Ph.D. offer - 2016

Optomechanics of MEMS sensors for high performance applications: towards ultra high-speed atomic force microscopy

Keywords: optomechanics, micro and nanosystems (MEMS and NEMS), instrumentation, metrology, atomic force microscopy (AFM).

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Laboratories: Laboratoire d'Analyse et d'Architecture des Systèmes (LAAS-CNRS) - Toulouse and Laboratoire Matériaux et Phénomènes Quantiques (MPQ-CNRS) - Paris.

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General context:

Optomechanics is a branch of physics that focuses on the interaction between light and mechanical objects [1, 2]. The motivation comes from the study of fundamental effects and quantum phenomena as well as from technological applications in the field of ultra-sensitive measurements. In particular during the last decade, the convergence between these concepts and fabrication techniques derived from semiconductors [3] and MEMS/NEMS has yielded simpler device structures and experimental environments. This fast growing research activity opens new perspectives and is undoubtedly a promising scientific route that will have a great impact for sensing applications, e.g. mass sensors for biological or chemical detection, inertial sensors (gyroscopes, accelerometers), force sensors (magnetic, mechanical stress…) [4, 5, 6].

Two key advantages arise from the use of the optomechanical interaction: first the measurement resolution of the mechanical displacement is boosted to the 10^{-18} m.Hz$^{-0.5}$ range typically [7, 8, 9], which is better by 3 orders of magnitudes than that usually obtained by the other transduction schemes of MEMS and NEMS devices. Moreover, it offers a measurement bandwidth of mechanical vibrations that exceeds 10 GHz. Integrated optomechanics thus opens new perspectives in the field of MEMS/NEMS sensors especially when an exquisite sensitivity and a large measurement bandwidth are desired.

Ph.D. framework and subject:

The main goal of the present research subject is to assess the quality of optomechanical devices regarding the requirements of a demanding application in the field of miniaturized sensors. The candidate will define the best conditions of exploitation of the optomechanical sensors and analyze the metrological properties in an experimental environment. This work is framed in the ANR OLYMPIA project that gathers 4 laboratories: LAAS-CNRS in Toulouse, CEA-LETI in Grenoble, MPQ in Paris and IEMN in Lille. The MPQ is an established player in optomechanics, and early developer of integrated nano-optomechanical approaches. The CEA-LETI will provide the OLYMPIA consortium with the optomechanical sensors. They will be fabricated in collaboration with IEMN that is renowned for its work started 10 years ago concerning MEMS based AFM probes. The LAAS-CNRS will develop the experimental set-up in which the optomechanical sensors will be integrated and that will give access to their metrological quality in a practical environment of use and application. Vibrating force probe for high-speed Atomic Force Microscopy (AFM) is the chosen application. It is a demanding application in terms of measurement resolution and bandwidth for which both LAAS and IEMN have acquired a strong expertise. In such a context, the optomechanical AFM sensor is a demonstrative choice to prove the applicative potential of optomechanical sensors because it will bring a breakthrough in the field, not only in terms of concept but also in terms of performances.

The candidate will:

- Design and built the optical units to drive and sense the optomechanical sensors:
  - Choice of the laser source and photo-detector with the best trade-off for portability, compacity, cost and performances;
  - Skills transfer between MPQ and LAAS-CNRS and integration of the optical unit into the AFM set-up;
  - Development of control interfaces to drive the vibration and analyse the optomechanical device displacement.

- Characterize the performances of the optomechanical AFM sensor in real conditions of use within the AFM set-up:
  - Study of noise sources of the sensor optomechanical transduction scheme;
  - Experimental characterization of the AFM sensor resolution and stability;
  - Modeling of the fluctuation sources and assessment of their global impact for AFM application in terms of measurement quality.

- Demonstrate a real AFM application and the added value of the optomechanical sensors:
  - AFM experiments using optomechanical sensors;
  - Performance analysis versus operating point;
  - Exploitation of the optomechanical sensors for experiments of interest: AFM images of reference samples and AFM spectroscopy.

More information / submit an application?

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