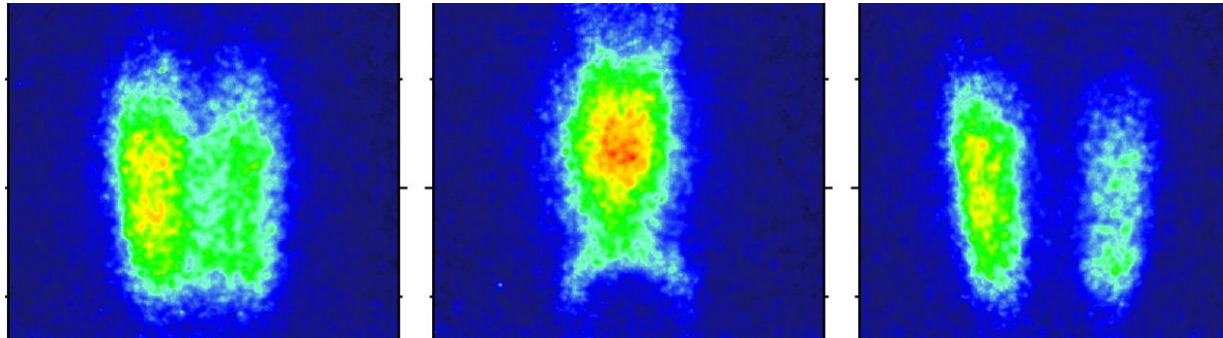


Exceptional service in the national interest



Carbon Monoxide Femtosecond TALIF in Turbulent Flames

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AIAA SciTech



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Research Team

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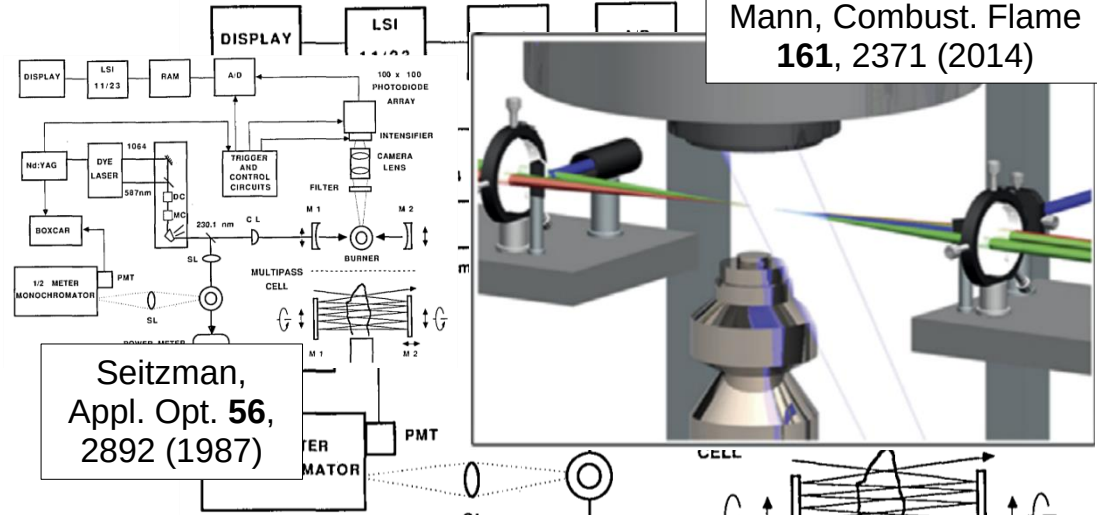
Introduction and Motivation:

Carbon Monoxide (CO):

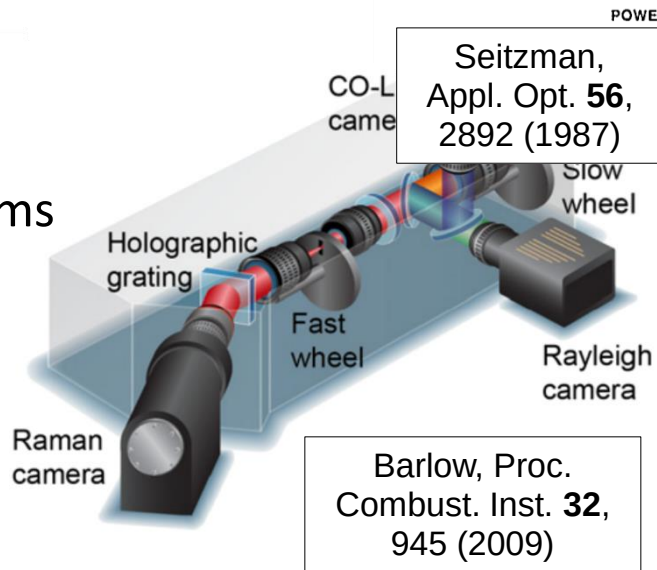
- Toxic
- Pollutant
- Indicator of incomplete combustion
- Key species in combustion chemistry

State-of-the-Art for CO Visualization:

- Two-photon CO (P)LIF
- Nd-YAG ns laser systems
- 10 Hz measurements
- Significant photolytic interferences

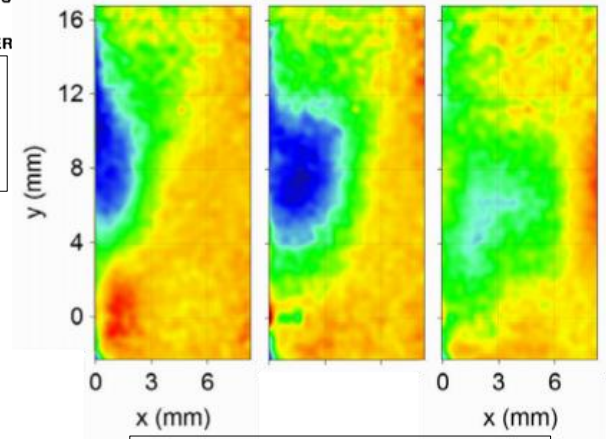


Mann, Combust. Flame **161**, 2371 (2014)



Seitzman, Appl. Opt. **56**, 2892 (1987)

Barlow, Proc. Combust. Inst. **32**, 945 (2009)



Richardson, Combust. Flame **168**, 270 (2016)

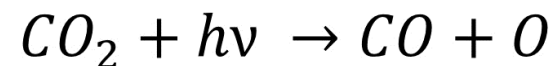
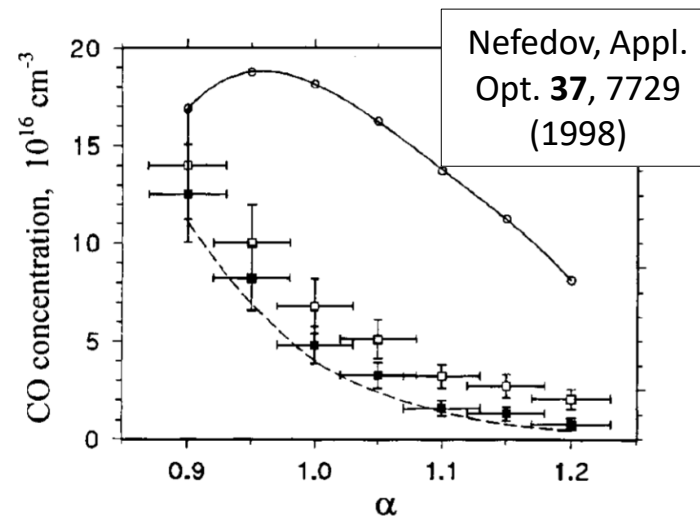
Motivation

Proposed improvements:

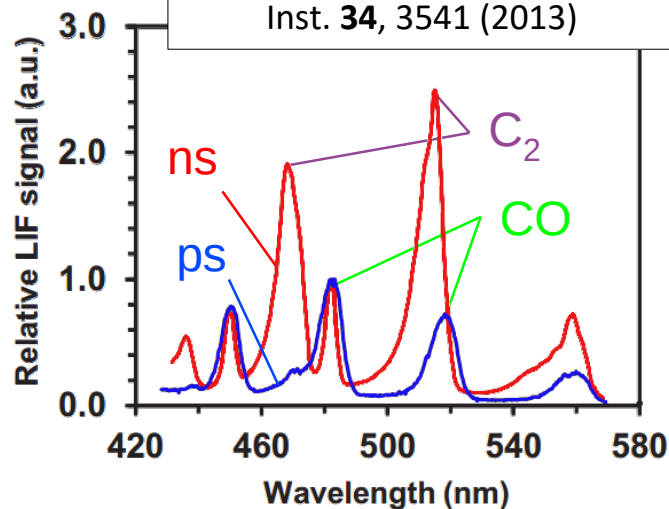
- Amplified fs laser systems
- 1000 Hz measurements
- Reduced photolytic interferences

Photolytic Interferences:

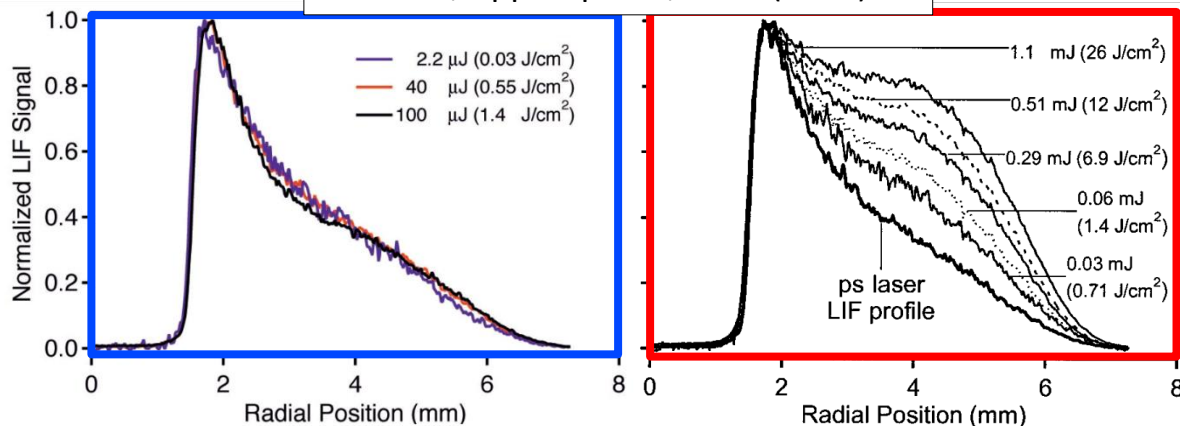
Perturbations to the flow or signal *caused by the laser* (e.g. photodissociation, photoionization, stimulated emission)



Brackmann, Proc. Combust. Inst. **34**, 3541 (2013)

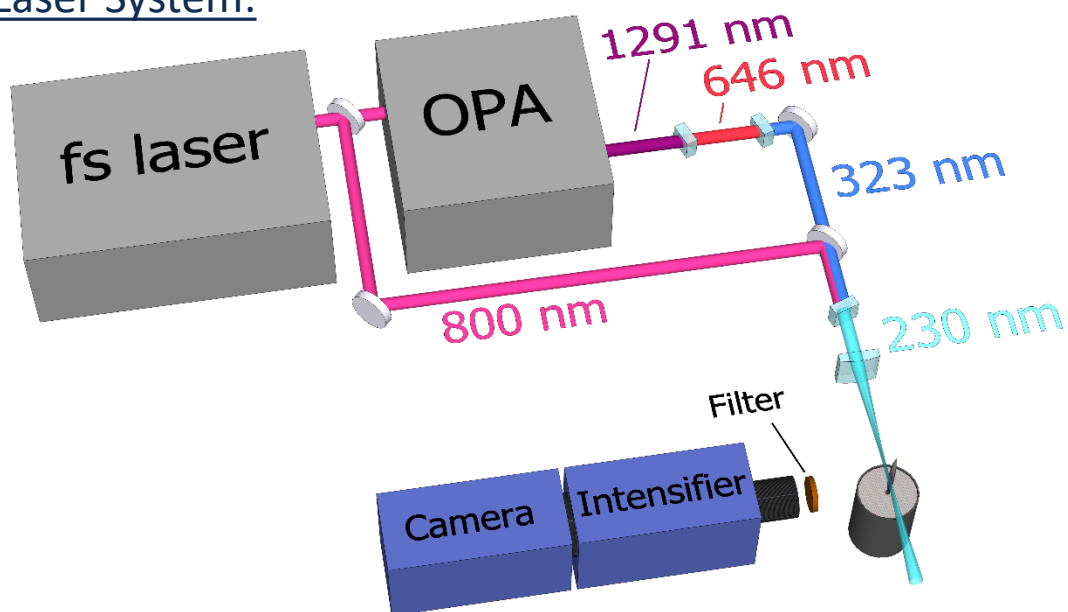


Frank, Appl. Opt. **43**, 2588 (2004)



Experiment Setup

Laser System:

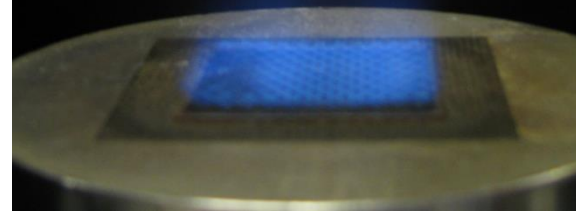


Experimental Details:

- 100 fs pulses at 1 kHz
- OPA pumped with 4 mJ
- Maximum of 30 $\mu\text{J}/\text{pulse}$ at 230 nm
- Methane-air flames

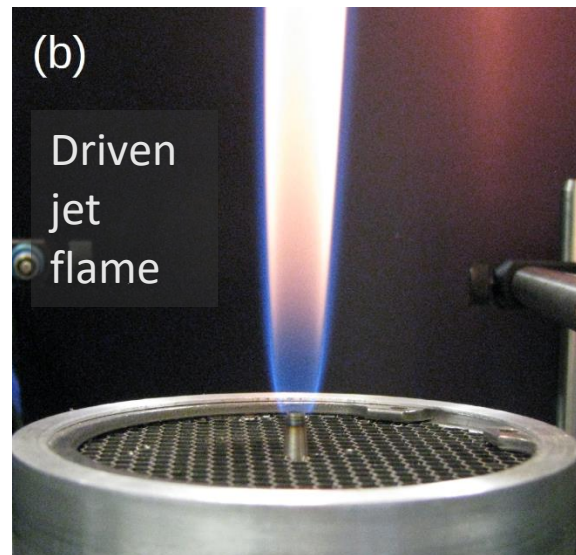
(a)

Steady
Hencken
flame

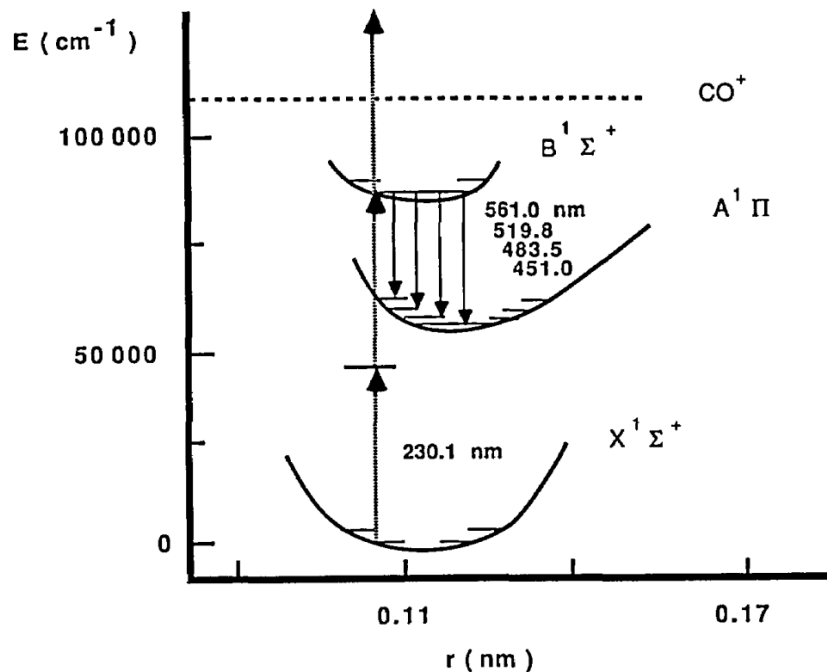


(b)

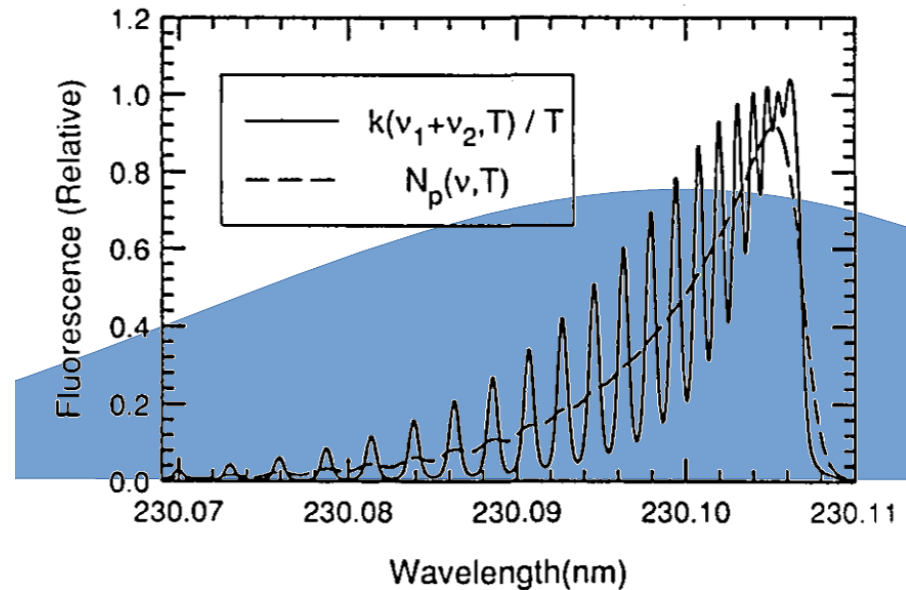
Driven
jet
flame



CO TP-PLIF Spectroscopy



Haumman, Opt. Lett. **11**, 775 (1986)



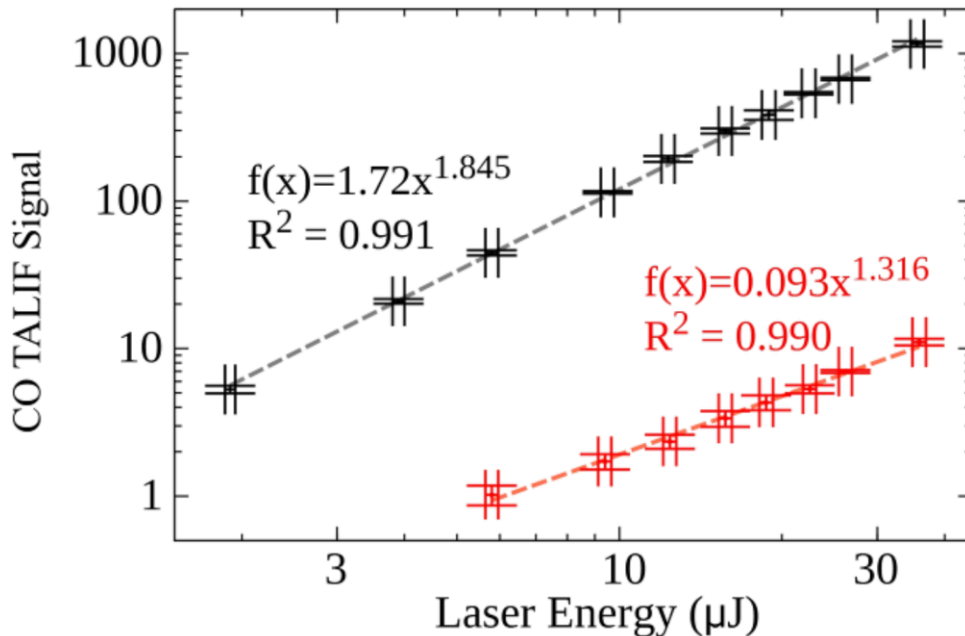
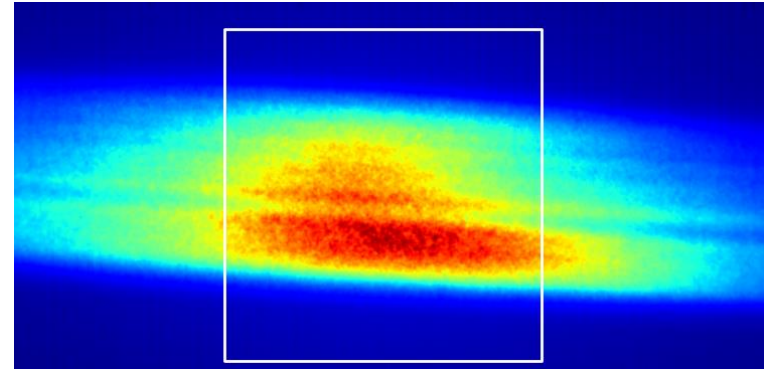
Seitzman, Appl. Opt. **56**, 2892 (1987)

$$I_{fl} = CN_{CO} I^2 \alpha(T, \omega, \Delta\omega, \Delta\omega_L)(A/A + Q)$$

Power Dependence:

- Steady methane–air Hencken flame
- Equivalence ratio = 1.3
- CO concentration = 4.0%
- Adiabatic temperature = 1810 K
- Reflected ND filters to reduce energy
- Average and σ from 10 sets of 200 images

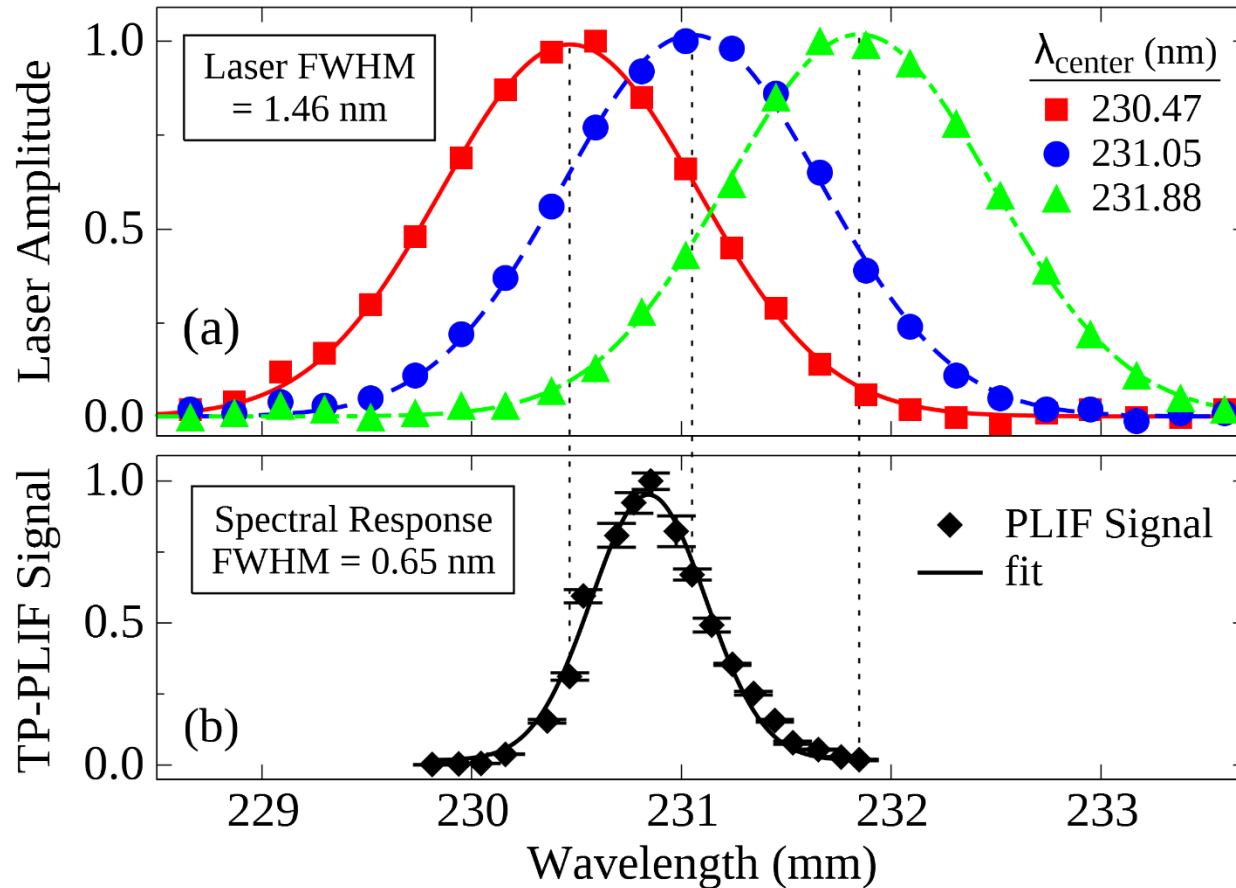
CO fs TP PLIF images from Steady Hencken flame



Steady Hencken Flame



Spectral Dependence:

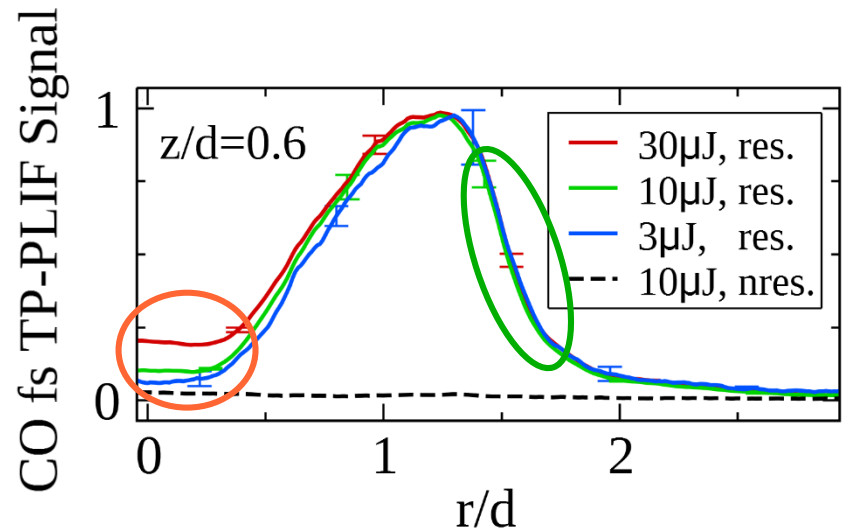
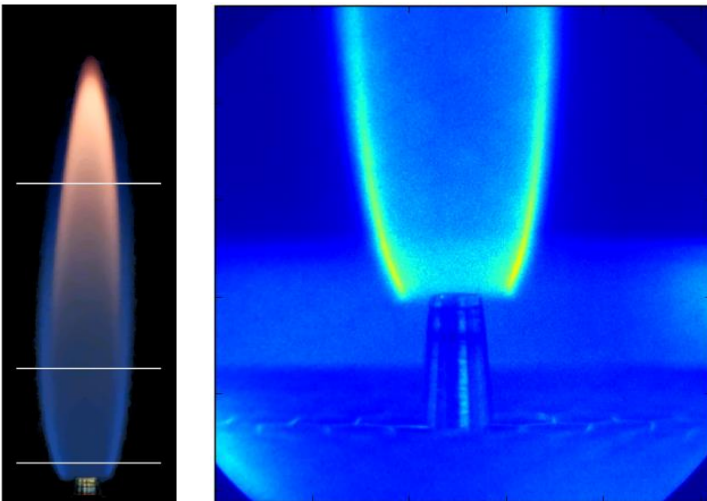


- Laser spectra recorded with fiber-coupled spectrometer
- Excitation wavelength changed using OPA and mixing crystals

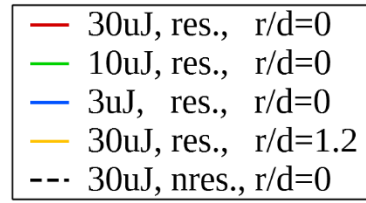
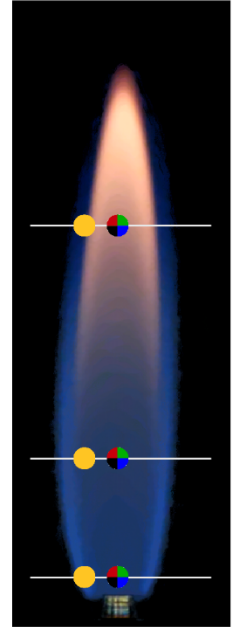
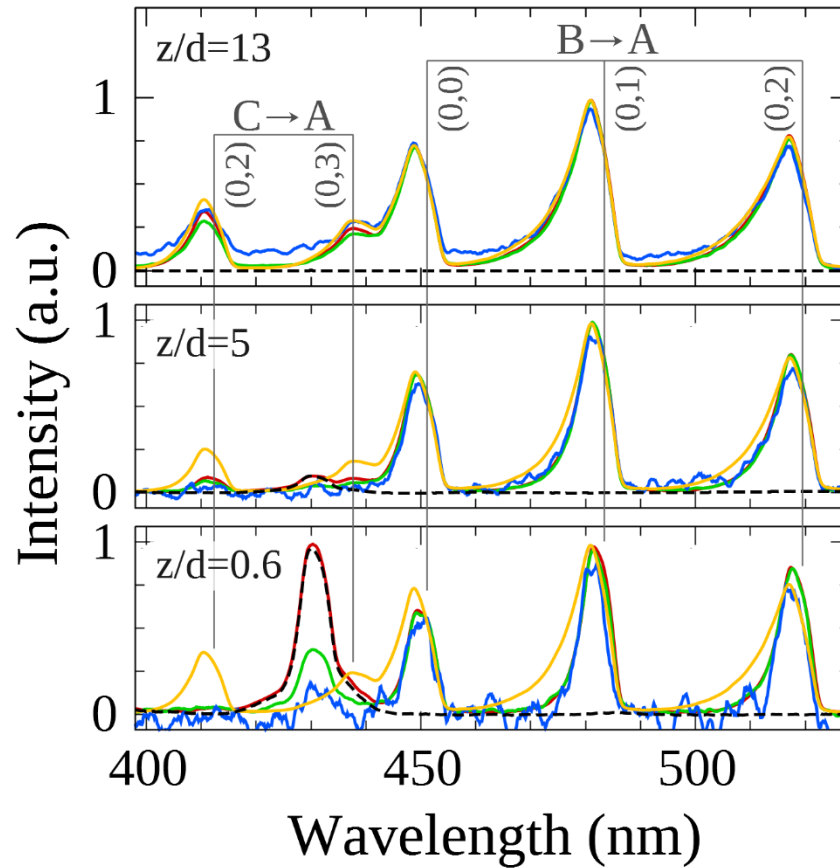
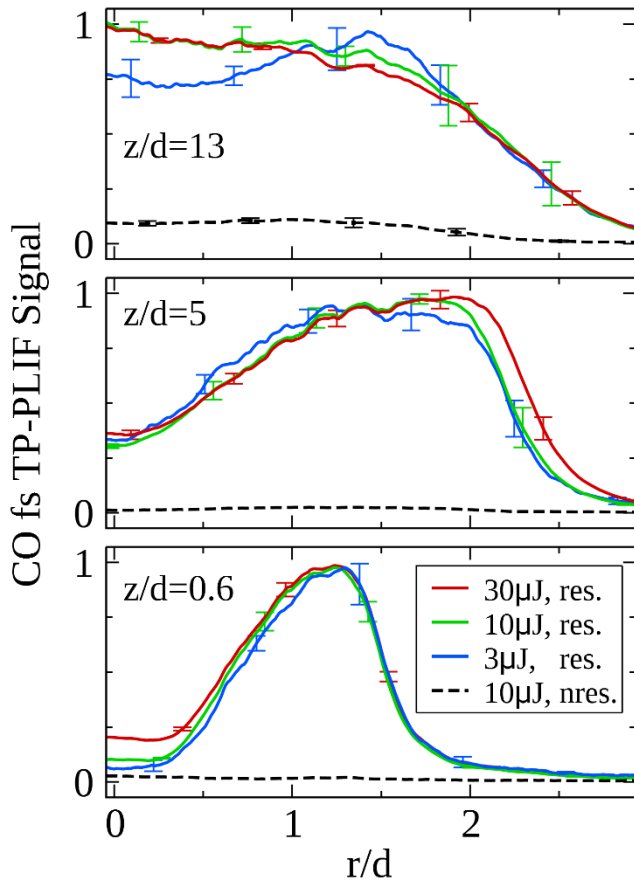
Photolytic Interferences

Jet Flame Data:

- Steady methane jet flame
- 10% CO₂ in coflow
- Average and σ from 10 sets of 200 single-laser-shot images
- Moving average of 10 applied to profiles



Photolytic Interferences

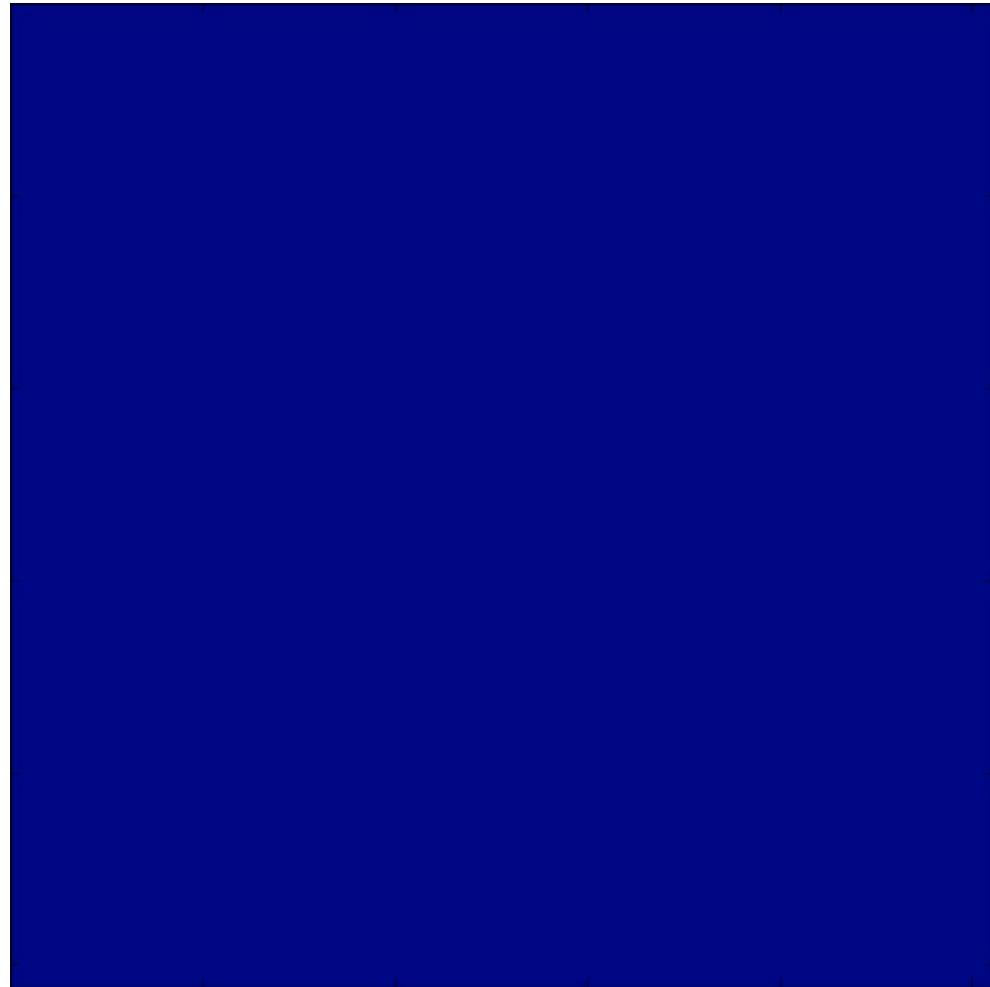


Richardson, et al., Opt. Lett. **42**, 875 (2017)

CO Visualizations at 1000 Hz:

Driven jet flame:

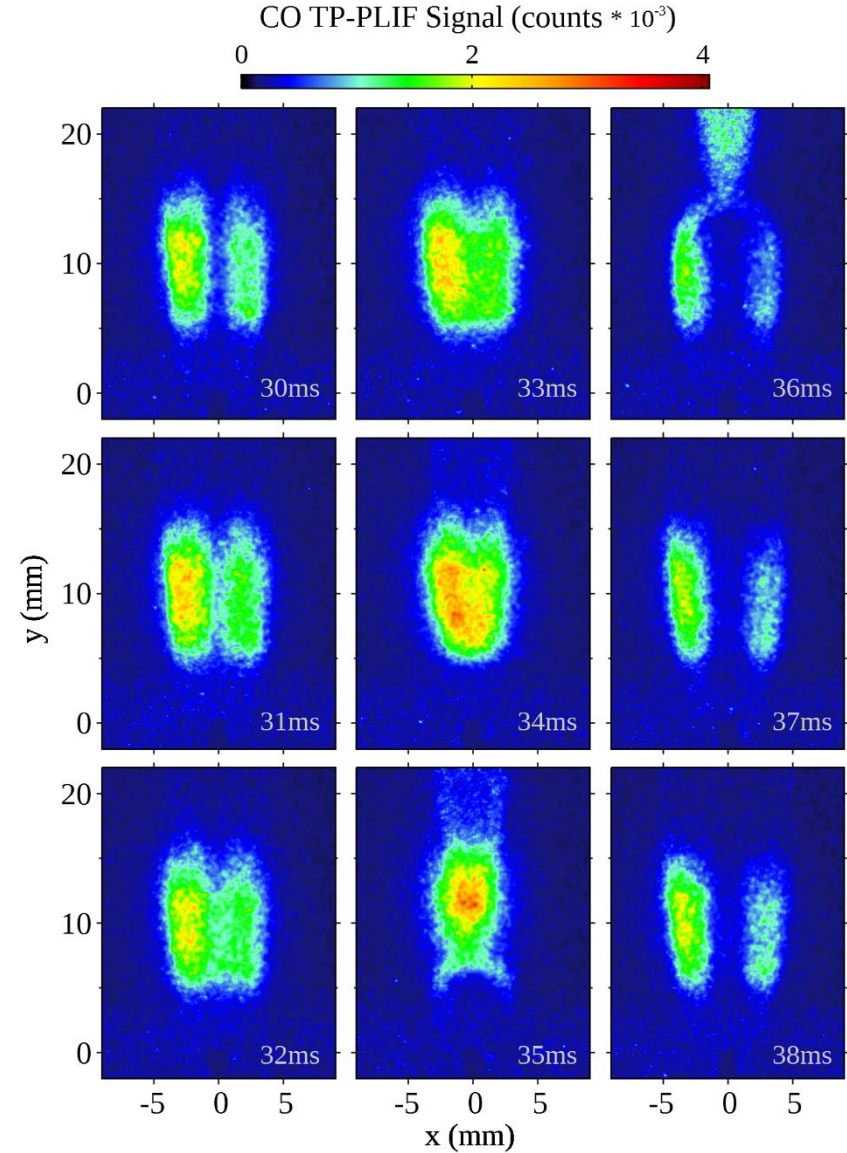
- Nozzle ID = 2.2 mm
- Average jet (methane) velocity = 7.6 m/s
- Average air coflow velocity = 0.33 m/s
- Reynolds number ~ 1000
- Driven at 60 Hz using a piston device in fuel line
- Single-laser-shot images acquired at 1 kHz



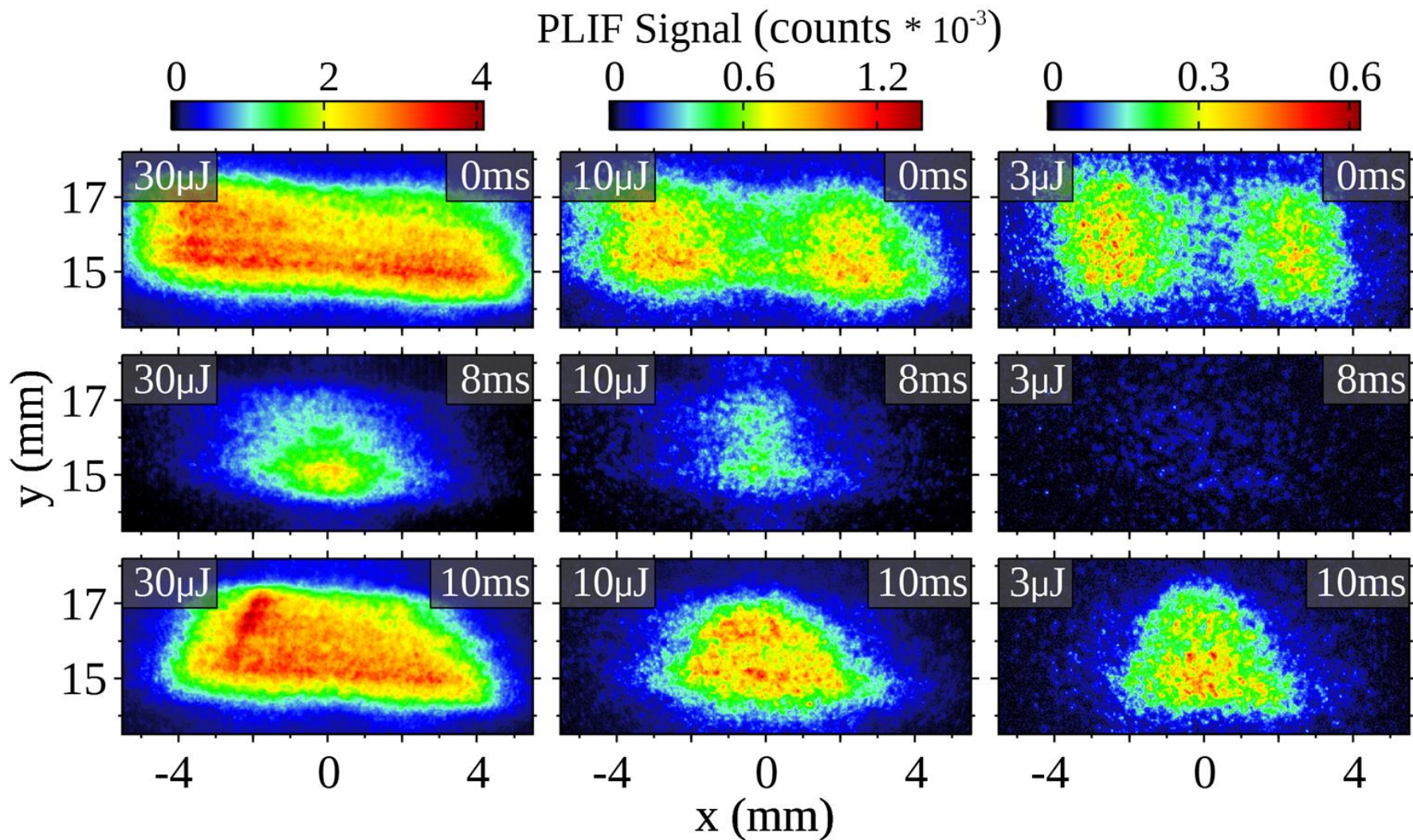
CO Visualizations at 1000 Hz:

Driven jet flame:

- Nozzle ID = 2.2 mm
- Average jet (methane) velocity = 7.6 m/s
- Average air coflow velocity = 0.33 m/s
- Reynolds number ~ 1000
- Driven at 60 Hz using a piston device in fuel line
- Single-laser-shot images acquired at 1 kHz



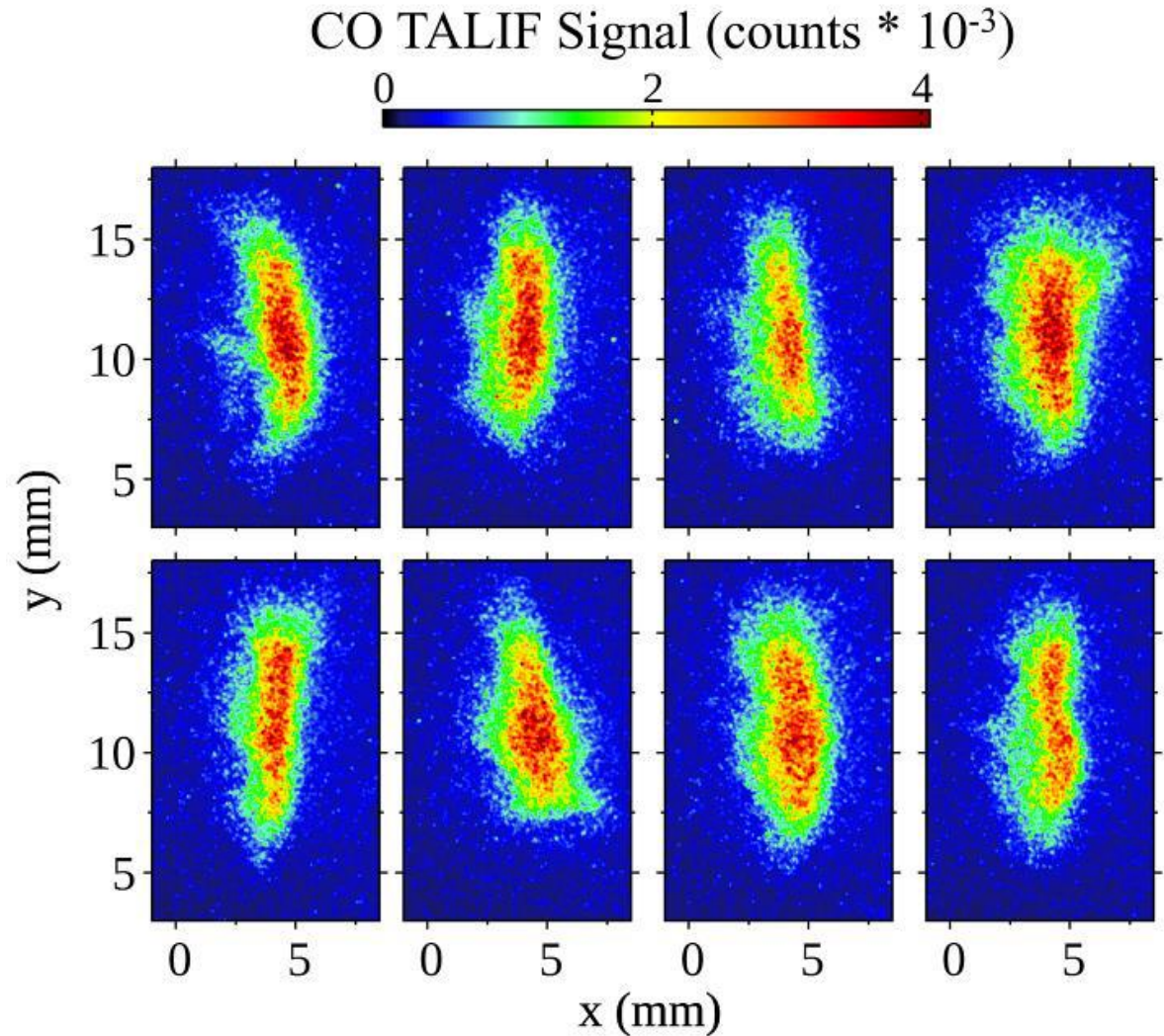
CO Visualizations at 1000 Hz:



CO Visualizations at 1000 Hz:

Unsteady jet flame:

- Nozzle ID = 2.2 mm
- Single-laser-shot images acquired at 1 kHz
- Fuel flow rate increased until flame became unsteady
- 1 kHz not fast enough to track flame fluctuations



Conclusions

- Two-photon CO PLIF performed with fs laser in steady and driven flames at 1 kHz
- Photolytic interferences studied in sooting diffusion jet flame
- Spectrally resolved emission characterized
- Single-laser-shot measurements with minimal photolytic interferences demonstrated in unsteady flame

Thank you for your attention!