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LAV
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Aerothermochemistry and Combustion Systems Laboratory

A new Sensor for Soot Measurements inside Combustion Systems

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7th ETH-Conference on Combustion Generated Nanoparticles

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Motivation

- **Determining the soot load within the exhaust system is not sufficient to understand the influence of relevant engine parameters and fuel composition effects on the sooting behaviour**
- **Test bench engineer has interest in on-line information about the soot content and soot temperature within the cylinder**
- **„Easy to use" device**

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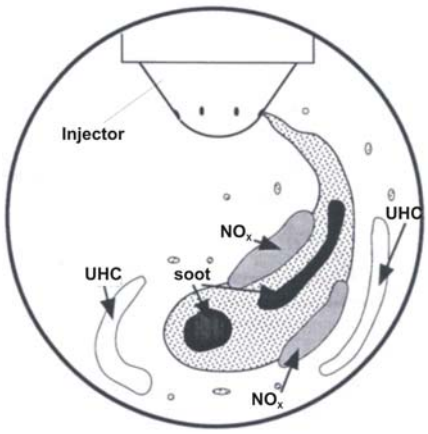
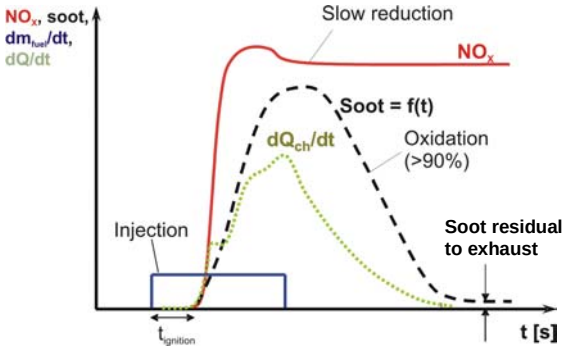
Soot formation within the combustion chamber





Actual soot mass results from the balance between soot formation and oxidation

$$\frac{dm_{soot}}{dt} = \left(\frac{dm_{soot}}{dt}\right)_{formation} - \left(\frac{dm_{soot}}{dt}\right)_{oxidation}$$

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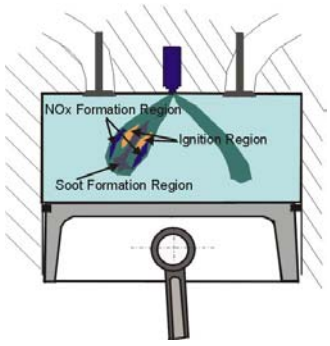
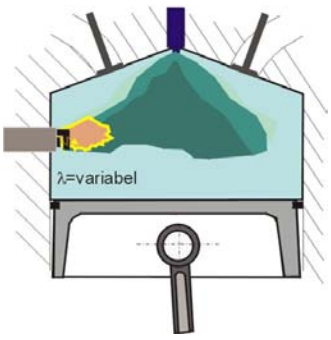
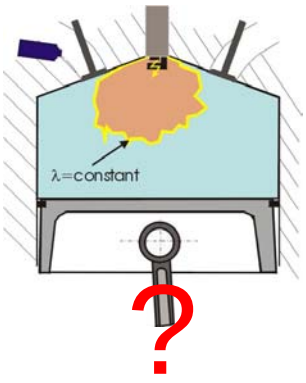
Possible sooting combustion systems

Diesel Engine	DI-Gasoline	Gasoline Engine







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Sensor prototype for pyrometry

Optical head

System

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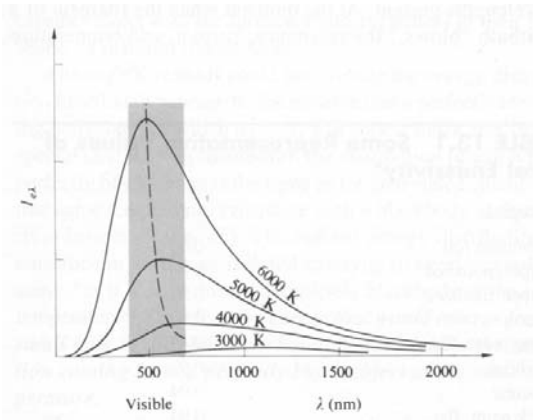
Theoretical background multicolor pyrometry



Planck's Law

$$I = \varepsilon \cdot I_b = \varepsilon \cdot \frac{2C_1}{\lambda^5\left[\exp\left(\frac{C_2}{\lambda T}\right) - 1\right]}$$

Law of Hottel and Broughton

$$\varepsilon_\lambda = 1 - e^{\left(-KL/\ \lambda^{1.39}\right)}$$

Combination

$$KL = -\lambda^{1.39} \ln\left[1 - \frac{\exp(C_2/\lambda T)}{\exp(C_2/\lambda T_a)}\right]$$

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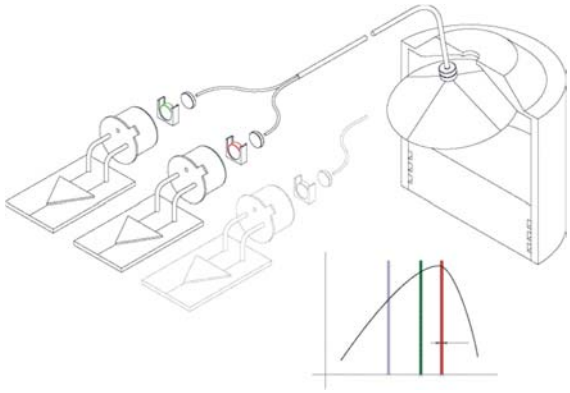
What signals are measured and what can be determined?



Measured signals

- TDC, increments CA
- pressure
- optical signal @ 550nm
- optical signal @ 650nm
- optical signal @ 750nm

Determined values

- fuel consumption
- heat release
- averaged combustion chamber temperatures
- soot concentration (KL)
- soot temperature (T)

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Experimental set-up

GDI-engine

1cyl. 4-stroke research engine

Bore:	*89.9 mm*
Stroke:	*86.6 mm*
Displacement:	*550 cm³*
Compression-Ratio:	*10*
Fuel:	gasoline ROZ 98.8

Running conditions

$n = 2000\ min^{-1}$
p_{mi} ~ 4bar

$t_{ignition}$:	-38 °CA
$t_{injection}$:	-84 °CA
$\Delta t_{injection}$:	2.4 ms
p_{rail} :	75 bar
EGR :	0 %
λ_{global} :	2.2

Used sensor

Parent sensor system developped at ETH

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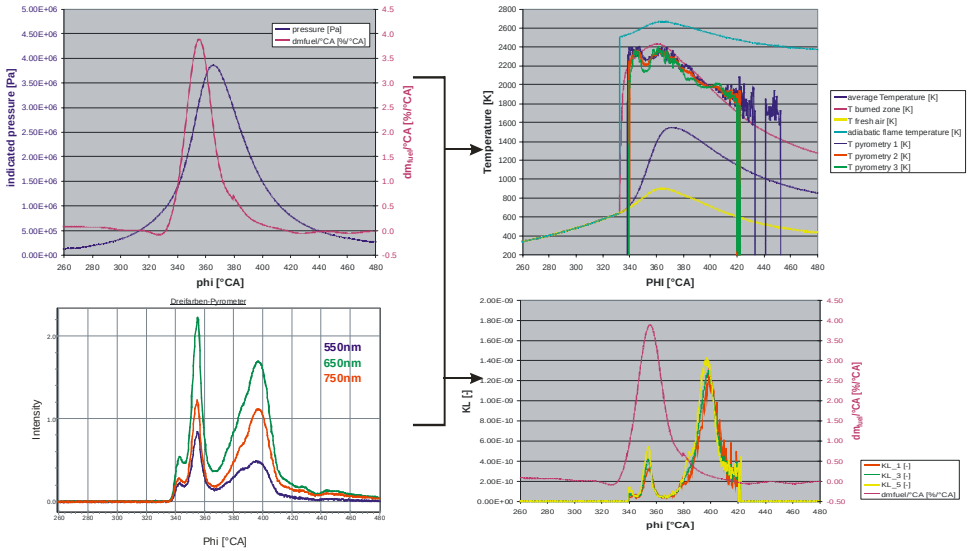
Measurement and evaluation of a single cycle (#1)



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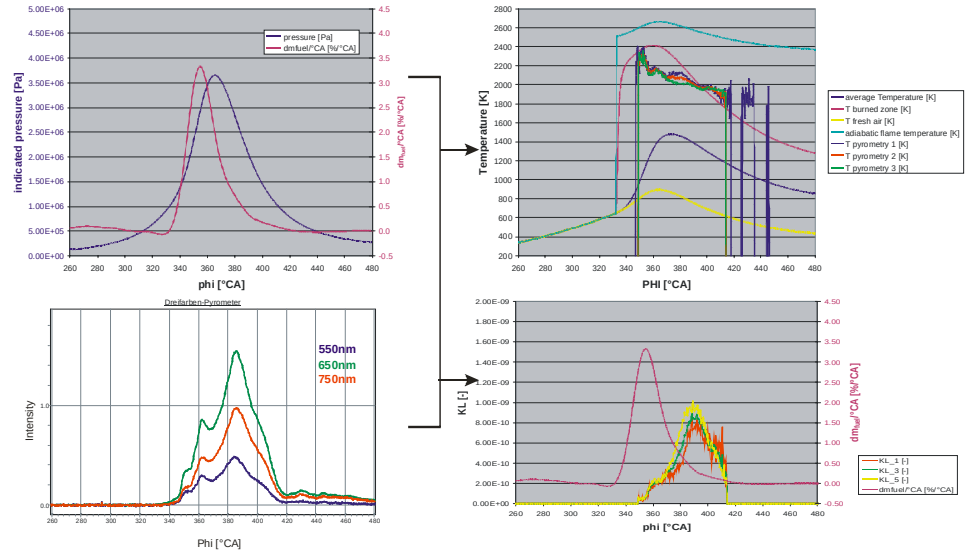
Measurement and evaluation of a single cycle (#2)



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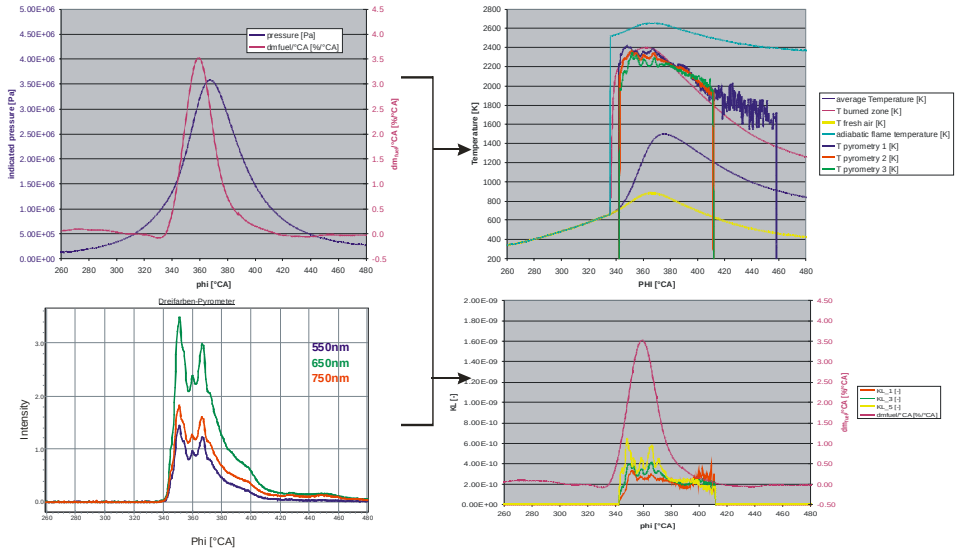
Measurement and evaluation of a single cycle (#3)



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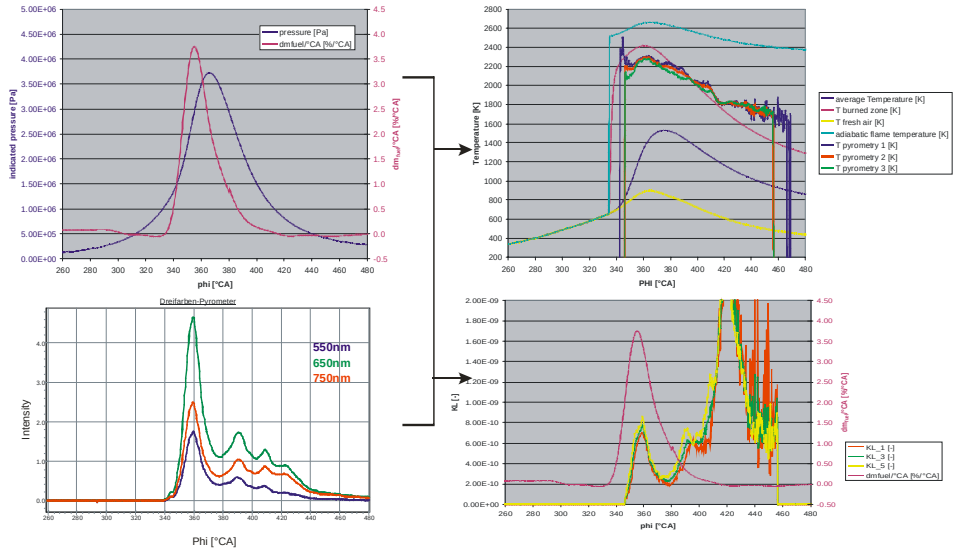
Measurement and evaluation of a single cycle (#4)



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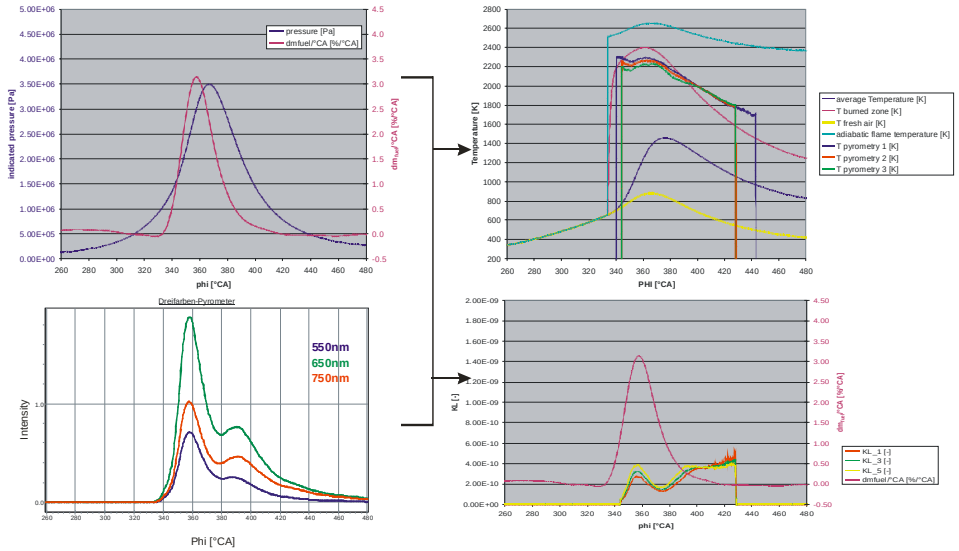
Measurement and evaluation the average of 72 cycles



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Summary

- soot measurements have been performed within the combustion chamber of a direct injected gasoline engine
- with a quasi 2-zone model the approximate temperature of unburned gas and burned gas could be deduced
- temperature was determined for 3 different pairs of signals; the differrence between them is less then 50K
- same has been done for the soot concentration (KL-factor)
- The cycle-by-cycle evaluation of the GDI engine shows strong variations which was expected

System has a high potential

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