PhD Position Offer

Modeling, fabrication and experimental characterization of weakly coupled MEMS arrays for mass detection

Subject: Modeling, fabrication and experimental characterization Study of weakly coupled MEMS arrays for mass detection

Laboratory: Femto-ST Institute – Department of Applied Mechanics

Receiving Institution: University of Franche-Comté – Faculty of Sciences and Techniques - 16 route de Gray 25000 Besançon

Time span: 3 years starting from September 2017

Field of research: Engineering science

Keywords: MEMS array, mode localization, mass detection

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Salary: 1 365 euros net/month (grant from the public department of education)

Context

The presence of small irregularities in nearly periodic structures may inhibit the propagation of vibration and localize the vibration modes. Under conditions of weak internal coupling, the mode shapes undergo dramatic changes to become strongly localized when small disorder is introduced, thereby confining the energy associated with a given mode to a small geometric region. This phenomenon, referred to as normal mode localization, has excited considerable interest in solid state physics over the years [1], [2], and more recently was rediscovered in the field of structural dynamics [3], [4].

This effect offers promising perspectives in terms of sensitivity in the field of biosensors dedicated to biological or environmental measurements.

This project falls within the framework of a collaboration between the MEMS team of the Applied Mechanics Department and the BioMicroDevice team of the Micro Nano Sciences &

Systems Department. Both departments are part of Femto-ST institute. This collaboration will be the opportunity to extend the actuation mode to piezoelectric materials and to develop the functionalization of the device.

Previous works carried out at the Department of Applied Mechanics

For 5 years the team MEMS Acoustics and Energy has developed research activities on modelling, fabricating and characterizing CMUT transducers.

The team has also a research activity dealing with mass detection at the nanometric scale:

- Nonlinear dynamic modeling of a carbon nanotube for mass detection (with geometrical and electrostatic nonlinearities) under primary [5] and parametric resonance [6],

- Functionalizing nonlinearities to improve the performances of NEMS sensors : use of simultaneous resonances (primary and super harmonic) to delay the instabilities due to 5th order nonlinearities [7].

Project description

The goal of the PhD is to investigate the potential of the mode localization effect in the field of mass detection. This work will thus include a part dealing with designing and modeling of a mass detector based on weakly coupled MEMS arrays. A second part of the work concerns the fabrication of the devices and their experimental characterization.

The physical principle referred takes advantage of the property of weakly coupled arrays known as mode localization. This phenomenon appears in weakly coupled systems in which a perturbation is introduced [8] [9]. In the targeted application, the perturbation will be a mass added on a functionalized surface of the array.

This principle has a high sensitivity, though to be an order of magnitude higher than the detection based on the frequency shift. This principle has already been partly investigated by Spletzer and al. [10], [11]. The major problem raised by the authors is that the manufacturing tolerances introduce initial disorder so that the system is not perfectly symmetric in its initial state.

The goal in this work is different and aims at taking advantage of the electrostatic interaction for three reasons:

- Generate the vibration in the array
- Control the veering through the DC voltage
- Read out the sensor with a capacitive measurement

The number of elements in the array will be an interesting parameter to study the wealth of information the sensor can give.

For the modeling, several lines of work are being considered:

- Extend the model to a n-elements array, starting from the model proposed by [10],
- Develop a model using the equations of the continuum mechanics

The model using the equations of the continuum mechanics enables the study of the nonlinearities that could be used to improve the performances of the sensor : simultaneous resonances [7] or parametric resonances [6] generated by the electrostatic interaction and internal resonances [12] or intrinsic localized modes in the case of a geometric nonlinearities (large displacements).

The second part of the study is to manufacture devices that allow the validation of the models developed in the first part. This work will use the facilities available at the technology center MIMENTO. It includes the layout mask design, the process flow, fabrication in the clean room and characterization of the devices using the equipment of the Department of Applied Mechanics (laser vibrometer, ultra-fast camera, impedance analyzer).

Qualifications

Candidates should have obtained a master's degree in mechanical engineering. Only candidates with very good grades from bachelor and master studies will be considered.

Rigorous and motivated, candidates must have good skills in modeling and numerical simulation in mechanical engineering, as well as a strong taste for experiment.

Application procedure

Applications must be submitted as one PDF file containing all materials to be given consideration. The file must include:

A letter motivating the application (cover letter)

Curriculum vitae

2 reference letters

Grade transcripts and BSc/MSc diploma

Candidates may apply prior to obtaining their MSc degree, but cannot begin before having received it.

The deadline for applications is 30 August 2017.

Bibliographie

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