Activities in The High Pressure Combustion Facility at Lund University

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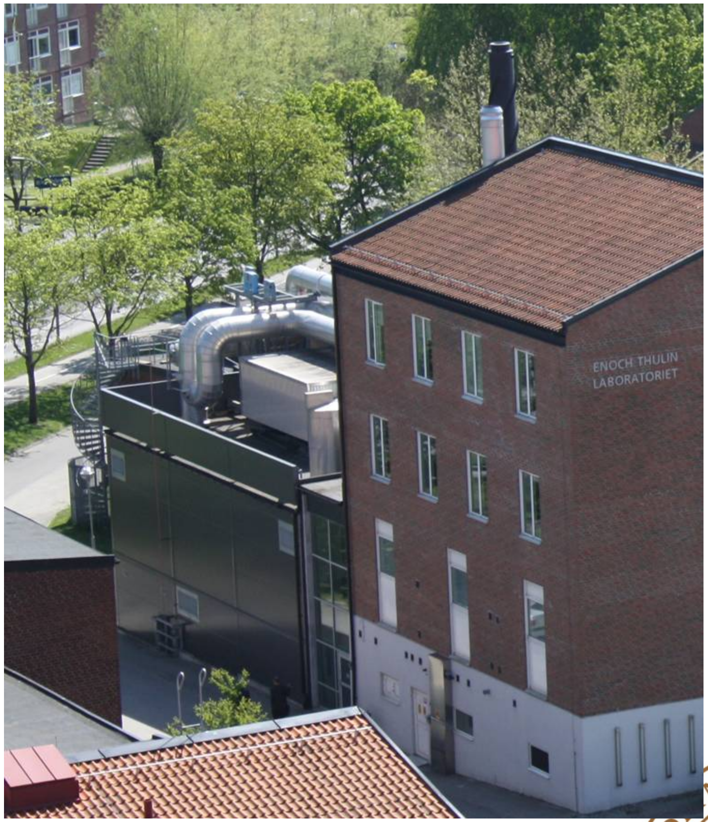
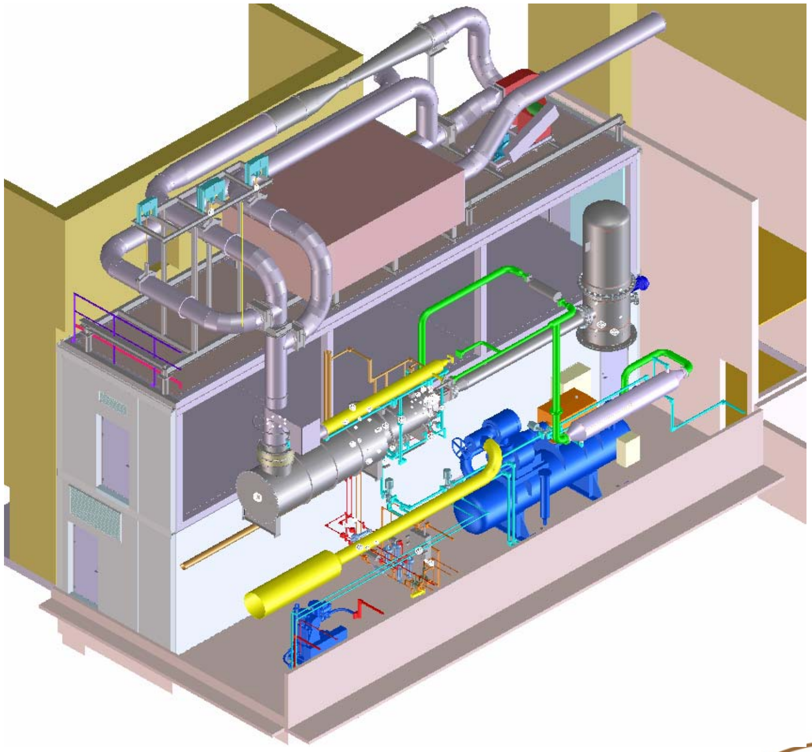
The High Pressure Combustion Facility

- Installed 2001 with the new Enoch Thulin laboratory, joint building for Lund University Combustion Centre, LUCC
- Phenomenological and applied
- Gas turbine and jet engine related combustion at elevated pressures
- Constitutes in combination with the optical laboratories in direct connection an exceptional facility for advanced studies of combustion applications of industrial and societal relevance
- One of four installations in the Large Scale Facility program at LUCC



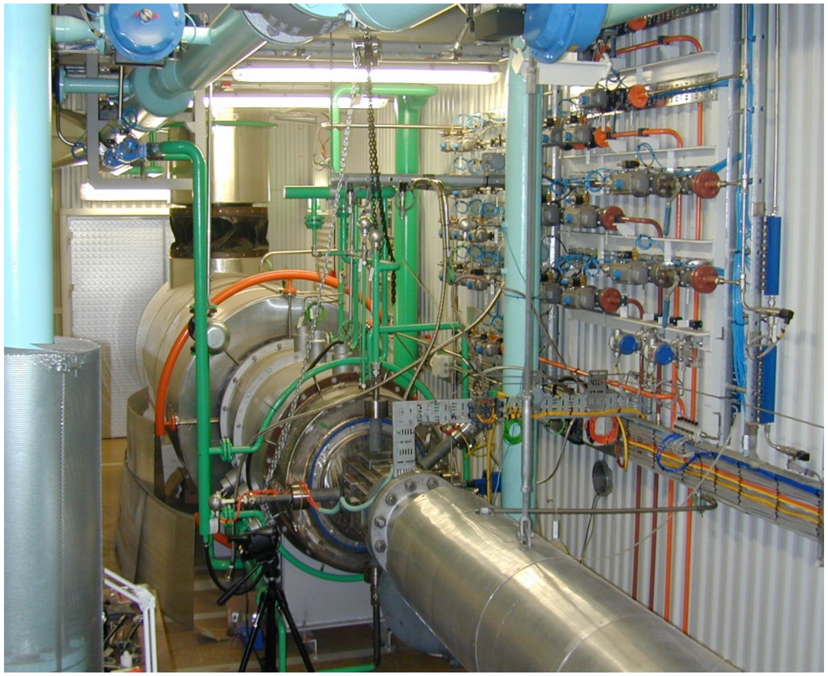
Technical specifications and features

- Four interconnected modules with direct access to the Enoch Thulin laboratory
- Single sector tests of burners for gas turbines and jet engines
- Rig specifications decided by scientific experts in the areas of gas turbine applications, diagnostics and modelling together with experts from industry

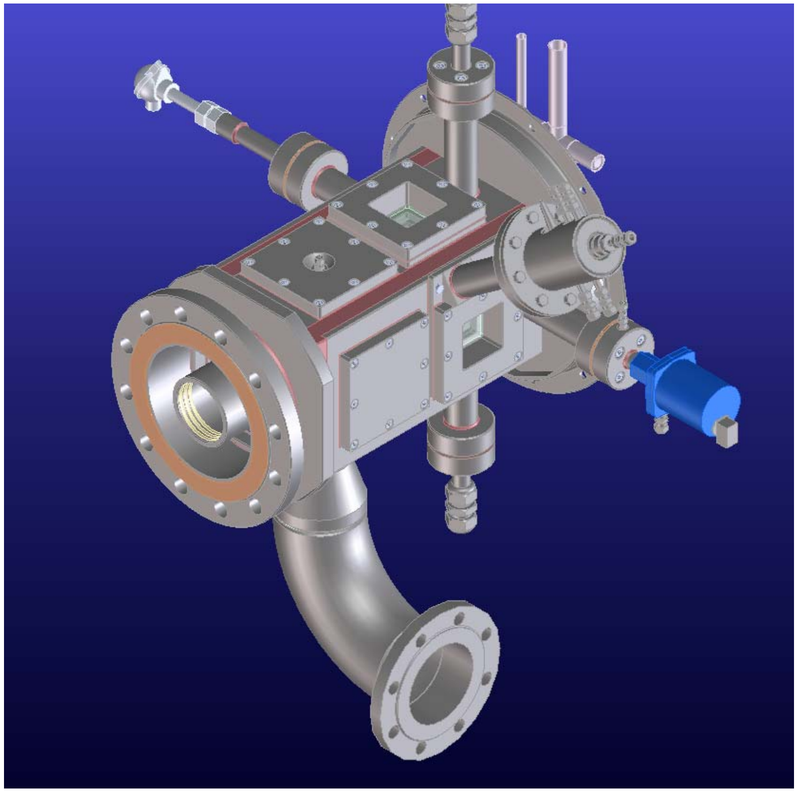


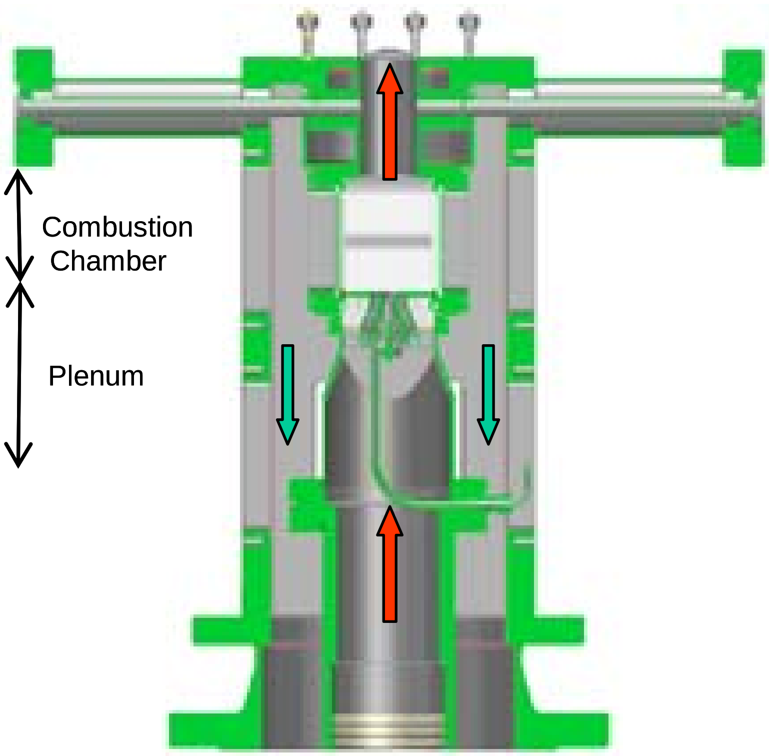
Technical specifications and features

- **Maximum air flow rate: 1,2 kg/s (air compressor 750 kW)**
- **Maximum pressure: 16 bar**
- **Preheated air temperature: up to 800 K (electrical heater 1 MW)**
- **Steam generator to allow for studies of combustion in humid air (125 kW)**
- **Systems for liquid and gaseous fuel, each system have two independent fuel supply lines (liquid 100 kg/h, natural gas 86 kg/h)**
- **Optical access to the combustion chamber**
- **Afterburner to facilitate fuel evaporation studies**



Test section





Objectives and fields of applications

- Increased detailed knowledge of the involved physical processes and the interaction between them,
- Test new diagnostic techniques in a semi-industrial environment prior to application in a full scale application
- Provide data for validation of combustion models
- Alternative fuels such as bio-mass derived gaseous or liquid fuels
- Combustion concepts such as LPP, RQL, etc.
- Burners for processes such as Humid Air Turbines, CO_2-free processes

Possible studies

- Combustion parameter evaluation
- Liquid fuel vaporisation studies
- Fuel/air mixing studies
- Ignition tets
- Laser diagnostic measurements (CARS, LIF/MIE, LDV, PIV) of temperature, species concentrations, vapour/liquid relation in vaporisation zones and velocity
- High speed video imaging

Projects

Project	Funding	Partners	Fuel	Objective	Period
FLAMESEEK	EU, LSF	Imperial College	CH4	Evaluation of a chemiluminescence sensor developed at IC.	2002
LOPOCOTEP	EU, LSF	Rolls Royce	Jet A	Application of several optical techniques for characterization of a LPP pilot burner.	2003-2004
OROBOROS	VINNOVA	Oroboros	Synthetic	Emission measurements on synthetic fuel that can be derived from biomass.	2004
FLAMELESS	EU	SIEMENS	CH4	Measurements of emission, dynamic pressure and OH LIF.	2004
KCFP	STEM		Natural Gas	Combustion in humid air.	2005
INTELLECT	EU	Rolls Royce	Jet A, Synthetic	Characterization of ignition and flame evolution LPP-duct. Laser diagnostic (OH LIF), high speed video, and measurements of dynamic pressure.	2005-2008
NFFP4	NFFP	VAC	Liquid	Evaporation tests	2007
INTELLECT	EU	STEM, Rolls Royce	Jet A, Synthetic	Ignition tests with a next generation LPP duct	2008
HEATTOP	EU	VAC	-	Sensor validation/surface temperature measurements on rotating objects	2006-2009
TLC	EU	SNECMA	Jet A, Synthetic	Fuel visualisation: time resolved / 3D, LIF/Mie, applied technique development	2007-2008

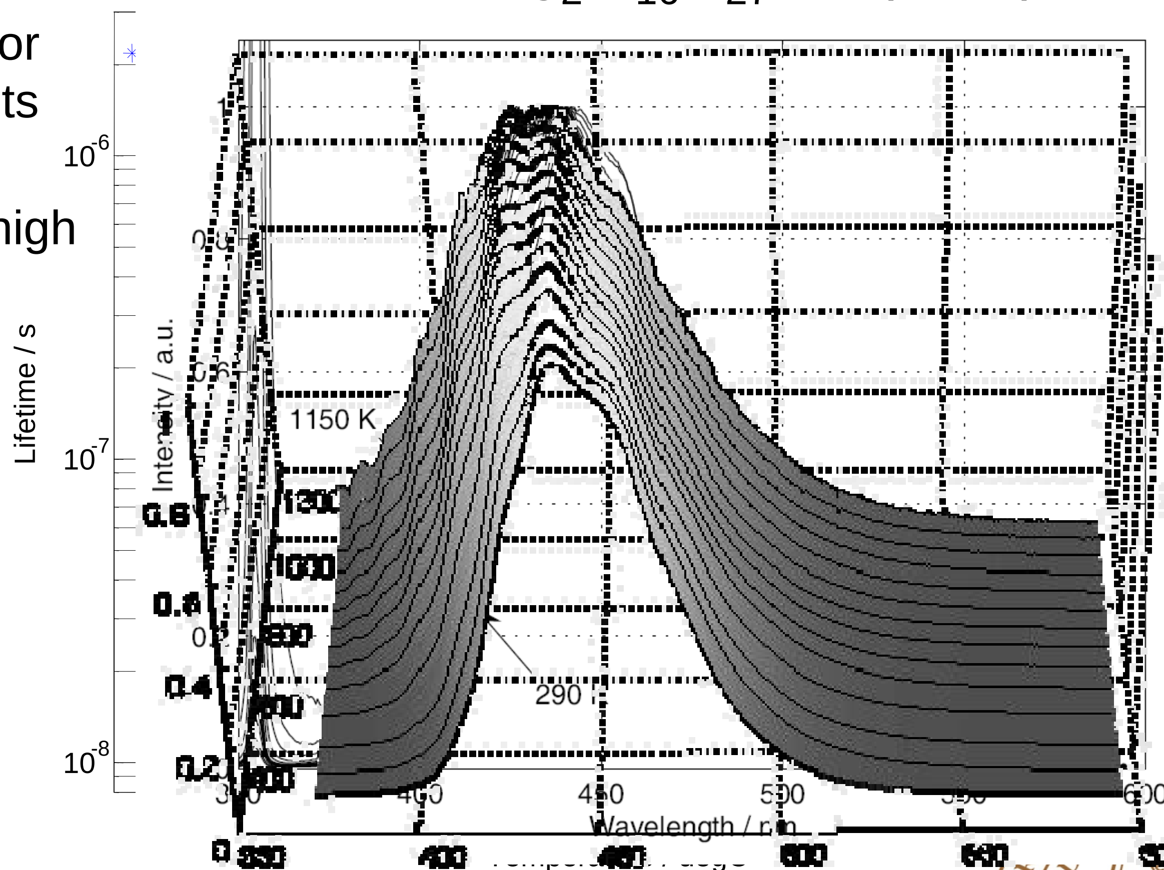
HEATTOP

- EU-project coordinated by SIEMENS, Germany
- Surface temperature measurements using thermographic phosphors
- Rotating object, 21 000 rpm

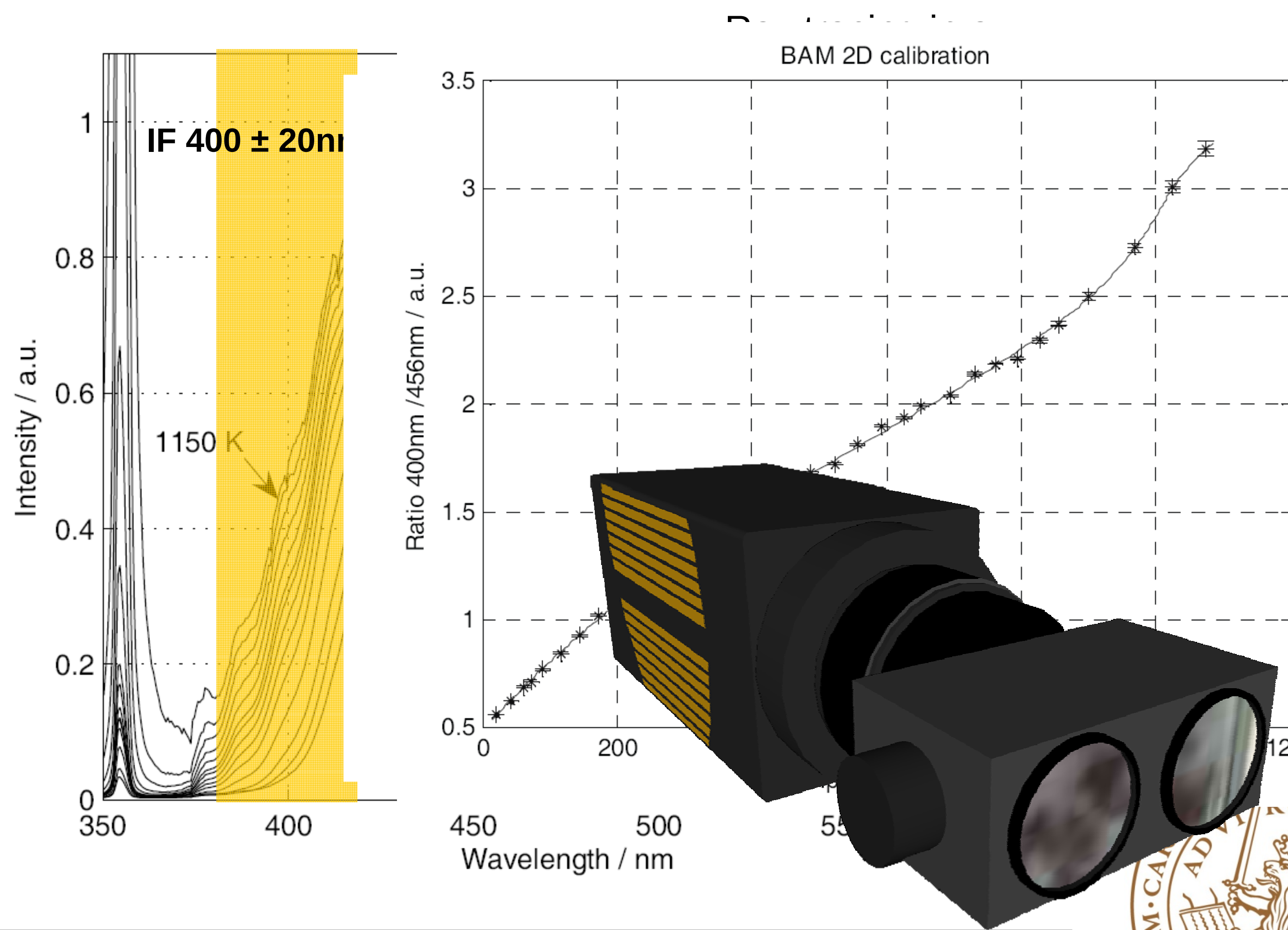
HEATTOP: Choice of blue phosphors

•The phosphor chosen from WP3 is $BaMg_2Al_{16}O_{27}$:Eu (BAM):

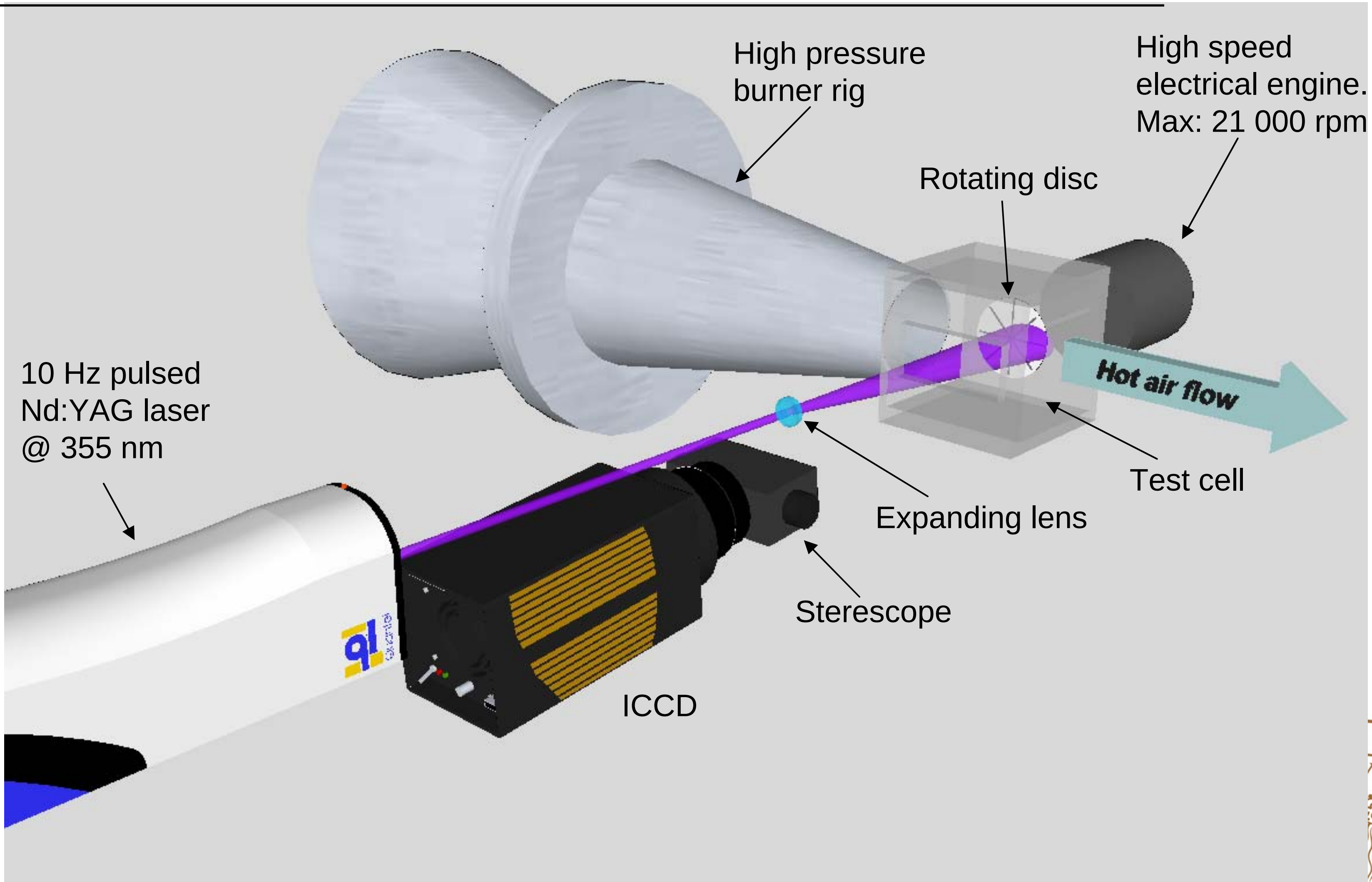
- Spectral change behavior makes 2D measurements possible
- Short lifetime and very high intensity enables fast measurements



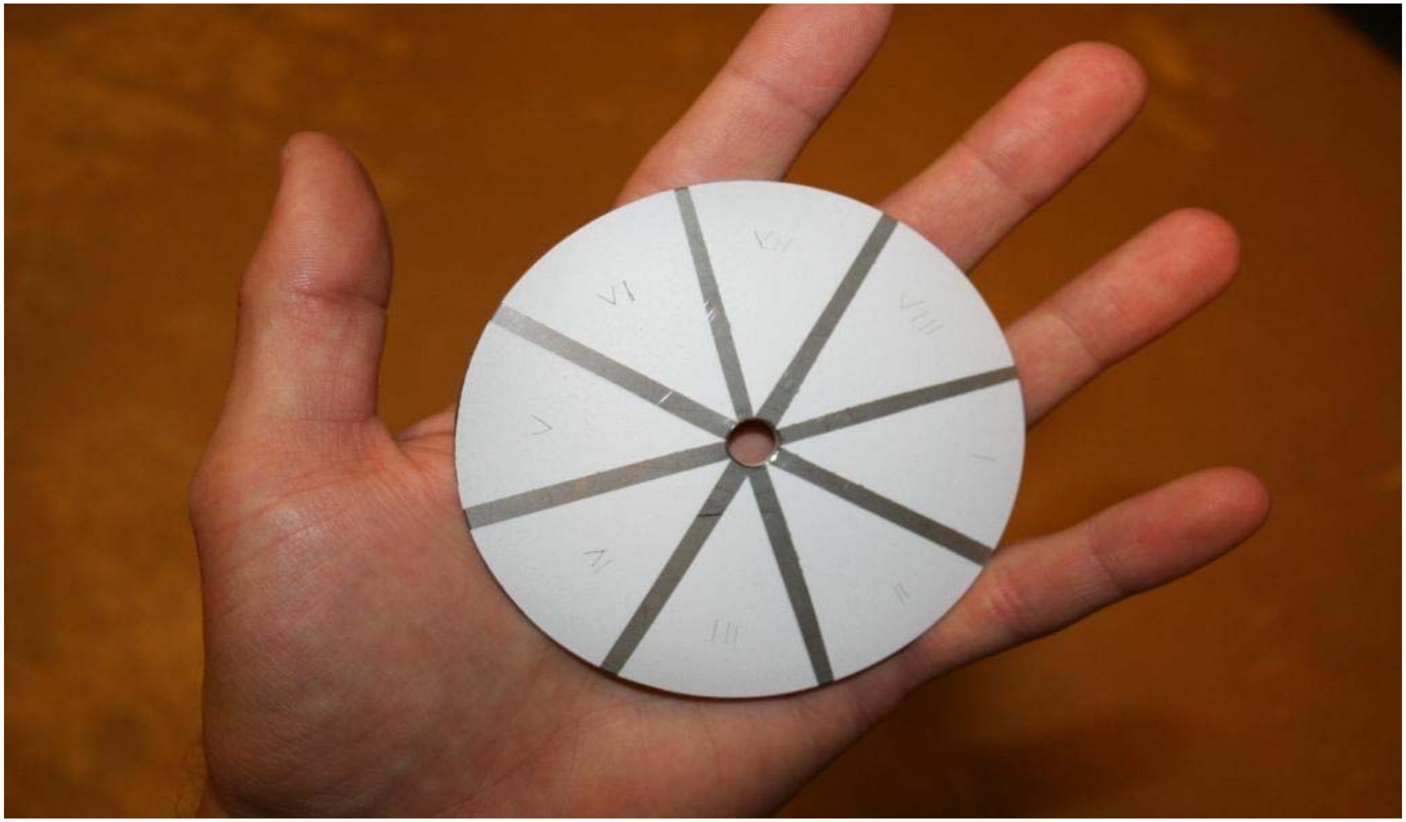
HEATTOP: The 2D measurement technique



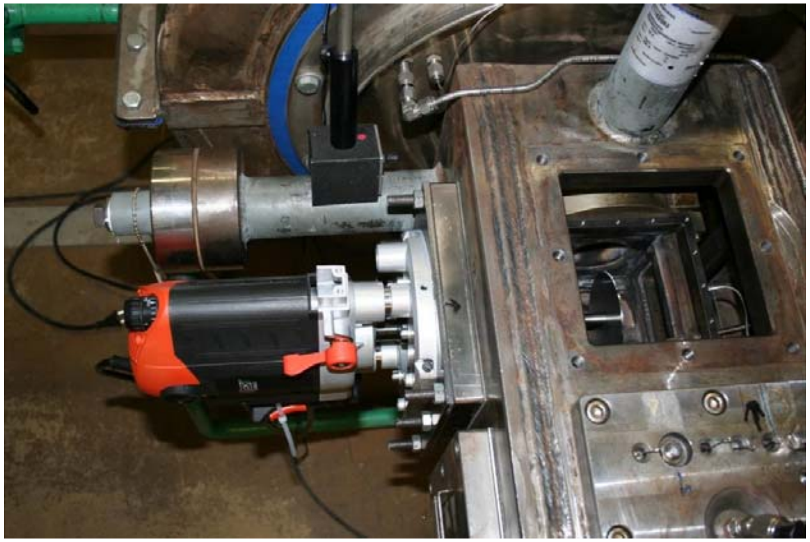
HEATTOP: Experimental Setup



HEATTOP: Experimental Setup

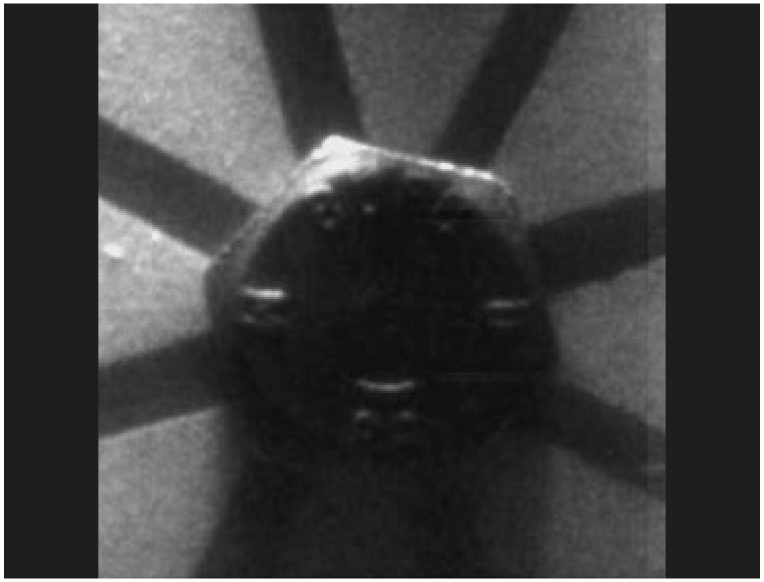


HEATTOP: Experimental Setup

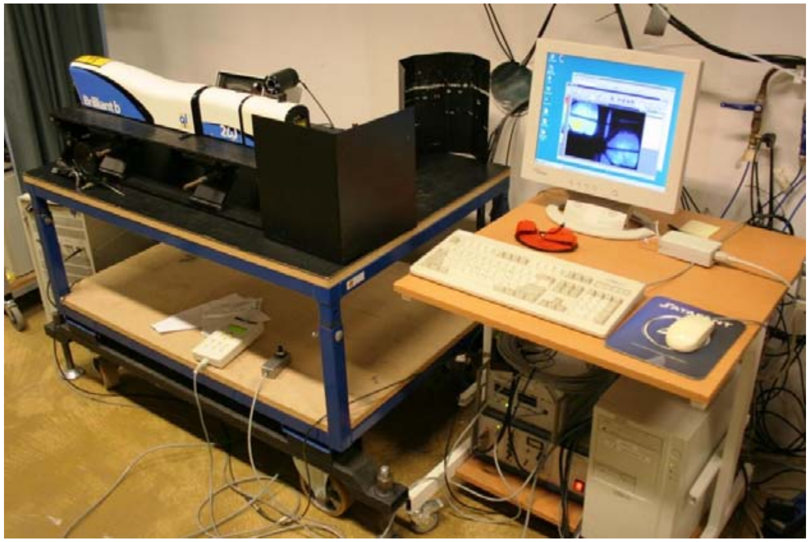


HEATTOP: Experimental Setup

- Slow motion of a high speed video of rotating disc, diameter 9 cm.
- Revolution: 21 000 rpm
- Speed at edge: 100m/s

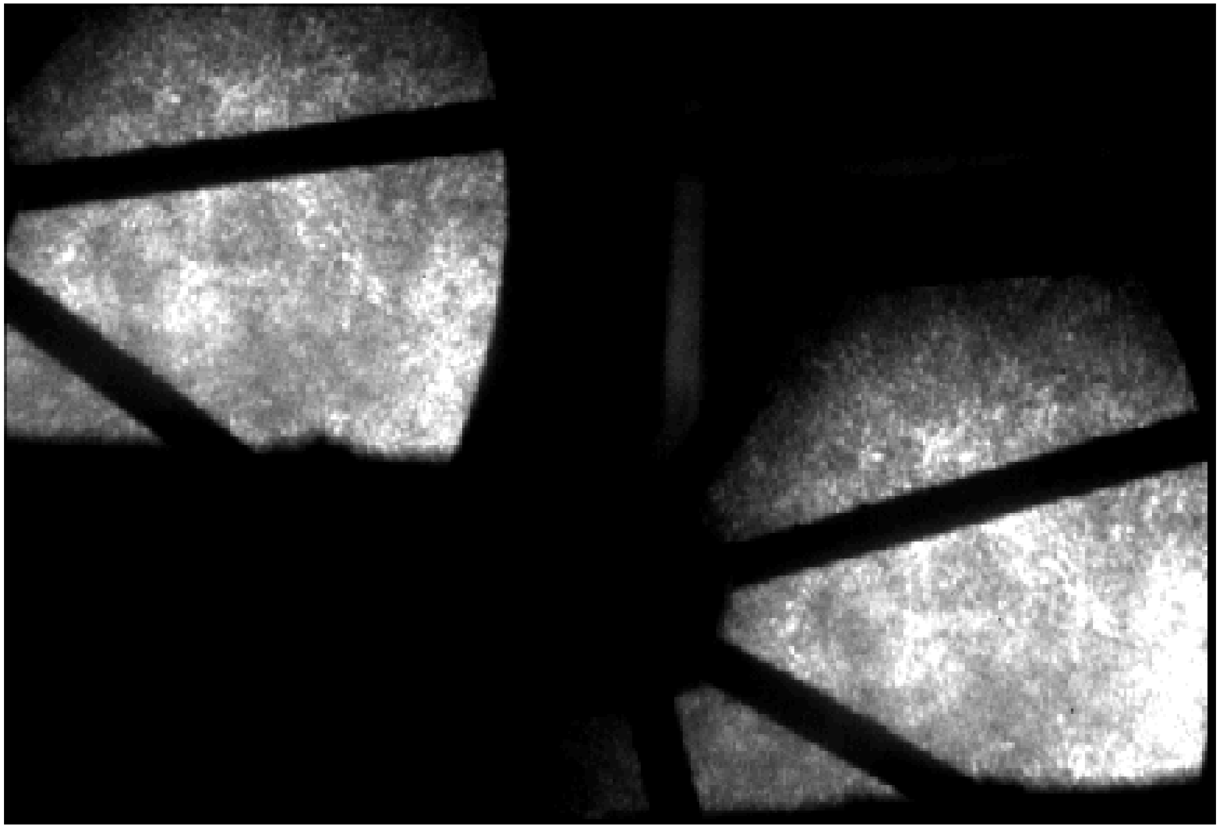


HEATTOP: Diagnostics Installation



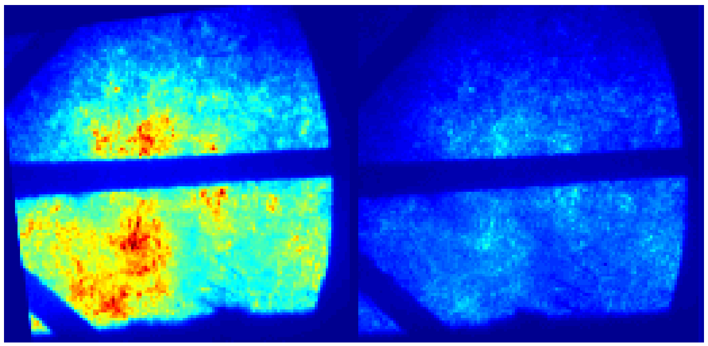
HEATTOP: Experimental rig Setup

Double image of disc through stereoscope

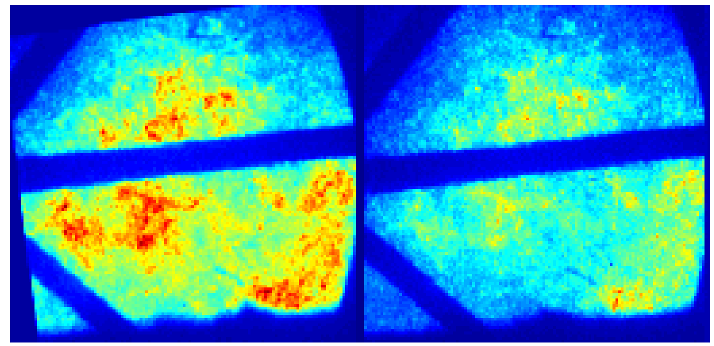


HEATTOP: Results

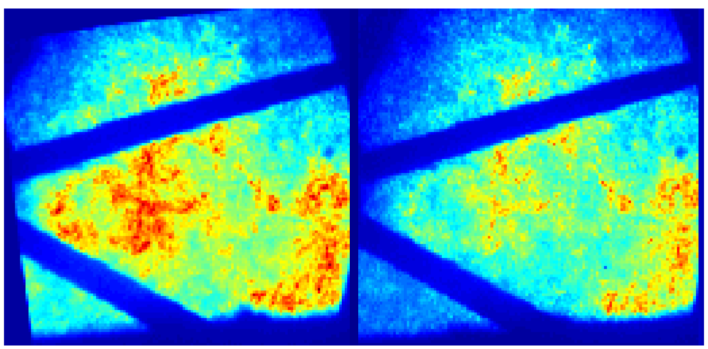
Roomtemp 1 bar



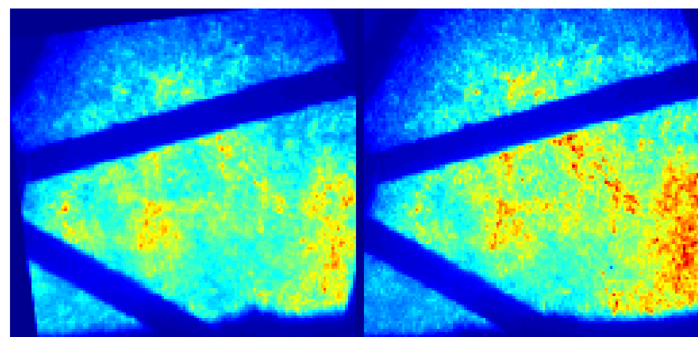
100 deg/C 2 bar



140 deg/C 5 bar



300 deg/C 5 bar

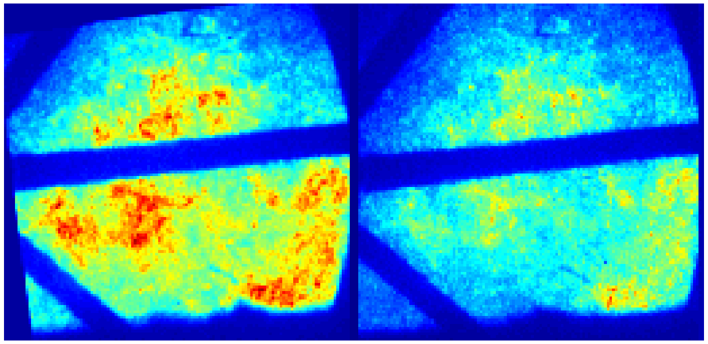


Left part of image: Disc through 456nm IF

Right part of image: Disc through 400nm IF

HEATTOP: Results

100 deg/C 2 bar



- 100 ns exposure time
- Fine structure visible
- Signal intensity no problem

HEATTOP: Conclusions

- Spectral properties of BAM well suitable for 2D measurement
- Temporal properties of BAM well suitable for high temporal resolutions measurements (τ : 2µs – 10ns)

TLC (Towards Lean Combustion)

- EU-project coordinated by SNECMA
- Fuel visualisation: time resolved / 3D
- Multi-YAG
- LIF/Mie

TLC: Time-resolved measurements

The aim was to investigate the benefits of less absorption of the laser sheet by the fuel when using longer excitation wavelengths

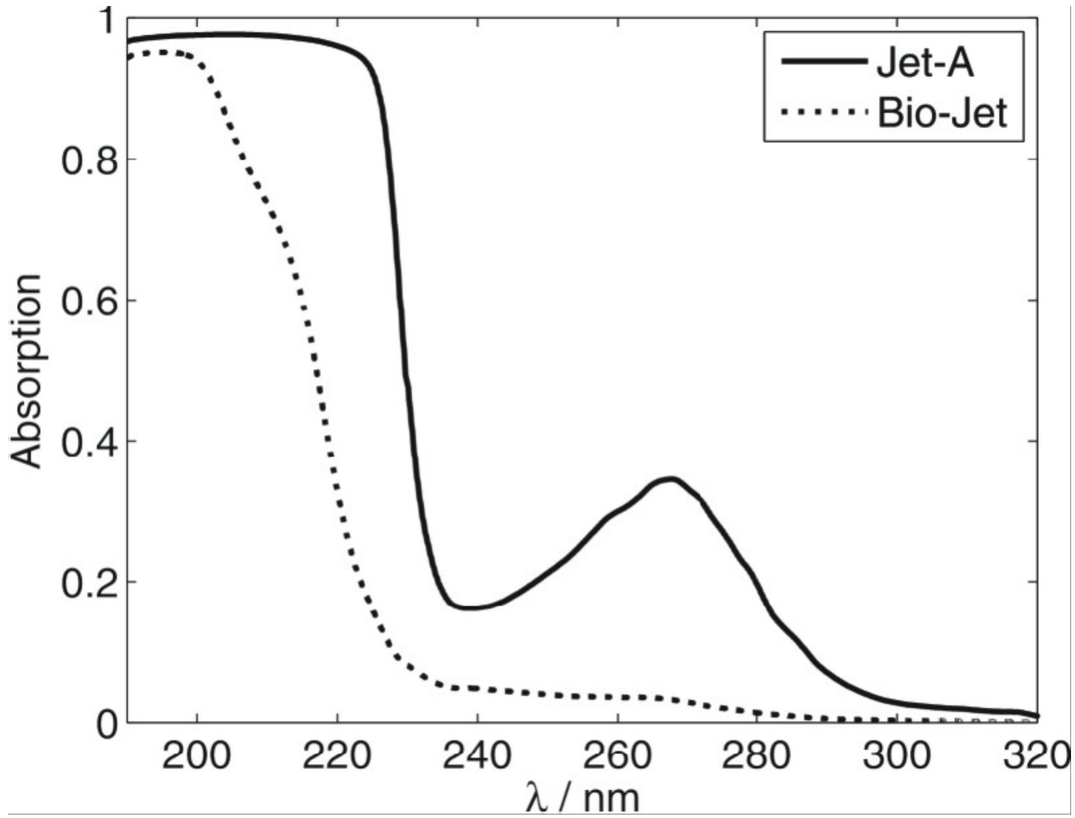
Time-resolve visualization of fuel LIF using the Multi-YAG laser system

Two fuels were tested, **Jet-A** and **Bio-Jet**, and two excitation wavelengths, **266** and **300** nm

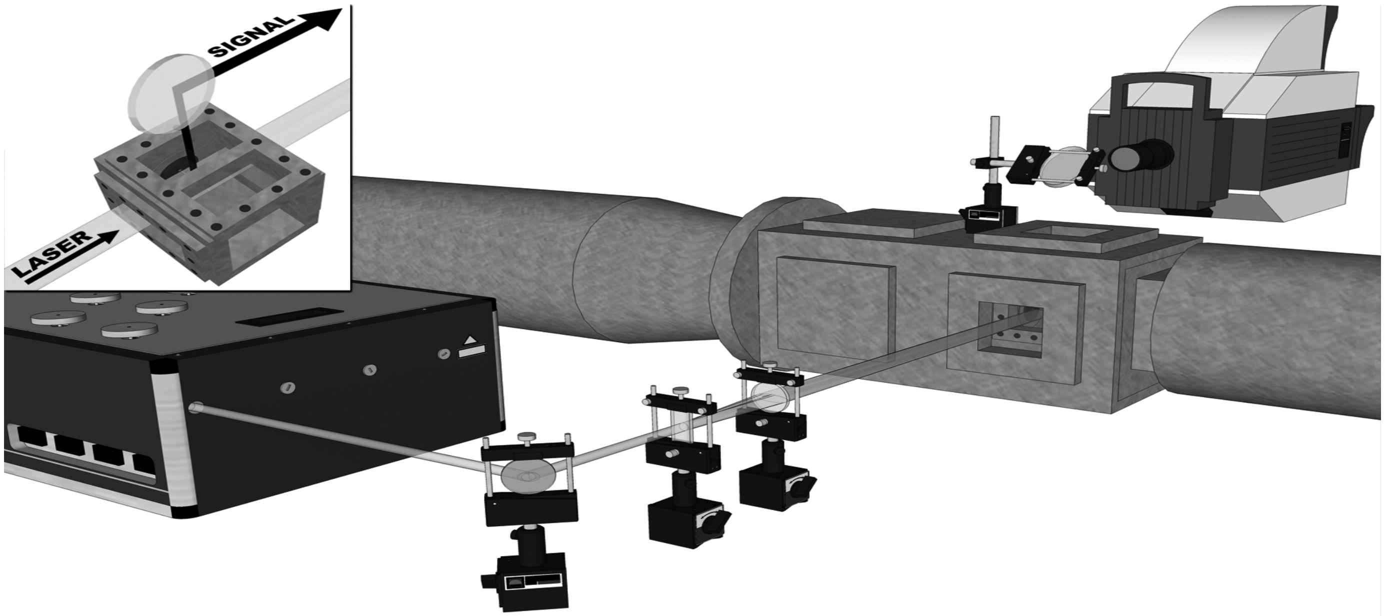
The 300 nm excitation wavelength was produced using an OPO laser source pumped by the Multi-YAG laser system

Three-dimensional fuel LIF, Mie scattering and OH LIF were performed for Bio-Jet

TLC: Absorption spectra

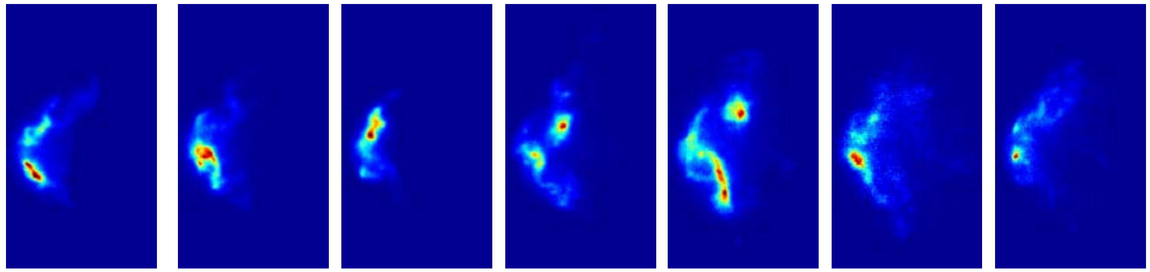


TLC: Experimental setup



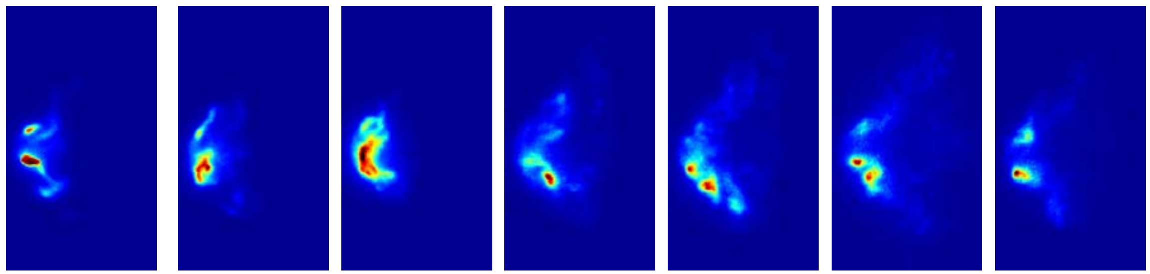
TLC: Time-resolved Fuel-LIF of Jet-A

AFR 82



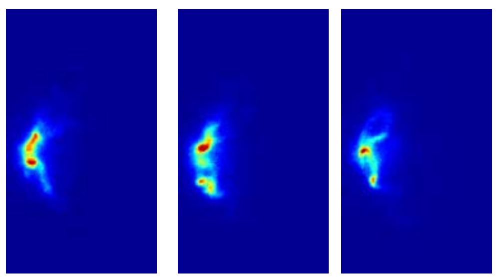
266 nm

AFR 46



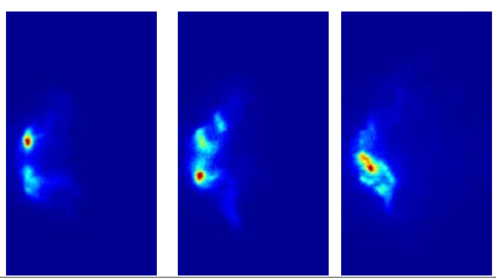
266 nm

AFR 82



300 nm

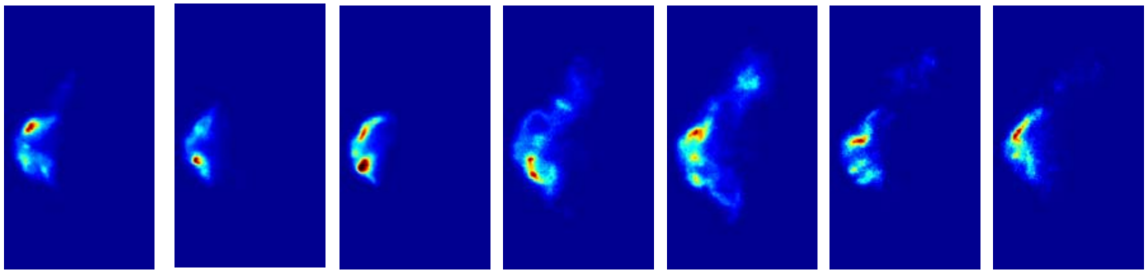
AFR 70



300 nm

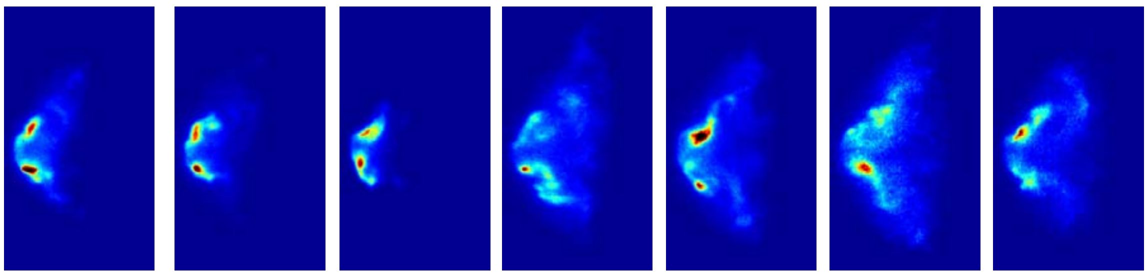
TLC: Time-resolved Fuel LIF of Bio-Jet

AFR 76



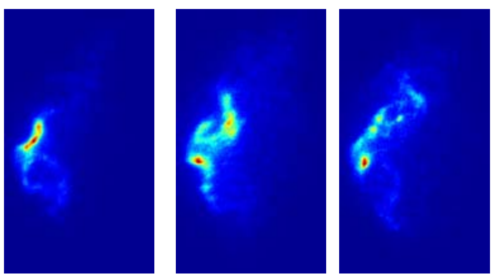
266 nm

AFR 49



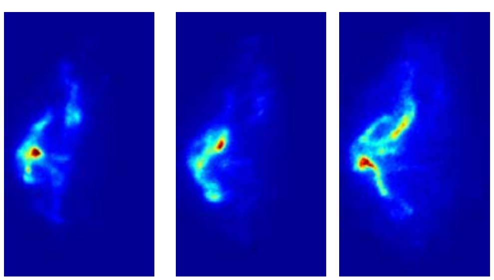
266 nm

AFR 83



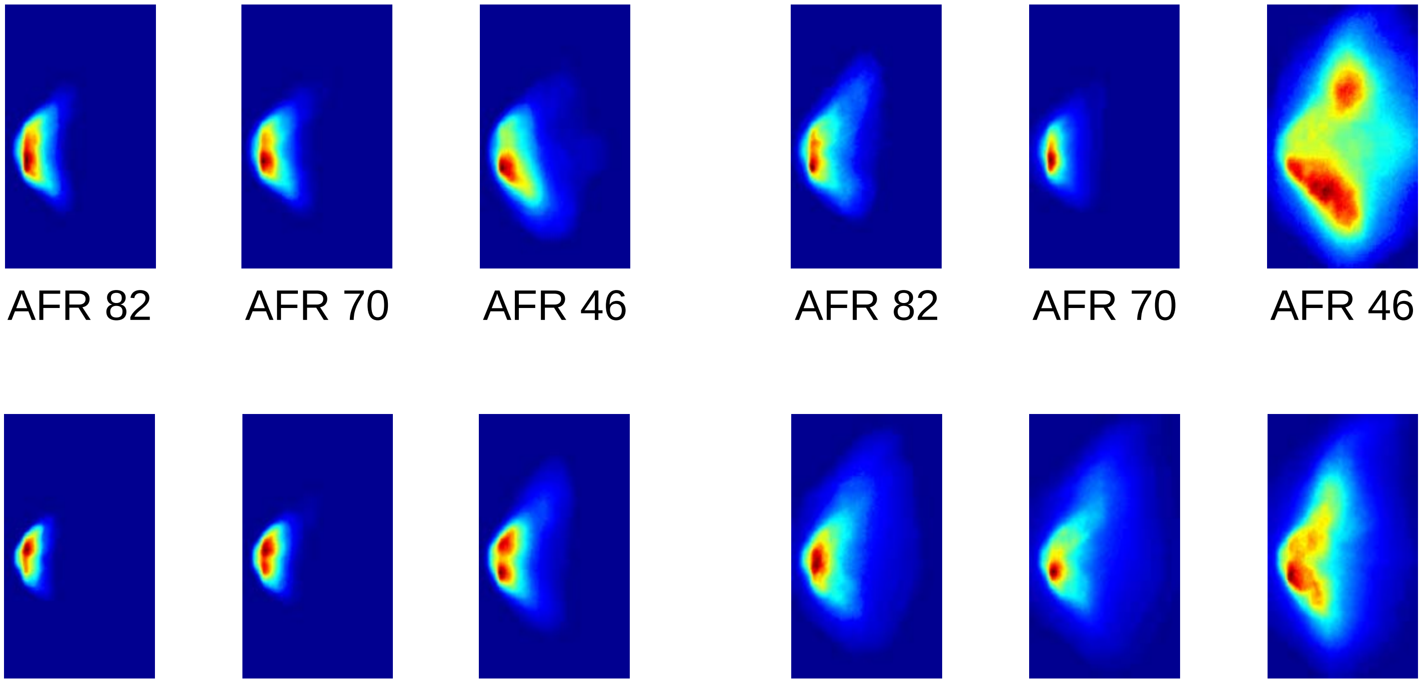
300 nm

AFR 76



300 nm

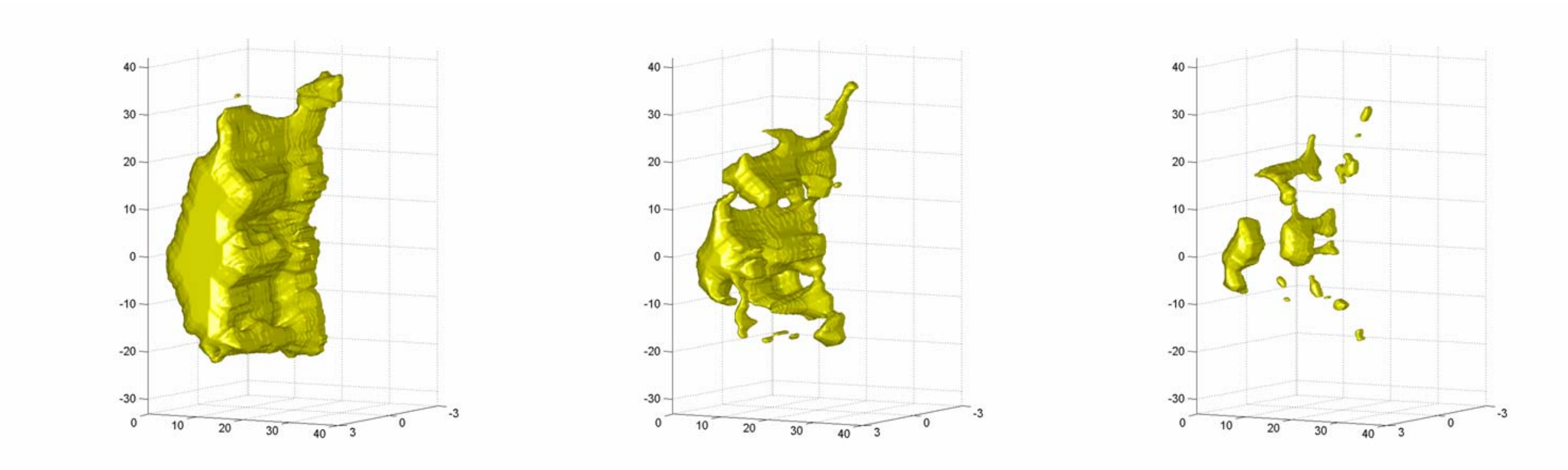
TLC: Average Fuel LIF images



Top row: Jet-A

Bottom row: Bio-Jet

TLC: three-dimensional Fuel-LIF of Bio-Jet



- Excitation wavelength 266 nm
- Seven closely spaced laser sheets, 6 mm
- Shape-based interpolation

TLC: Conclusions

Minor improvements possible when using 300 nm at the high absorbing Jet-A fuel, further investigations needed

For the low absorbing Bio-Jet fuel excitation at 266 nm favored excitation at 300 nm mainly due to higher laser energy at 266 nm than at 300 nm

From the 3D plots the "v-shape" of the fuel from the injector is clearly seen

See also at the 33rd Symposium, Beijing:

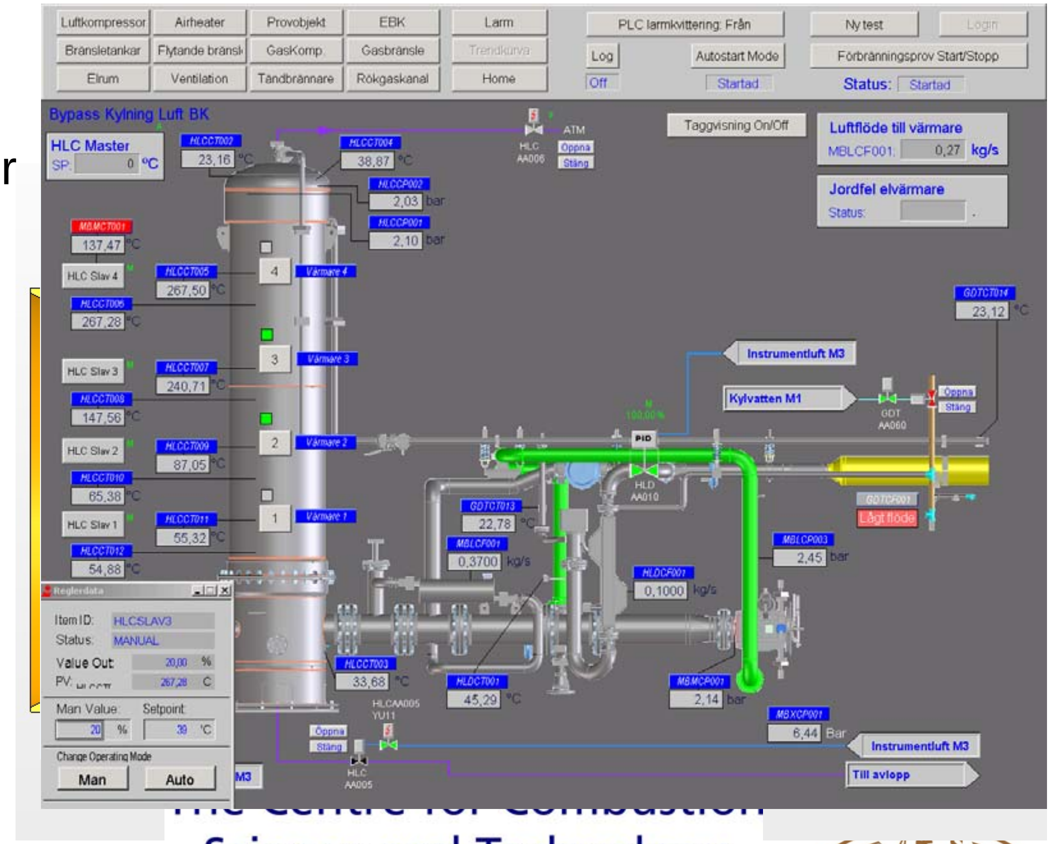
C. Knappe et al.: Surface Thermometry using Laser-Induced Phosphorescence: A Study on Phosphor Layer Thickness in Engine Combustion

A. Lantz et al.: Time-resolved laser diagnostics measurements in a gas turbine pilot burner at elevated pressure

(WIP-posters)

Recent, ongoing & planned activities

- Redesign of air heating system to allow for longer runs at low air flow rates
- New larger test section is under construction, installed autumn 2010
- Test campaign on SIEMENS RPL-burner late summer 2010
- Test campaign on SIEMENS LXB, winter 2010 (approx.)
- From 2010: integrated with the CECOST-program, the high pressure combustion facility constitutes a national resource



Science and Technology

Acknowledgement

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- Funding:
  - European Union
  - Swedish Energy Agency