



ONR MURI “Fundamental Studies of Nonlinear Optics and Laser-plasma Phenomena in Gases and Solids Using High-power LWIR Lasers”, October 25-26, 2018

Comparison of broadband microwave generation from single and two-color ultrafast mid-IR laser-produced plasmas in atmosphere

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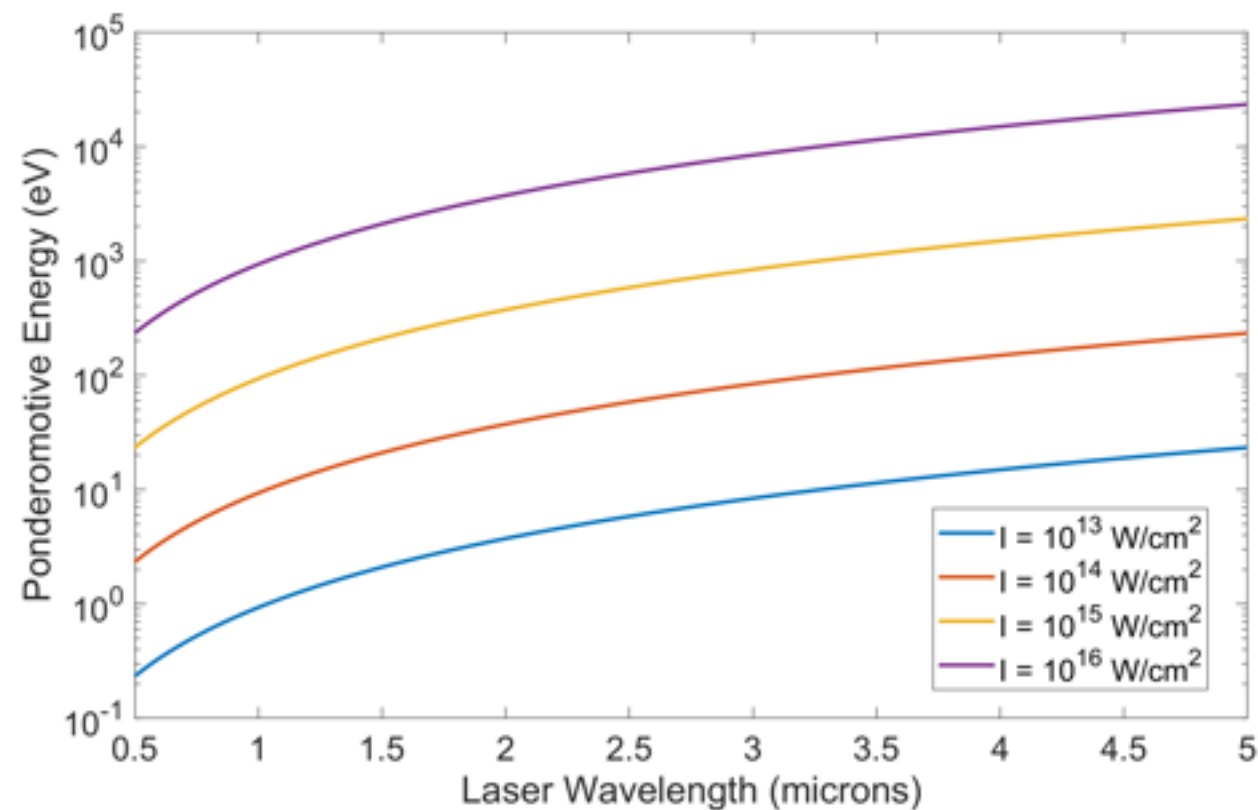
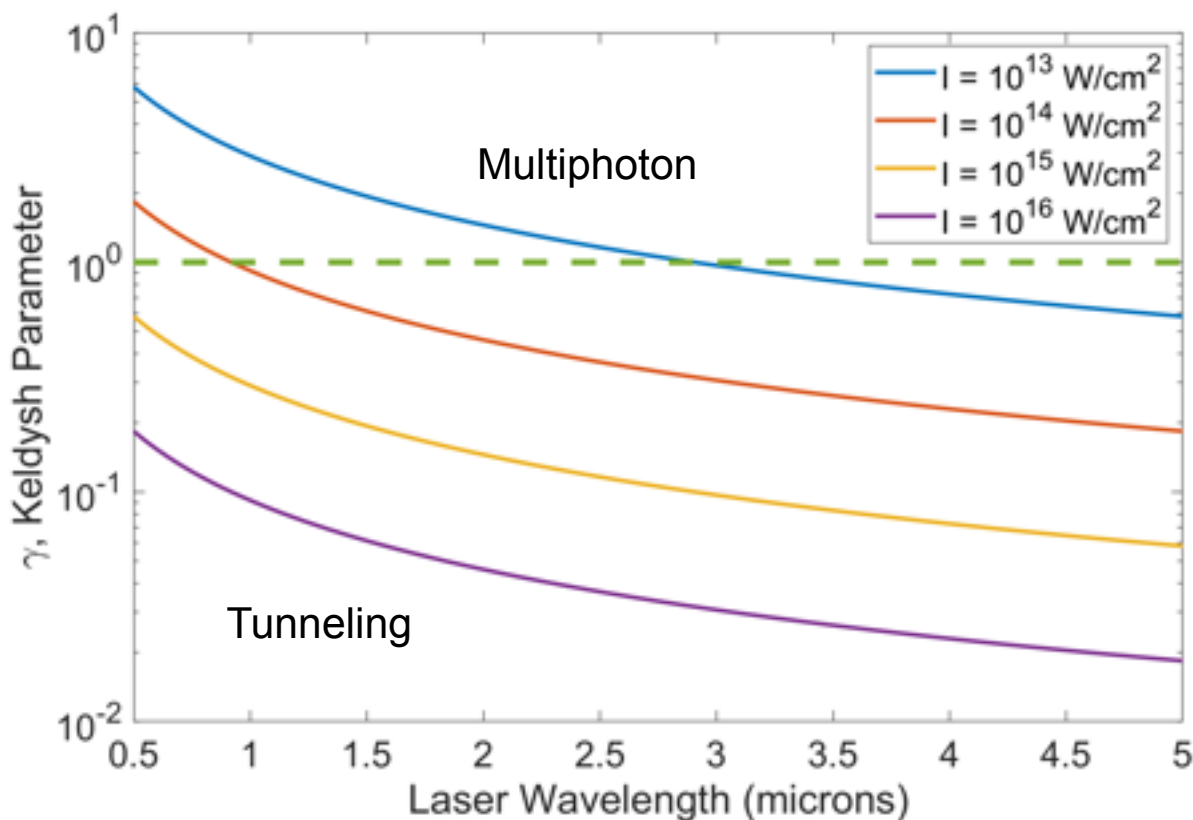
Robert Schwartz, Anastasia Korolov, Dogeun Jang, Daniel Woodbury, Ki-Yong Kim, Howard Milchberg



Karl Krushelnick

Laser-Plasma Physics in the Mid-IR

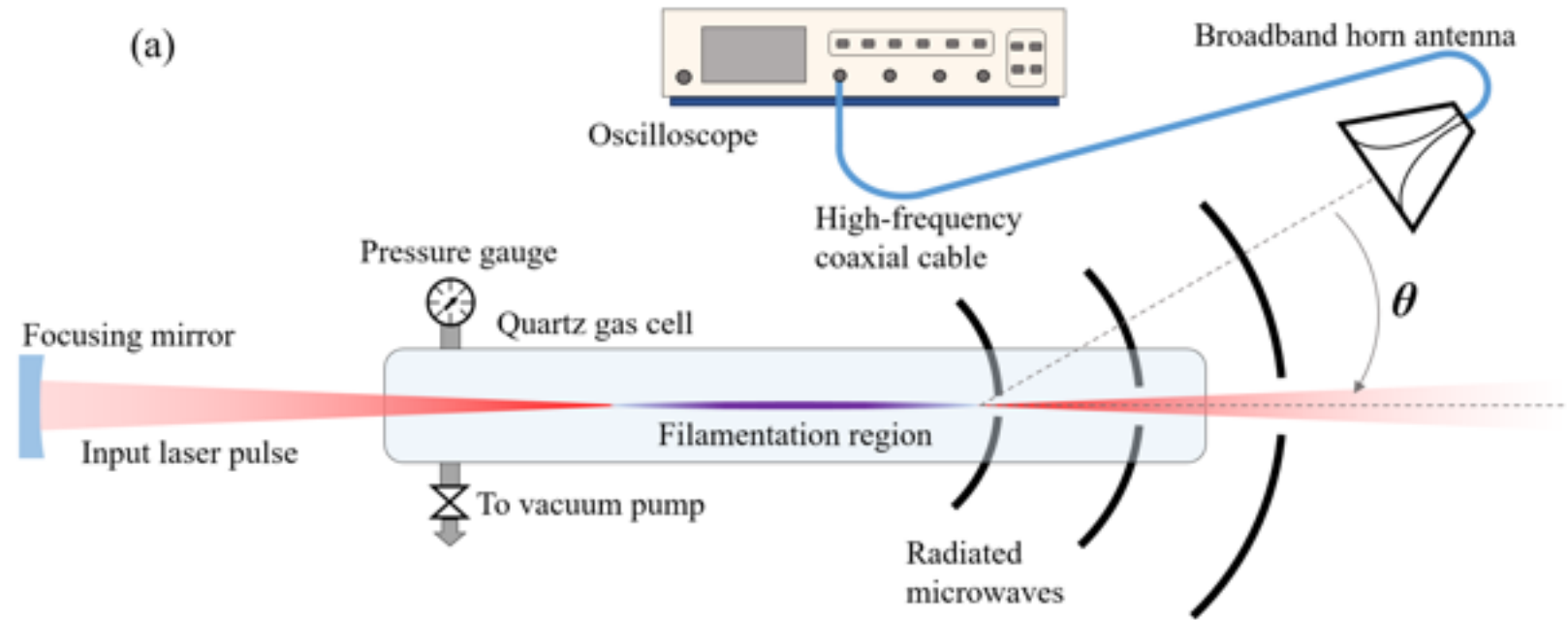
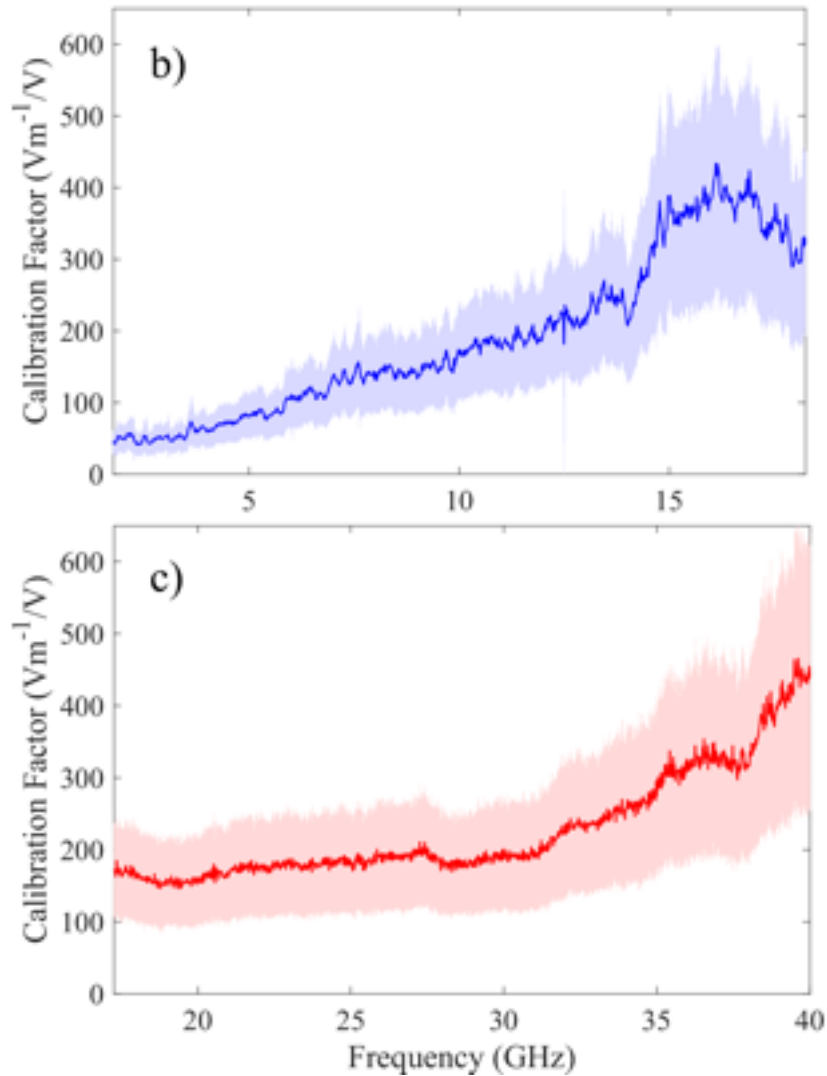
- Most experiments are performed in the near IR using Ti:Sapphire (800 nm) or YAG/glass lasers (~1000-1100 nm)
- Transition from multiphoton to tunneling ionization; ATI rate and electron energy spectra are wavelength dependent
- At long wavelength electron quiver and ponderomotive motions are in general more energetic for a given pulse intensity



Single vs Two-Color Air Plasma

- Yield of secondary radiation is related to current driven by the laser pulse in the plasma
- Previous studies almost exclusively treat THz generation – how might the microwave generation be related?
 - Is a similar pressure dependence to that reported for THz measurements observed?
 - Is microwave yield also increased in a two-color scheme?
 - Conversion efficiency?

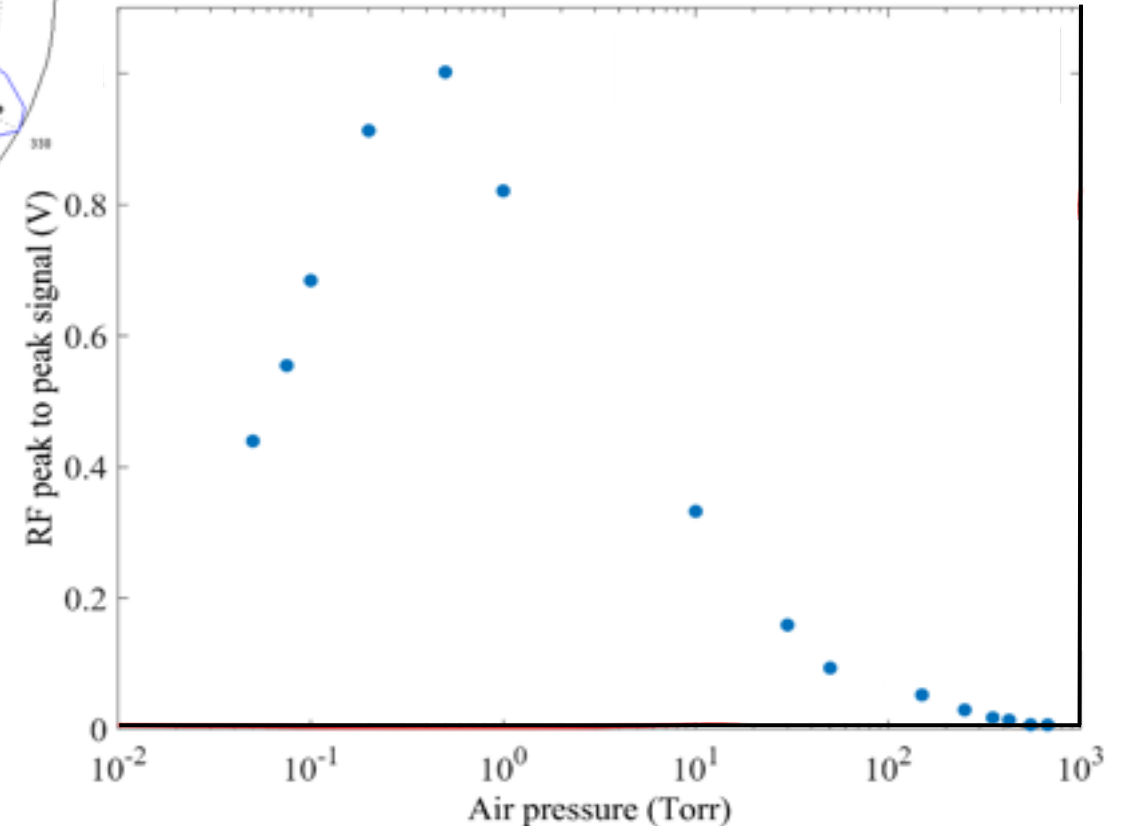
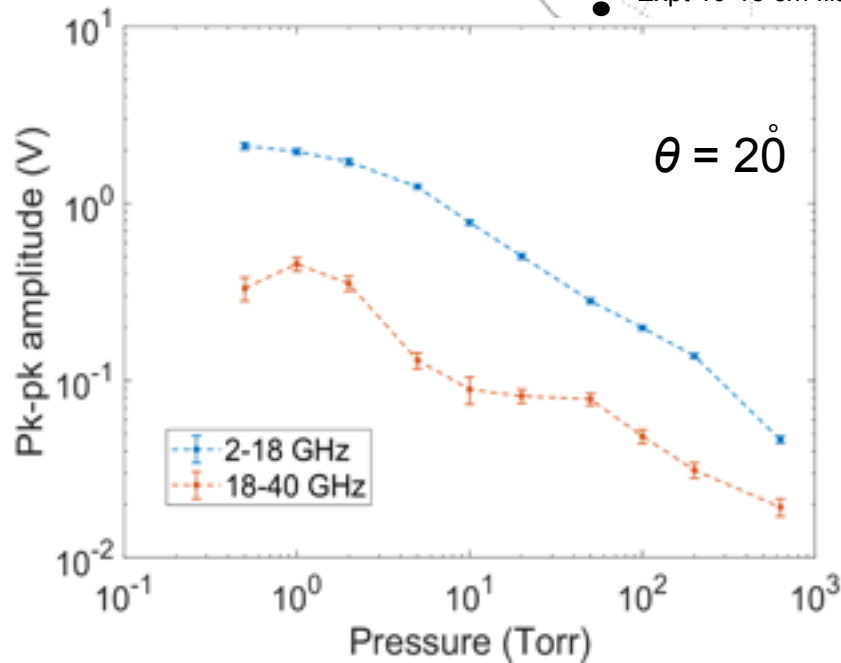
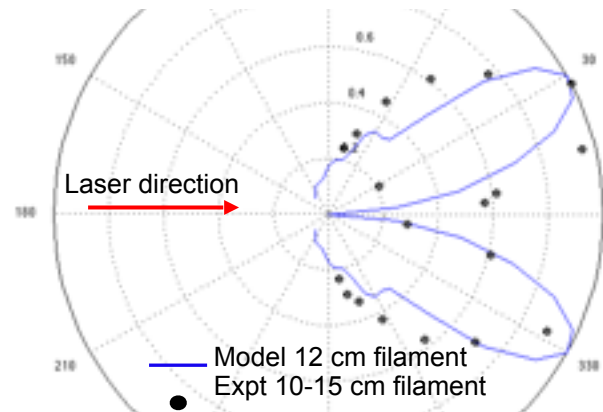
Experimental Setup: Single Color 800 nm



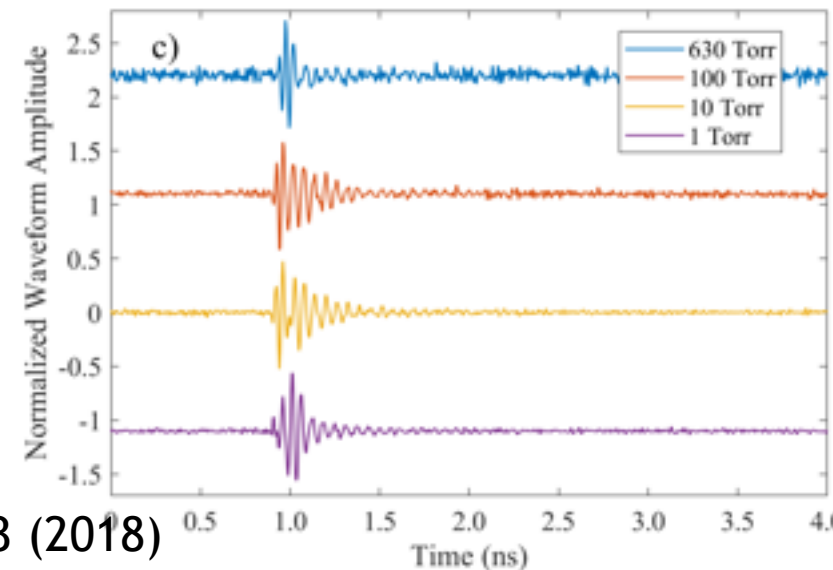
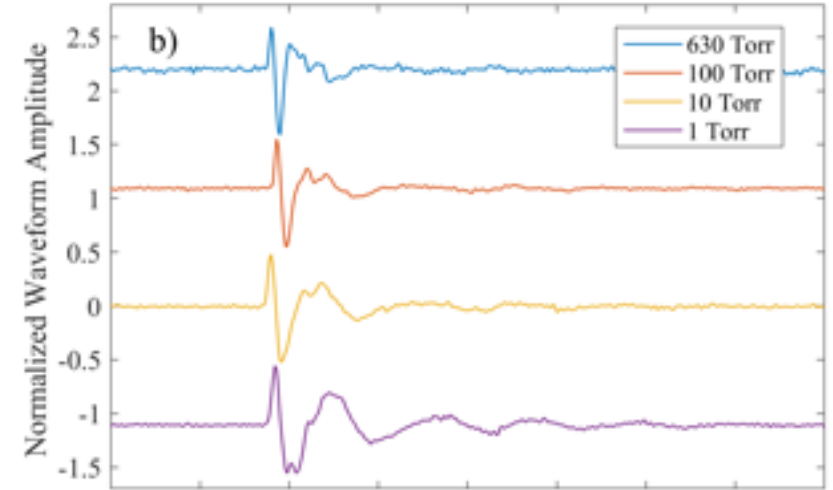
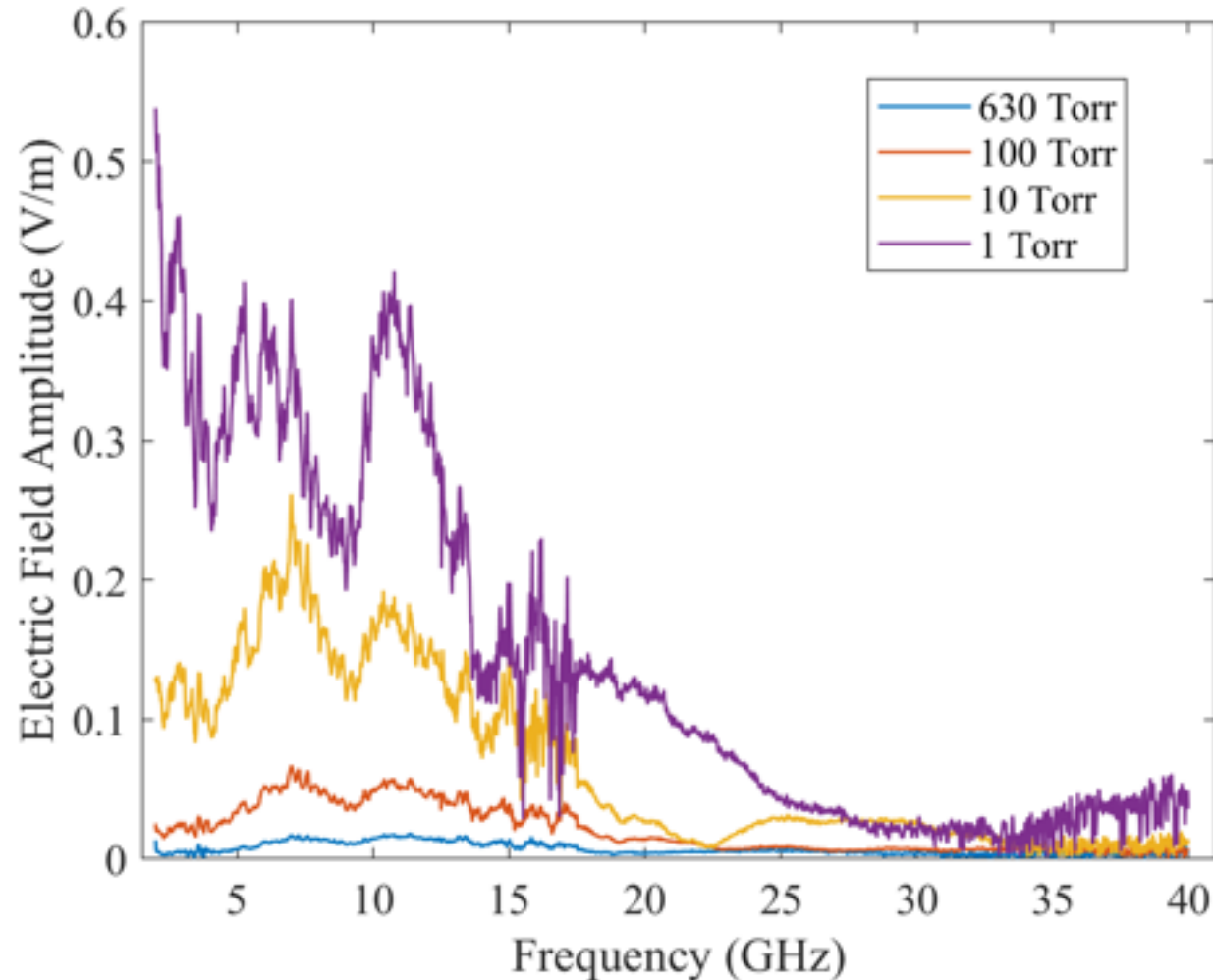
Single color RF Pressure Dependence

Pressure sensitivity as reported for THz, but dependence is much stronger

Yungjun Yoo et al. The 9th International Symposium on Ultrafast Phenomena and Terahertz Waves (ISUPTW) © OSA 2018 TuE2

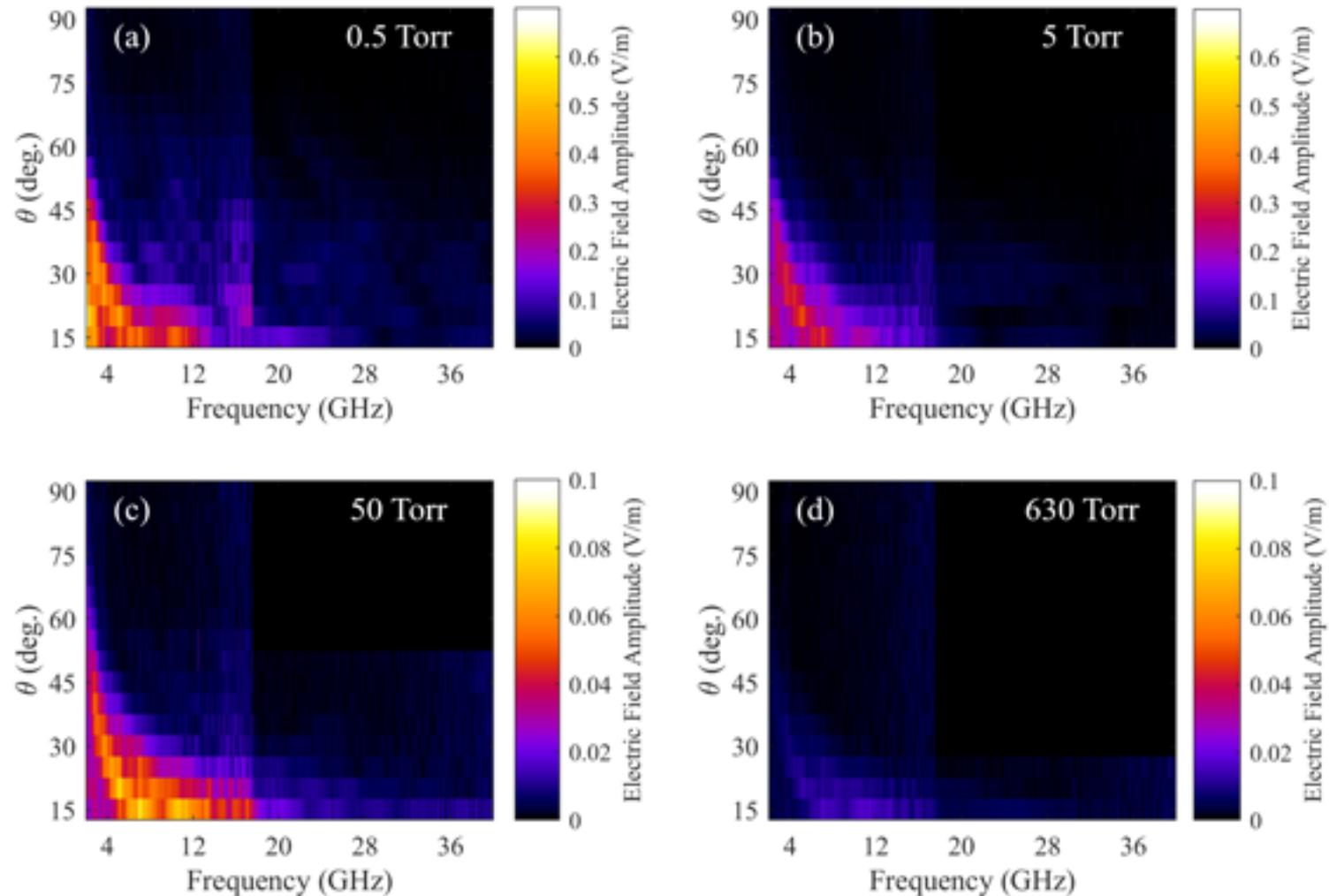


Calibrated RF power spectral density measurements @ 800 nm

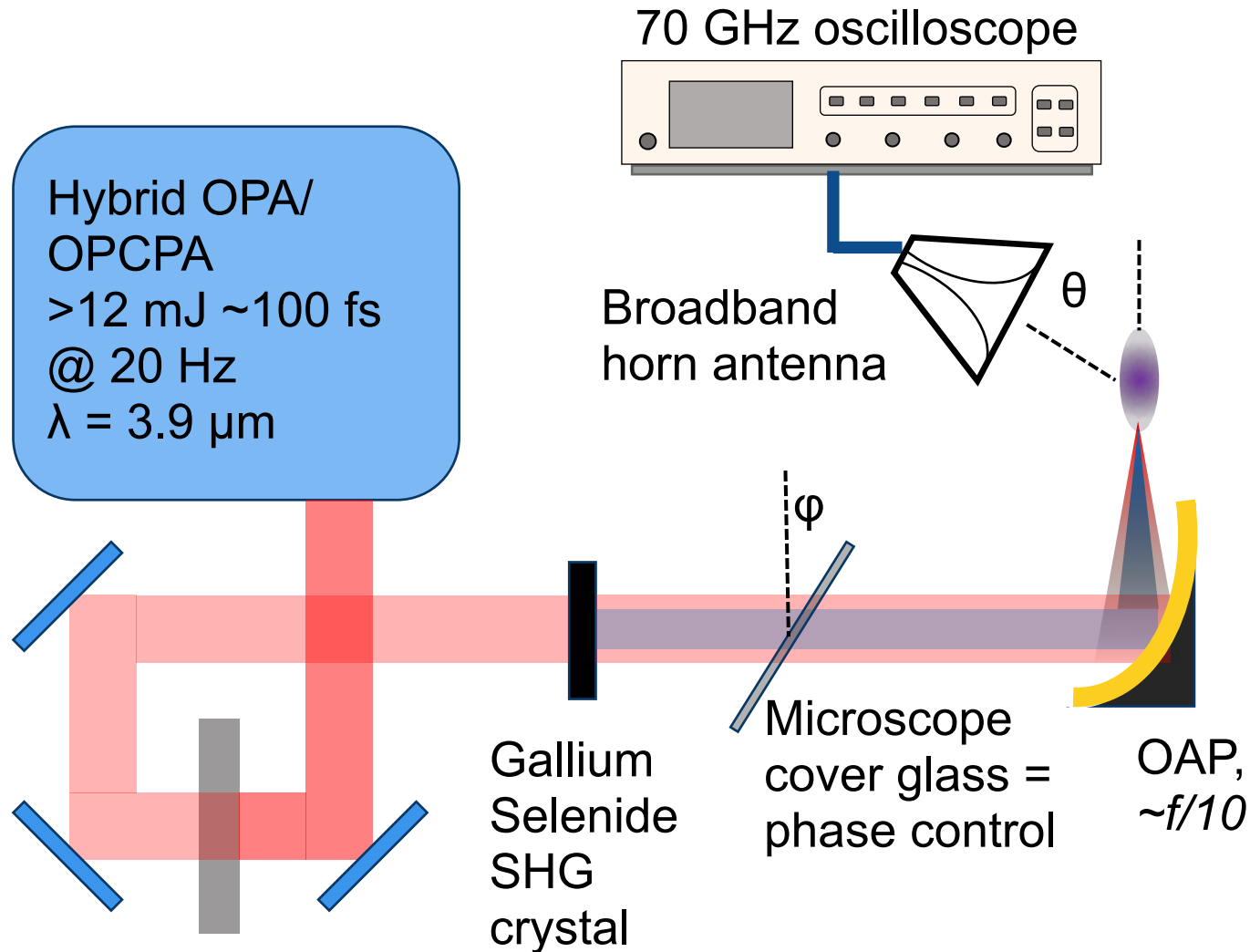


Englesbe et al. Optics Letters 43 pg 4953 (2018)

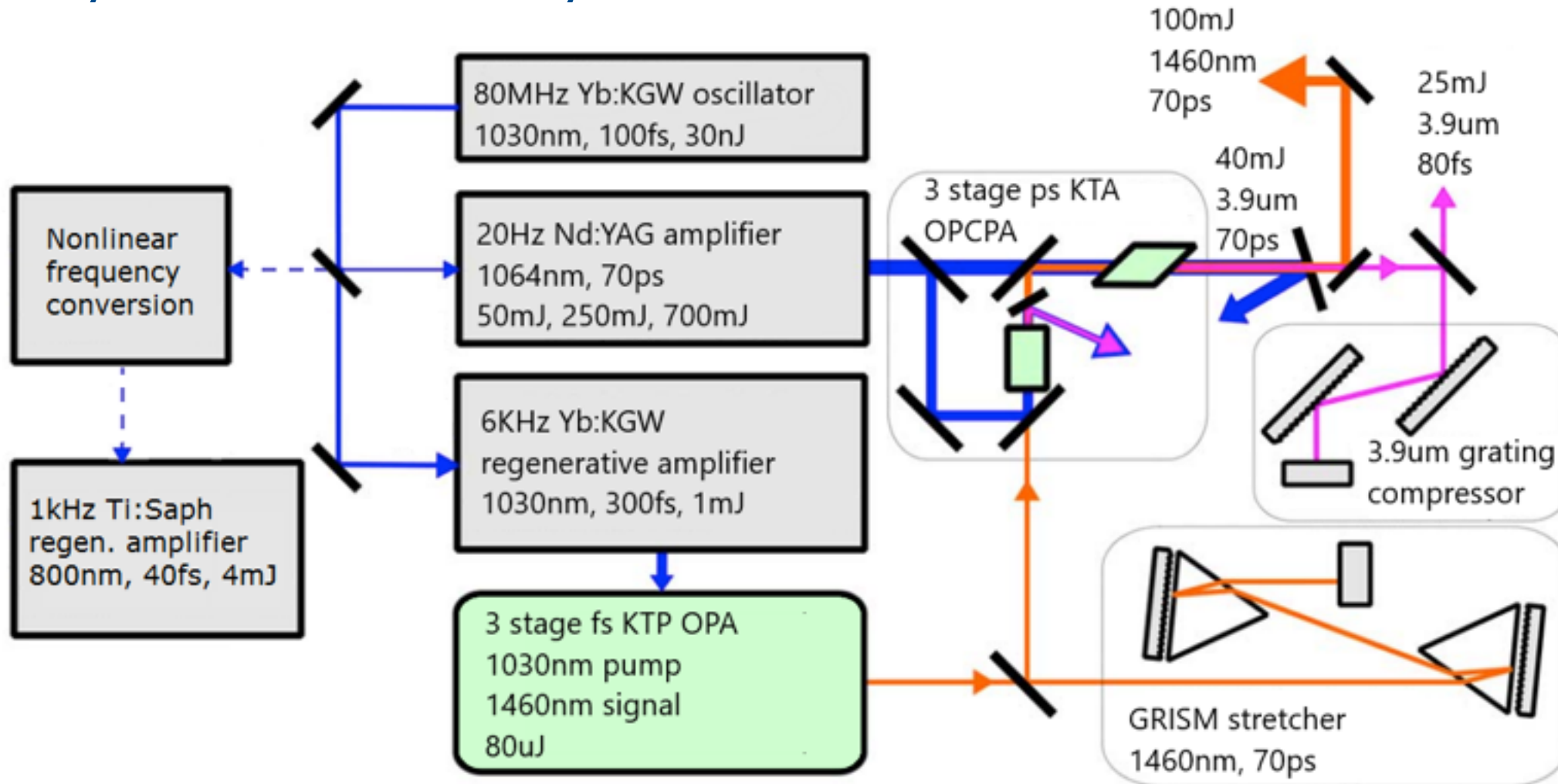
Angular dependence of power spectral density



Experimental Setup: Two color 4 μm and 2 μm

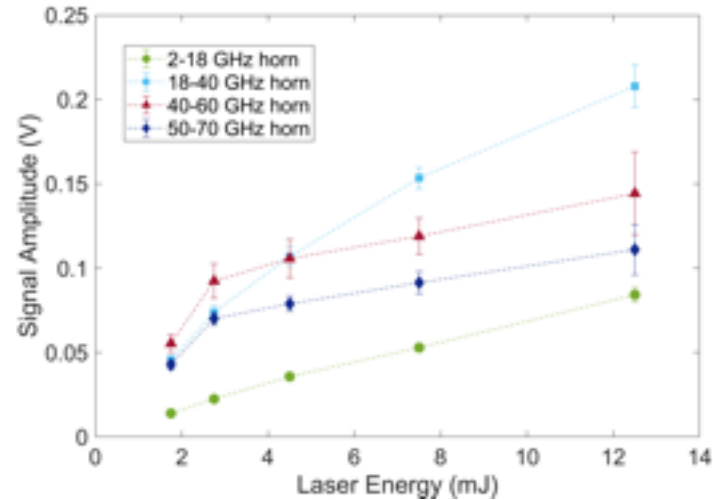


Maryland MIR laser system

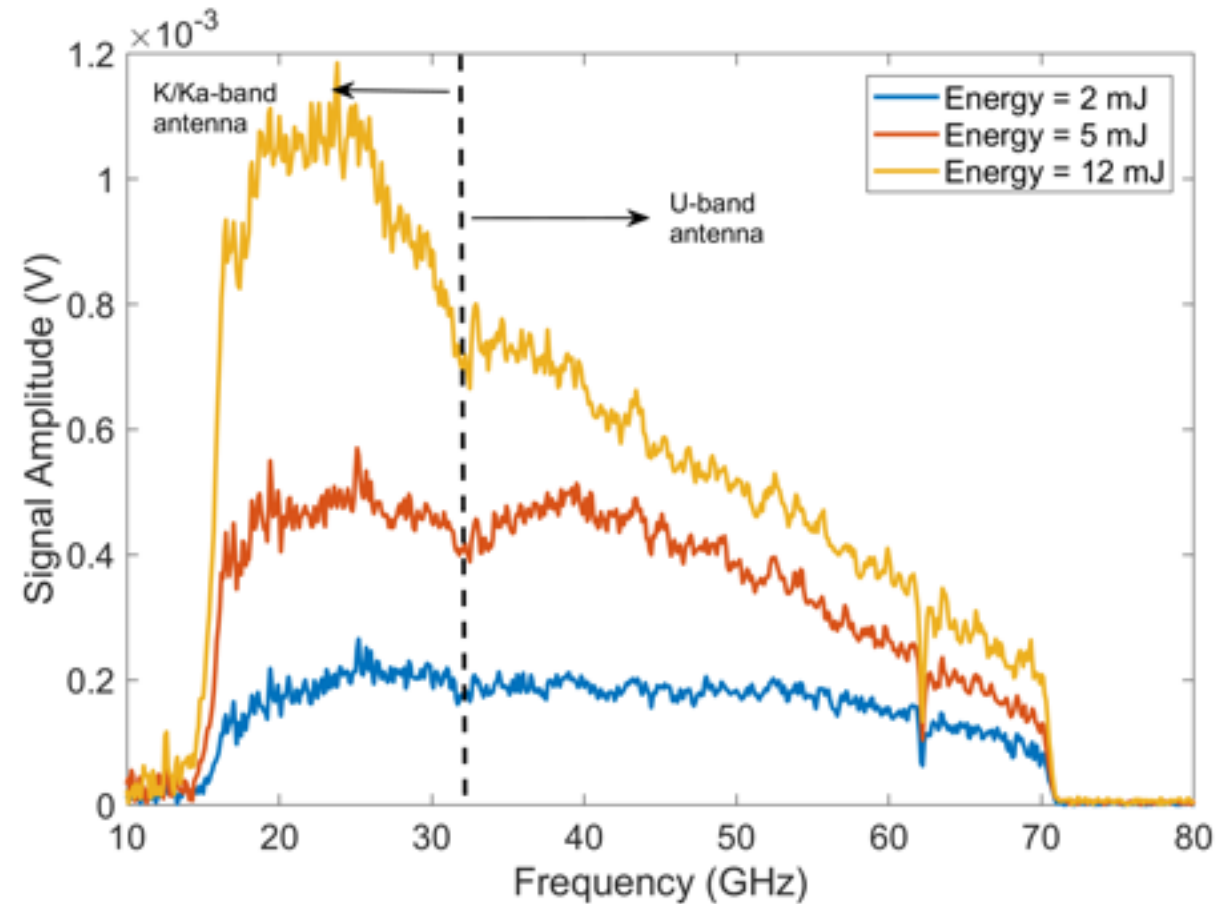


G. Andriukaitis et al. Optics Letters 36 pp. 2755-2757 (2011)

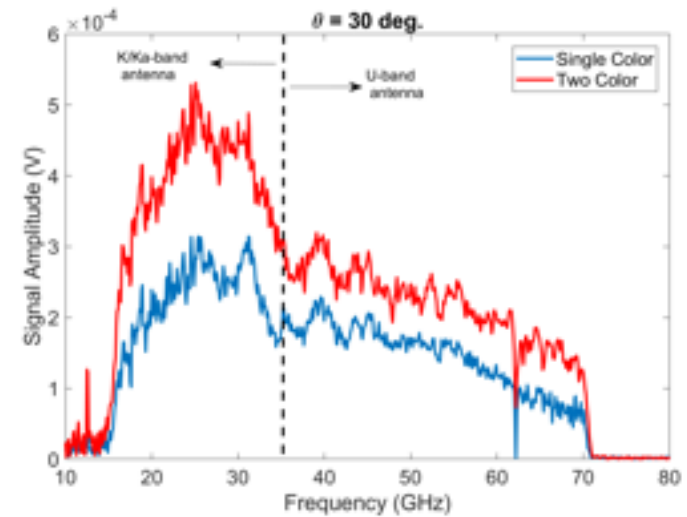
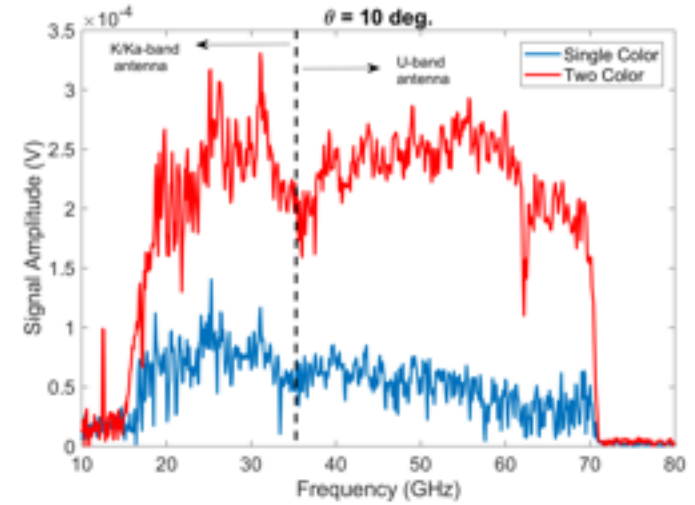
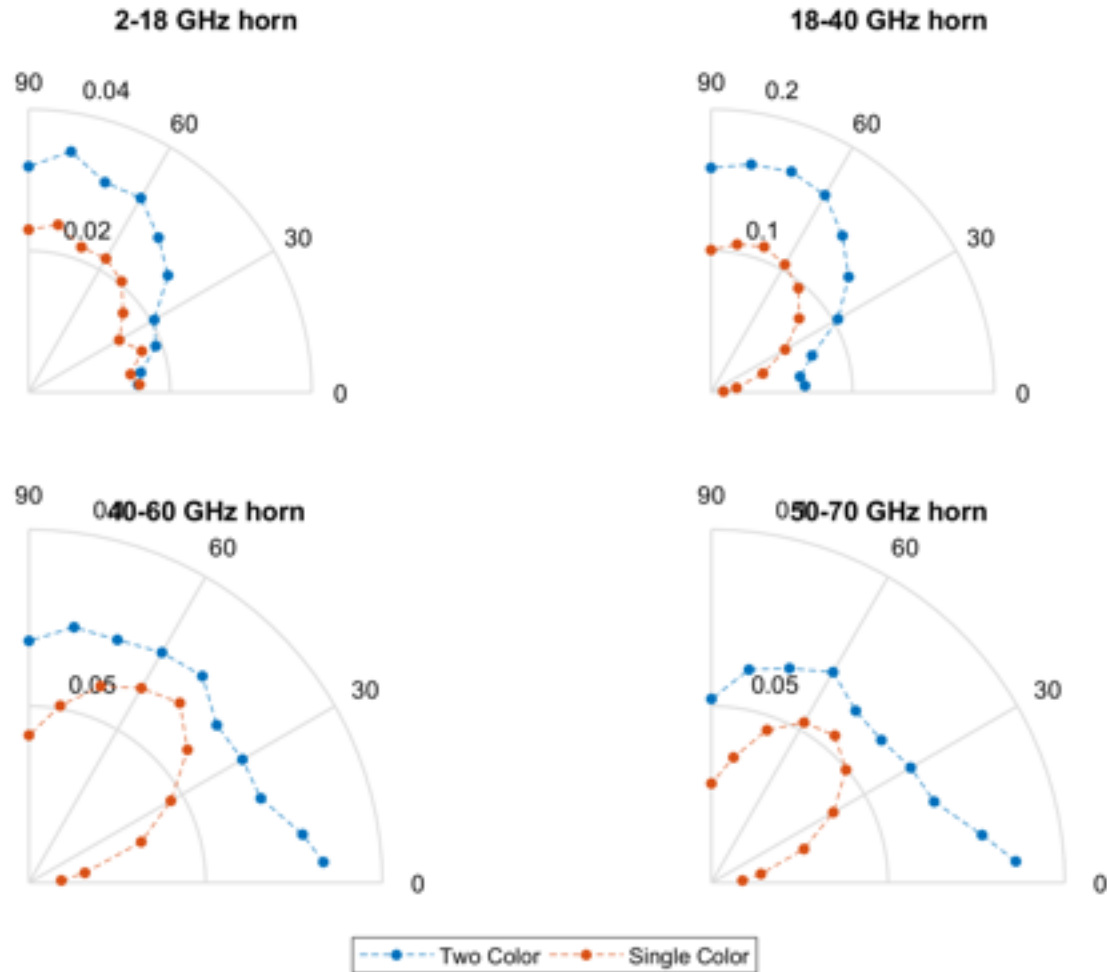
Microwave Generation with Focused 3.9 μm Pulses



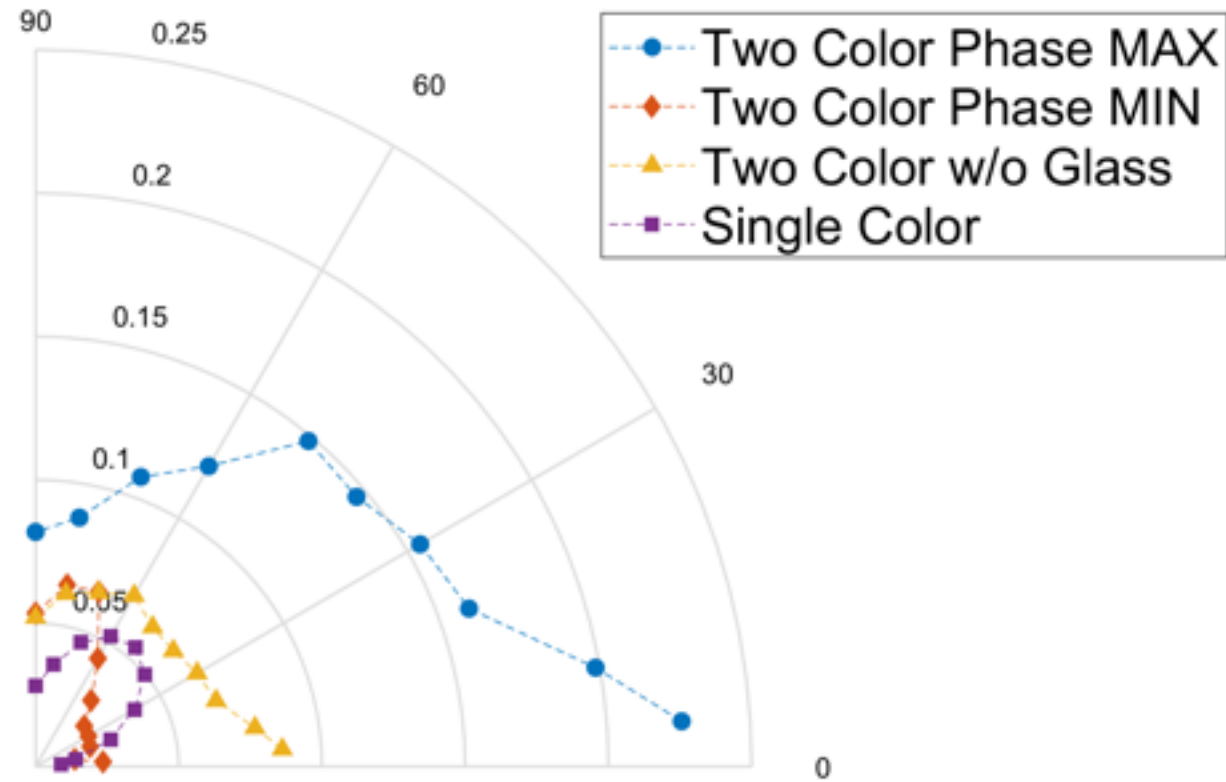
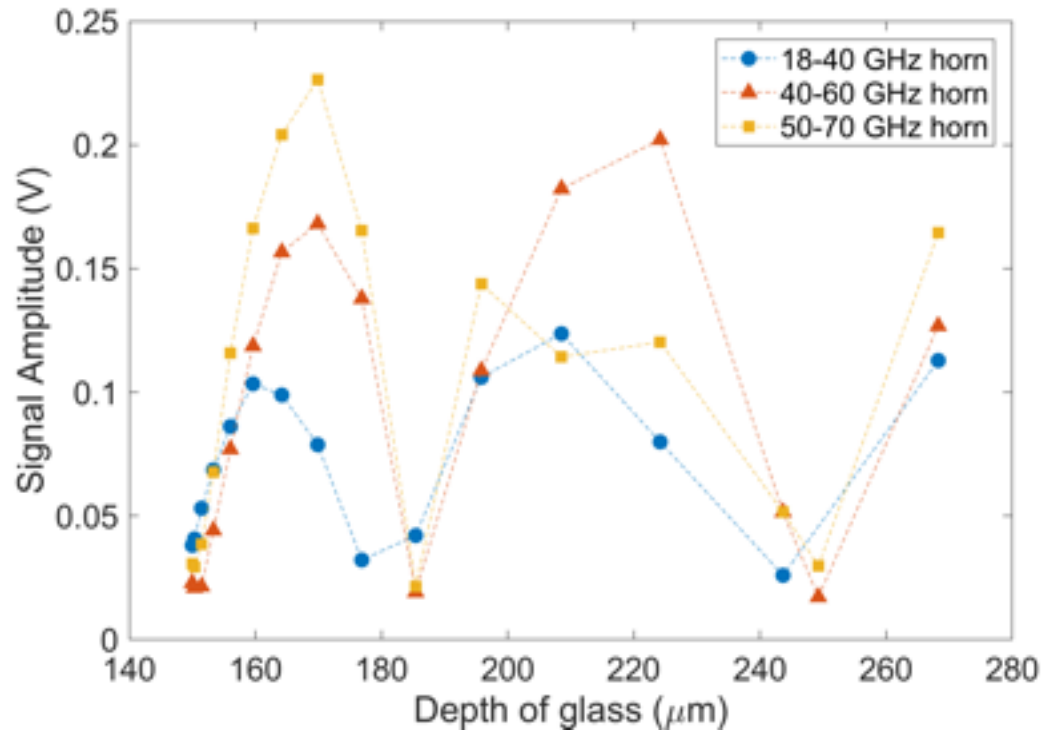
- Microwaves generated in single color case
- Roughly linear increase in yield across measured frequency range



Microwave Amplitude Comparison: Single and Two Color

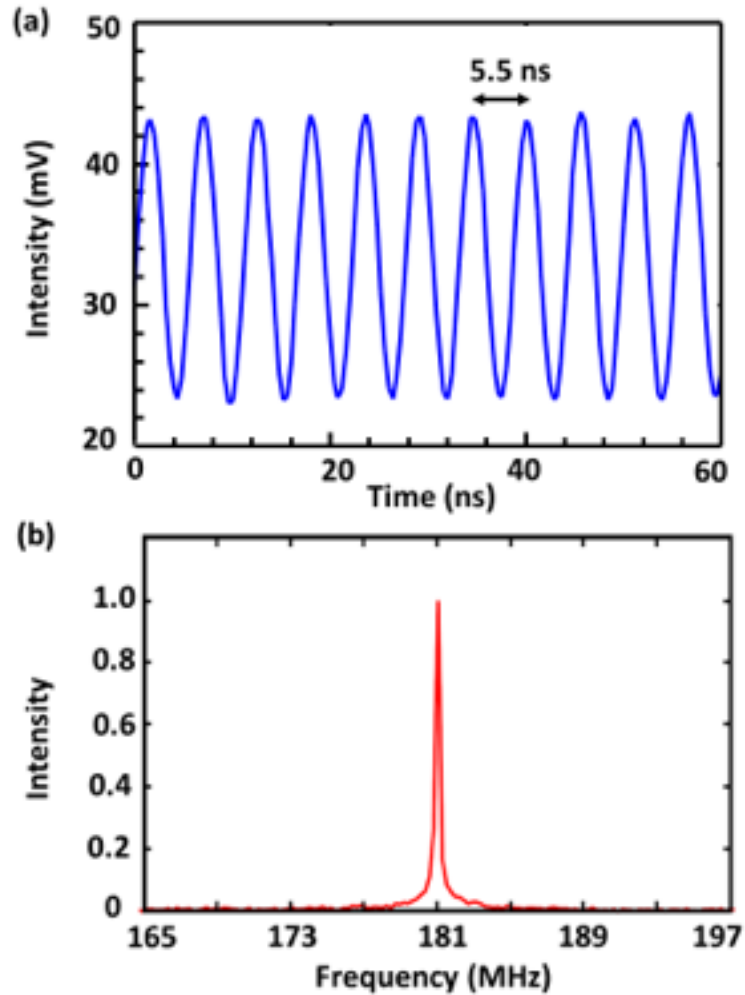


Microwave Yield is Sensitive to Relative Phase

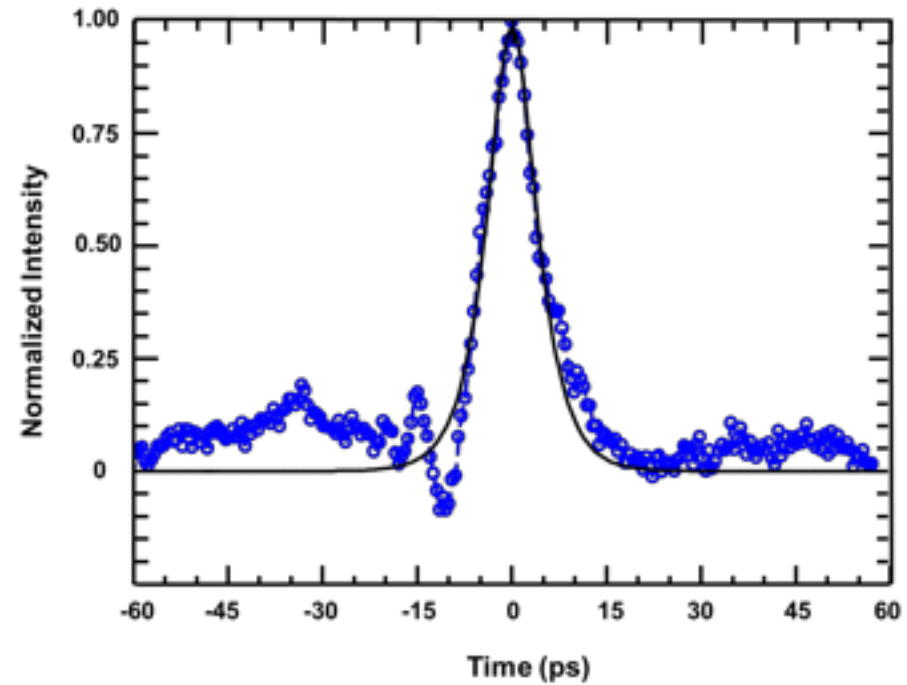


50-70 GHz horn

Fe:ZnSe Modelocked Laser Results



Autocorrelation Trace



PRF= 181 MHz Sech² fit=8.9 ps

Conclusions and Future Work

- The plasma produced by mid-IR pulses produces broadband emission well into the millimeter wave range
- The lower frequency microwaves and higher frequency millimeter waves have slightly different emission patterns
- The yield of millimeter waves is very sensitive to the relative phase of the laser harmonics, similar to THz generation
- Comparison of 2/4 micron microwaves with 0.4/0.8 micron

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Questions?