Preparation for the Application of CARS Thermometry in LOX/CH_4-Spray-Flames

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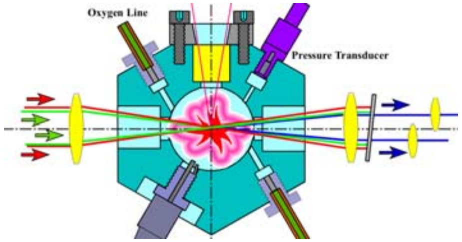
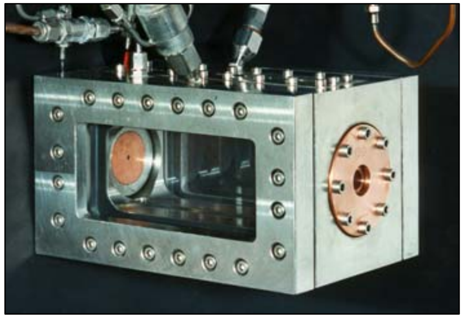
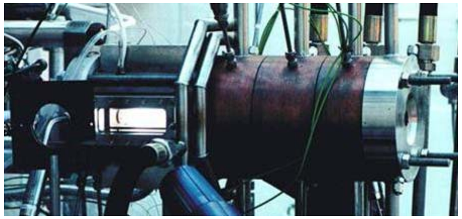
diagnostics of CH_4/O_2-flames: roadmap (1/2)







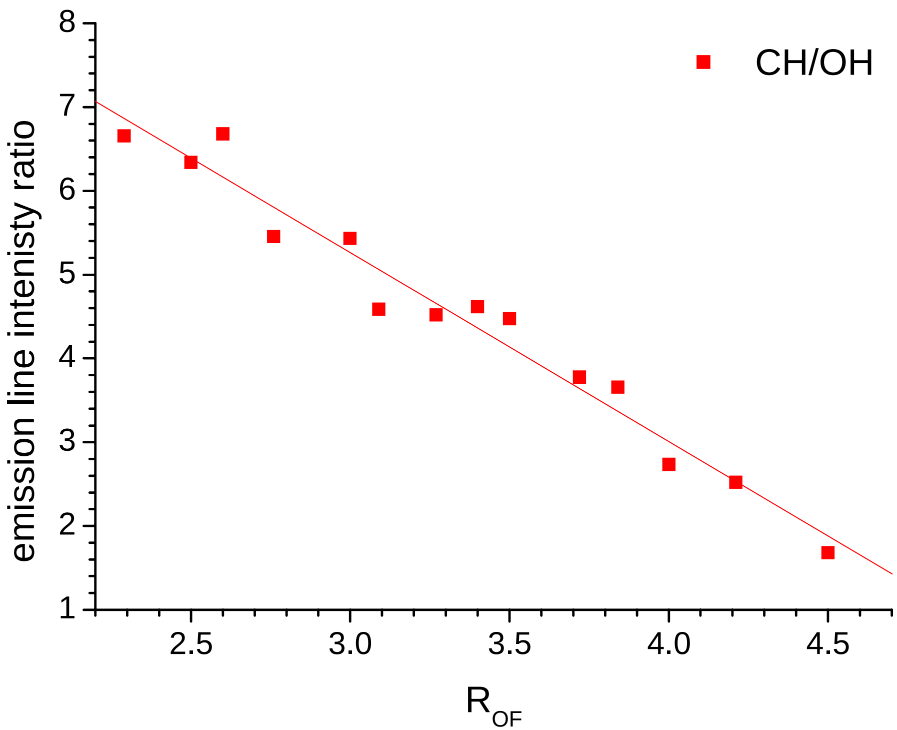
experimental set-ups

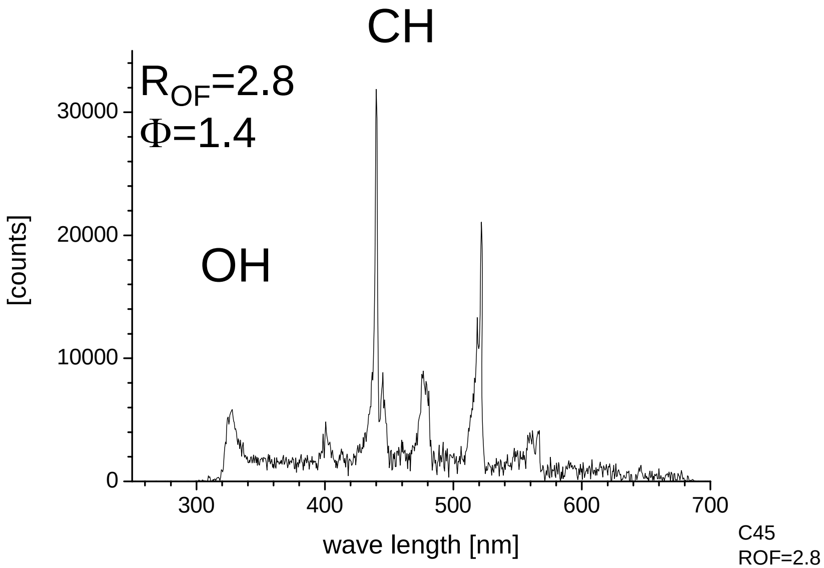
- matrix burner (P_C< 2 MPa)
- pulsed HP burner (P_C < 10 MPa, high T)
- micro-combustor at the M3.1 test bench (LOX/CH_4 spray combustion, P_C < 1 MPa)
- combustor C at the P8 test bench (LOX/CH_4 spray combustion, P_C < 10 MPa)

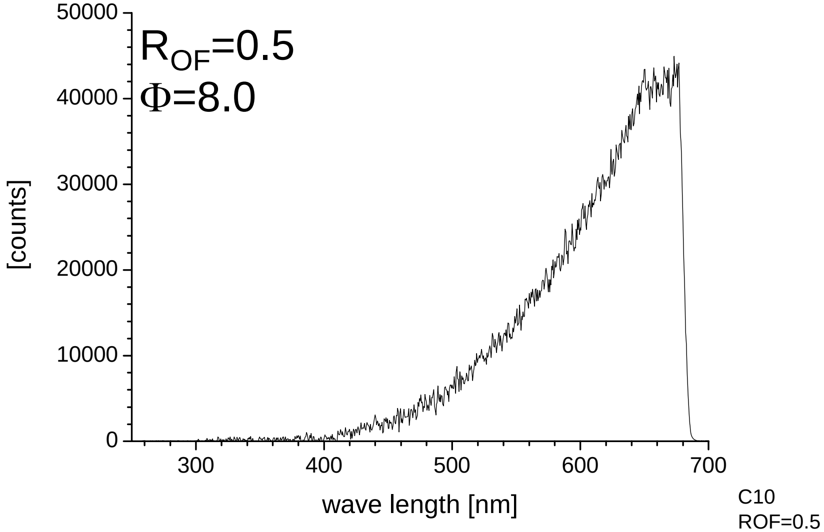
objectives

- what can we learn from CH_4/O_2-flame emission spectroscopy?
- CARS adaptation at laboratory-burners

CH/OH-emission intensity ratio (1 bar)

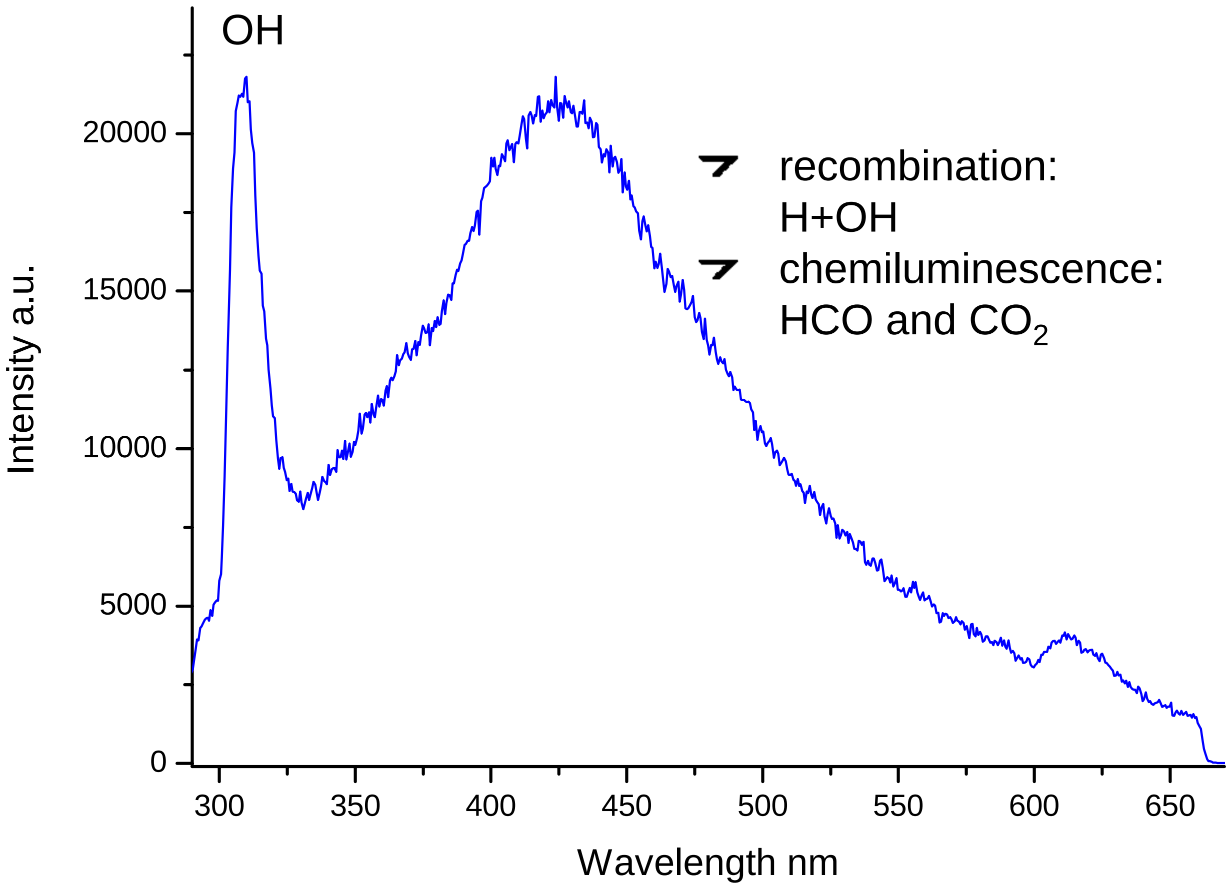






- linear dependence of line intensity ratio on mixture ratio
- low R_{OF}: soot formation

CH_4/O_2-flame emission spectra (60 bar)



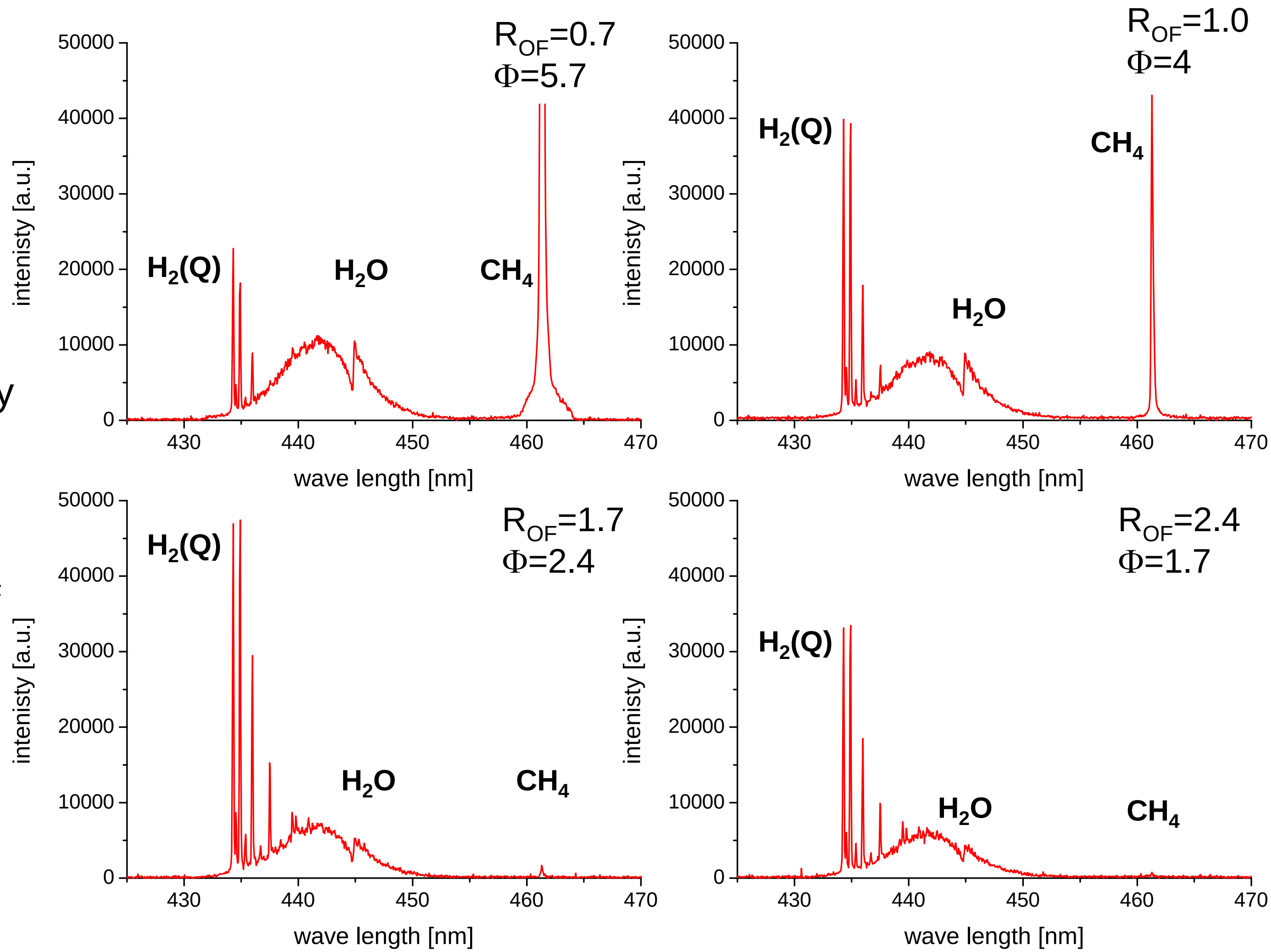
- recombination: H+OH
- chemiluminescence: HCO and CO_2

- at high pressure CH- or C_2 signals can't be identified in the emission spectrum

H_2, H_2O, and CH_4 CARS spectra for R_{OF}=0.7-2.4 (Φ=1.7-5.7)

with increasing mixture ratio:

- CH_4 signal intensity vanishes
- good H_2 signal intensity for all R_{OF}



lessons learned

conclusion from laboratory experiments:

CH_4-CARS spectra

- observed only in rich flames for $\Phi>2.7$ ($R_{OF}<1.5$)
- in diffusion flames signals are expected only on the fuel rich side of the flame front (unburned, cold methane)

H_2-CARS spectra

- observed with good signal quality in the burned gas. Molecule of choice for thermometry

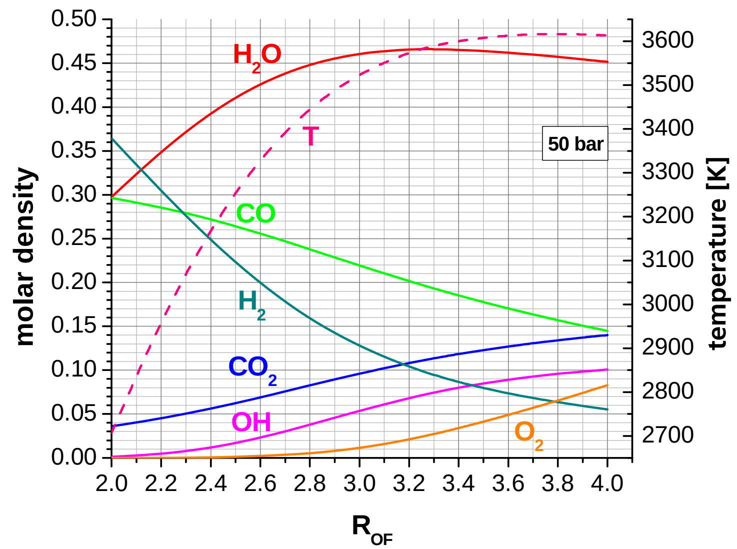
H_2O-spectra

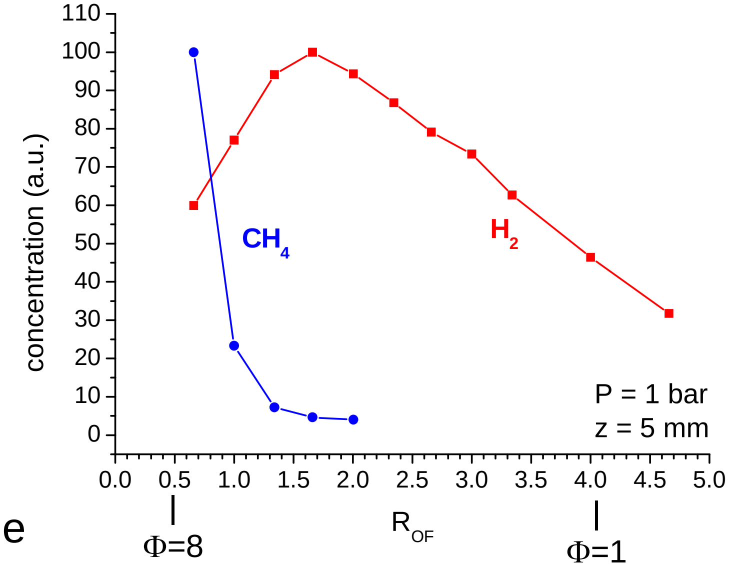
- signal interference with non-resonant CARS

strategy for CARS in CH_4/O_2-flames:

2 probe molecules: CH_4 as reactant
H_2 as reaction product

1 probe molecule: H_2, due its availability in a wide region in the reactive flow.

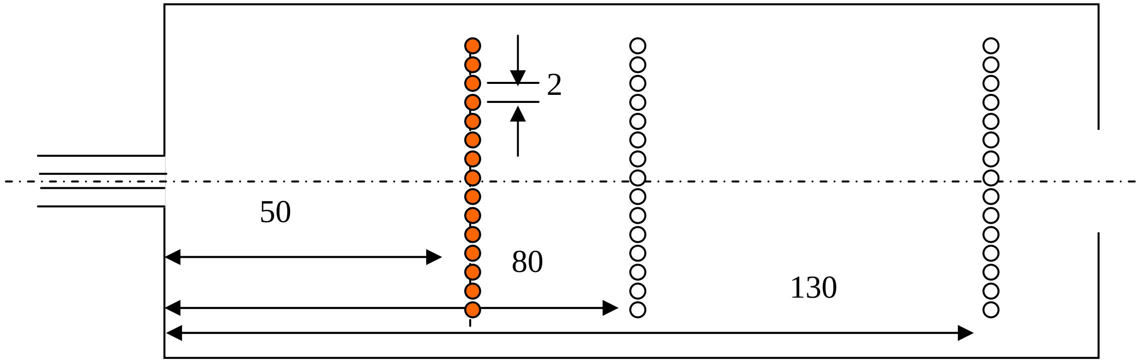


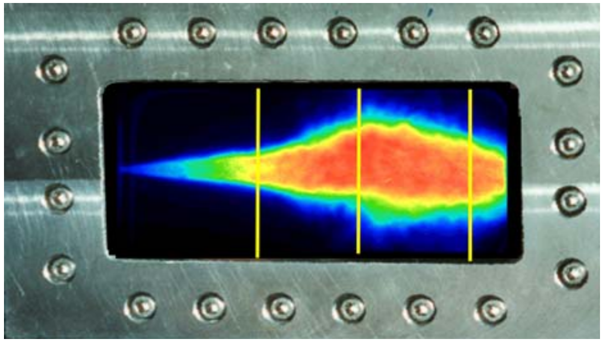


CARS application at M3.1

measurement locations

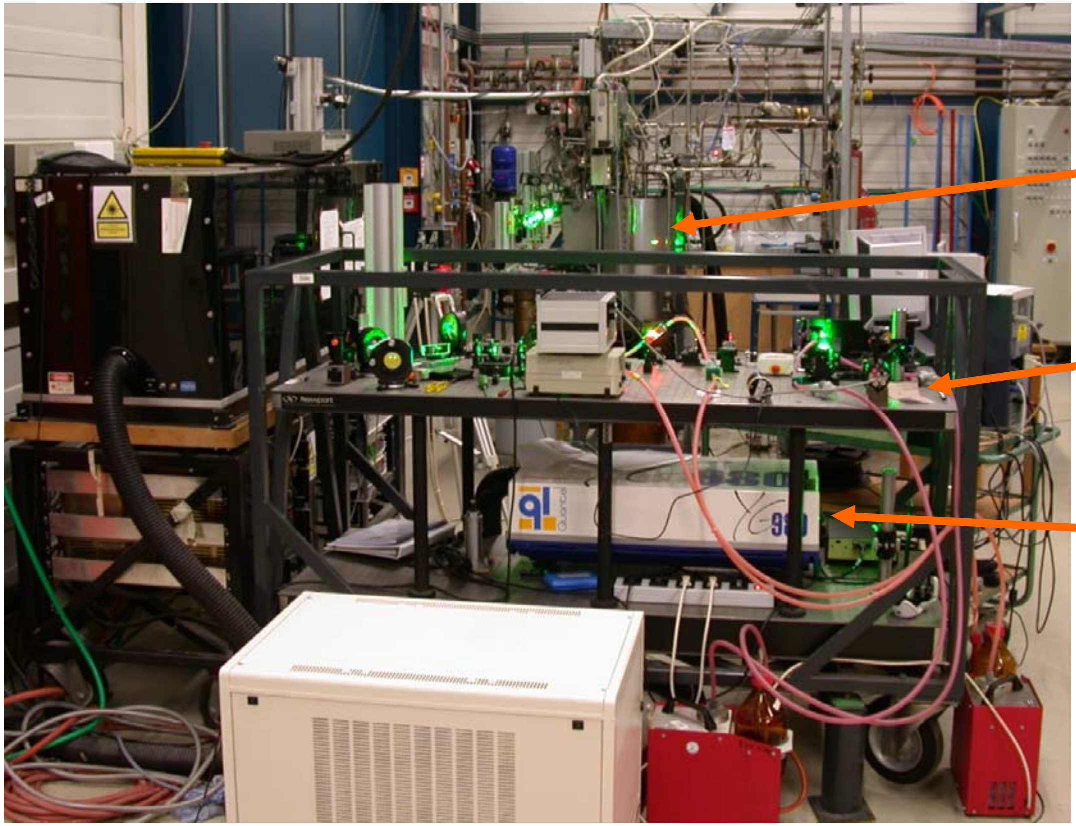
- 50 mm downstream injector faceplate
- r= -15 ...15 mm, Δr=2mm





CARS application at M3.1

optical set-up at M3 test bench



LN_2-cooler for LOX and H_2

dye-laser (Stokes)

Nd:YAG-laser (pump)

CARS application at M3.1

status

- run time of micro combustor extended to 7s

- housing of flash lamps and Nd:YAG crystal damaged
- low performance of new igniter
- no H_2 at first measurement location

- only data from one measurement location available today
- work continues

development of CARS-diagnostics for high pressure CH_4/liquid oxygen spray combustion

INTAS project

partners:

- DLR Lampoldshausen
- ONERA (DMPH), Palaiseau
- General Physics Institute of the RAS (GPI)
- Central Institute of Aviation Motors (CIAM), Moscow

project structure

- upgrade of pulsed burner for CH_4/O_2-combustion
- CFD simulation of ignition and combustion in the pulsed burner
- CARS spectroscopy in the pulsed burner
- Simulation of CARS spectra
- Comparison of CARS codes
- CARS system for single shot thermography at high pressure
- application to high pressure CH_4/liquid oxygen spray combustion

development of CARS-diagnostics for high pressure CH_4/liquid oxygen spray combustion (cont.)

key idea from V. Smirnov, GPI:

simultaneously

- detection of H_2-CARS signal and
- determination of the H_2-line width

- no need to determine the density of all eventual collision partners in a CH4/O2-flame during the measurement
- the broadening coefficients of these collision partners need not been known.

presented at ECONOS conference, Smolenice, 2006:
V.I.Fabelinsky, V.V.Smirnov, O.M.Stel'makh, K.A.Vereschagin, A.K.Vereschagin, W.Clauss, M.Oschwald: "New Approach to Single Shot CARS Thermometry of High Pressure, High Temperature Hydrocarbons Flames"

development of CARS-diagnostics for high pressure CH_4/liquid oxygen spray combustion (cont.)

HIGH RESOLUTION SINGLE SHOT DBB-CARS SPECTROMETER

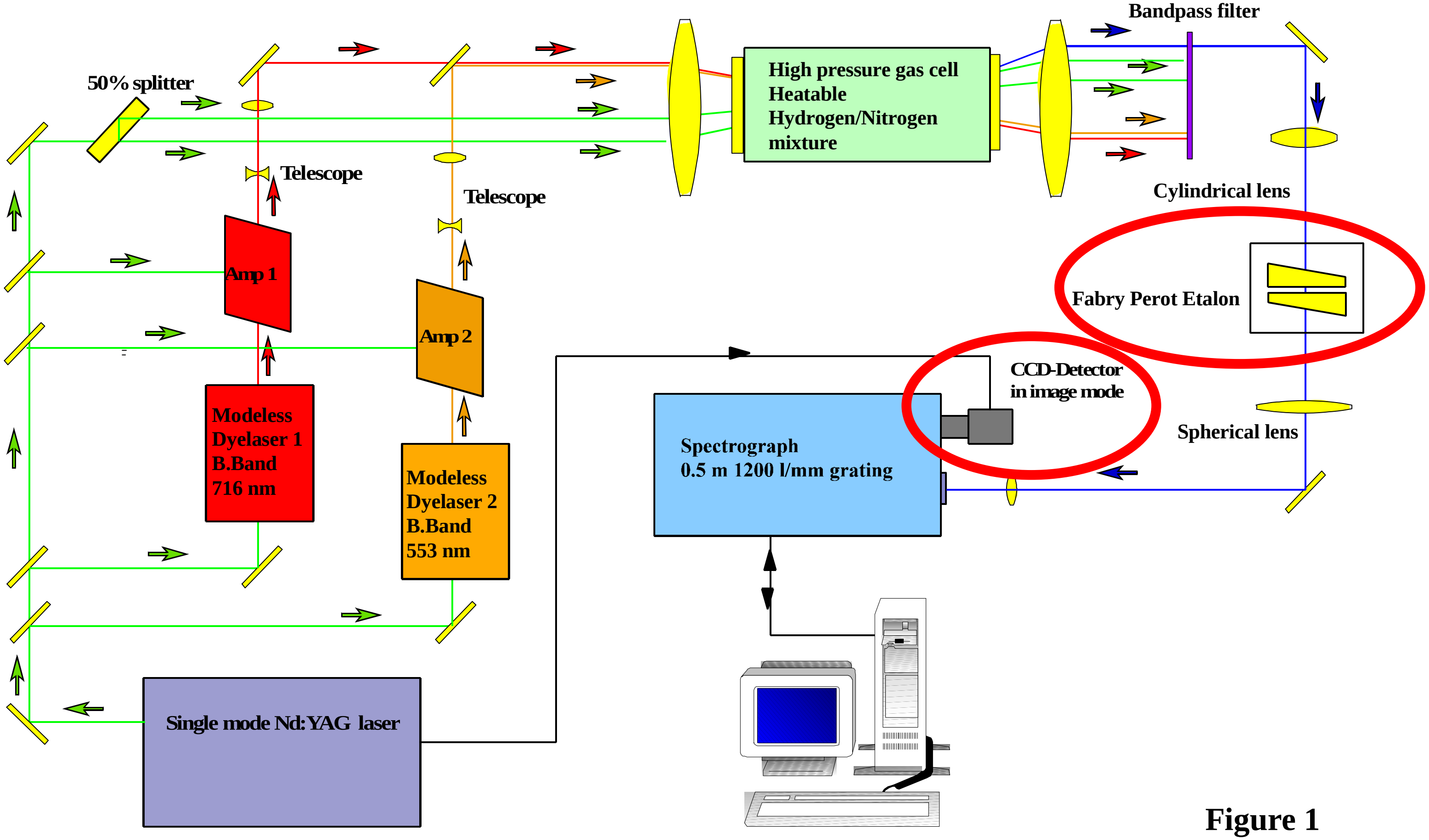
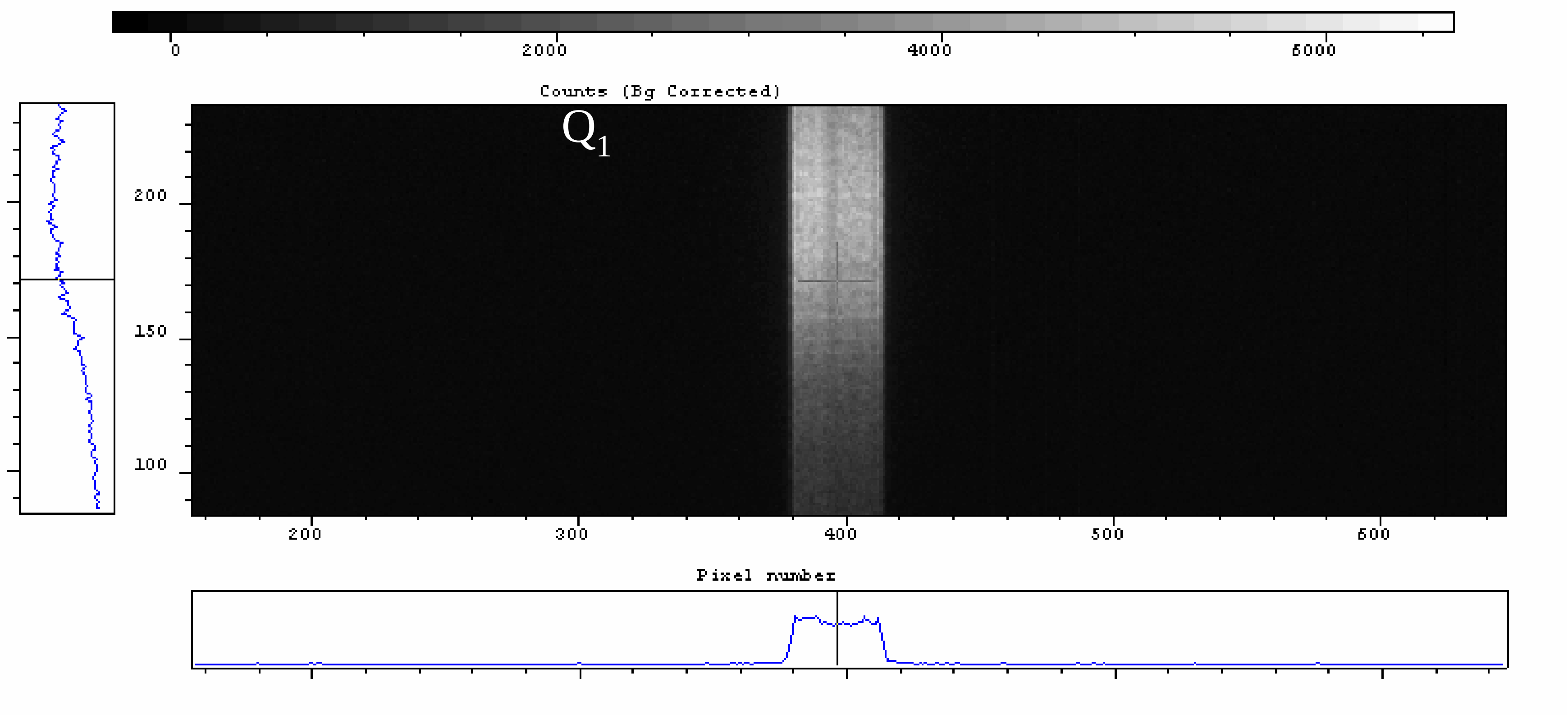


Figure 1

development of CARS-diagnostics for high pressure CH_4/liquid oxygen spray combustion (cont.)

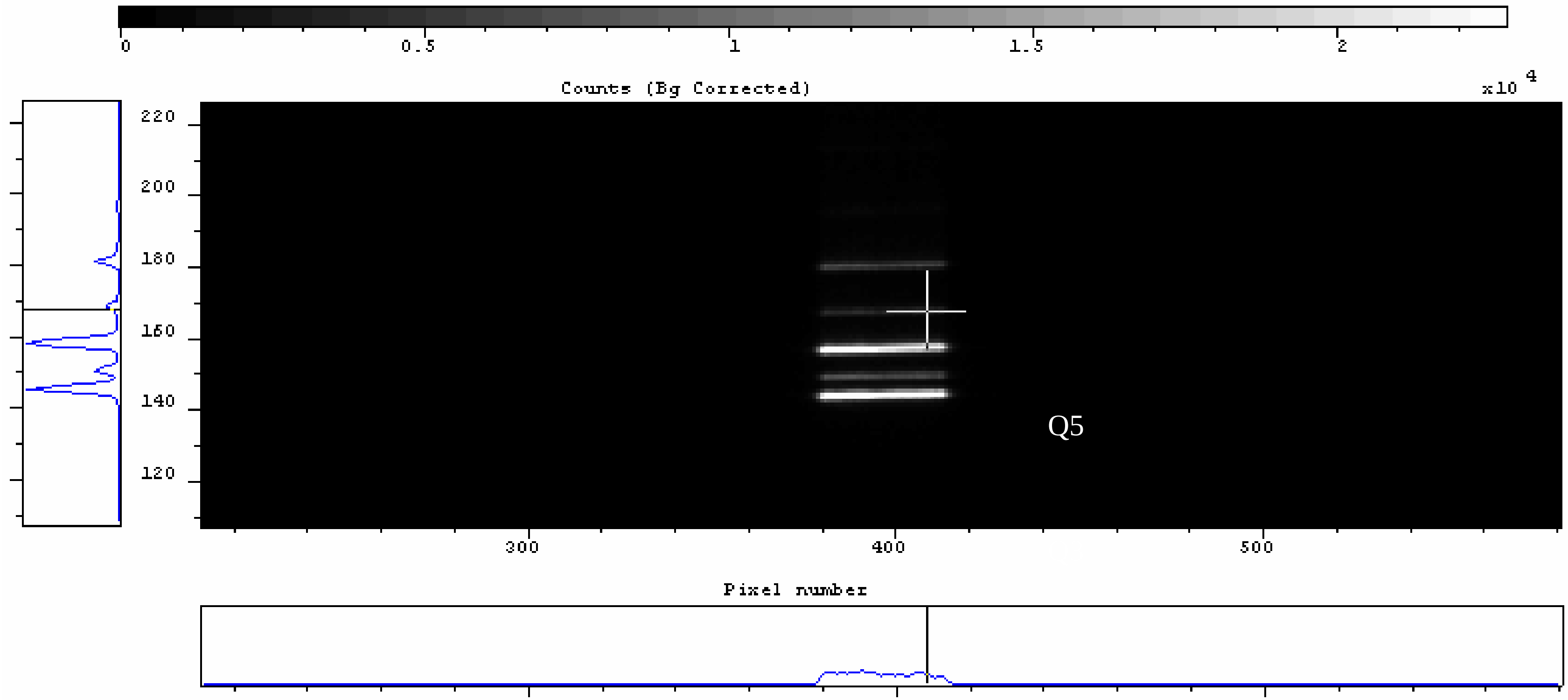
NON- RESONANT DBB-CARS SPECTRA
in gas cell



Fabry-Perot interferometer removed

development of CARS-diagnostics for high pressure CH_4/liquid oxygen spray combustion (cont.)

DBB - CARS SPECTRA OF H_2 Q-BRANCH
in gas cell



Heated cell with mixture H2 : N2 = 1 : 10, T = 960 K, P=5 bar
Fabry-Perot interferometer removed

development of CARS-diagnostics for high pressure CH_4/liquid oxygen spray combustion (cont.)

DBB-CARS OF H2 Q-BRANCH
in gas cell

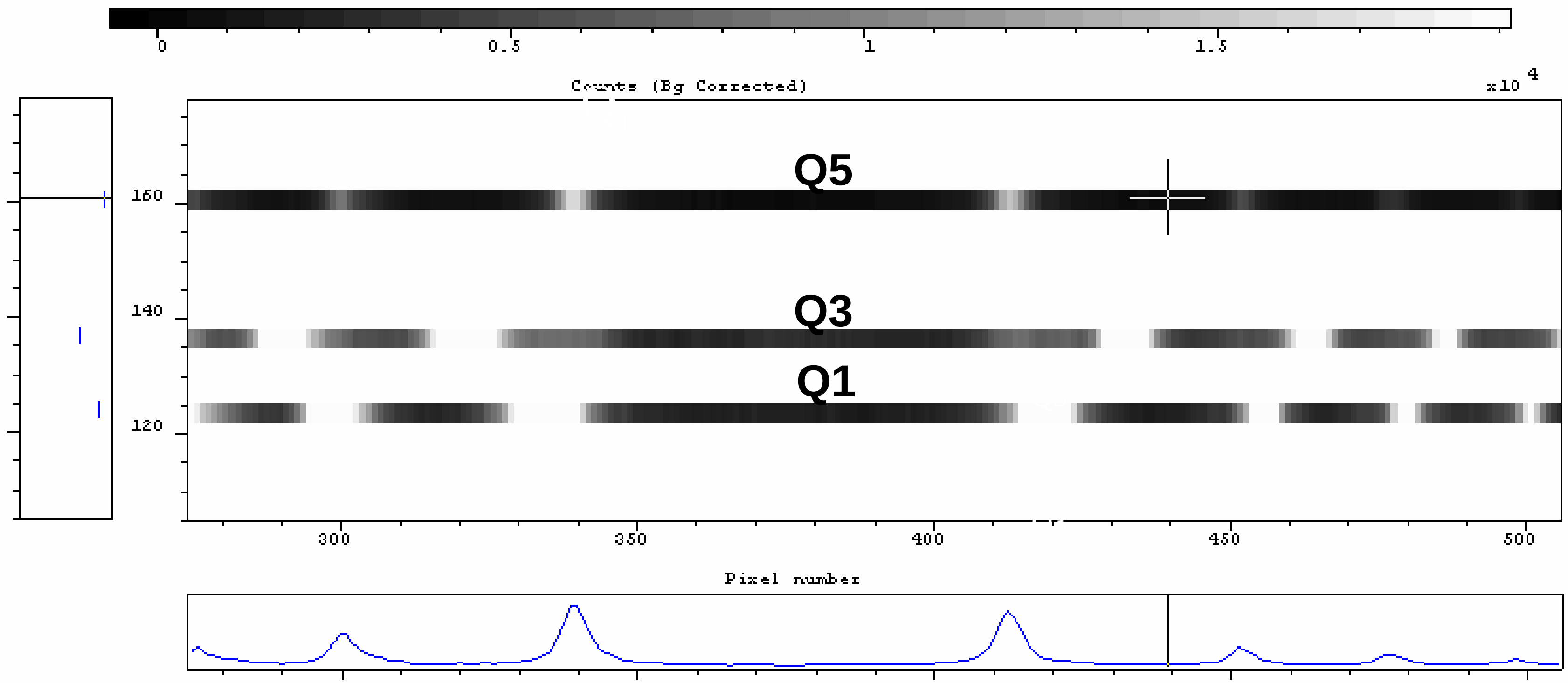
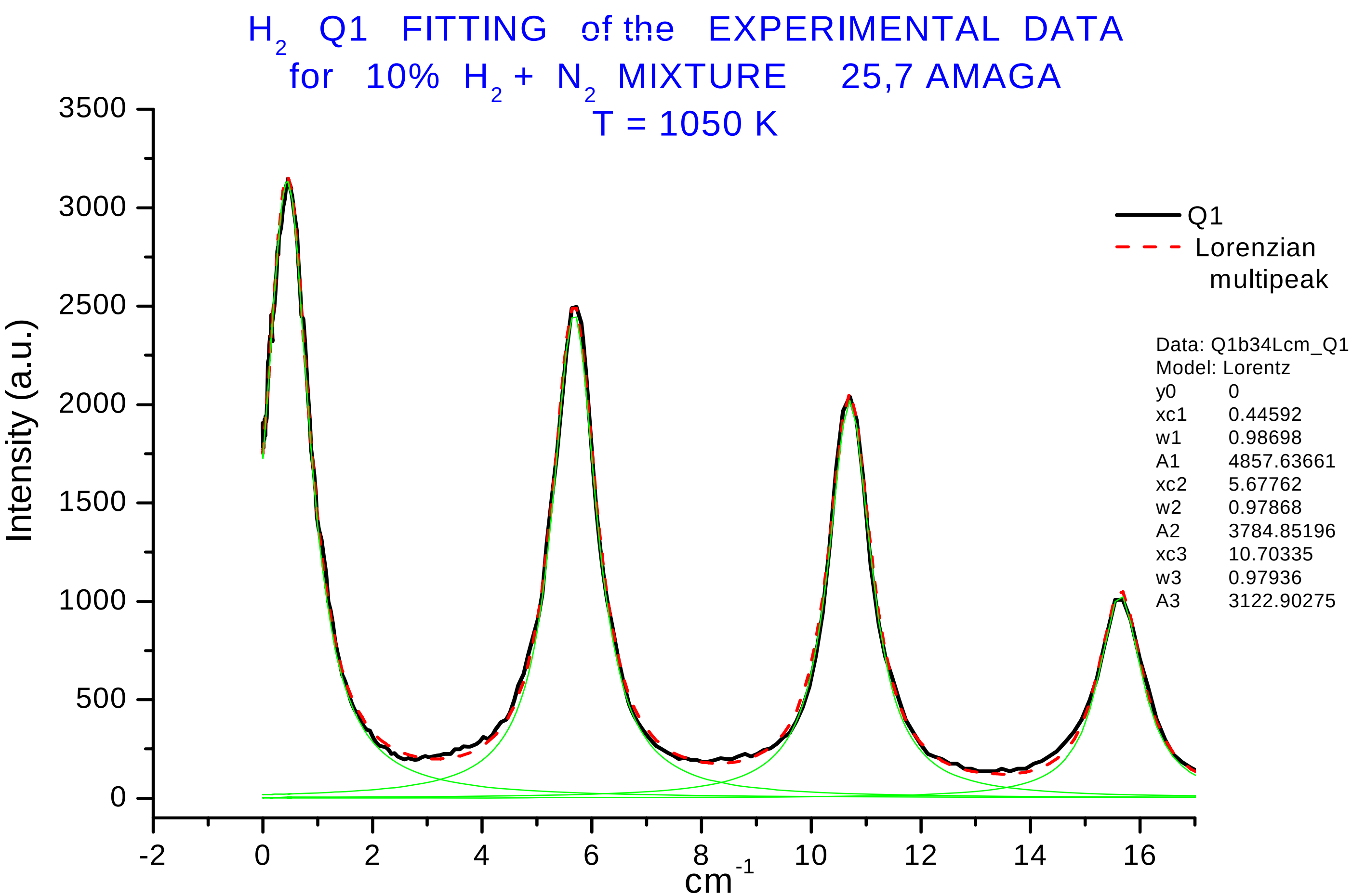


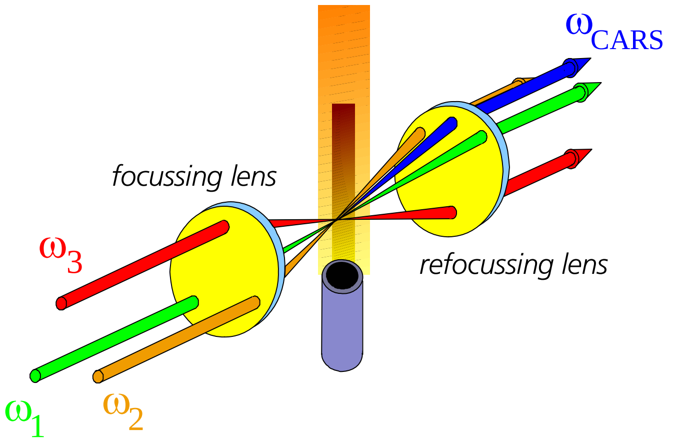
Image of Single shot Fabry-Perot Interferogram

development of CARS-diagnostics for high pressure CH_4/liquid oxygen spray combustion (cont.)



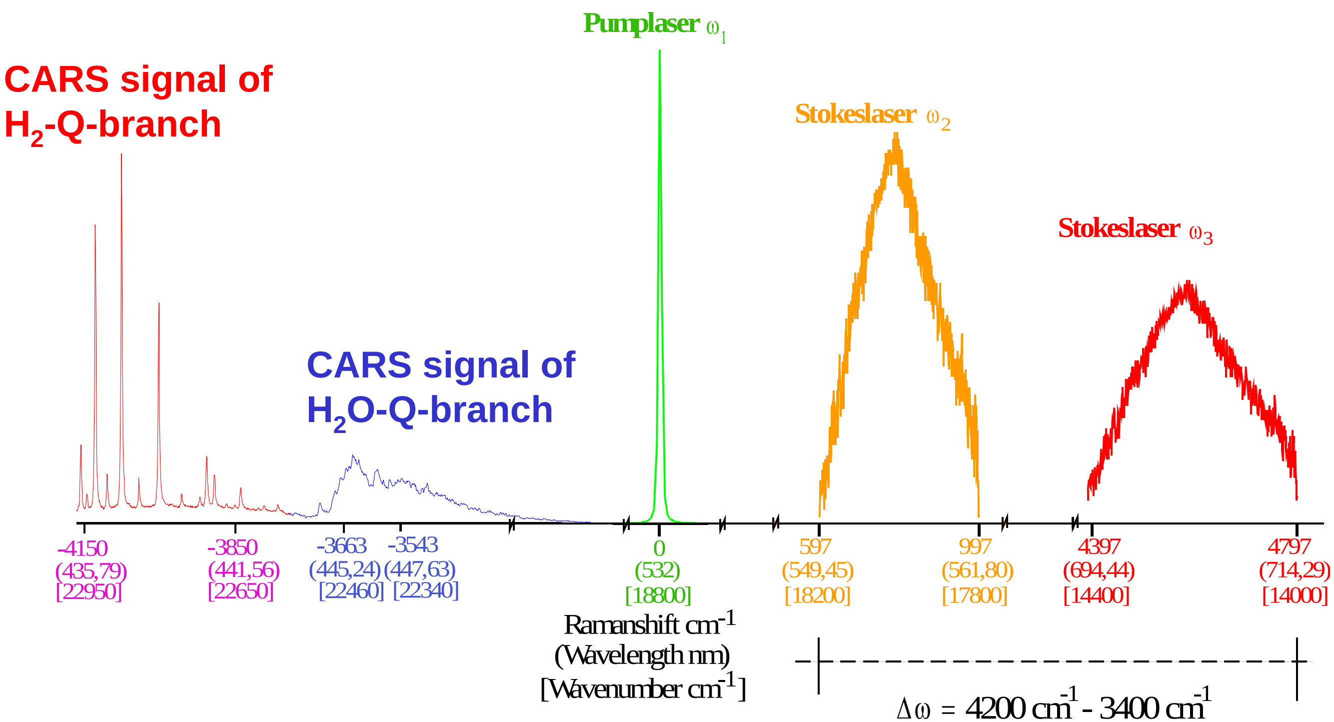
supplementary slides

CARS diagnostics

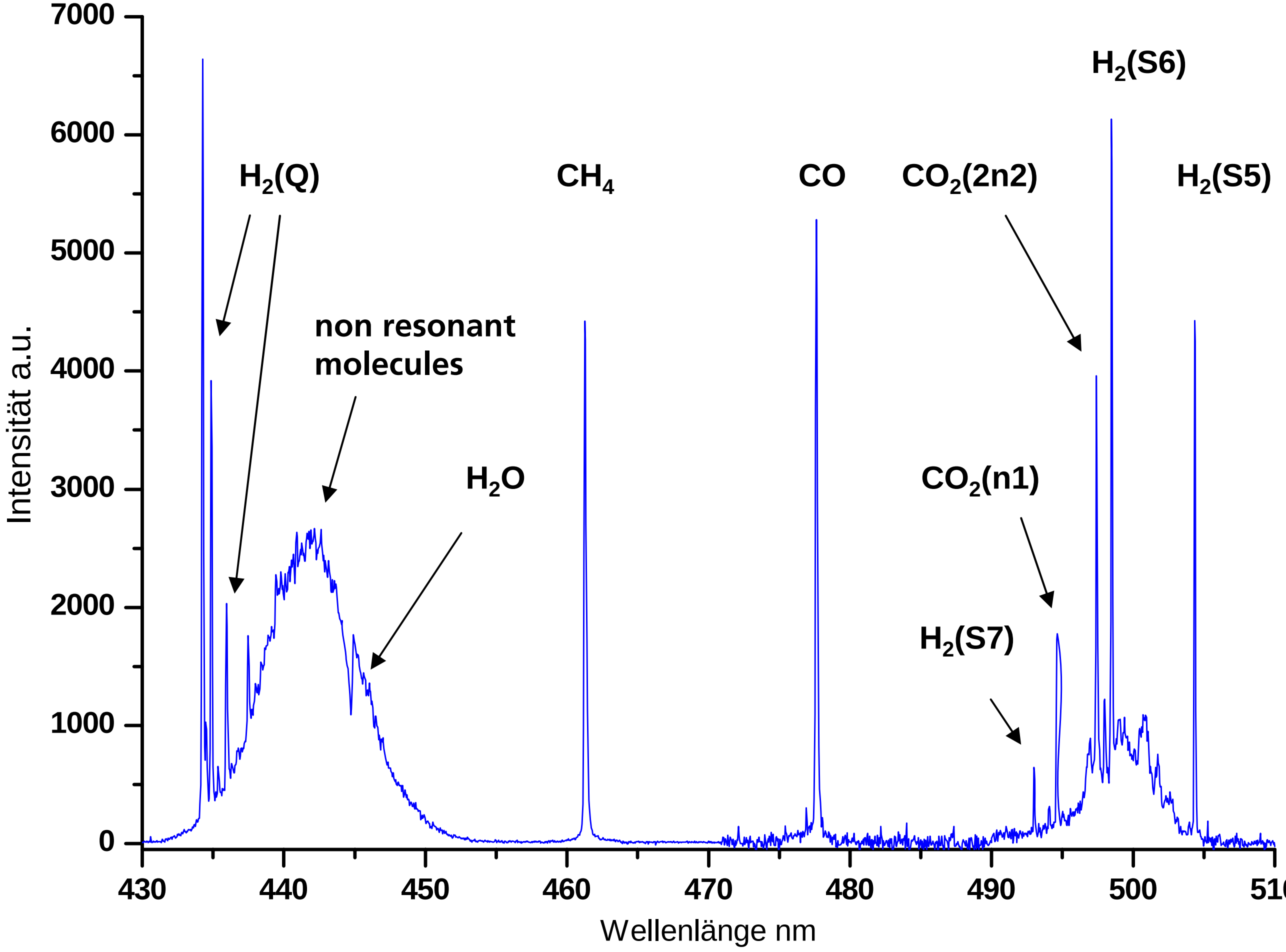


measured physical properties

- temperature
- species concentration
- progress of mixing and combustion



CARS spectra from atmospheric CH_4/O_2-flame



R_{OF}=3.3
Φ=1.2

- CARS-signals from H_2, H_2O, CH_4, CO, CO_2

approach for tests at M3.1

set-up for CARS application at the micro combustor

constraints:

- no application of DBB-CARS approach at test facility
  - simultaneous detection of H_2 and CH_4 with one laser system demonstrated in laboratory flame with dual broadband CARS
  - adjustment of two dye lasers to unstable under test facility conditions (thermal drifts, vibrational loads)
- two CARS laser systems not available for the tests
- no subsequent CARS generation of H_2- and CH_4- signals
  - high test time requirement for mapping of temperature field in the micro-combustor:
    for one radial profile in the spray flame, spatial resolution Δr=2mm:
    15 locations x 10 tests/location = 150 tests / 8 test days / 4 test weeks

approach:

- detection of H_2-CARS with BB-CARS
- simultaneous detection of H_2O to get maximum information