Development of a Package for a Triaxial High-G Accelerometer Optimized for High Signal Fidelity

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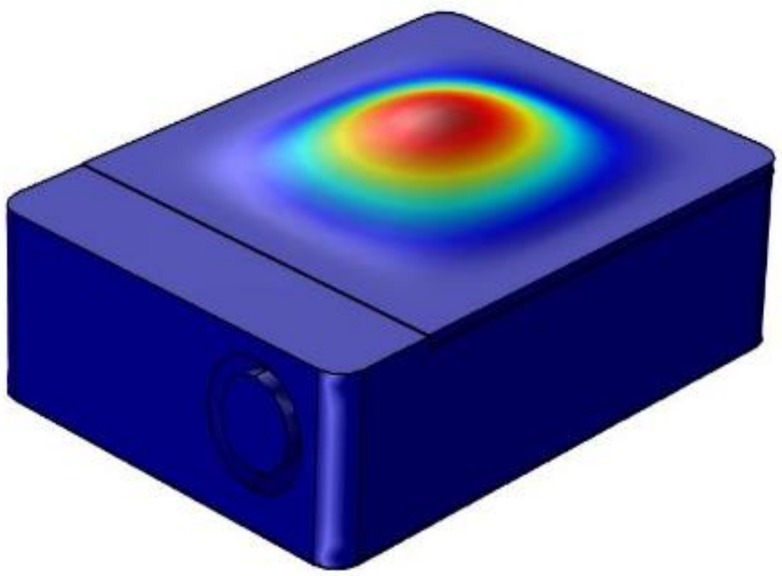
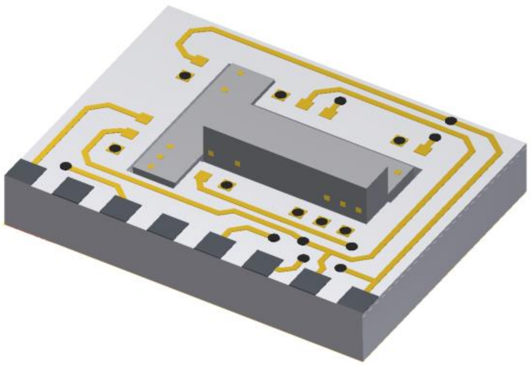
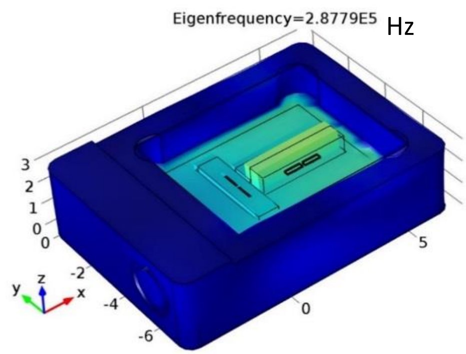
Fraunhofer EMI

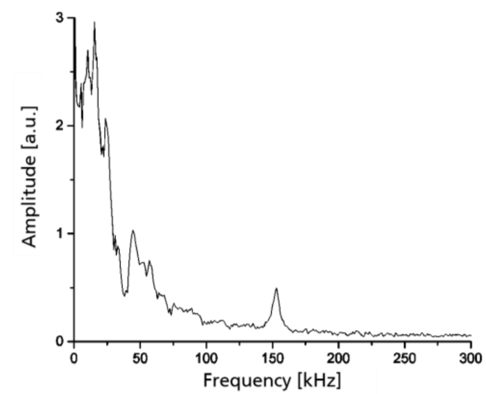


AGENDA

- What is „high-g“
- Goal and Requirements
- Numeric Simulation
  - Package Design
  - Simulation Methods
  - Results
- Experimental Tests
  - Realised Prototype
  - Eigenfrequency
  - Triaxial Measurement
- Summary

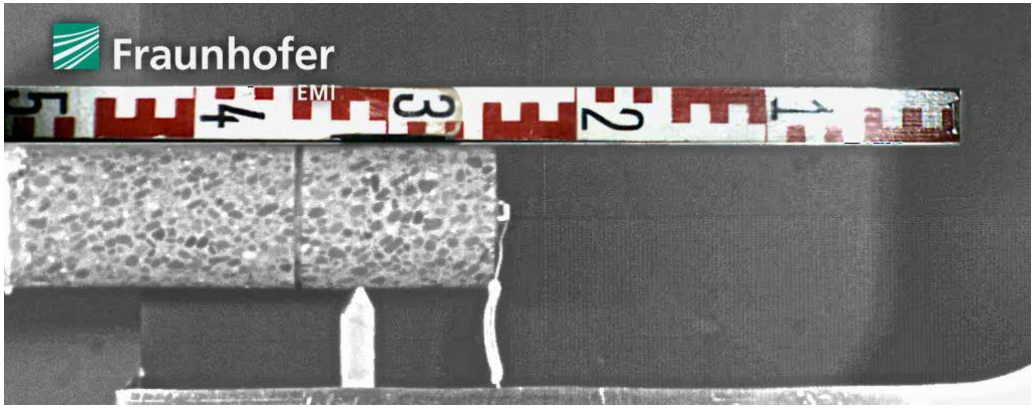






What is „high-g“

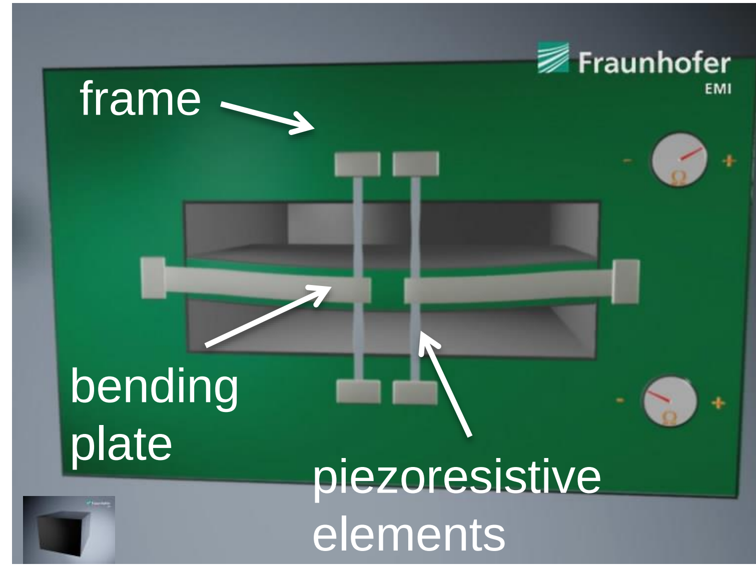
- Examples for acceleration:
  - Gravity 9,81m/s² ≙ 1 g
  - Limit for roller coaster 6 g
  - Breaking point of humans 10 g
  - Crashtests 50-100 g
  - Testing sensors and electronics 1.000 g
- Special application „high-g“:
  - Material characterization 100.000 g
  - Ballistic experiments 100.000 g

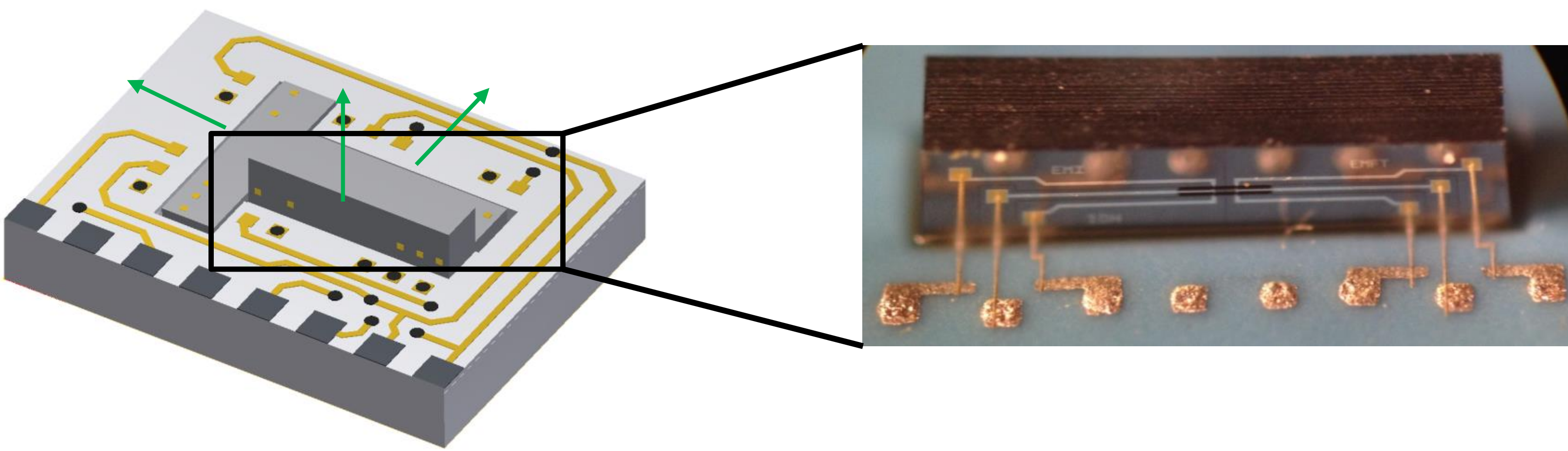


Goal and Requirements

- Starting point of this work:
  - Piezoresistive sensor chip
  - 3D-setup on Al_2O_3-ceramic plate

    → Sensor element
  - Uniqueness:
    - standing sensor chip for Z-axis
    - 90° contacting via Aerosol-print-jet

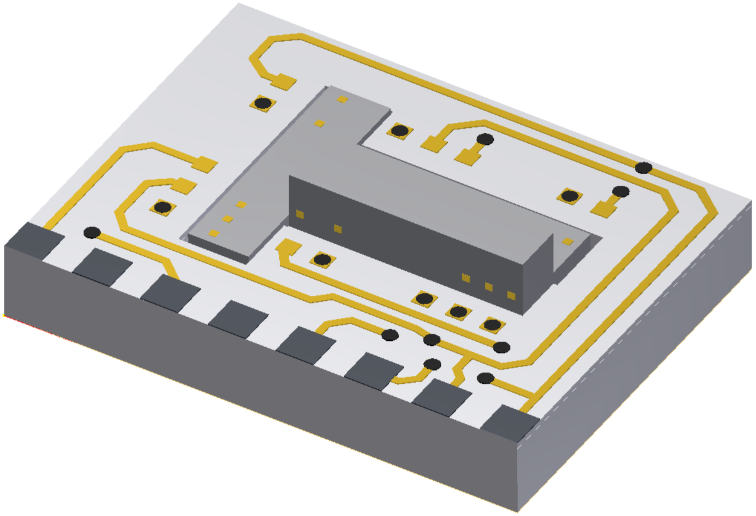




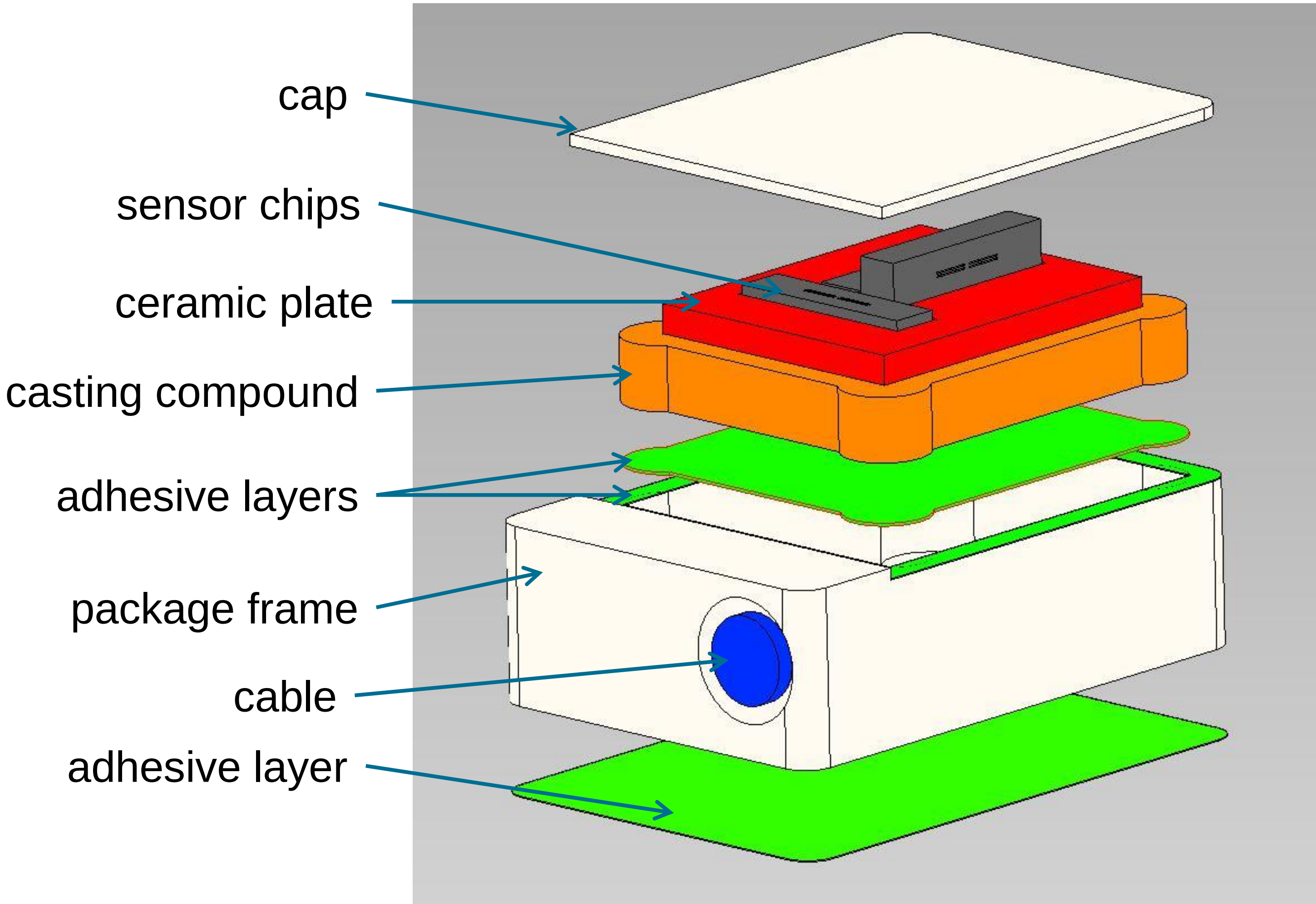
Goal and Requirements

- Development of a Package for a Triaxial High-G Accelerometer
  - Wired
  - Shock-proof (up to 100.000 g)
  - Electromagnetic shielding
  - Functional for -40 - 80° C
  - High bandwidth (aim: 100 kHz)
    - Max. 5%-deviation
- Characterization of first prototype

  → Functional, robust and feasible sensor

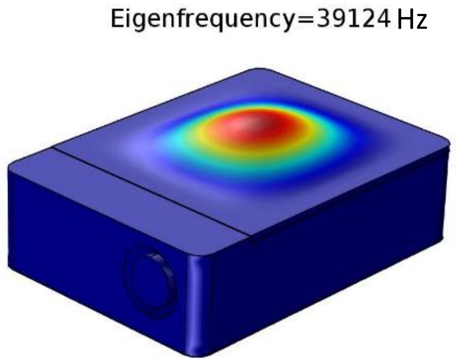


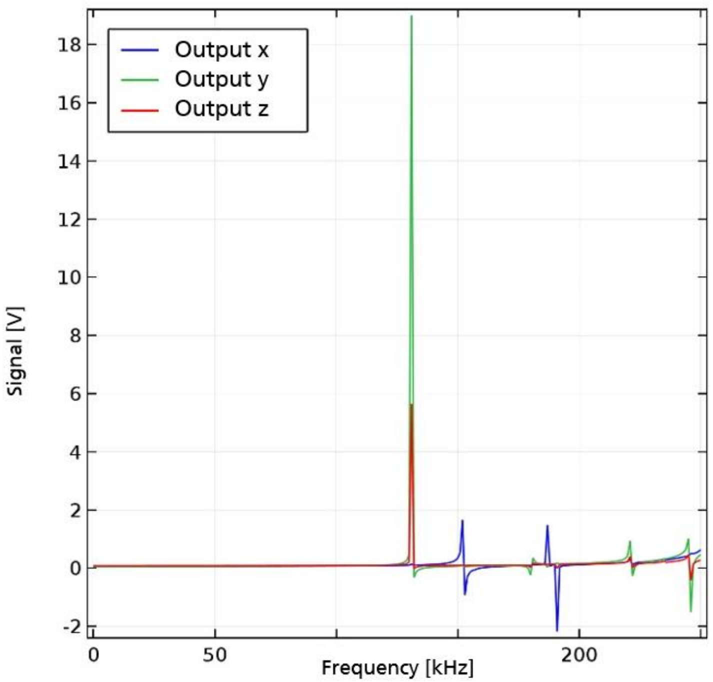
Numeric Simulation
Package Design



Numeric Simulation
Simulation Methods

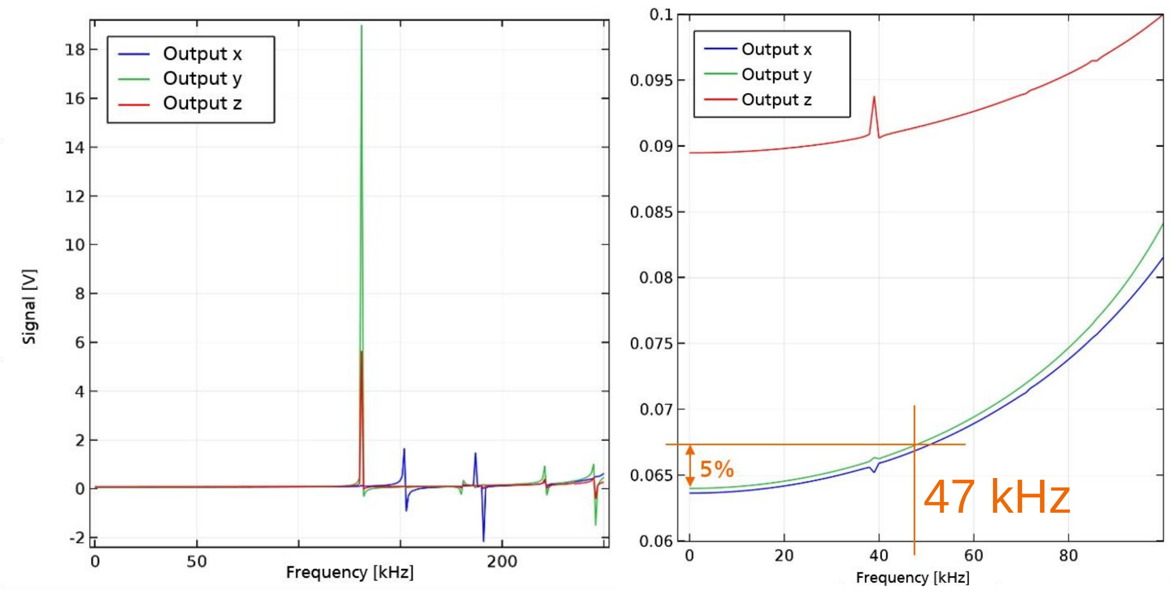
- Modal analysis:
  - Shape and frequency of the Eigen modes of the sensor
- Frequency spectrum analysis:
  - Excitation frequency varied
  - Computing of the electrical output signal of the sensor at
    - 100.000 g
    - 1 V supply voltage
- Use of COMSOL Multiphysics
  - Structural Mechanics
  - LiveLink for Inventor





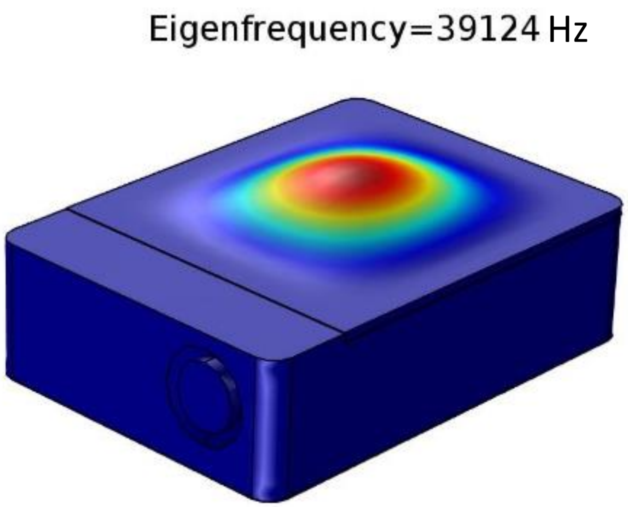
Numeric Simulation Results

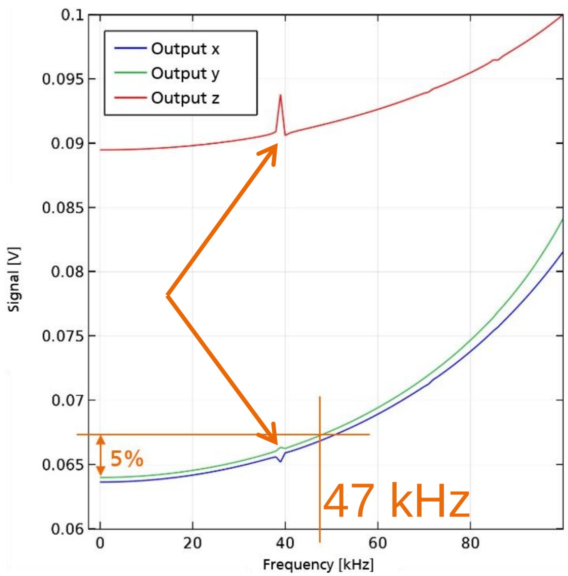
- Used package parameters:
  - Material: Titanium (E/ρ = 26,4)
  - Wall thickness: 1 mm
  - Cap thickness: 0,2 mm
- Adhesive: epoxy (Young's modulus: 2,5 GPa)
- Adhesive layer sensor element: 50 µm
- Adhesive layer sensor: 20 µm



Numeric Simulation
Results

- First mode: 39 kHz
  - Oscillation of the cap
  - Only little influence on the sensor signal





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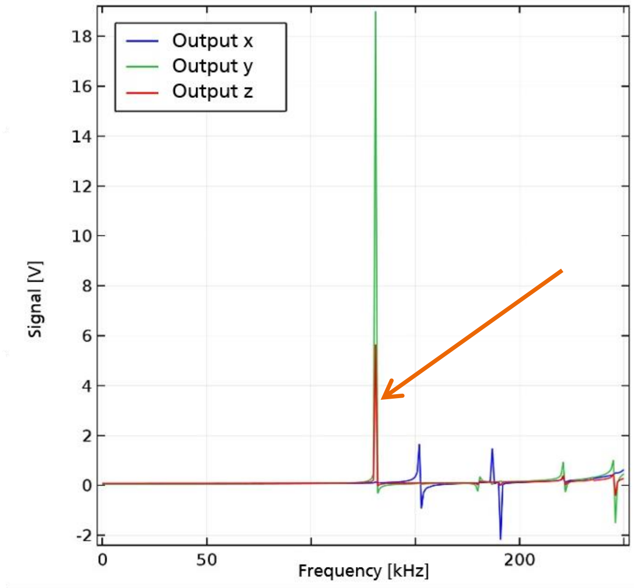
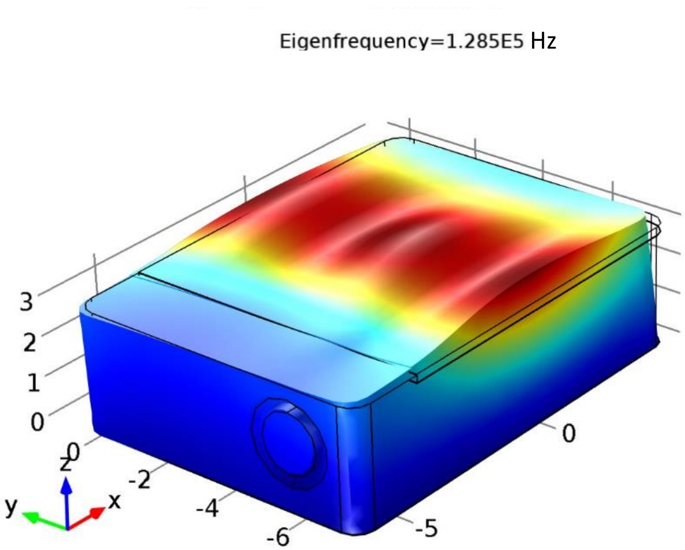
Numeric Simulation Results

- Package mode: 128 kHz
  - First mode with noticable movement within the package
  - Quite high influence on the sensor element





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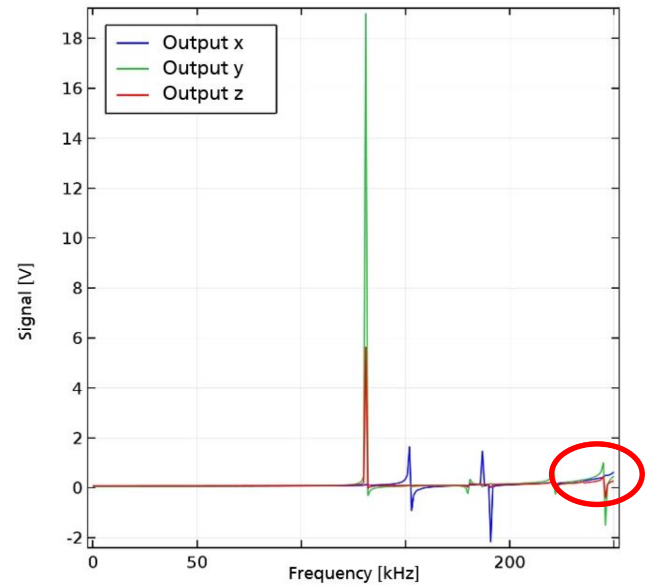
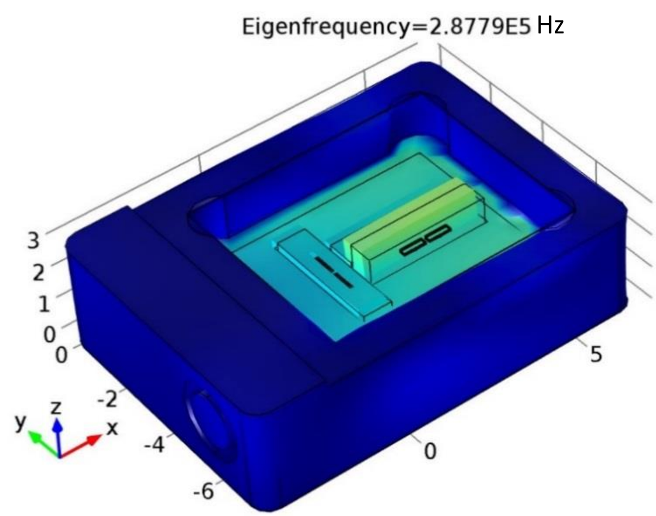
Numeric Simulation Results

- Sensor element mode: 287 kHz
  - Mode with main displacement within the sensor element
  - Expected to be main influence on the sensor signal
  - Frequency was not simulated





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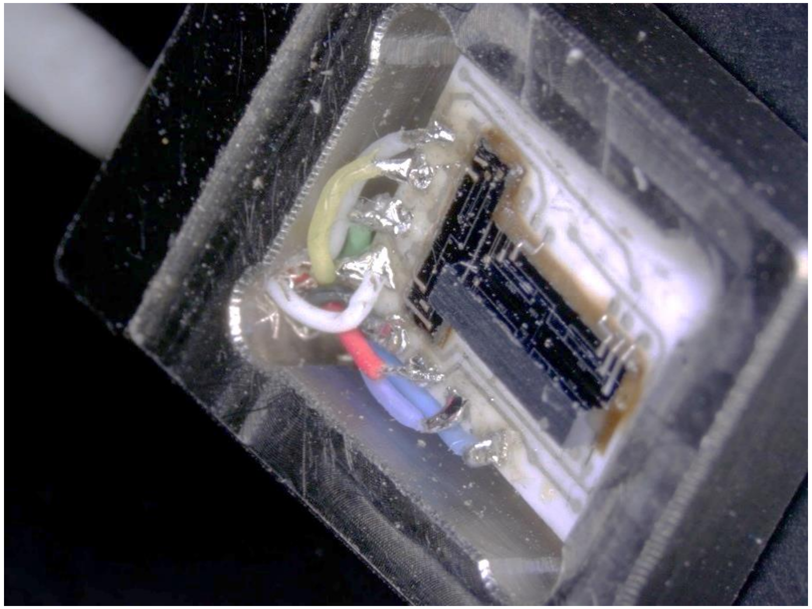
Experimental Tests
Realised Prototype

- Prototype parameters:
  - Wall thickness: 1,5 mm
  - Cap thickness: 0,2 mm
  - Material: Titanium
  - Adhesive layers
    - Thickness: 20-70 µm
    - Young‘s modulus: 0,56 GPa
- Adapted simulation:



Layer thickness	5%-limit	Package mode	Sensor element mode
20 µm	30 kHz	98 kHz	200 kHz
70 µm	16 kHz	67 kHz	129 kHz

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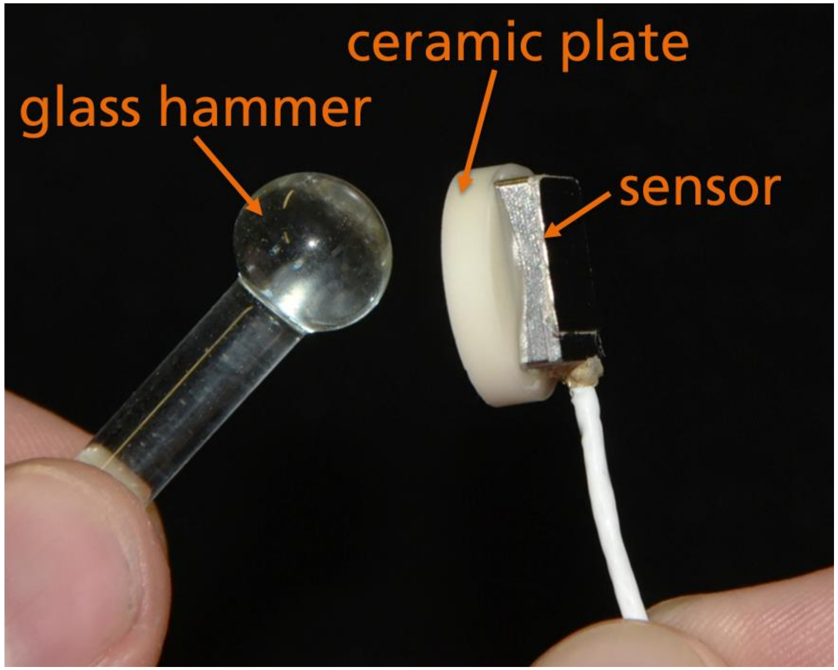
Experimental Tests
Eigenfrequency

- Excitation of sensor via a transient impulse
  - FFT of the signal

    → Frequency spectrum of the signal
  - Relevant Eigen frequencies

    → Peak within the spectrum

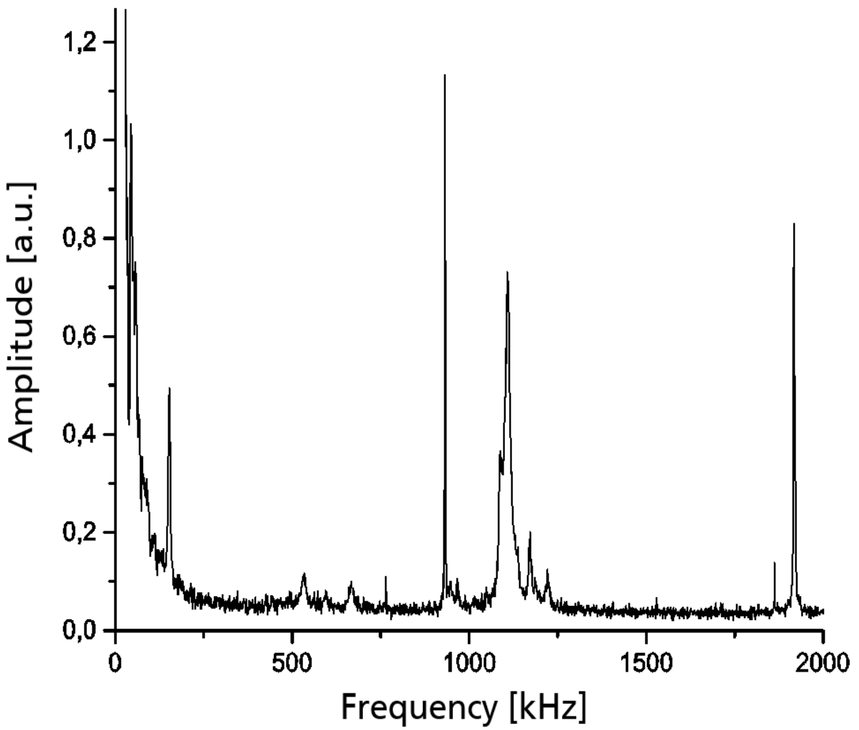


Experimental Tests
Eigenfrequency

- Eigen frequency of the sensor chip:
  - Expected: 1 MHz
  - Measurement: 930 kHz

- Influence of the package:
  - Expected among 129-200kHz
  - Measurement: 153 kHz

→ Measured values coincide with the results of the numeric simulation



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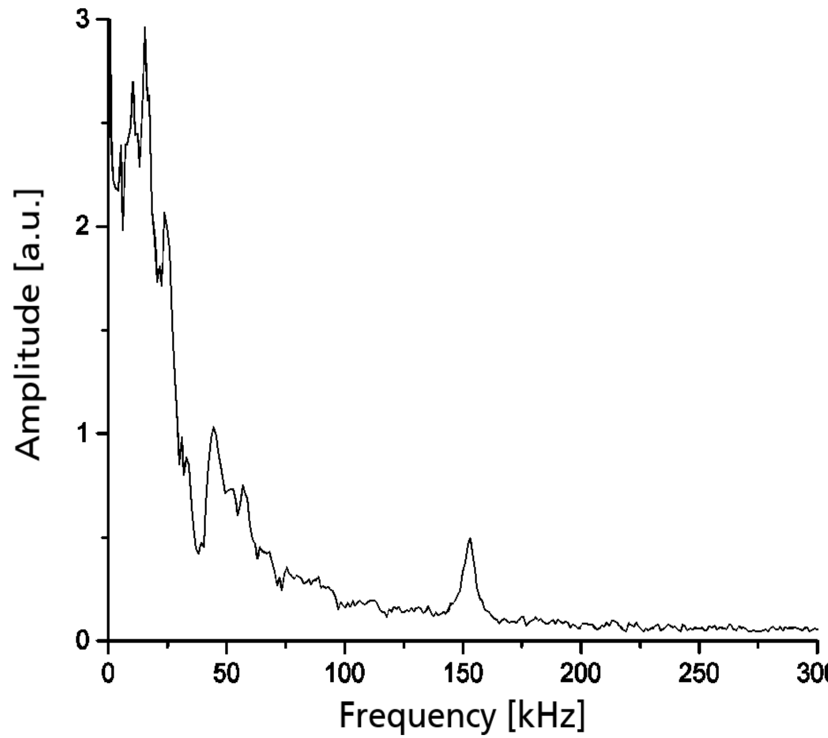
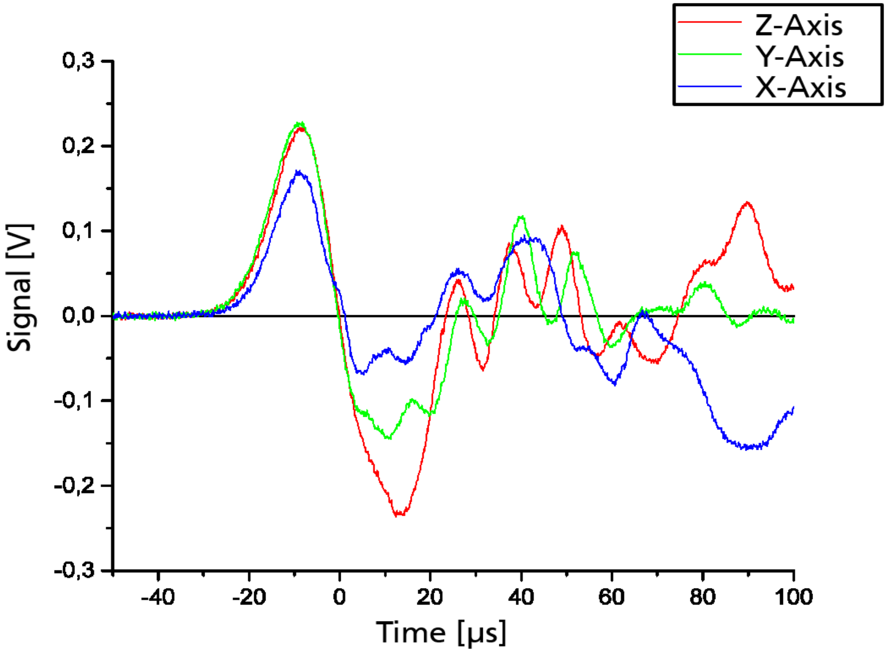


Experimental Tests
Triaxial Measurement

- Acceleration on all three axes
  - Uniaxial Shock divided to all axes equally due to attachment angle
  - Impulse: 8600 g each axis
  - Expected sensitivity:
    - 1,30 µV/V/g (± 30%)
- Measured sensitivity
  - X-axis: 1,00 µV/V/g
  - Y-axis: 1,33 µV/V/g
  - Z-axis: 1,30 µV/V/g

  → Corresponds with the expected values of simulation and previous work



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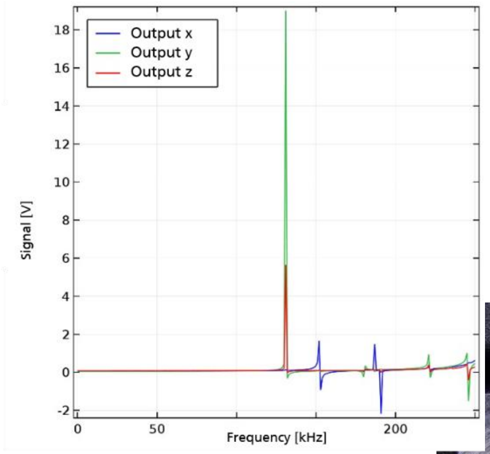
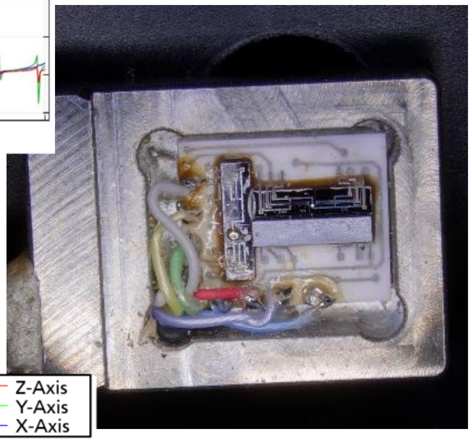
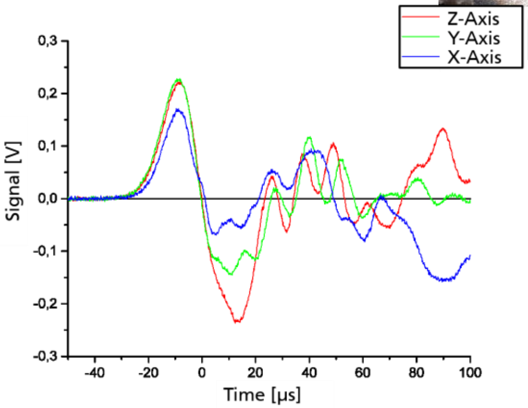
Summary

- A package was designed and modelled
- Its behaviour was examined via simulation
- A prototype was built and characterized
- The simulation could be verified with the experimental results







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Thank you for your attention!

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