Laser techniques for flame and combustion thermometry

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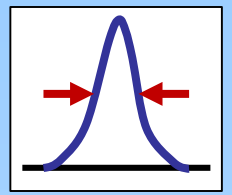
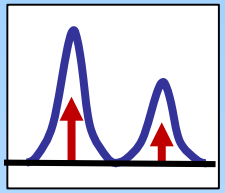
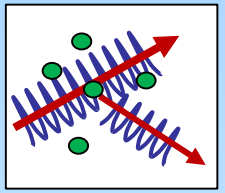
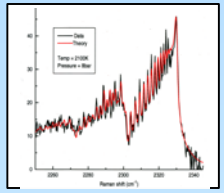
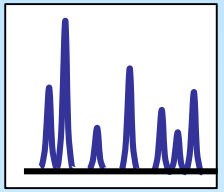
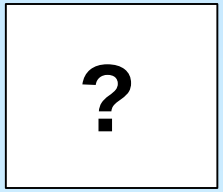
Department of Physics

Laser techniques for thermometry

- ***Tuneable Diode Laser absorption spectroscopy, TDLAS***
  - *Doppler width of spectral line intensity*
- ***Laser induced fluorescence spectroscopy, LIF***
  - *Relative intensity of spectral lines*
- ***Laser Rayleigh scattering***
  - *Density dependence of scattered intensity*
- ***Coherent Anti-Stokes Raman Scattering, CARS***
  - *Spectral intensity of scattered light*
- ***Degenerate Four-Wave Mixing spectroscopy, DFWM***
  - *Spectral intensity of scattered light*
- ***Laser induced grating spectroscopy, LIGS***

The importance of precision

- Validation of theory and/or models

  e.g. Reaction rates exponentially sensitive to temperature

- Distinguishing “uncertainty” from “variability”

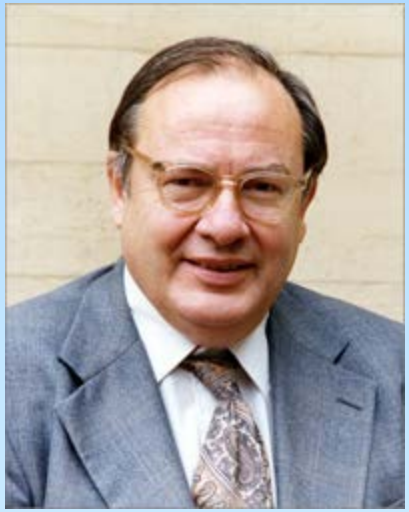
  e.g. Cyclic variability in IC engine combustion

- Relative measurements are easier than absolute

  e.g. Comparison of charge cooling for bio-fuels

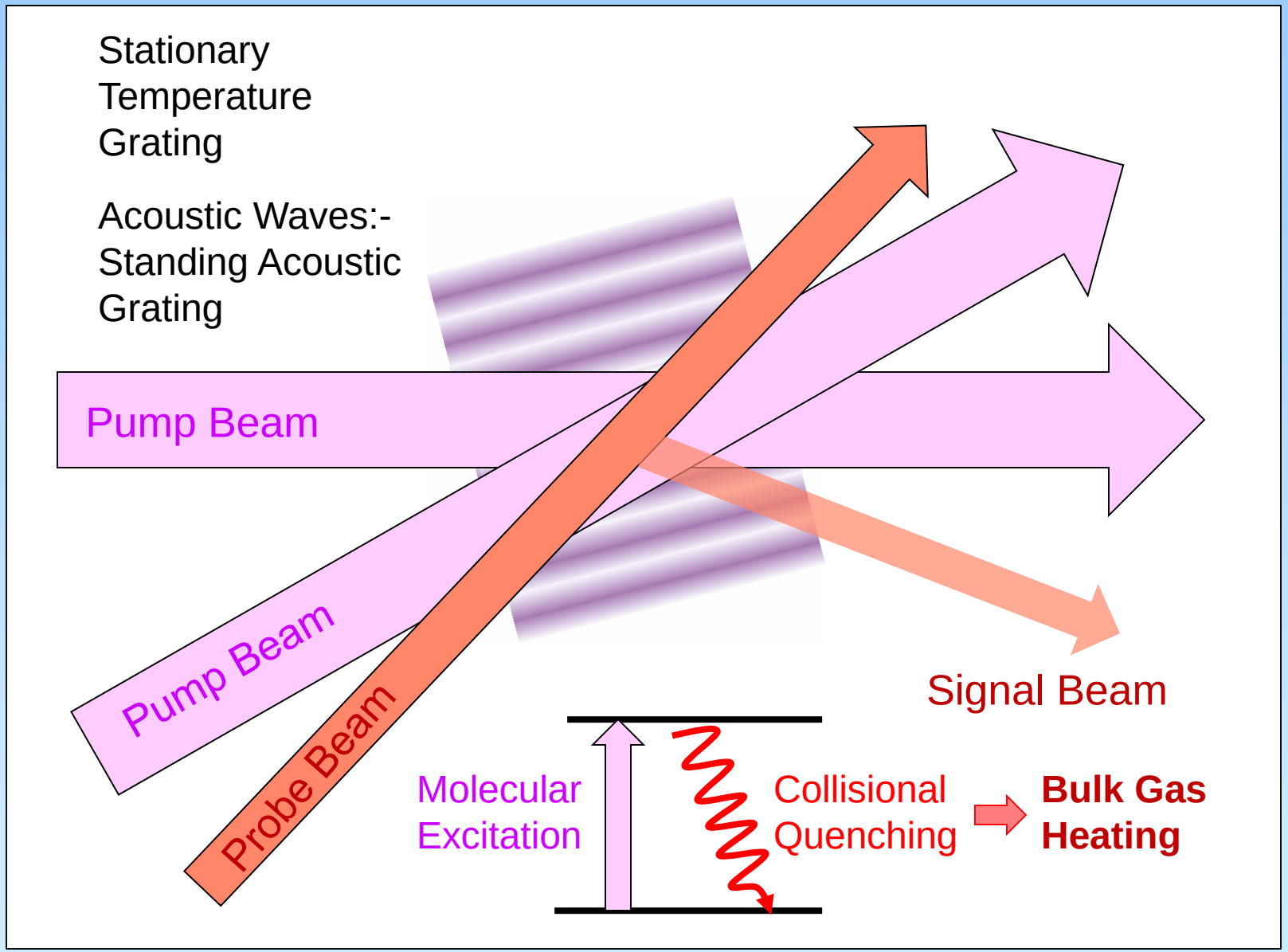
The secret of precision

"Never measure anything except a frequency"

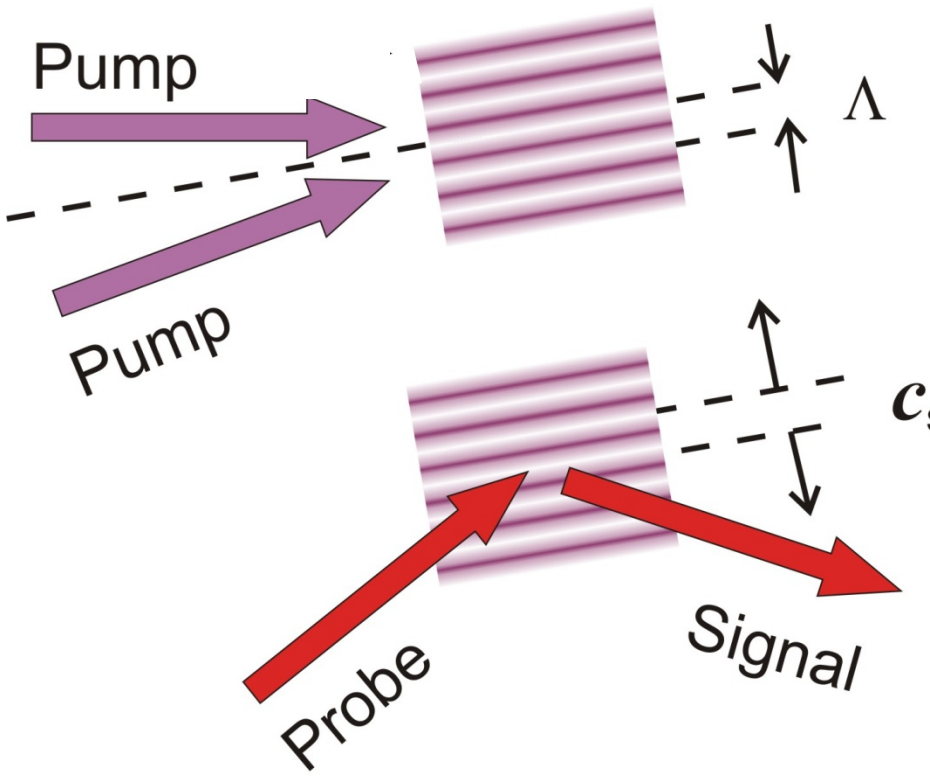


Arthur Schawlow
1921 – 1999
Nobel Prize for Physics, 1981

Laser Induced Thermal Gratings



Laser induced thermal gratings



Λ Grating period,

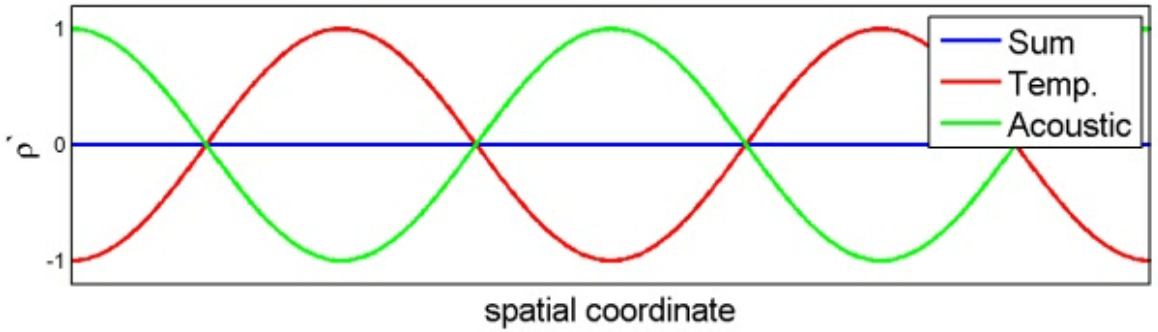
c_s Sound speed,

Oscillation frequency c_s/Λ

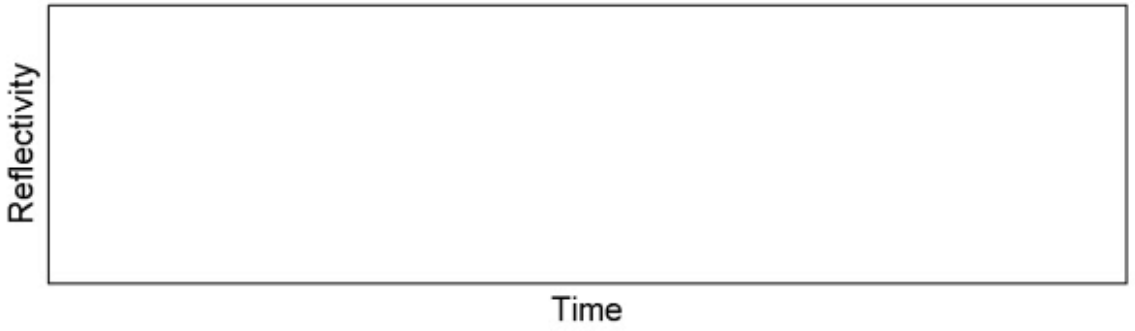
Grating Evolution

Temperature
Acoustic
Sum

Density perturbation ρ



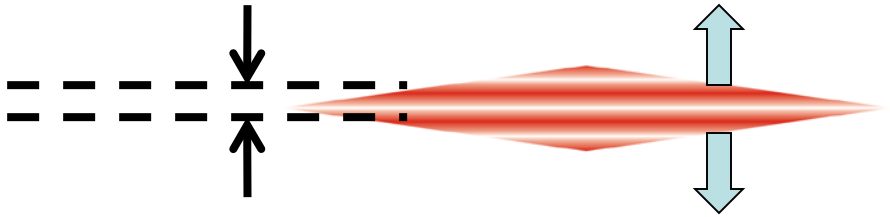
Grating Reflectivity



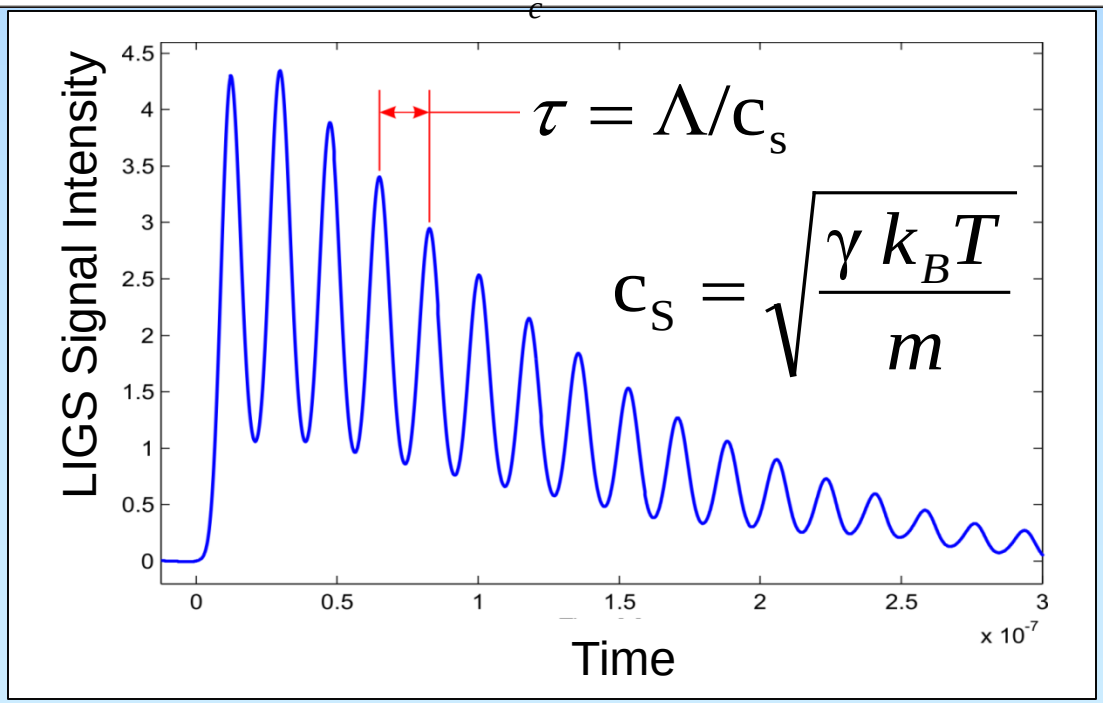
Oscillation of LIGS signals

Grating spacing, Λ

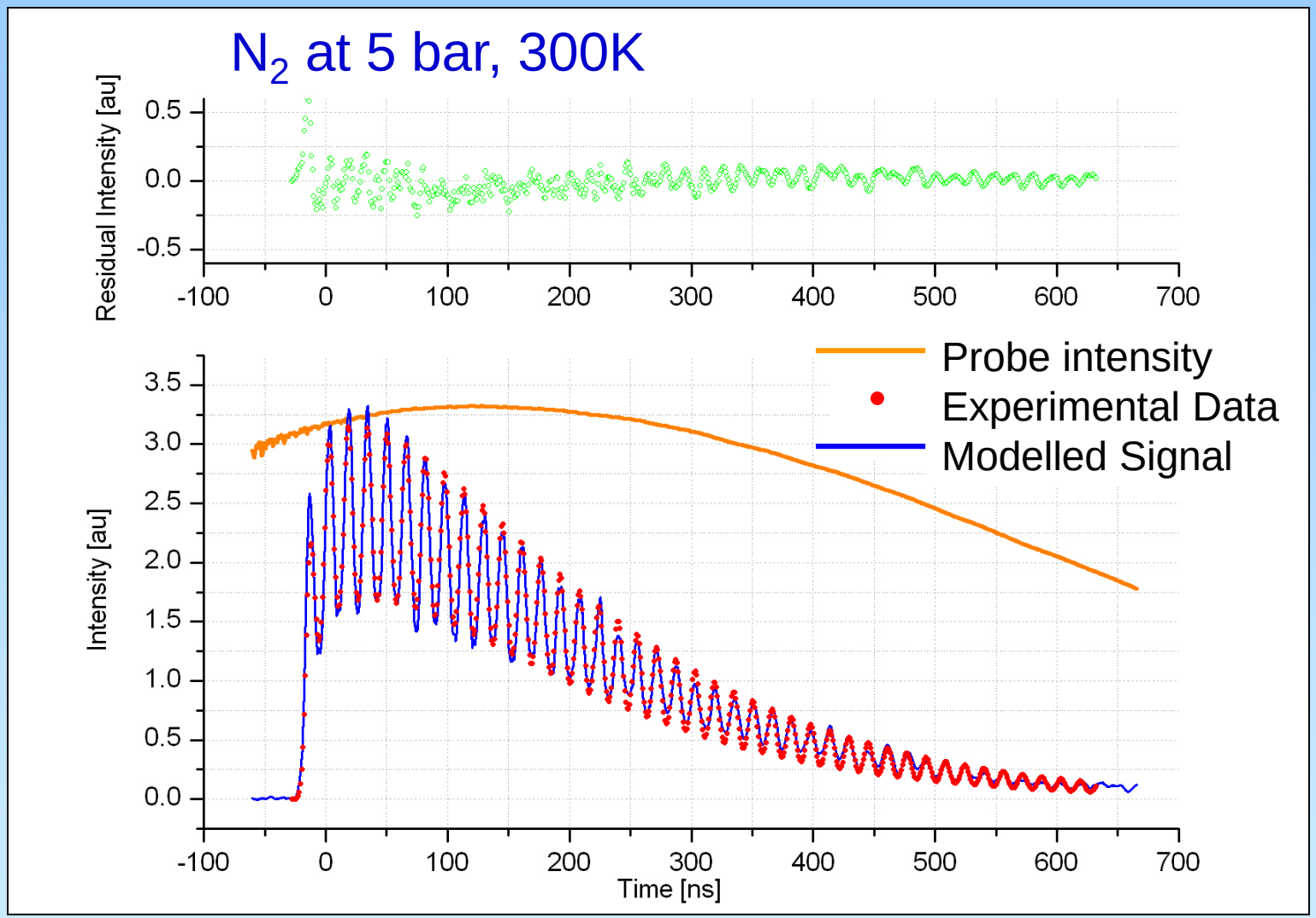
Sound speed, c_S



LIGS signal oscillates at frequency: $f_{osc} = \frac{c_S}{\Lambda}$

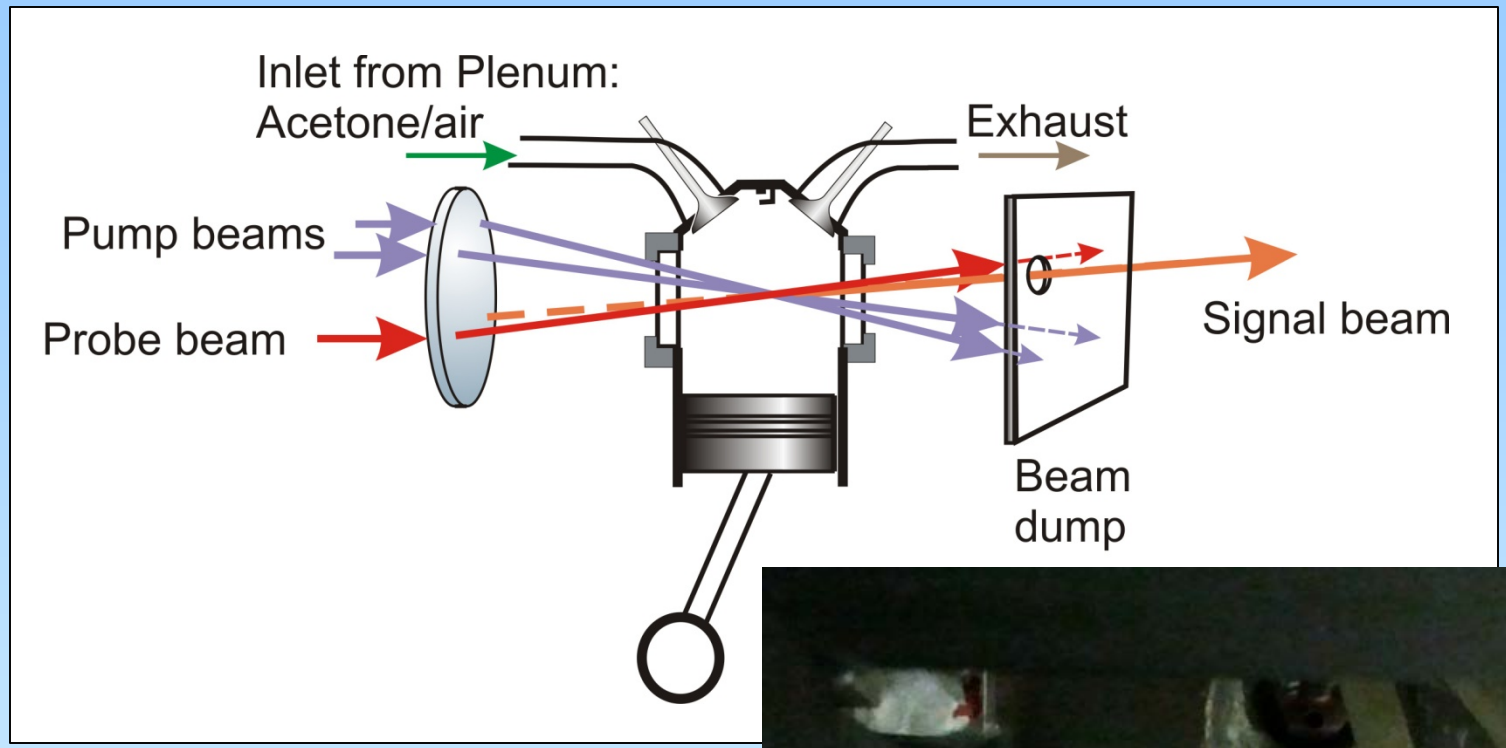


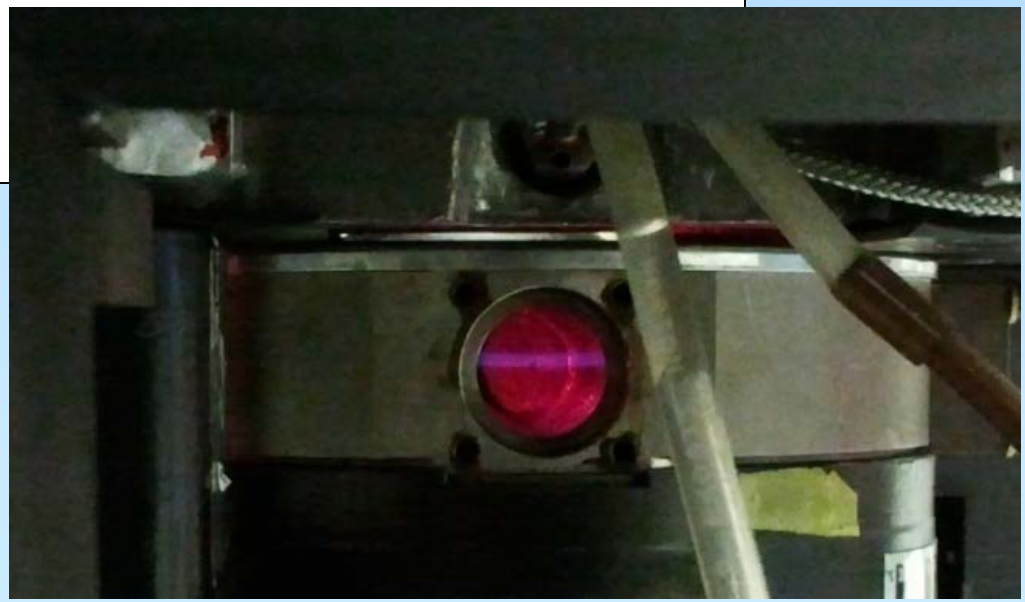
Cell-based measurement: LITGS in NO_2 / N_2



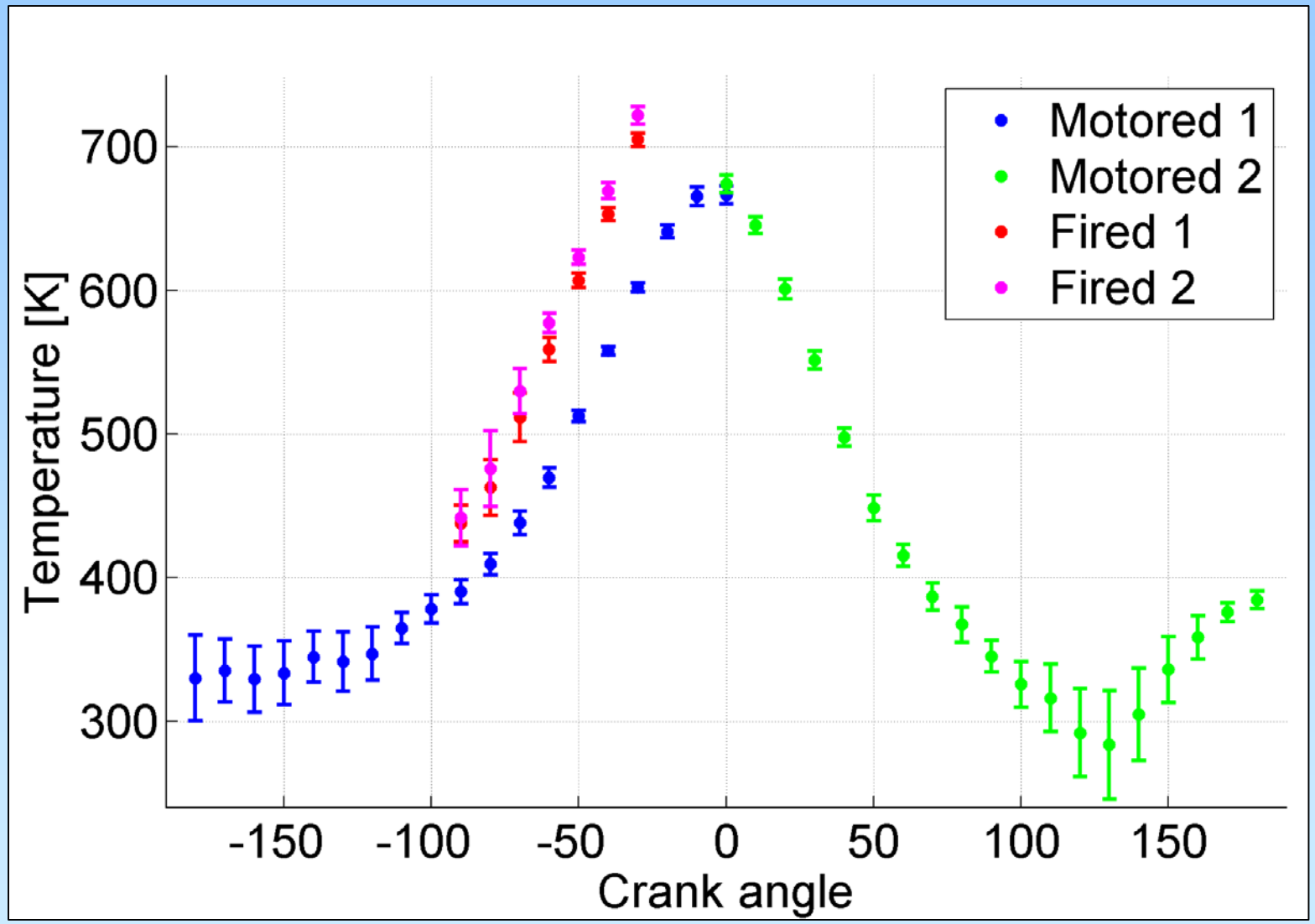
Temperature precision ± 0.1%

LIGS Thermometry in Direct Injection Spark Ignition DISI engine

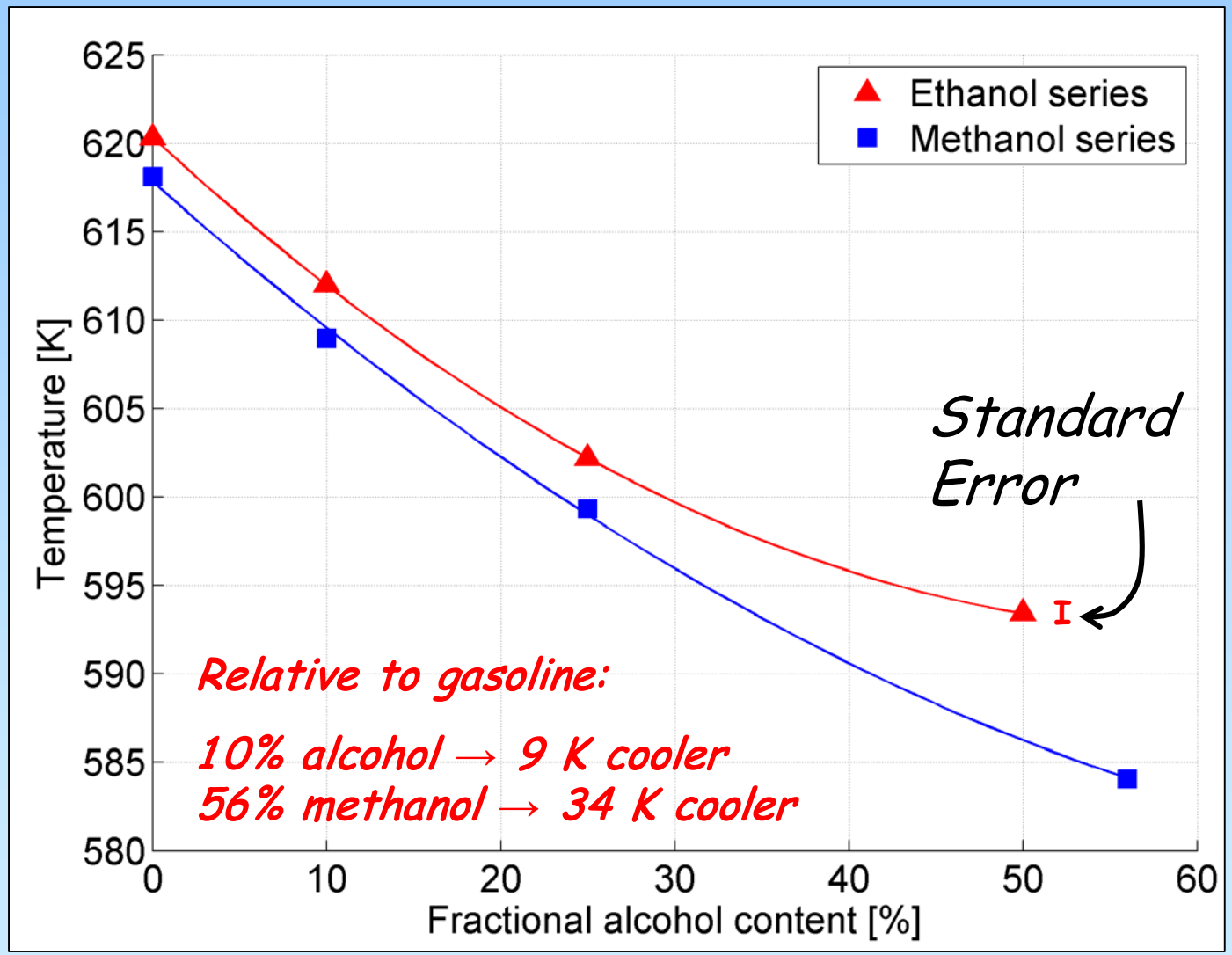




Temperature measurement over a cycle

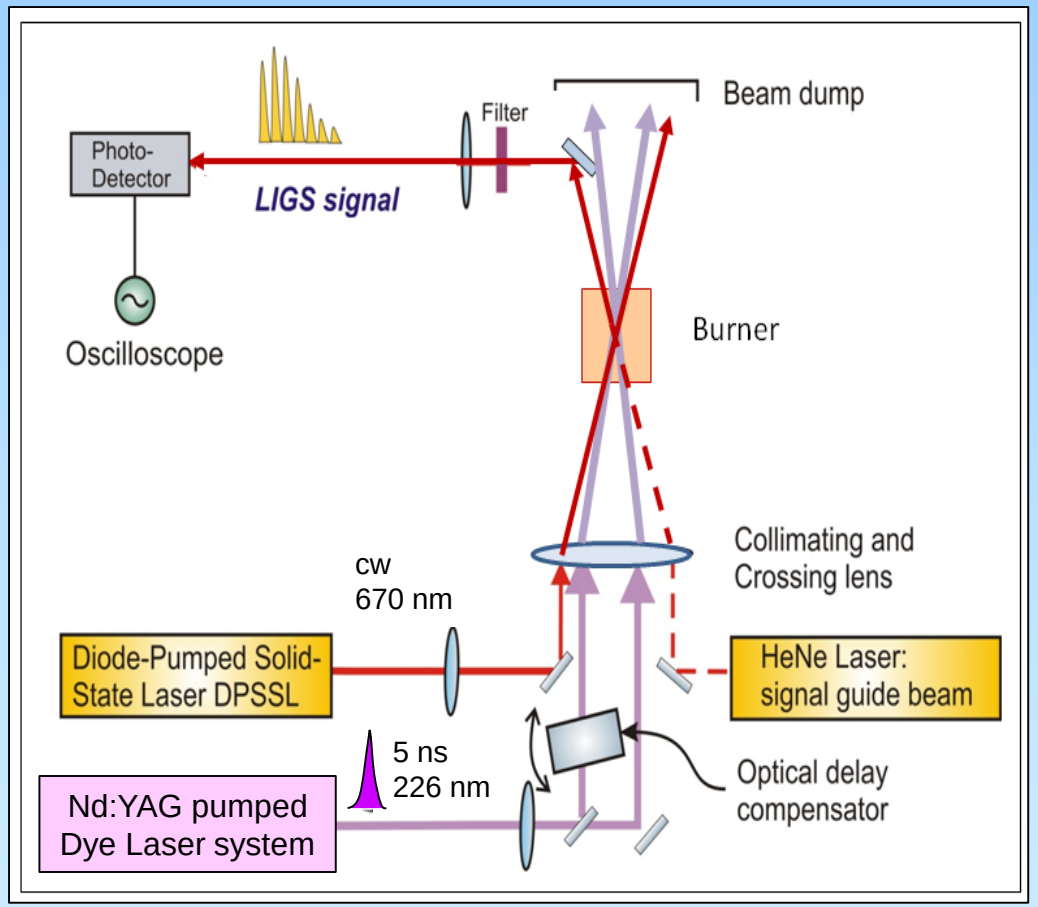


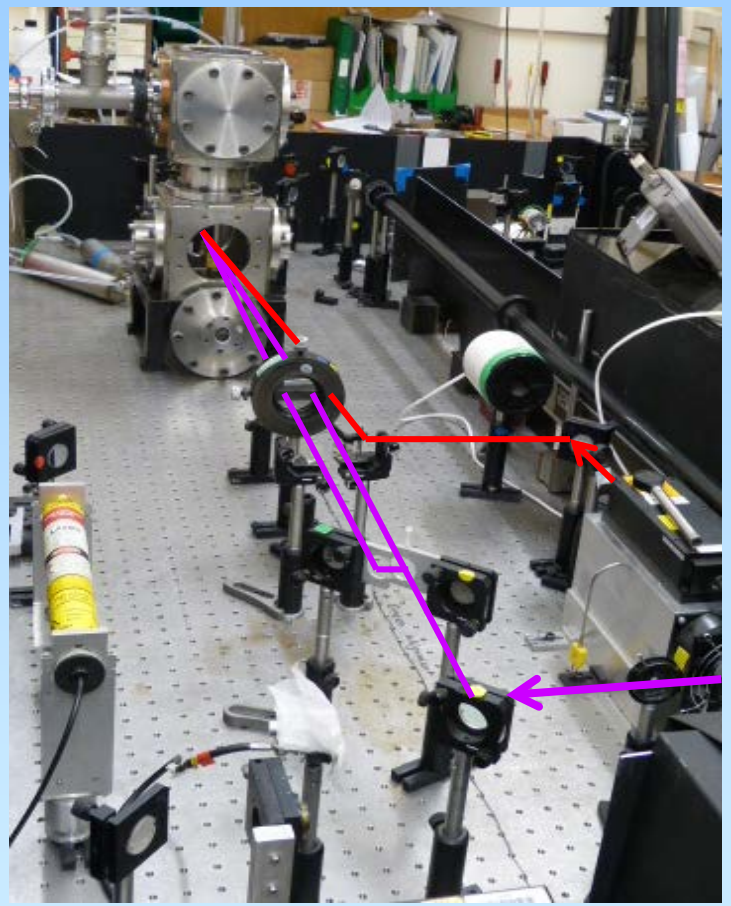
Charge cooling with gasoline/alcohol blends



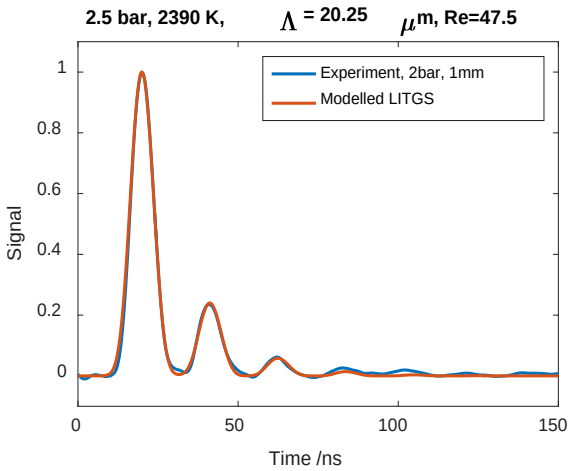
Ben Williams, Megan Edwards, Richard Stone, John Williams and Paul Ewart
Combustion & Flame, 161 270–279, (2014)

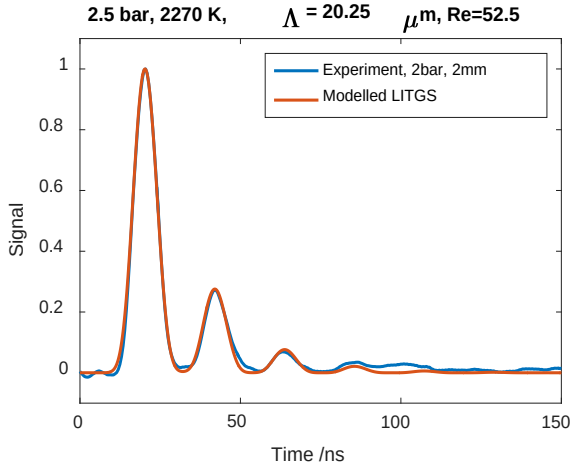
Traceable flame temperature standard

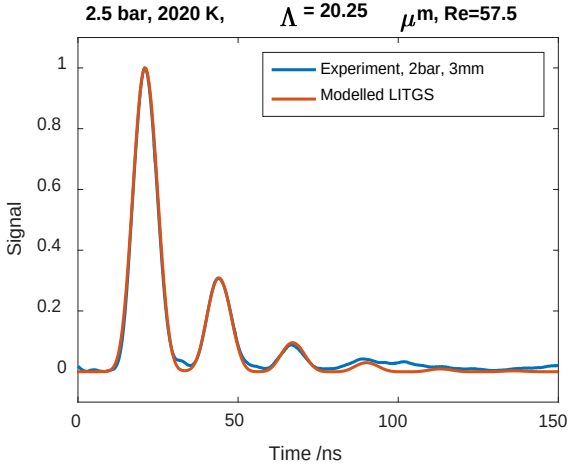


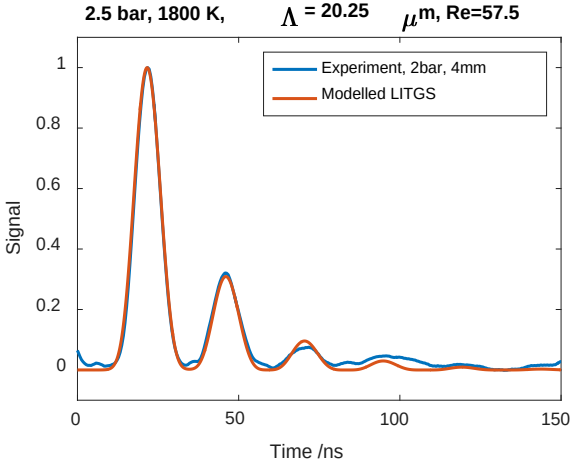


Temperature vs HAB at 2.5 bar

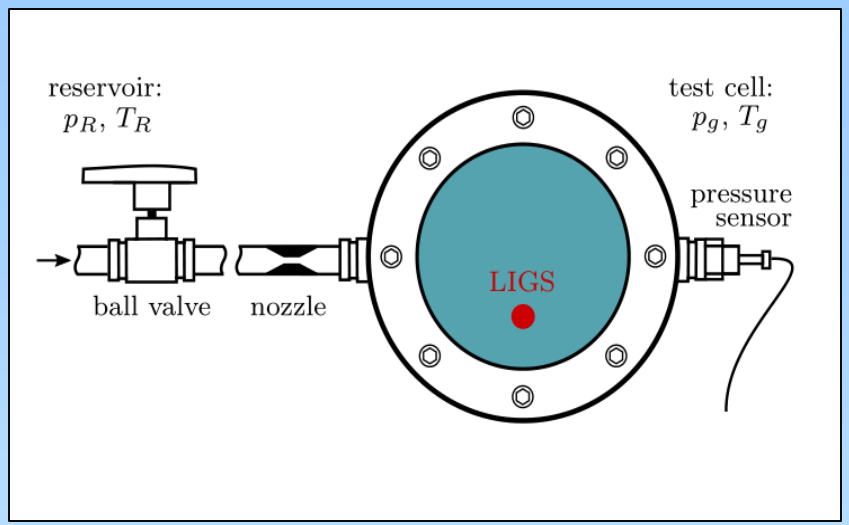


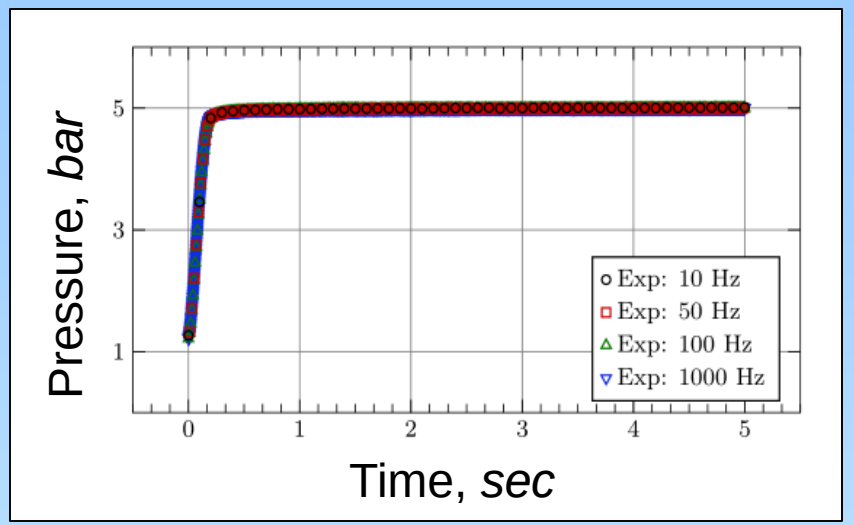


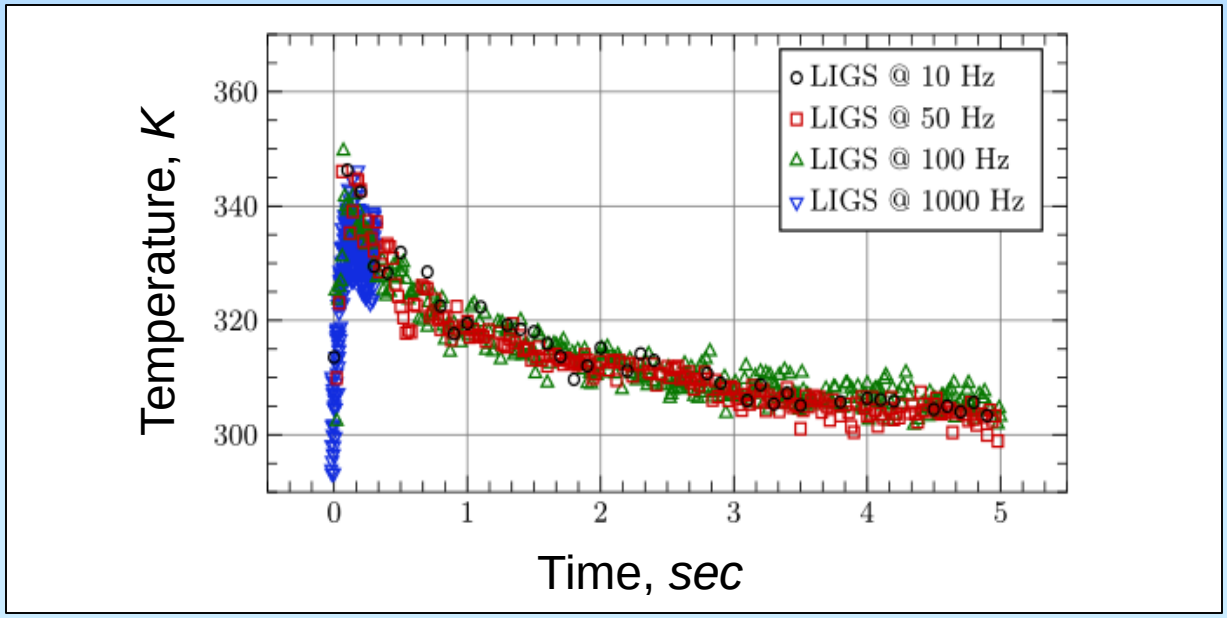




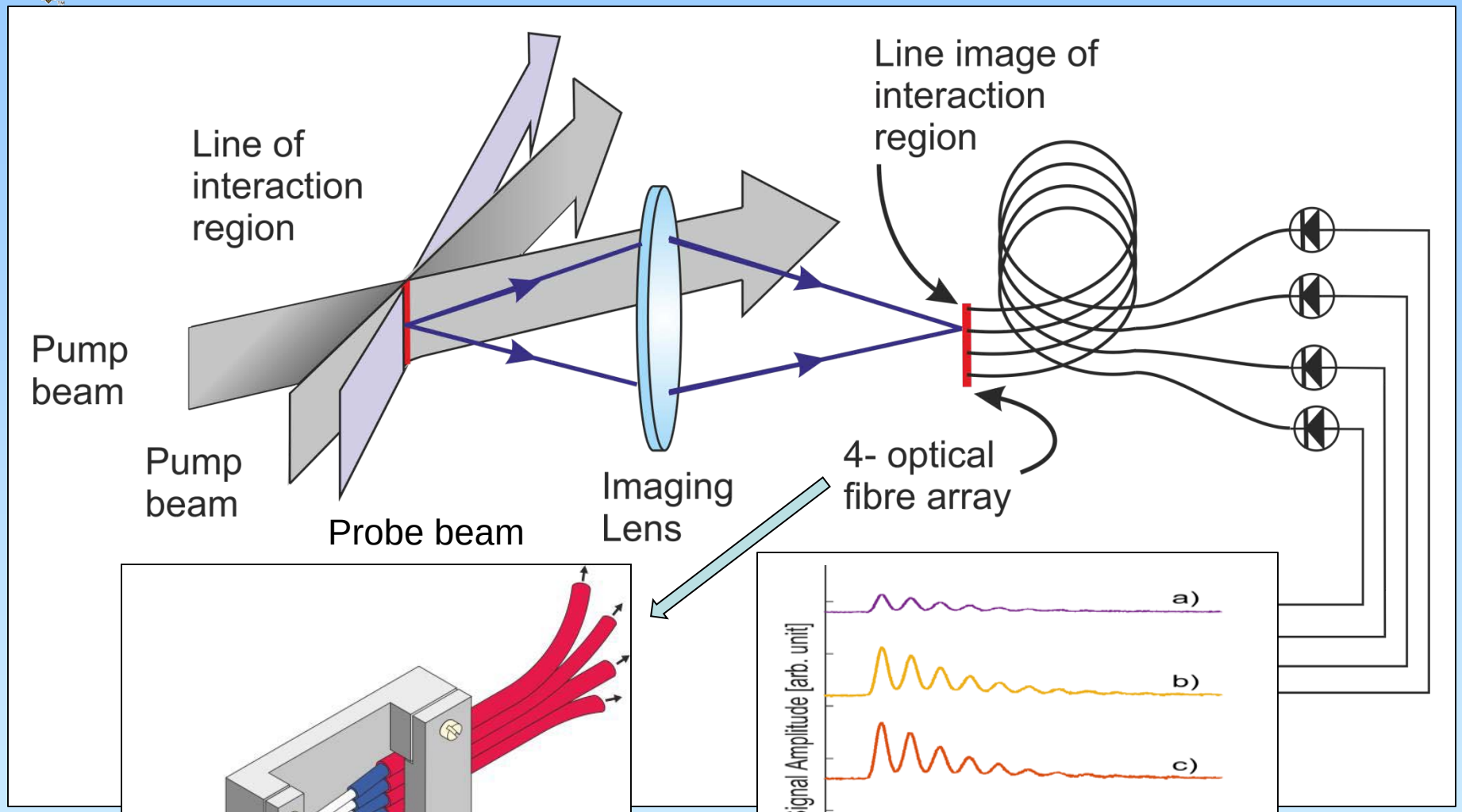
High speed LIGS



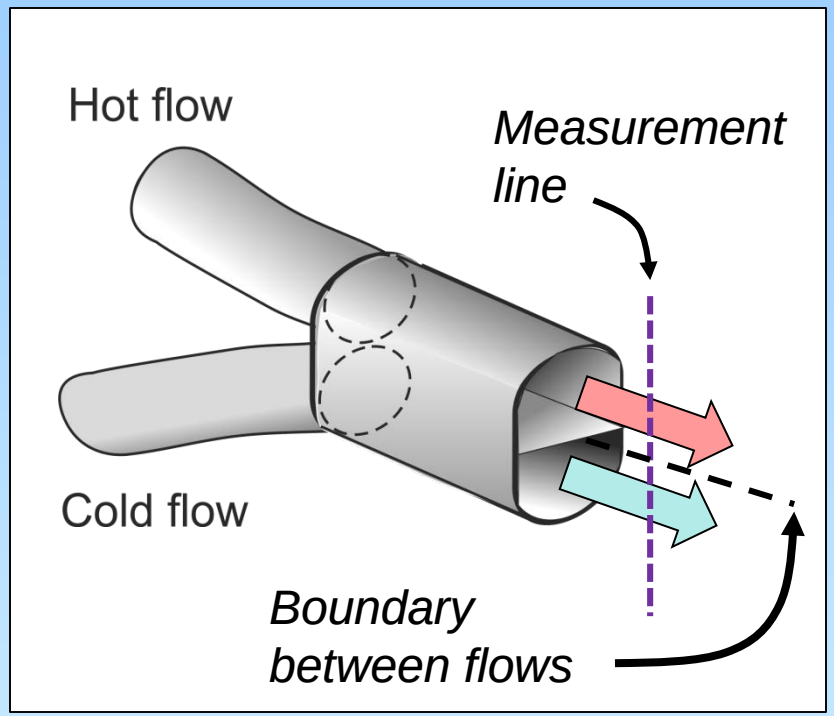


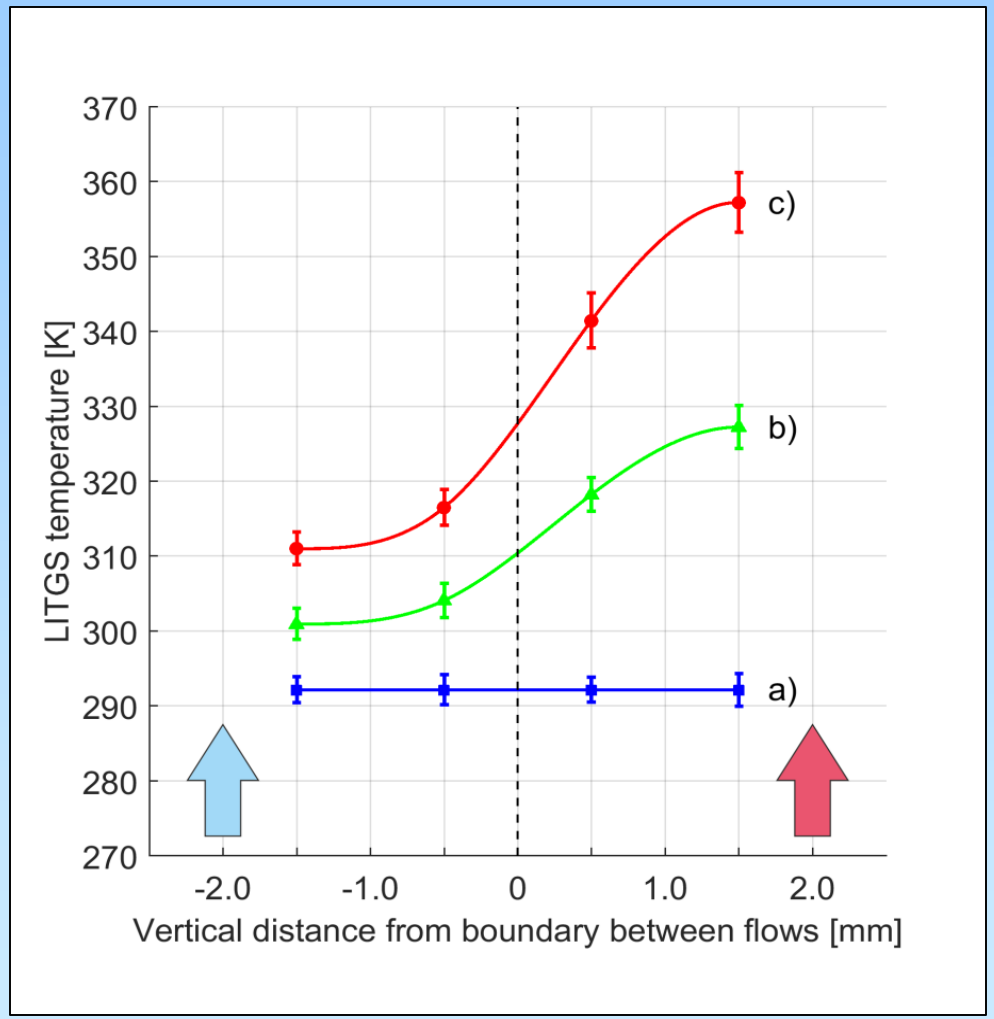


Multi-point 1-D LIGS

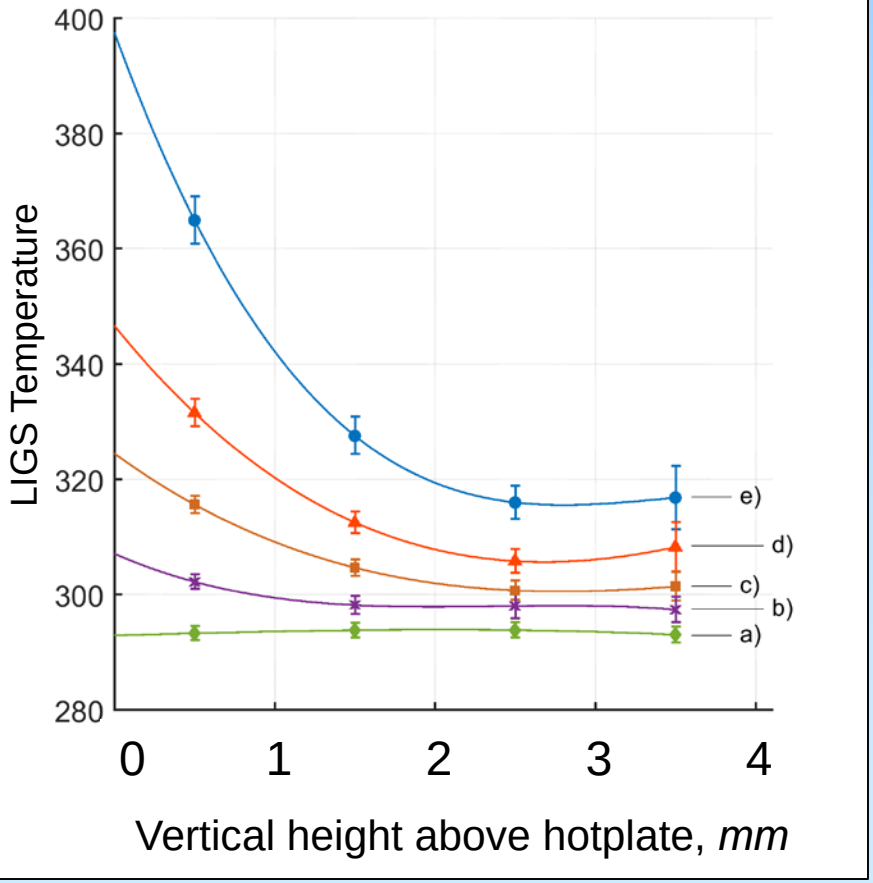


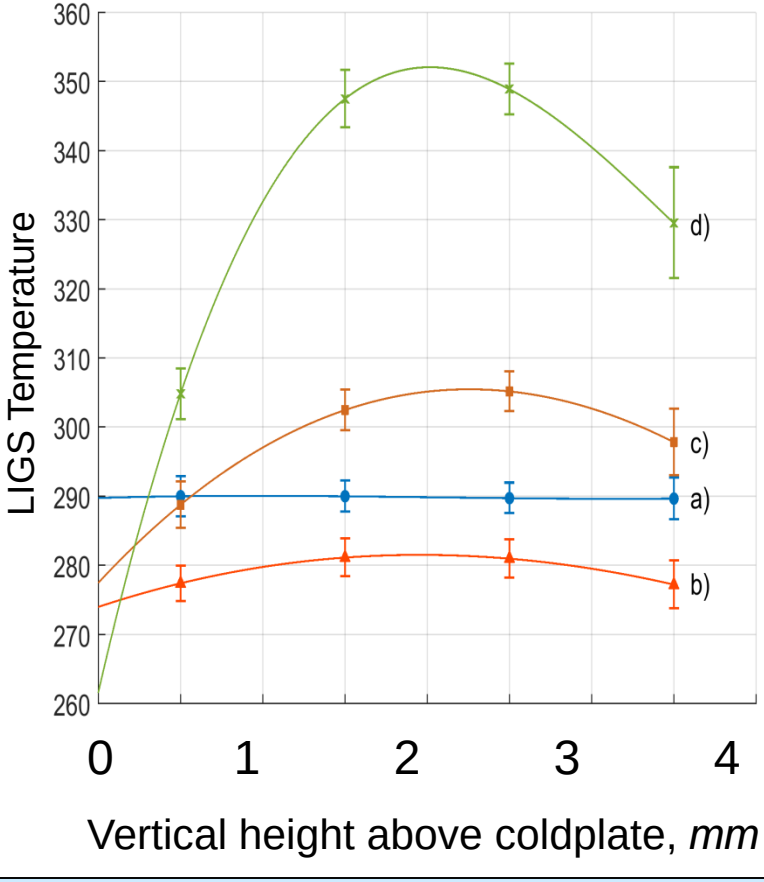
Temperature gradient in gas flows



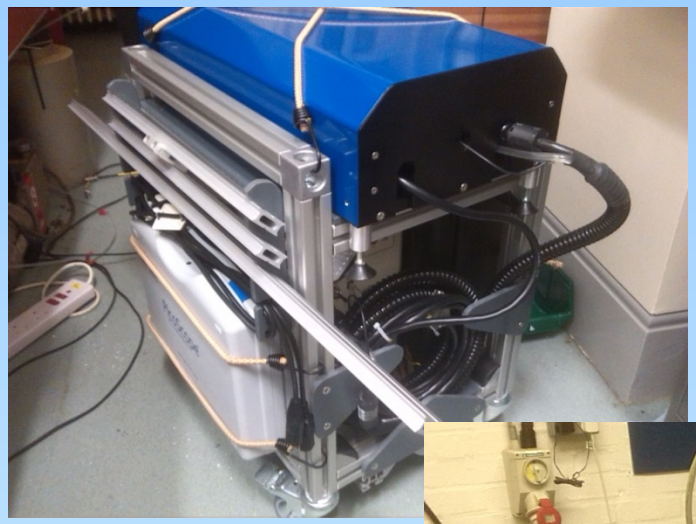


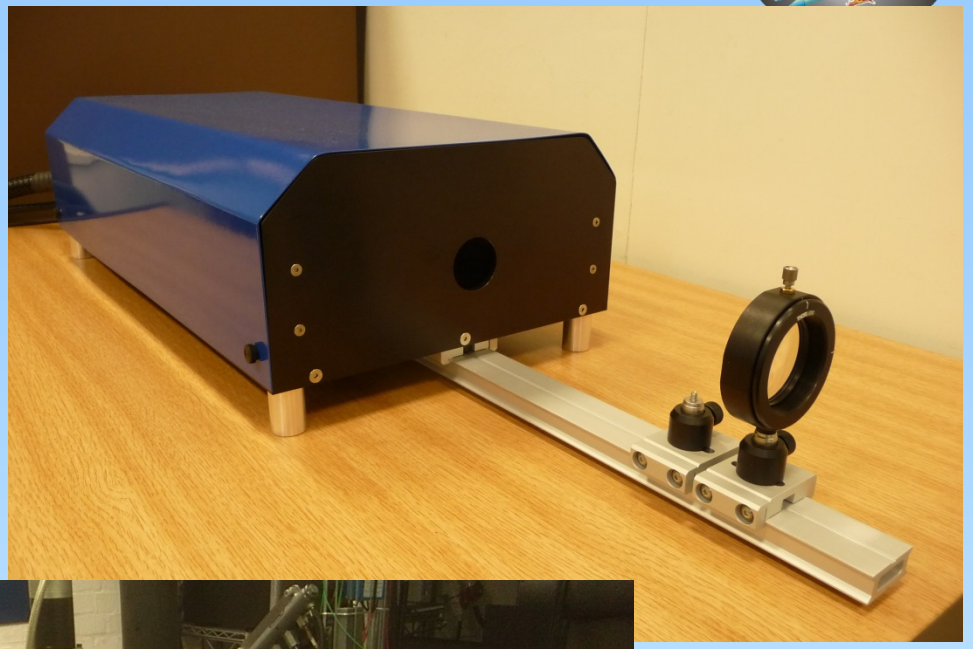
Temperature measurement in boundary layers

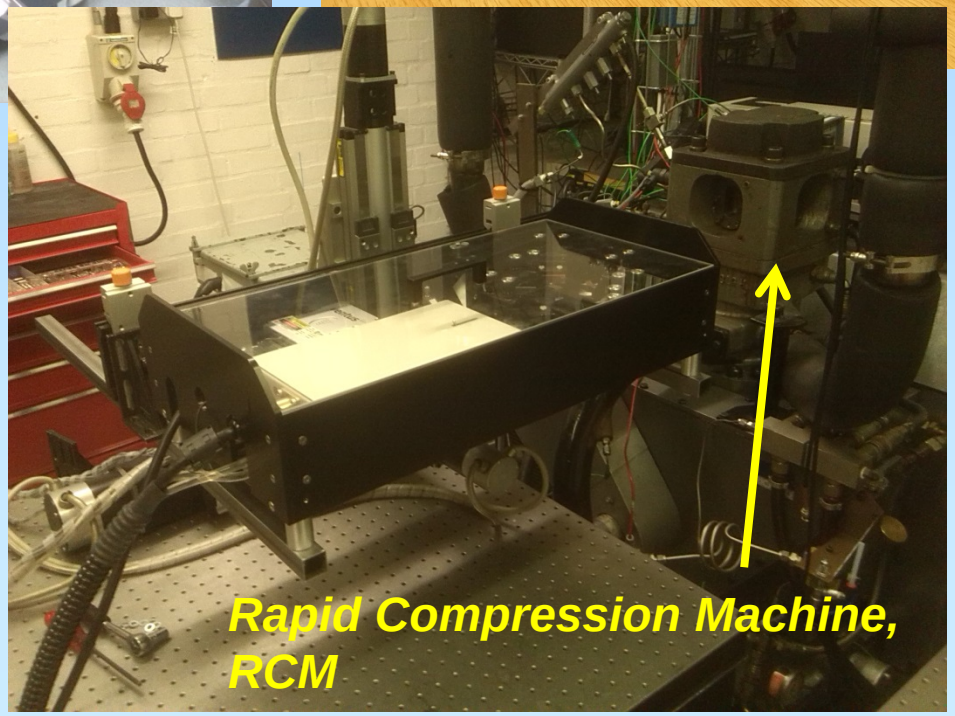




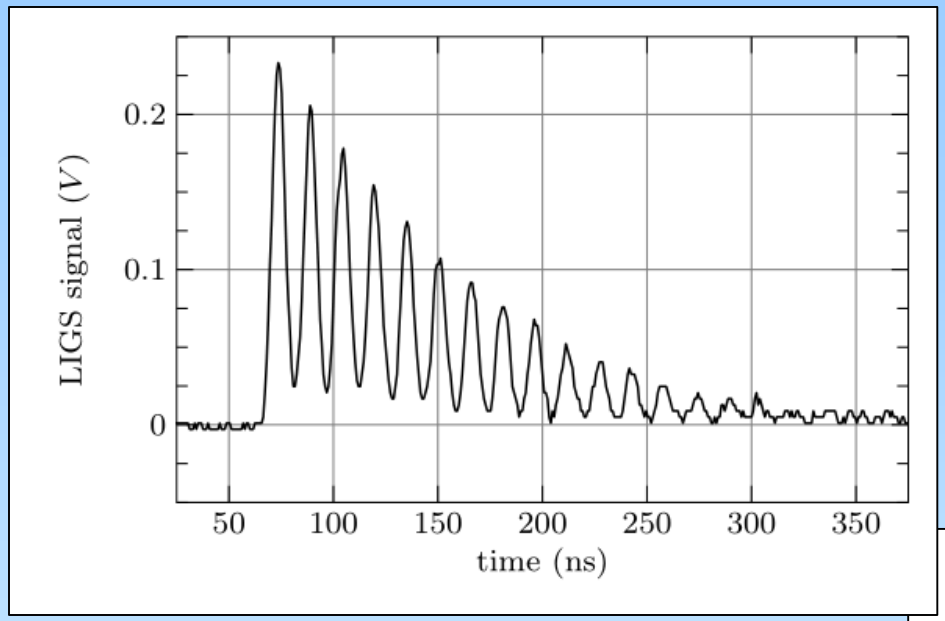
Portable LIGS thermometer



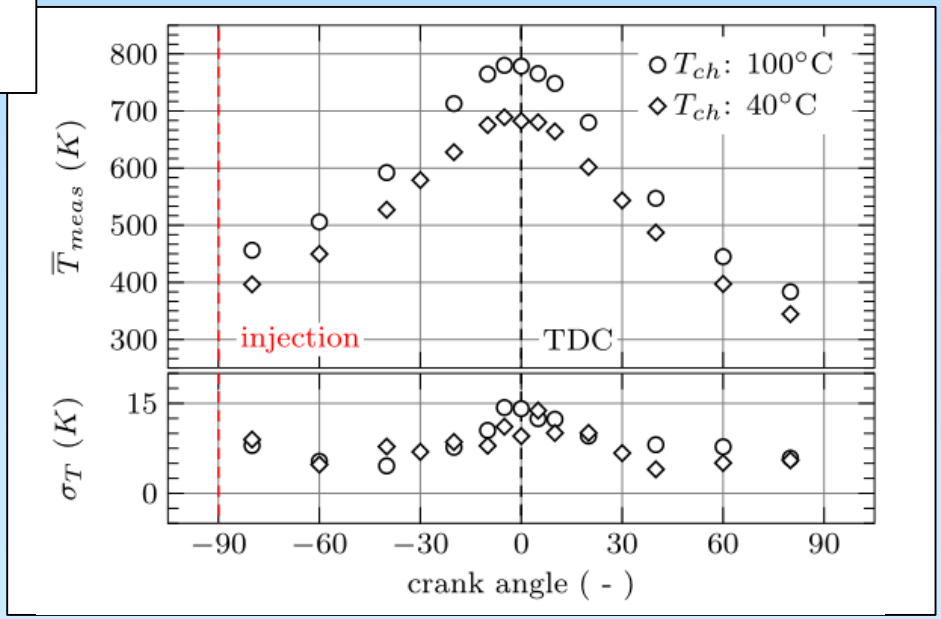




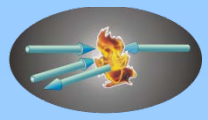
LIGS in Rapid Compression Machine



LIGS signal under Diesel conditions
Pressure 10 – 100 bar,
T = 800 @ TDC



Conclusions: LIGS thermometry



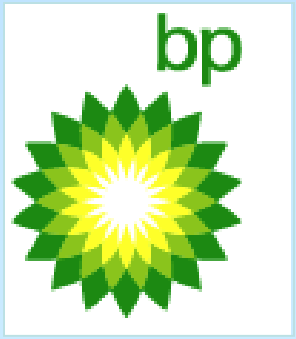
- LIGS temperature precision: 0.1 – 1.0%
- “Real World” Applications

  e.g. IC & Diesel engine diagnostics
  Portable LIGS thermometer
  Multiple point measurements

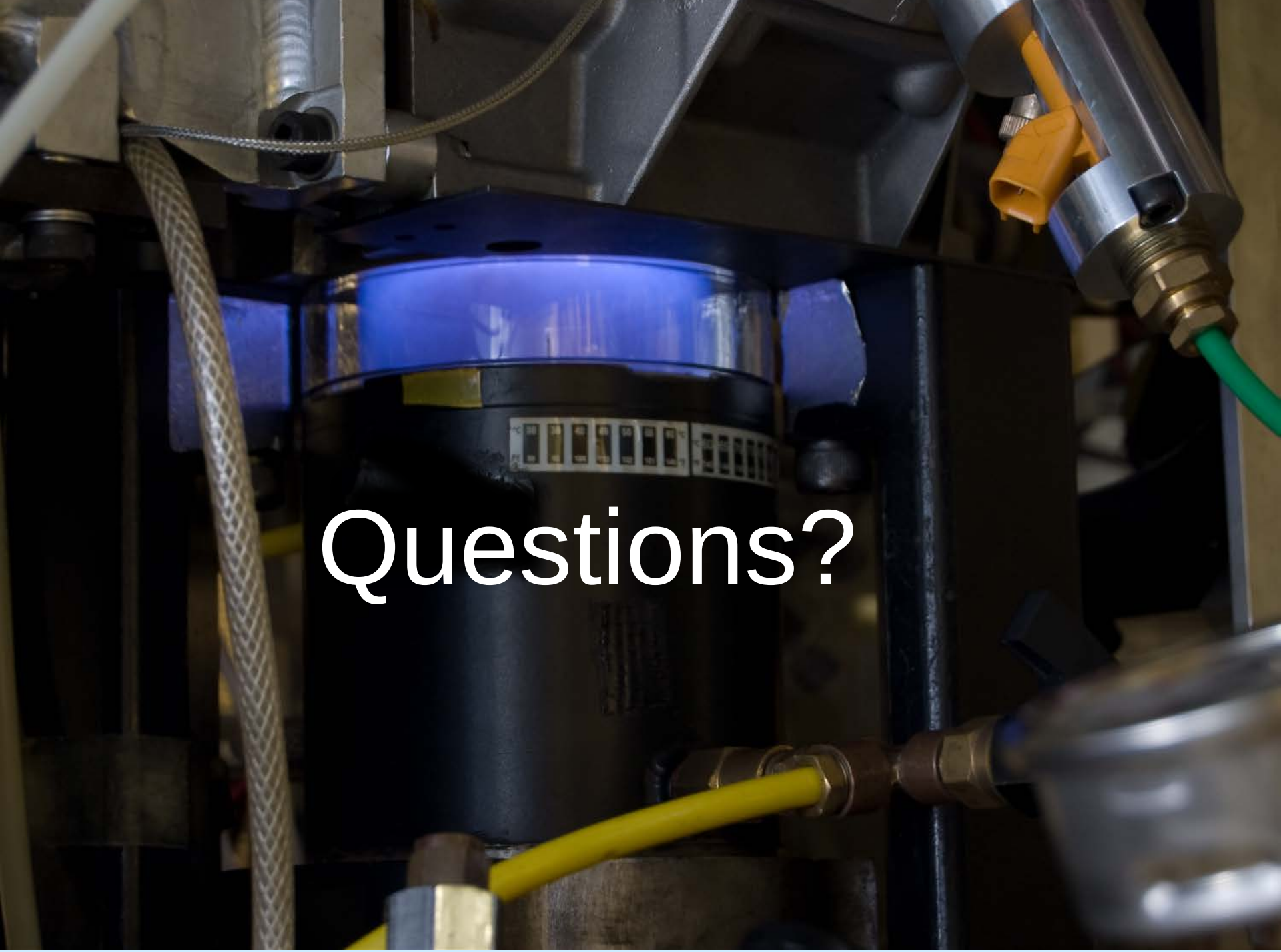
- Calibrated standard for flame temperatures:
  1000 – 3000 K
- Future work

- High speed measurements, Hostile environments, Hypersonics, Shock tube studies etc.

Acknowledgments



Dr Ben Williams
Professor Richard Stone
Dr Rob Stevens
Dr Megan Edwards
Dr Anna-Lena Sahlberg
Dr Felix Förster
Mr Andrew Luers


Questions?