarization dependence of harmonics and polarization of harmonics
- Compare results to unidirectional pulse propagation equation (UPPE) models as done previously for ZnSe [3],[7]
- Consider effects on harmonics as pump wavelength is shifted above or below 3.6 μm

Related Talk

❖ Michael Hastings, *Modeling Harmonic Generation in Polycrystalline ZnSe* (FM4M.2)

References

[1] H. Liang et al. *Nat. Commun*. **8**, 141 (2017).
[2] M. Baudrier-Raybaut et al., *Nature* **432**, 374 (2004).
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[4] A. Tokmakoff, *Dispersion properties of mid -infrared optical materials*, Univ. of Chicago (2016) http://tokmakofflab.uchicago.edu/documents/Dispersion of mid-IR optical materials.pdf
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Acknowledgements

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