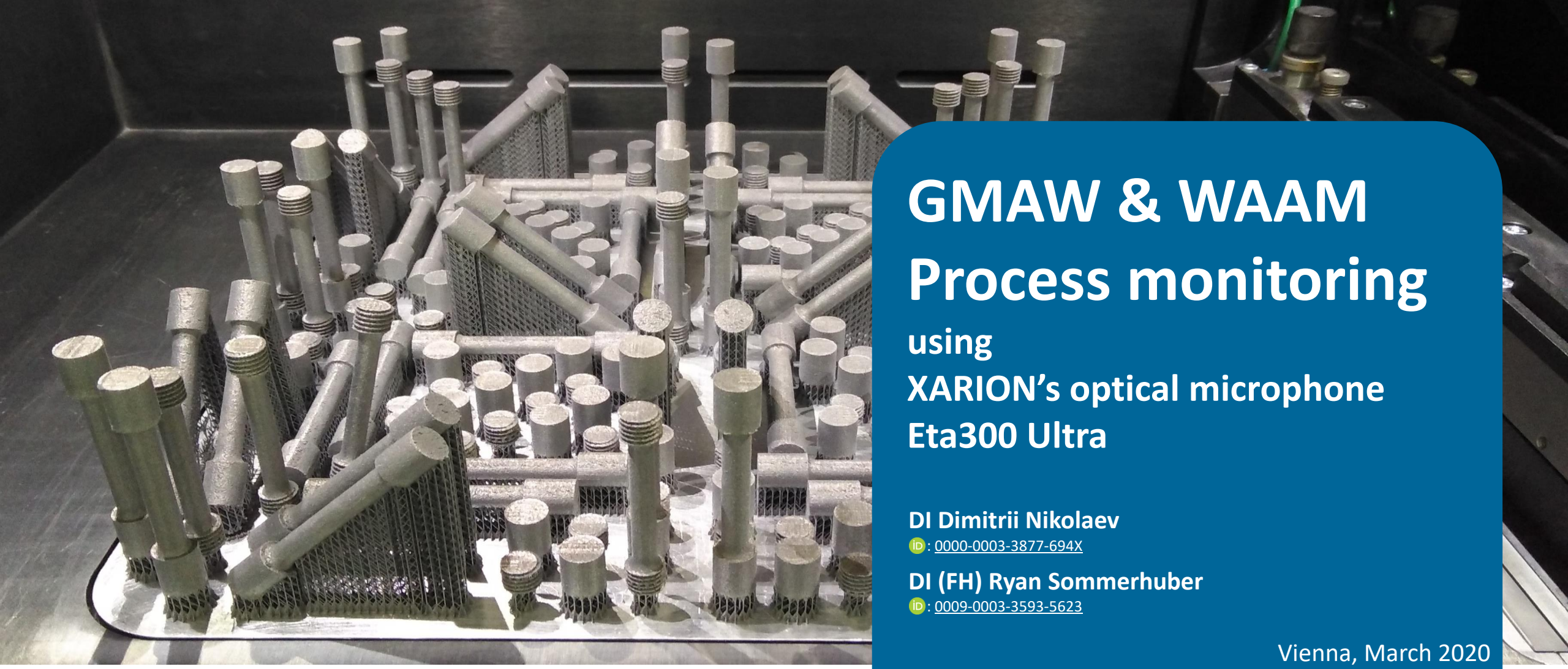


GMAW & WAAM Process monitoring

using XARION's optical microphone Eta300 Ultra

DI Dimitrii Nikolaev
iD: 0000-0003-3877-694X

DI (FH) Ryan Sommerhuber
iD: 0009-0003-3593-5623

Vienna, March 2020

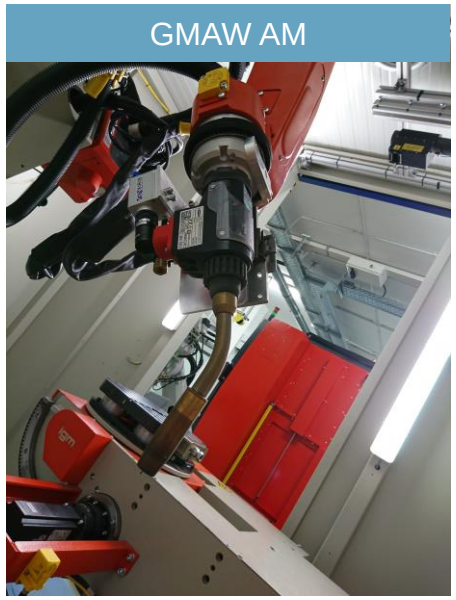
TU WIEN IFT
Institute of Production Engineering and Photonic Technologies
Univ.Prof. Dipl.-Ing. Dr. techn. habil. Friedrich Bleicher

xarion laser acoustics

Motivation| process monitoring for GMAW additive manufacturing

Technology / Process: Metal additive manufacturing (AM) by:

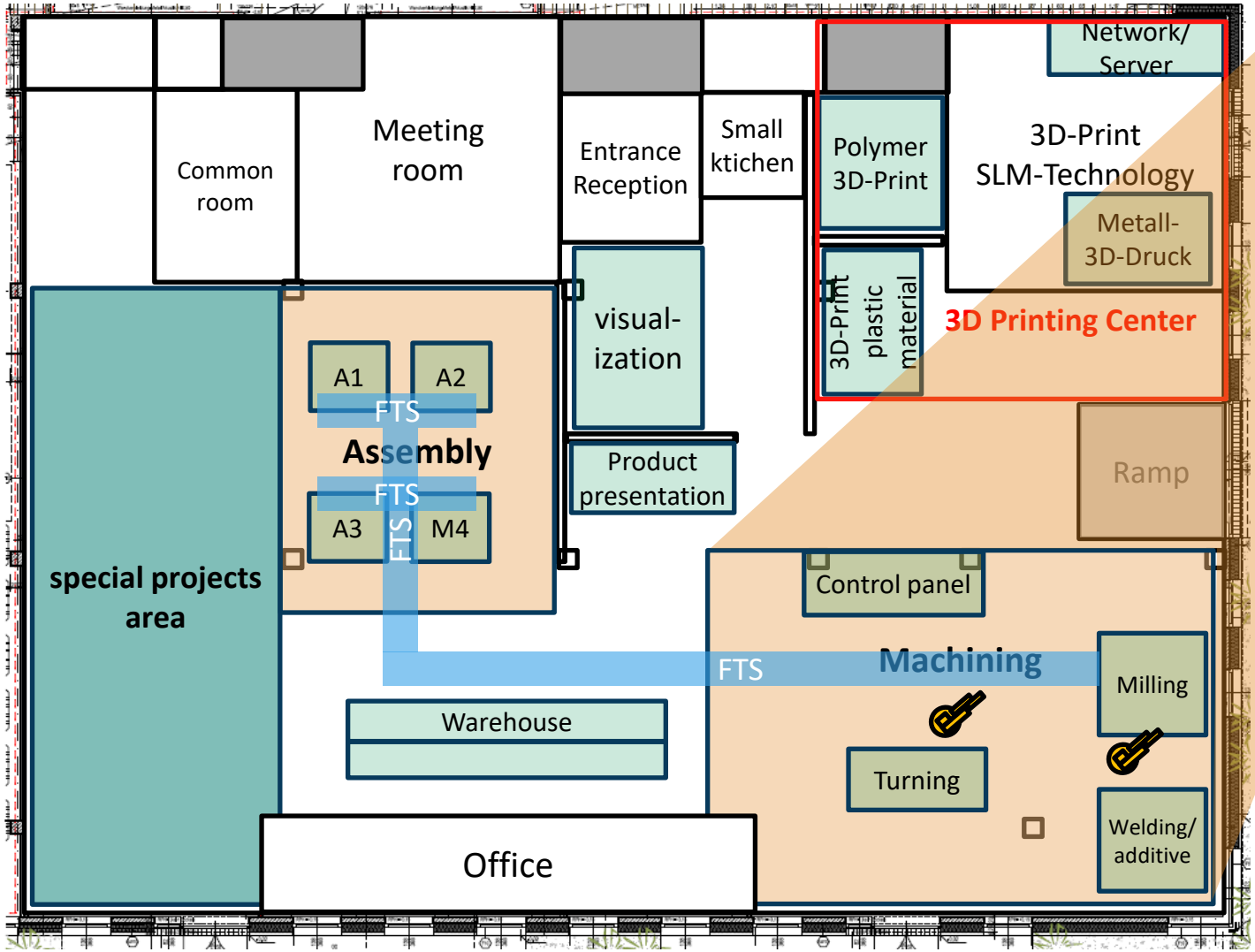
- Wire-based direct energy deposition (DED) by Gas Metal Arc Welding (GMAW), also known as wire and arc additive manufacturing (WAAM)



→ XARION's-sensor could be used for process monitoring [1]

- Crack propagation monitoring may be advantageous for high strength materials [2, 3]

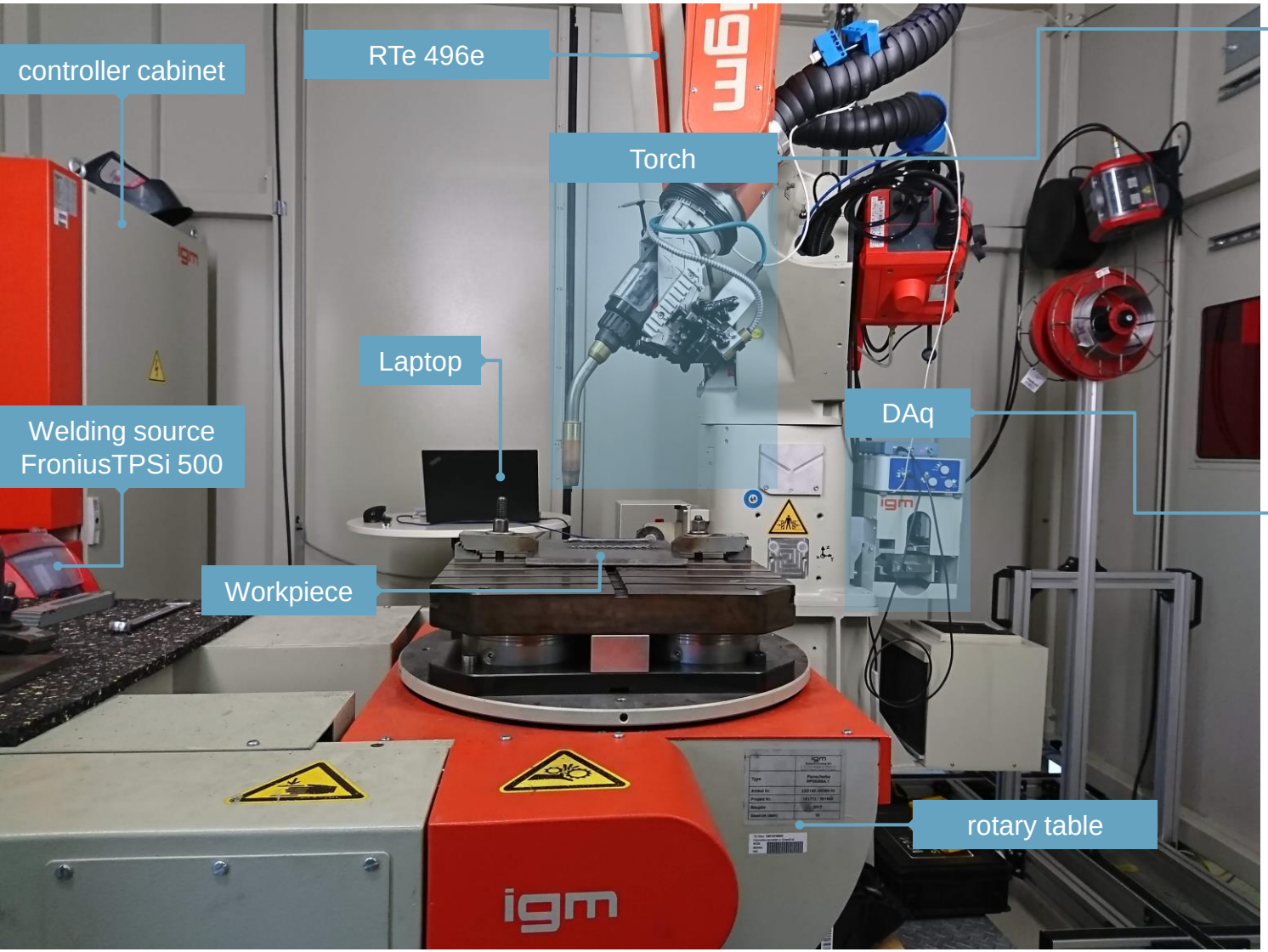
Test Environment | Pilot factory of TU Wien



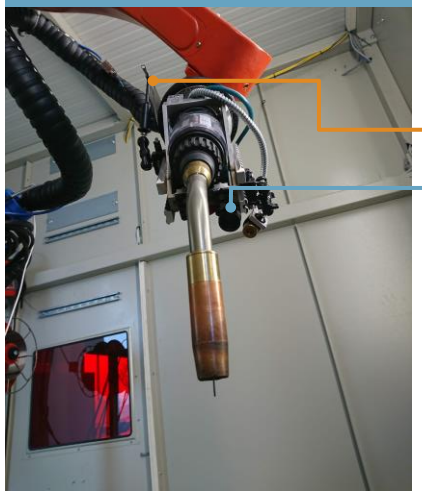
Machining cells with robots and AGV
milling – turning – welding/additive

- 850 m² (9 150 ft²) building space,
- 25 workplaces for scientific staff,
- one conference room

Test rig | Robot welding cell overview and initial measuring setup



Sensors on the torch



XARION's microphone head

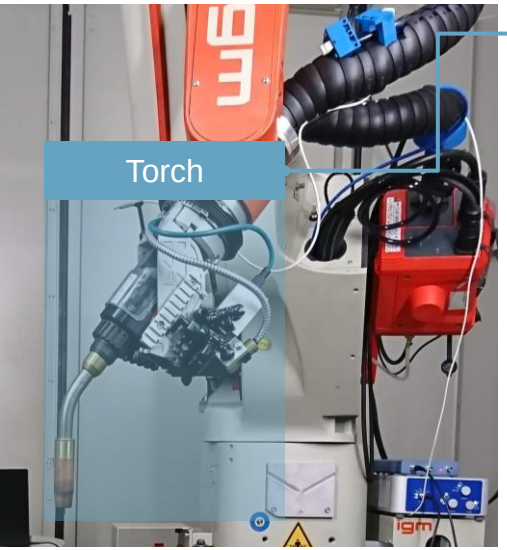
Xiris industrial HDR Camera

DAq - Components

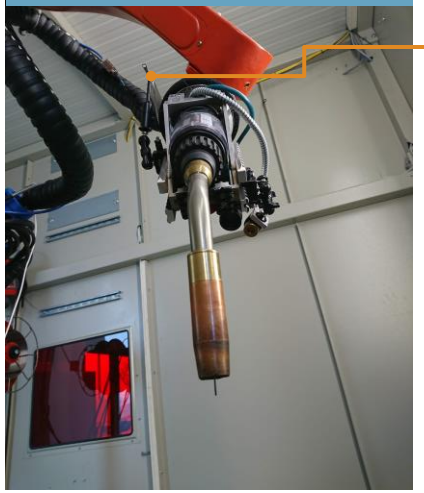
PicoScope 4262 ADC

XARION's microphone controller Eta300 Ultra

Test rig | improved microphone placement

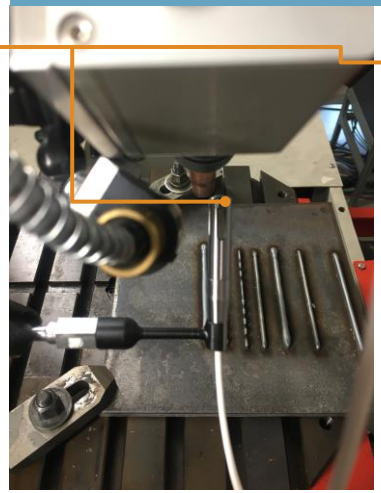


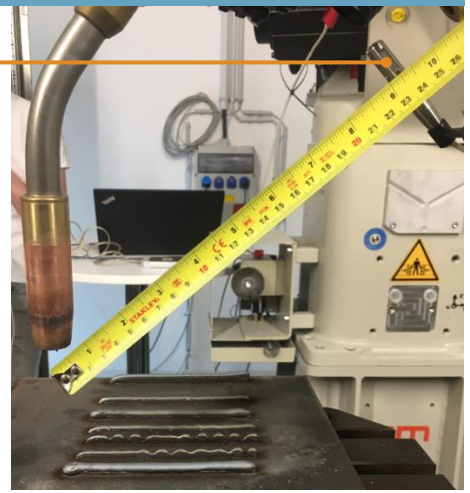
original mic placement



XARION's microphone head

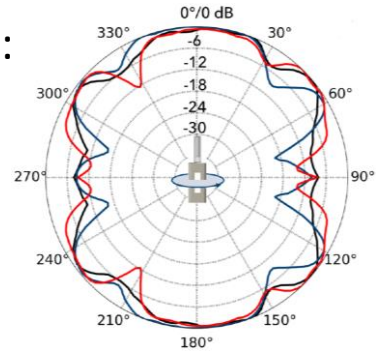
new mic placement

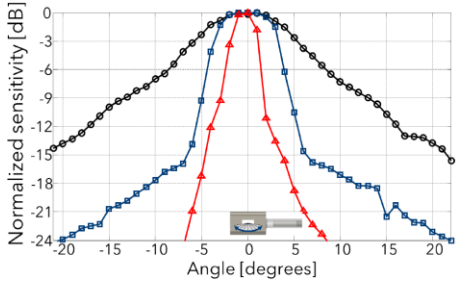




The new position and orientation of the optical microphone were considered:

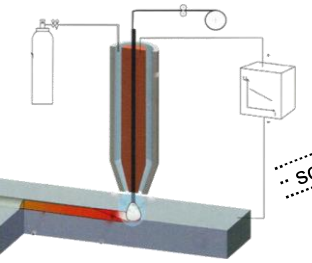
- **direct sight on the arc**
  better utilisation of the microphone's directional response
- **narrower placement**
  reduced impact of acoustic attenuation in air
- **Protection kit**
  to protect the optical microphone head from spatter





Test rig | new DAq chain, sampling rate and resolution

Physical phenomenon:
electrical arc



Microphone

BW: 10 Hz – 1 MHz

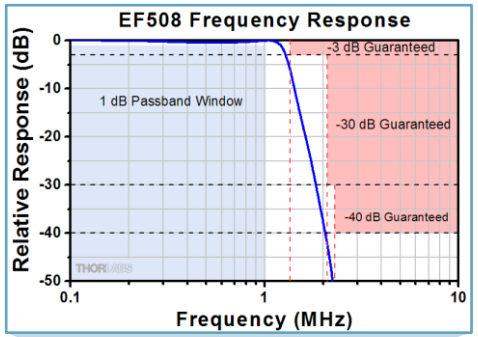
optical fiber

Eta300 ultra

cut-off freq: 10 kHz
gain: -12 dB

AC 1:1
[V_p 15V]

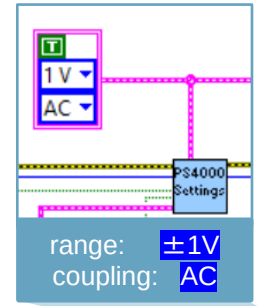
LP-Filter EF508



AC 1:1
[V_p 15V]

PicoScope 4262

USB
[16bit@2MHz]



range: ±1V
coupling: AC

AC 1:10
[V_p 15V]

HF-MES

HF-MES

AC 1:1 or 1:10
BNC-SMB Coax

Pre-amplifier

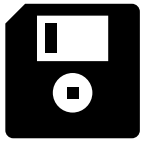
Ethernet cable
AC

ADCs

[25 MHz/ch@16 bit]
[4 MHz@24 bit]

FPGA

FFT
[$F_{res}=f_s/512$]



Environment | Background noise sources

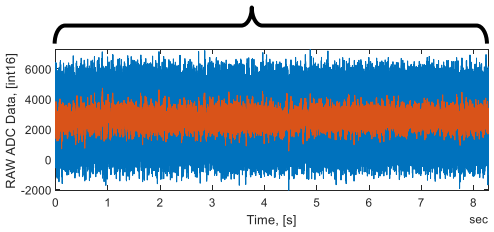
Continuous sources:

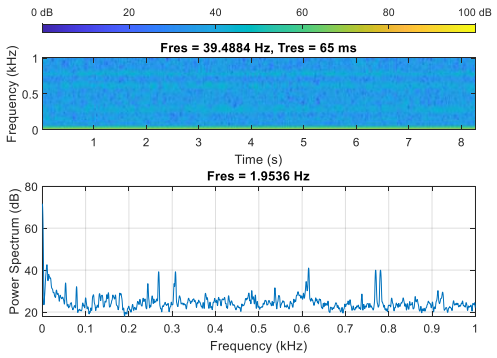
- Coolant pump of the welding source
- Random workshop noise (e.g. hammer impacts, other machines, speech, etc.)

During the welding process:

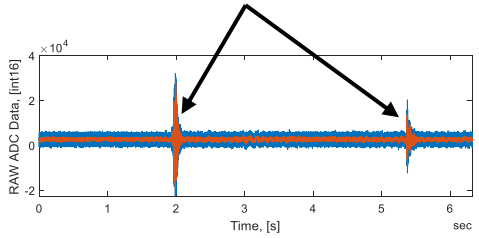
- Fume extraction
- Robot brakes and drives

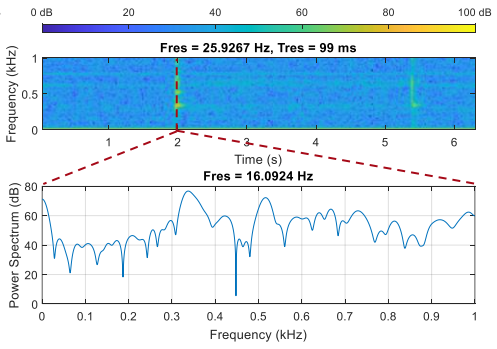
Coolant pump operation, Shop floor noise



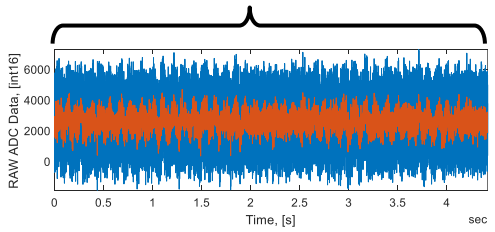


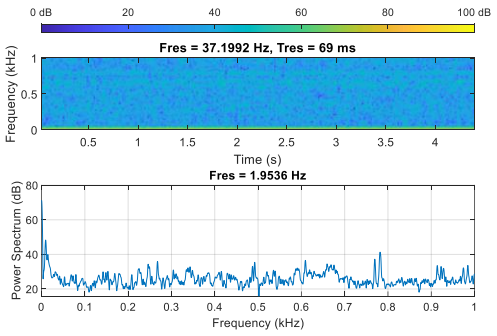
Robot brakes on/off



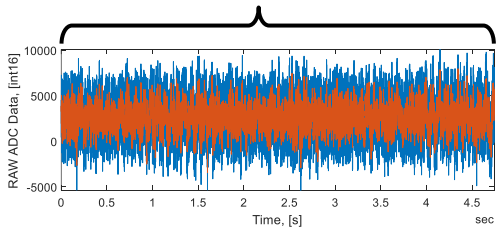


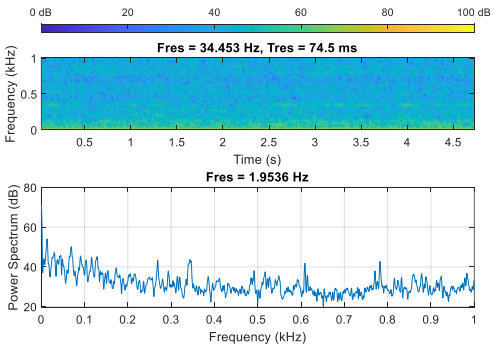
Axis controller operation



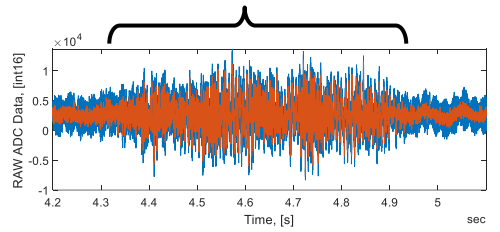


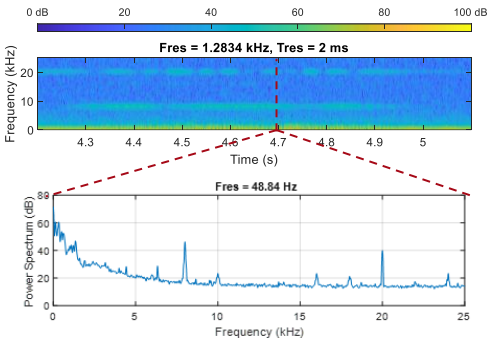
Fume extraction operation





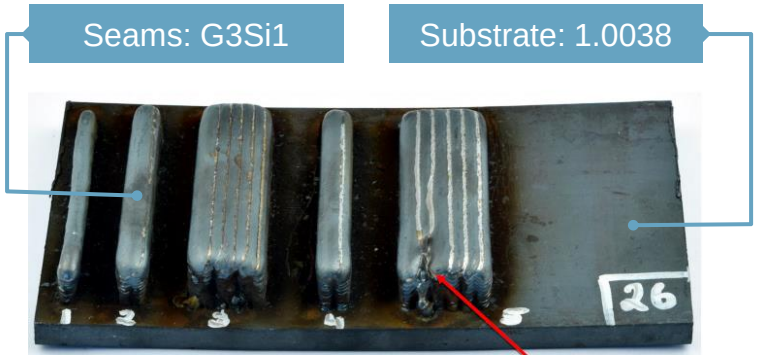
Robot movement





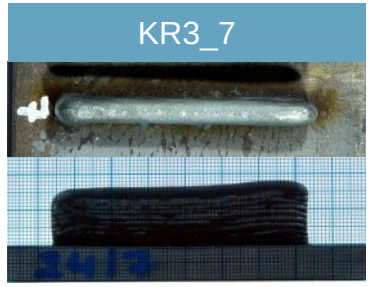
Welding | Materials and process parameters

Grade / Alloy Nr.	Mechanical properties and chemical composition									
G3Si1	Yield strength [MPa]					565				
	Tensile strength [MPa]					455				
	Element	P	Mn	Mo	Cu	S	C	Si	Ni	Cr
	[Vol.%]	0,013	1,46	0,01	0,07	0,012	0,08	0,85	0,04	0,03
1.0038 [DIN EN 10025-2]	Yield strength [MPa]					≥ 235				
	Tensile strength [MPa]					360-510				
	Element	P	Mn	N	Cu	S	C			
	[Vol.%]	0,035	1,40	0,012	0,55	0,035	0,17			

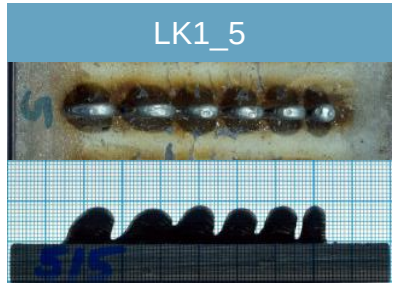


Seam Nr.	Parameter set	Torch speed [cm/min]	Wire Ø [mm]	Wire feedrate [m/min]	Char. line	Gas flowrate [l/min]	Arclength correction [mm]	Dynamic correction ratio
1	KR3_7	20	1,2	2,1	3148	12	0	0
2	LK1_5	80		1,67		12	4	0

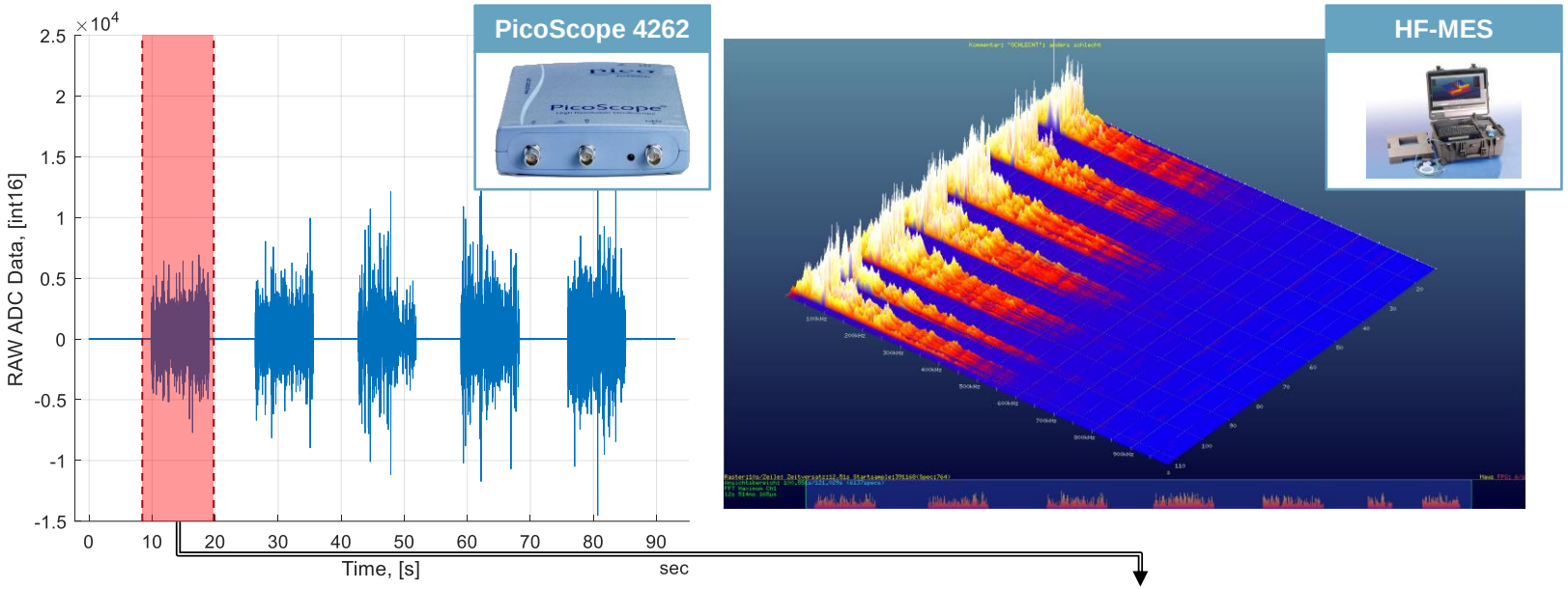
stable process

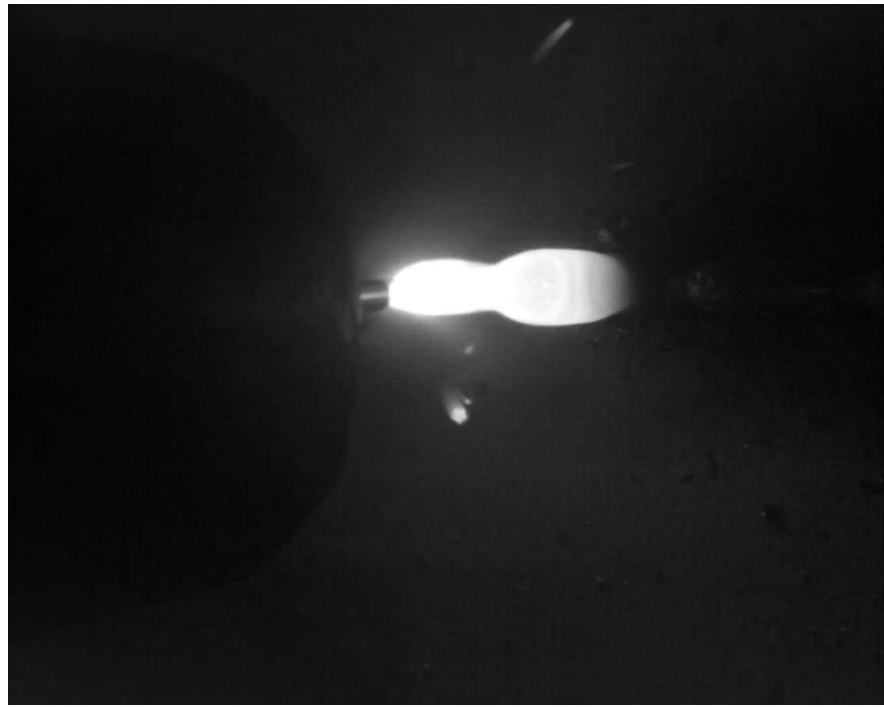


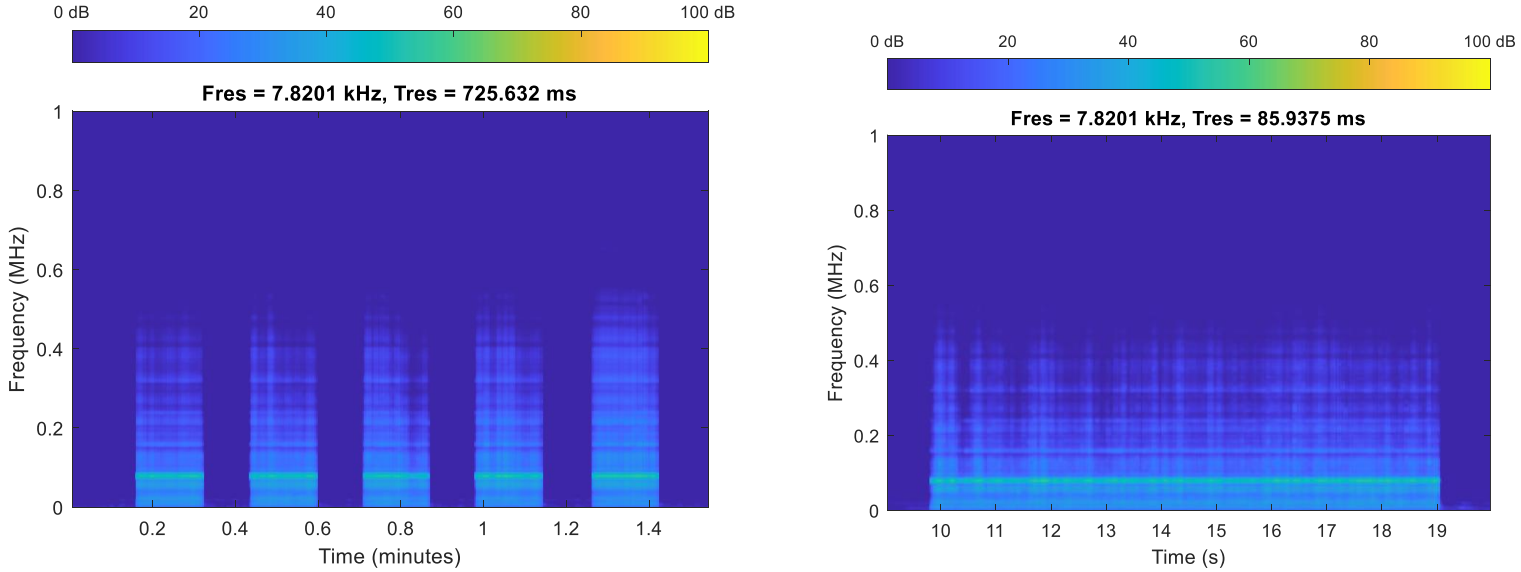
unstable process



Welding | unstable parameter set

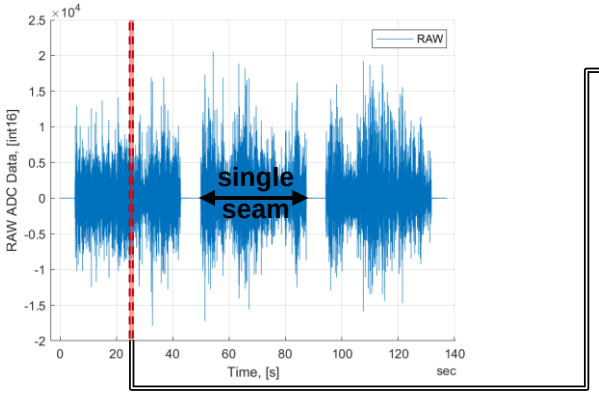


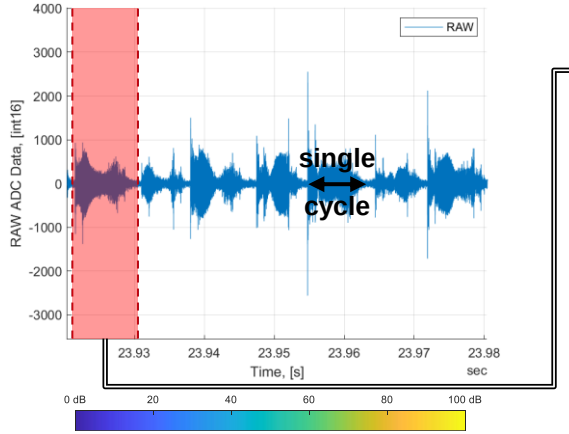


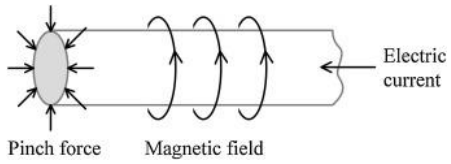


Dataset available under [4]

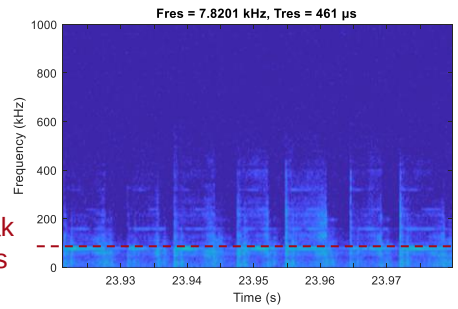
new DAq chain | 80 kHz peak





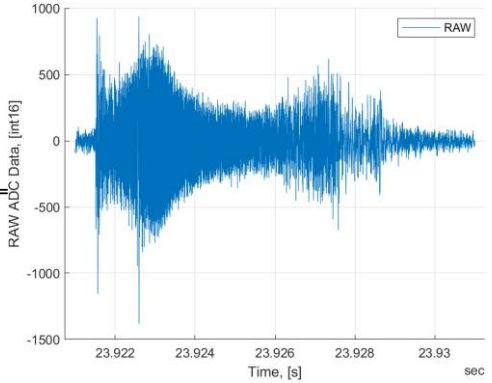


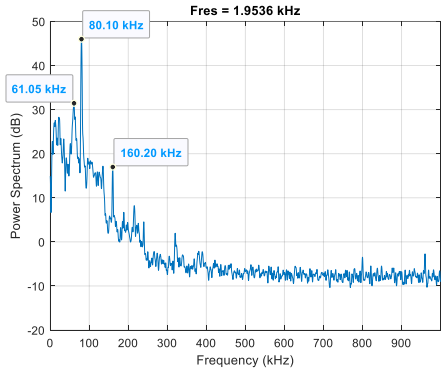
[5]

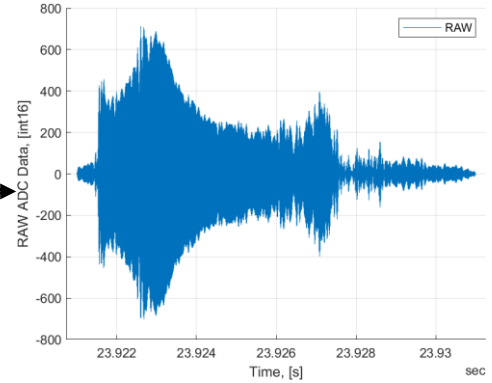


80kHz peak during the process

Bandpass
F_p = 70..90 kHz

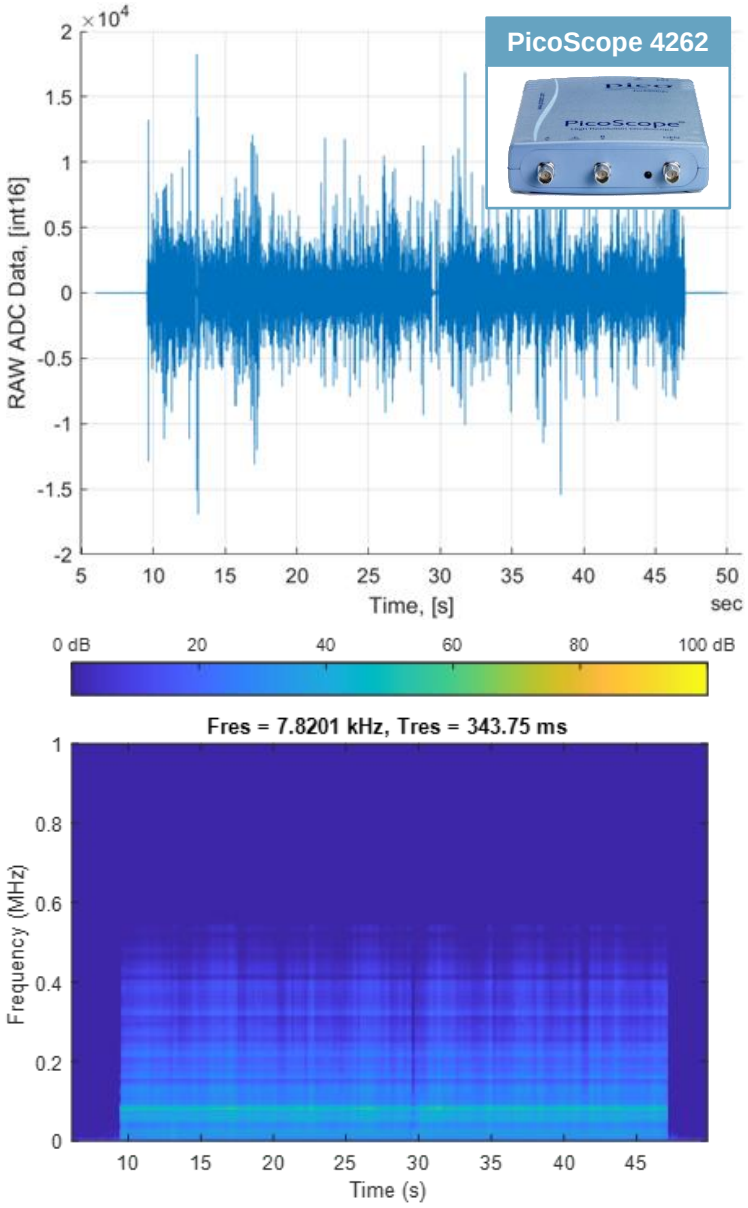


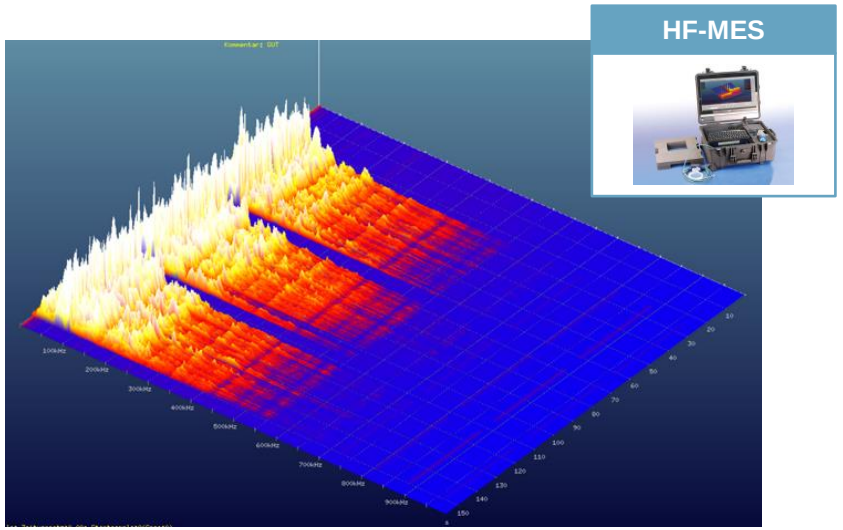


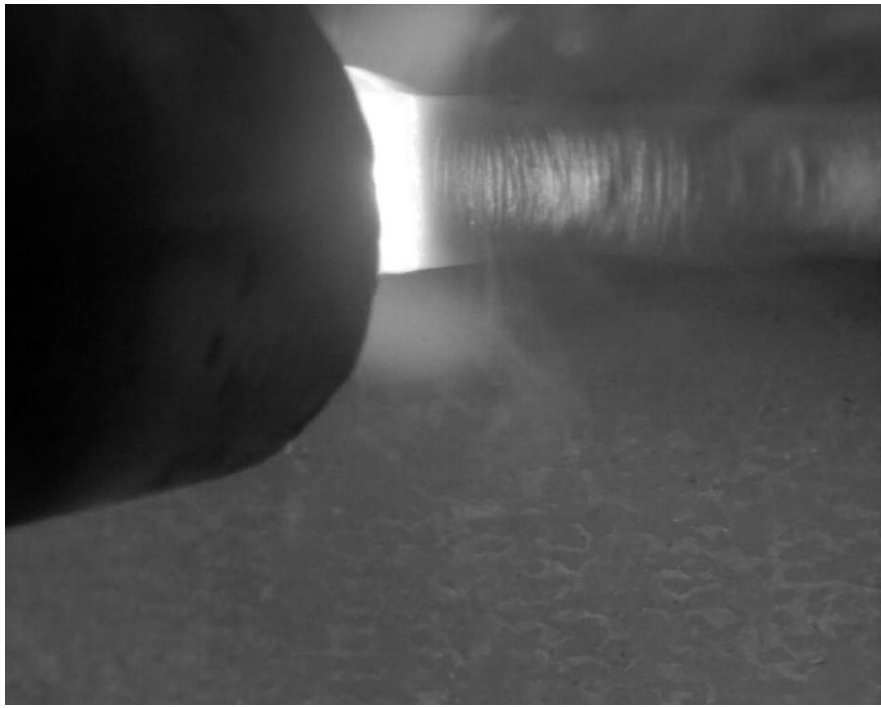


- According to Wang et al. [5], ultra-high-frequency current modulation at up to 80 kHz leads to better droplet formation and smaller size of the drops due to pinch forces.

Welding | stable parameter set







Dataset available under [4]

Conclusio

Measurement setup:

- Background noise has a clear frequency signature
  - → can be filtered out or spread over the whole bandwidth (white noise)
  - → does not affect actual signals
- Microphone placement and orientation have been adjusted to allow measurement in a high-frequency range
- DAq-chain parameters have been adjusted to prevent signal saturation and aliasing
- Performed measurement using two different measuring chains for cross-validation

Process monitoring:

- Process activity can be identified with an optical microphone
- Process (dis-)continuity can be identified with an optical microphone
- Process-related frequencies can also be detected in a high frequency range up to ~580 kHz
- A clear peak (detected at 80 kHz) is related to the modulation of the arc current for better droplet formation.
- A difference in the stability of the acoustic spectrogram between stable and unstable MAG welding processes was detectable using XARION's Eta300 Ultra technology

References

[1] L. Grad, J. Grum, I. Polajnar, and J. Marko Slabe, ‘Feasibility study of acoustic signals for on-line monitoring in short circuit gas metal arc welding’, *International Journal of Machine Tools and Manufacture*, vol. 44, no. 5, pp. 555–561, Apr. 2004, doi: 10.1016/j.ijmachtools.2003.10.016.

[2] Z. Han, H. Luo, J. Cao, and H. Wang, ‘Acoustic emission during fatigue crack propagation in a micro-alloyed steel and welds’, *Materials Science and Engineering: A*, vol. 528, no. 25–26, pp. 7751–7756, Sep. 2011, doi: 10.1016/j.msea.2011.06.065.

[3] T. M. Roberts and M. Talebzadeh, ‘Acoustic emission monitoring of fatigue crack propagation’, *Journal of Constructional Steel Research*, vol. 59, no. 6, pp. 695–712, Jun. 2003, doi: 10.1016/S0143-974X(02)00064-0.

[4] D. Nikolaev and R. Sommerhuber, ‘GMAW & WAAM Process monitoring using XARION Eta300 Ultra laser microphone’. Zenodo, Mar. 02, 2020. doi: 10.5281/ZENODO.7768265.

[5] D. Wang, C. Wu, Y. Suo, L. Wang, and Z. Liang, ‘Effect of pulse frequency on arc behavior and droplet transfer of 2198 Al–Li alloy by ultrahigh-frequency pulse AC CMT welding’, *Journal of Materials Research and Technology*, vol. 8, no. 5, pp. 3950–3958, Sep. 2019, doi: 10.1016/j.jmrt.2019.07.003.

Contact

TU Wien
Institute of Production Engineeringand Photonic Technologies

Getreidemarkt 9/BA/8 OG
1060 Vienna
AUSTRIA

T +43 1 58801 31101
E office@ift.at

XARION Laser Acoustics GmbH

Ghegastrasse 3
1030 Vienna
Austria

T +43 1 9076076 0
E opticalmicrophones@xarion.com