Thermographic Phosphors for Temperature Measurements

Subtask 3.4 D: Application of Laser Techniques for Combustion Dlagnostics

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Background

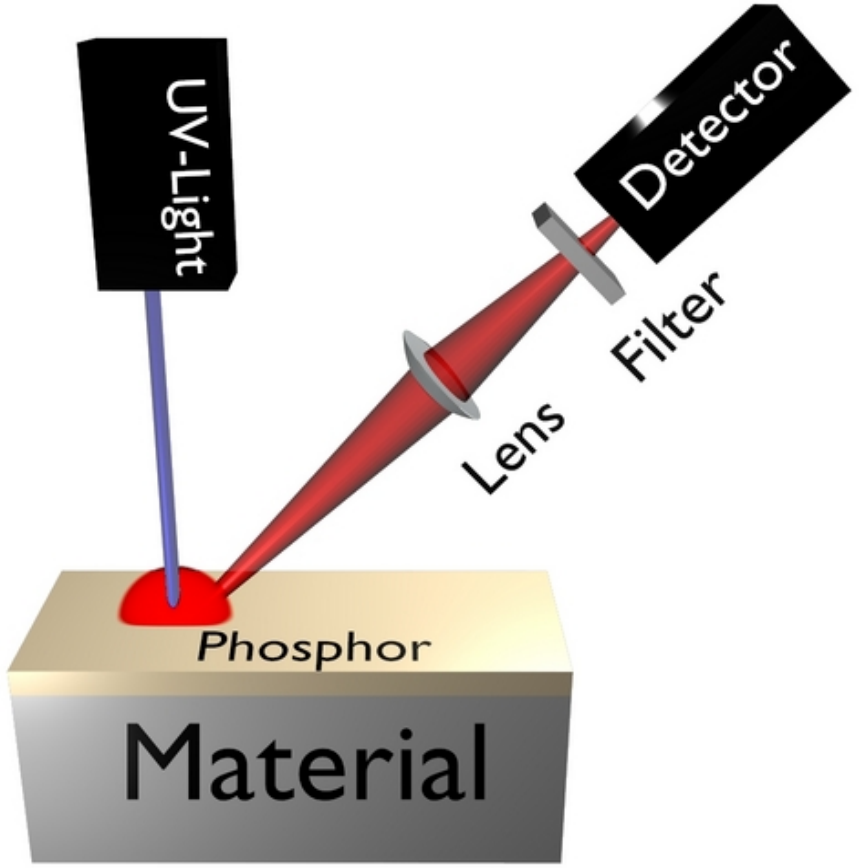
- **A. Omrane:**
  - **Thermometry using laser-induced emission from thermographic phosphors: development and applications in combustion, Doctoral thesis, Lund University, 2005.**
- **G. Särner:**
  - **Laser-Induced Emission Techniques for Concentration and Temperature Probing in Combustion, Doctoral thesis, Lund Univeristy, 2008.**

Thermographic phosphors

- Introduction/Background/Theory
- Thermometry methods
  - Temporal approach
  - Spectral approach
  - Calibration
  - 2D measurements
- Applications
  - Fires
  - Aero engines

Thermographic phosphors for temperature measurements

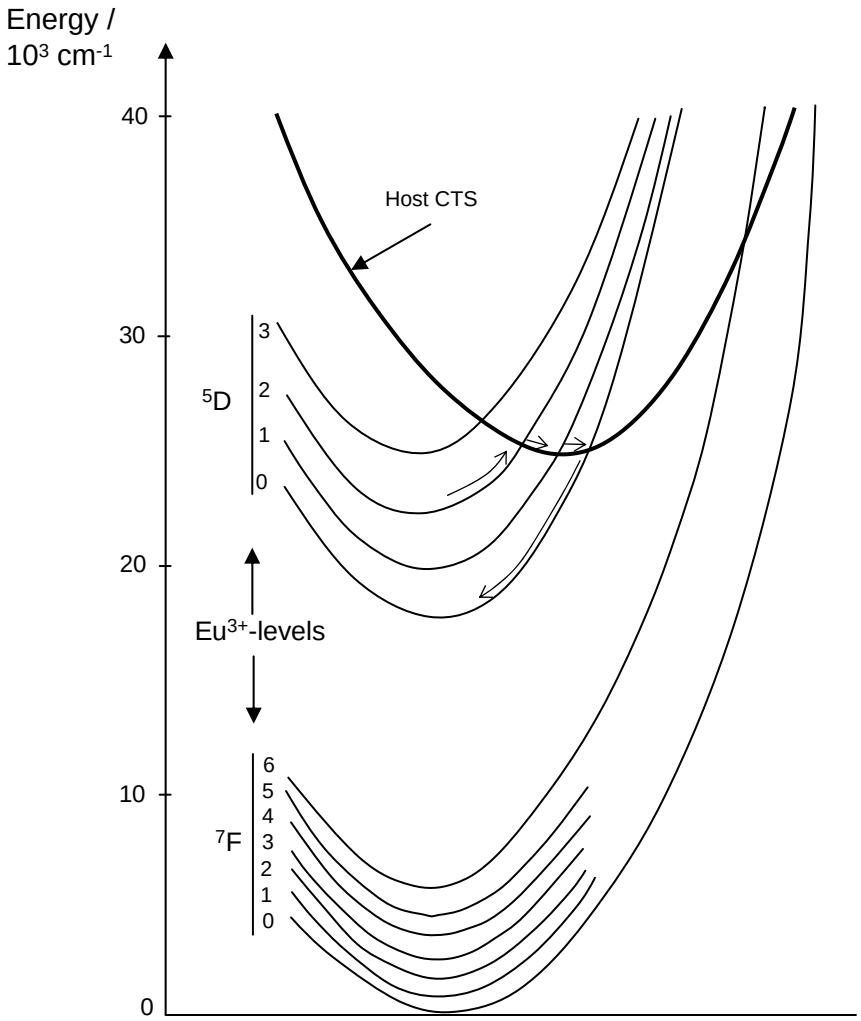
- Industrial and scientific applications.
- Powder(1-10µm), sensitivity from cryogenic to 2000K.
- Excitation: UV (light), laser, e-beam.



Physical description

- Host inorganic material (ceramic) doped with and an activator (rare earth metal)~1 %.
- Host material transparent, laser energy absorbed by the activator.
- Through complex interactions in the electronic configuration of the activator and the host, temperature will influence the spectral and temporal behaviour of the emission

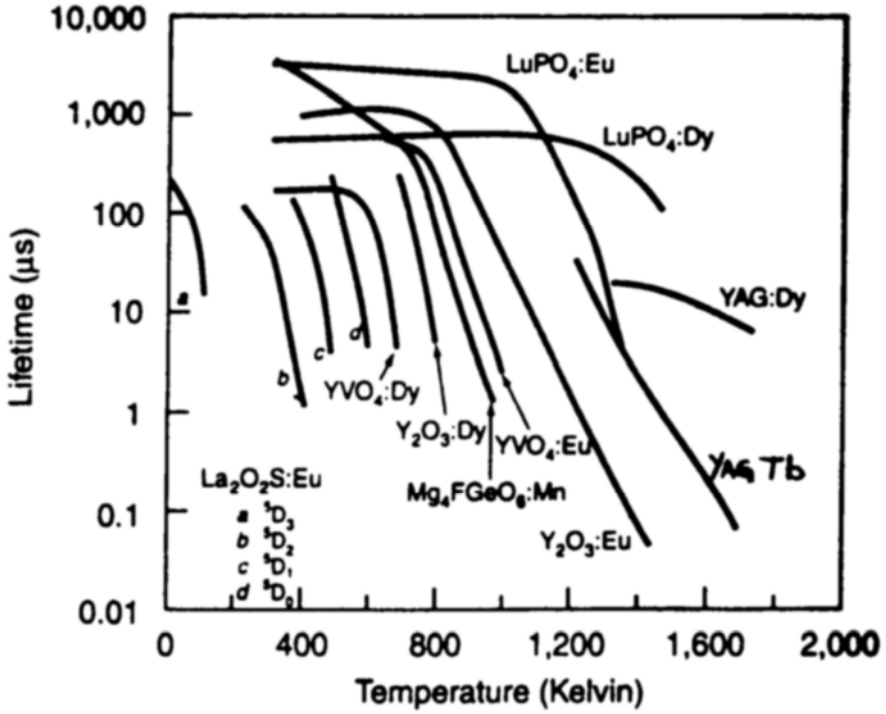
Energy level diagram of an activator and a host

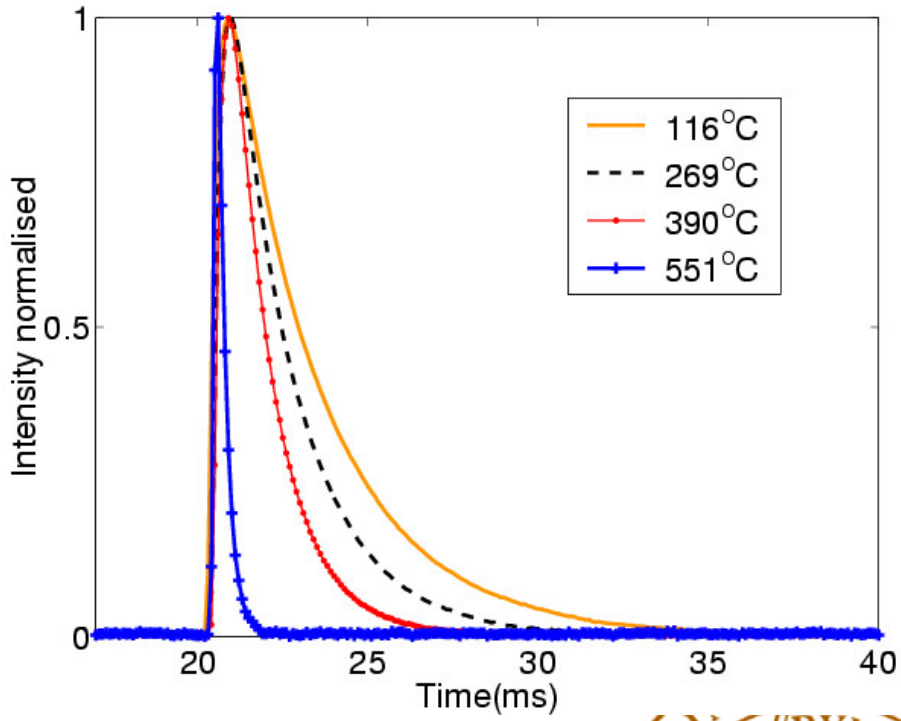


Thermometry Methods

- Lifetime method: Decay time.
- Spectral method: Ratio between emission lines.
- Emission line shift and line broadning.
- Absorption
- Excitation

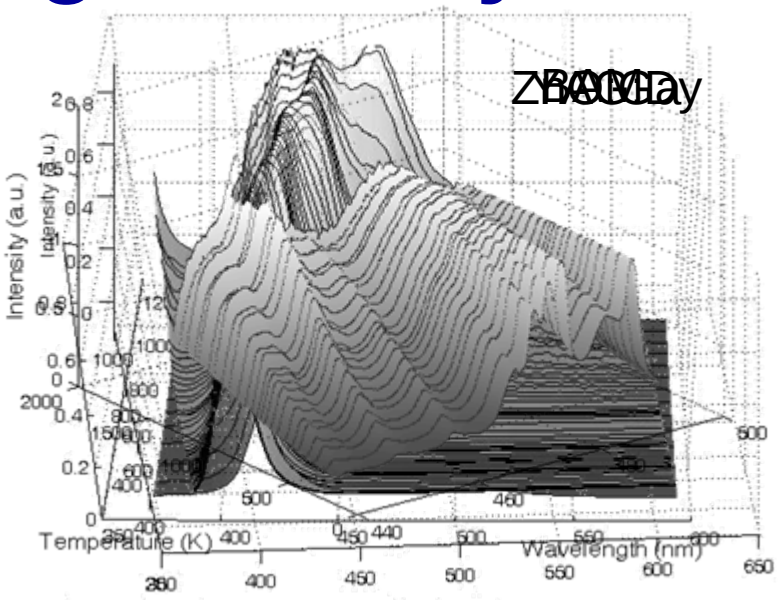
Lifetime method: Decay time

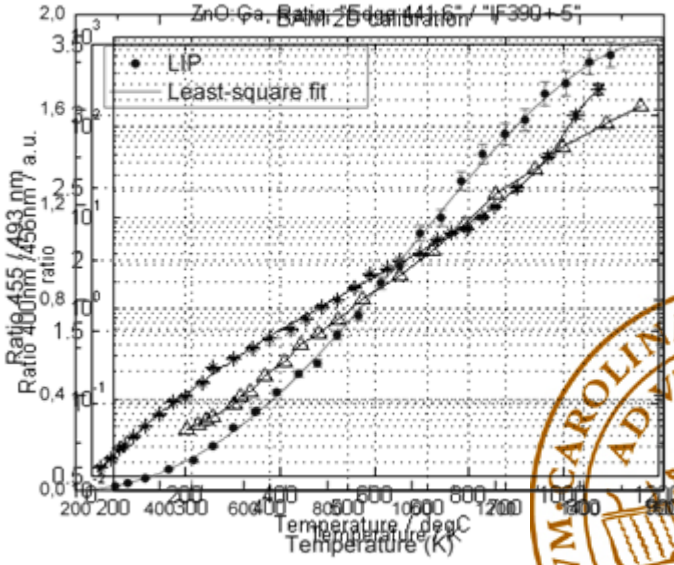




Thermometry using intensity ratio

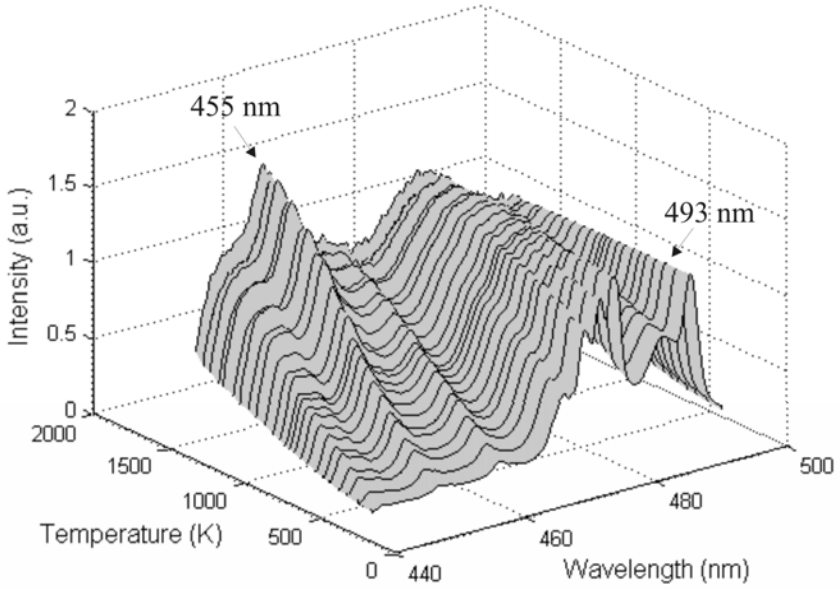
- Temperature dependent emission spectrum
  - Emission peak that broadens with temperature
  - Emission peak wavelength shift with temperature
  - Emission peak gain intensity in expense of another peak

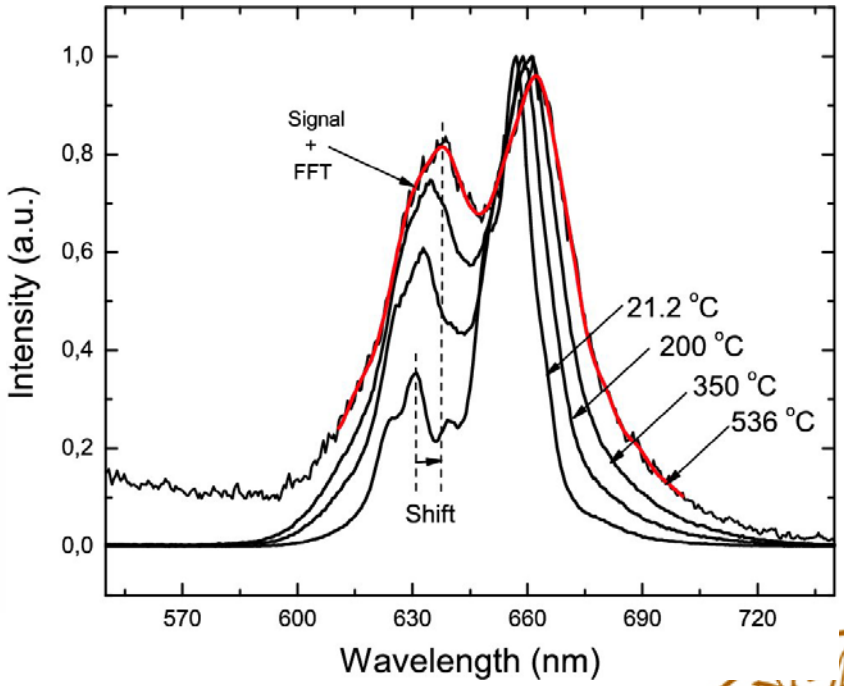




- The ratio between two spectral regions can be calibrated to temperature
- Easy to use for 2D measurements

Spectral method: Ratio between emission lines.

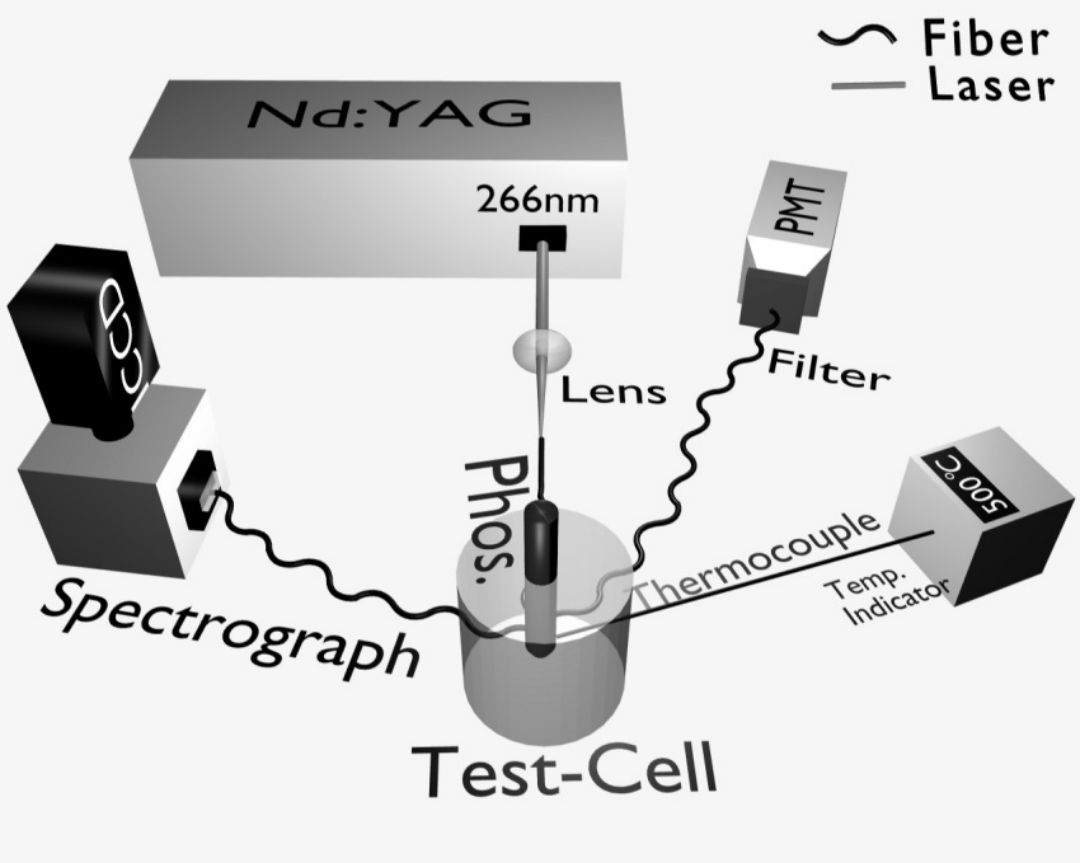




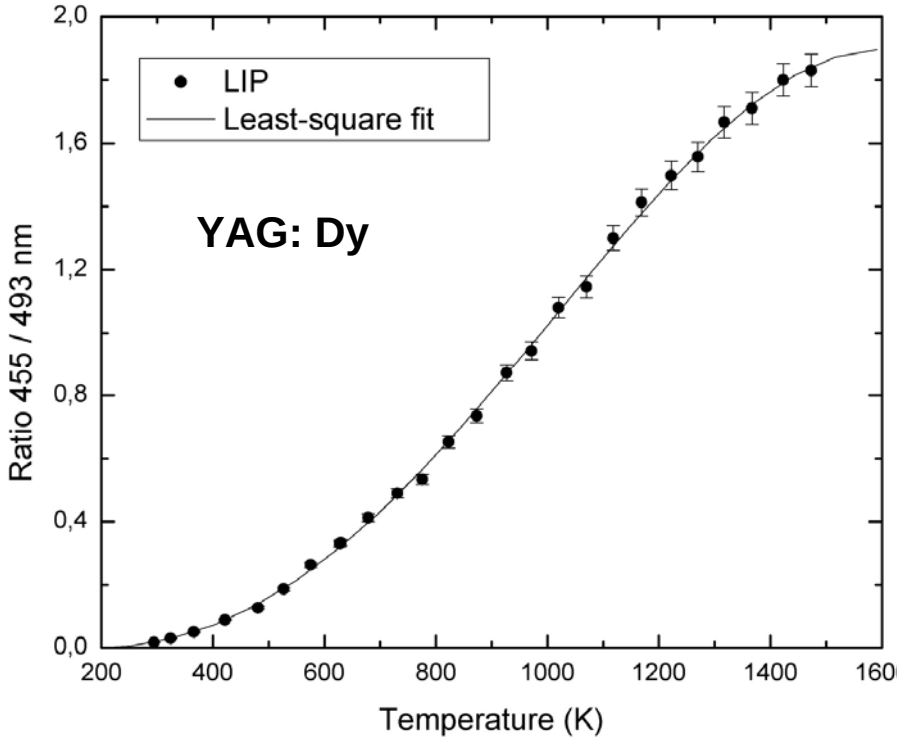
YAG : Dy

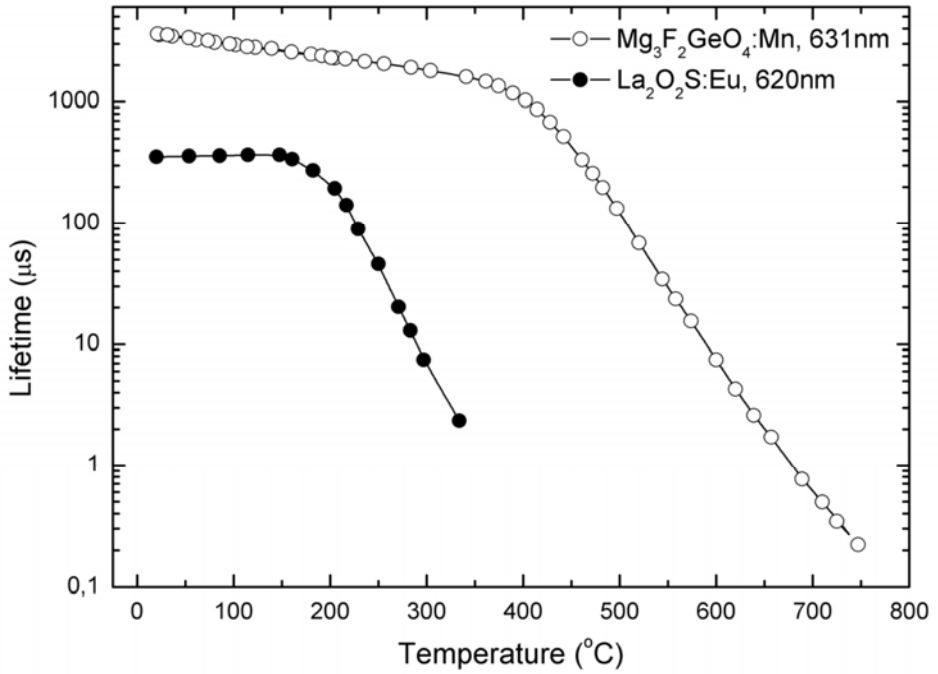
Mg_3FGeO_4 : Mn

Calibration procedures

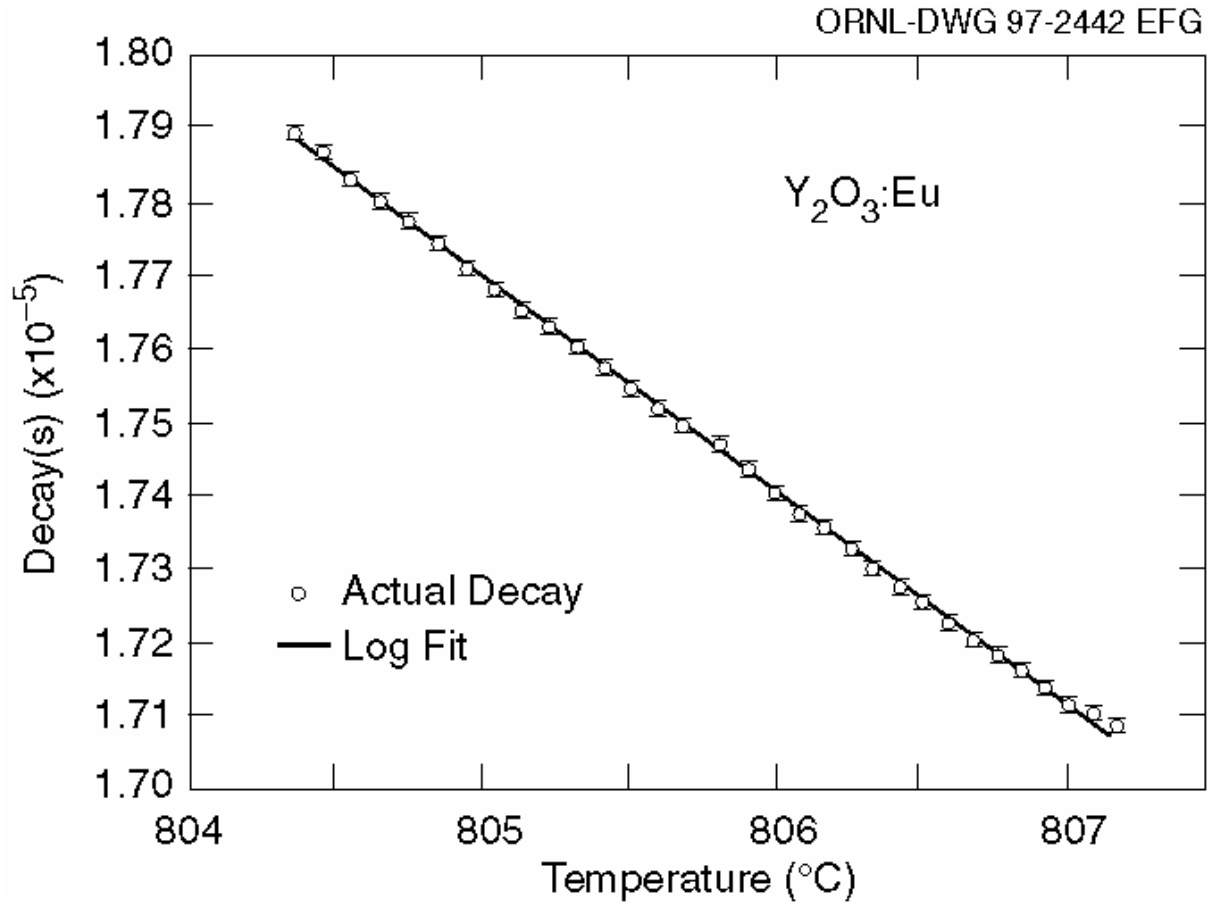


Calibration procedures





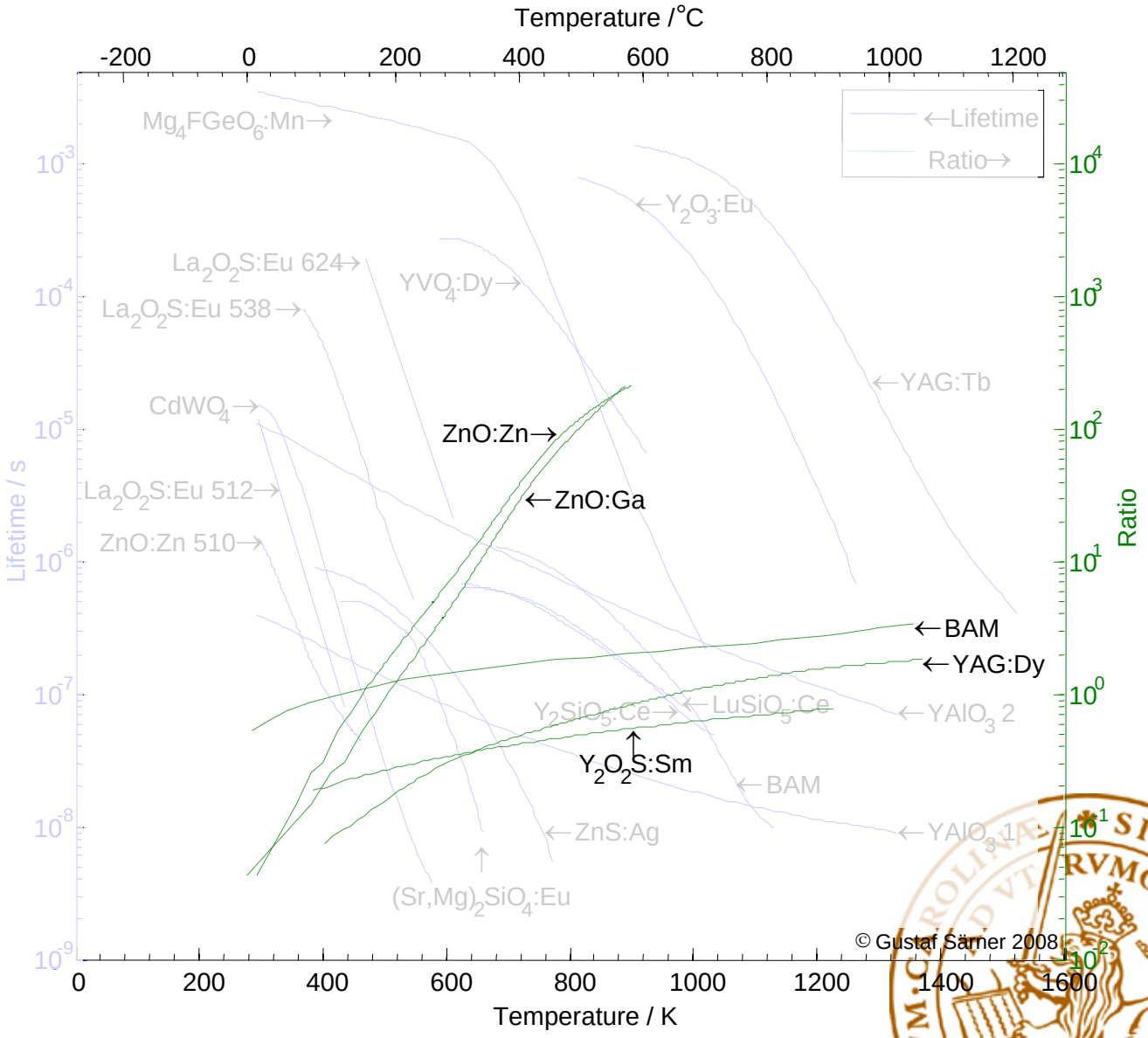
Precision limits are <10 mK for some phosphors and conditions



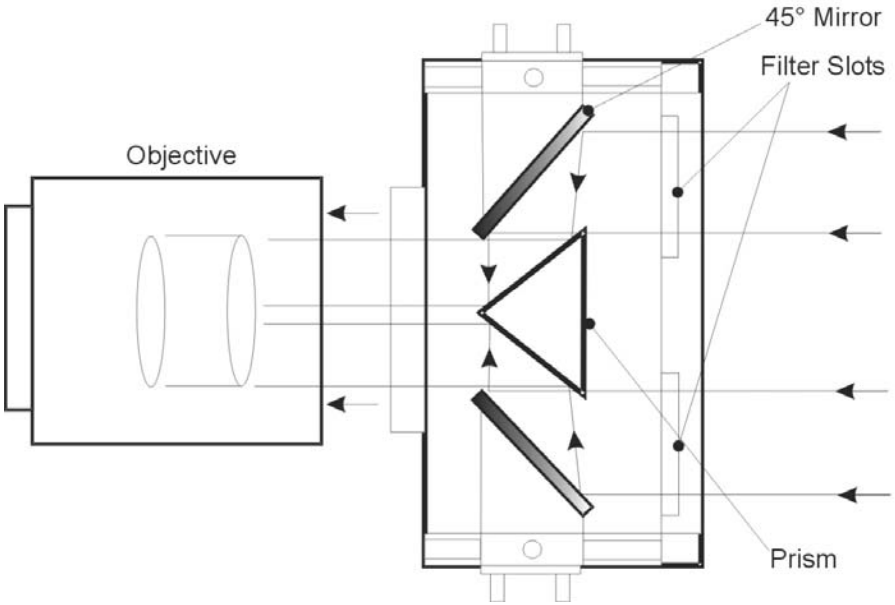
Cates, M.R., et al "Ultra High Precision Phosphor Thermometry Near 1100 K," *Proceedings of The 8th Symposium on Temperature, Chicago, IL USA, NIST, American Institute of Physics (AIP), College Park, MD USA, 10/21/2002-10/24/2002.*

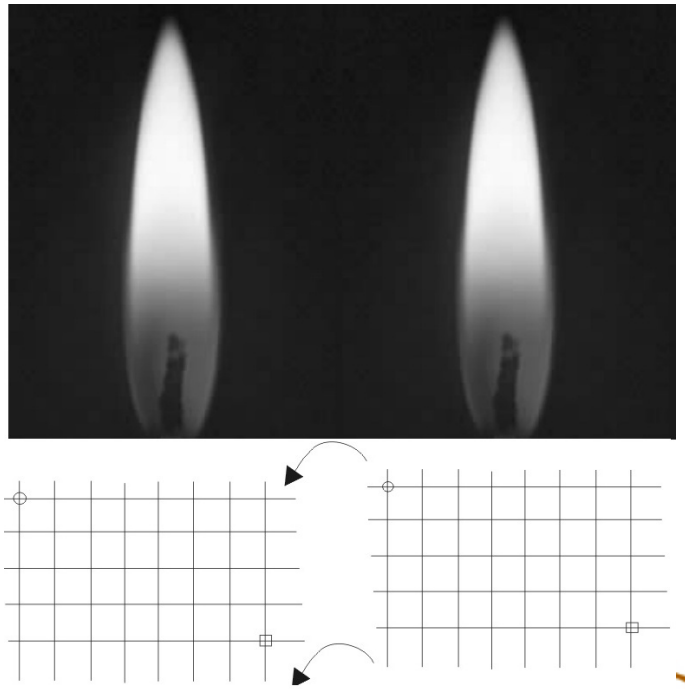
Phosphor thermometry possibilities

- Lifetime
  - $Mg_4FGe_6:Mn$
  - $Y_2O_3:Eu$
  - $La_2O_2S:Eu$
  - $YVO_4:Dy$
  - YAG:Tb
  - ZnO:Zn
  - $(Sr,Mg)_2SiO_4:Eu$
  - $CdWO_4$
  - ZnO:Ag
  - BAM
  - $LuSiO_5:Ce$
  - $Y_2SiO_5:Ce$
  - $YAlO_3:Ce$
- Ratio
  - $Y_2O_2S:Sm$
  - YAG:Dy
  - BAM
  - ZnO:Zn
  - ZnO:Ga

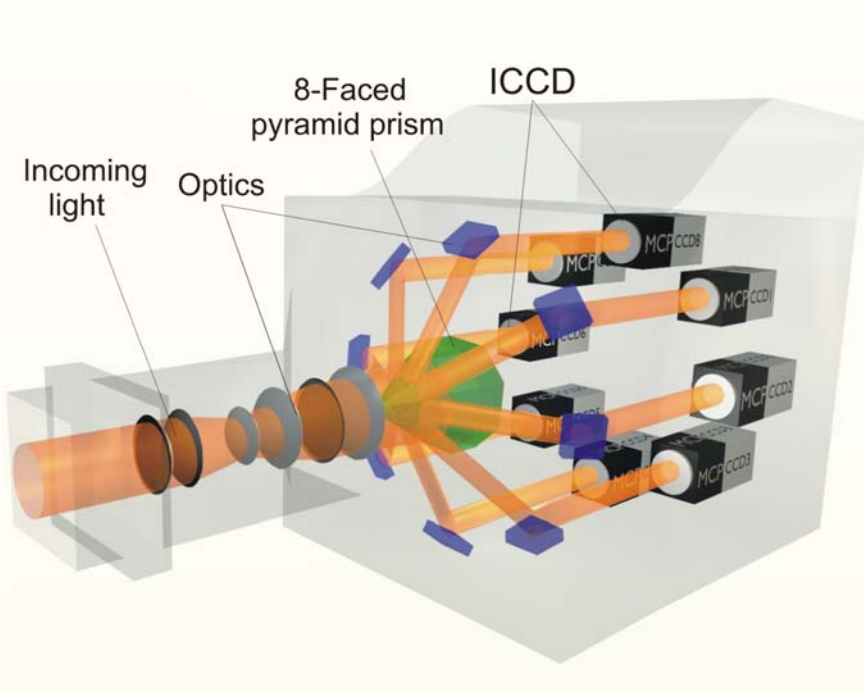


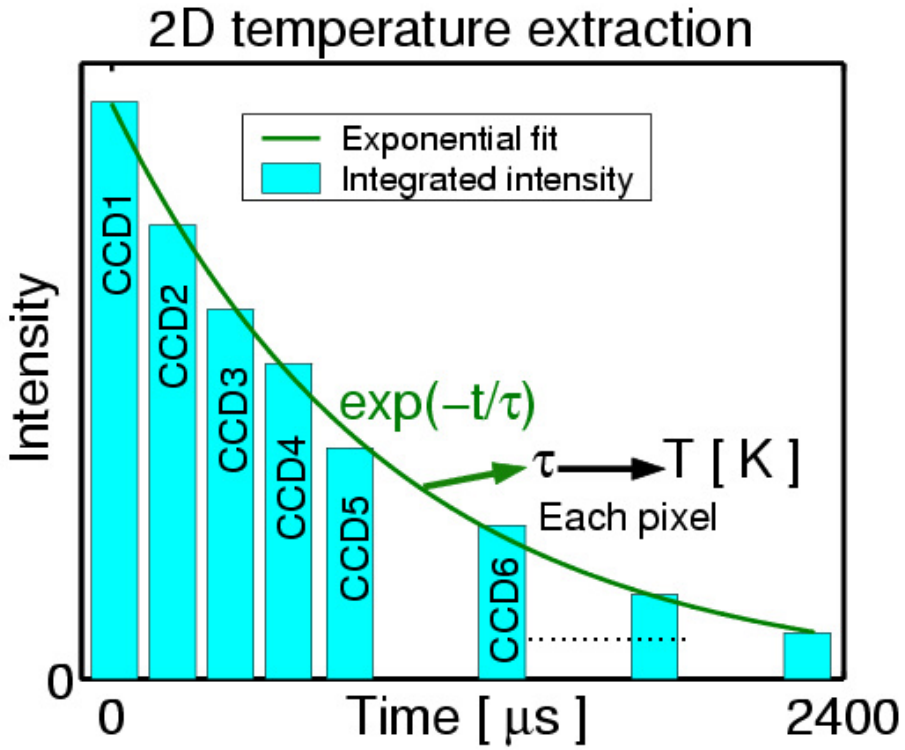
2D measurements: Spectral method



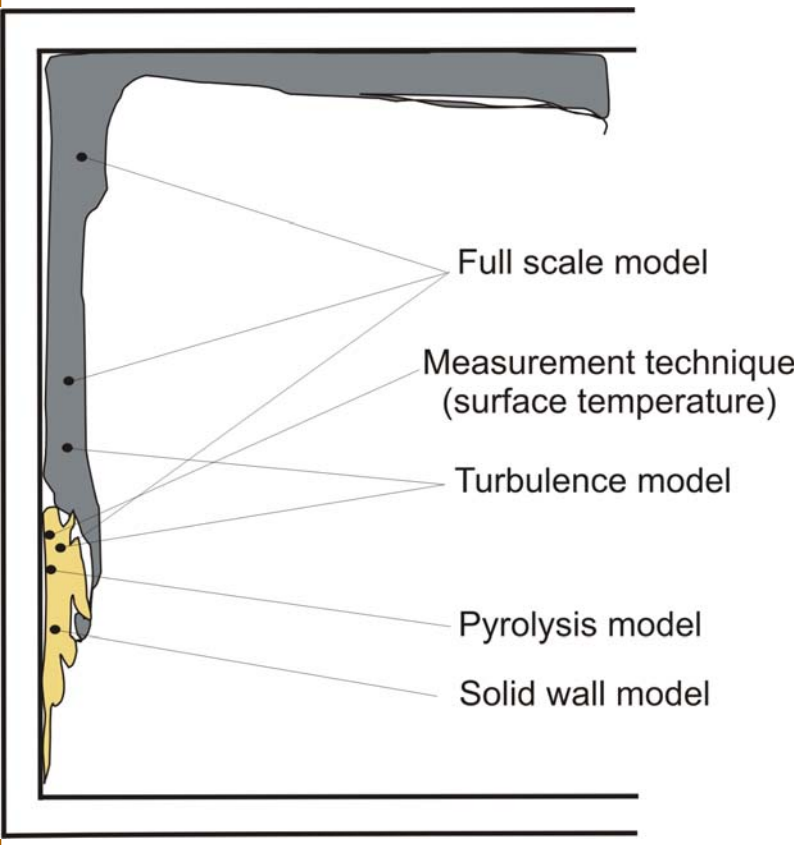


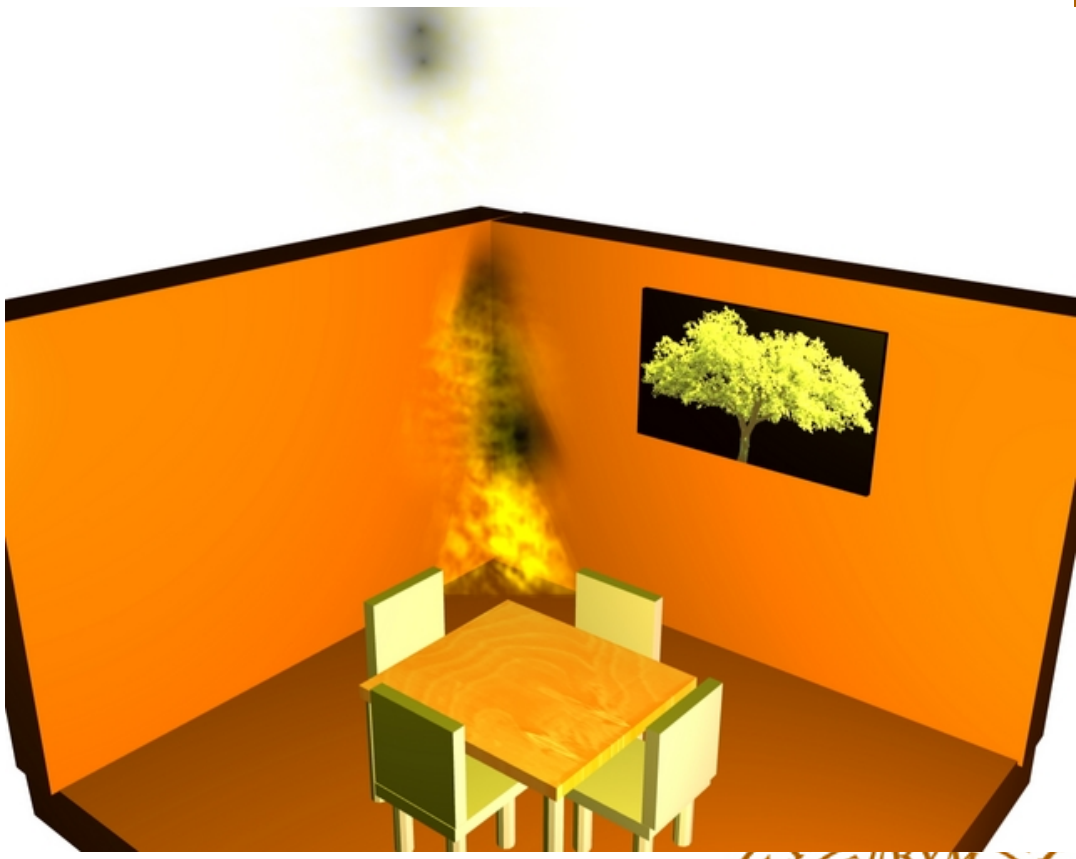
2D measurements: Temporal method



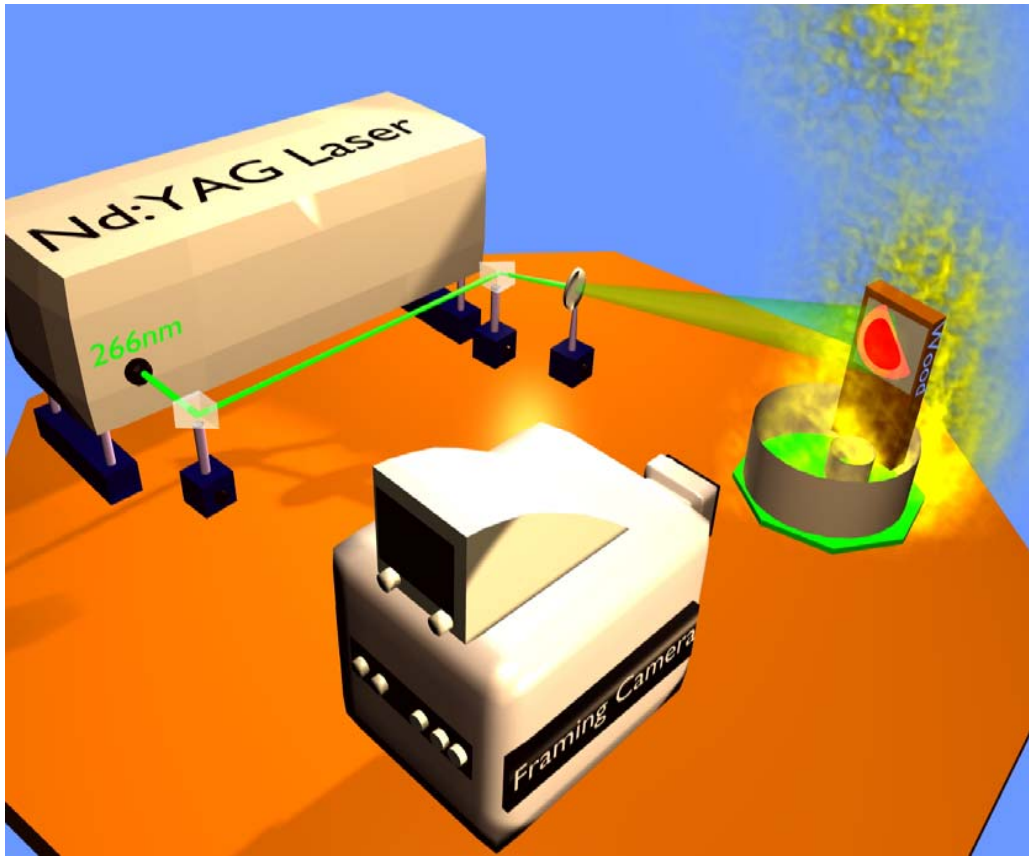


Application 1: Fire studies



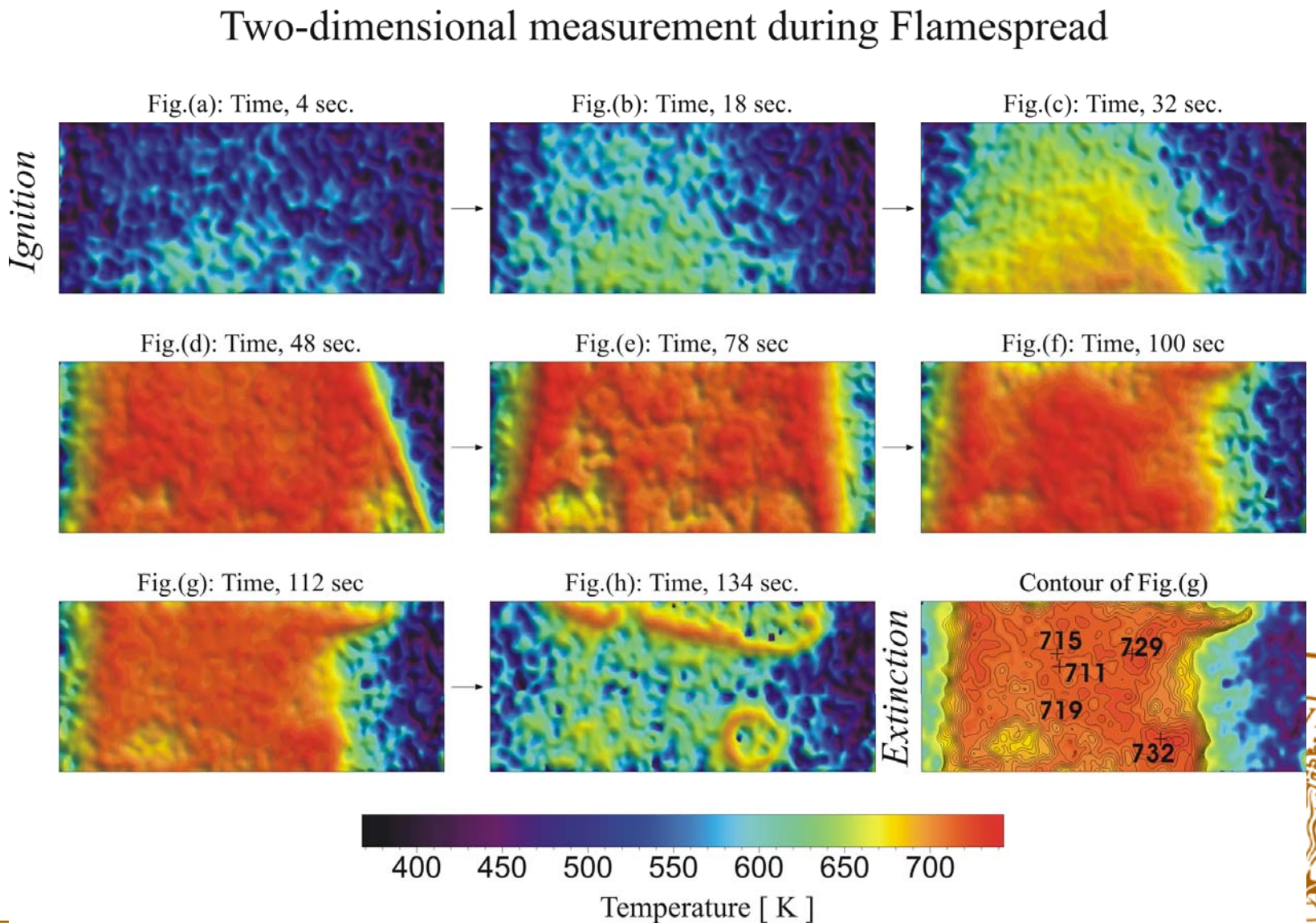


Experimental setup

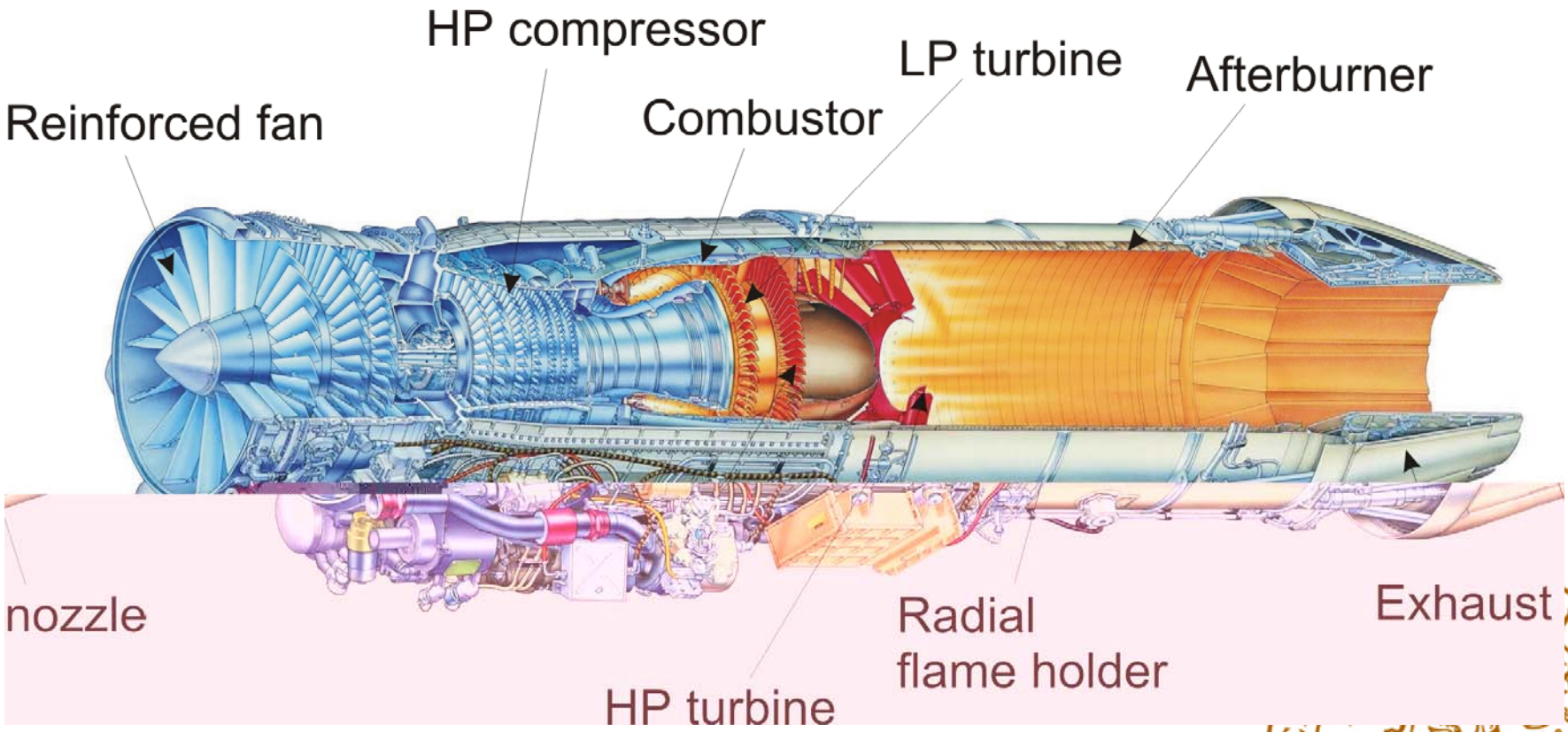


- Excitation 266 or 355 nm
- Fuel: Alcohol and Heptane.
- Detection: Framing Camera.
- Material: LDF and PMMA.

Results

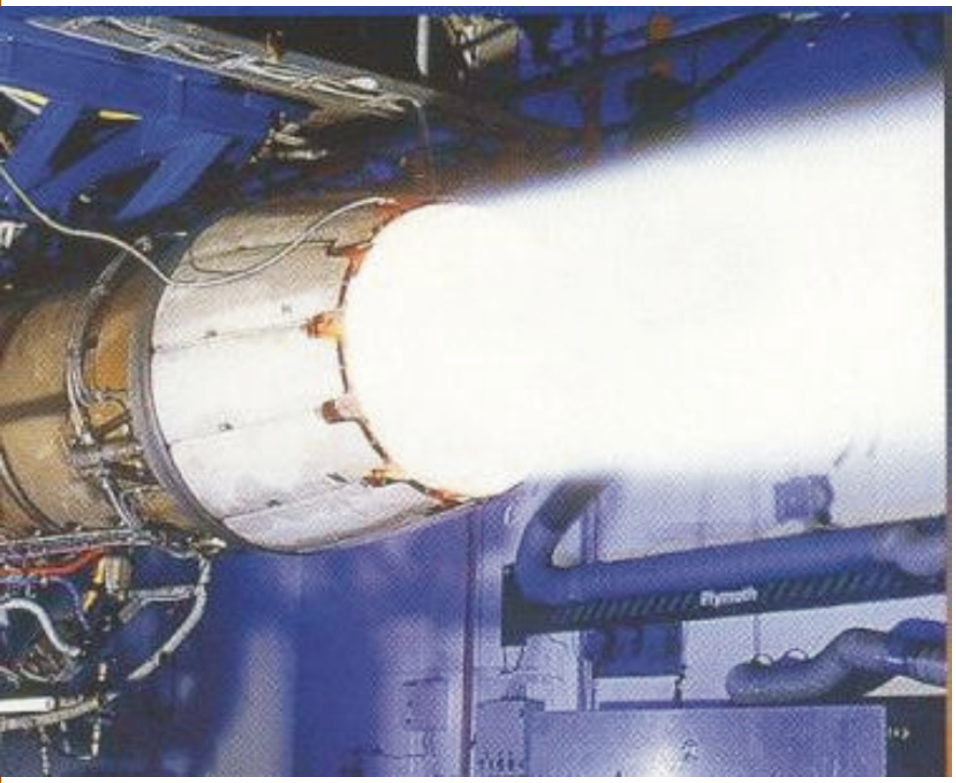

Two-dimensional measurement during Flamespread
Fig.(a): Time, 4 sec.
Fig.(b): Time, 18 sec.
Fig.(c): Time, 32 sec.
Ignition
Fig.(d): Time, 48 sec.
Fig.(e): Time, 78 sec
Fig.(f): Time, 100 sec
Fig.(g): Time, 112 sec
Fig.(h): Time, 134 sec.
Contour of Fig.(g)
Extinction
715
729
711
719
732
400
450
500
550
600
650
700
Temperature [K]

Application 4: Aircraft engine

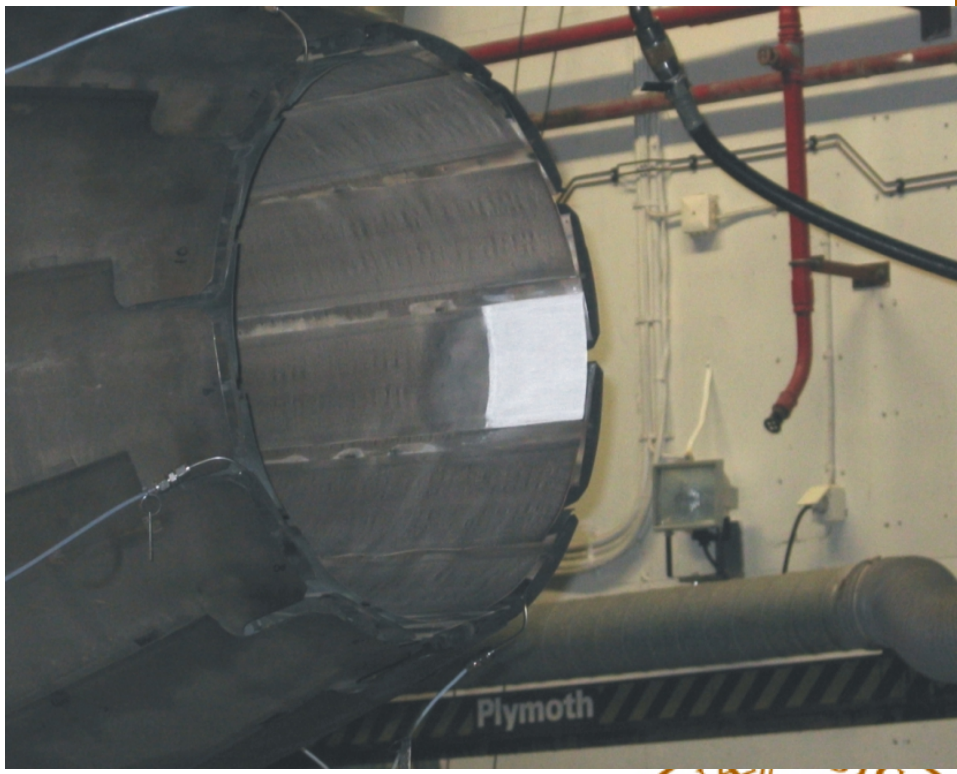


Experimental

Engine at full load



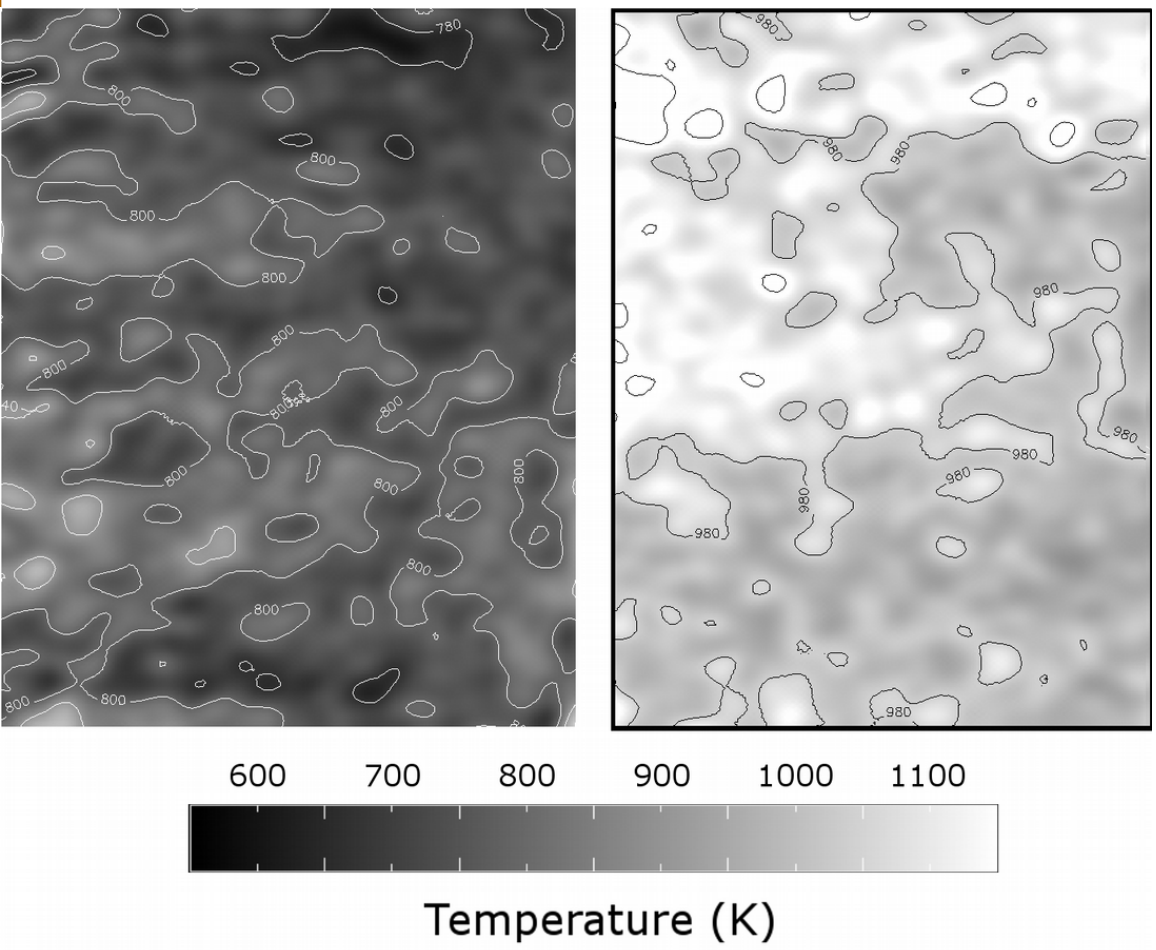
Investigated Surface



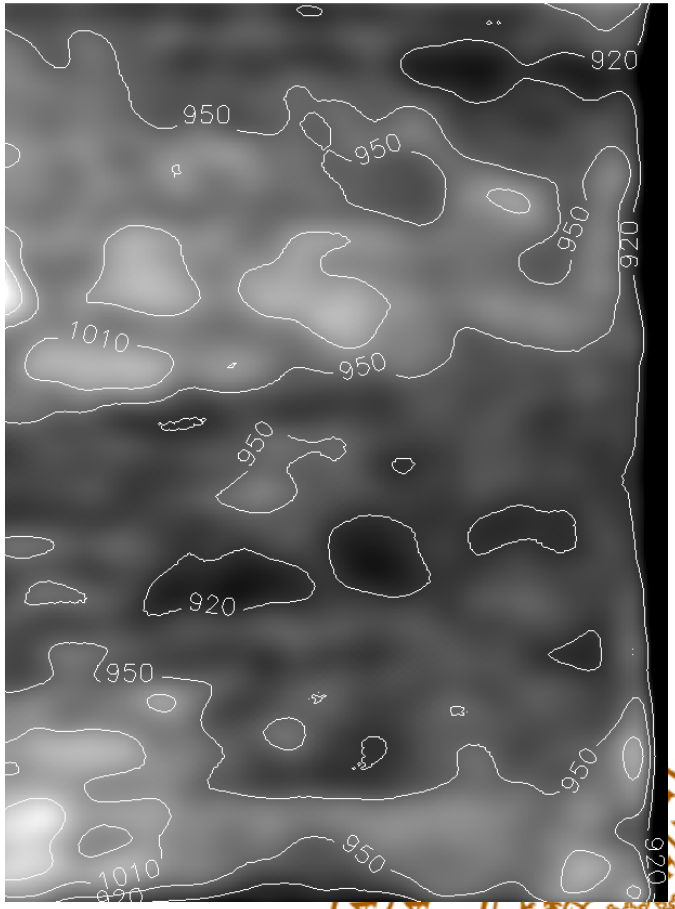
- Use of YAG:Dy
- Excitation at 355 nm
- Emission at 458 and 493 nm

Experimental

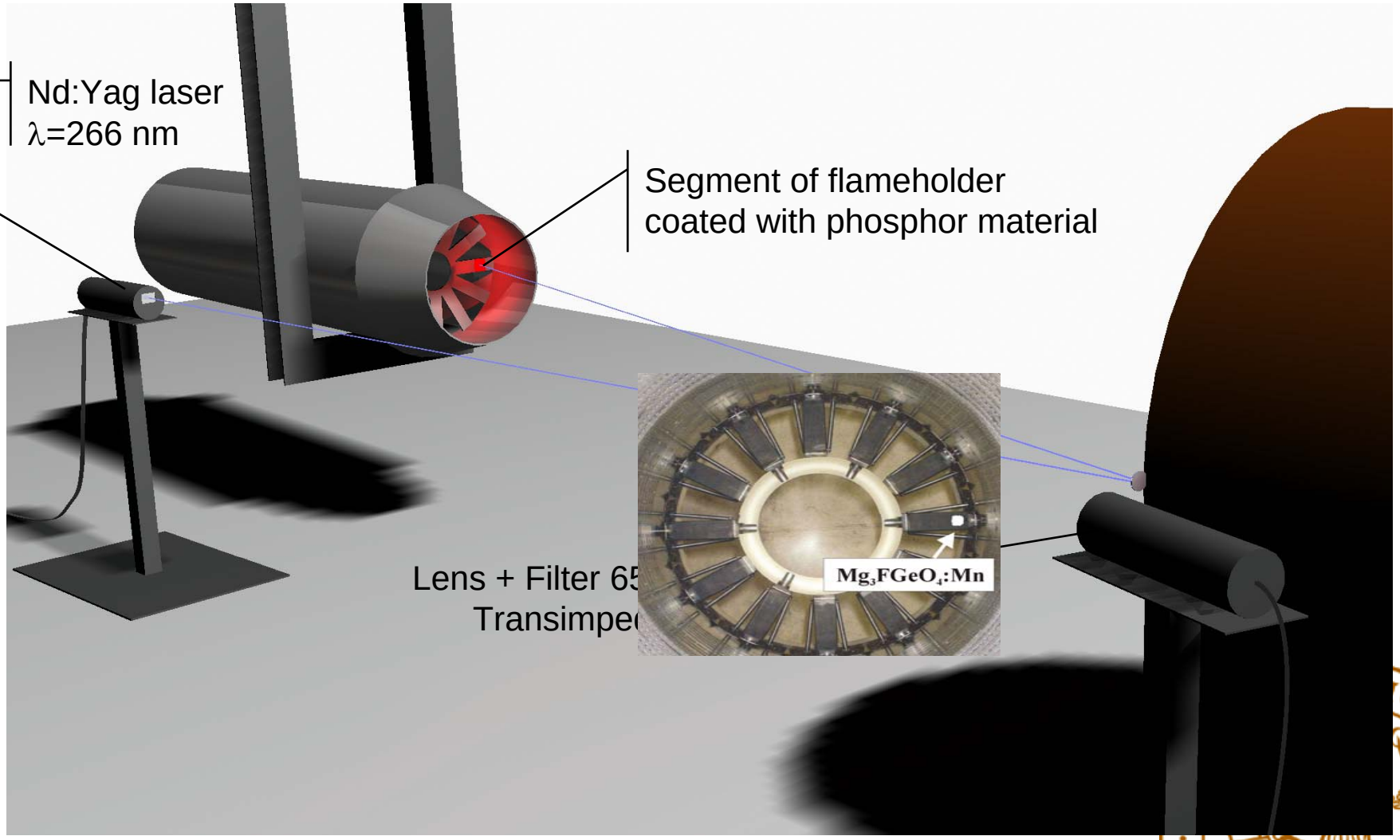
Single Shot



Averaged Temperature Image



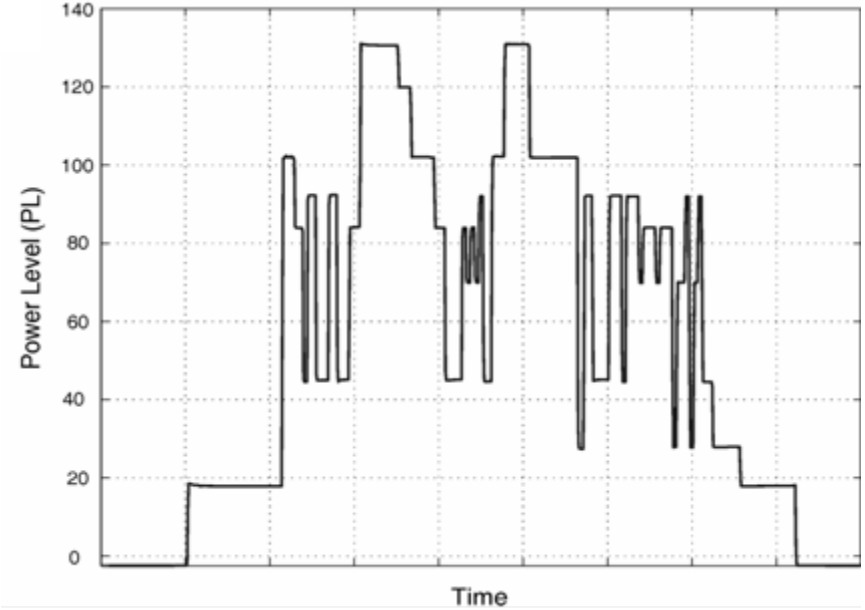
Experimental arrangement



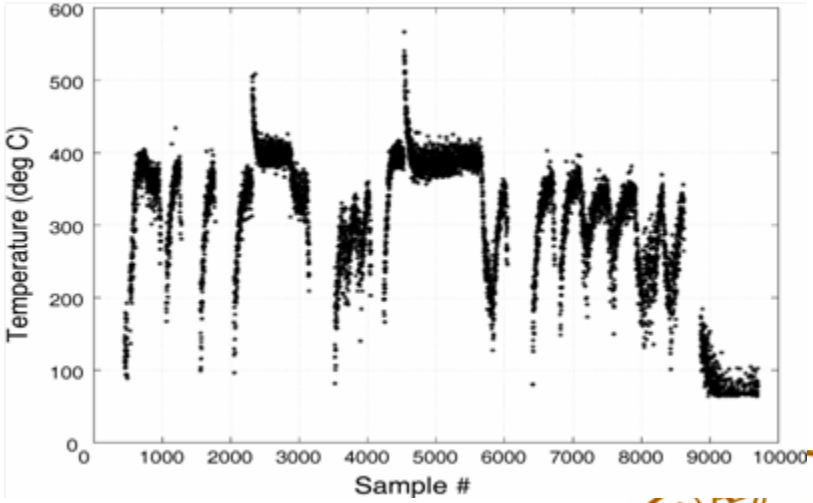
Results

Temperature data (lifetime decays) was recorded at the repetition rate of the excitation laser (10 Hz).

Signals were sampled using a 1 GHz bandwidth oscilloscope (LaCroy).

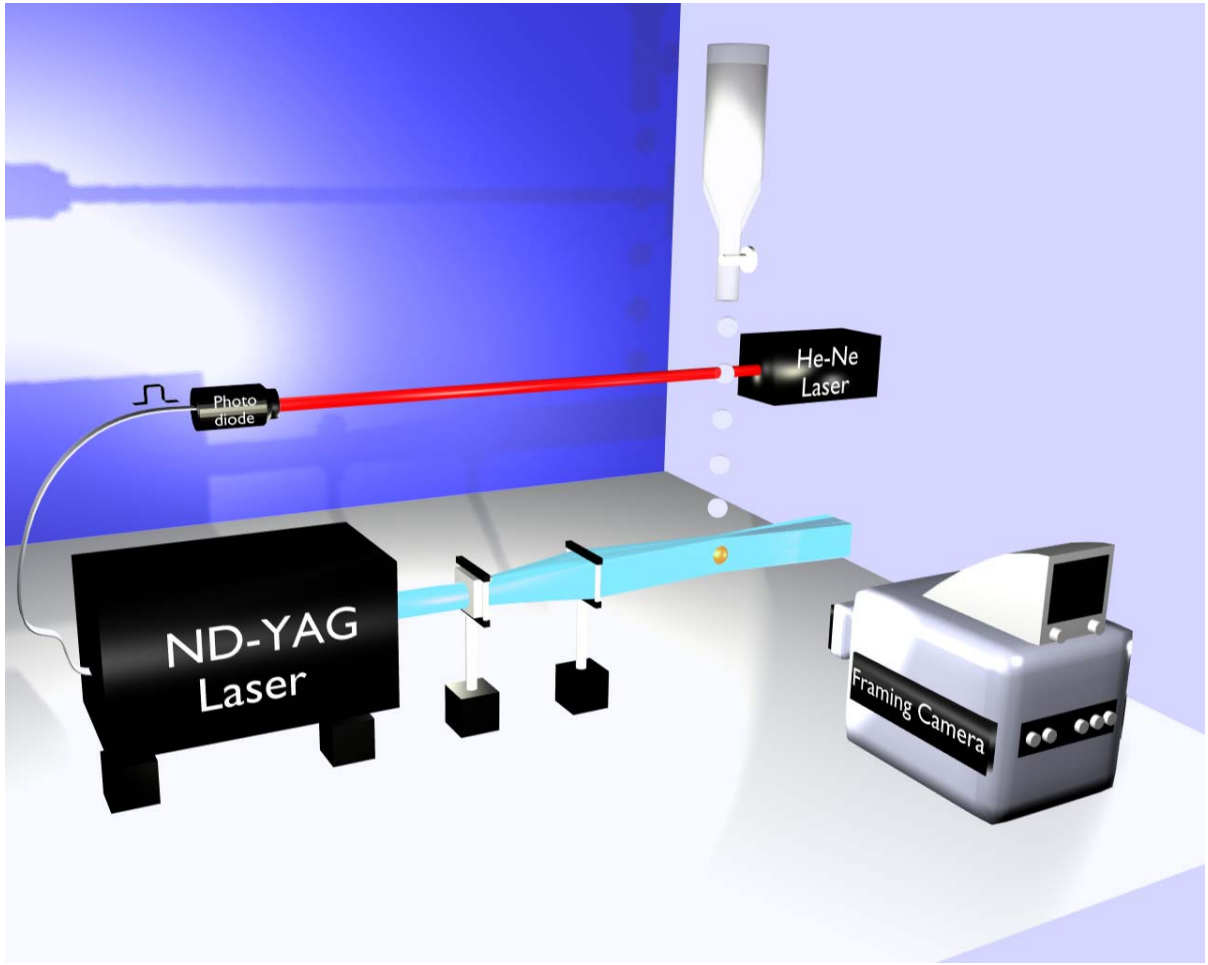


Power Level (PL) versus time for test cycle B.

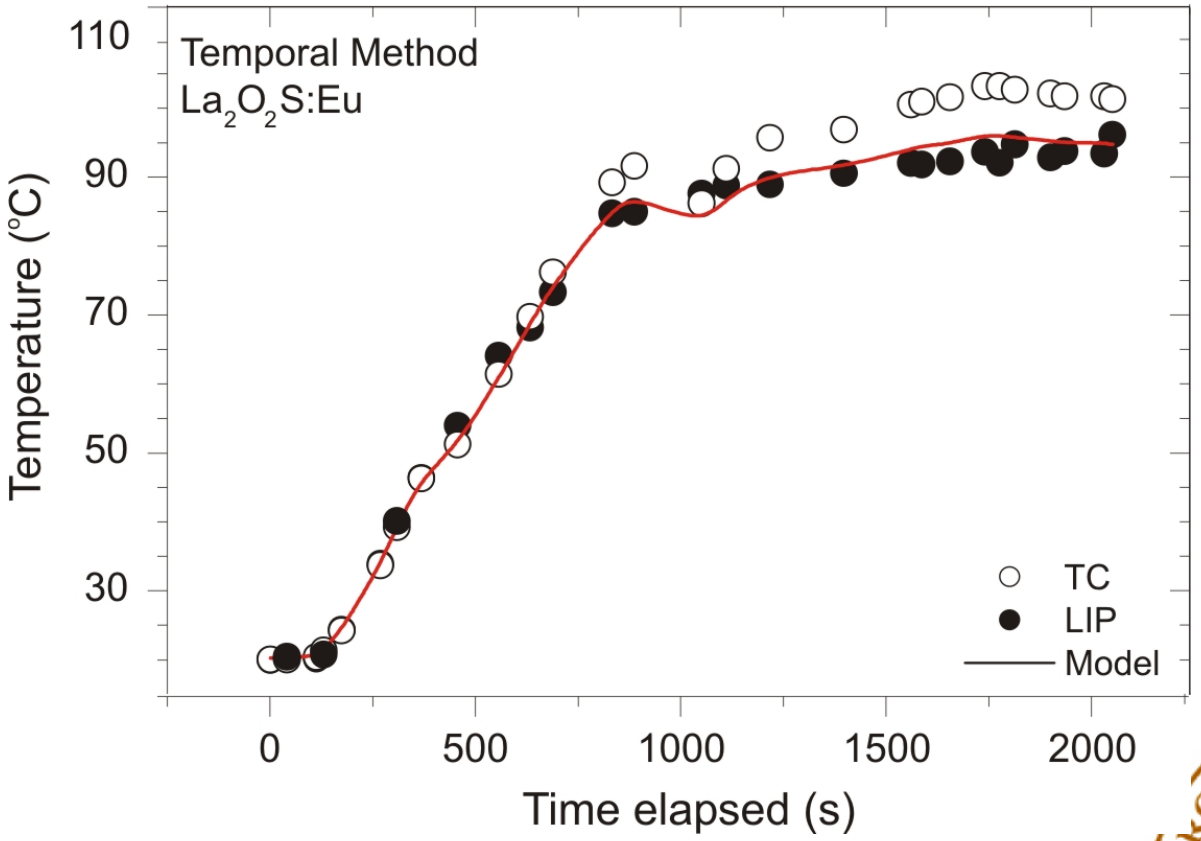


Temperature data measured for test cycle B.

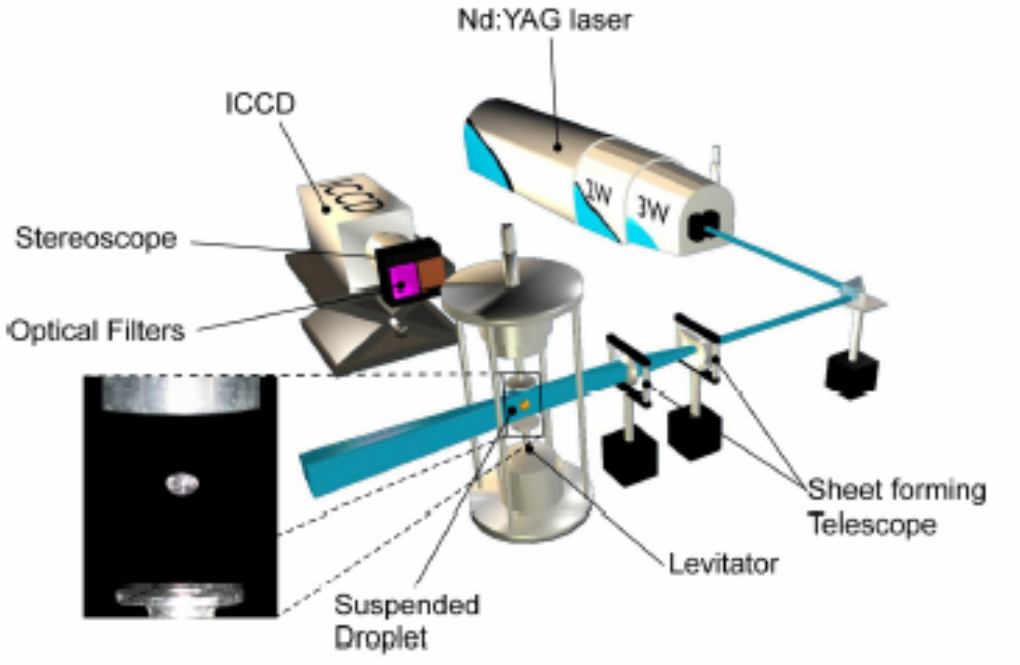
Application 5: Droplet/spray

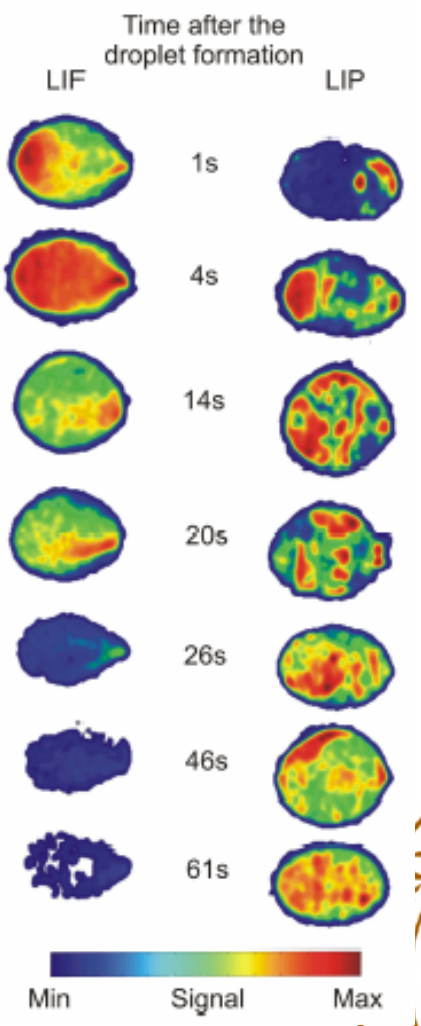


One-point measurements

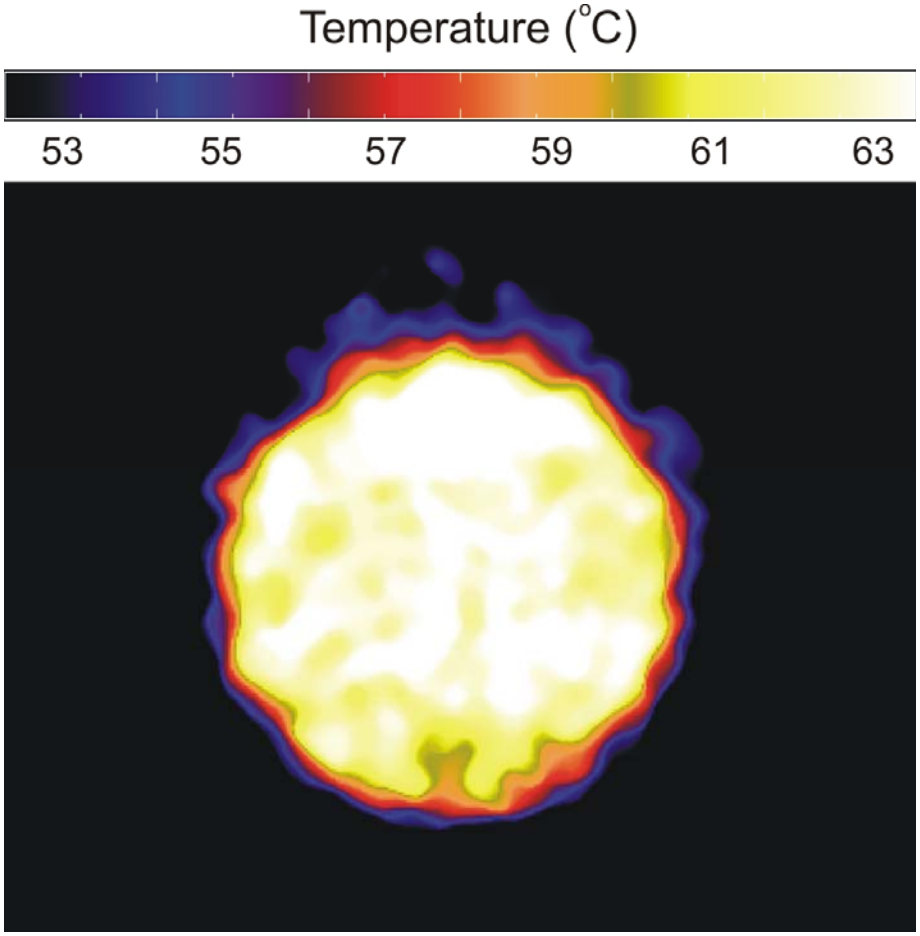


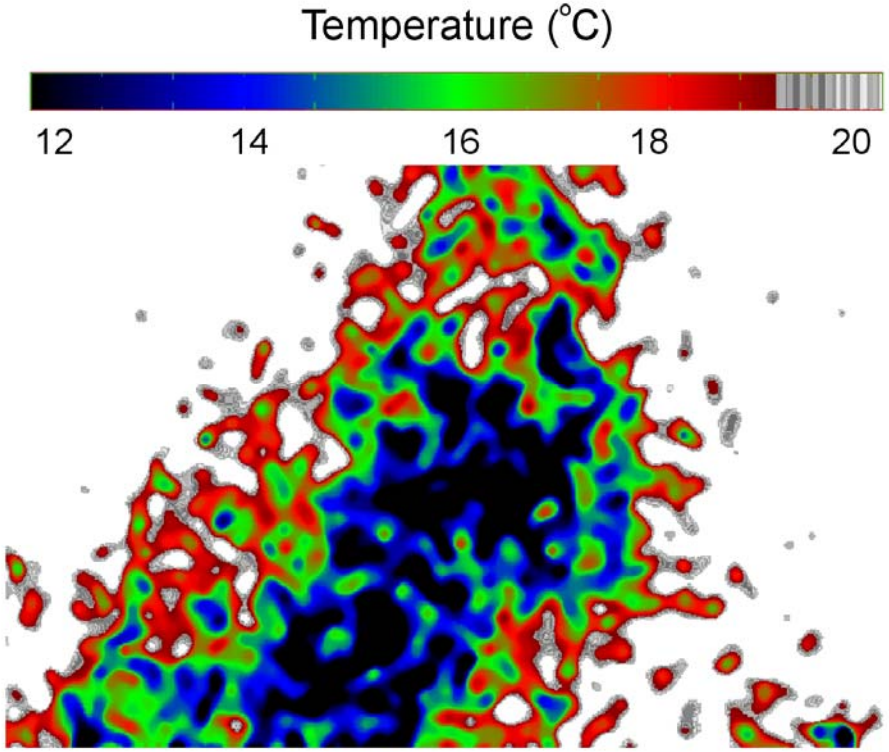
Droplets in acoustic levitation





Results: Droplets and Sprays





Results: Realistic spray