Title: **Nanorobotic Origami unfolded at the end of optic fiber**

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Host laboratory: FEMTO-ST AS2M department, Micro-Nano Robotics team
Funding: doctoral institution contract

Scientific context:

The need for characterization systems and/or nanorobots to operate at very small dimensional scales is increasingly emerging as a result of the downscaling of many objects. It involves characterizing systems of nanometric dimensions or manipulating nanometric objects. These needs are considerable and cover a wide range of applications, but there is a lack of available solutions [1]. Significant efforts are being made to study two approaches:

- Some commercial systems are operating at their limits and allow to demonstrate interesting results but for some specific applications. Among them, we can mention the AFM [2]
- The very strong limits of commercial systems push many research teams to study riskier approaches aimed at new principles of actuation, motion transformation, measurement... for example miniature robotic origami [3][4][5], rotation by highly deformable metamaterials [6], flexible retractable structures [7] or deformable [8].

Among these original solutions, making nanosensors or active structures at the end of the optical fiber is an answer to this need. It is a real challenge, both technical and theoretical. The latest work on this issue led to major publications in 2018, such as [9] (Figure 1). The state of the art is the realization of passive force sensors at the end of the fiber or grippers based on the implementation of a 3D printed metamaterial system.

Fig. 1 :microgripper at the end of an optic fiber

Thesis work

In this thesis, we propose another approach, based on **the unfolding of a structure set up at the end of the fiber with the help of robotic means under SEM**. This involves pre-cutting a structure at the FIB, setting it up, assembling it and generating its deployment at the end of the fibre and allowing its use using the available optical flow. The terminal or intermediate parts of the end-of-fiber structure could be mirrors, or coated or uncoated filters, single-layer reflectors or multilayer filters at certain wavelengths of interest.

The supervisors of the thesis have an expertise in the design, realization, modeling and ordering of origami-based structures and assembly under SEM, in particular (1) the realization of folded and assembled structures at the end of the fiber: micro-house [10] (2) modelling and control of flexible MEMS structures: micro-mirrors [11] (3) study and realization of principles of electrothermal and thin layer piezo micro-actuators [12][13][14] (4) realization of ultra-precise optical fiber end assemblies with integrated optical measurement [15][16].

The first objective is to invent new structures at the end of the fiber based on origami and assembly. The second objective is to use optical cavity measurements to determine the positions and displacements of the system at the end of the fiber. This will allow the use of force sensors. The third objective is to control the structure to carry out nanomanipulation operations. This requires physical modelling of the structure's behaviour and "robotic" modelling, this theoretical work would be an original contribution compared to the highly experimental work presented by the international community.

We wish to develop work based on our expertise in the production of microfabricated and assembled active structures and offer an alternative approach to the work carried out with printed metamaterials. Finally, it is therefore a question of designing and controlling origami/assembly-based systems both in the field of end-of fiber force sensors but also by bringing the control to make the systems active.

Surrounding of the PhD. thesis

The PhD. fellow will be part of the AS2M department (Automatic Control and Micro-Mechatronic Systems) of the FEMTO-ST Institute (www.femto-st.fr/). FEMTO-ST is a joint research institute which is affiliated to four representative entities: CNRS, UFC, ENSMM and UTBM. FEMTO-ST hires more than 700 employees (among biggest French laboratories in engineering sciences) involved in different fields of engineering science, it is A+ ranked (best mark at the national level). It is organized according to 7 research departments and runs a microfabrication technology center, which is recognized nation-wide. Among them, the AS2M department is one of largest teams involved in the fields of micro-nano-robotics, micromechatronics and control especially for micro and nano-assembly in Europe and in the world. PhD. Students benefit from a stimulating and fruitful working environment that enables them to get the best of their potential.

AS2M also hosts the MICRO-ROBOTEX (http://projects.femto-st.fr/microrobotex/fr) platform that has been funded by the PIA (Programme d'Investissements d'Avenir) equipex program and is a part of the national network for platforms of excellence called ROBOTEX. MICRO-ROBOTEX provides a highly competitive and very recent instrument at the international level to academic and industrial researchers in nanotechnologies. In particular, it is equipped of a SEM with a wide chamber, that includes a focusing ion beam, a gas injection system and 14 DoF manipulation micro/nano-stages inside the chamber. MICRO-ROBOTEX represents a unique environment for automated micro/nano-assembly and position/force feedback manipulation and characterization of samples. A specific interface has also been developed to enable real-time interaction with all equipment's which offers the possibility to achieve simultaneously and dynamically several motions, collect and use multiple sensory feedback in a unique way.

Required skills:

The thesis work requires a multidisciplinary profile. It will be necessary to develop high-level skills in modelling deformable microsystems (origami) in order to understand their behaviour and control them, and in manufacturing these systems under SEM.

The required profile is that of a Master 2 student or a final year engineering student with a background in mechatronics with a high level of skills in physics and mechanics. Knowledge of modelling, multiphysics simulation and numerical calculation software is an important point. He/she has good written expression skills English (and French if possible). Open-minded, he/she will be led to work in a team and must be able to communicate easily. Listening, dynamic and persevering to carry out a 3-year research project.

Application procedure:

Applicants should send a cover letter, a CV, their transcripts (M1, M2 or last two academic years), M1 rankings if available as a single PDF file to the following email addresses: philippe.lutz@femto-st.fr, cedric.clevy@femto-st.fr, jy.rauch@femto-st.fr

The application must be sent before June 7, 2019.

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