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X-Sense2 RTD 2013

FNSNF

A passive micromechanical broadband amplifier for environmental acoustic emission monitoring

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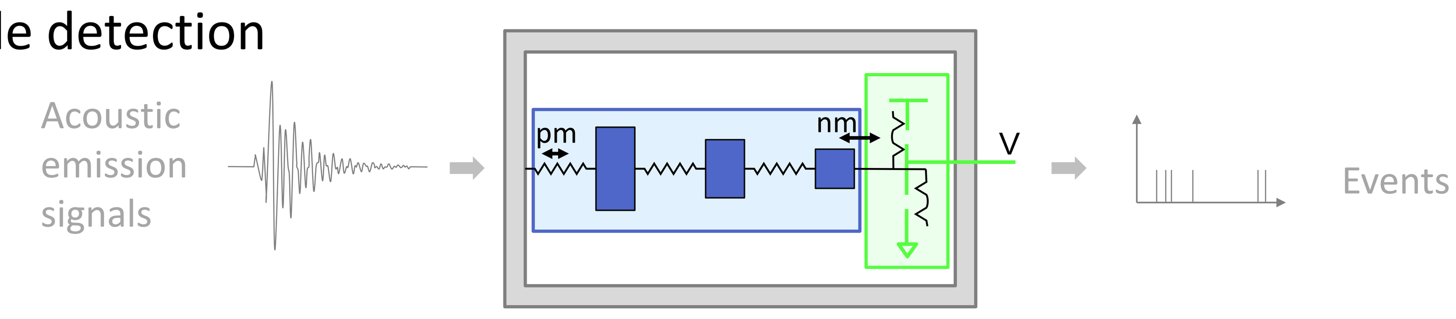
Motivation

Objective: MEMS ultra-low power acoustic emission trigger for rock slide detection

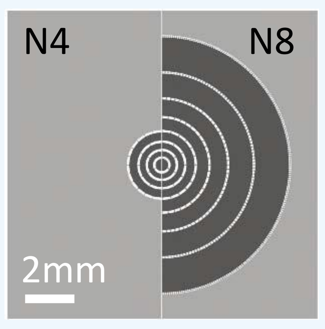


A coupled mass-spring system enables
- Purely mechanical **amplification** of incoming vibrations
- **Frequency selectivity**
- at **zero power** expense

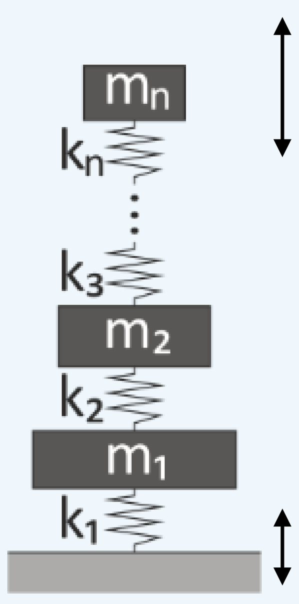
Threshold-detection by an electro-mechanical trigger features
- **Static threshold control**, no power intensive sampling
- High on-off ratios
- Reduced computational load

Concept

The mechanical amplifier consists of concentrically arranged ring-shaped masses with following design constraints (i = 1, … n):



- $$\frac{k_i + k_{i+1}}{m_i} = \omega_0$$
- $$\frac{m_{i-1}}{m_i} = 2$$

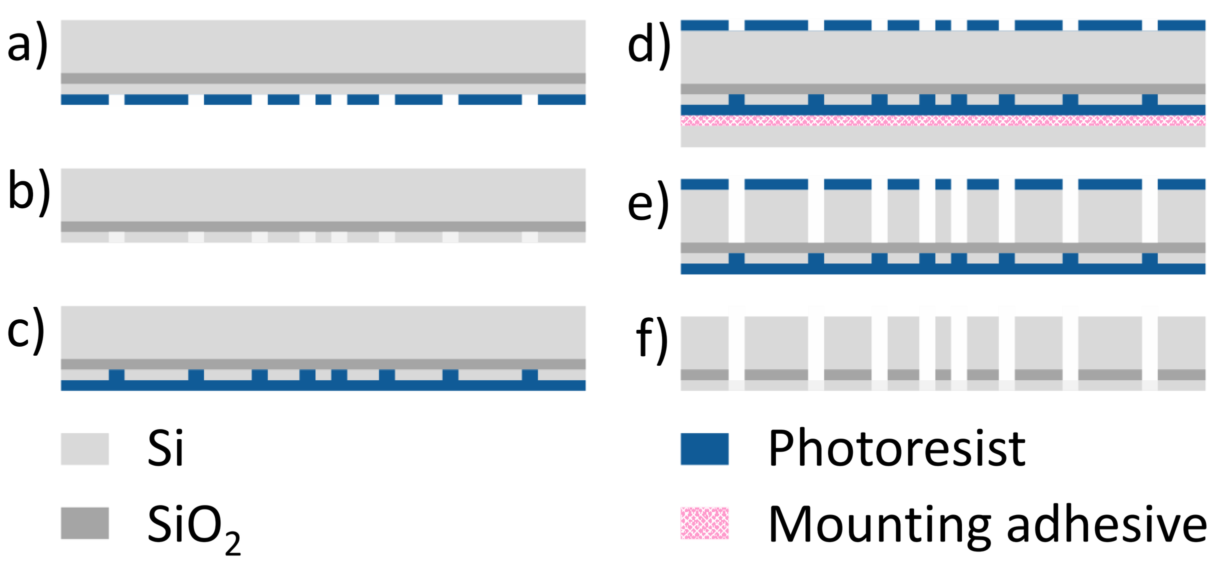


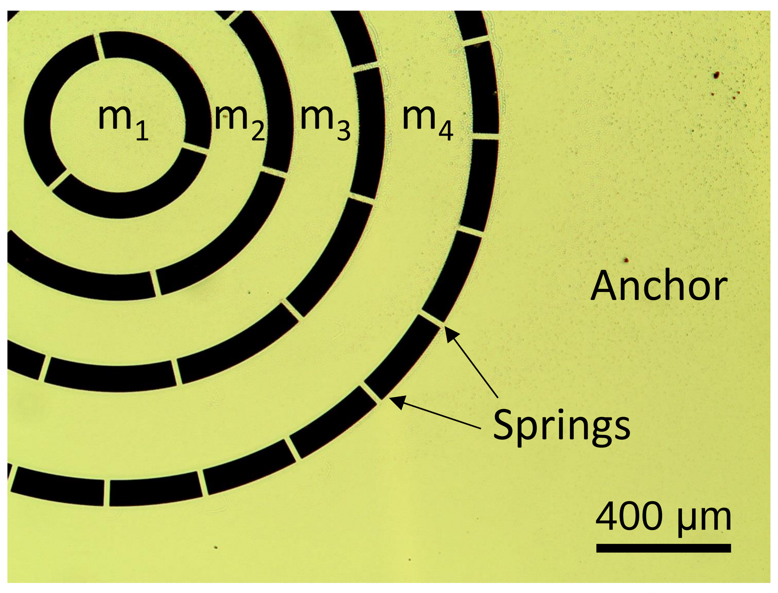
Weak vibrations exciting the outer-most mass and traveling towards the center mass are amplified, if they are within the allowed frequency band.

Methods

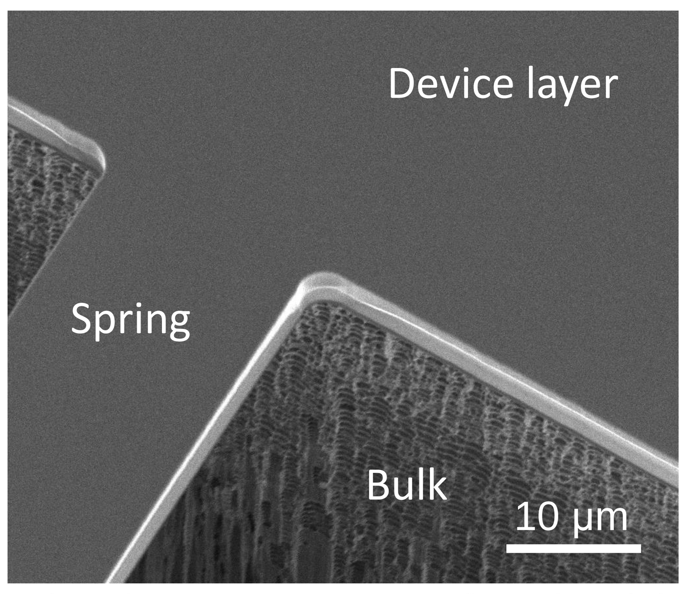
Fabrication

a) and b) patterning of spring/ device layer, c) spin coating of protective photoresist layer, d) and e) DRIE patterning of handle layer on support wafer, e) device after oxide removal with RIE





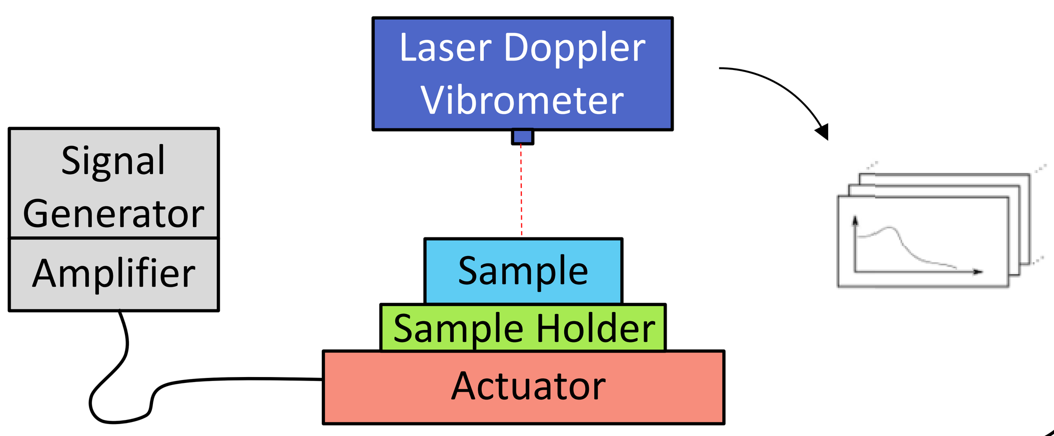
Optical microscope partial top view of N4.



Tilted SEM image of a double clamped beam (spring).

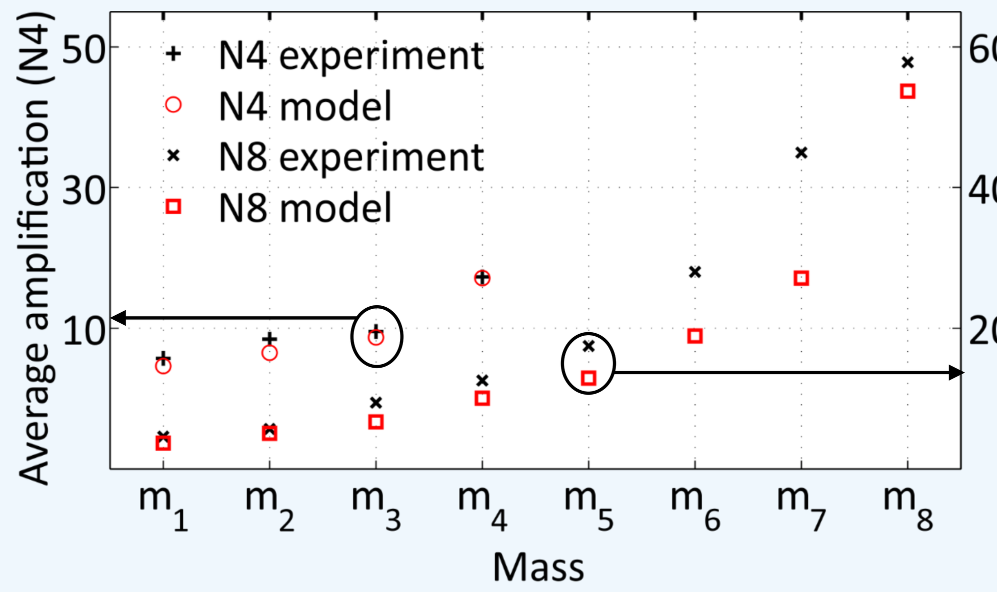
Characterization

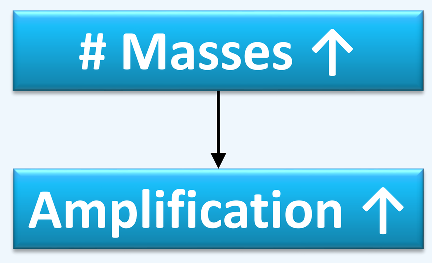
Samples were excited on a shaker and characterized with a Laser Doppler Vibrometer (LDV).



Results

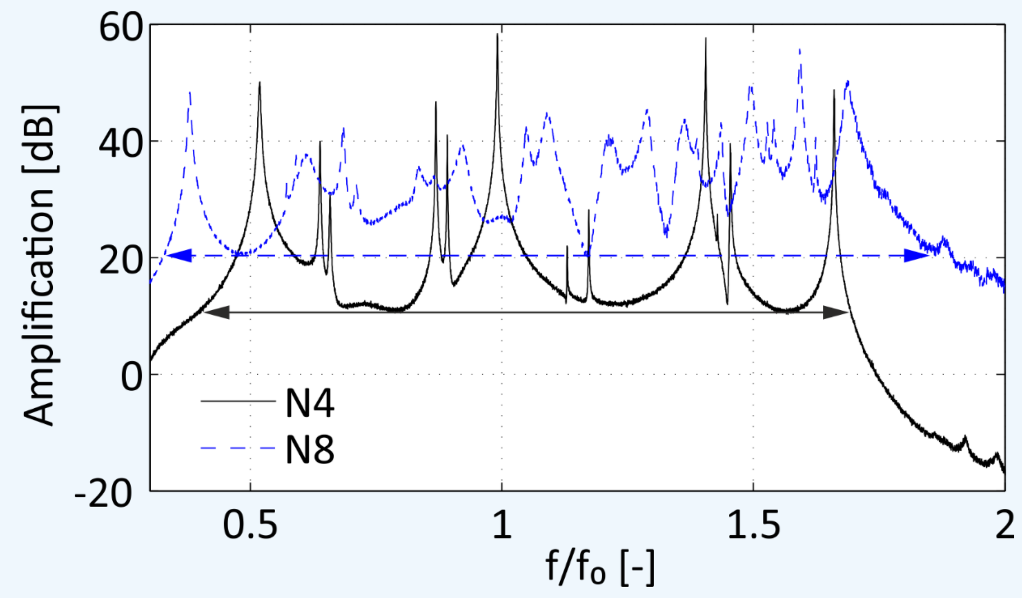
Average amplification

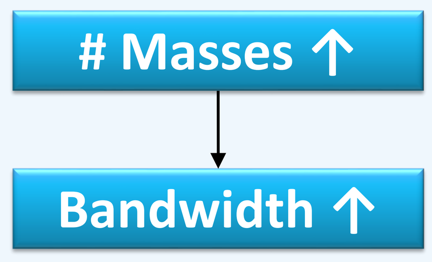




Average amplification at each mass of N4 and N8 is shown. A 3-times higher amplification can be observed at the center mass for N8.

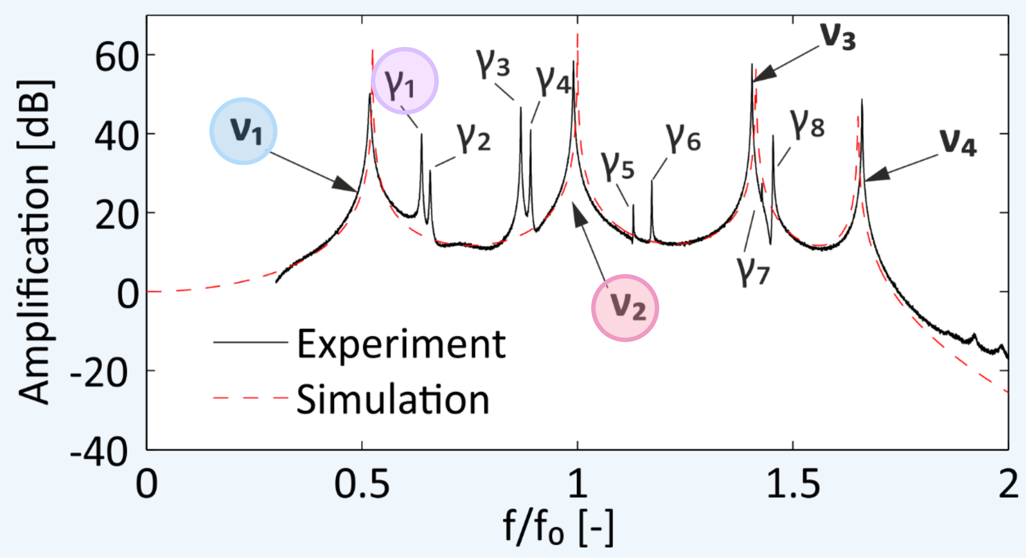
Transfer function



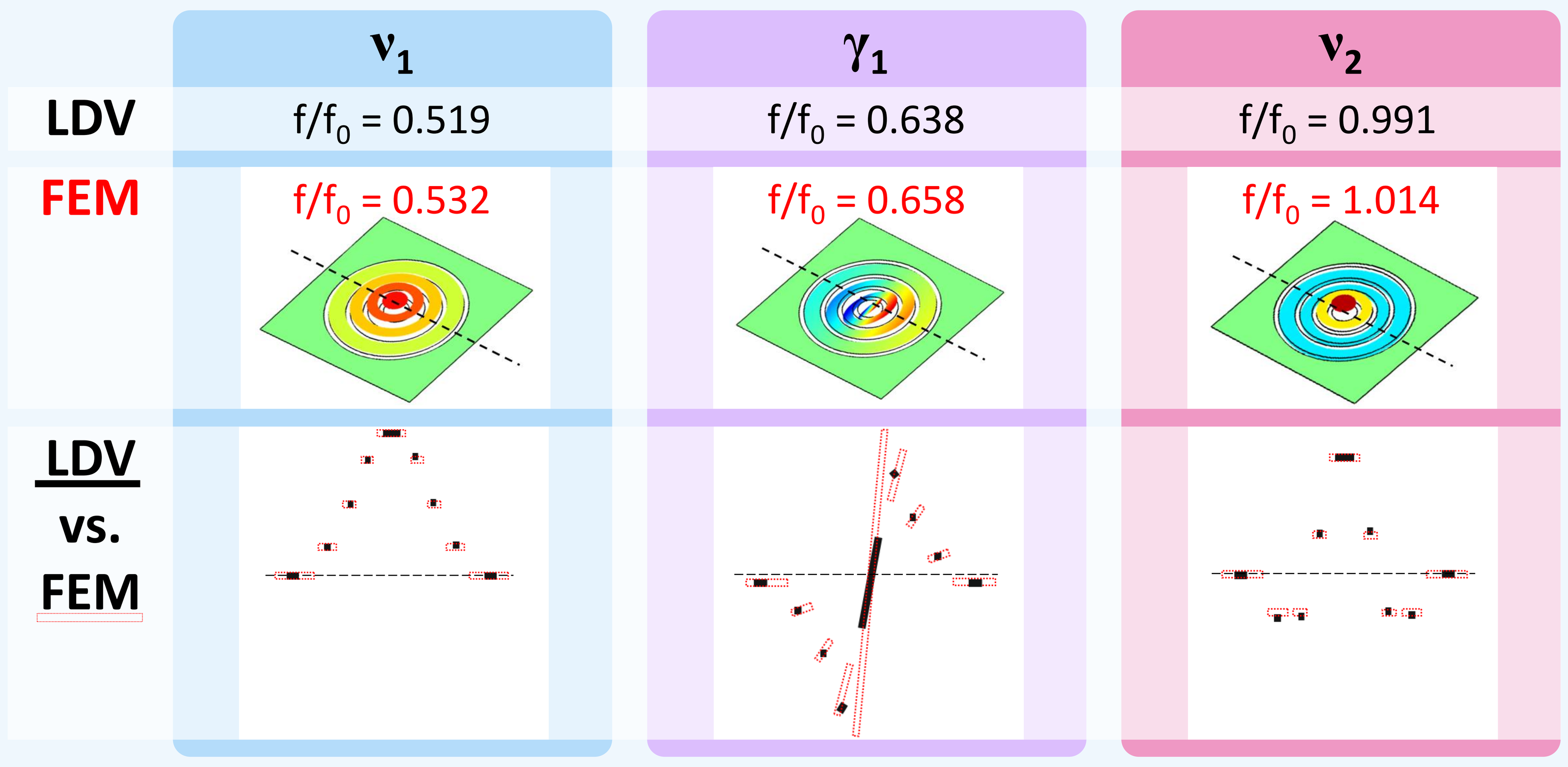


Transfer functions of the central masses of N4 and N8 are given. N8 shows a higher average amplification over a broader normalized bandwidth.

Mode shapes



The transfer function of the N4 is compared to a 1D mass-spring model. Additional peaks occure due to the 3D motional freedom of the masses in the real device (γ_i: normal modes, ν_i: gimbal modes).



Conclusion

- By increasing the number of coupled masses the average amplification and normalized bandwidth can be increased
- Average amplification and normalized bandwidth can be approximated with a 1D lumped model
- Gimbal mode shapes can be simulated with FEM, showing good correlation with Laser Doppler Vibrometer measurements

Acknowledgments
- Yunjia Li for helpful discussions and support in process development
- FIRST-CLA cleanroom staff of ETH Zürich as well as cleanroom staff at BRNC in Rüschlikon
- This research has been funded by Nano-Tera.ch, a program of the Swiss Confederation, evaluated by SNSF

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