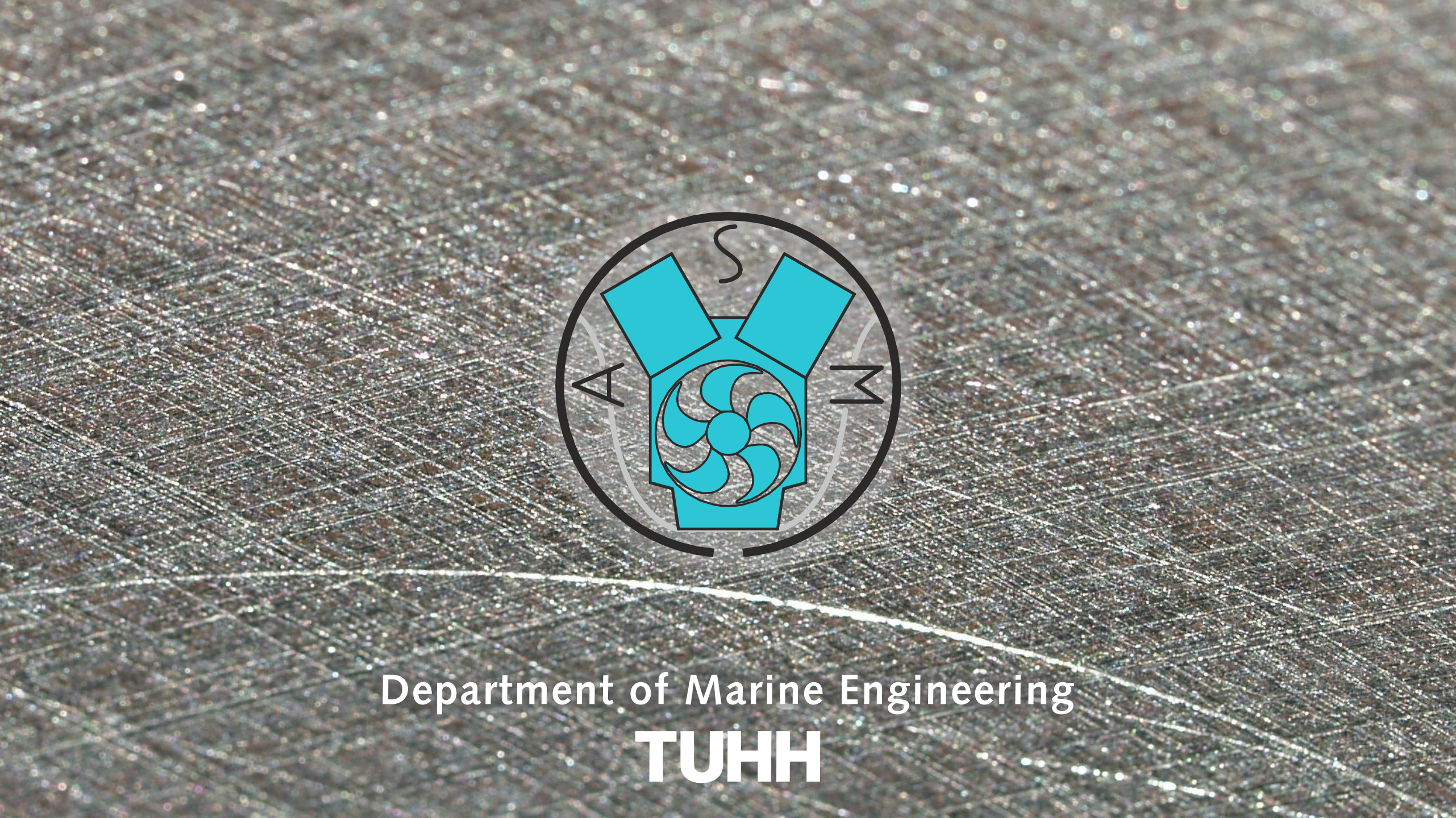

Department of Marine Engineering
TUHH

LED-INDUCED-FLUORESCENCE MEASUREMENTS AT AN LNG DUAL-FUEL MARINE ENGINE TEST BED

12th Dessau Gas Engine Conference

Dessau-Rosslau | May 06 2022

Baptiste Hochfellner

TUHH

- The test bed
- The measurement technology
- Findings from the measurement results

Marine Engine Test Bed at Hamburg University of Technology.

Nominal (gas mode)	Unit	Value
Engine speed	rpm	750
Mean piston speed	m/s	10
Power	kW	372
Break mean effective pressure	bar	18.5
Torque	kNm	4.7
Charge air pressure	bar	4.2

Nominal operational parameters.

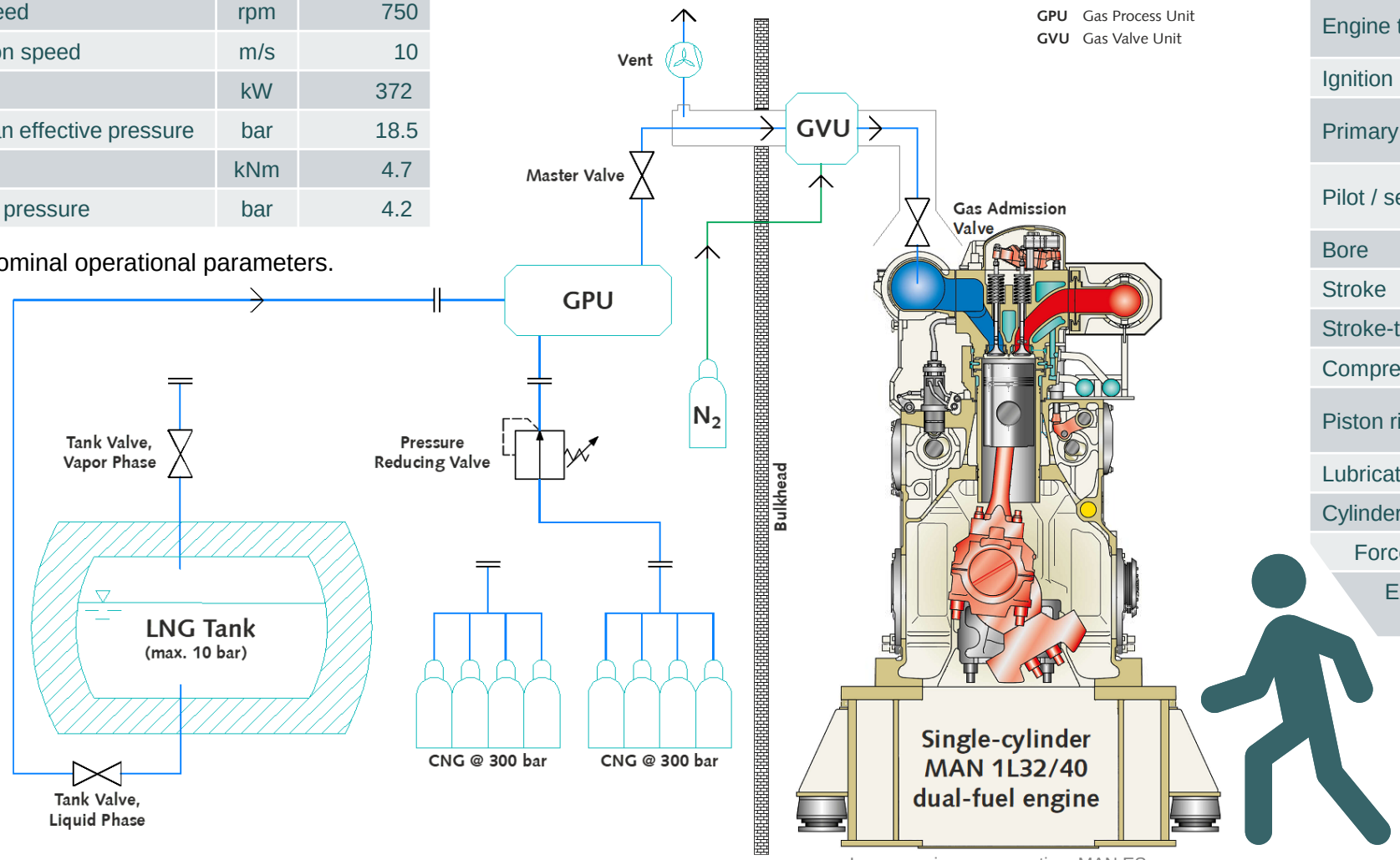
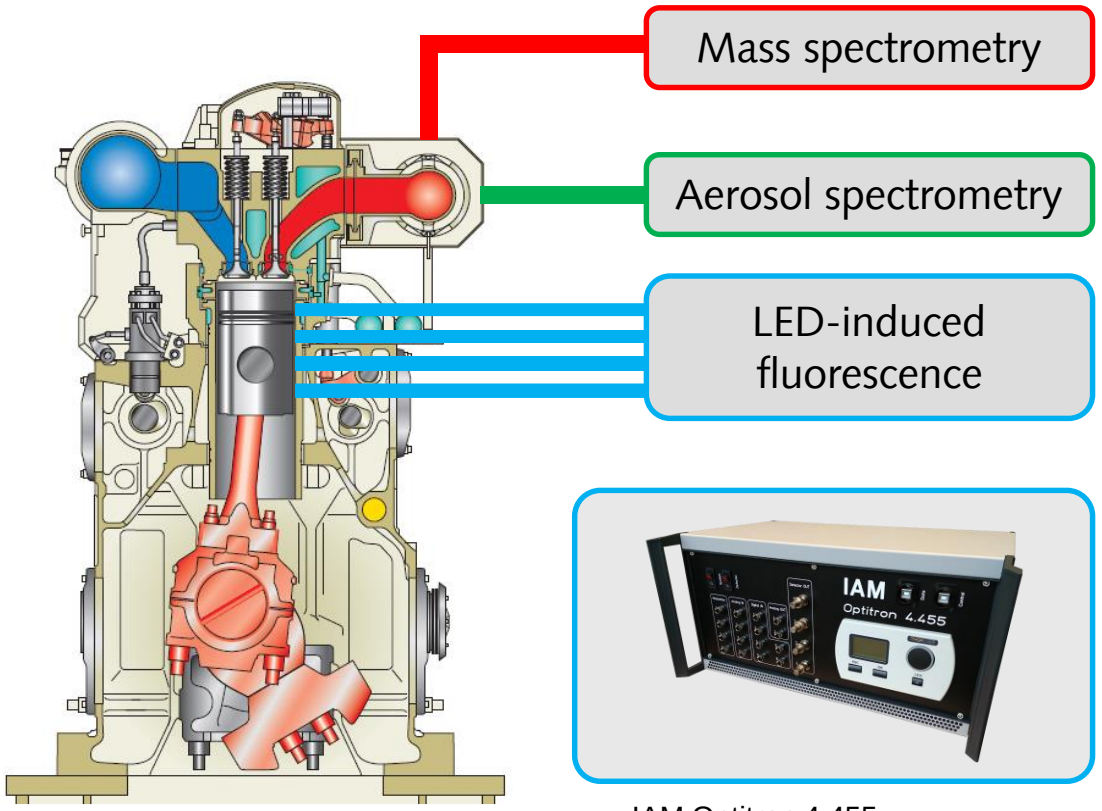


Image engine cross section: MAN ES

Parameter	Value
Engine type	Medium-speed four-stroke dual-fuel, single cylinder
Ignition in gas mode	Self-ignition of pilot fuel
Primary fuel	Natural gas (LNG/CNG) intake manifold injection
Pilot / secondary fuel	EN590, MGO, MDO Common Rail at 1600 bar
Bore	320 mm
Stroke	400 mm
Stroke-to-bore ratio	1,25
Compression ratio	12
Piston ring layout	2x compression ring 1x oil control ring
Lubrication system	Dry sump lubrication
Cylinder lubrication	Oil supply via ducts in liner
Forced induction	Variable (compressor unit)
Exhaust back pressure	Variable (adjustable valves)

Engine parameters.

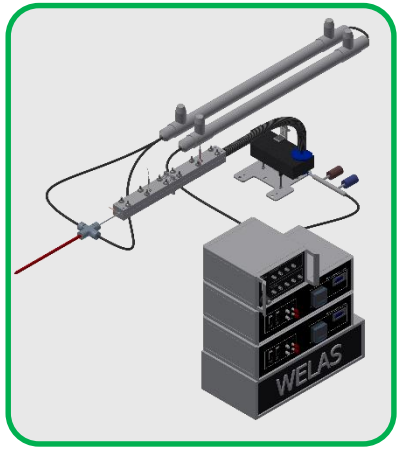
Measurement Systems from FVV-project Lubrication Large Bore Engines.



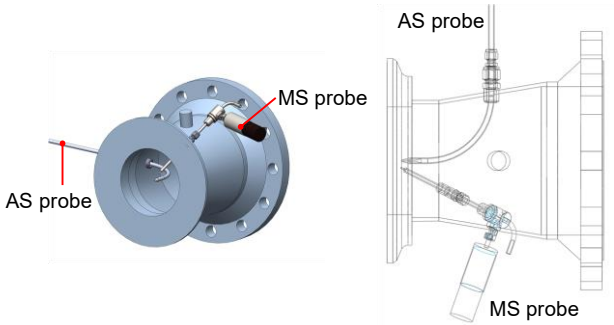
Engine cross section. MAN ES

IAM Optitron 4.455. Image: IAM eV

Lubrisense LUB360.
Image: Lubrisense GmbH



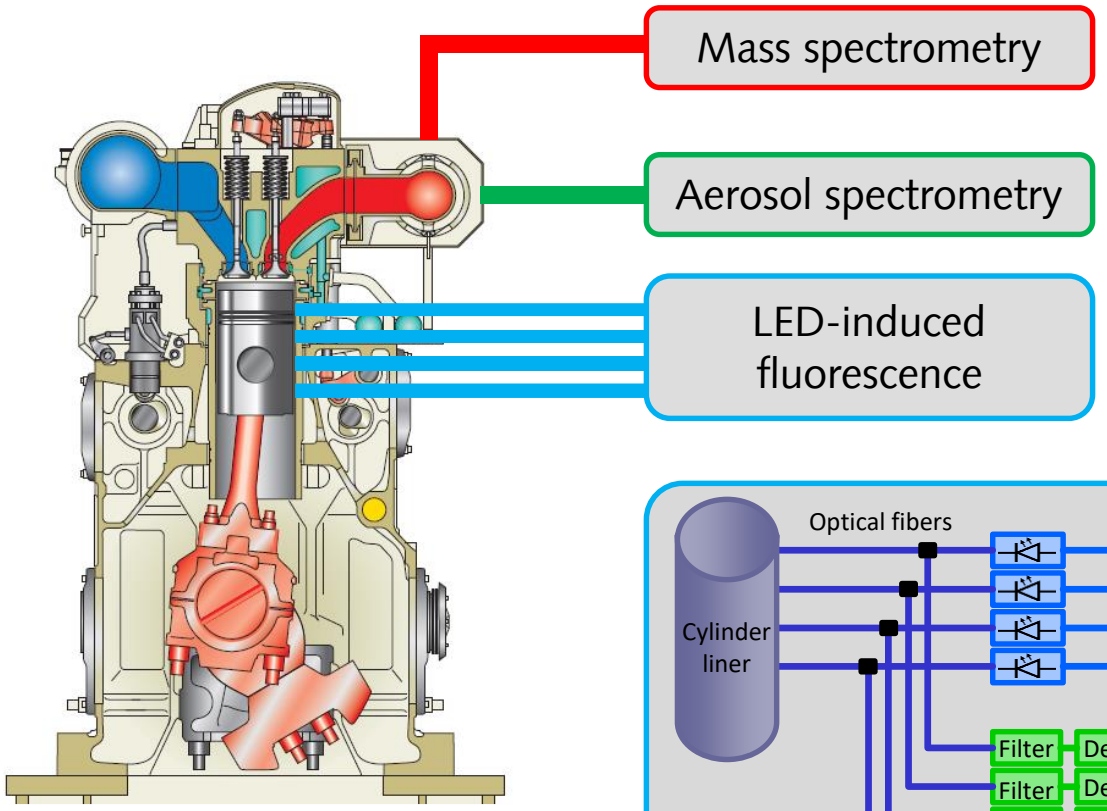
Palas Welas 2070H.
Image: IAM eV



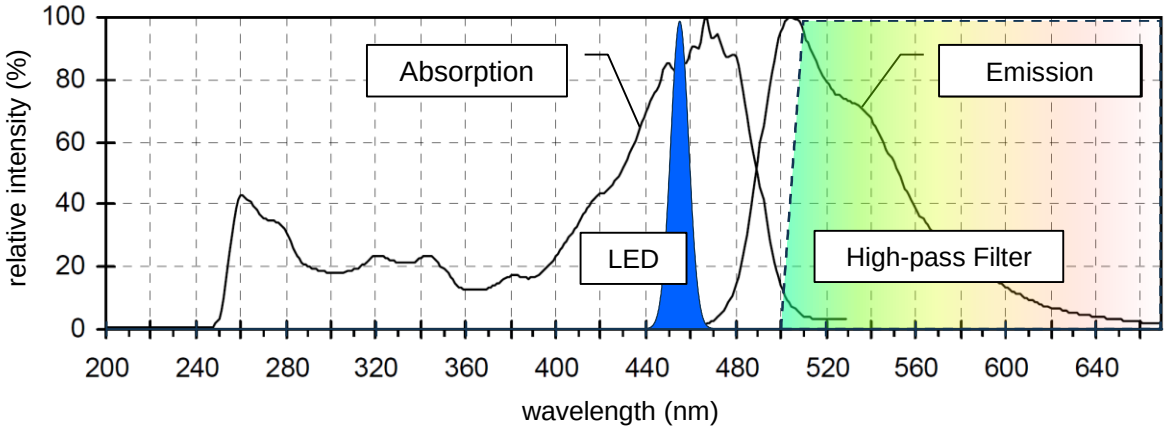
Emission measurements probe positions. Image: IAM eV

FVV
Research Association for Combustion Engines

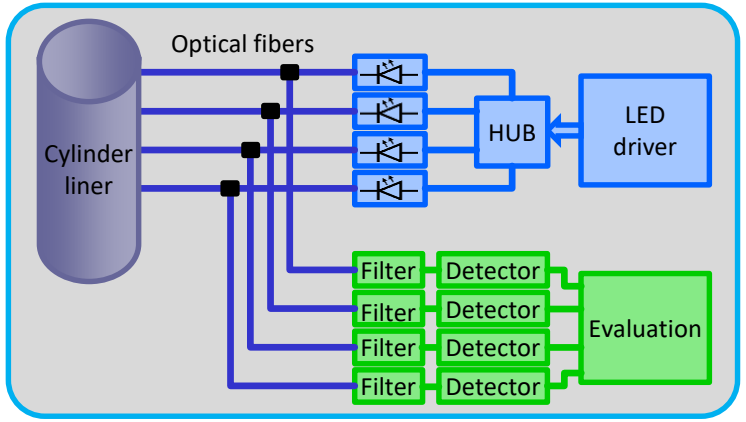
Using the Principle of Fluorescence to investigate the oil film.



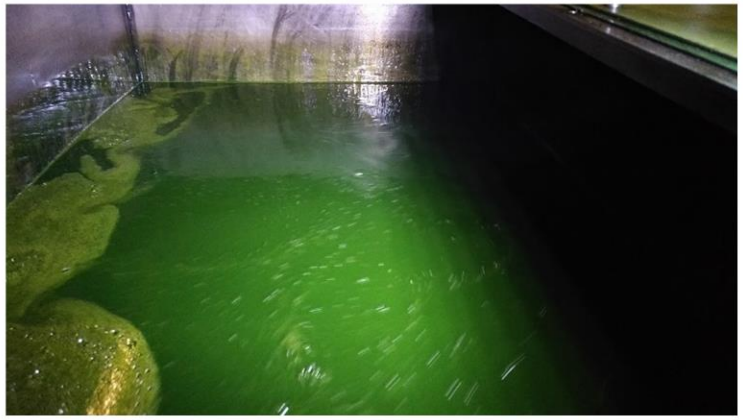
Engine cross section. MAN ES



Fluorescent properties of agent Lumilux by Honeywell. Adapted from Honeywell International Inc.

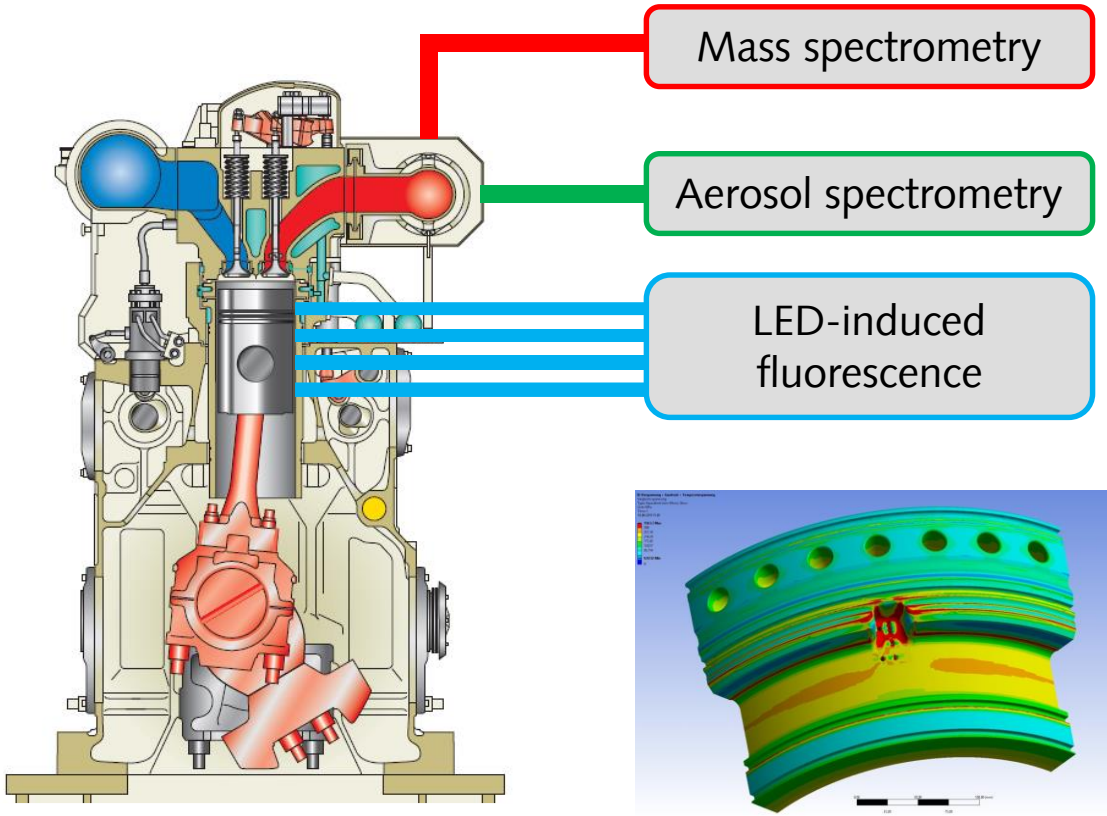


Oil film thickness measurement system.

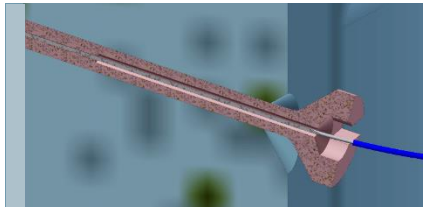


Engine oil mixed with fluorescent agent.

Application of measurement system in a newly designed cylinder liner.

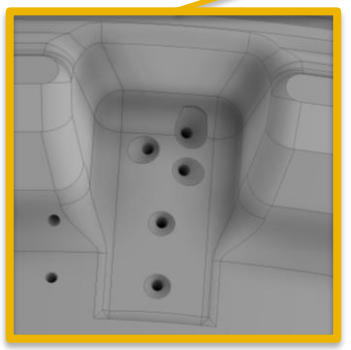


Engine cross section. MAN ES

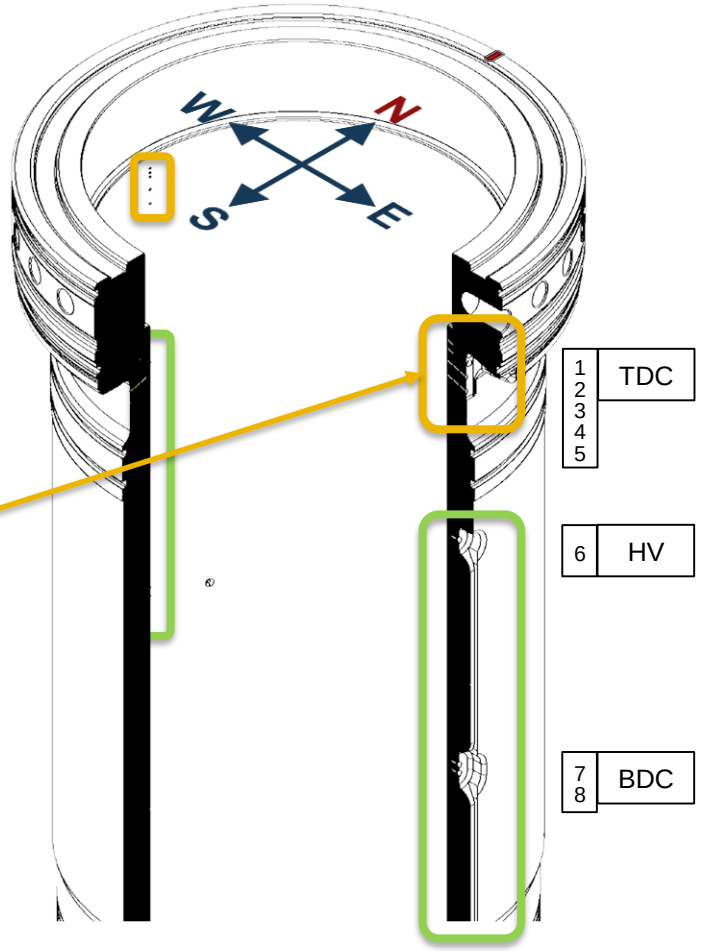


Application of optical fibres.

FE analysis of cylinder liner.



Cutouts in cylinder liner.



Cylinder liner adapted for measurements.

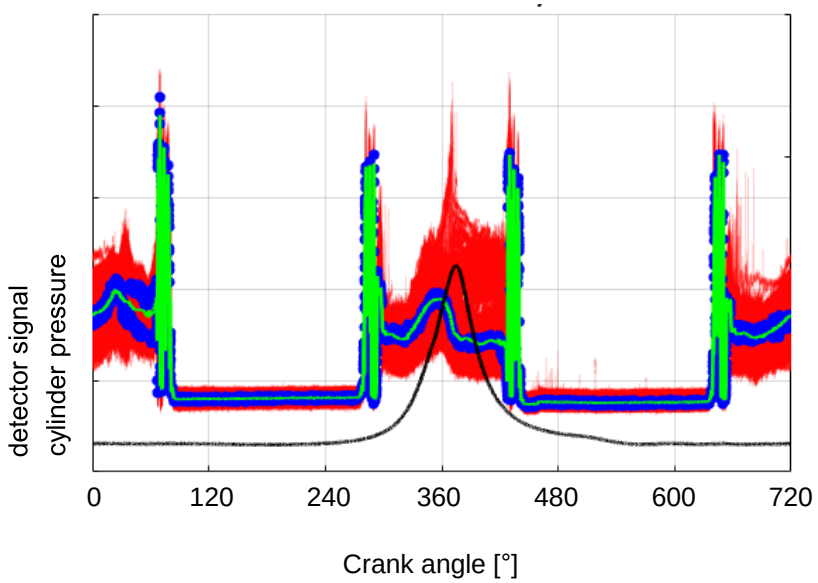
First assessment of retrieved data shows potential.

Speed	525	rpm
Load	1,72	kNm
Position	W6	(HV)
No. cycles	1626	

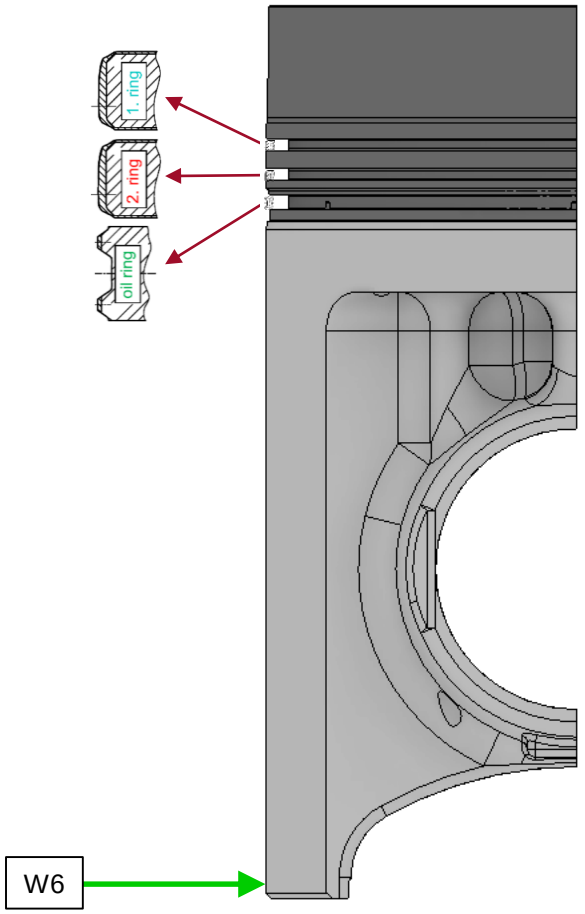
Raw signal

Arithmetic mean

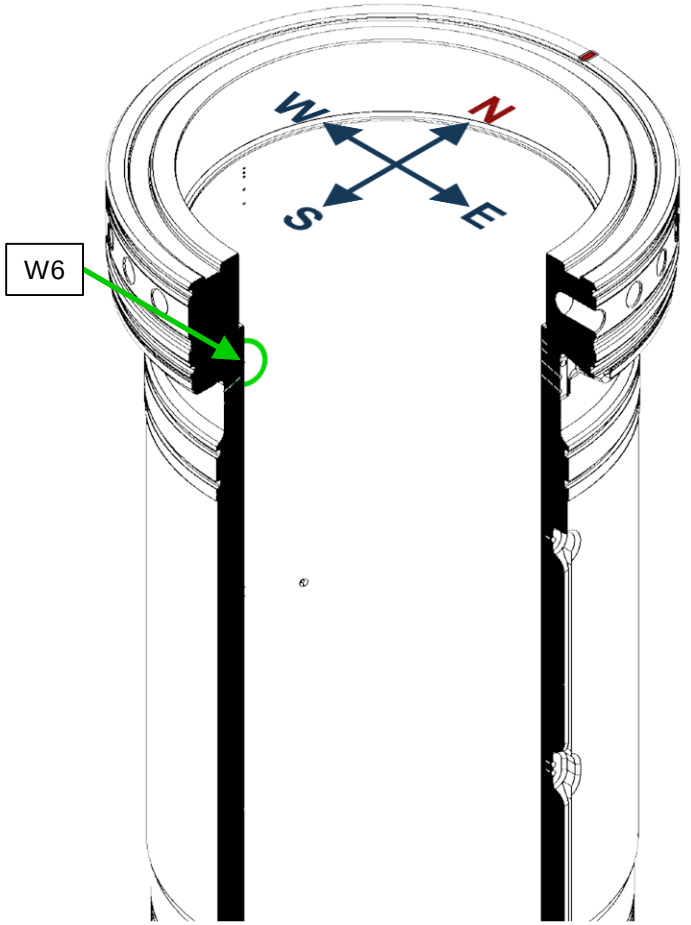
Statistically most frequent value



Detector signal over crank angle for full cycles of four-stroke engine. IAM eV



Piston and piston rings.

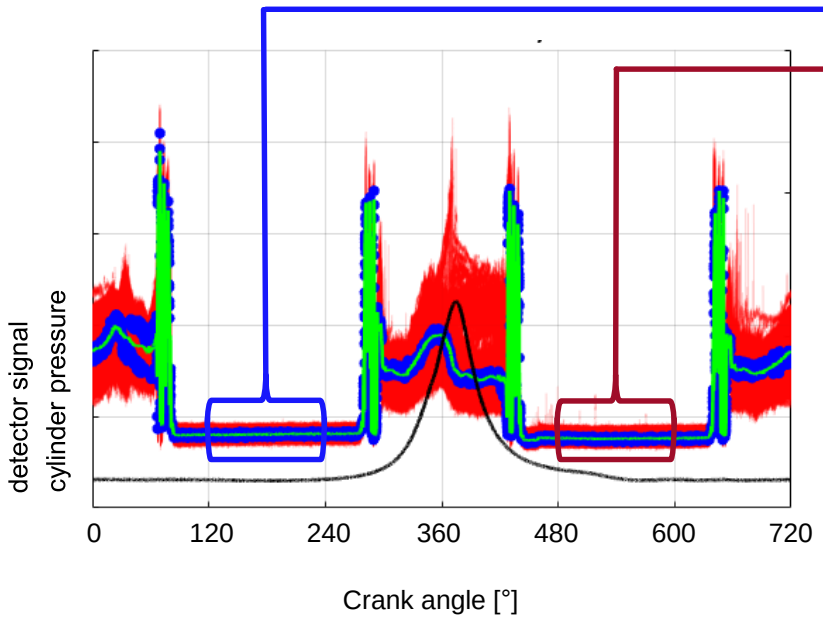


Cylinder liner adapted for measurements.

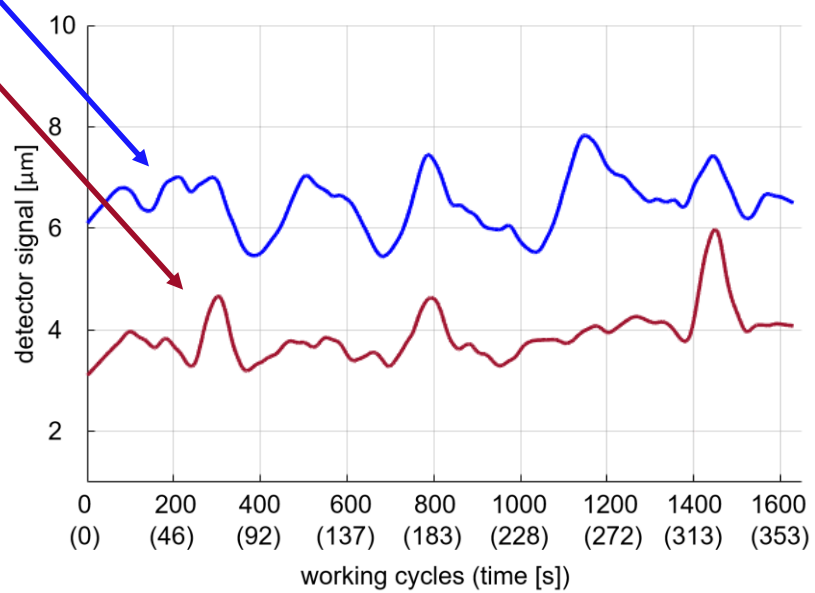
First assessment of retrieved data shows potential.

Speed	525	rpm
Load	1,72	kNm
Position	W6	(HV)
No. cycles	1626	

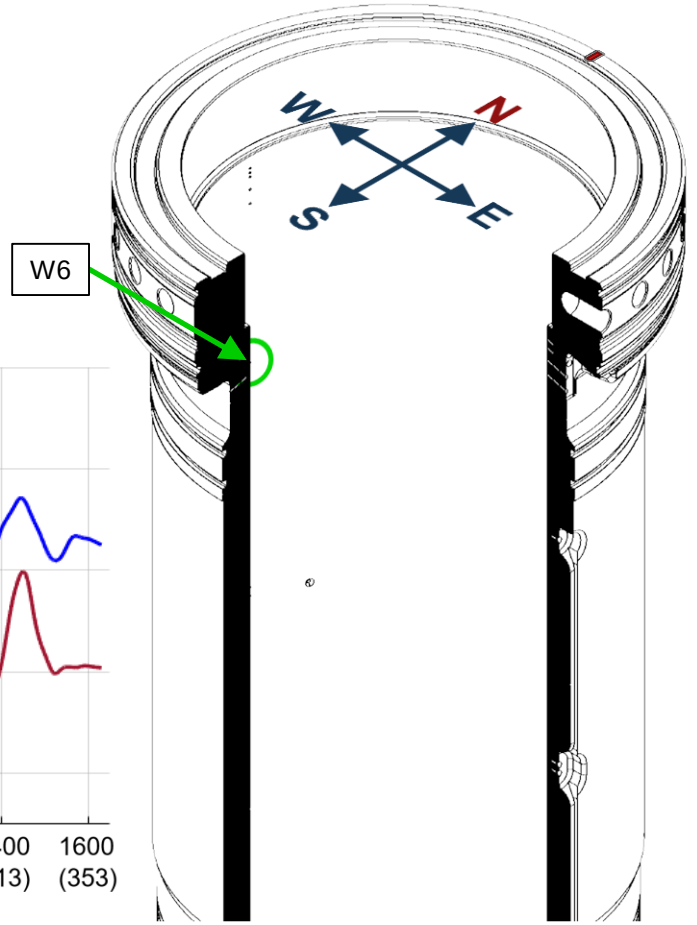
Raw signal
Arithmetic mean
Statistically most frequent value
Mean signal 120 – 240 °ca
Mean signal 480 – 600 °ca



Detector signal over crank angle for full cycles of four-stroke engine. IAM eV



Calibrated oil film thicknesses over number of working cycles and time. IAM eV



Cylinder liner adapted for measurements.

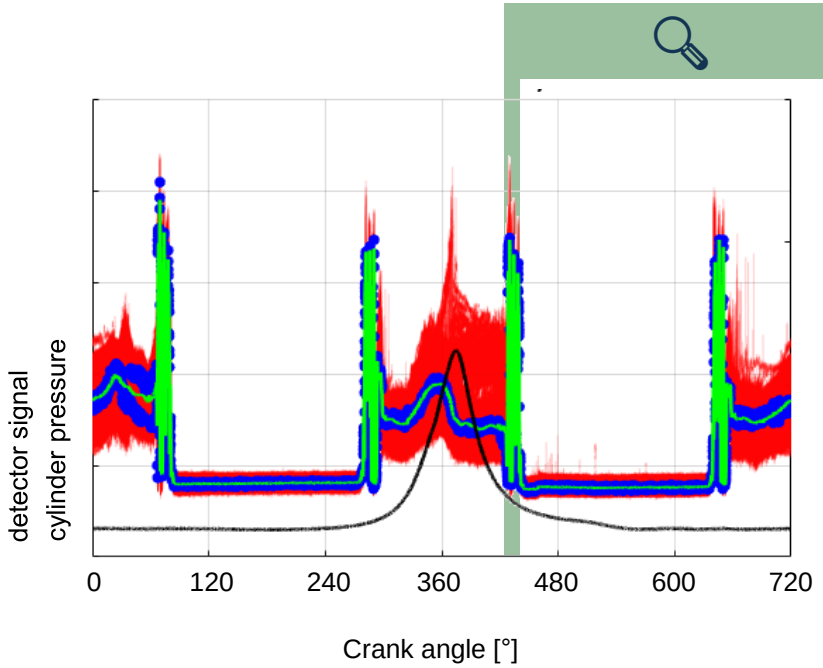
Identifying of components passing the measurement position.

Speed	525	rpm
Load	1,72	kNm
Position	W6	(HV)
No. cycles	1626	

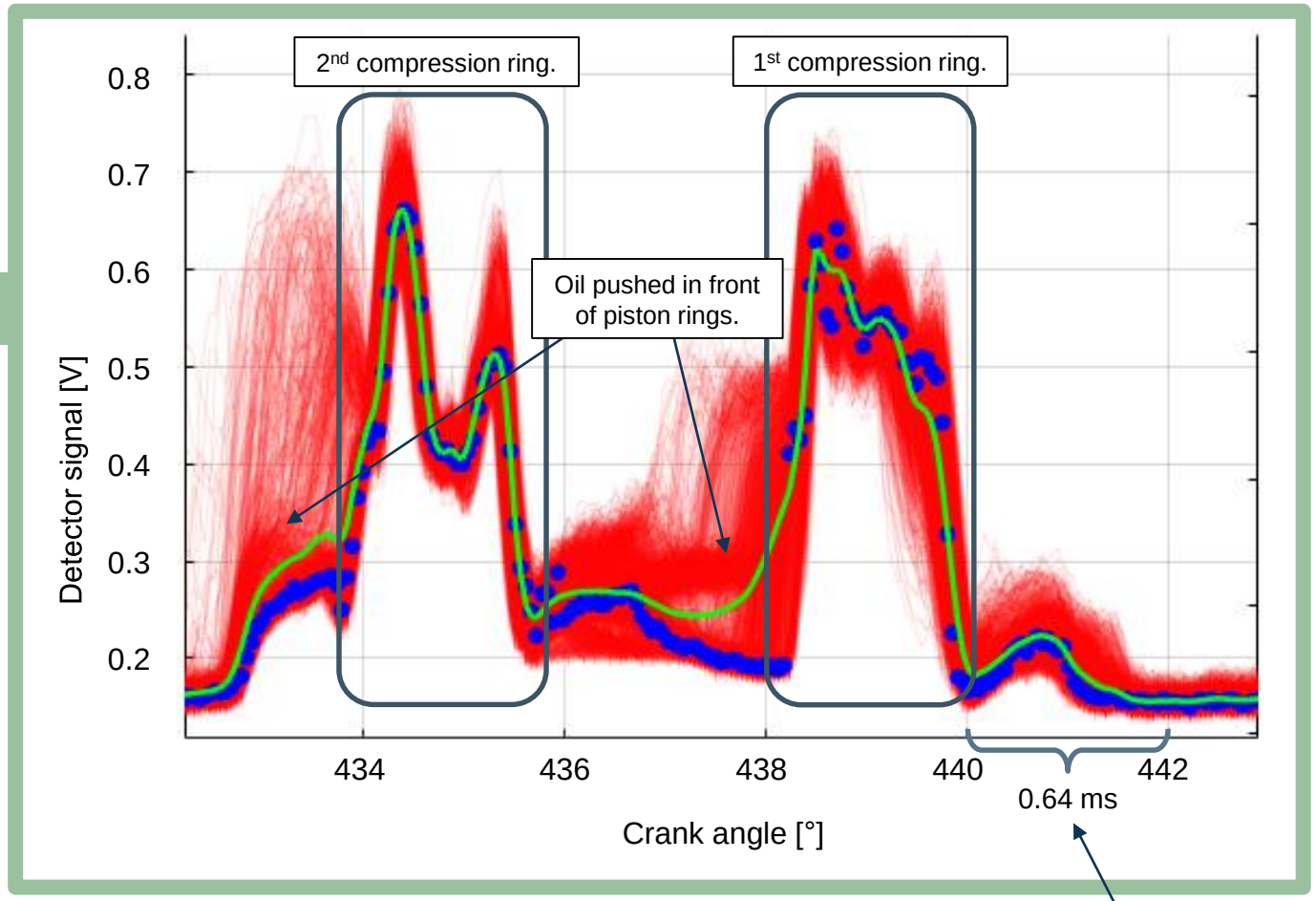
Raw signal

Arithmetic mean

Statistically most frequent value



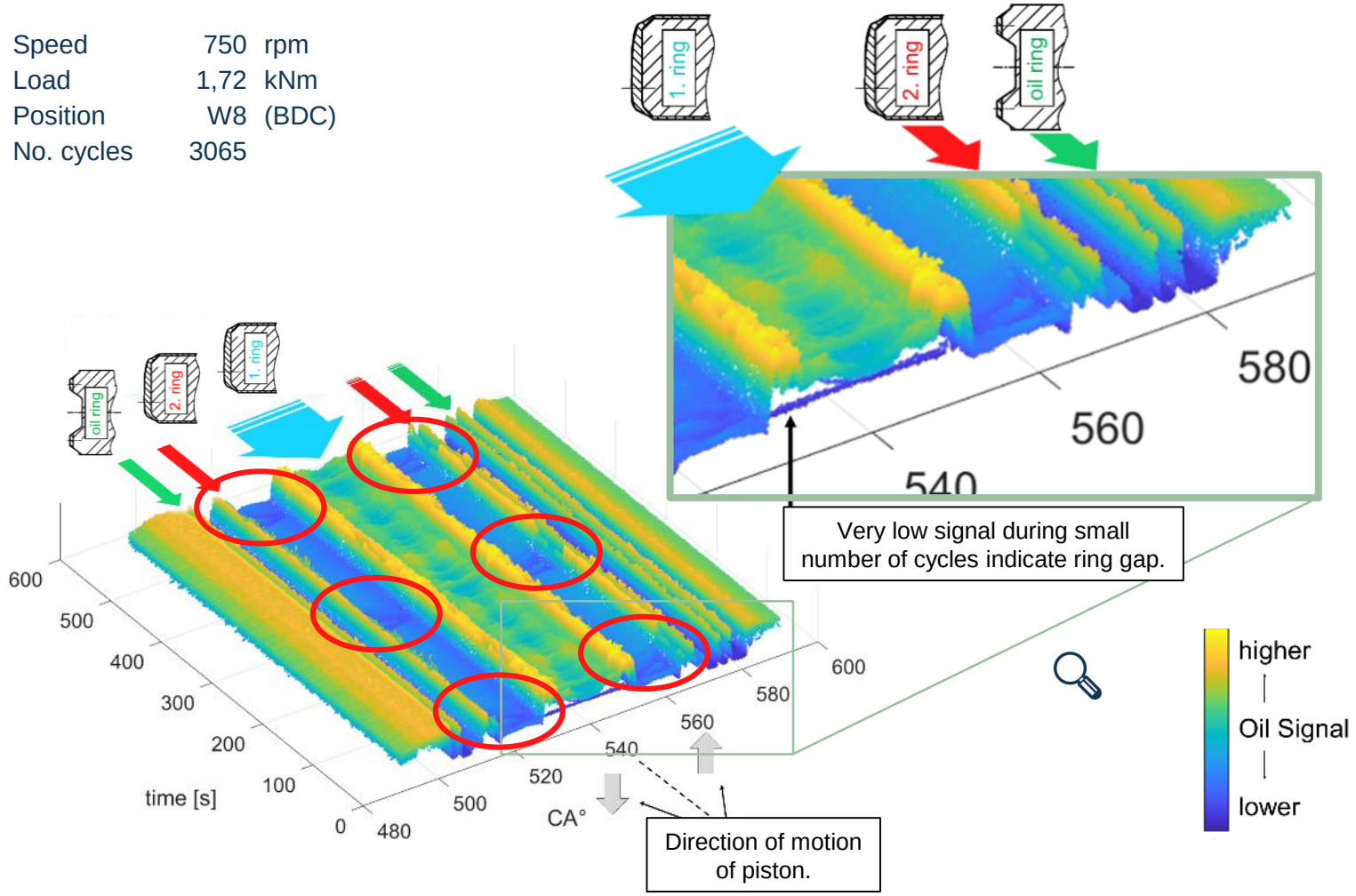
Detector signal over crank angle for full cycles of four-stroke engine. IAM eV



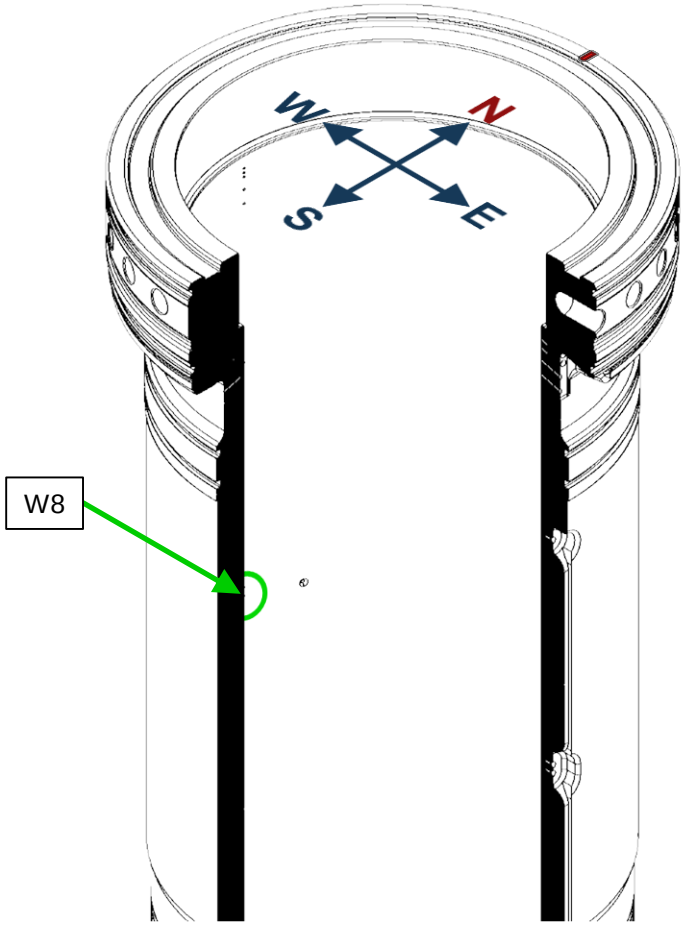
Detector signal over crank angle. IAM eV

Identification of piston ring gaps and influence on oil layer.

Speed	750	rpm
Load	1,72	kNm
Position	W8	(BDC)
No. cycles	3065	



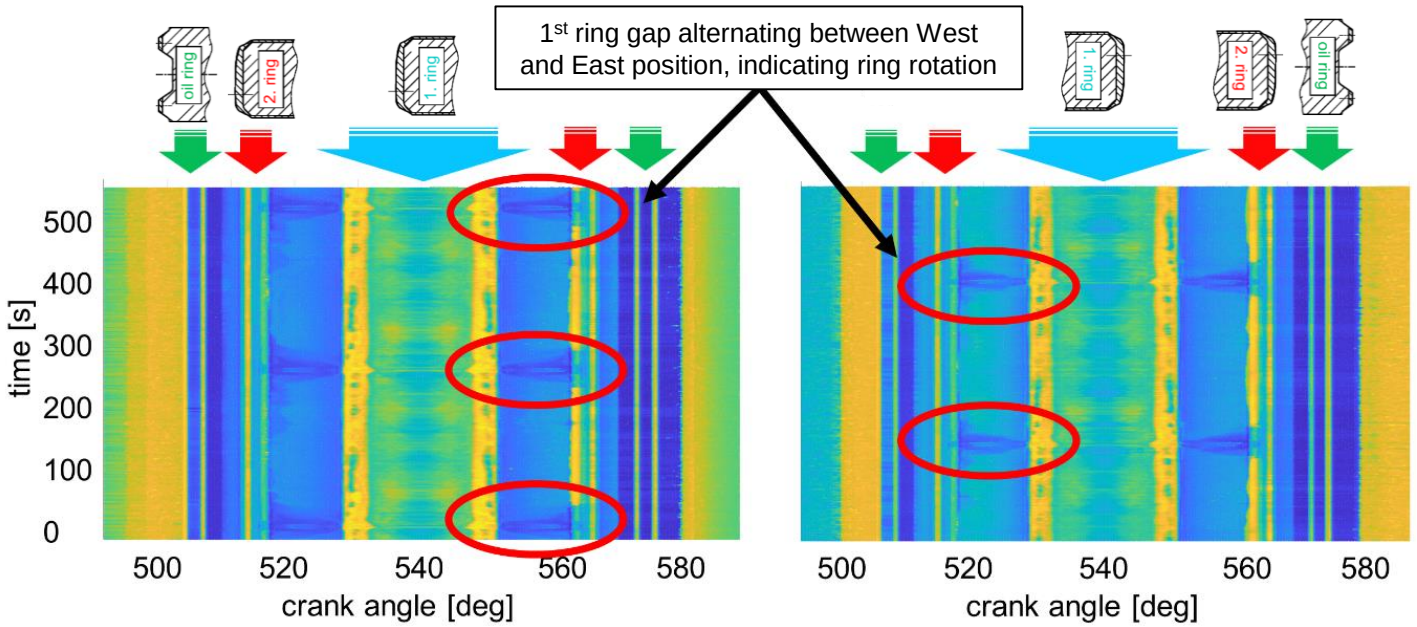
Raw signal of oil film measurements of lowest measurement position over crank angle, distributed over time. IAM eV



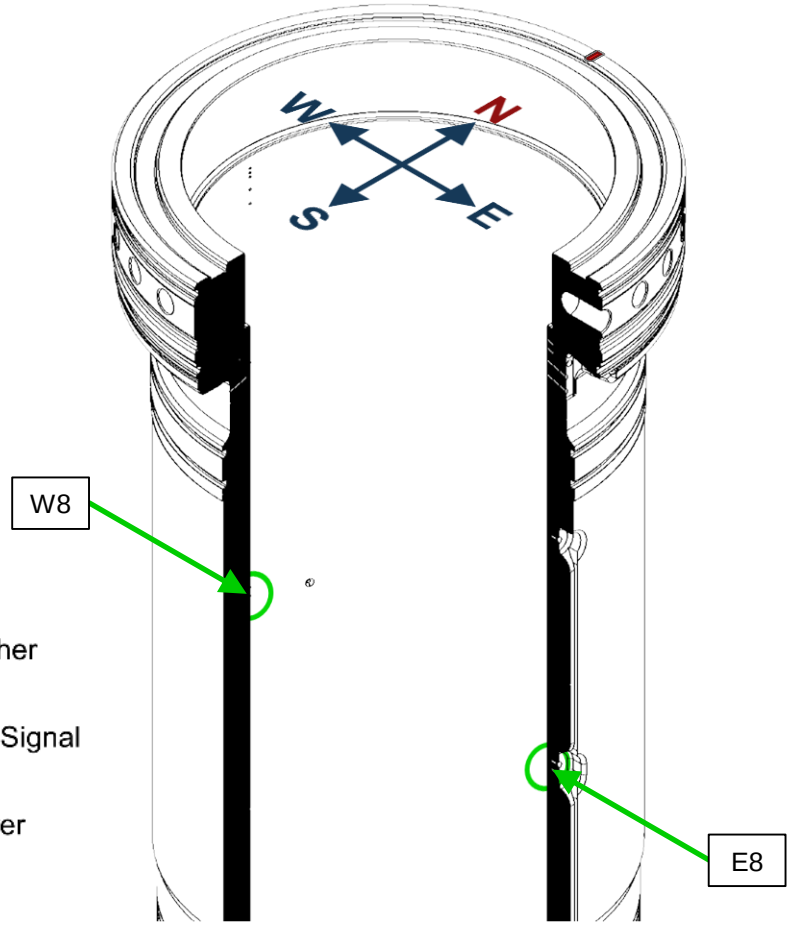
Cylinder liner adapted for measurements.

Determining ring rotation.

Speed	750	rpm
Load	1,72	kNm
Positions	W8+E8	(BDC)
No. cycles	3065	



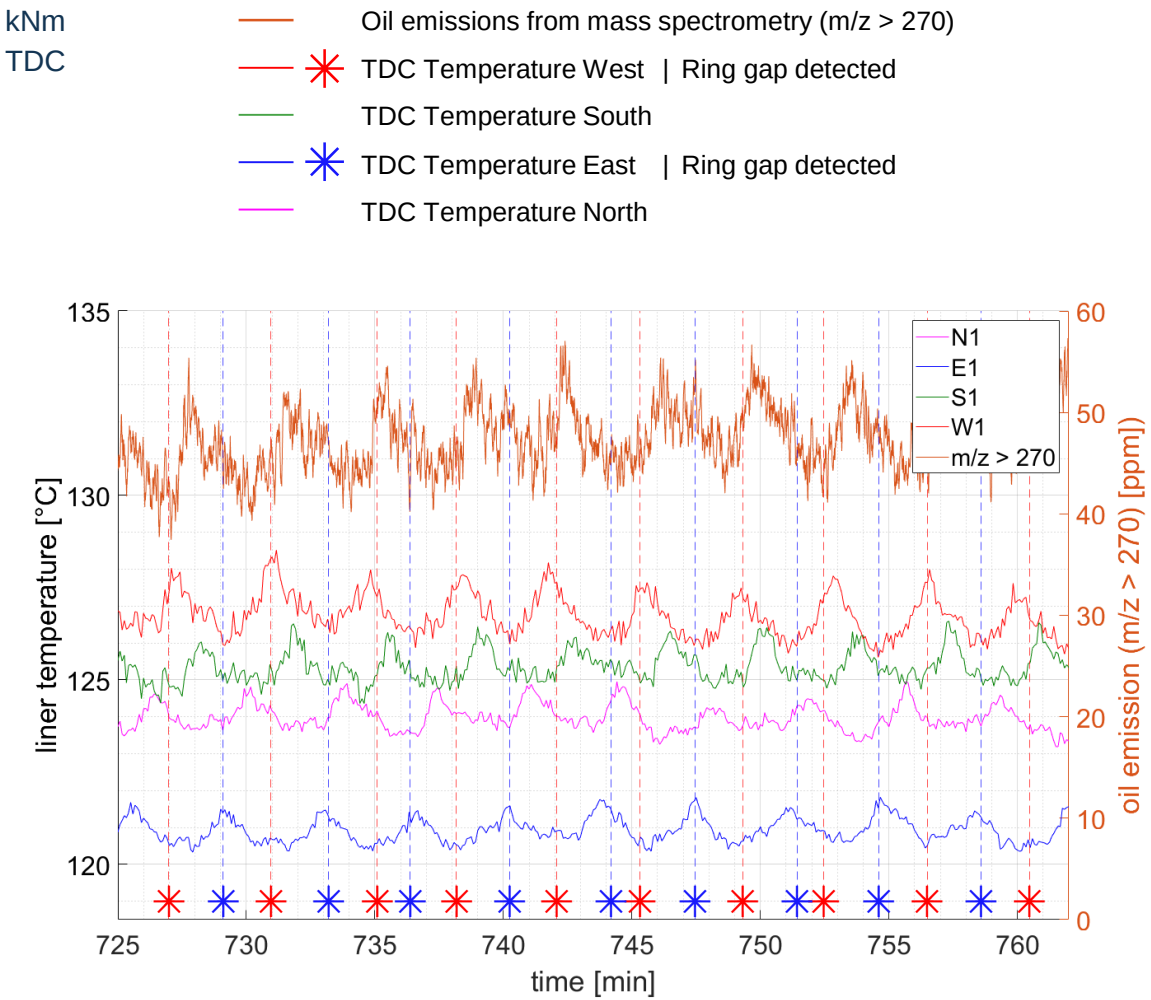
Raw signal of oil film measurements of lowest measurement position distributed over crank angle and time. Left: western (W) measurements. Right: eastern (E) measurements. IAM eV

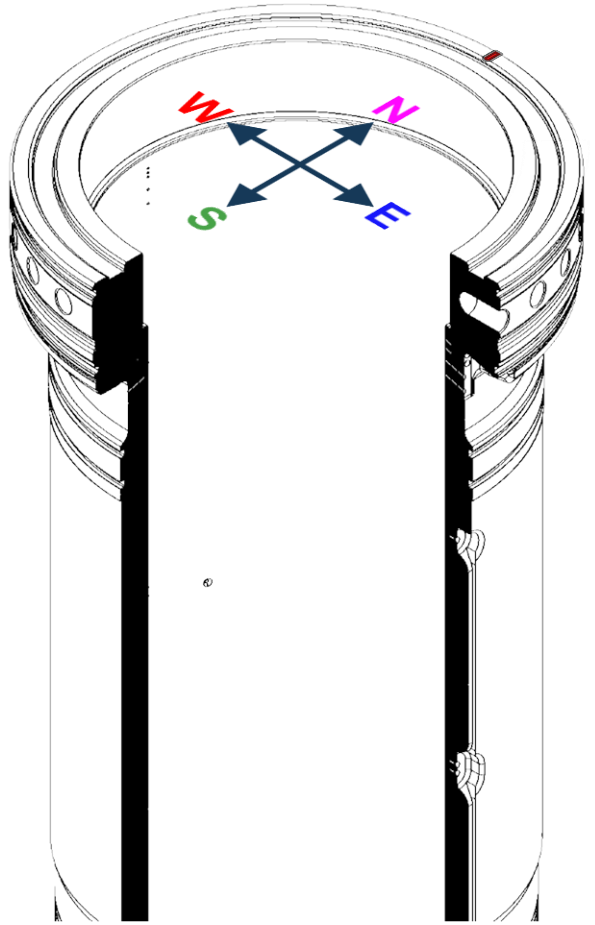


Cylinder liner adapted for measurements.

Combining of oil film thickness data with further data.

Speed	750	rpm
Load	1,72	kNm
Position	all at	TDC
No. cycles	13875	





Cylinder liner adapted for measurements.

Combining of oil film thickness data with further data.

Speed	750	rpm
Load	1,72	kNm
Position	all at	TDC
No. cycles	13875	

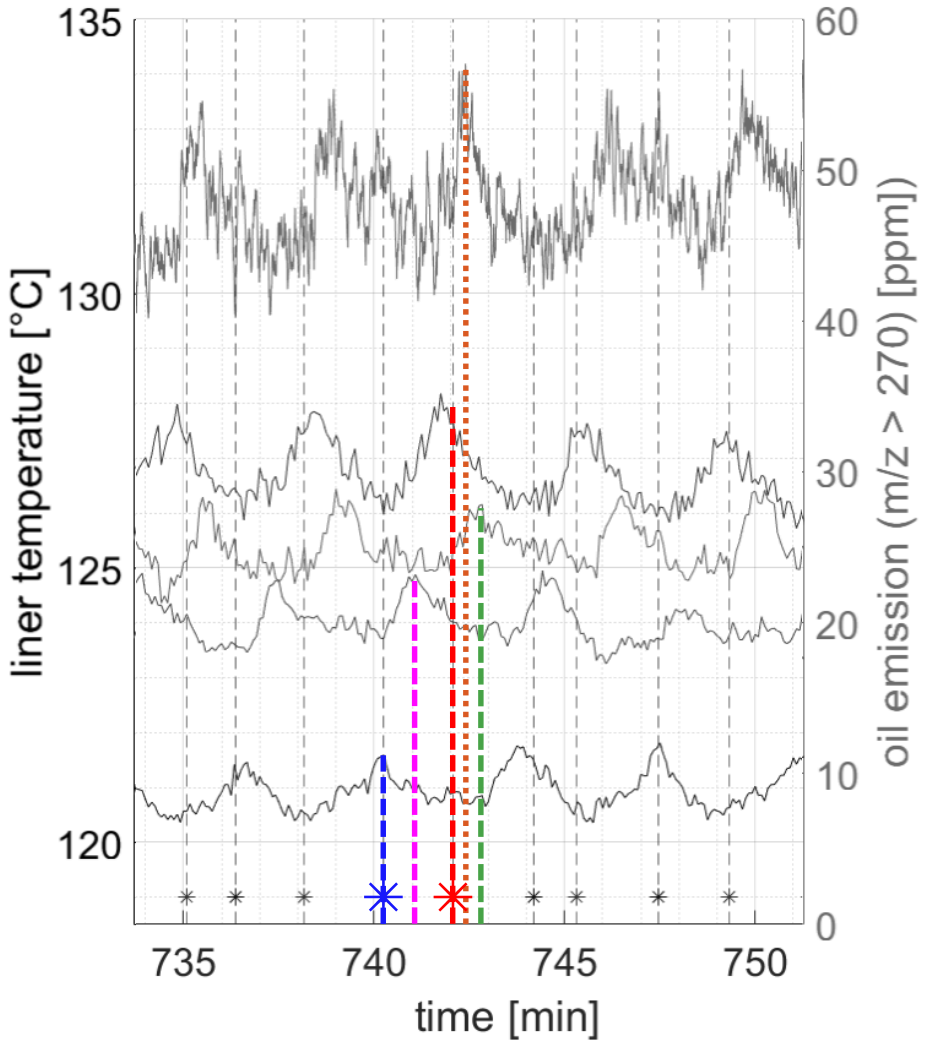
- Oil emissions peak
- TDC Temperature peak West
- TDC Temperature peak South
- TDC Temperature peak East
- TDC Temperature peak North

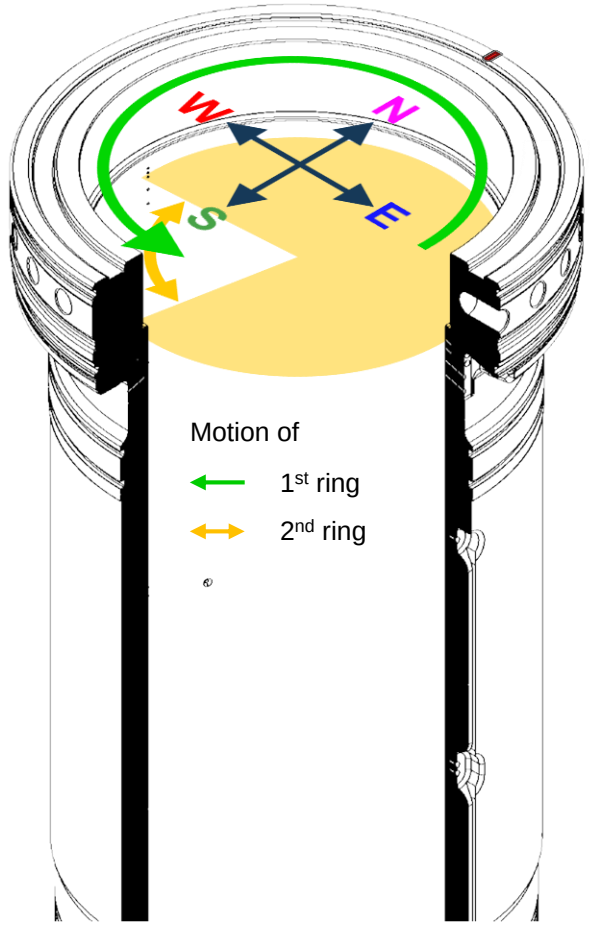
1st compression ring

Counter clockwise rotation with ca. 4…5 min per full rotation.

2nd compression ring

Oscillation of ring gap between West and South position is likely.





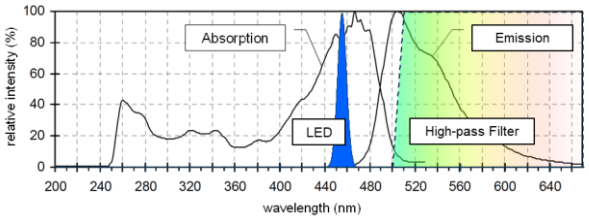
Cylinder liner adapted for measurements.

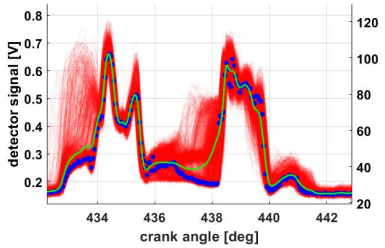
Conclusions

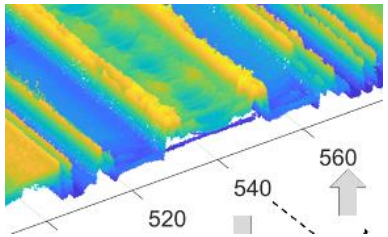
→ Fluorescence measurement system has been applied successfully.
- Signal strength is generally good. Data acquisition is reliable.
- Signal strength of TDC measurement positions deteriorates quickly.
- For absolute thickness values a calibration is necessary for each fraction of component passing the measurement position.

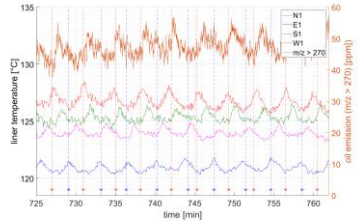
→ Measurements provide an insight into the oil layer.
- The measurement technique is particularly well suited for detecting changes over the time axis.
- Suddenly occurring phenomena such as blow-by, reverse-blow-by, knocking, misfiring can be identified and analyzed.
- Ring rotation and its influence on the oil film can be analyzed.

→ Combination with other measurements for a thorough investigation of effects.





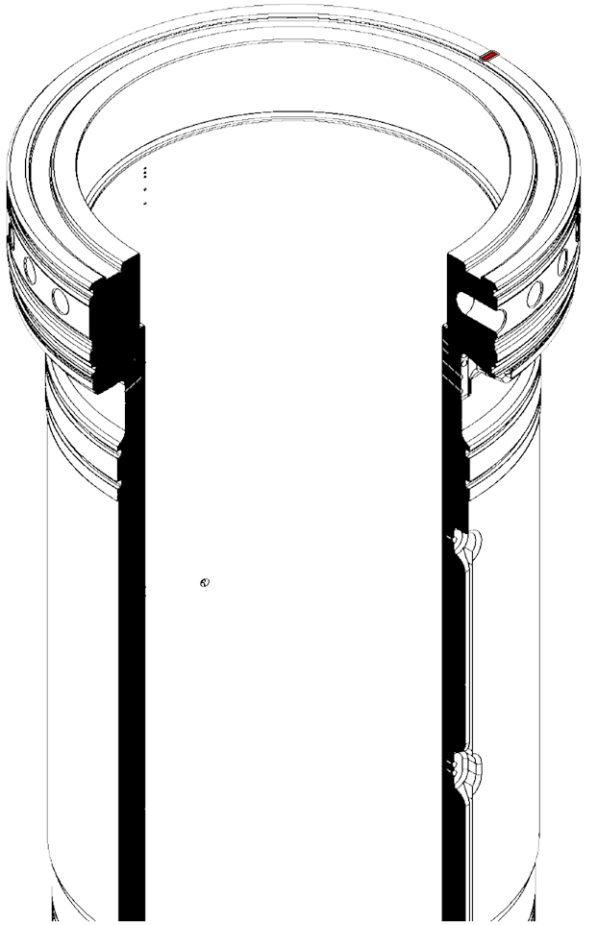




What’s next?

→ With existing cylinder liner:
- Calibration of certain fractions of component passing measurement position.
- Varying of operational parameters.
- Investigation of abrupt operational changes, e.g.
  - Changeover from Diesel operation to Gas operation,
  - Load shedding.
- Operation with different fuels.

→ New cylinder liner design.
- Different measurement positioning pattern.
- Honing of cylinder liner with optical fibers installed.
- Different surface properties (honing).



Cylinder liner adapted for measurements.

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