Characterizing filament-induced breakdown spectroscopy through highly scattering media

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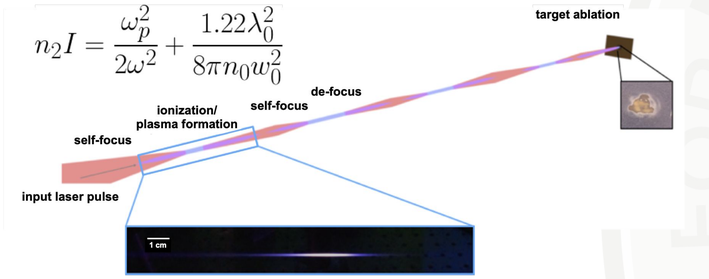
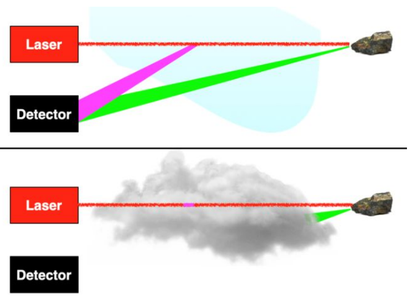
Introduction and Motivation

- Ultrafast laser-induced plasma spectroscopy (LIBS) can be used as an active interrogation technique for remote detection in nuclear applications (SNM, environmental sensing).
- Laser filamentation leads to a dramatic improvement in range, and opens the door for waveguiding and fog clearing effects.
- Real environmental conditions can affect target exciting capabilities and signal collection capabilities.

$$n_2 I = \frac{\omega_p^2}{2\omega^2} + \frac{1.22\lambda_0^2}{8\pi n_0 w_0^2}$$

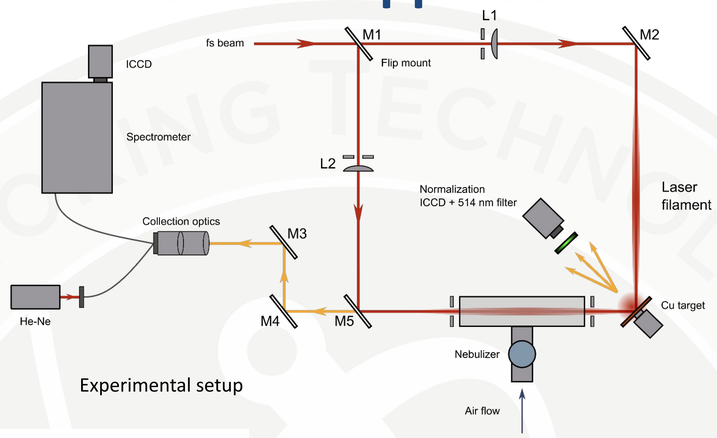




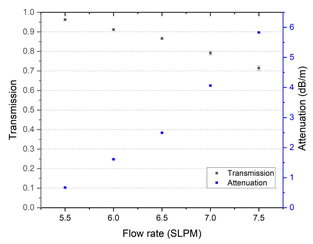
Time scale	Gas dynamics effect
~10 ns	Plasma recombination
~100 ns	Pressure wave (fog expelling)
~1 µs	Pressure equilibrium
~1 ms	Thermal equilibrium

Induced gas hydrodynamics induces the cloud clearing mechanism.

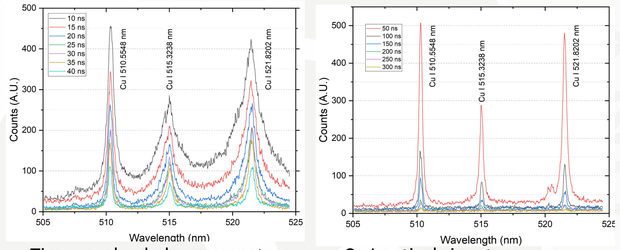
Technical Approach



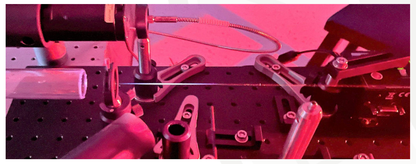
Experimental setup



Cloud chamber characterization. He-Ne transmission in steady state

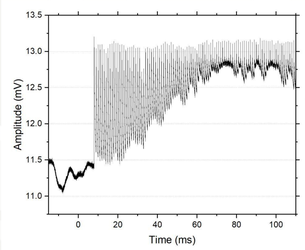


Time resolved plasma spectroscopy. Cu I optical signatures are collected in a 350 ns time window after the laser pulse.

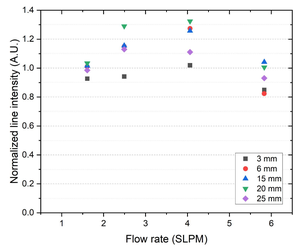


Laser filament in air. The nitrogen fluorescence shows an extended region of high peak power.

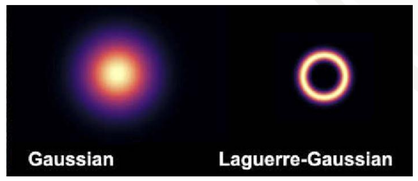
Results



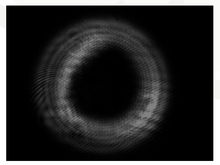
He-Ne probe shows clearing time scale when filament clearing occurs.



On-axis 515 nm line intensity versus cloud density. There is a notable increase in transmission. Waveguiding and clearing are not separable effect in this experiment



Beam profile can induce different multifilament structures ⟶ Waveguiding.



He-Ne profile imaging let us visualize the anti-waveguiding effect of Gaussian beams produced filament⟶ Antiwaveguiding

Expected Impact

- If successful, we expect to better understand the underlying mechanisms involved in the use of ultrafast laser for LIBS in complex environmental conditions.

MTV Impact

- Networking & connections with National Laboratory partners.
- Collaboration with MTV partners at University of Florida.
- Interest from National laboratory ventures: LBNL, PNNL and LANL.
- Strong interest from DTRA.

Conclusion

- Laser filamentation can provide localized transmission improvement that might help signal collection through highly scattering media in LIBS applications.
- Anti-waveguiding effect deteriorates the ability to retrieve the plasma emission. It seems to be anti-correlated with cloud density.

Next Steps

- Studying Gauss-Laguerre beams for optical guiding effects through optical probing.
- Experiments and modelling aiming to understand mechanisms of fog clearing, separating the effects of drop expelling and shattering.

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