Broadband microwave emissions from LWIR picosecond laser ablation with pre-ionization

AE125 Close Out

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Broadband emissions from pulsed laser ablation

Extreme nonlinear optics of ultra-short pulse lasers enables research and applications across the entire electromagnetic spectrum…

RF EMP

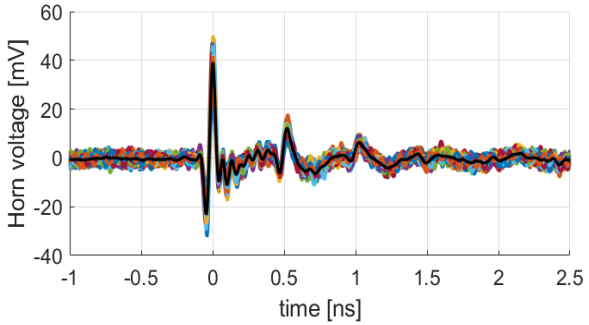
Parametric Conversion

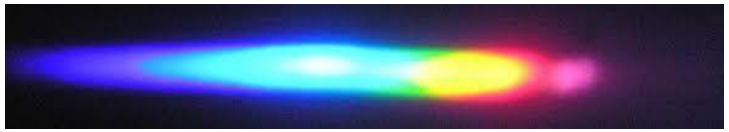
High Harmonic Generation

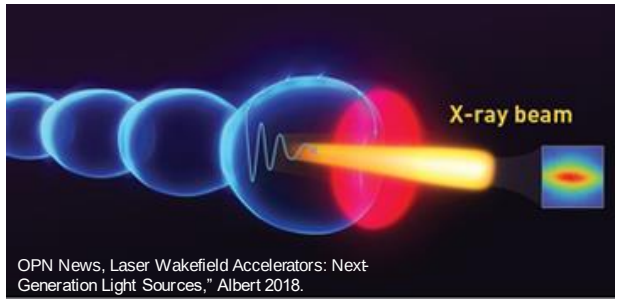
Terahertz Sources

Optical Supercontinuum

Accelerator-based light sources



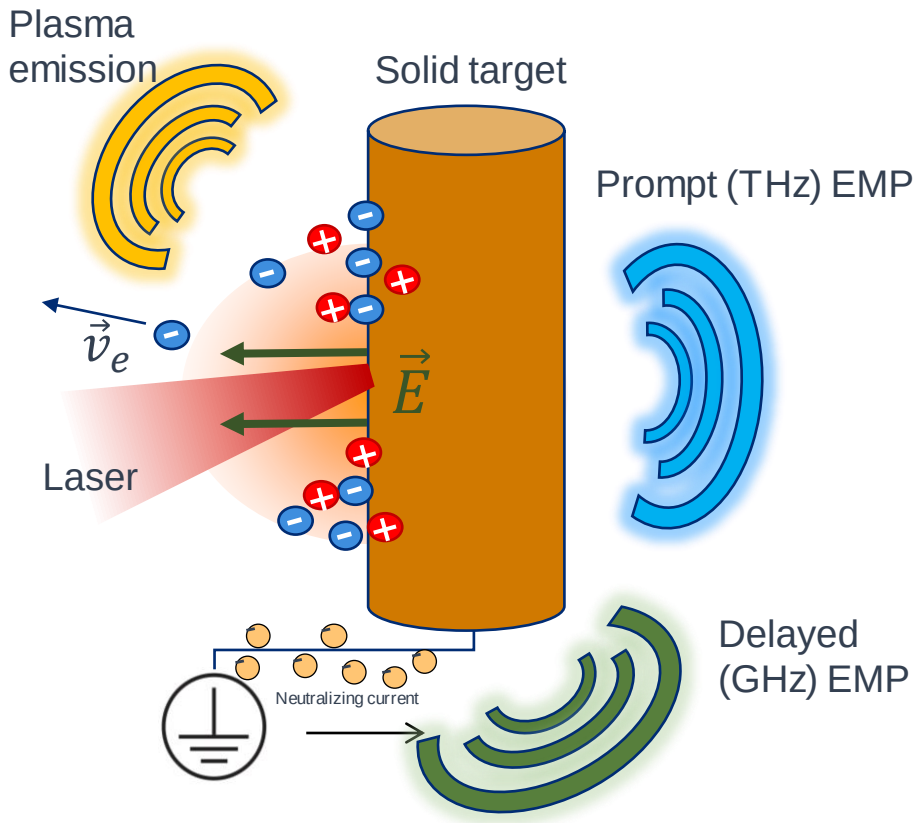




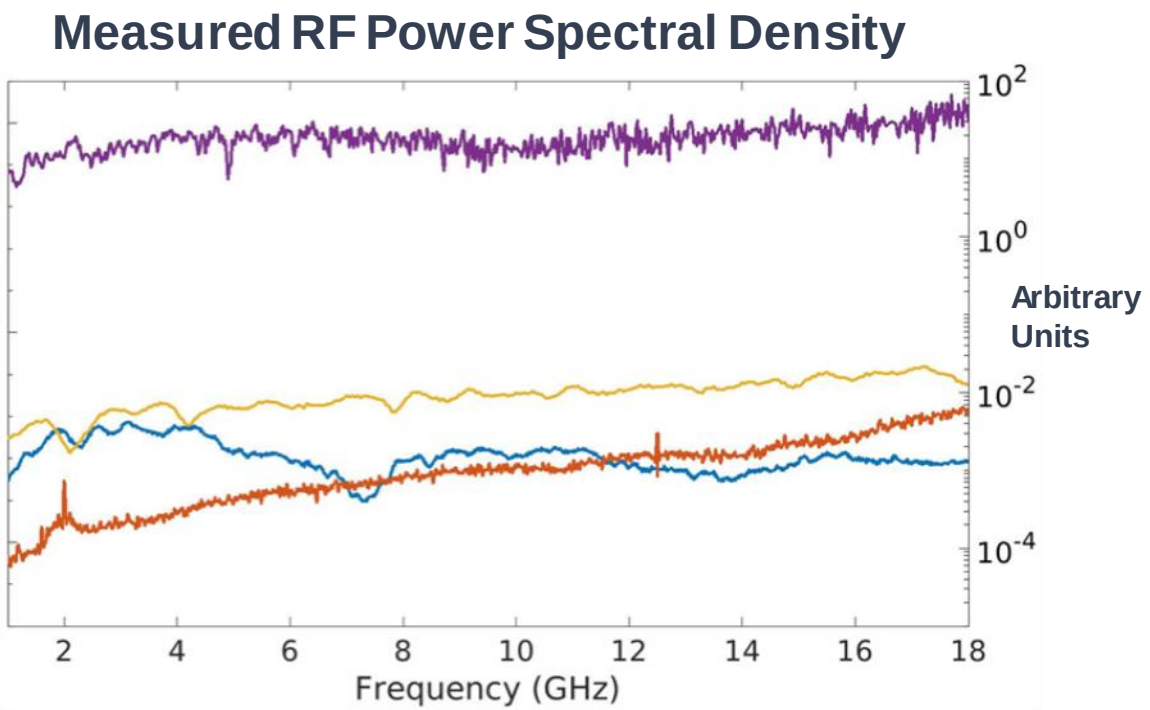
OPN News, Laser Wakefield Accelerators: Next-Generation Light Sources," Albert 2018.

RF Emissions From Short Pulse Laser Ablation

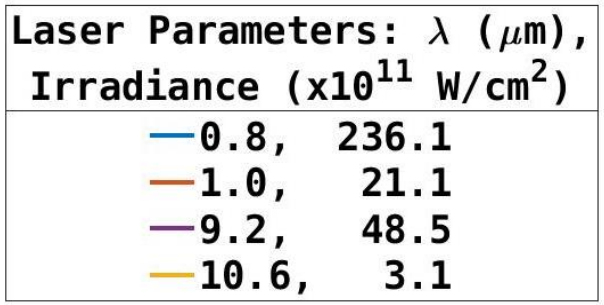
- Low-frequency (RF) emissions measured from ablation as early as 1970's
- Typically found in large laser facilities with lasers reaching relativistic intensities
- Recent work has investigated "atmospheric" and relatively low intensity sources of EMP from laser-plasma interactions
- Three main sources of low frequency emission
  - "Rectification" physics
  - Long scale-length plasma currents
  - Target charging and neutralization



Wavelength Scaling into the LWIR



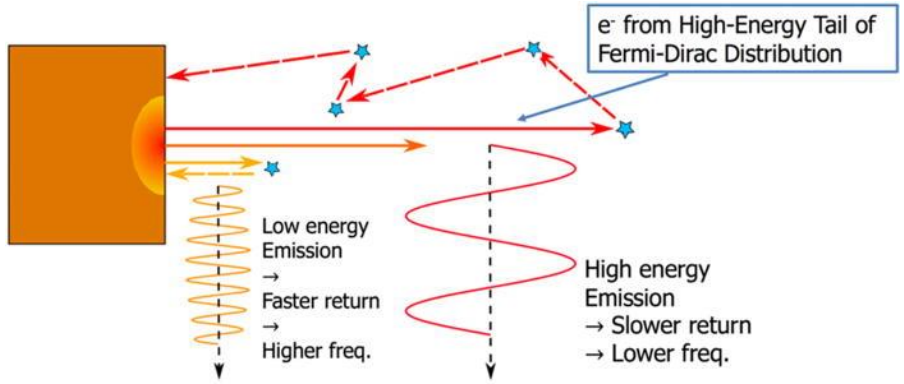
λ (microns)	Energy (joules)	Duration (fs)
0.8	.04	50
1.0	.03	1300
9.2	3	2000
10.6	.01	3000



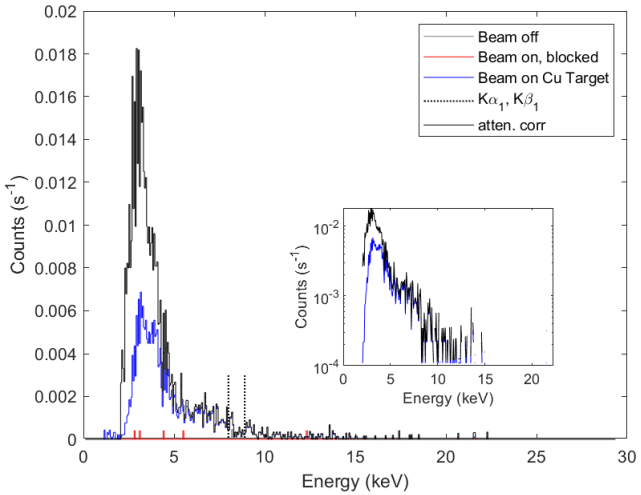
- FY22 results exceeded expectations!
- Orders of magnitude improvement across all frequencies achieved with BNL laser
- Led to funding for proprietary beam time in FY23

Key experimental questions

- How does RF emission change with laser incidence angle and intensity? Can we match theoretical models?
  - How does emissions strength compare between dielectric and metal targets?
- Does pre-ionization increase the RF emission from solid targets similar to what we see in the NIR?
  - What pulse separation time scale improves RF emission?
  - Does pre-ionization improve LWIR absorption by the plasma?
- Can we detect a temperature electron population through keV bremsstrahlung? Does the electron temperature correlate with RF emission?



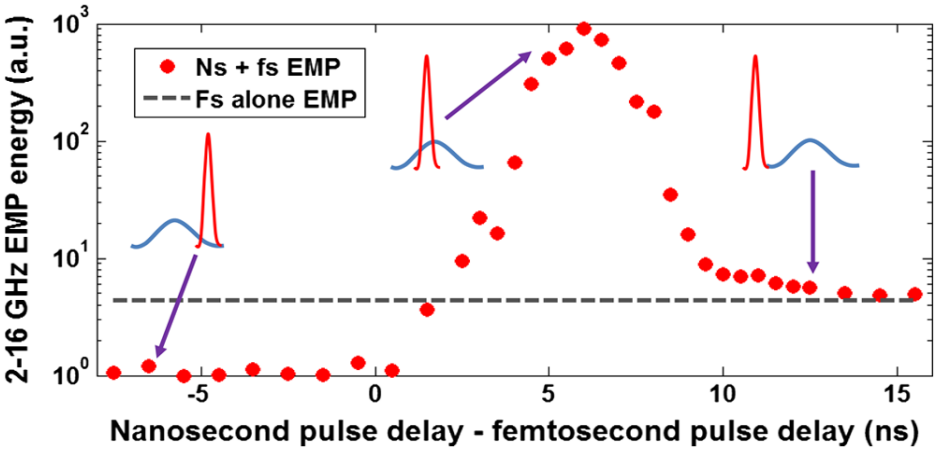
"Dynamic sheath formation and sub-THz radiation from laser–metal interactions" [Phys. Plasmas 27, 073101 (2020)]



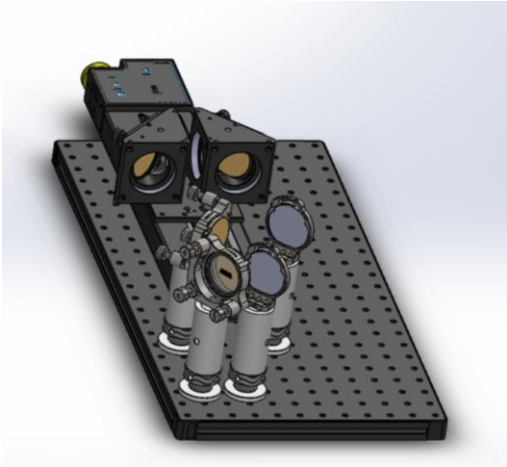
X-ray emission spectrum measured from USPL ablation of copper wire in air

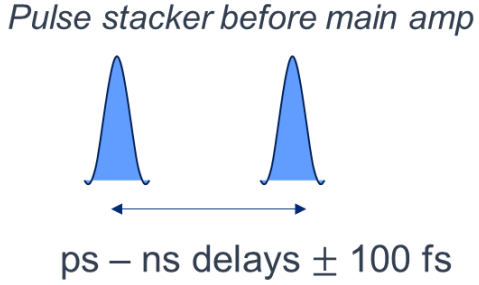
Target pre-ionization

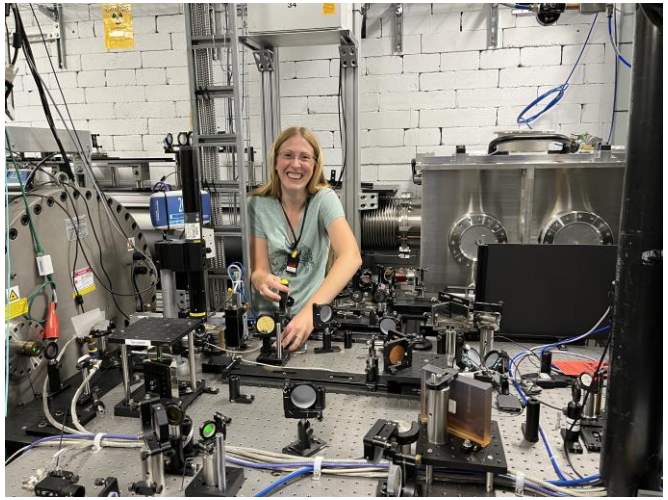
- Previous work at JHU/APL showed orders of magnitude increase in RF emissions from pre-ionized dielectric targets with NIR drive lasers
- Hypothesize improved laser absorption at the critical density layer in the expanding plasma causes a higher electron temperature

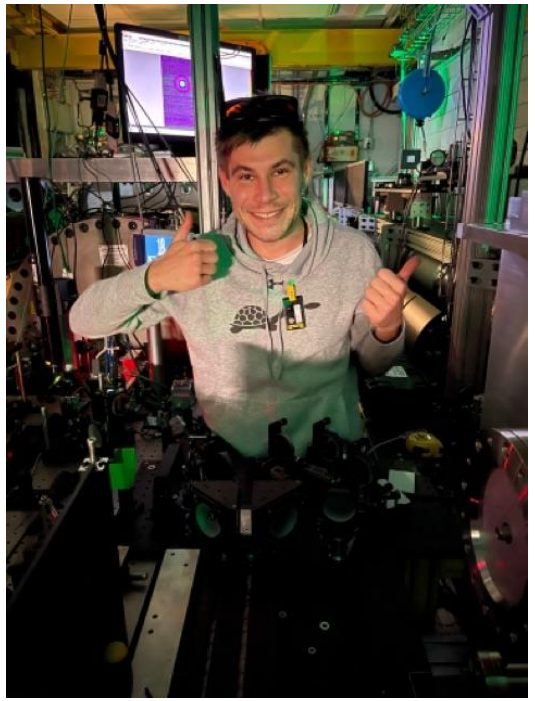


S. Varma, J. Spicer, B. Brawley, and J. Miragliotta, "Plasma enhancement of femtosecond laser-induced electromagnetic pulses at metal and dielectric surfaces," *Opt. Eng.*, vol. 53, no. 5, p. 051515, 2014.

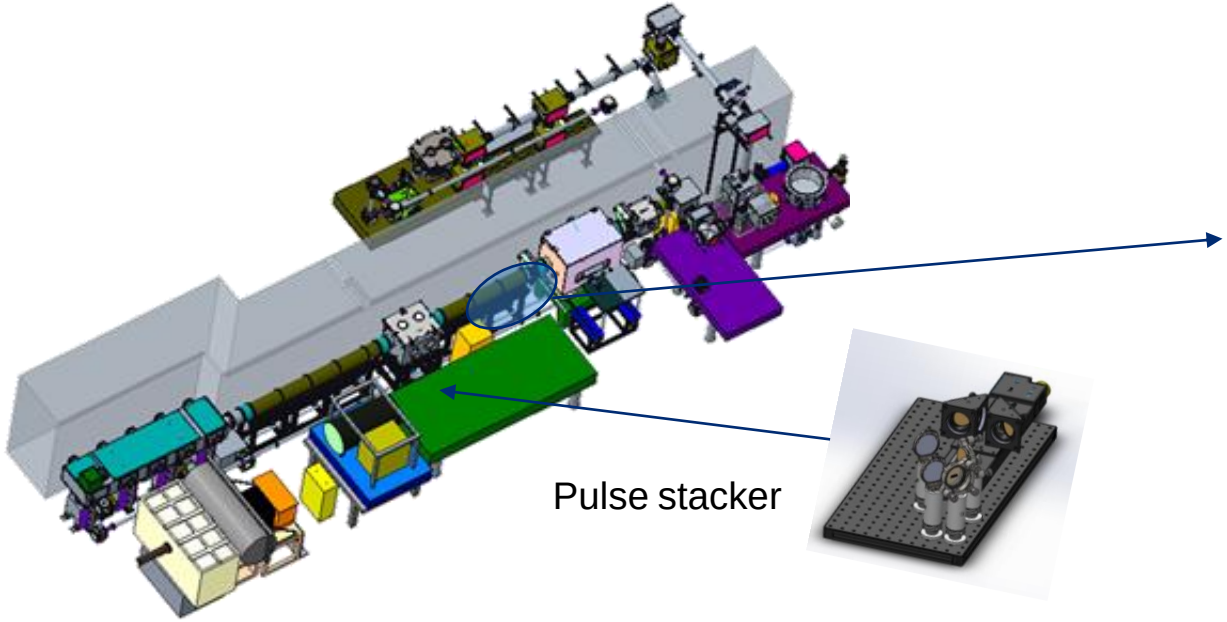




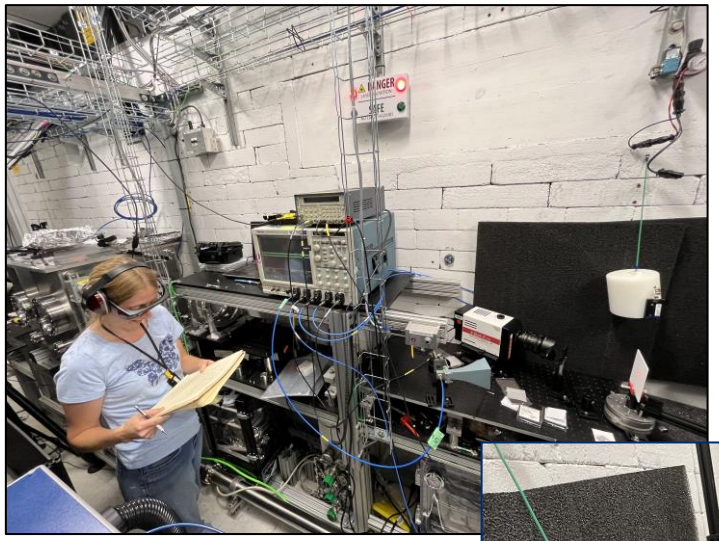


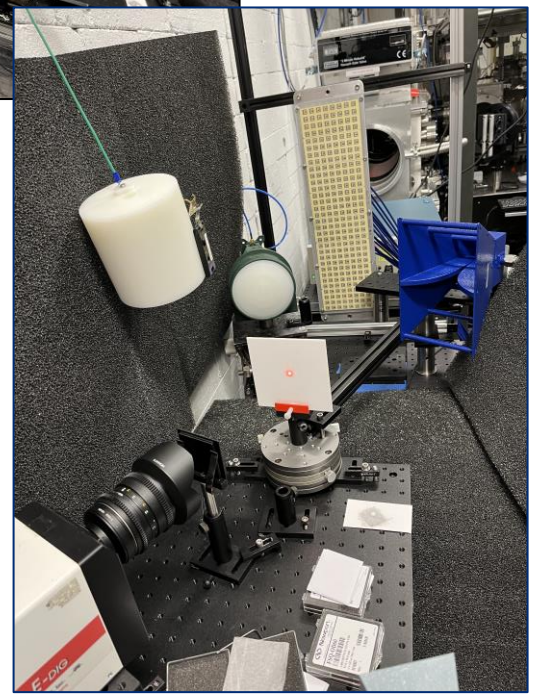


Experiment layout and diagnostics



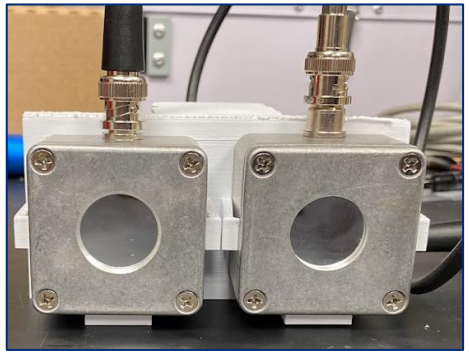
Pulse stacker

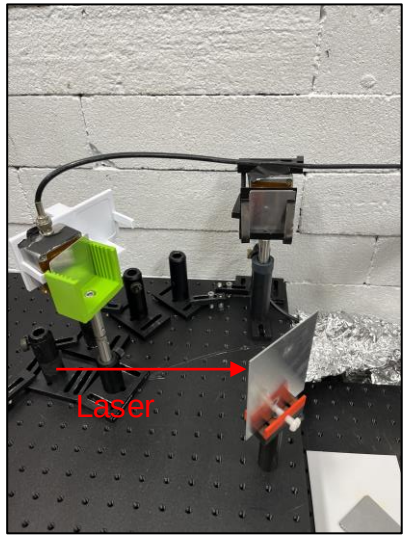




- RF collection equipment
- ICCD for spot size measurements
- X-ray ‘spectrometer’ (filter based)
- “DUT” electronics

APL Designed and built X-ray photo detector, filters added to measure various x-ray fluxes





Conclusions

- AFRL and JHU/APL performed joint experiments at BNL in August 2023 to study low frequency emissions from laser-solid interactions
  - Installed a simple pulse stacker between the regen and power amp of the BNL CO2 laser
  - Measured x-rays emissions from solid targets in air
  - Measured RF emissions as a function of laser fluence on target
- To date results are not publicly releasable, but in the future we may be able to publish some results comparing our measurements to basic physical emissions processes
- Continued interest in using the ATF facilities for “air-based” experiments including studies related to filamentation of LWIR pulses in a turbulent atmosphere

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APPLIED PHYSICS LABORATORY