The Photofol project

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LAST introduction
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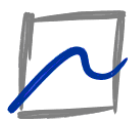
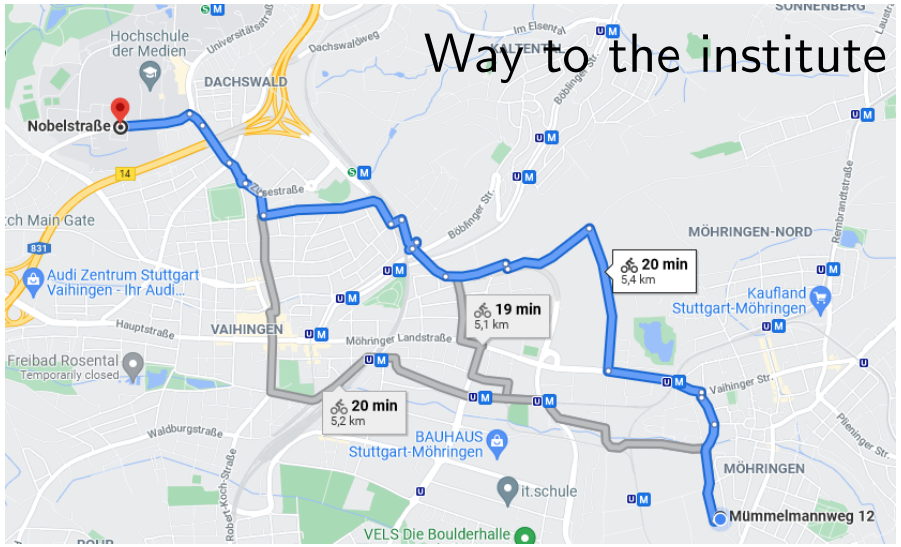


Laboratory of
Acoustics

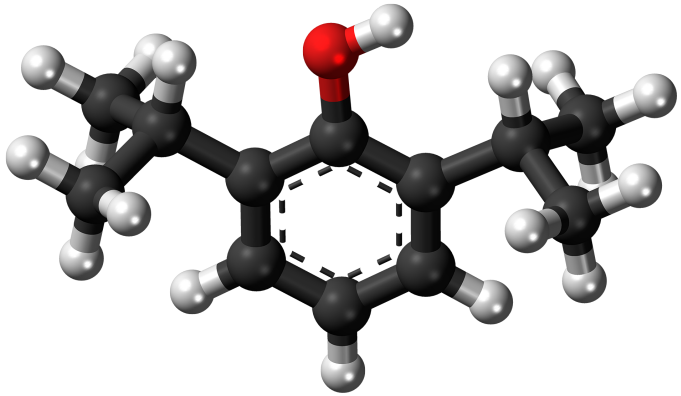
Fraunhofer
IBP

My current situation

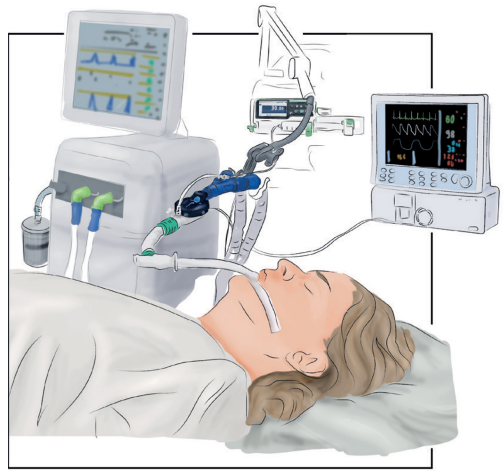


The Photofol project

- Photoacoustics + propofol
  - Photoacoustic detection of
  - propofol in the exhaled breath
- Application, challenges of propofol
  - Anesthesia, given into blood
  - Challenge: real-time monitoring of propofol concentration in surgery
  - Mass spectrometry too expensive
- Project objectives
  - Photoacoustic detector prototype
  - Detect 1 ppb in $10\,\mathrm{s}$ time
  - Instrument design to companies
- Project partners
  - LMU Klinikum, München
  - Fraunhofer IBP, Stuttgart

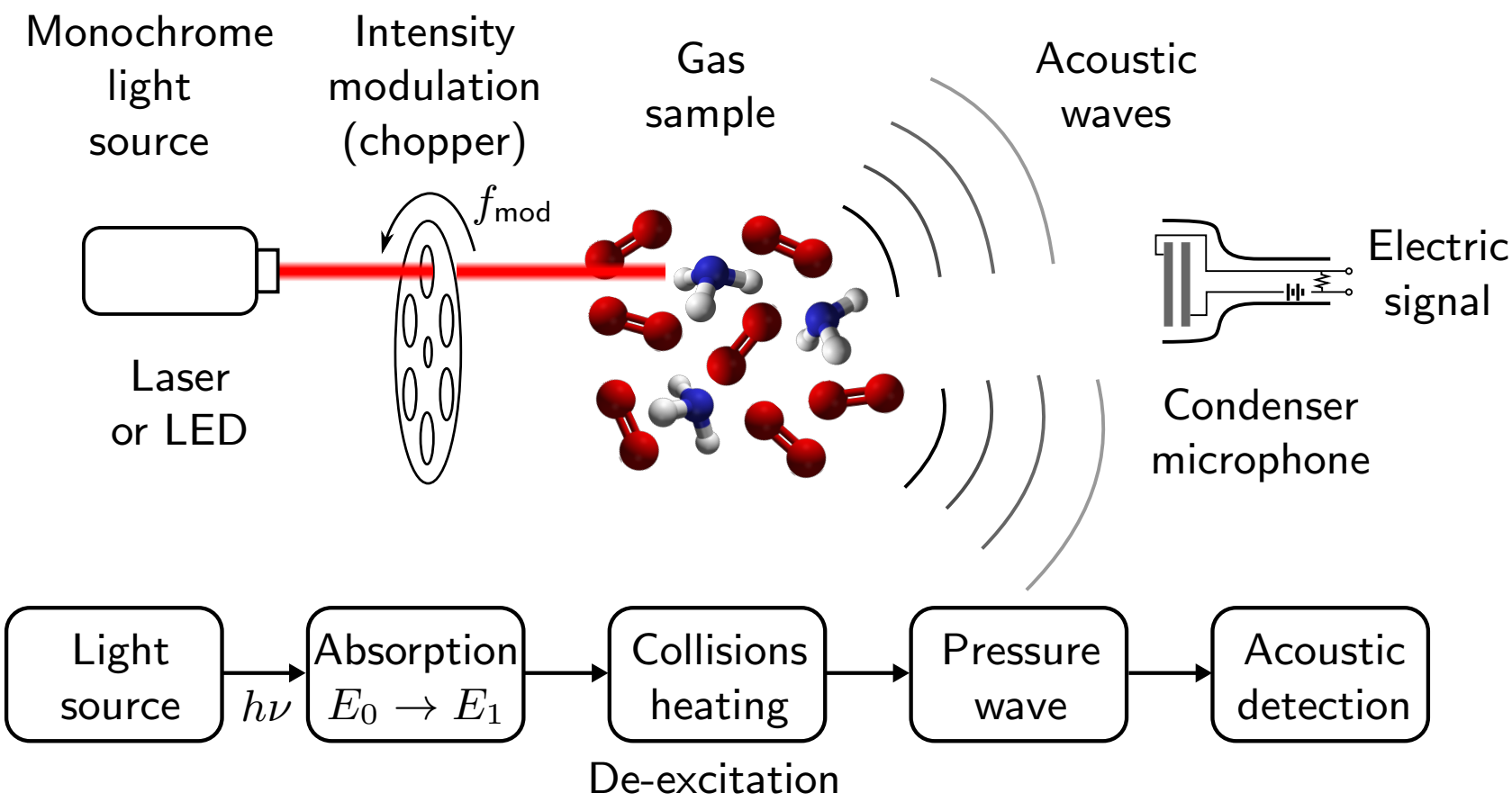


Propofol molecule ($C_{12}H_{18}O$)



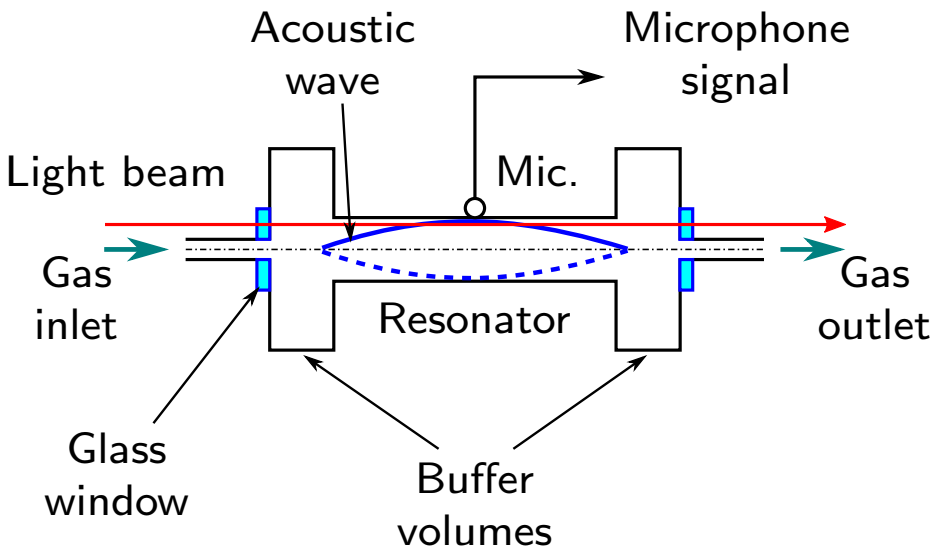
Anesthesia using propofol

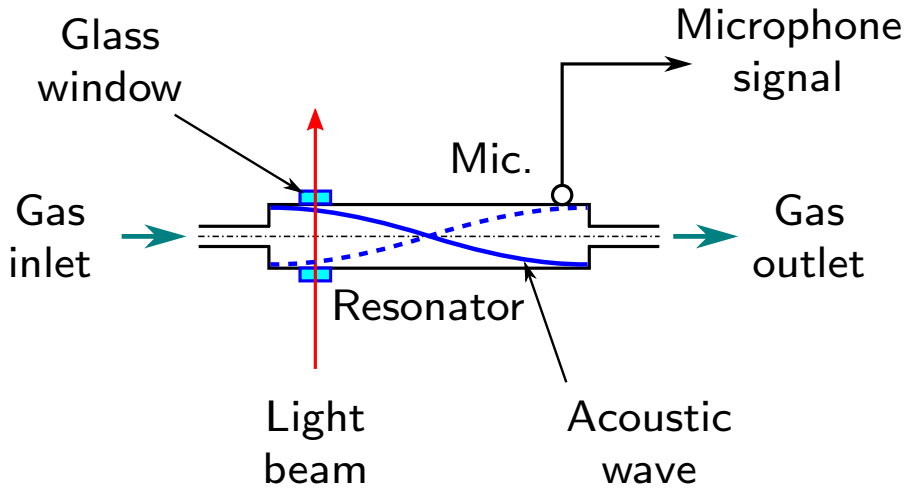
The photoacoustic effect



- Light wavelength is chosen based on the gas specie to be detected
- Modulation frequency f_{mod} is the resulting acoustical frequency

Photoacoustic detection using a resonator





- Acoustical resonator
  - Amplifies the wave
  - Improves the SNR
- Excitation of the longitudinal eigenmode
  - Open cell with buffers
  - Closed cell
- Cells for azimuthal or radial modes also possible
- Flow through the cell
  - Gas sample must pass through the cell
  - Laminar flow
  - $50–200\,\mathrm{cm}^3/\mathrm{min}$

Concentration measurement

- Heat as an acoustical source

$$\frac{1}{c^2}\frac{\partial^2 p}{\partial t^2} - \nabla^2 p = \underbrace{\frac{\kappa - 1}{c^2}\frac{\partial H}{\partial t}}_{\text{Heat source}}$$

- Light is absorbed at whole length of the cell $(0 \leq x \leq L)$

$$H \propto \int_0^L \mathrm{e}^{-\alpha x}\,\mathrm{d}x = \mathrm{e}^{-\alpha L} - 1 \approx -\alpha L \qquad \alpha L \ll 1$$

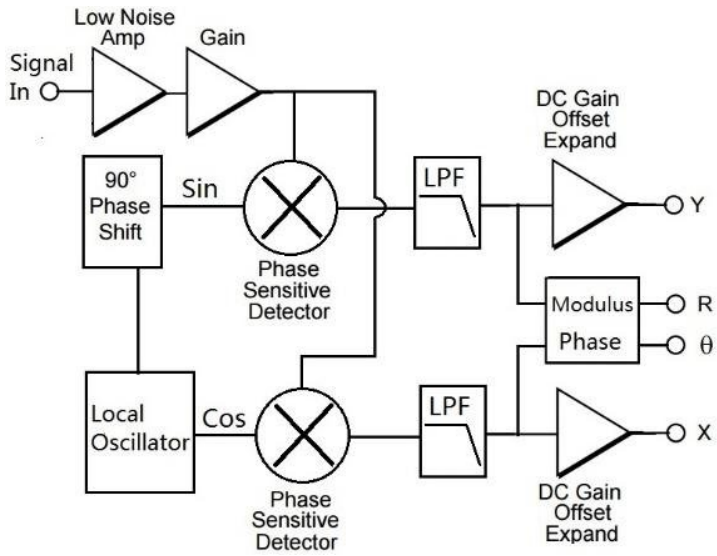
- Non-resonant and resonant detection

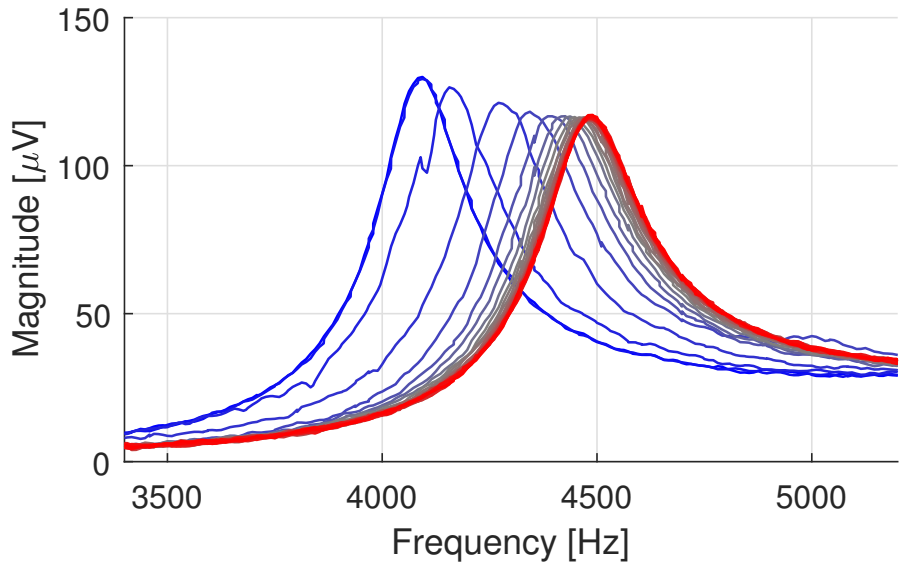
$$p_0 \propto \frac{P_0}{V\omega}\alpha L \qquad\qquad p_0 \propto \frac{QP_0}{V\omega}\alpha L$$

- The signal p_0 is
  1. **Linearly proportional to** α ($\sim$ **concentration**) over many magnitudes, the light power P_0, and the quality factor Q
  2. Inversely proportional to the cell volume V and frequency ω

The photoacoustic signal and its processing

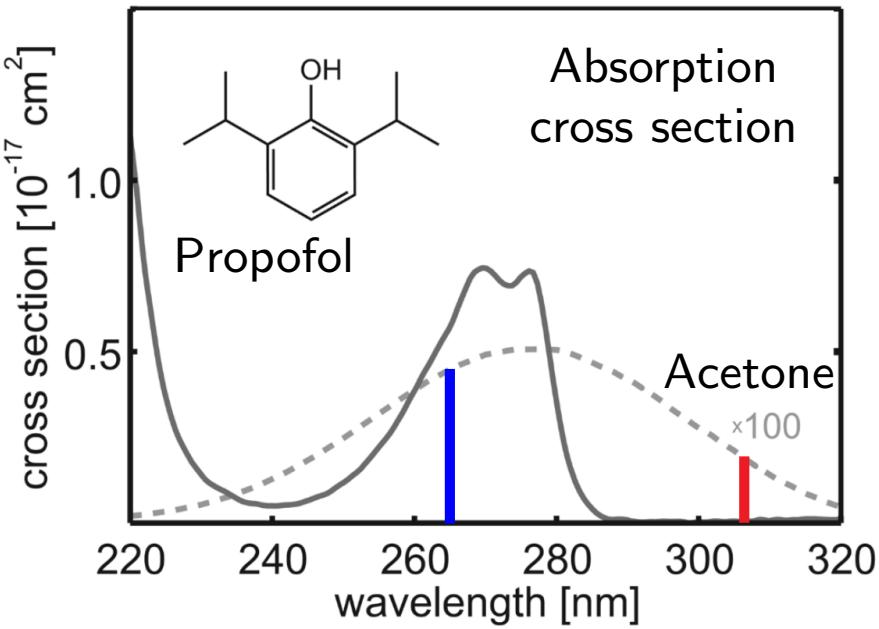
- Components of the signal
  1. Useful signal, $\propto$ concentration
  2. Window (background) signal
     coherent, different phase
     $\propto$ optical power
  3. Additive noise
     acoustical & electrical
     non-coherent, very large
- Signal processing
  - Lock-in detection
    (vector voltmeter)
  - Coherent sampling
  - Direct digital lock-in detection
    for MEMS microphones
    (possible patent)

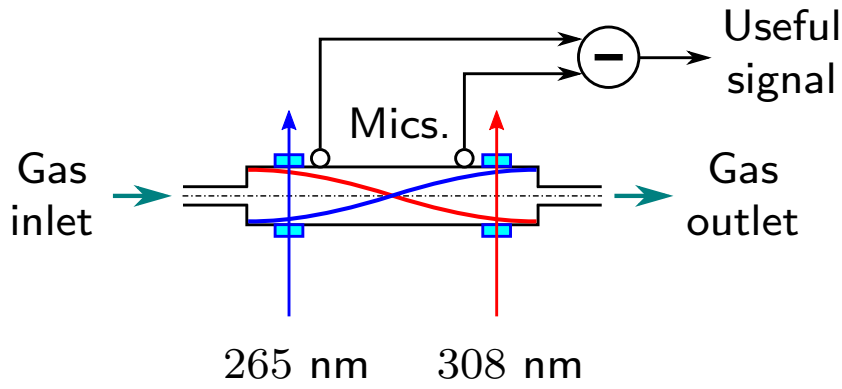




Challenges are many ...

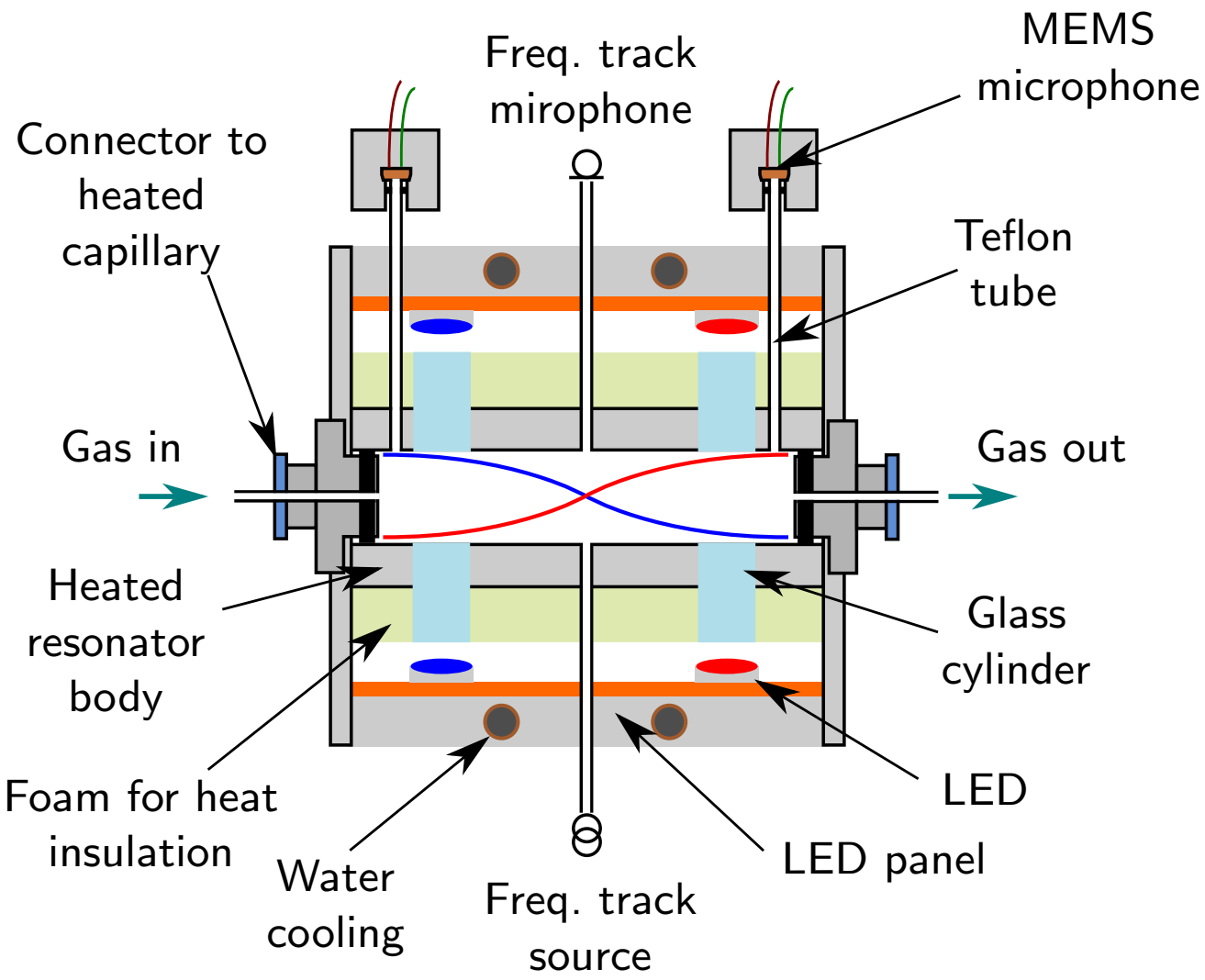
- Adsorption / desorption, H_2O
  - Propofol adsorbs to walls
  - Walls heated $> 100°C$
  - Microphones up to $70°C$
  - Measure farther from walls
- Light sources
  - UV power LEDs
  - Cooling is needed
- Temperature and CO_2
  - Speed of sound changes
  - Frequency tracking needed
- Acetone C_3H_6O
  - Natural in human breath
  - Can be high (e.g. diabetes)
  - Differential measurement





Differential detector

The current cell design



- Prototype cell built
  - Gas system
  - Flow control
  - LED control
  - Heating
  - Water cooling
  - MEMS mics
  - Acoustically OK
- Dimensions
  - Length: $42\,\mathrm{mm}$
  - Diameter: $7\,\mathrm{mm}$
- To be tested
  - Equalization
  - Sensitivity

Activities at the BME

- Participation in teaching
  - Online classes last year (mainly programming)
  - Supervising undergraduate students
  - PhD student: Mihály Ulveczki
- Projects
  - Currently: ANIMA – development of the VCT
  - Drone detection project finished this summer
- Collaboration
  - Research with colleagues from the Dept. of Hydrodynamic Systems
  - We recently submitted a journal paper

Thank you for your kind attention.