# Investigation of sound fields in ultrasound cleaning baths and correlation with the erosion effect

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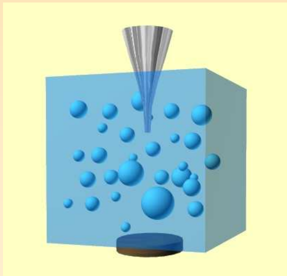
# Motivation

## Sound field



## Cavitation

## Effect

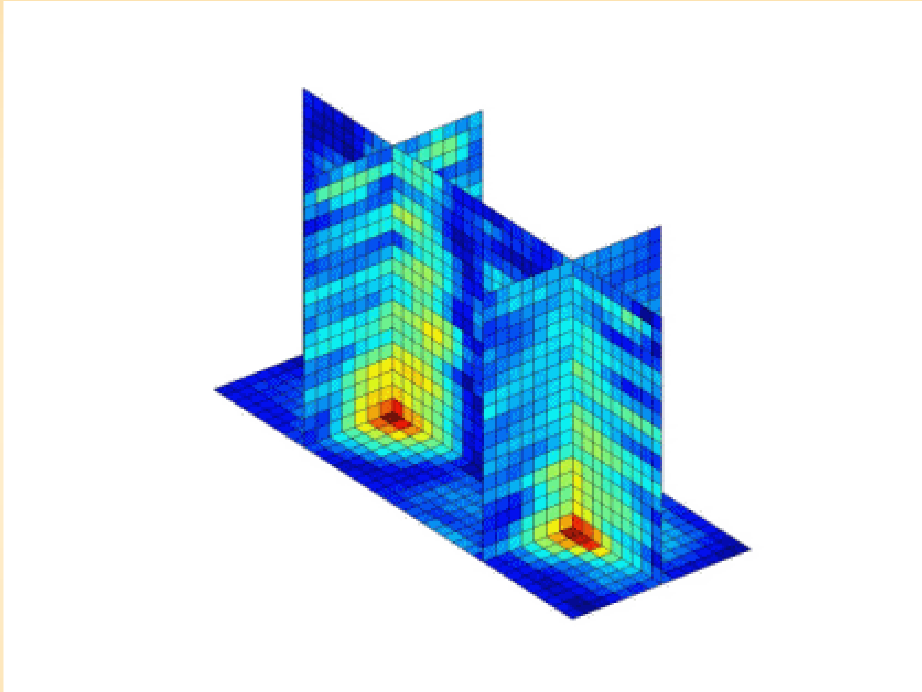
- geometry
- excitation

- complex
- N- particle interaction
- stochastic

- no principles
- no optimization
- empirical

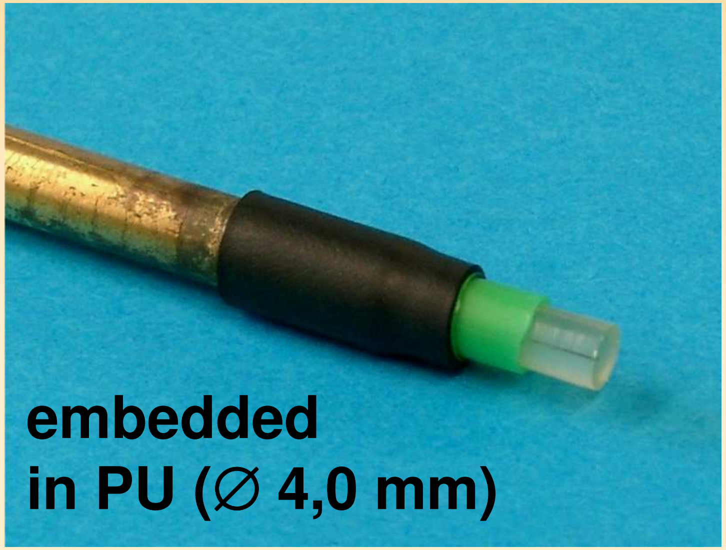
# Topics

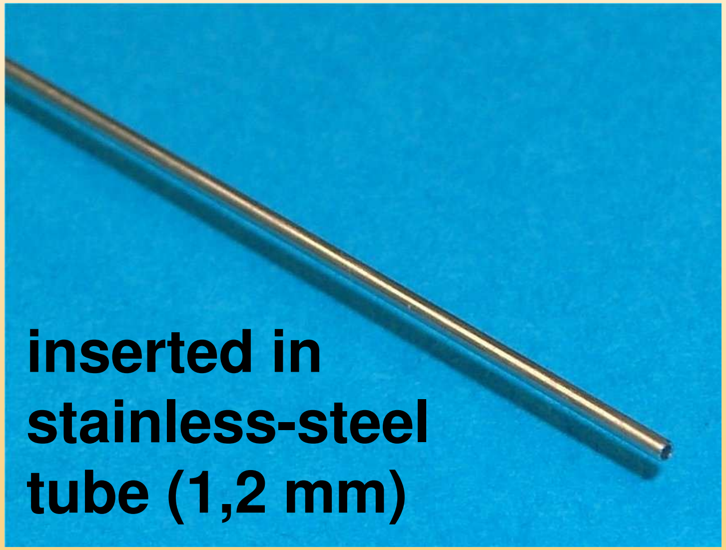
- Sensor principles
- Determination of spectral parameters
- Quantification of the cleaning effect
- Correlation between sound field parameters and erosion
- Conclusions



# Sensors

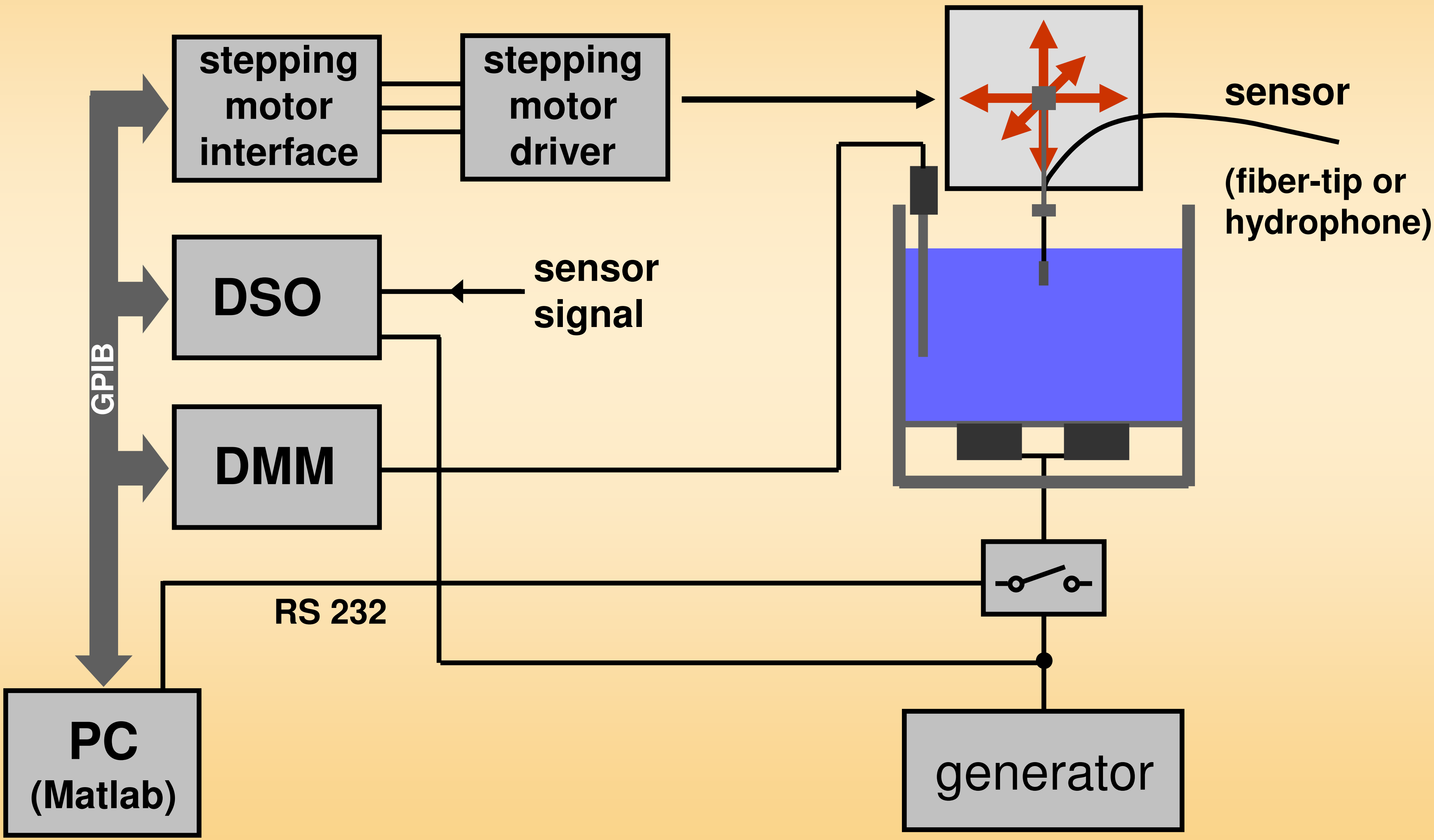
## Fiber-Sensors



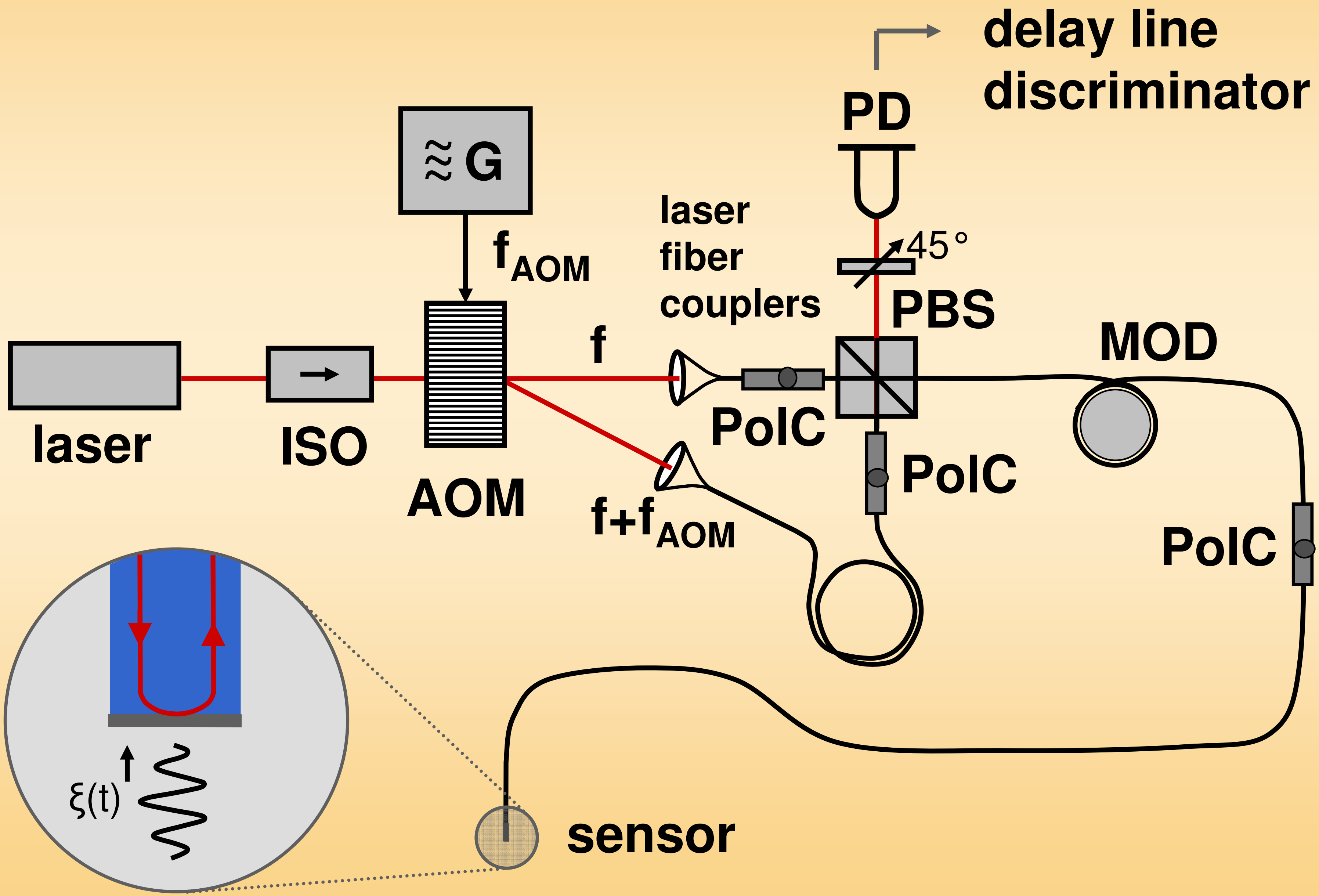




## Hydrophones

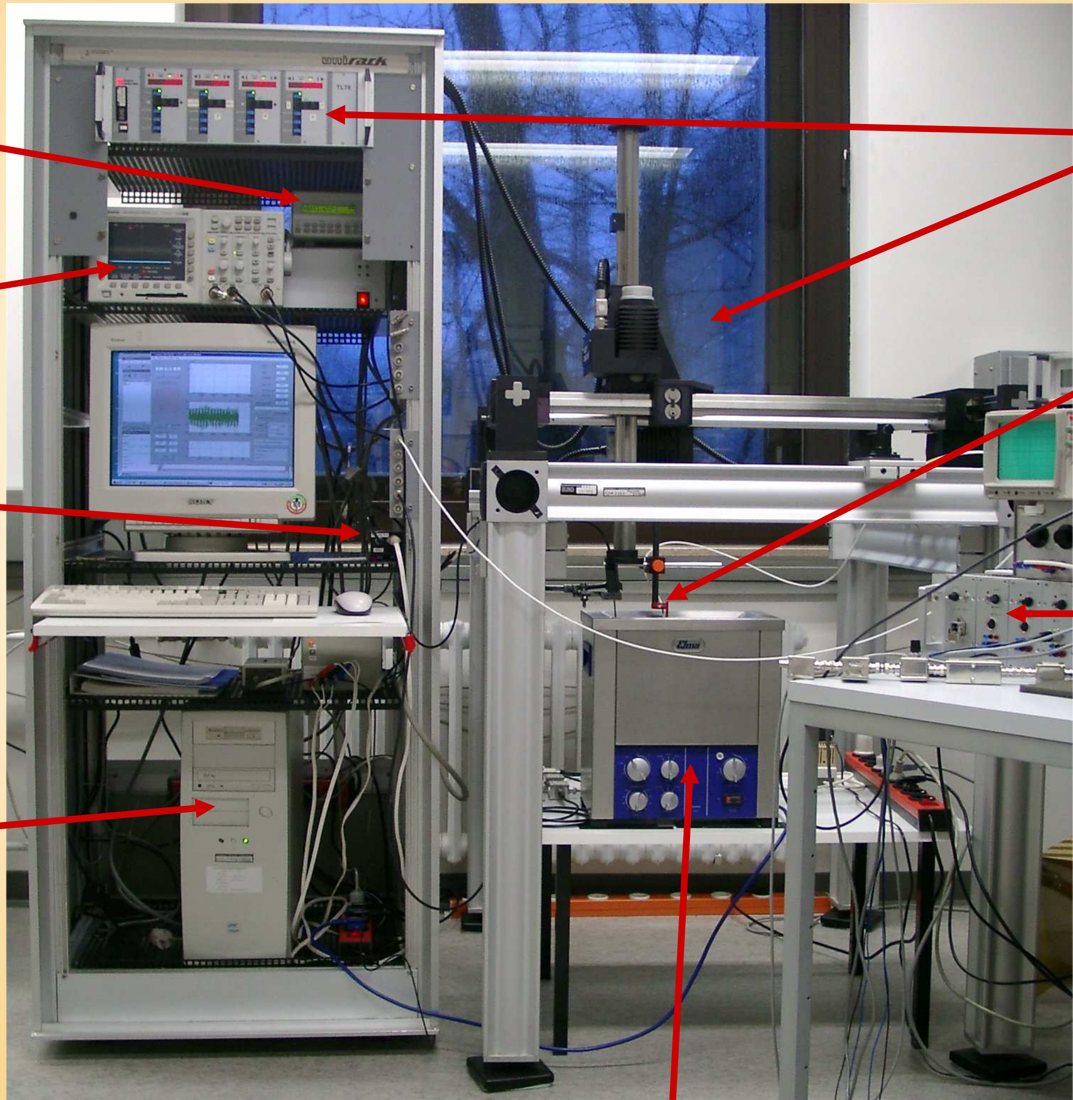

# 3D-Scanning-System



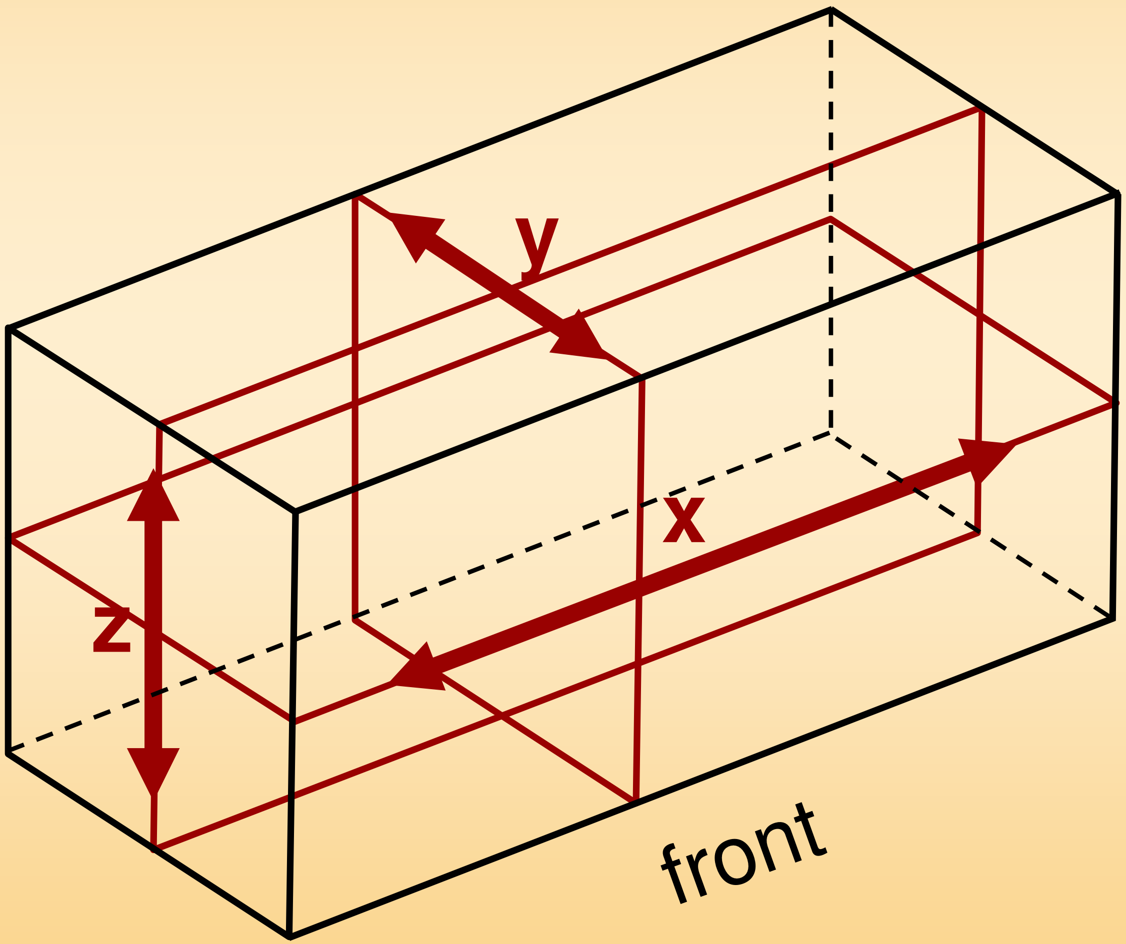
# Heterodyne Interferometer



# Experimental setup



# Orientation of scan planes

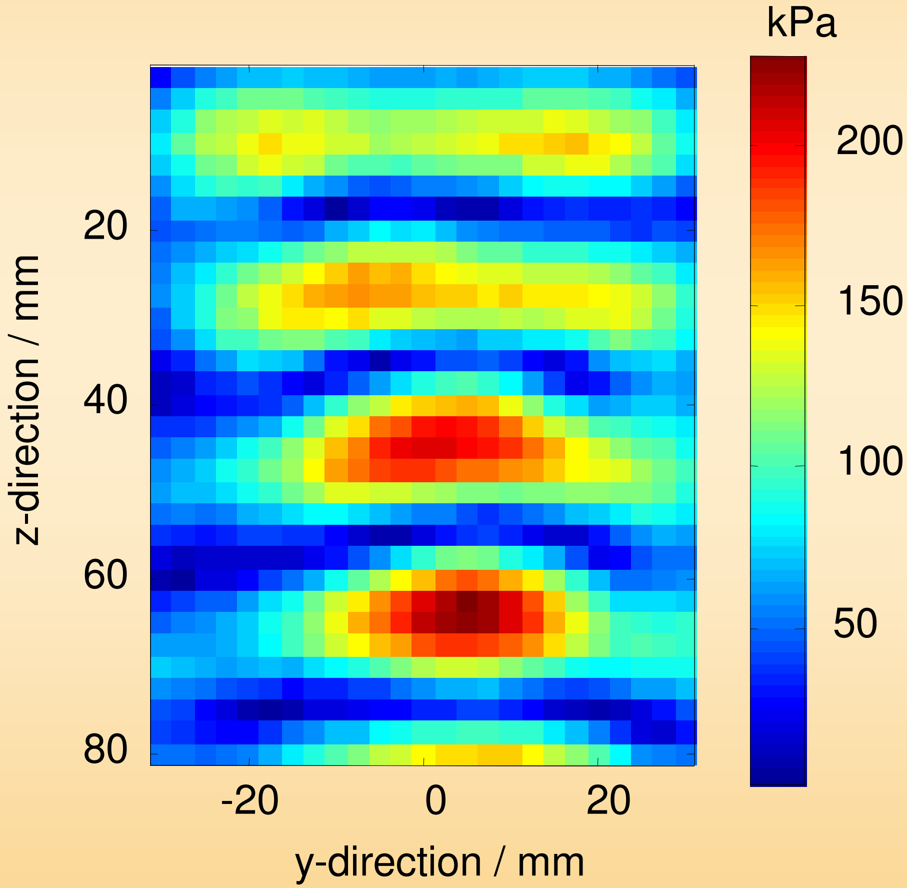



**Control of measurement conditions by:**

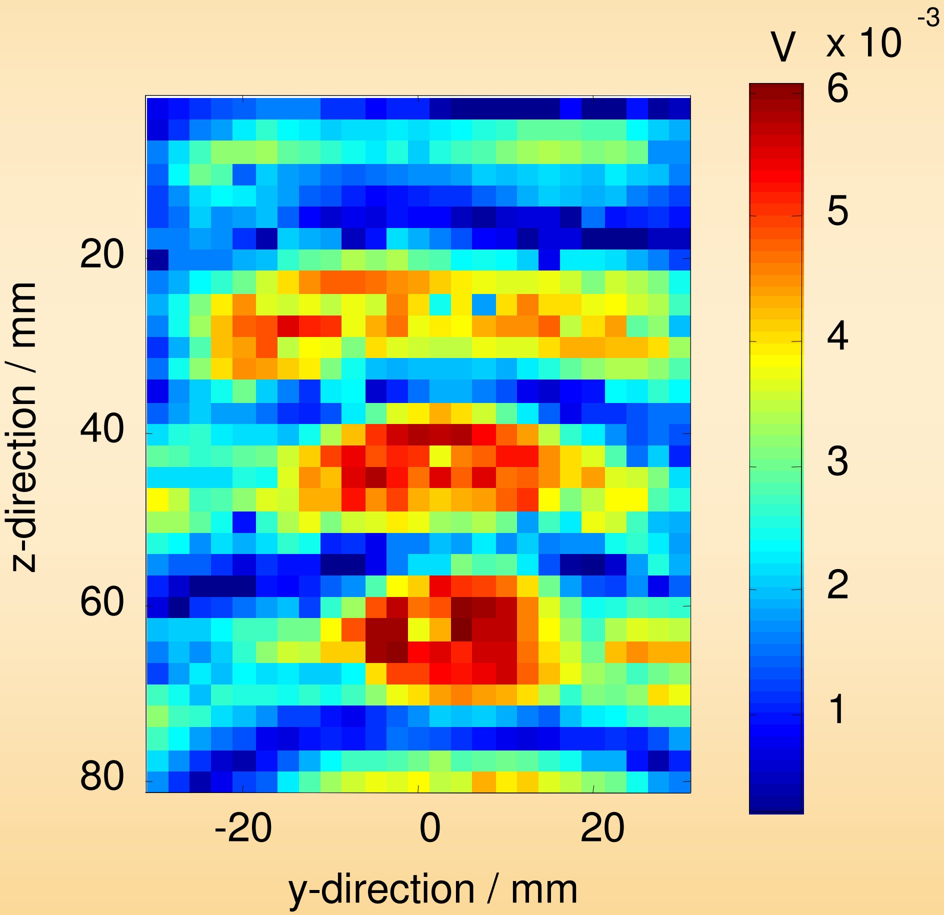
- **external excitation**
- **controlled temperature**
- **stabilized water level**
- **calmed water surface**

# Comparison of sensor principles

**$f_0$ - Hydrophone B&K 8103**

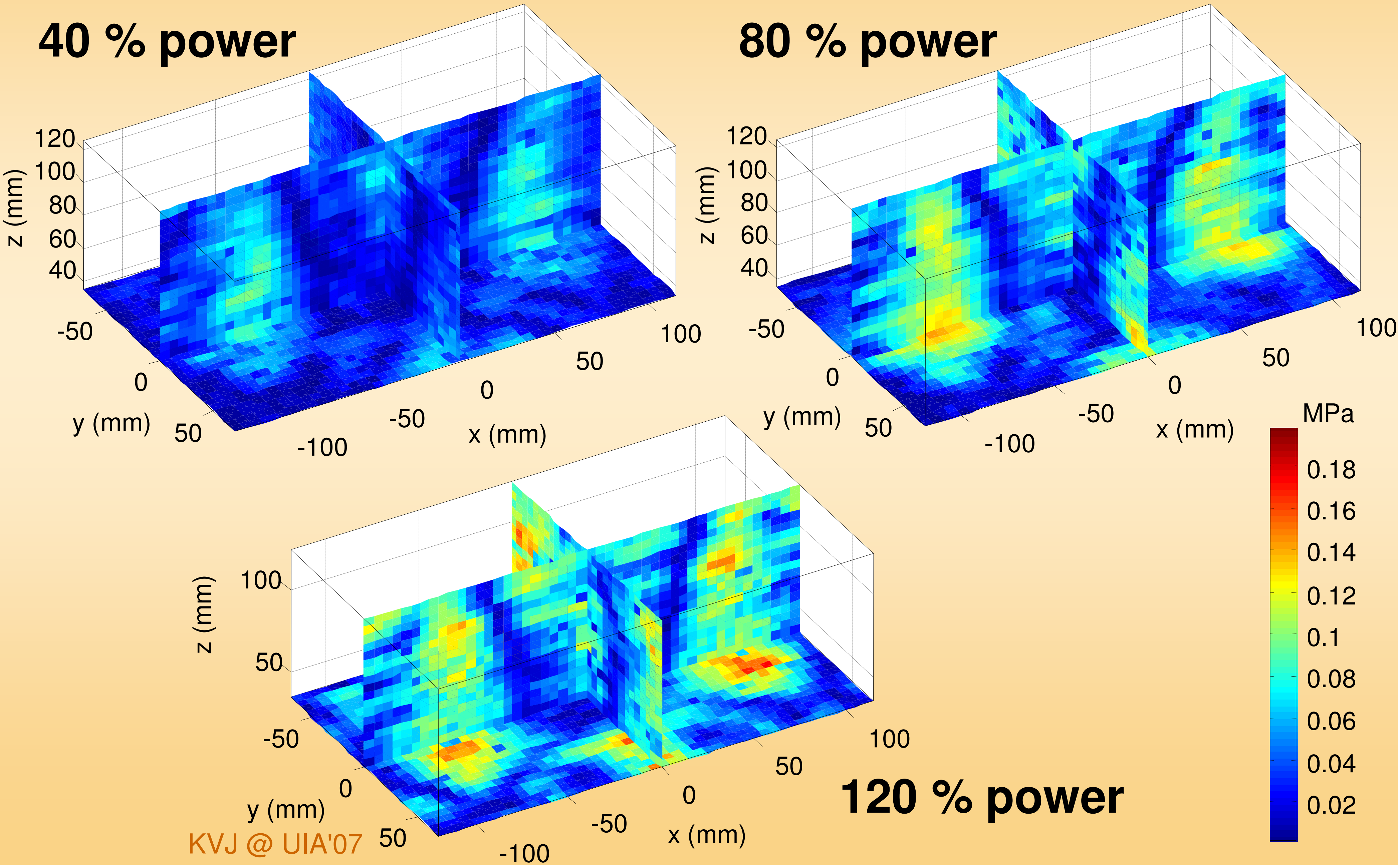



**$f_0$ - Fiber Sensor (steel tube)**

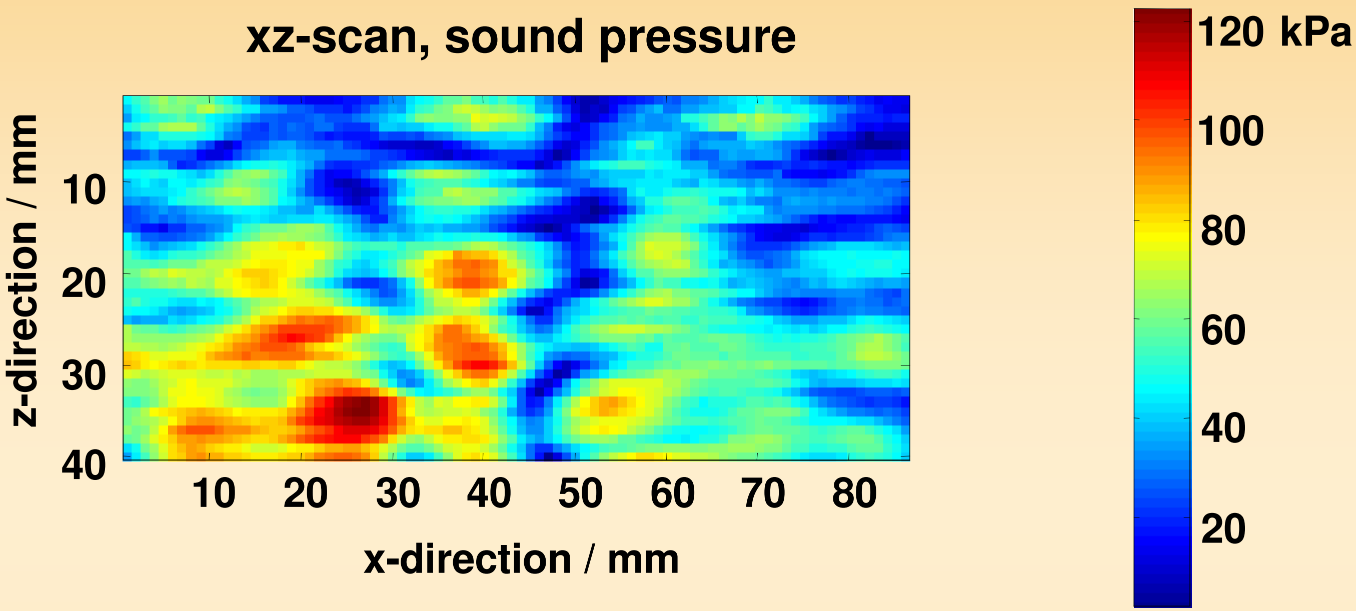


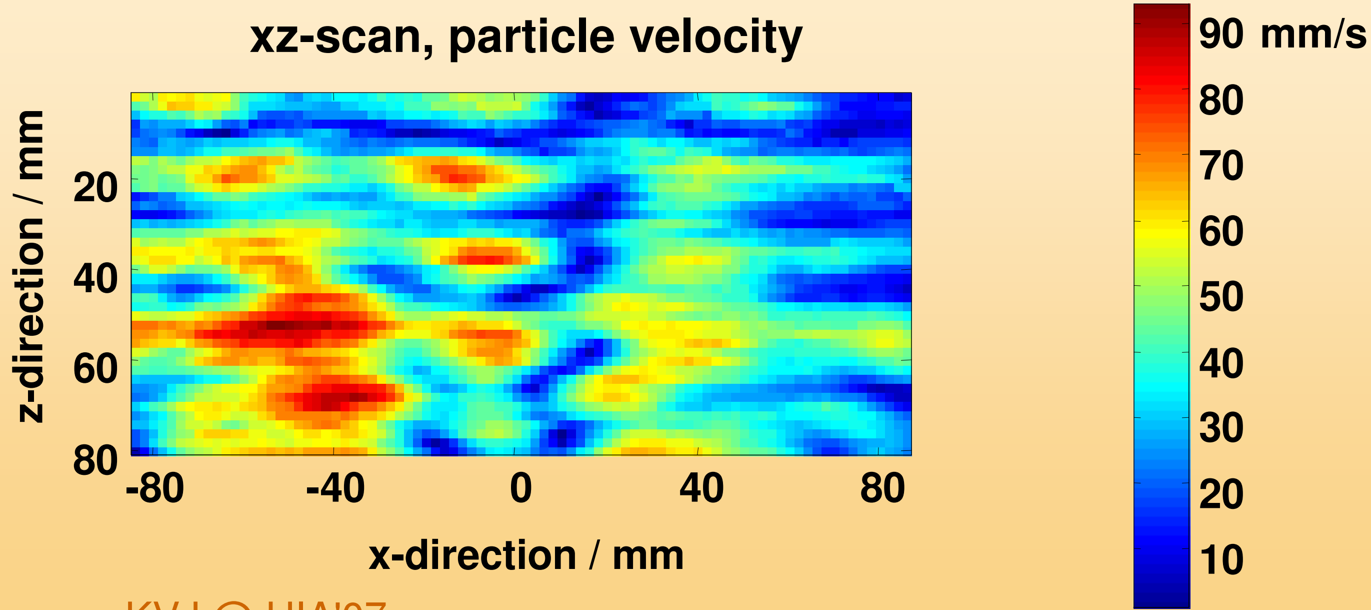
# Sound Field and Powerlevel

**Elma T760/DH**
**$f_0$=45 kHz**



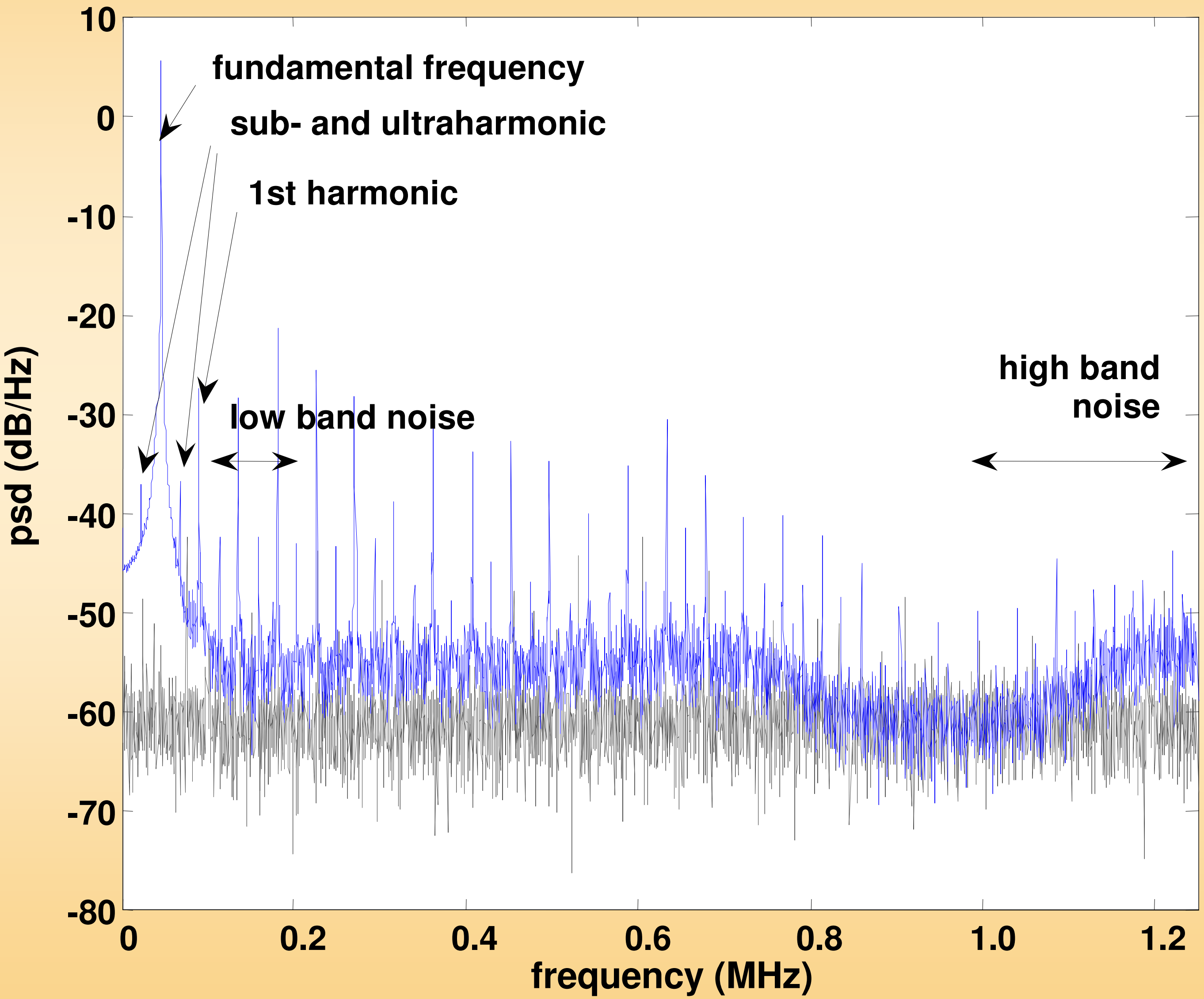
# Quasi-simultaneous acquisition of sound pressure and particle velocity




$f_0$=45 kHz
Elma TI-H-5

# Spectral parameters




**Sound pressure of the**
- **Fundamental**
- **Harmonic**
- **Sub-harmonic and**
- **Ultra-harmonic**

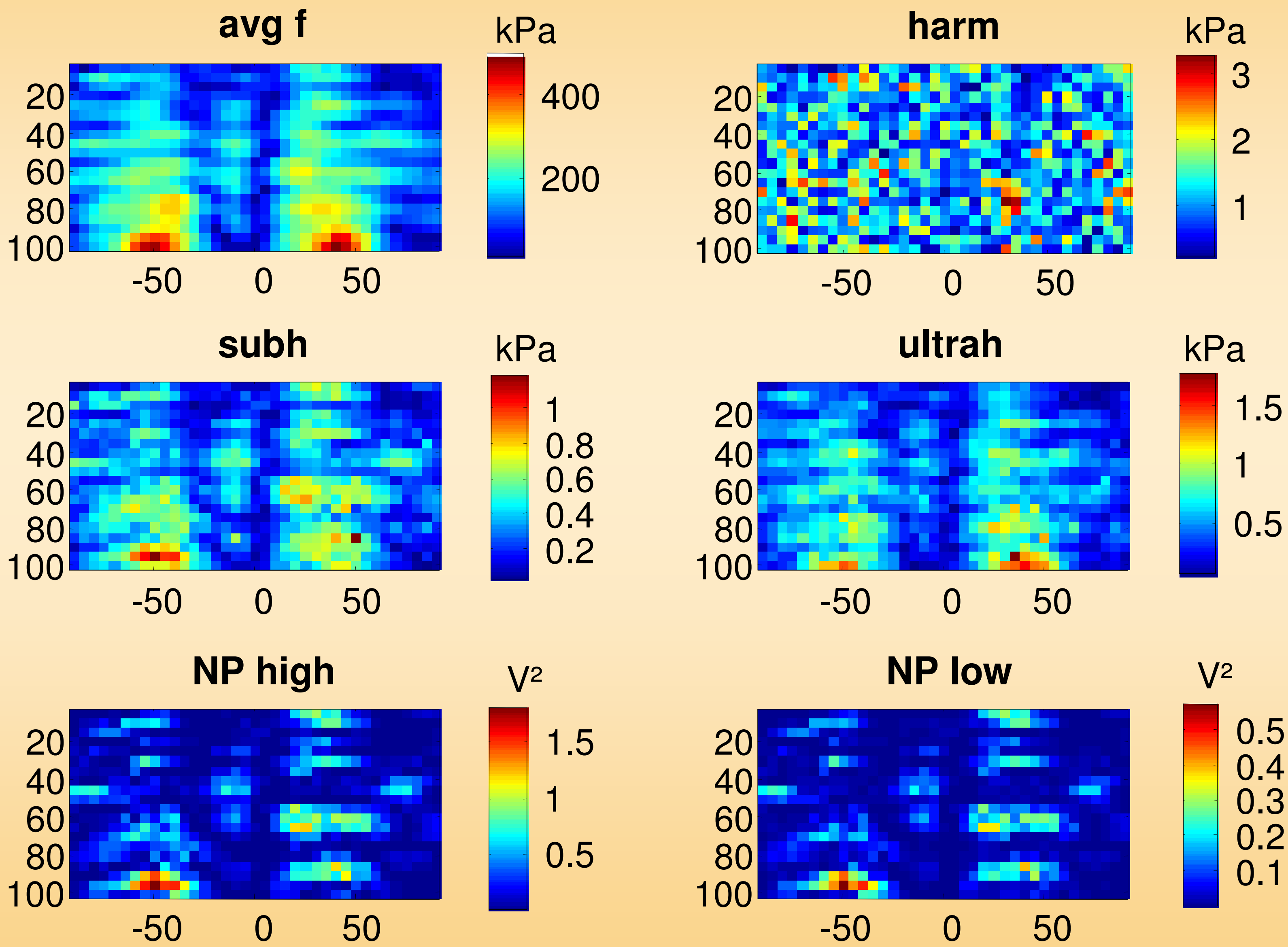
**Frequency component.**

**Averaged Noise**

**Power in the**
- **low (100 kHz – 200 kHz) and**
- **high (1.00 MHz – 1.25 MHz)**

**Frequency band.**

# Mapping of spectral sound field parameters




Elma TI-H-5 (xz-plane), hydrophone

# Evaluation of the cleaning effect

- **Mass loss of samples**
  - aluminium cube
  - cast (as solid or in grooves)
  - carbon plates
- **Perforation of foils**
  - aluminium foil
- **Reduction/cleaning of reference soiling**
  - blacked glass plate
  - rough ceramic plate with lead pencil

# Quantification of the Erosion Effect

1 original image scanner → Error correction (local disturbances) → 2 image with equalized background

↓

selective detection of disorders

↓ regions containing dents and indents

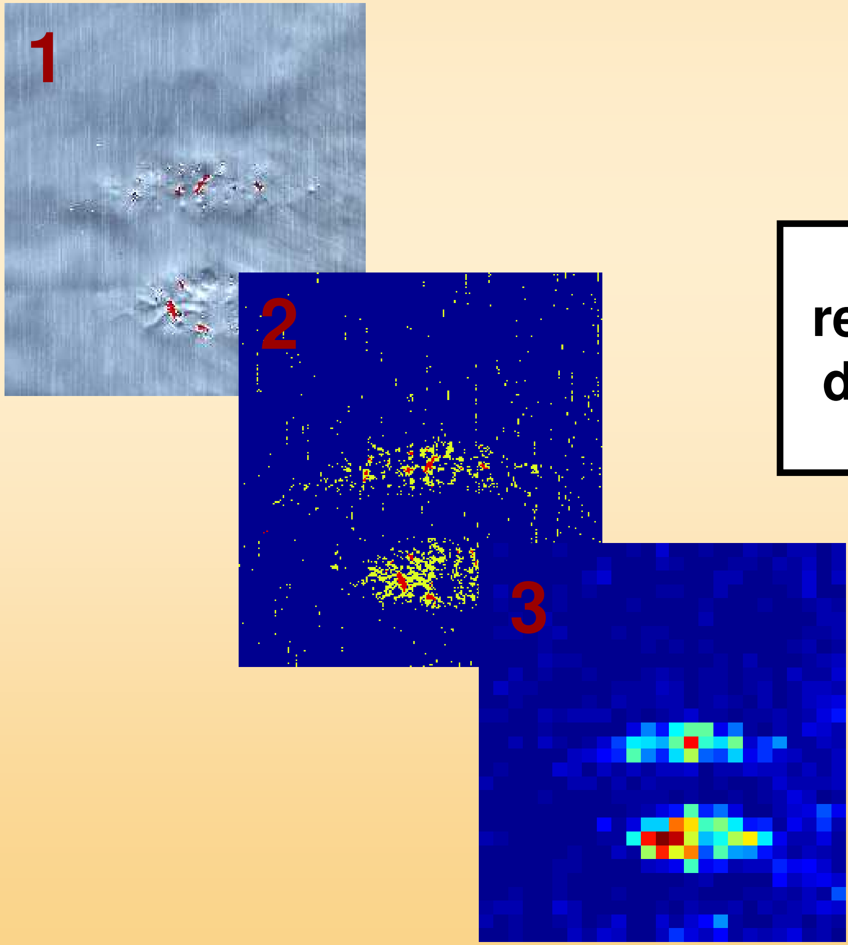
↓ regions containing perforations

↓

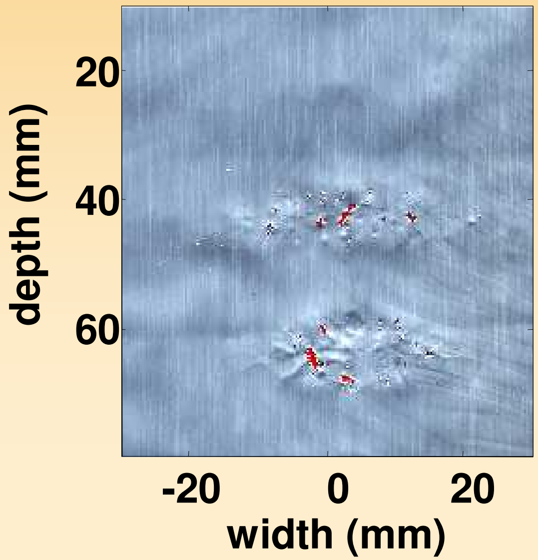
counting of pixels per raster

↓

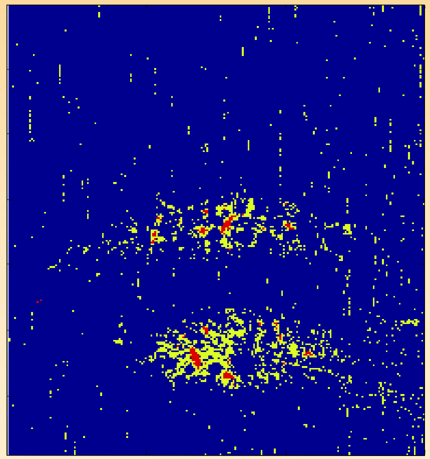
3 erosion density map



# Quantification of the Erosion Effect

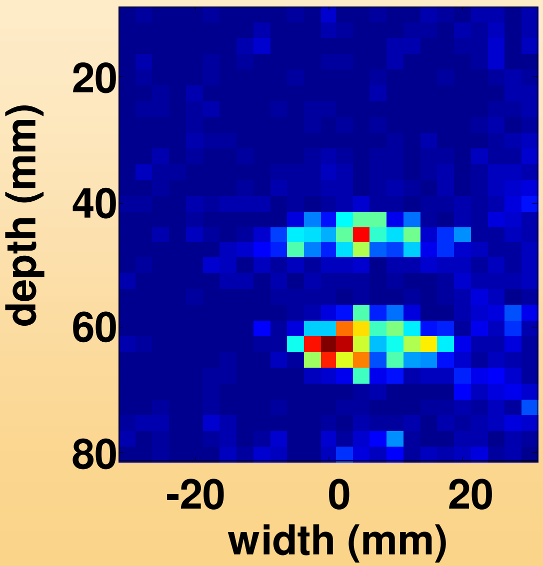



scanner photo

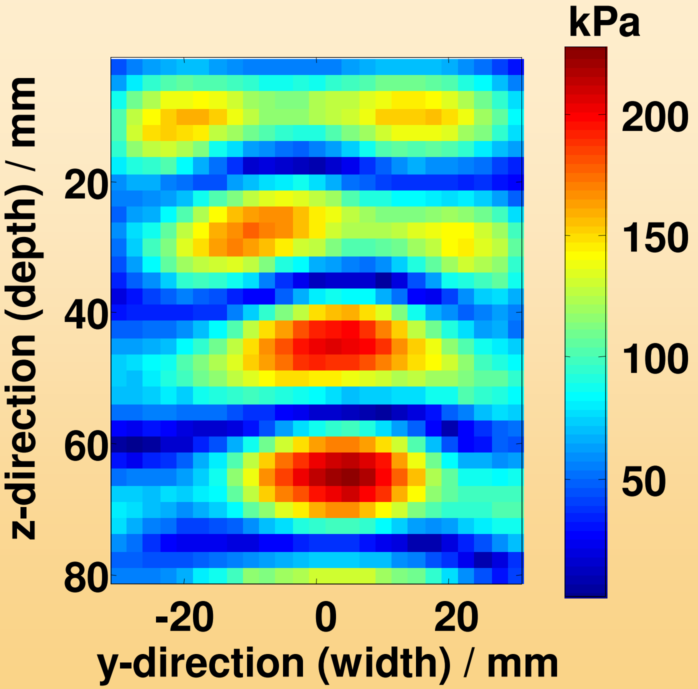


detected perforations and dents/indents

dents / indents
perforations



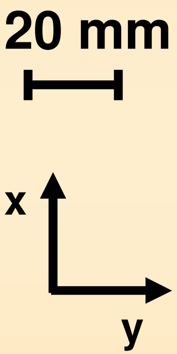

erosion map

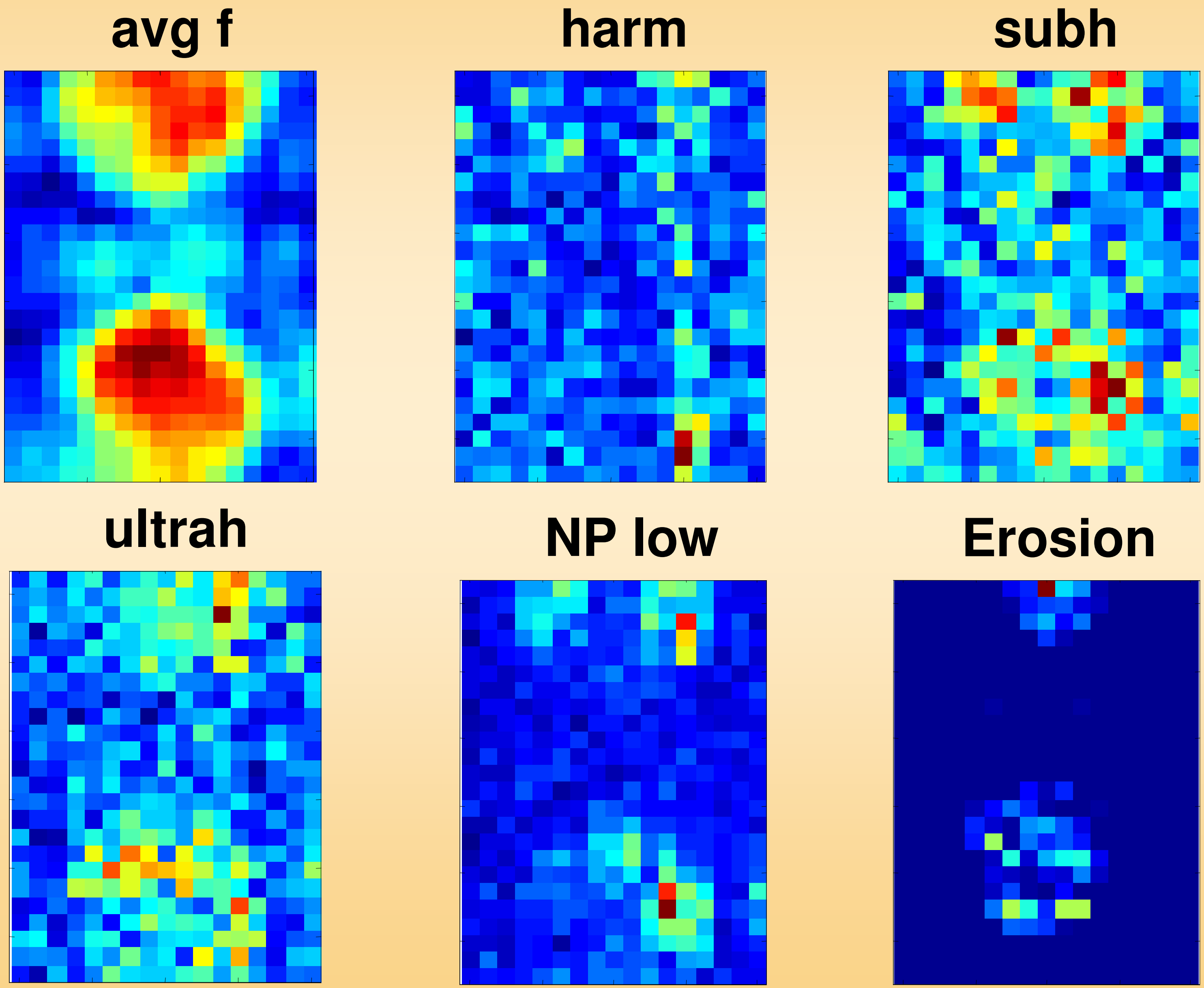



$f_0$ – sound pressure (TC 4038)

# Mapping of spectral parameters and the quantified erosion effect

**Example 1**




**xy-plane**
**(16.5 mm above bottom)**
**scan raster width: 5 mm**

# Corresponding 2D - correlation coefficients

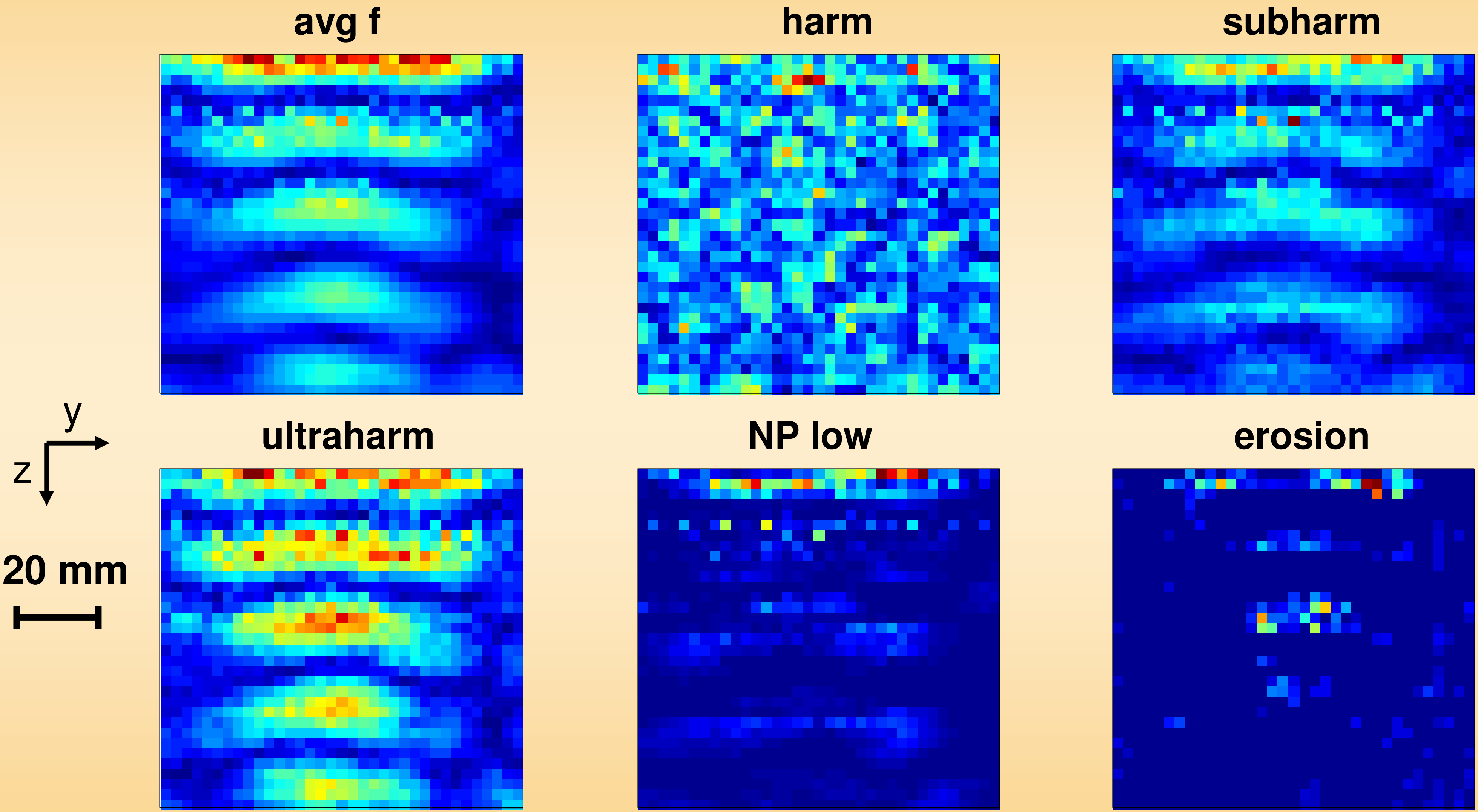
**Example 1**

| | avg f | avg t | avg a | harm | subh | ultrah | NP high | NP low | Erosion |
|---|---|---|---|---|---|---|---|---|---|
| avg f | 1.000 | 0.999 | 0.997 | 0.081 | 0.572 | 0.659 | 0.552 | 0.619 | 0.472 |
| avg t | - | 1.000 | 0.997 | 0.078 | 0.573 | 0.659 | 0.552 | 0.618 | 0.470 |
| avg a | - | - | 1.000 | 0.106 | 0.580 | 0.663 | 0.561 | 0.627 | 0.468 |
| harm | - | - | - | 1.000 | 0.127 | 0.211 | 0.241 | 0.238 | -0.092 |
| subh | - | - | - | - | 1.000 | 0.389 | 0.643 | 0.647 | 0.158 |
| ultrah | - | - | - | - | - | 1.000 | 0.376 | 0.442 | 0.207 |
| NP high | - | - | - | - | - | - | 1.000 | 0.953 | 0.110 |
| NP low | - | - | - | - | - | - | - | 1.000 | 0.154 |
| Erosion | - | - | - | - | - | - | - | - | 1.000 |

**Cleaning Vessel: Elma TI-H-5, extern excitation**
**f= 45 kHz, degassed water $c_{O2}$ < 3 mg/l**

# Mapping of spectral parameters and the quantified erosion effect

**Example 2**




**yz-plane (from surface down to 45 mm above bottom)**

**scan raster width: 2.5 mm**

# Corresponding 2D - correlation coefficients

**Example 2**

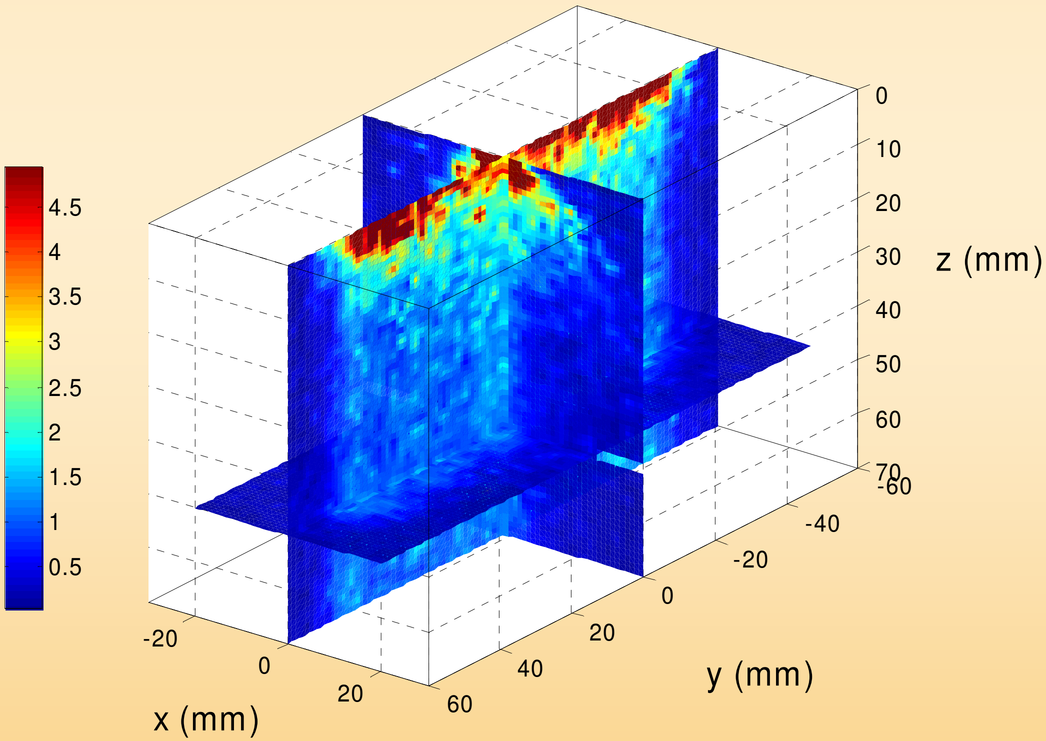
| | avg f | avg t | avg a | harm | subh | ultrah | NP high | NP low | Erosion |
|---|---|---|---|---|---|---|---|---|---|
| avg f | 1.000 | 0.992 | 0.974 | 0.256 | 0.902 | 0.918 | 0.705 | 0.641 | 0.425 |
| avg t | - | 1.000 | 0.969 | 0.242 | 0.900 | 0.945 | 0.667 | 0.596 | 0.410 |
| avg a | - | - | 1.000 | 0.287 | 0.891 | 0.912 | 0.690 | 0.622 | 0.404 |
| harm | - | - | - | 1.000 | 0.234 | 0.234 | 0.184 | 0.174 | 0.079 |
| subh | - | - | - | - | 1.000 | 0.776 | 0.853 | 0.784 | 0.397 |
| ultrah | - | - | - | - | - | 1.000 | 0.473 | 0.396 | 0.363 |
| NP high | - | - | - | - | - | - | 1.000 | 0.980 | 0.394 |
| NP low | - | - | - | - | - | - | - | 1.000 | 0.366 |
| Erosion | - | - | - | - | - | - | - | - | 1.000 |

**Cleaning Vessel: Elma TI-H-5, extern excitation**
**f= 45 kHz, $O_2$-saturated water $c_{O2}$ = 6 mg/l**

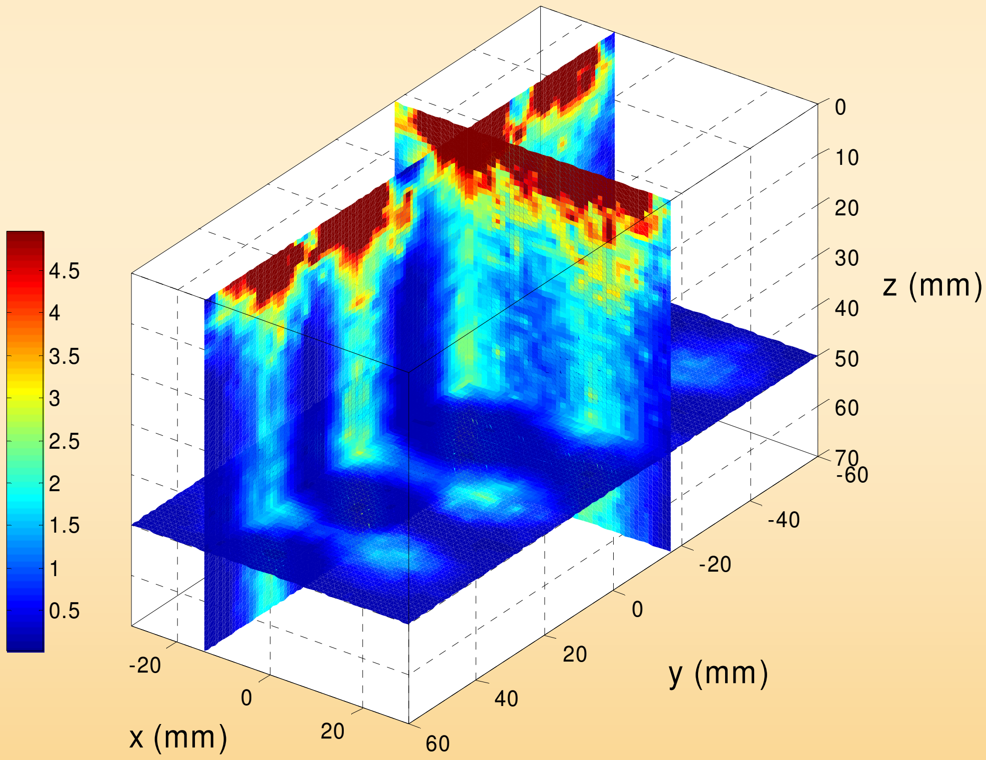
# Application: Sound field optimization of an Megasonic Cleaner

**$f_0$=1 MHz**

**relative intensity old version:**

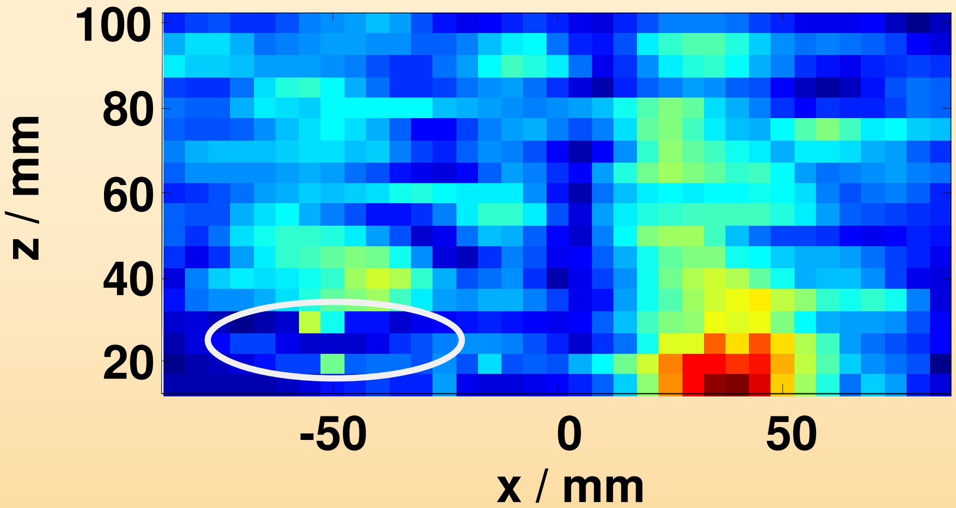



**relative intensity new version:**

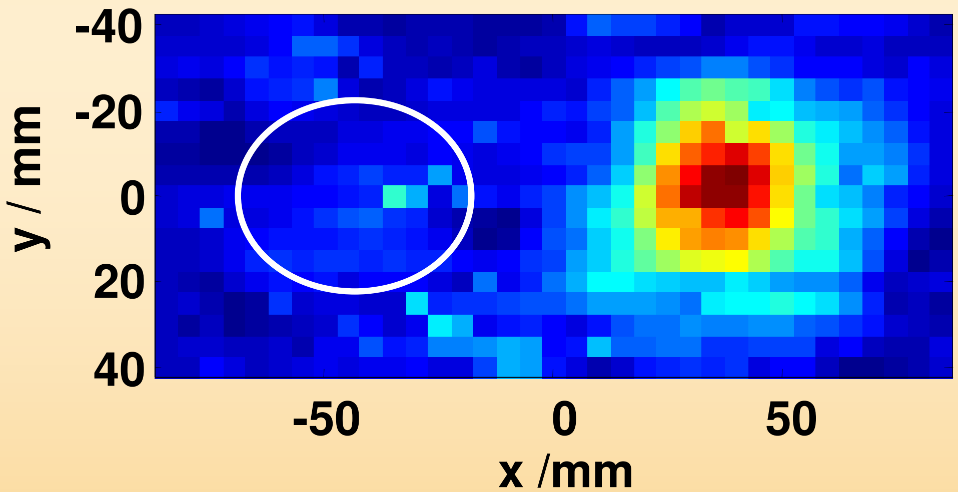


# Application: Detection of transducer failure

**Detection of a transducer failure during the scan procedure**




**Repetition of the scan in the perpendicular plane**



# Conclusion

**The measurement of spectral sound field parameters allows the spatial localization of regions of effective cleaning and supports the user in his search for the best position inside an ultrasound cleaning vessel. Also, it provides an important tool for the design of an optimal sound field geometry.**