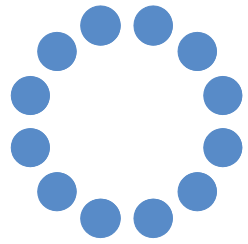


COMBUSTION BAY ONE

advanced combustion management



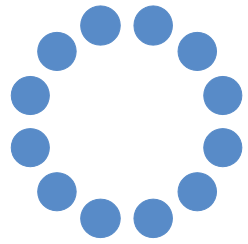
COMBUSTION BAY ONE

Engine health monitoring and refined combustion control based on optical diagnostic techniques embedded in the combustor

emótiòn

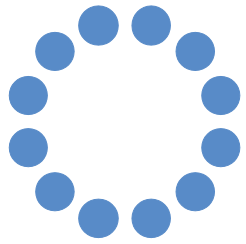
Project review and outlook

Fabrice Giuliani, CBOne

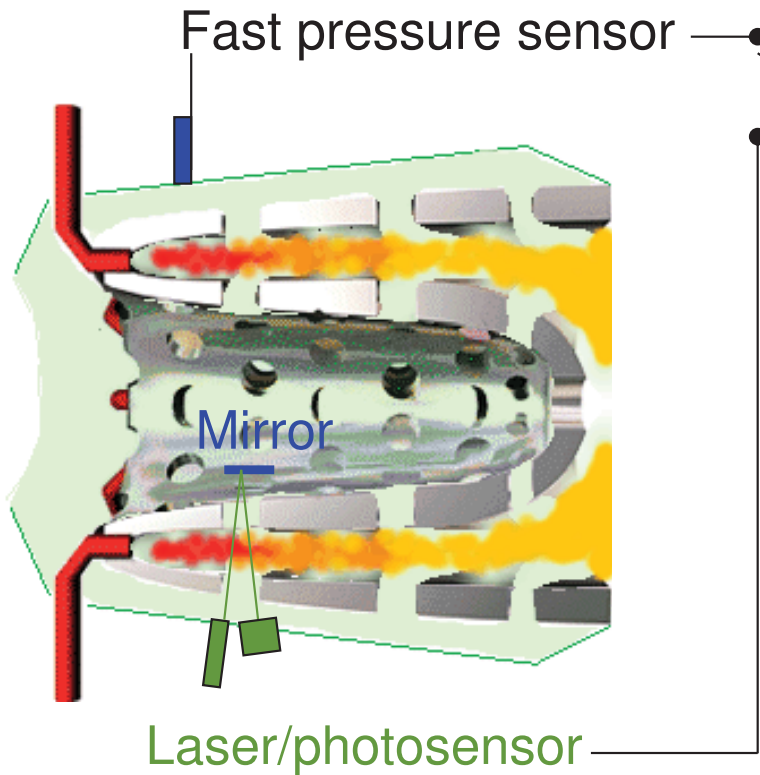


FFG / Take-Off / emotion

- Exploration project
 - National funding FFG, Austrian Fonds for Applied Research
 - Start 10/2015, end 03/2016 (18 Months)
- Consortium:
 - Combustion Bay One e.U. (CBOne, leader)
 - FH Joanneum / Institute of Aviation (IAV)



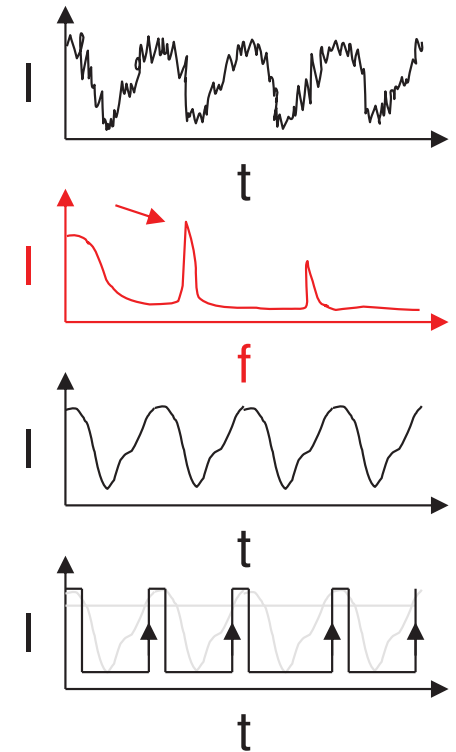
Towards embedded optical measurement techniques



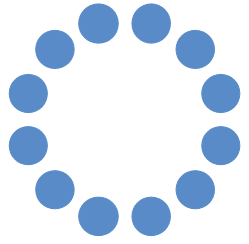
Spectral analysis

Ad-hoc filtering

Phase-locked trigger



Towards conditioned measurement techniques / control

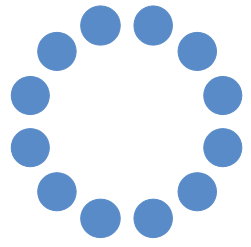


Motivation

Optical measurement techniques:

- Non intrusive
- Flame diagnostic
- Combustion (in)stability
- Standard for laboratory / test rig measurements

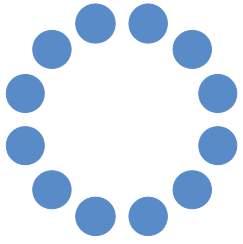
Supporting Slides:
Habilitation Giuliani



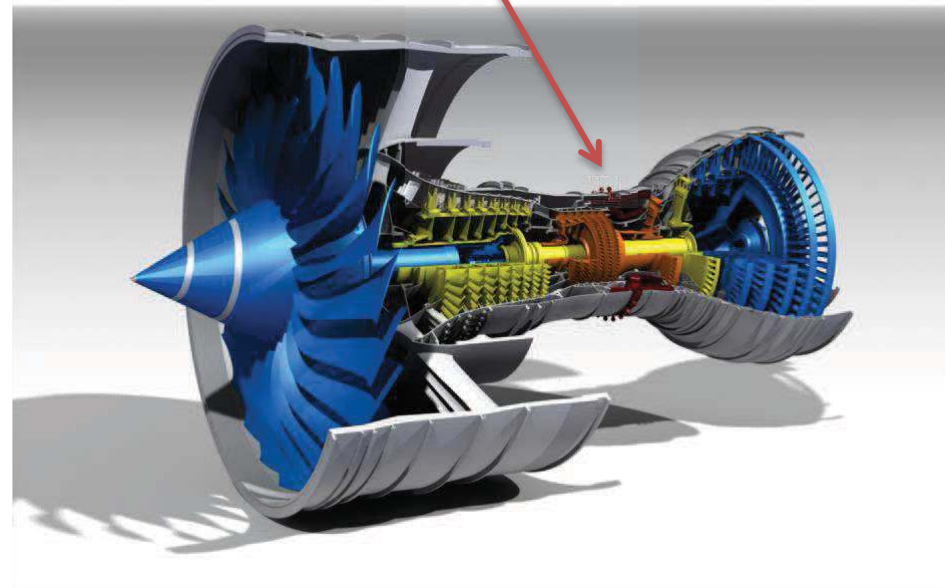
Requests from the aeroengine manufacturer

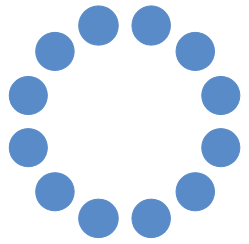
The probe should inform in real-time about the following:

- if there is a flame or not
- if the ignition sequence is successful
- what are the current operation conditions
- detect the presence of combustion instabilities



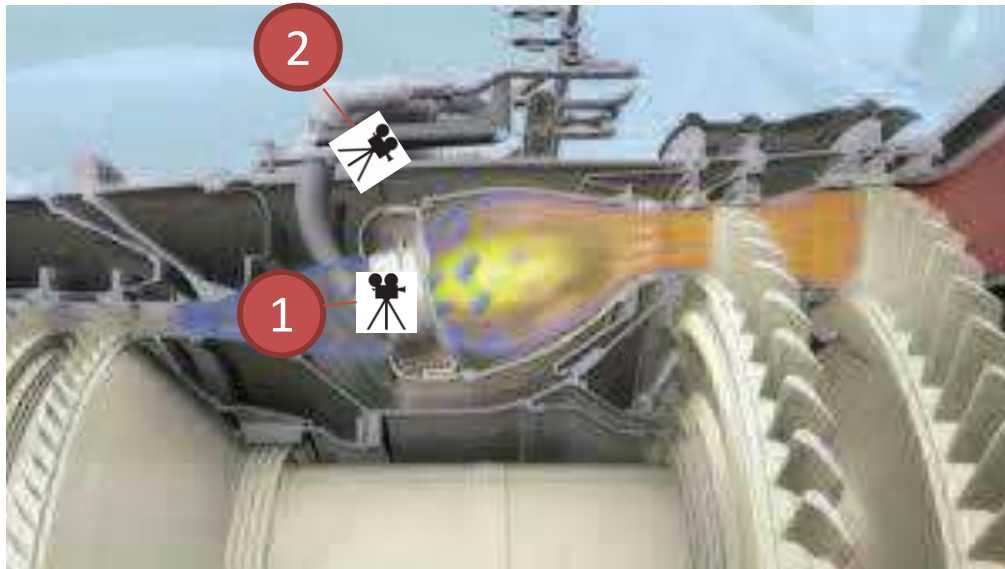
Objective: each turbofan combustor is equipped with 4 to 8 of such miniature optical sensors





Idea: observe in real time the combustion with help of miniature cameras

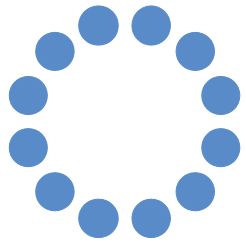
Two strategies:



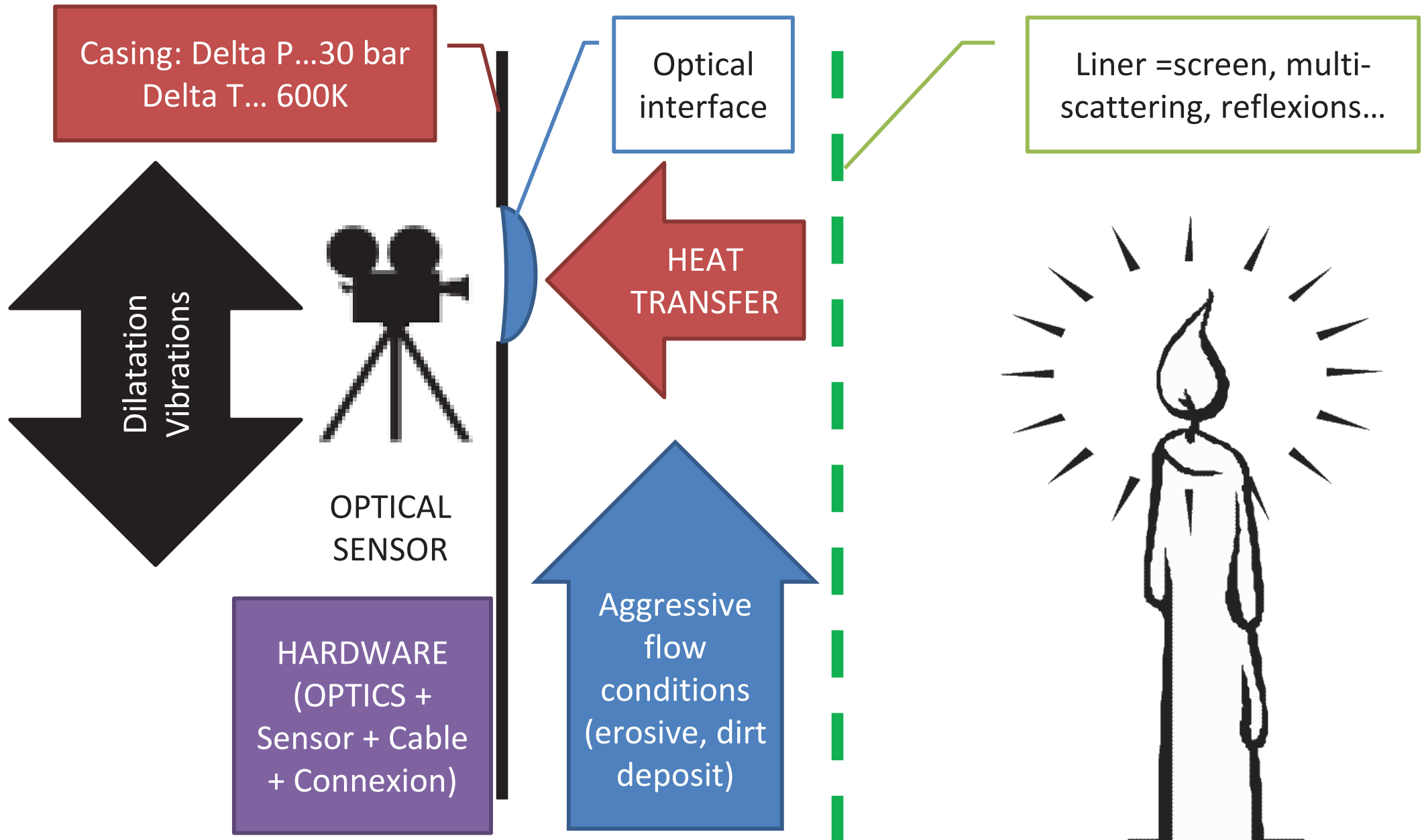
1. Place the camera in the injector and see the flame throughout the injection
2. Place the camera on the pressure casing, and see the flame through the cooling holes

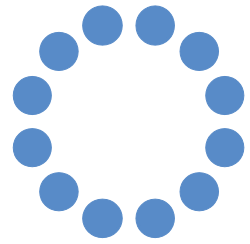


The challenge is the design of a robust optical system with low intrusiveness (miniature) placed in an hot environment

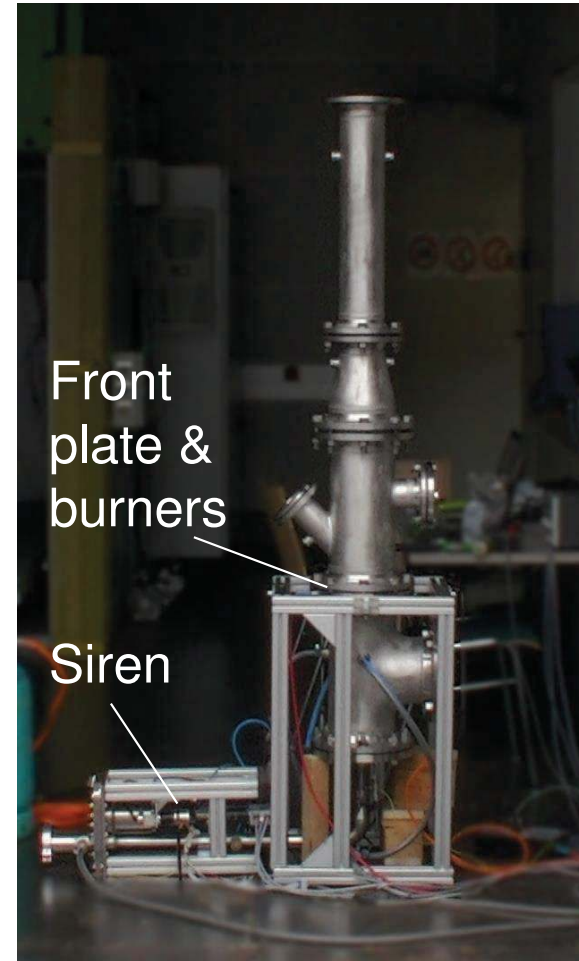
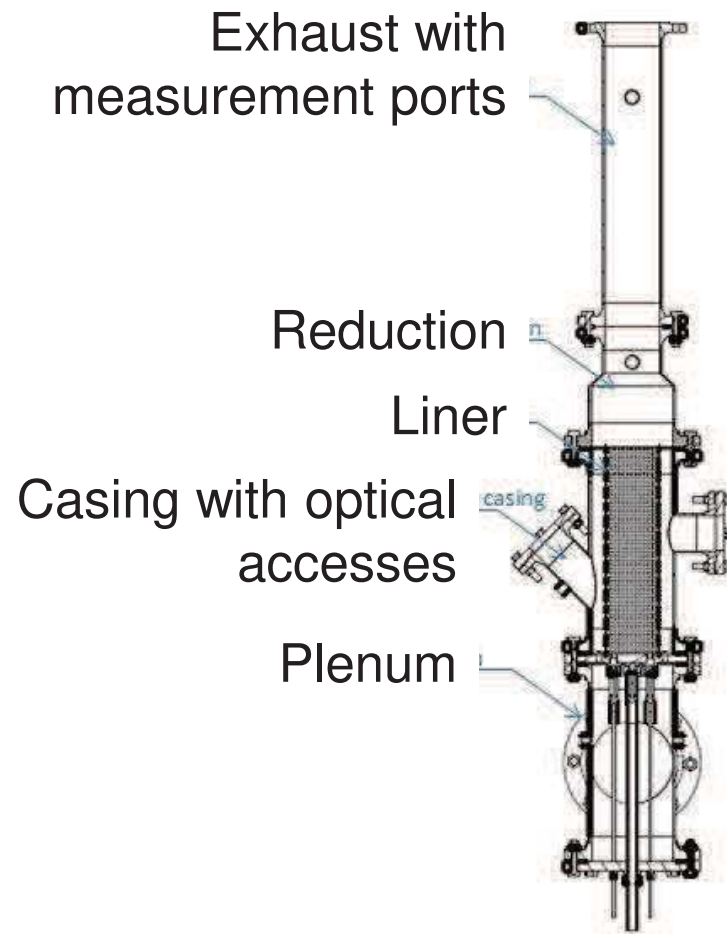


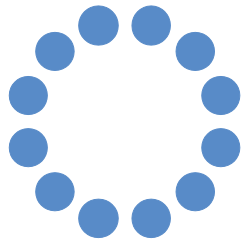
Technical challenge





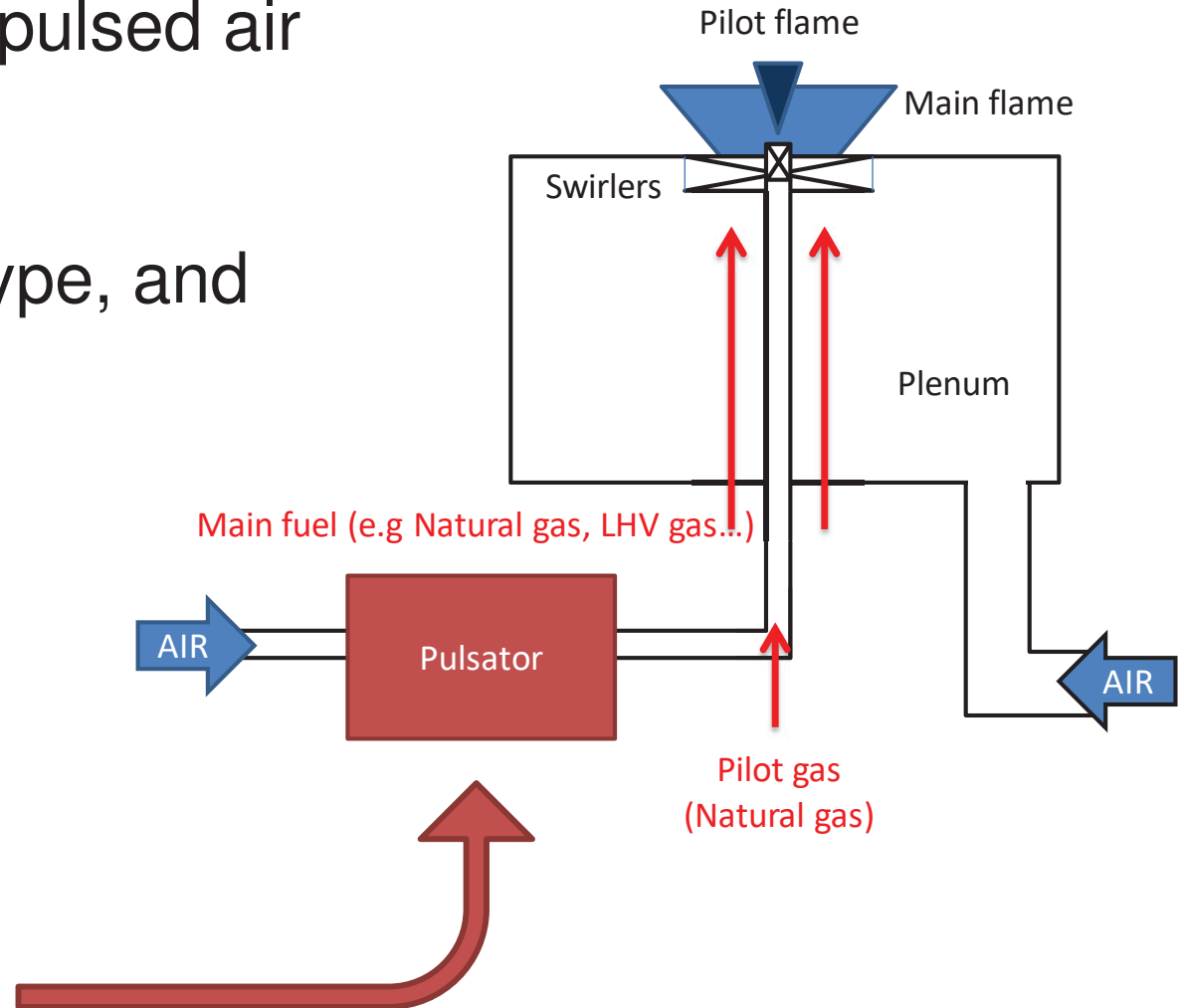
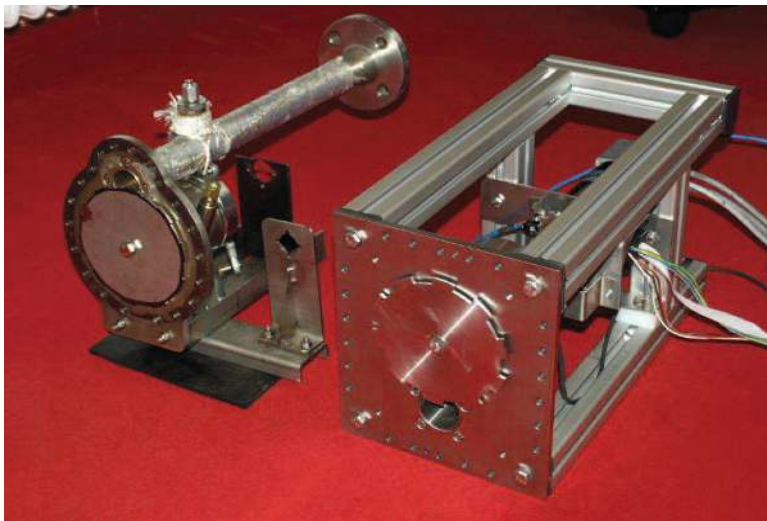
the MethaNull Test Rig

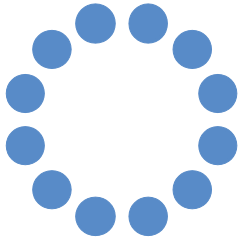




Combustion stability analysis

- Similar experiments with pulsed air injection as for MethaNull
- picture: historical prototype, and commercial version





(other projects: equipment for the investigation on injection diagnostics)

rePorT (see EVI GTI 2016 for details)

Programm MethaNull

CASING OF THE ROTATING WHEEL

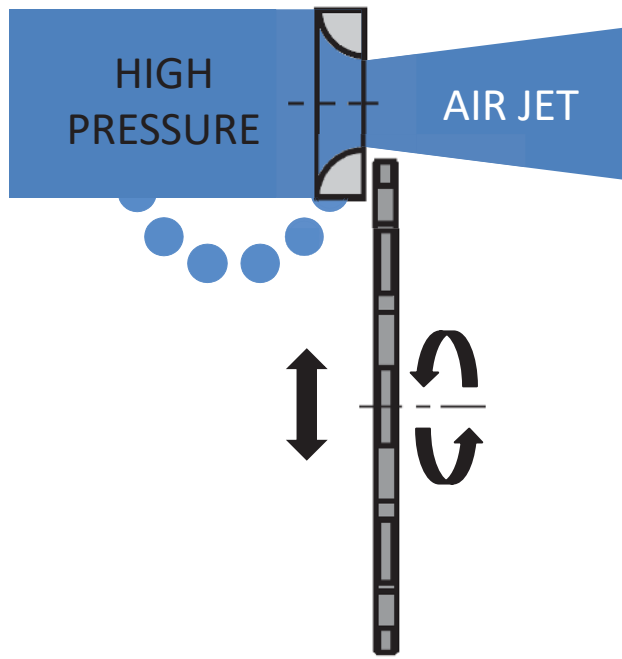
NOZZLE

INLET / HIGH
PRESSURE
SIDE

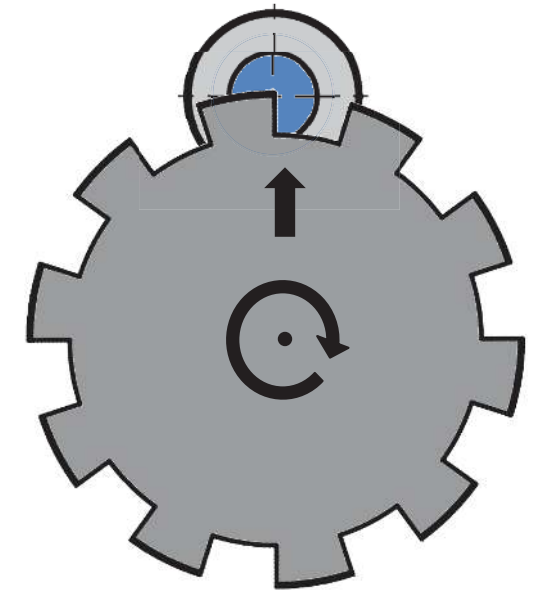
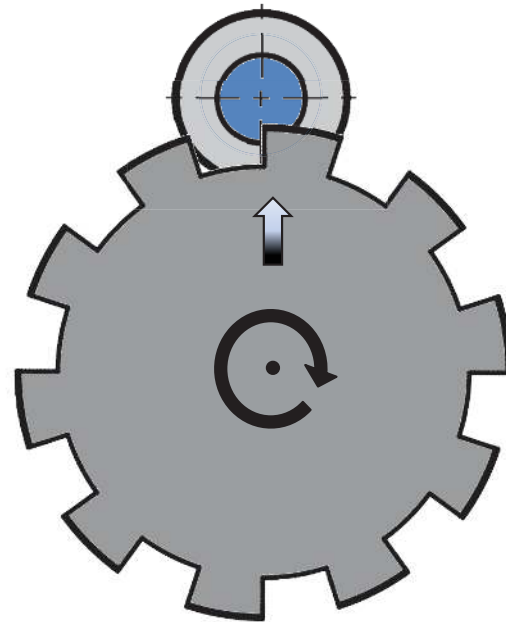
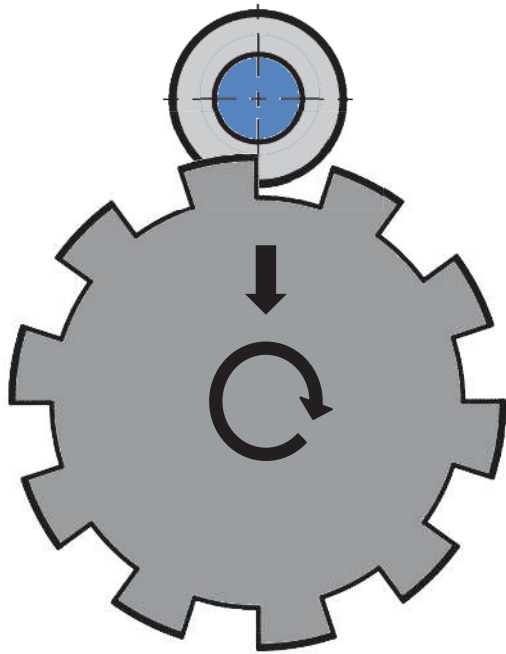
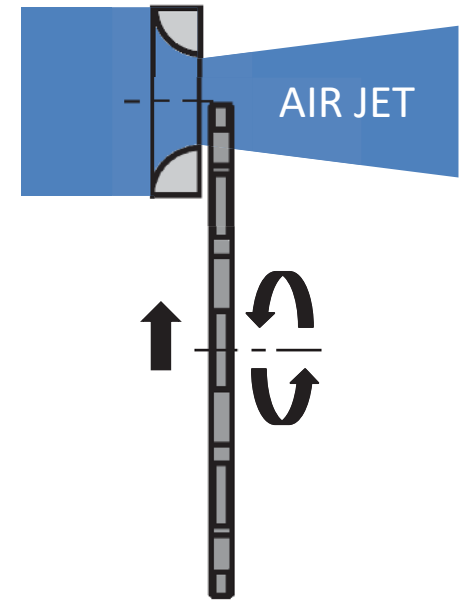
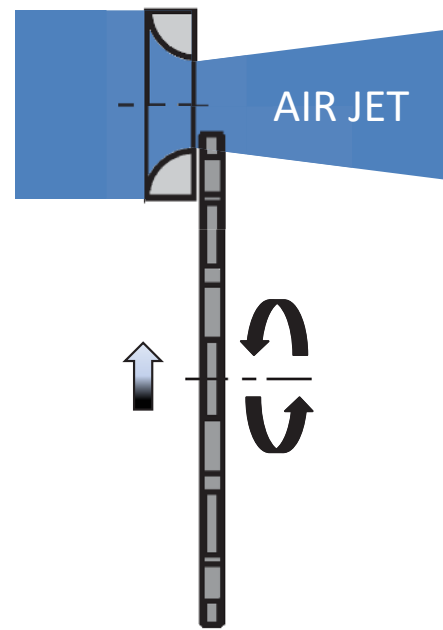
MECHANISM FOR MOVING IN
/ MOVING OUT THE WHEEL
FROM THE JET

MECHANISM FOR
TRANSMISSION & CONTROLS
OF THE ROTATING WHEEL

OUTLET / LOW
PRESSURE SIDE



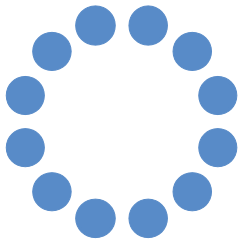
LOW
PRESSURE



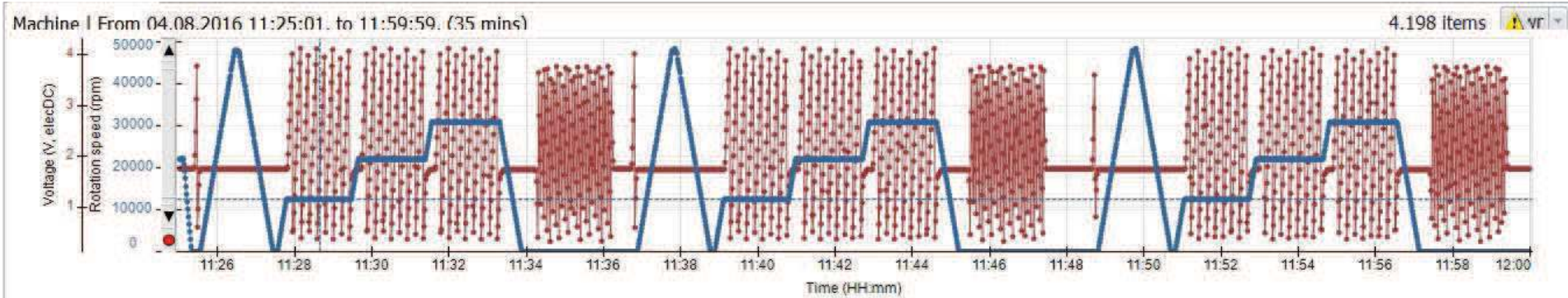
NO PULSATION

MODERATE PULSATION

STRONG PULSATION



Flame transfer function using order tracked measurements

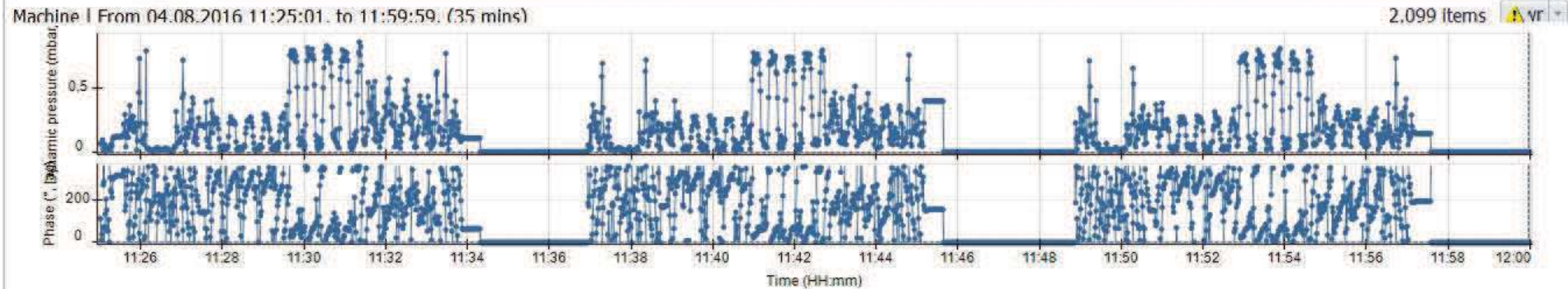


Legend | Machine

Curve	Timestamp	Speed	State	Main cursor	Location
■ Tacho02 FlameExcitation...	<input checked="" type="checkbox"/> 04.08.2016 11:28:38,5	N/A		(12503 rpm @ 04.08.2016 ...	+1,570...
■ Dyn14_SirenAngle > DC...	<input checked="" type="checkbox"/> 04.08.2016 11:28:38,5	N/A		(1,53 V elecDC @ 04.08.20...	+90° EU

Time/APHT Group all Compensation Baseline

Trend Plot (2) ×

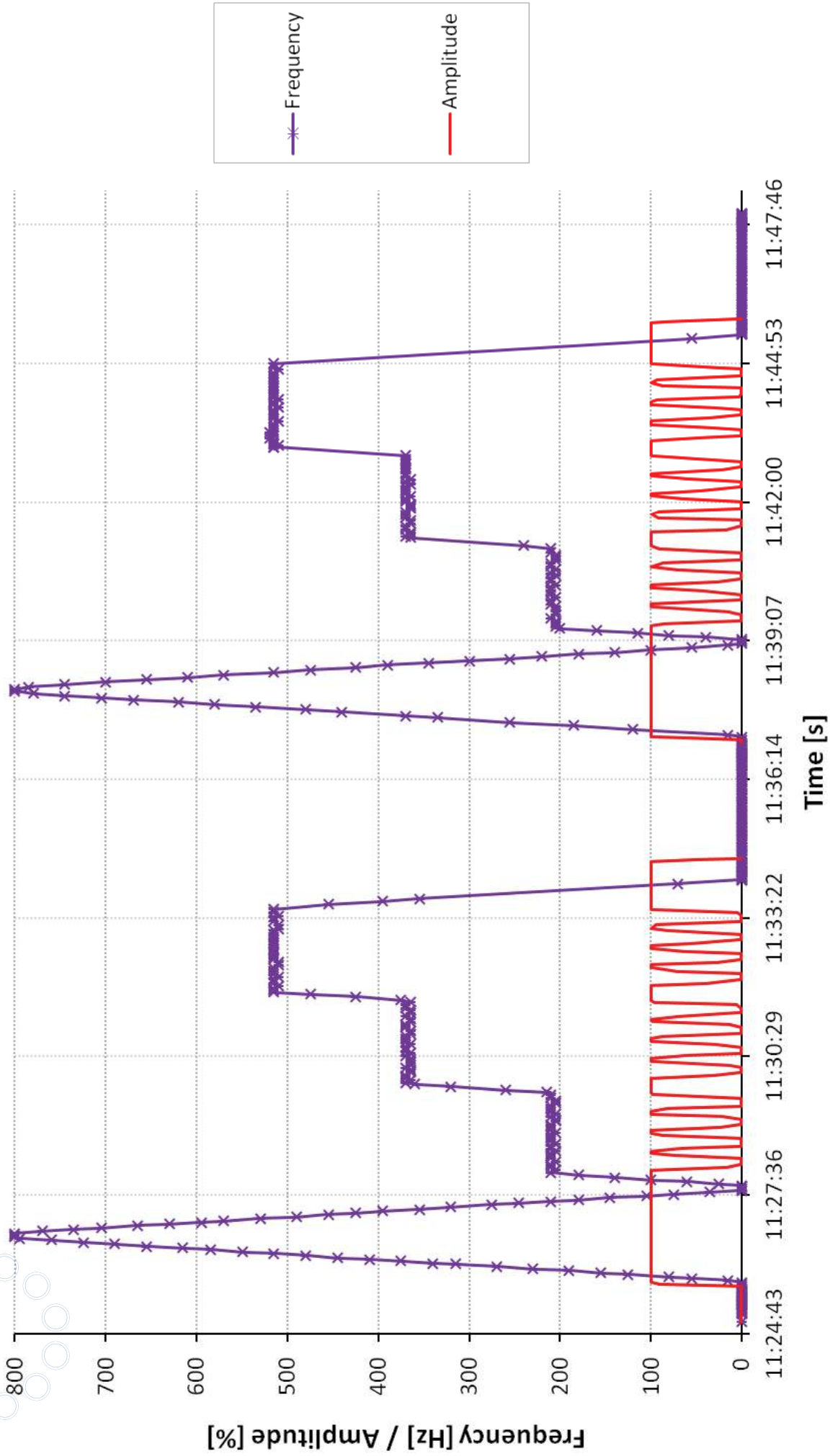


Legend | Machine > Dyn04 CP04 EU

Curve	Timestamp	Speed	State	Main cursor	Slow roll	Location
■ 1X Vector	<input checked="" type="checkbox"/> 04.08.2016 11:59:59,	0 rpm		0 mbar s_pk 0° lag @ 04....		+90° EU

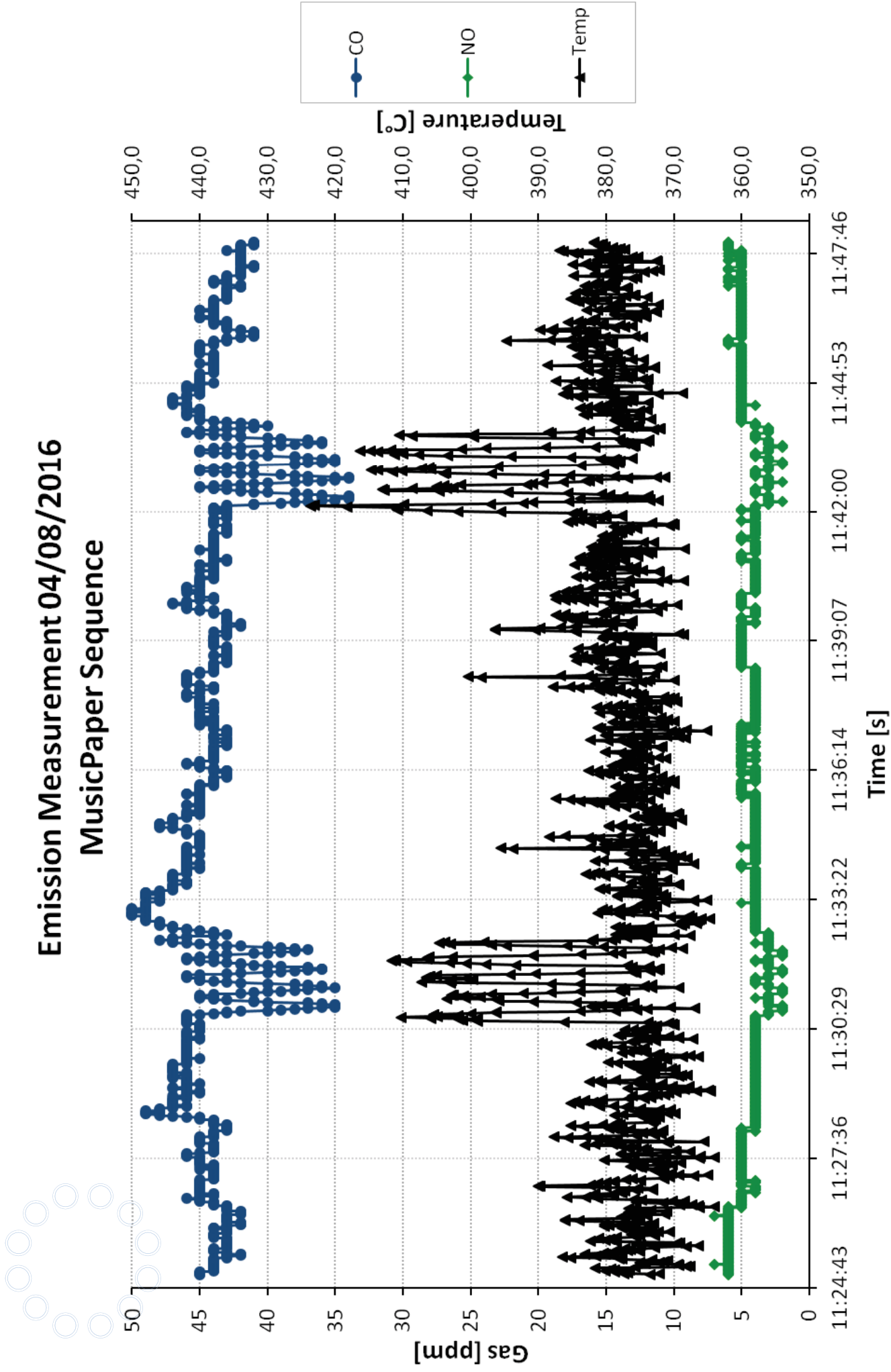
Sirene Output 04/08/2016

MusicPaper Sequence



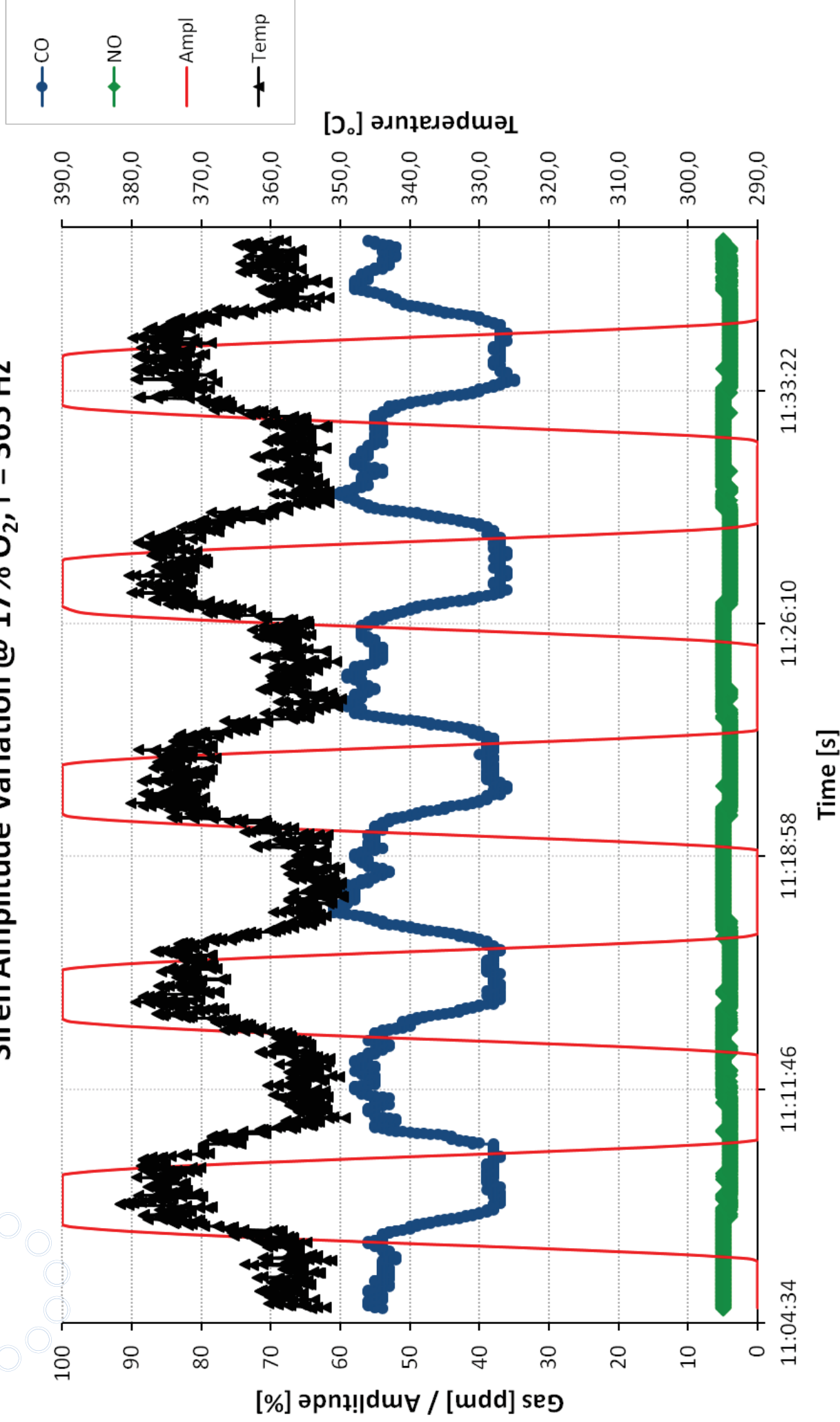
Emission Measurement 04/08/2016

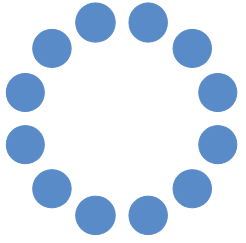
MusicPaper Sequence



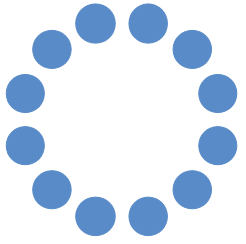
Emission Measurement 03/06/2016

Siren Amplitude Variation @ 17% O₂, f = 365 Hz

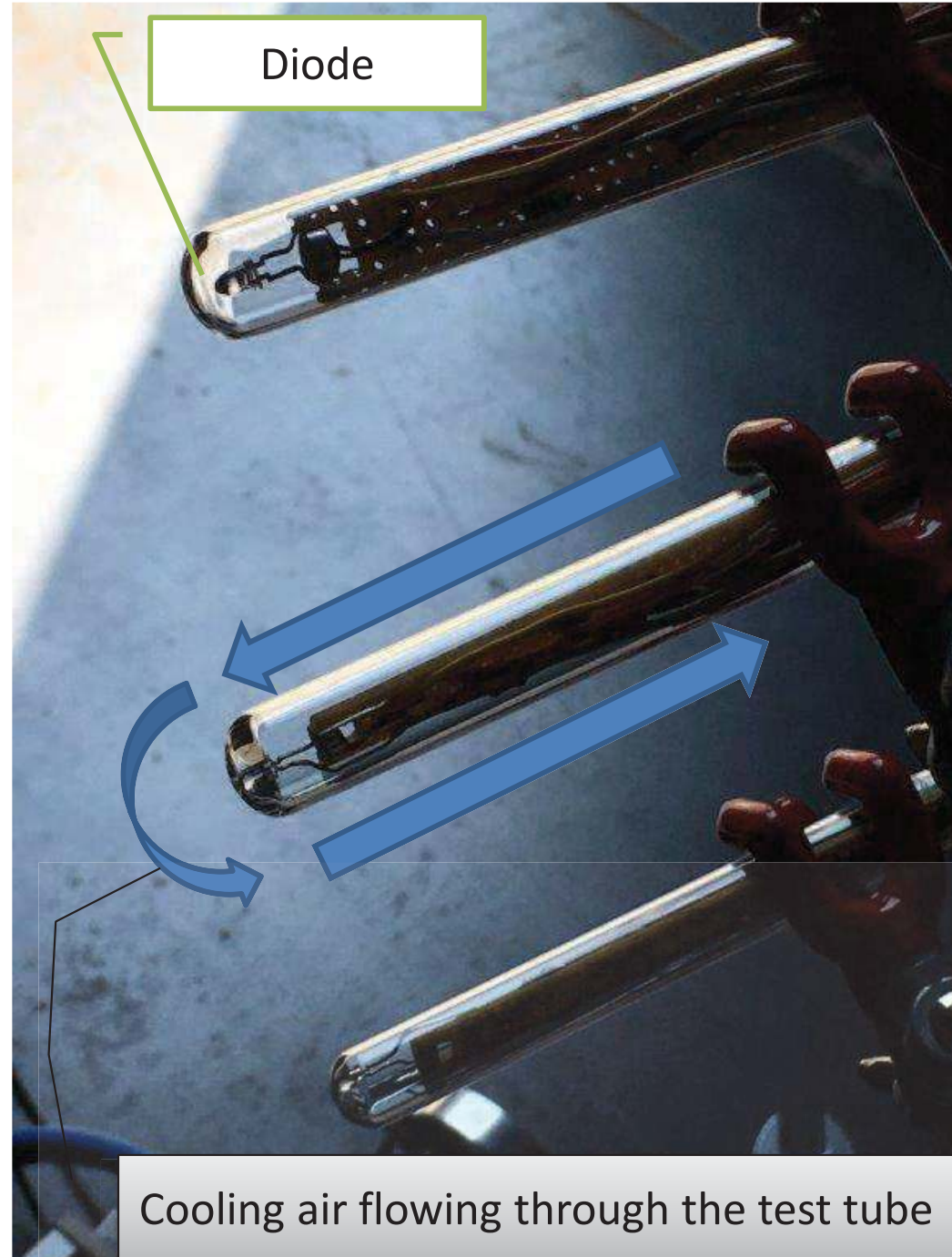


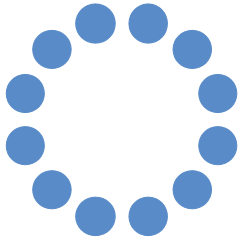


(back to emotion)



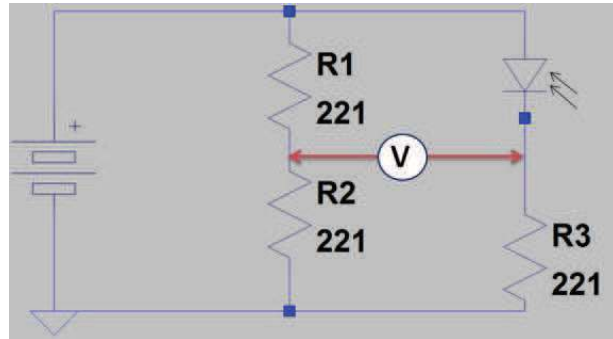
I. The emotion probe



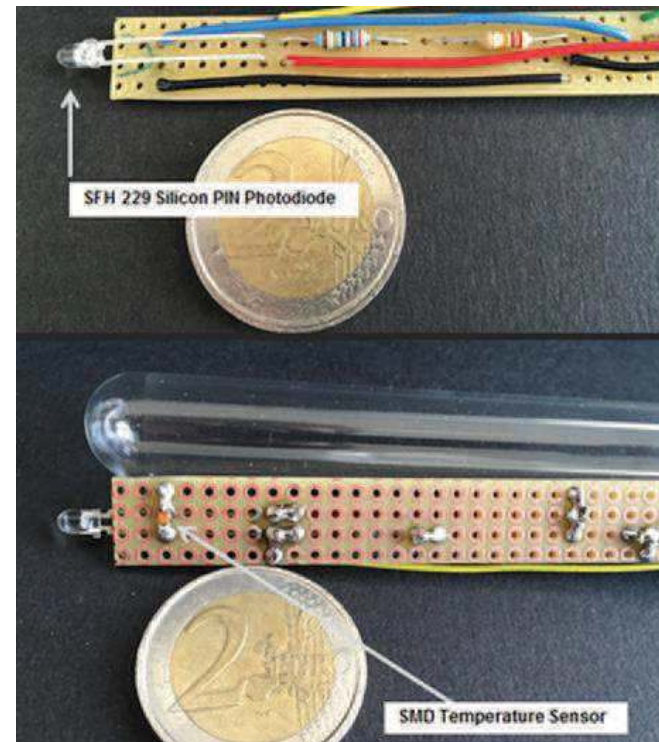
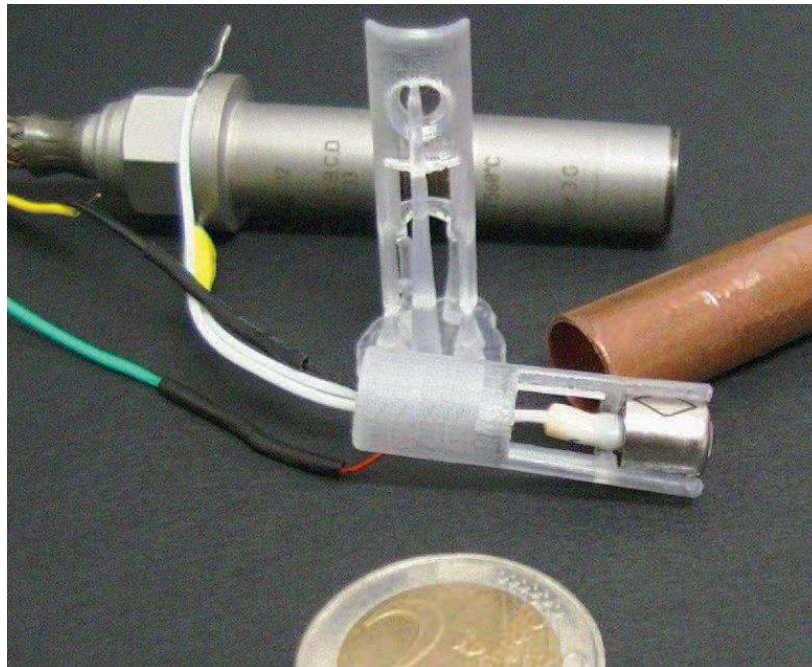
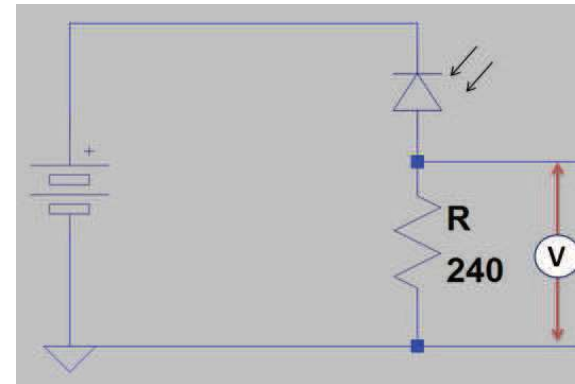


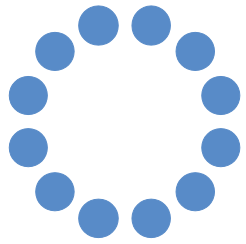
Circuits and sensors

Wheatstone-Bridge:

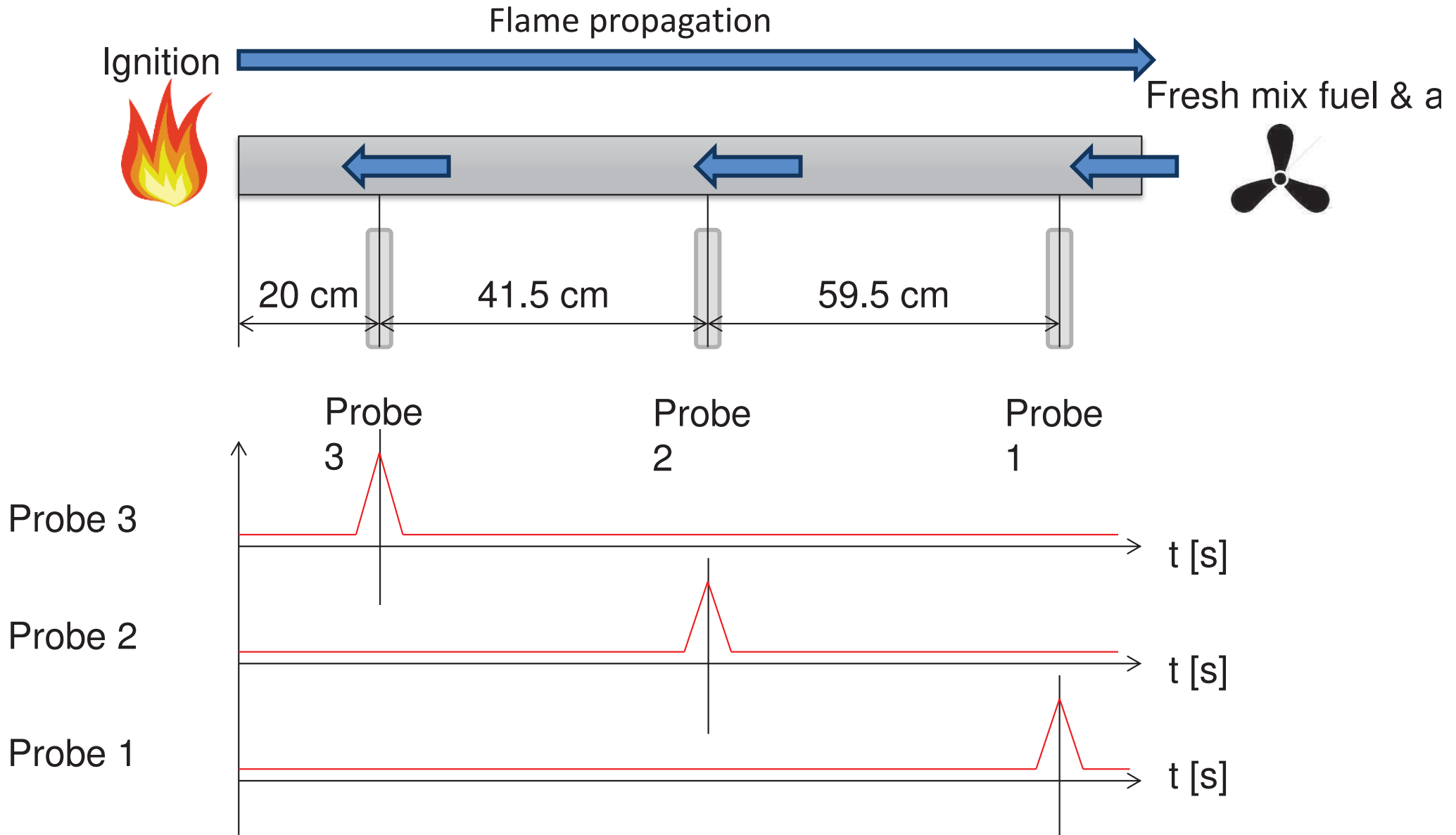


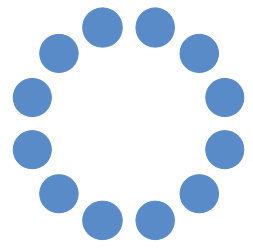
Reverse circuit:



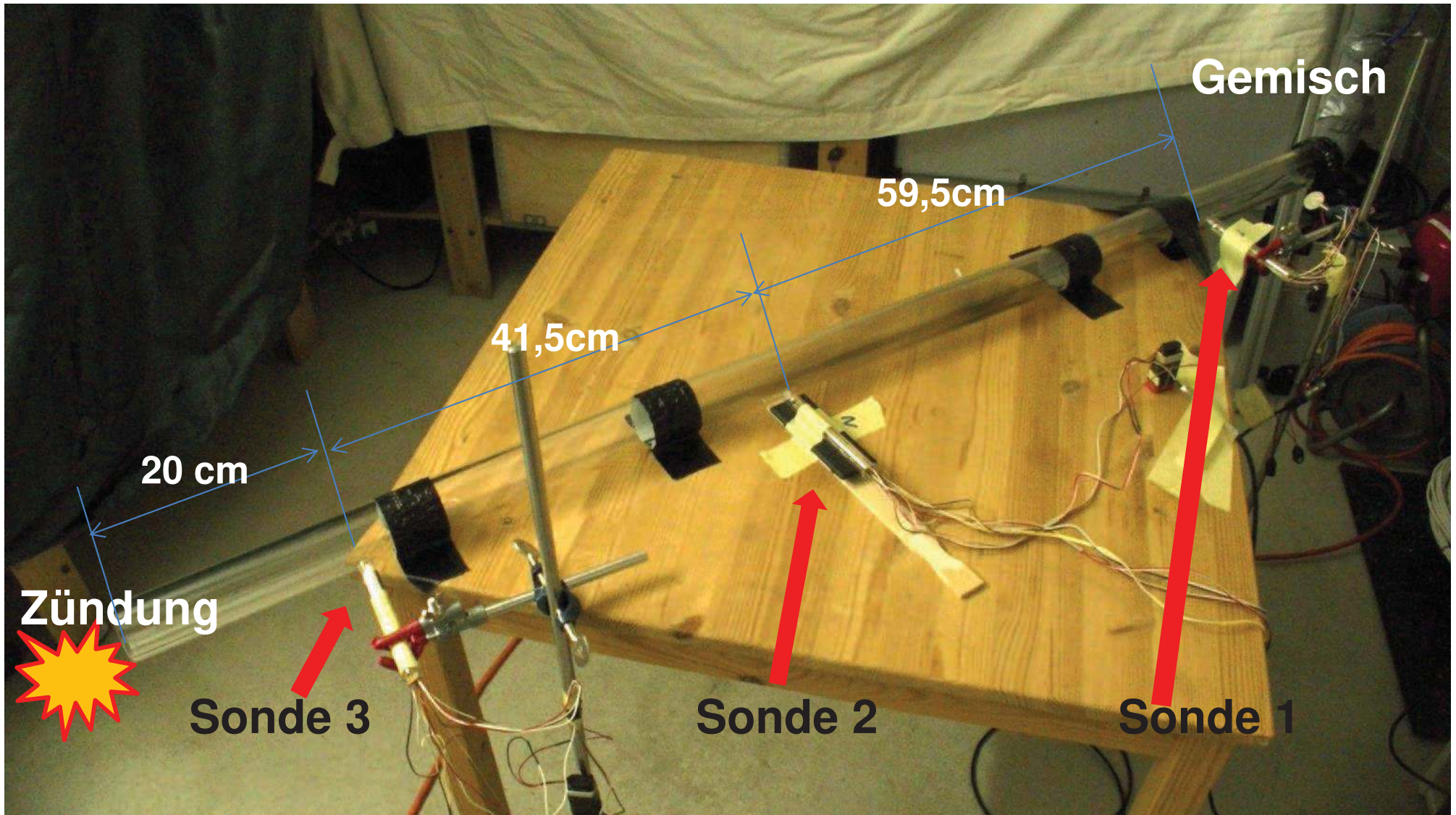


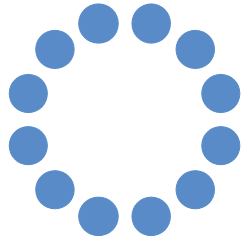
II Flame propagation speed



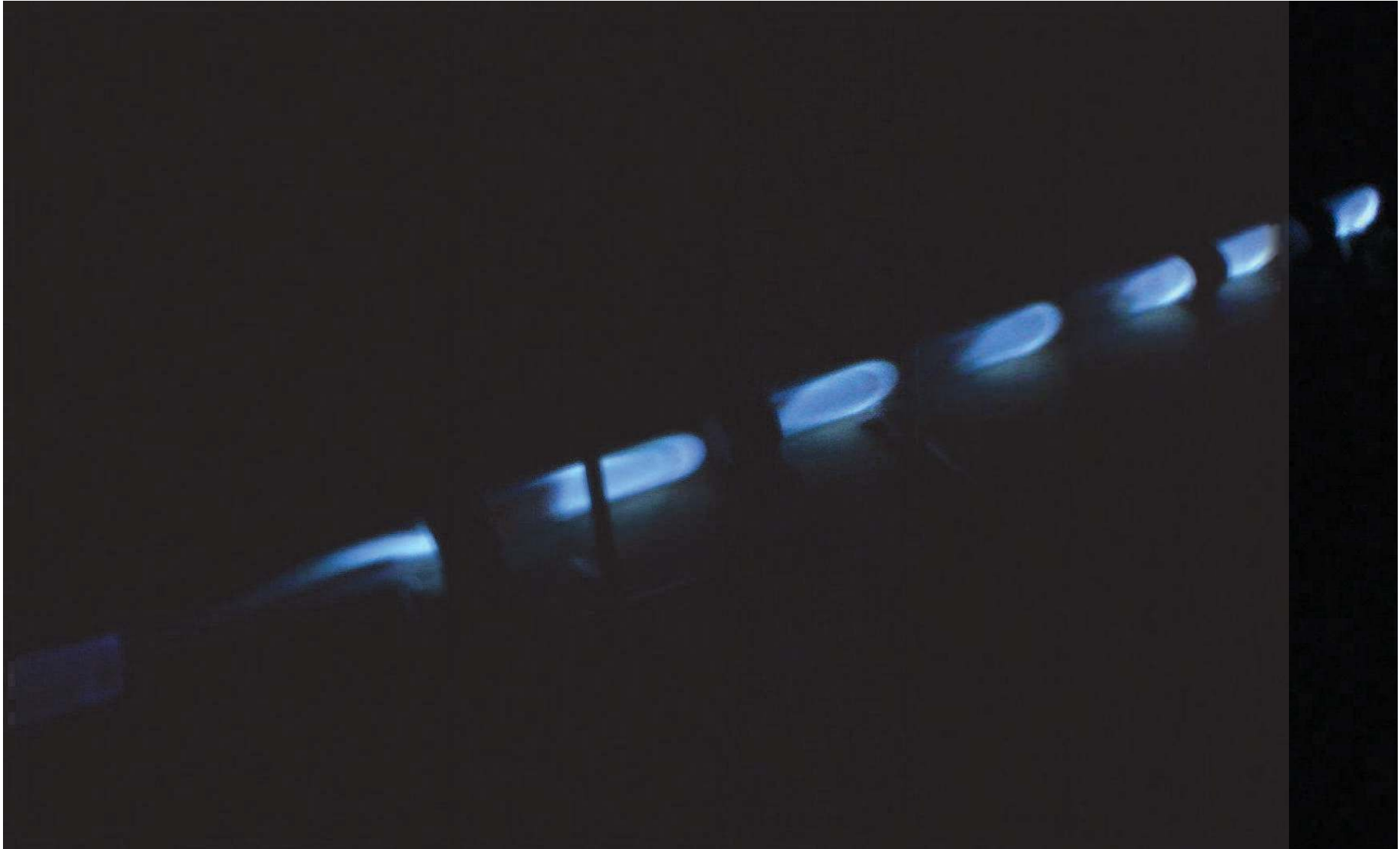


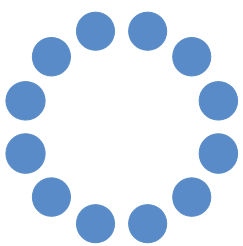
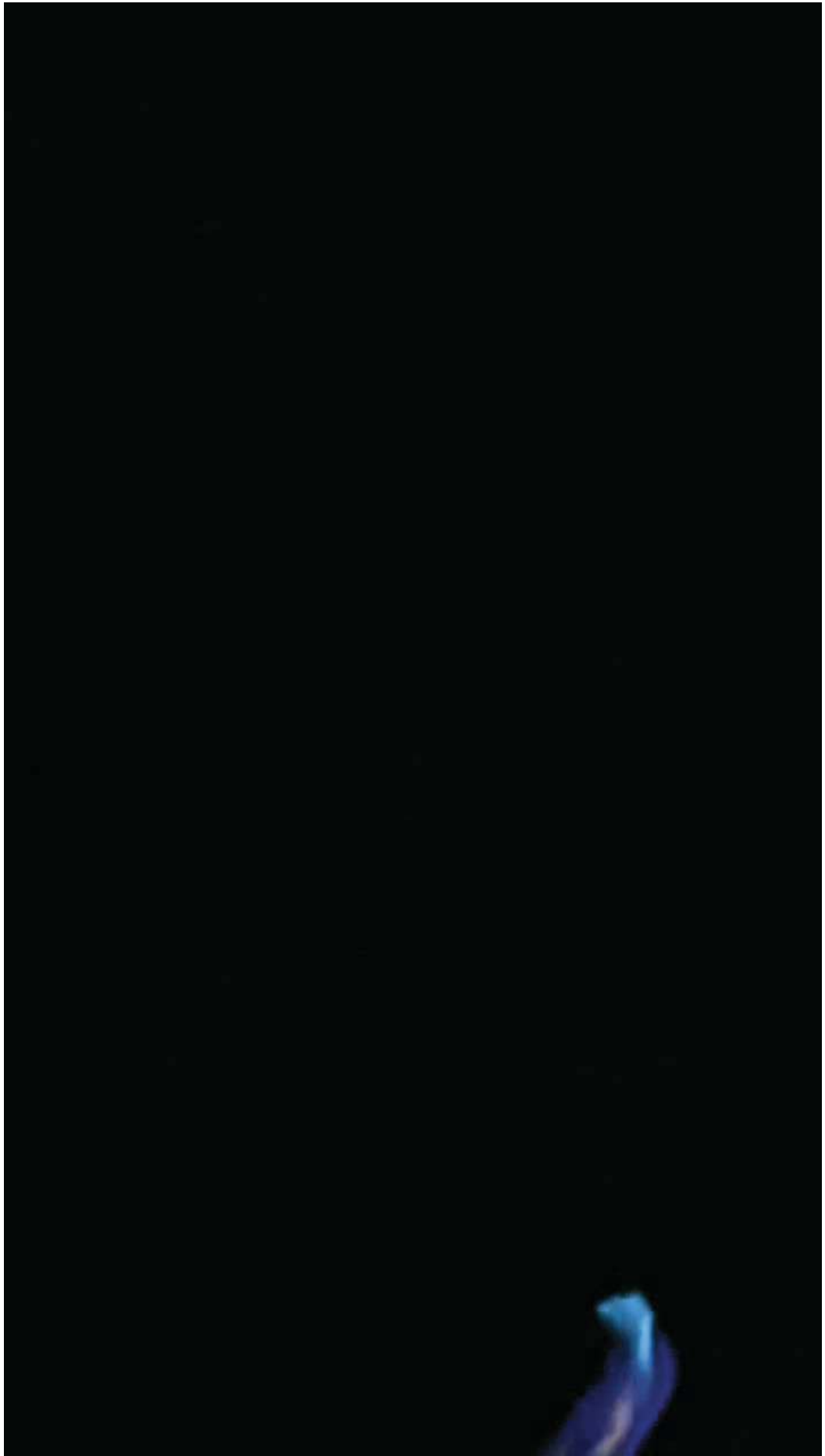
Set-up

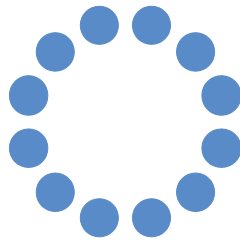




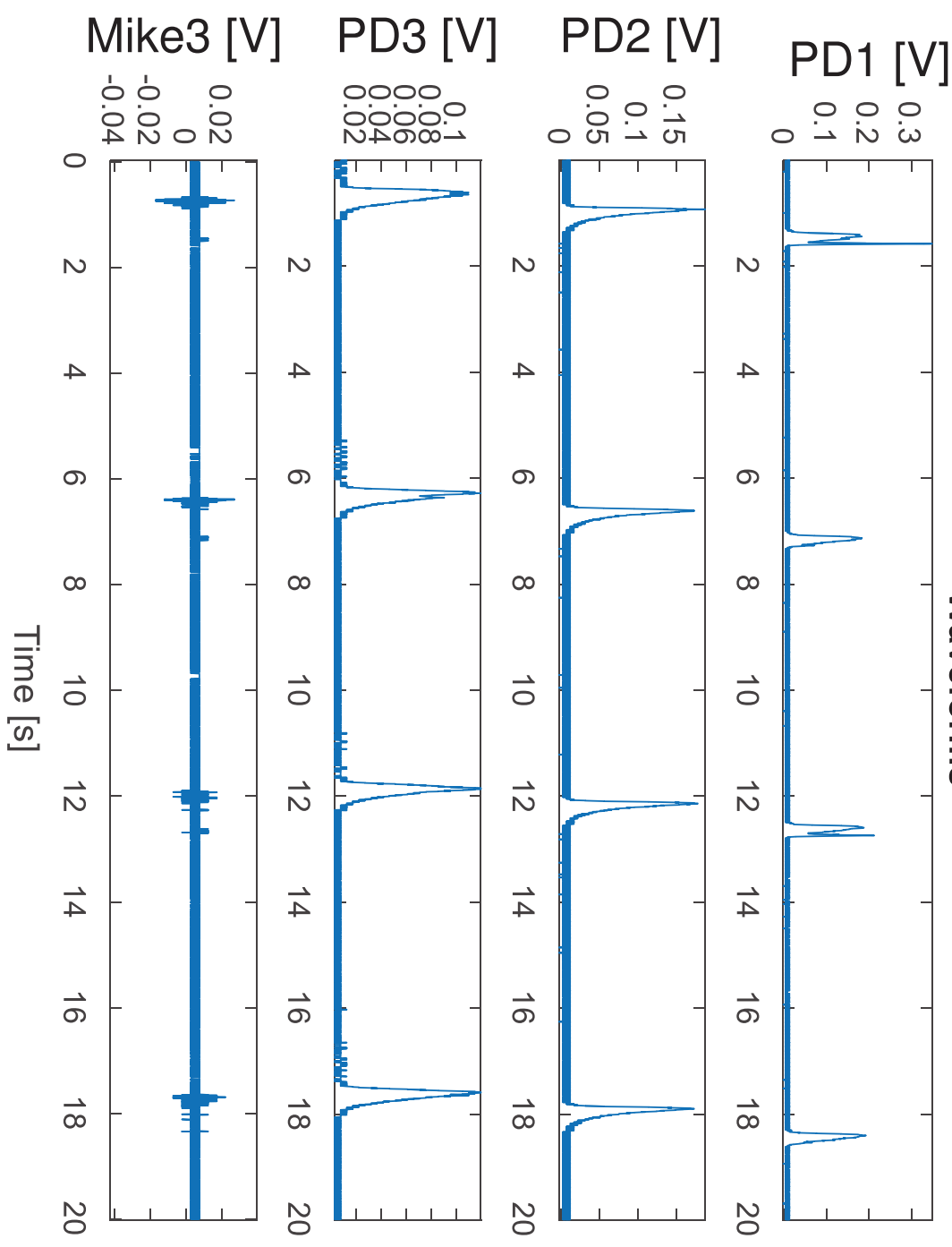
Successive flame locations during one shot

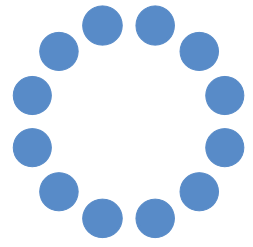






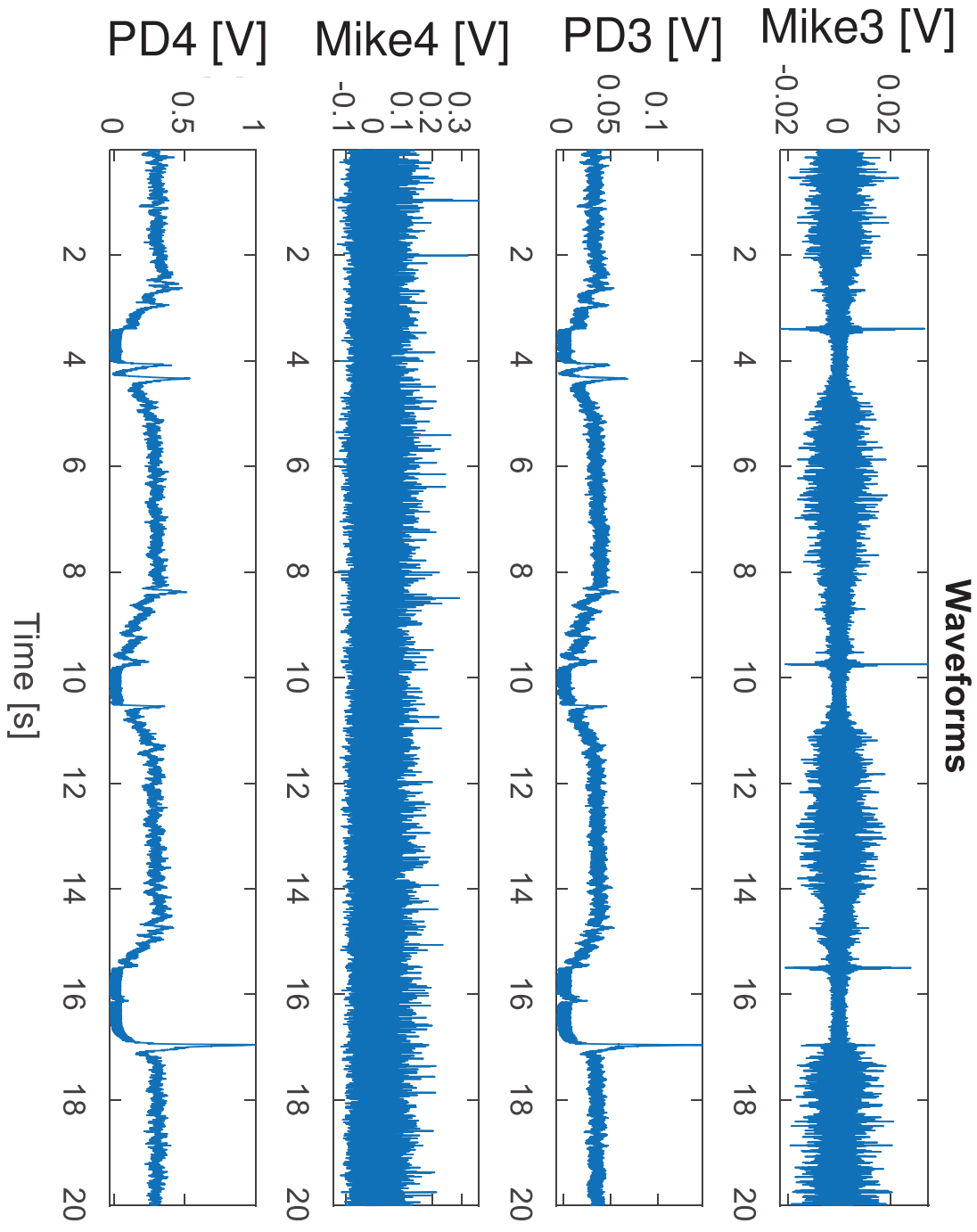
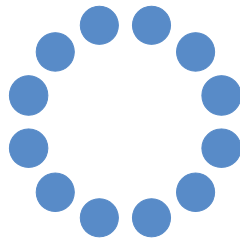
Waveforms

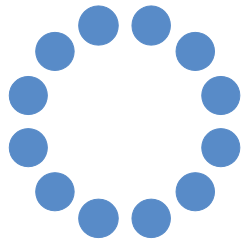




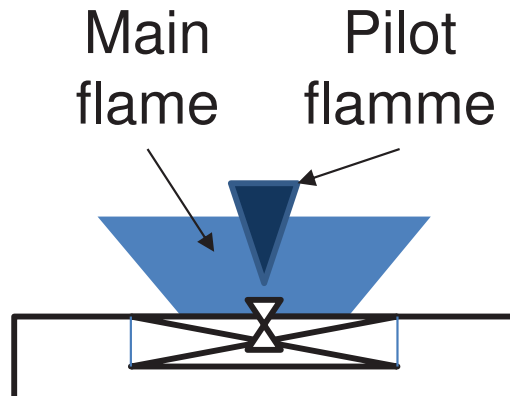
III Flame load transients, and flash-back





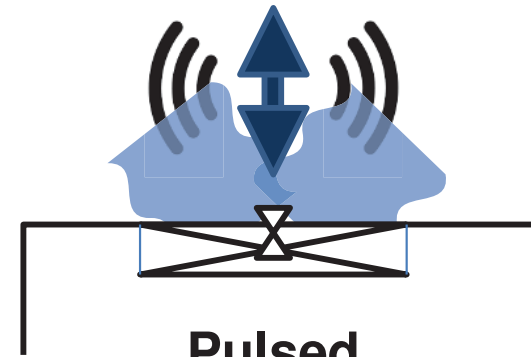


IV Combustion instability



Conventional

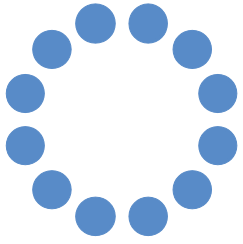
(Steady-state flows)



Pulsed

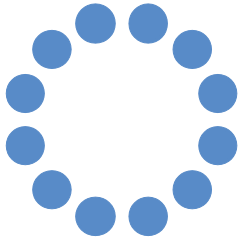
(Shaker=pilot flame, excited itself by the pulsator)





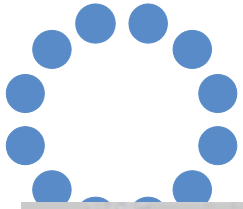
Stable combustion – MehtaNull Test rig:



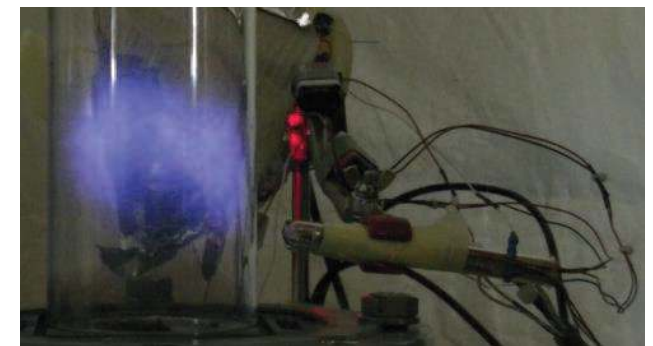
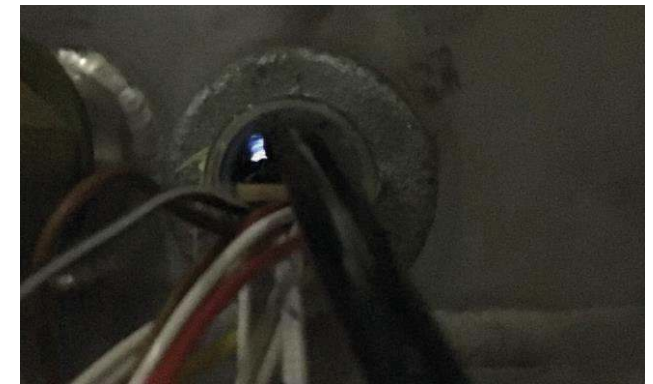
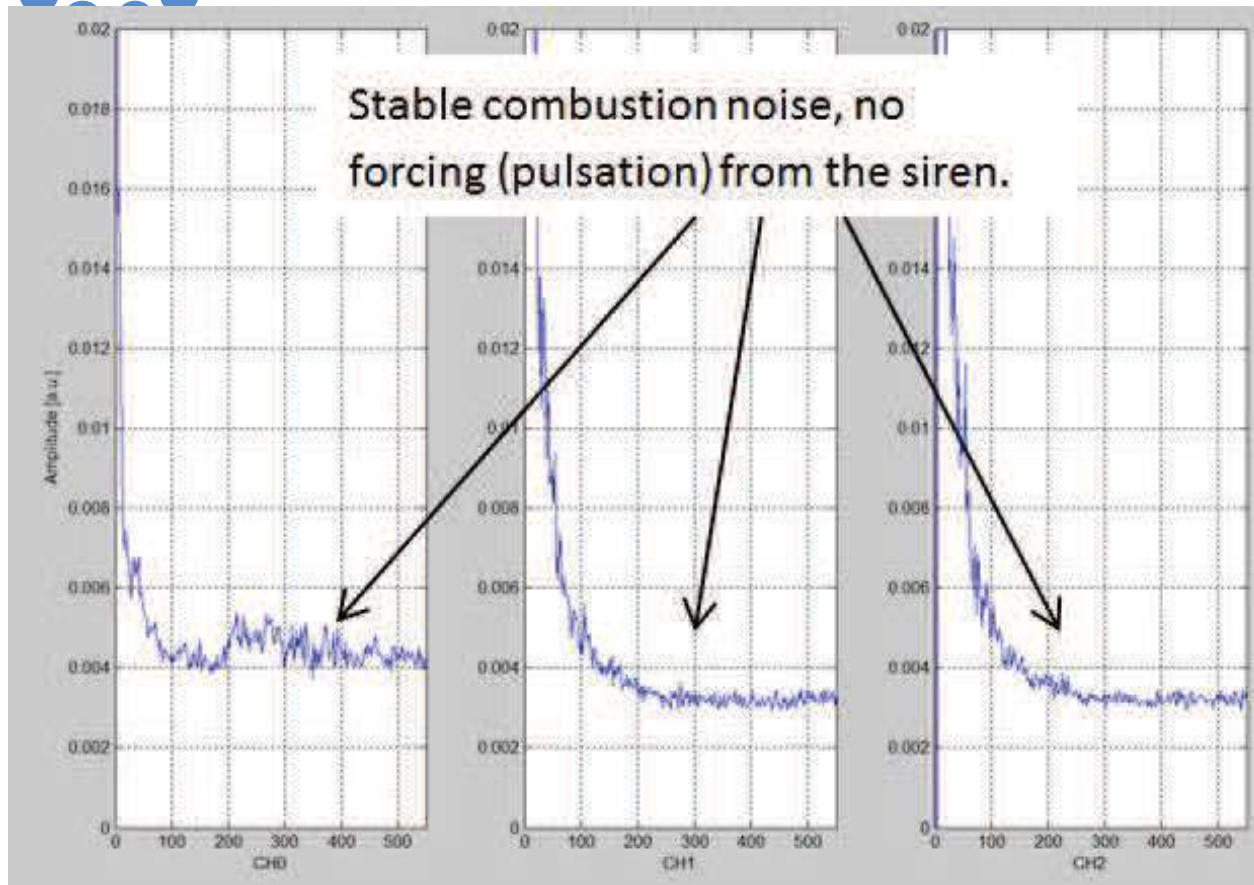


Forced combustion instability – MethaNull Test rig:

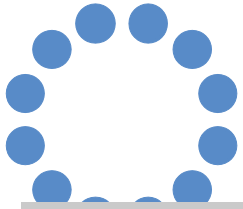




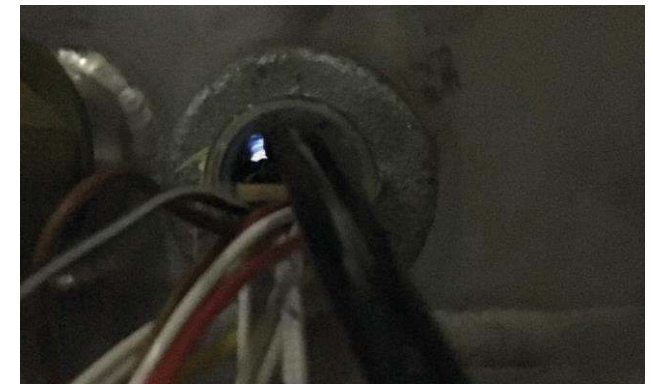
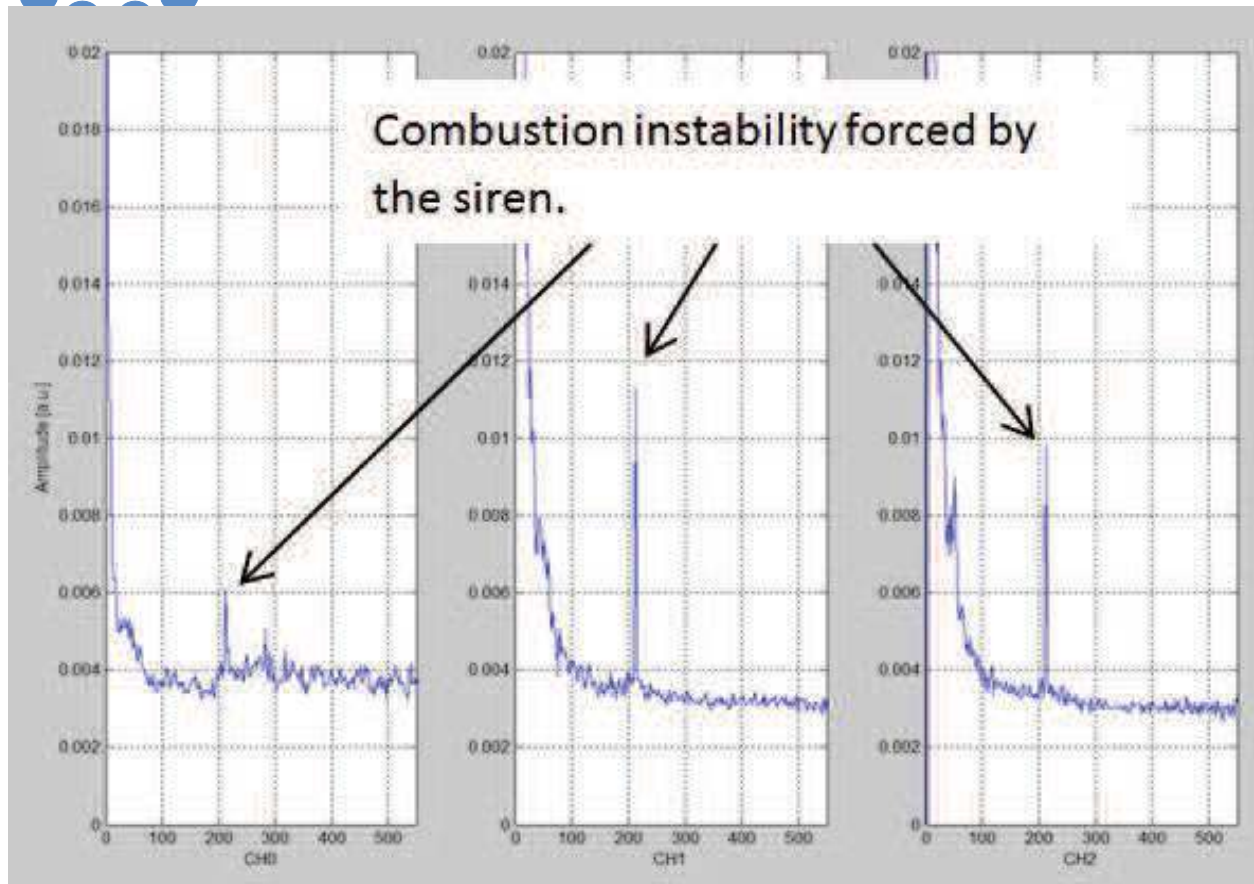
Spectral analysis, steady state



CH0 ... PD with a Wheatstone-Bridge circuit
CH1 ... PD with a reverse direction circuit
CH2 ... PD with a reverse direction circuit

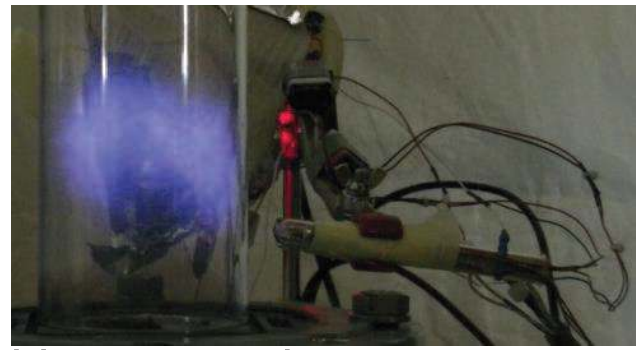
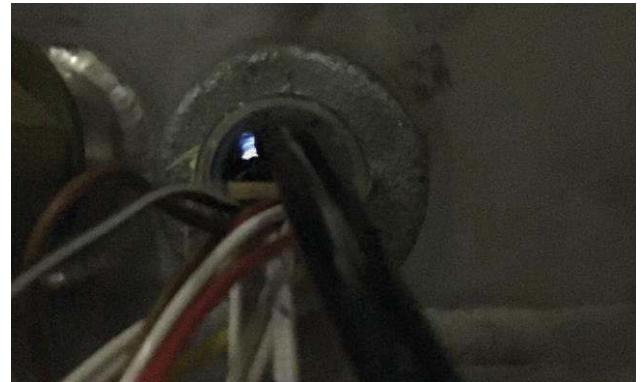
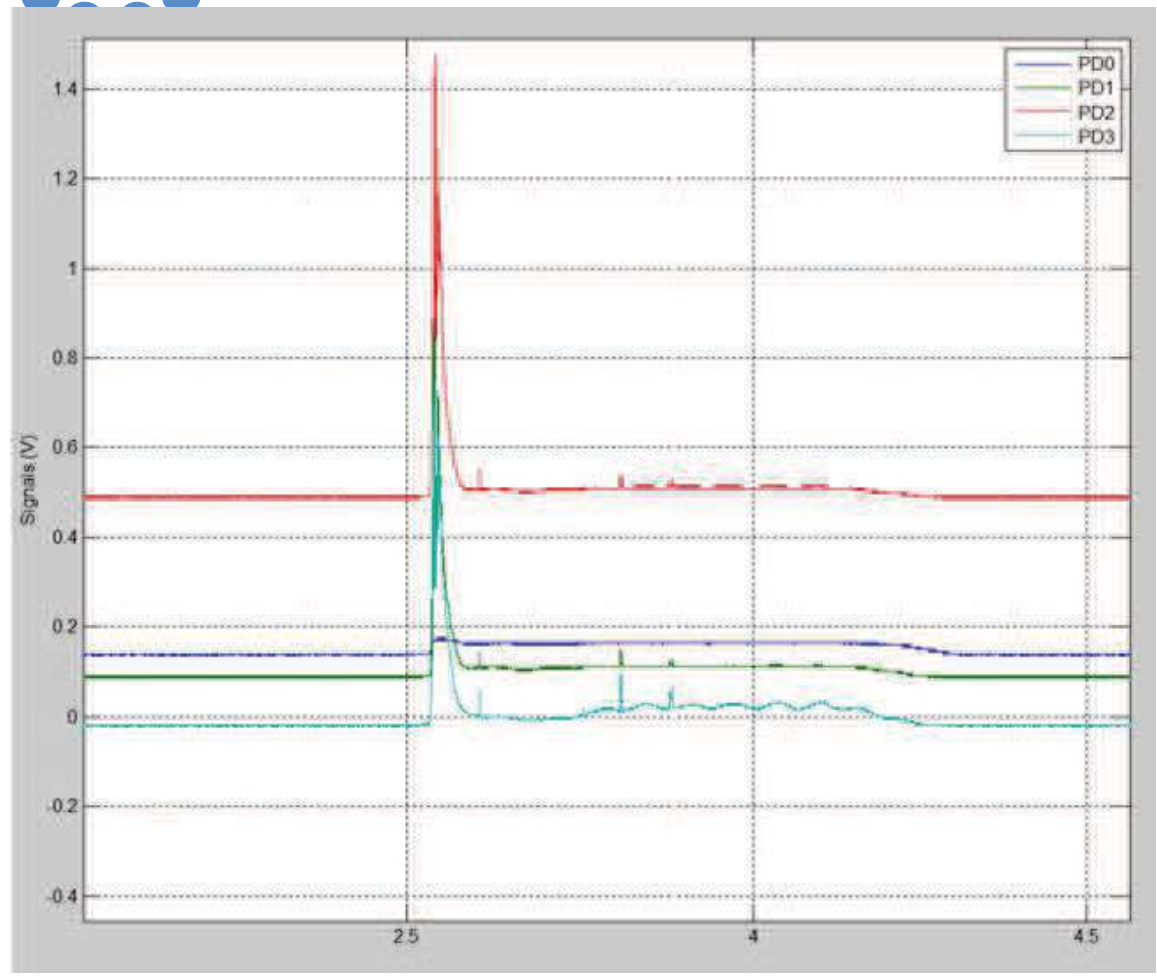
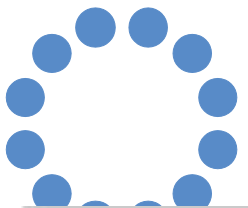


Spectral analysis, forced combustion instability

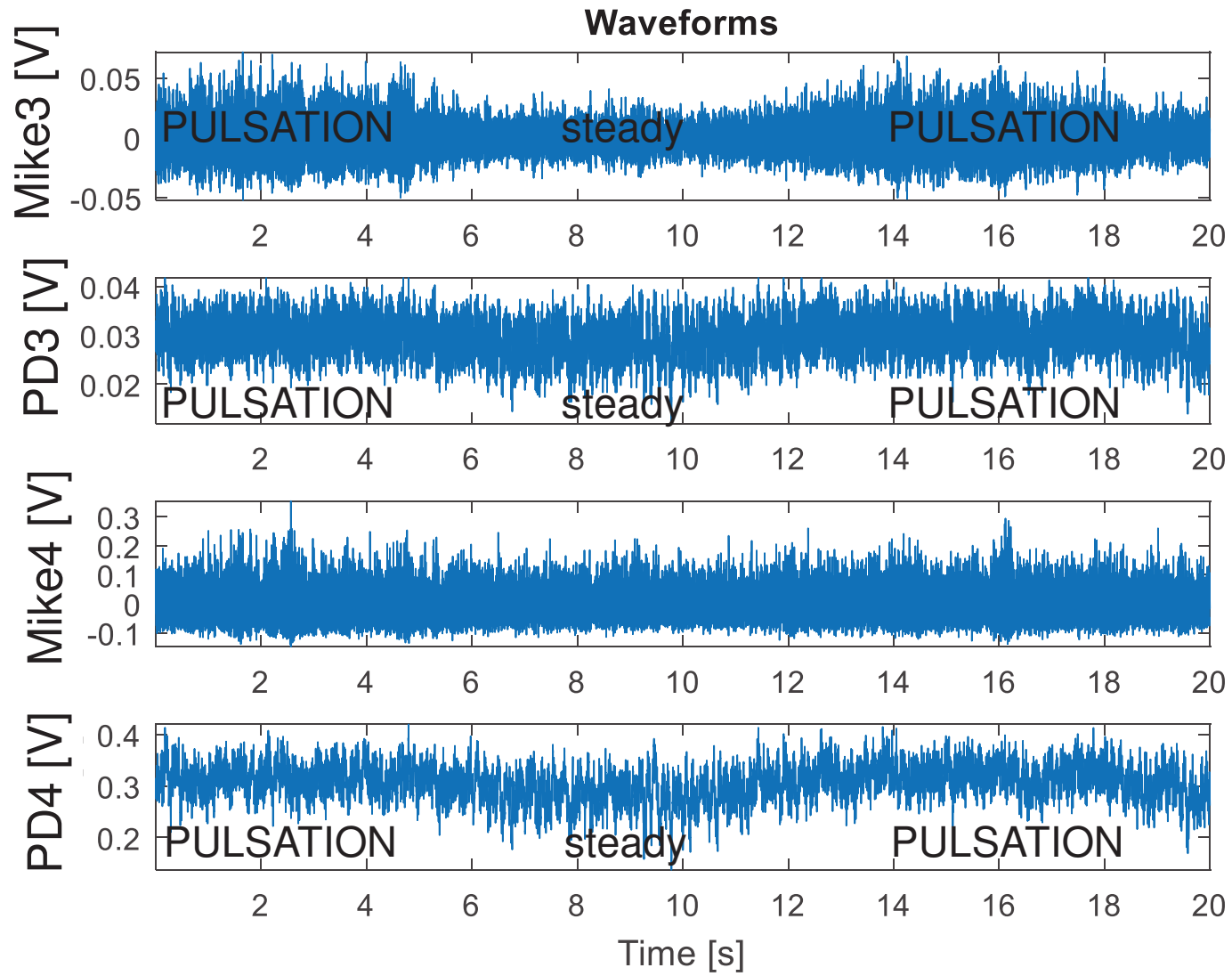
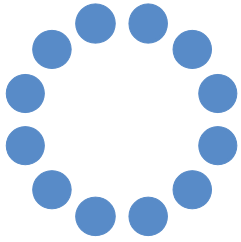


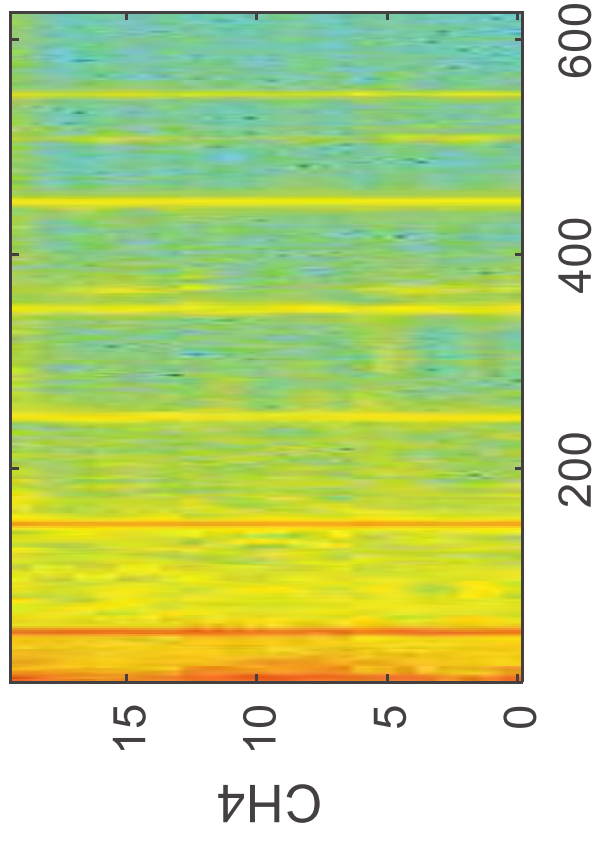
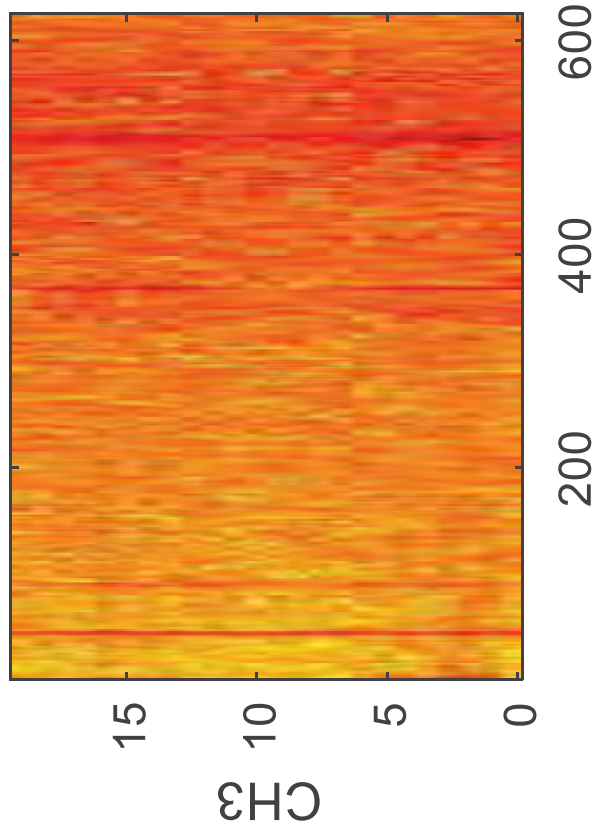
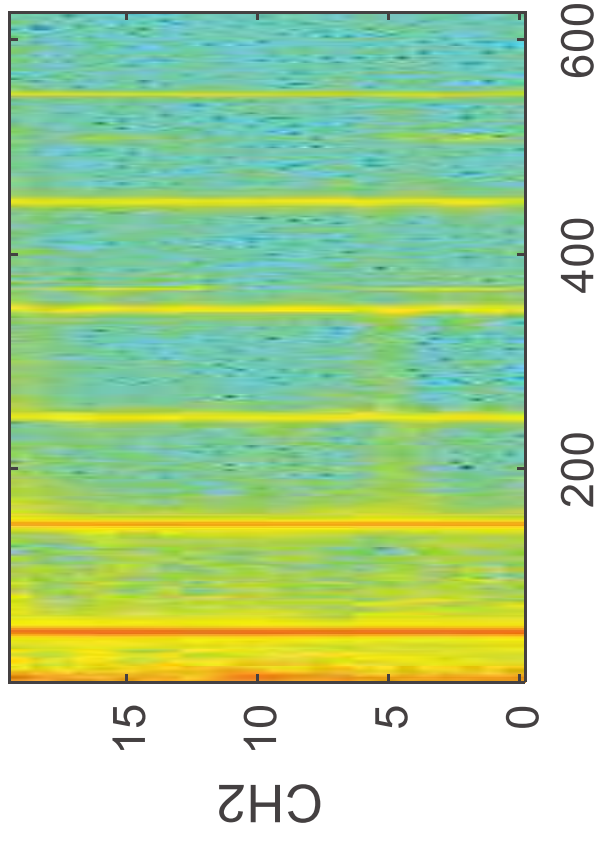
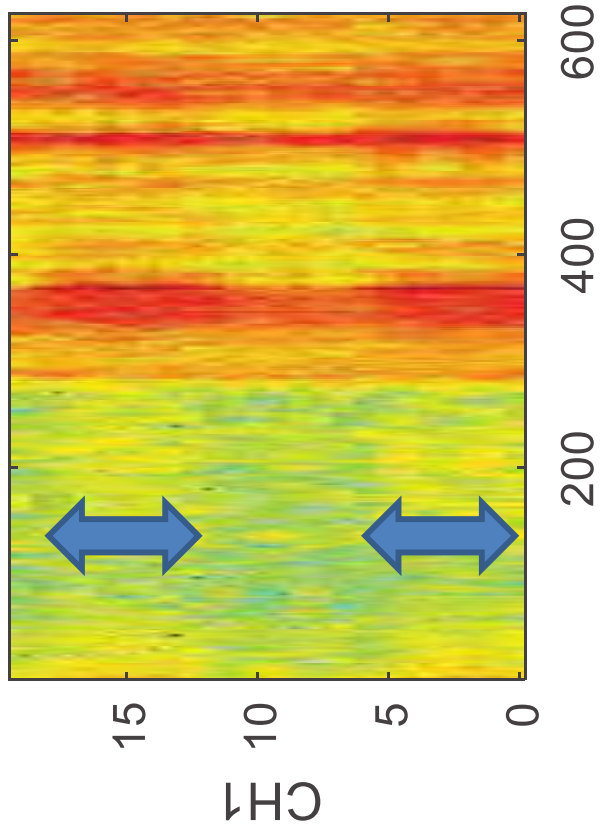
CH0 ... PD with a Wheatstone-Bridge circuit
CH1 ... PD with a reverse direction circuit
CH2 ... PD with a reverse direction circuit

Ignition process



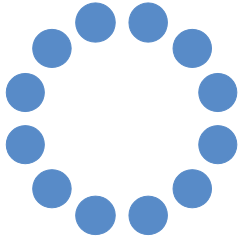
- PD0 ... PD with a Wheatstone-Bridge circuit
- PD1 ... PD with a reverse direction circuit
- PD2 ... PD with a reverse direction circuit and placed in a test tube
- PD3 ... PD with a reverse direction circuit and a different resistor (1.8M Ω instate of 240 k Ω like PD1 and PD2)



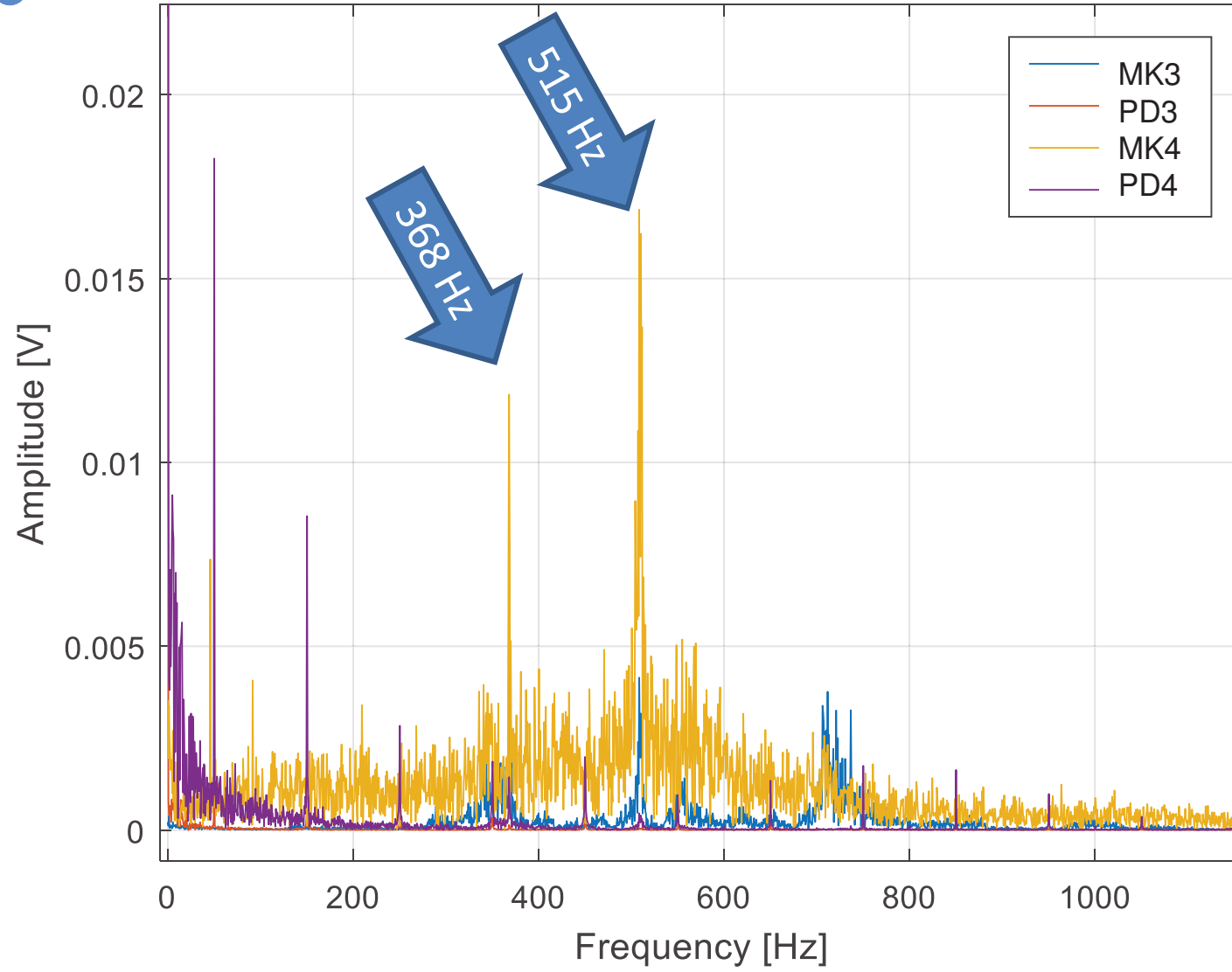


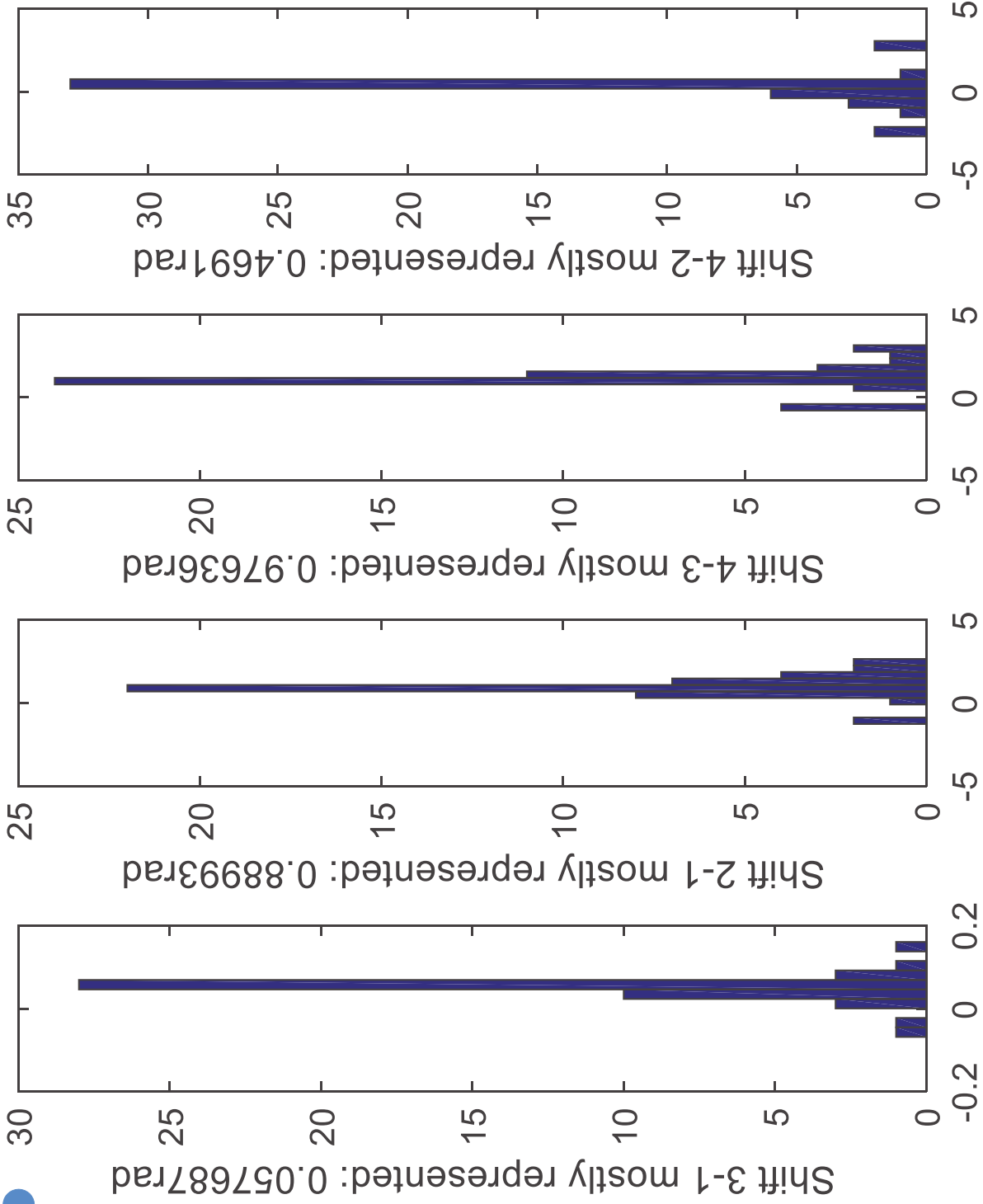
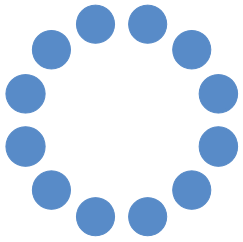
All plots: ordinate time [s]

versus abscissa frequency [Hz]

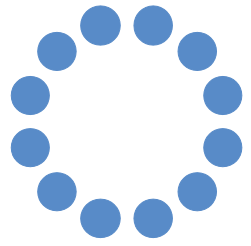


Amplitude spectrum



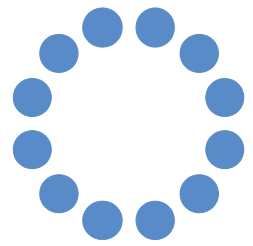


All plots: Phase shift histograms [rad, modulo 2 pi]



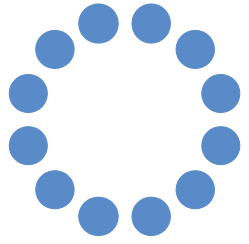
Results

- ✓ Flame detection
 - ✓ Ignition success
 - ✓ Flame load
 - ✓ Flame instability
- + reference signal for modal analysis



Towards **emótiòn** II

- High pressure experiments
- Wavelength-specific diodes -> flame diagnostic
- Advanced integrated optics: optic interface + bandpass filter + Fourier lens
- Packaging -> Probe diameter 6mm inclusive cooling



Conclusion

- Video probe results -> DGLR presentation
- Very positive results on the side of the photosensors type photodiode
 - Patenting
 - One article submitted to ASME Turbo Expo 2017
- Next opportunity for a FFG / Take-off collaborative project: submission early March 2017

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