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A MEMS motion sensor with frequency selective mechanical amplification

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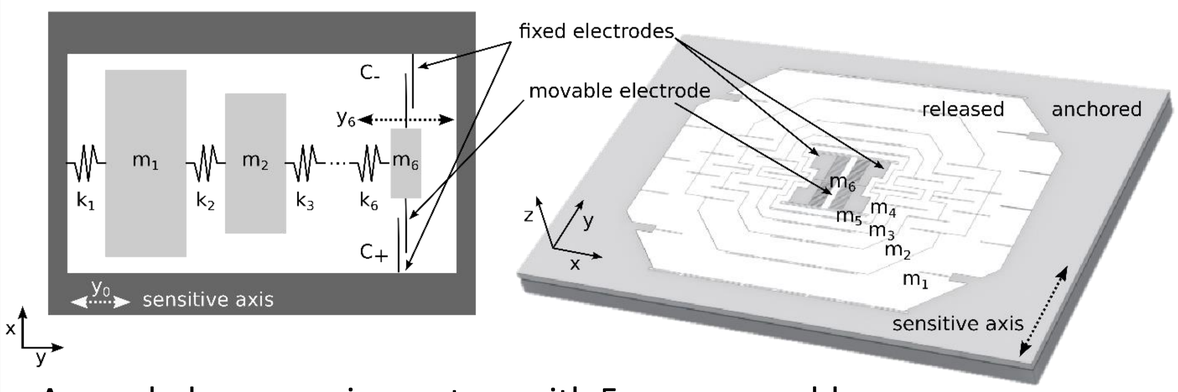
Motivation

Structural monitoring of geological structures requires the detection of small signals in the low kHz regime. The signals are usually extending over a broad frequency range. State of the art resonant sensors however are restricted to a single resonance and therefore do not respond to the full spectrum of the signal. We propose a broadband motion sensor that amplifies the signal in the frequency range of 3-13 kHz with a minimum (mean) amplification of 16 dB (23 dB) and can be read out capacitively.

Concept



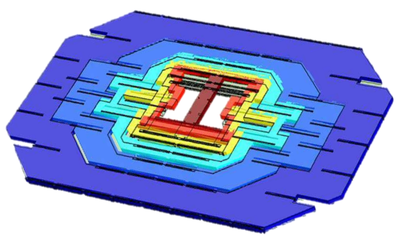
A coupled mass-spring system with 5 masses enables

- Purely mechanical **amplification** of incoming vibrations
- **Frequency selectivity**
- at **zero power** expense

The last mass is connected to a differential capacitance for continuous read out.

Finite Element Analysis

Design rule
$m_n > \ldots > m_1$
$k_n/m_n = \ldots = k_1/m_1$

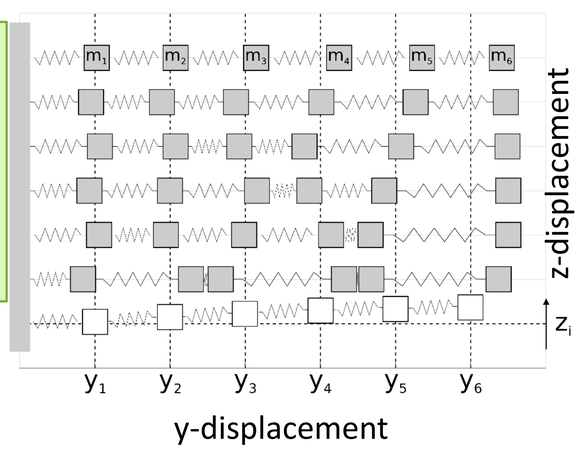


ν_1 displacement field

y-modes

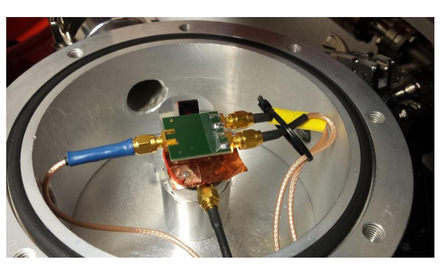
ν^1, 3.3 kHz	
ν^2, 5.8 kHz	
ν^3, 8.3 kHz	
ν^4, 10.5 kHz	
ν^5, 12.0 kHz	
ν^6, 12.8 kHz	
γ^1, 17.3 kHz	first z-mode

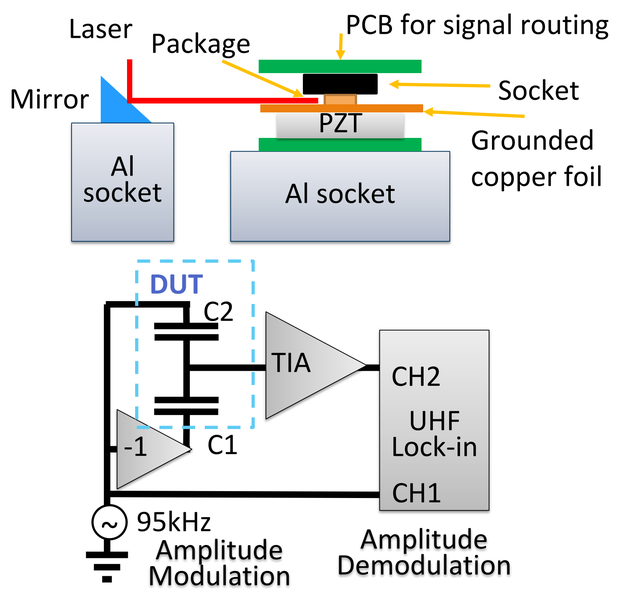
FEA y-z mode-shapes



Characterization

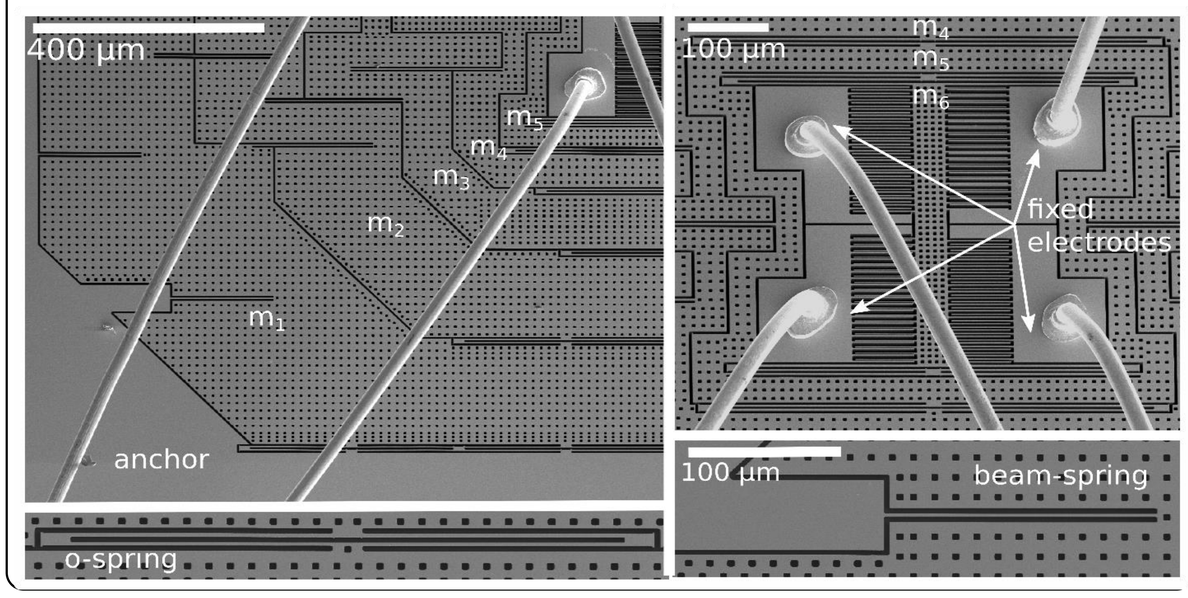
- Top:
  Optical characterization with Laser Doppler Vibrometer
- Bottom:
  Capacitive characterization with amplitude modulation



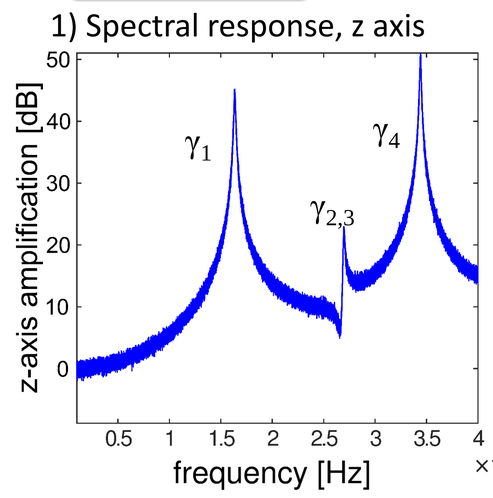


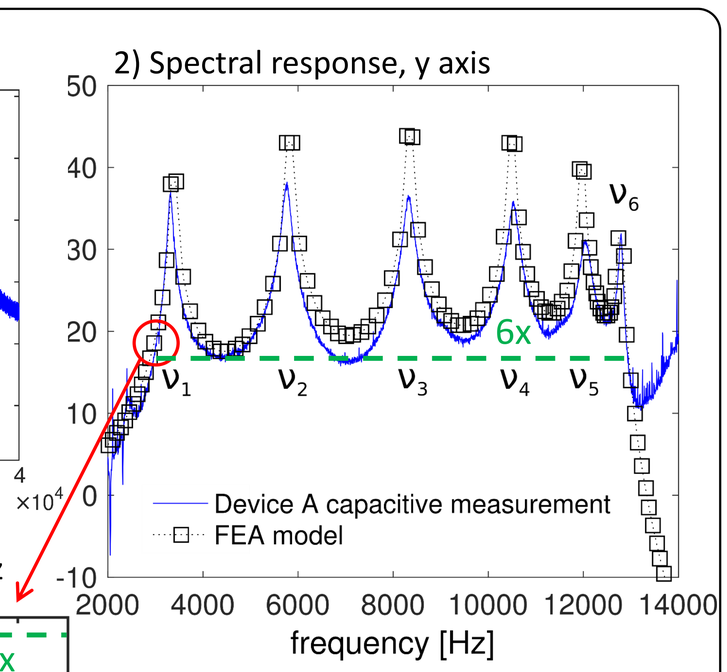
Fabrication

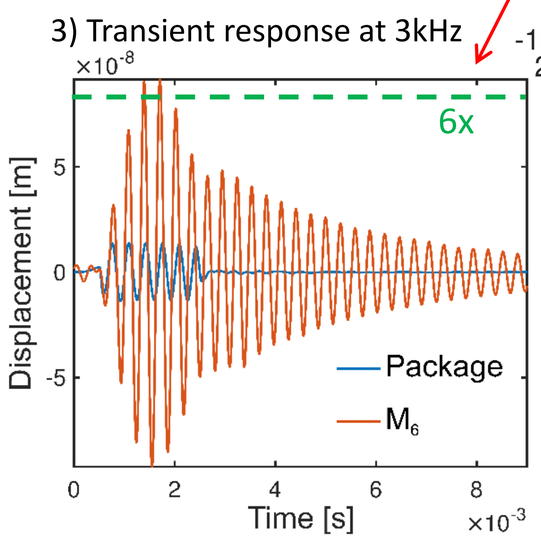
1. PECVD deposition 500 nm SiO_2
2. 1.2 µm Photoresist
3. DRIE SiO_2 etch
4. ICP Si etch
5. Dicing
6. SiO_2 HF vapor release
7. Evaporation 4/40 nm Cr/Au
8. Die and Wire Bonding



Results







1. Undesired out of plane (z) modes are outside of the targeted bandwidth
2. Capacitive measurements vs. FEA simulated y-axis amplification
   - 3-13kHz bandwidth
   - Baseline amplification: 16 dB (6x)
   - Mean amplification: 23 dB (14x)
3. Transient response to a short 3kHz sine input

Conclusion

- A MEMS motion sensor with mechanical amplification of minimum (mean) 16 dB (23 dB) within the frequency band of 3-13 kHz was designed, fabricated and characterized
- Z-modes are designed to be outside the target bandwidth for increased axis selectivity
- Transient measurements show that the amplification is reached after only three periods of the input signal, making the device useful for the detection of short acoustic bursts

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