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ICOS-Temperature

for time-resolved in-cylinder temperature and water concentration analysis

The **Internal Combustion Optical Sensor** (**ICOS-Temperature**) system from LaVision allows analysis of time-resolved in-cylinder temperatures and water concentrations in an internal combustion engine. The minimally invasive sensor is available with a choice of in-cylinder probes. The system delivers crank angle resolved single cycle and cycle averaged temperature and water concentration curves over many consecutive cycles.

Applications

- gas temperature and water concentration indication during mixture formation
- EGR influence on charge temperature
- charge cooling using water injection
- supercharging, downsizing, HCCI
- simulation validation

Advantages of the Internal Combustion Optical Sensor system

- highly time resolved for crank angle resolution
- no gas sampling, measures directly inside the cylinder
- precise single cycle analysis
- fully resolved consecutive cycles for measurement on transient phenomena
- choice of non-invasive and minimally invasive probes

Operating principle

The measurement system is based on the interaction of light with water molecules: infrared light is absorbed within a certain wavelength range by the presence of water molecules. A light source generates a fast flashing burst of infrared light. A built-in spectrometer derives temperature and water concentration information from a spectral fingerprint in the light returning from the probe after passing through the measurement section. The **ICOS-Temperature** system is contactless and no gas sample extraction is needed. Data are measured without time delay and temporal smearing.

The **ICOS-Temperature** system from LaVision measures at data rates of up to 23 kHz and is crank angle synchronized during engine operation. It can be used to analyze either motored or fired engine cycles in both stationary and dynamic operating conditions. The **ICOS** design is insensitive to contamination of optics and allows long operation periods.

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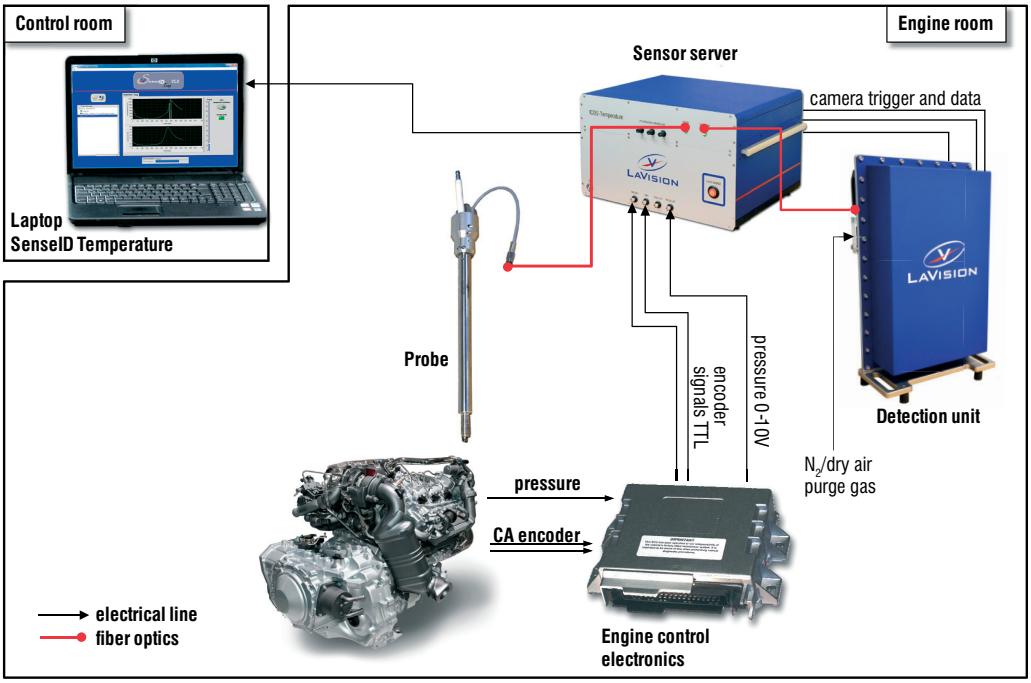
Basic layout

The system consist of:

- sensor server including light source
- detection unit
- laptop remote control unit
- pair of optical fibers
- **ICOS-Temperature** probe (e.g. line-of-sight, spark plug, M5)
- sensor software SenseID Temp



The **ICOS-Temperature** engine probe and the detection unit are each connected to the sensor server by a single optical fibre. The light source inside the sensor server produces infrared light pulses which are transmitted through the optical probe and to the detection unit. A part of the light pulse goes directly to the detection unit and is used as a reference signal without absorption. The light transmitted to the probe is passes through the measurement section and then returns back to the sensor server. Absorption from water molecules present in the measurement path leaves its temperature dependent spectral fingerprint in the light pulse. After returning from the probe this light pulse is routed to the detection unit for spectral analysis.

All data recording, synchronization and basic processing are performed by the sensor servers' internal micro PC. This is connected via TCP/IP to the laptop remote control unit in the engine's control room, from where the complete system is safely controlled.

The **ICOS-Temperature** system has a choice of dedicated probes. Please refer to the "**ICOS Probes**" datasheet for more information.

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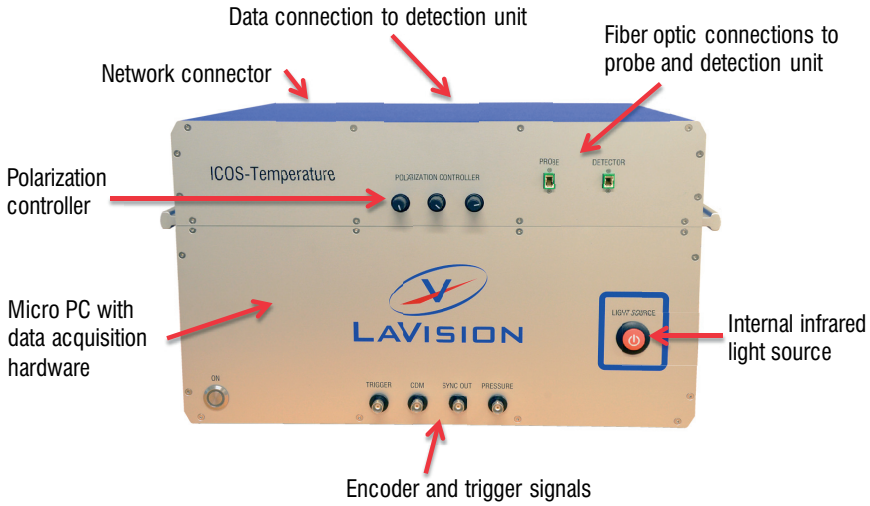
Sensor server

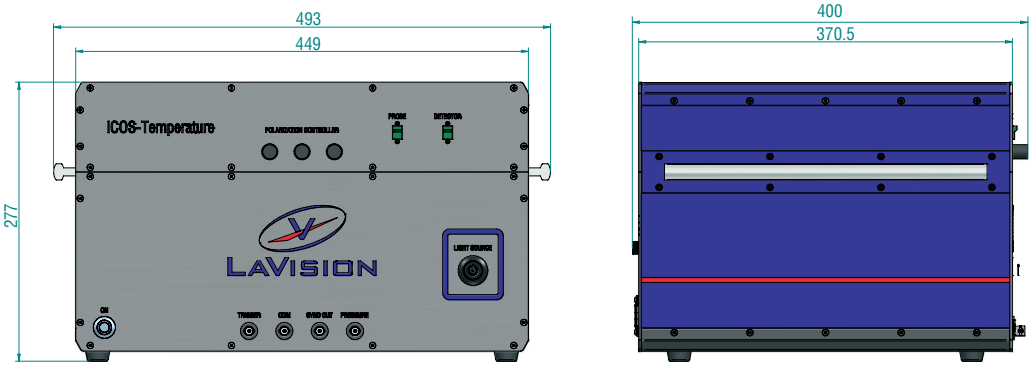
The sensor server is the central unit for data acquisition and trigger control of the engine's encoder signals and other external systems (e.g. test bed or camera systems) in the complete measurement system. It contains the infrared light source, fiber optic and electrical components for data recording and synchronization with the engine.



External input signals

For engine synchronization external signals are required. These signals are generally available on all engine test beds:

Trigger	TTL level triggers via BNC connection once per cycle or once per revolution
Crank angle division marker	TTL level triggers via BNC connection for common crank angle divisions (typically 1-10 trigger per crank angle)
Pressure	pressure signal from charge amplifier via BNC connection (0-10V)



Dimensions (W x H x L)	493 mm x 277 mm x 400 mm (including connectors)
Weight	20.5 kg

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Specifications

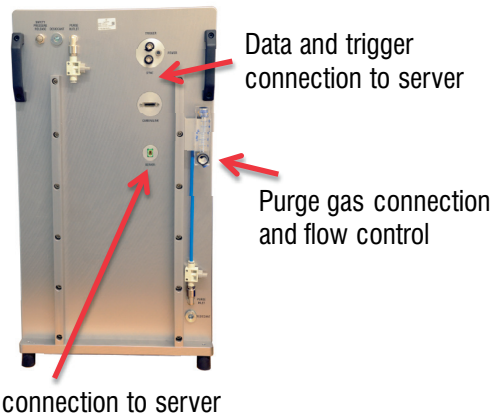
Measuring principle	IR absorption of water molecules
Indicated quantities	gas temperature, water vapor mole fraction
Measurement error (temperature)	<20 K @ 3 vol% H_2O (T=273 K-900 K; P ≤ 30 bar)
Measurement error (mole fraction)	<0.2 vol% @ ≥1.0 vol% (T=273 K-900 K; P ≤ 30 bar)
Acquisition rate	23 kHz
Response time	43.5 µs
Data acquisition	crank angle resolved multiple cycles
Light source central wavelength	1310 nm
Light source classification	CLASS 1 LASER PRODUCT (IEC/EN60825-1:2014)

IEC/EN60825-1:2014

Power requirements	100 – 230 VAC 50 – 60 Hz Max. 2 A Fuse 4 A slow

Detection unit

The detection unit consists of an infrared spectrograph and high-speed line camera mounted in a sealed enclosure. The camera records infrared absorption spectra with and without water absorption in the measurement path. The spectral data is recorded and processed on the server.



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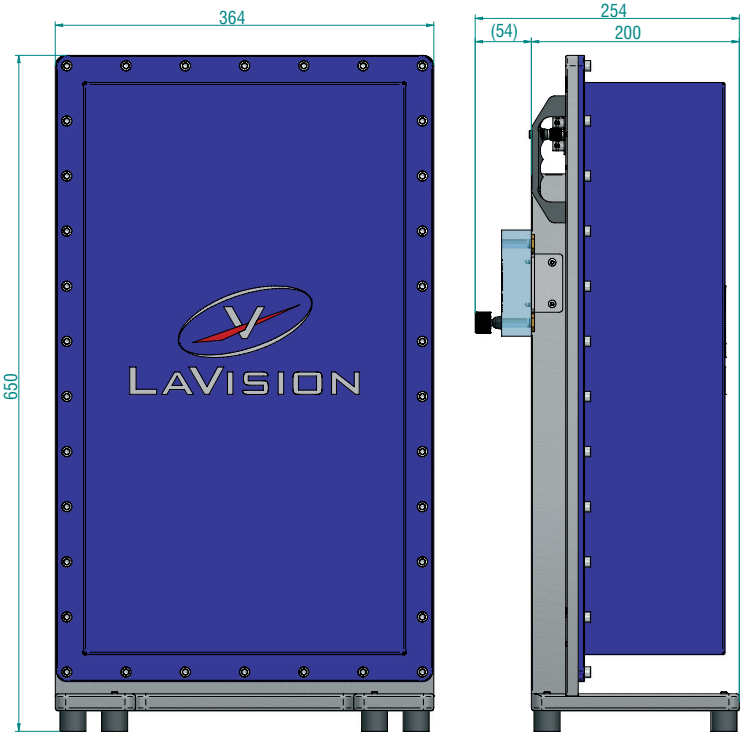
Purge supply

The detection unit requires purging with dry inert gas to avoid water vapor absorption in the detection unit itself. The level of purging depends on the ambient humidity levels. Following purging conditions are recommended:

Purge gas	nitrogen or dry air
Flow rate	1 Nlpm
Connection	push-fit for 6 mm (outer diameter) tubing

Dimensions



Dimensions (W x H x L)	364 mm x 650 mm x 254 mm (including connectors)
Weight	26.3 kg

Specifications

Sensor format	1024 pixels
Acquisition rate	23 kHz (corresponding reference and absorption spectra recorded at 46 kHz)
Digital output	14 bit
Power requirements	100 – 230 VAC
(AC adapter supplied)	50 – 60 Hz
	< 1.0 A

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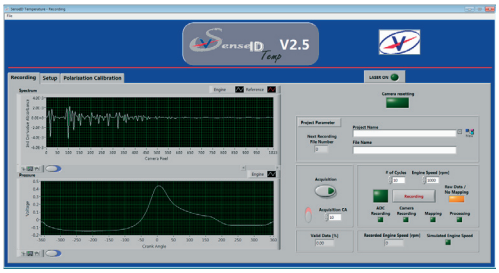
Remote control laptop

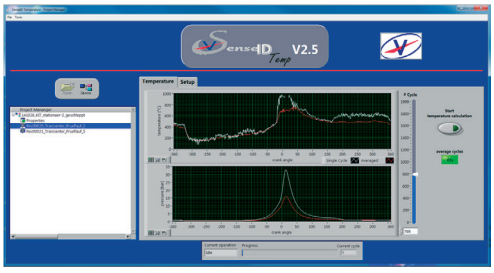
The laptop remote control unit enables the operation of the **ICOS-Temperature** system remotely. It is pre-configured to connect to the sensor server via LAN cable connection (20 meter cable supplied). The laptop has all necessary software pre-installed.

SenseID Temp

The SenseID Temp software consists of 2 modules: recording module and processing module.

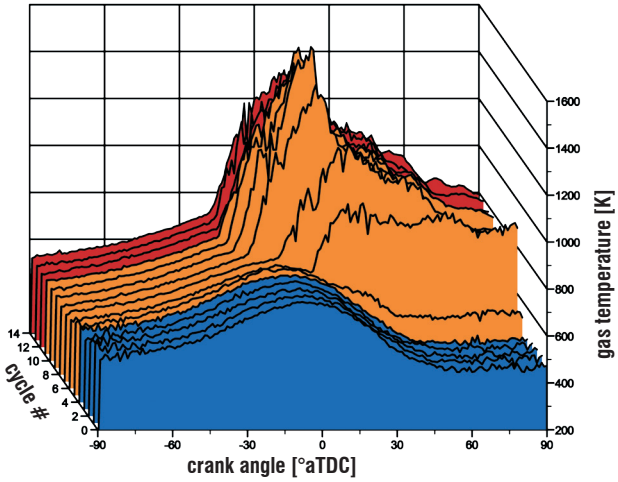
The recording module is installed on the sensor server. It is remotely accessed from the remote control laptop. It is used to record spectral data, engine encoder and pressure signals. All recorded data is synchronized to engine crank angle. Recordings can be made over multiple consecutive cycles. There is a live display to monitor signal strength. An online monitor to increase measurement accuracy by optimizing the light polarization is also included.





The processing module is pre-installed on the remote control unit. It has a project manager to select recordings form the recording module. Using engine parameters and the cylinder pressure information the software calculates gas temperature and water mole fraction. The results are automatically mapped to each engine crank angle. For each recording the software calculates results for individual cycles or averaged over all cycles in a recording. There are options to calculate results over user specified crank angle and cycle ranges. The processed data are viewed in SenseID or DaVis and can be exported to ascii file format.

Temperature



In cylinder temperature traces near TDC during transient tip-in engine operation

The system measures the spectrally resolved absorption of water molecules in the near infrared. The water absorption spectrum, which changes with temperature, pressure and concentration, is compared to a spectral database. The water vapour temperature in the measurement path is determined by a best fit matching algorithm.

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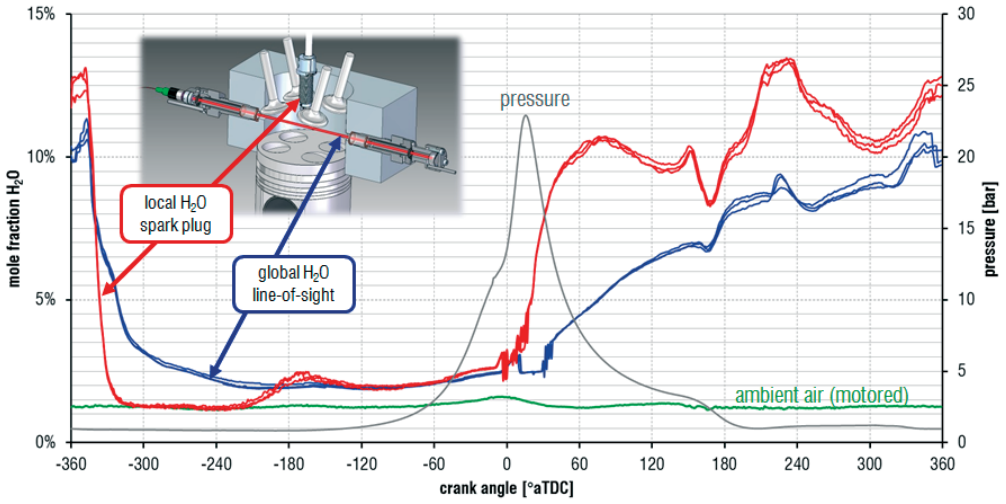
Water concentration

Simultaneously to the temperature the absolute strength of the absorption is used to determine the water vapor mole fraction in the measurement volume. This provides a measure for the water concentration.



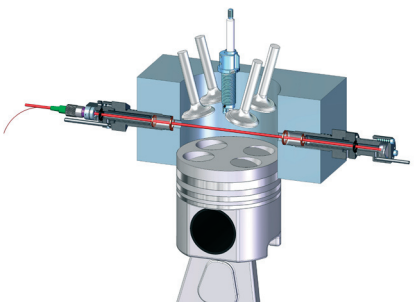
Comparison of local (at spark plug) and cylinder averaged water concentration during fired engine operation. Also shown is water concentration for motored cycle and indicated pressure

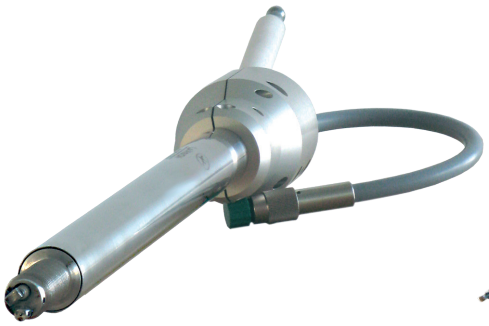
Engine access

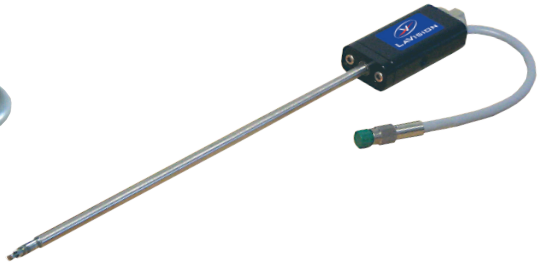
The **ICOS-Temperature** system has three different options of optical access:

Probe	Advantages
Line-of-sight probe	Suitable for any engine condition, especially high loads, measures the integral average across the cylinder. Recommended choice for temperature measurements.
Spark plug probe	Very convenient access to any production type engine by replacing the spark plug by the M12 or M14-probe, while maintaining full ignition capability. Measures locally at the spark plug.
M5 probe	Minimally invasive probe fits into standard M5 pressure transducer bores. Measures locally at the cylinder wall.

Please refer to our "**ICOS Probes**" datasheet for more details.







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Operating and measurement range

The safe operating range is defined by the probe being used (see also engine access above). The measurement range is restricted to the validated range (see specifications). The measurement precision within this range is largely determined by the signal-to-noise ratio of the absorption spectrum. The absorption strength is proportional to the number of water molecules in the measurement path. This is directly proportional to following factors:

- water vapor concentration
- pressure
- measurement path length

Measurement range limits are reached for low signal-to-noise ratios, which are determined by the above factors. Measurements under unfavorable conditions, e.g. motored operation with low relative humidity intake air, when using the spark plug probe (short absorption path length = 12 mm) are often limited to higher pressure parts of the engine cycle. The water density at intake pressure may be below the detection limit but will rise above the detection limit during the compression stroke. Line-of-sight probe measurements inherently have much longer measurement paths (typically absorption path length = 2x engine bore) and do not suffer from such signal-to-noise limitations.

Ordering information

Part number	Description
1106072	ICOS-Temperature sensor server including light source
1106074	ICOS-Temperature detection unit
1104205	Laptop remote control unit
1105180	SenseID Temp software package
1106075	Set of optical fibers
Probes	
1106082	Line-of-sight probe for ICOS-Temperature (needs sealing insert 1106083)
1106083	Standard sealing insert (M14)
1106070	ICOS-Temperature M12 spark plug probe
1106071	ICOS-Temperature M14 spark plug probe
1106073	ICOS-Temperature M5 sensor probe
Accessories	
1106067	Set of mirrors (5 units) for spark plug probe
1106068	Set of mirrors (5 units) for M5 probe
1106046	Adapter set M5 to M10
1106047	Adapter set M5 to M12
1106085	M12 to M14 adapter with tool

Nov-17

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