Thesis title: Design, 4D-printed fabrication, Control and Characterization of Soft-Microrobots

Host Laboratory: FEMTO-ST Institute, AS2M Department in collaboration with the Roberval Institute

Major of the thesis: Robotics

Keywords: Design, modelling (Finite Element Modelling, physics and data based), kinematic control, soft robotics, control of robot-environment interactions, robotics at small scales, experimentation

Job description of the PhD thesis

Context of the PhD thesis:

To meet growing needs in the fields of healthcare and manufacturing, microrobotics brings highly original and powerful solutions but is expected to undergo a paradigm shift by combining dexterity, compactness, workspace, and precision [SLY16][MKB25][JCO25]. Several promising approaches are being investigated including 4D printing i.e. 3D printed structures that can deform with time [JMC21][KJB23][LLH25], folding of active planar substrates [BWR21][LEI23] or planar smart surfaces [VJ22][NPH25]. In this context, a highly promising approach has recently been developed through collaboration between the FEMTO-ST Institute (the AS2M and MN2S departments) and IS2M. It involves using Two-Photon Stereolithography (TPS) to fabricate micro-nano-robots made of photo-activated materials mounted at the tips of optical fibers. The main goal is to design the first generation of microrobots by combining complex 3D structures with photo-thermo-multi-reactive polymers [SS20][ABR21] and can efficiently interact with their working environment (ability to control force, achieve tasks such as manipulation) [ABR24]. Such robots do not yet exist and would enable the resolution of numerous practical problems, whether in the field of minimally invasive surgery, cell manipulation, or the manipulation and assembly of industrial components for which such tools do not yet exist but would possess unique capabilities. In this scope, Roberval also recently demonstrated the capability to actuate and sense by lasers (fibers and steering mirrors) at small scales covering modeling and control aspects with success which will strongly contribute to the proposed approach [MHD24][NPH25].

This PhD thesis builds on these very recent works that led to the development of a thermosensitive polymer (based on PNIPAM) with properties that are particularly disruptive for the field of microrobotics compared to commercially available polymers, such as its ability to generate large motions and the possibility of remote activation via a laser beam. A 4D printing process has also been developed to successfully fabricate actuators from this polymer, as well as to create multi-material structures combining these actuators with 3D-printed passive components. These initial proof-of-concepts have also been subjected to multiphysics modeling and experimental quantification of their performance. The initial results obtained as part of the national ANR PNanoBot project (see Figure 1) are extremely promising [SBC25].

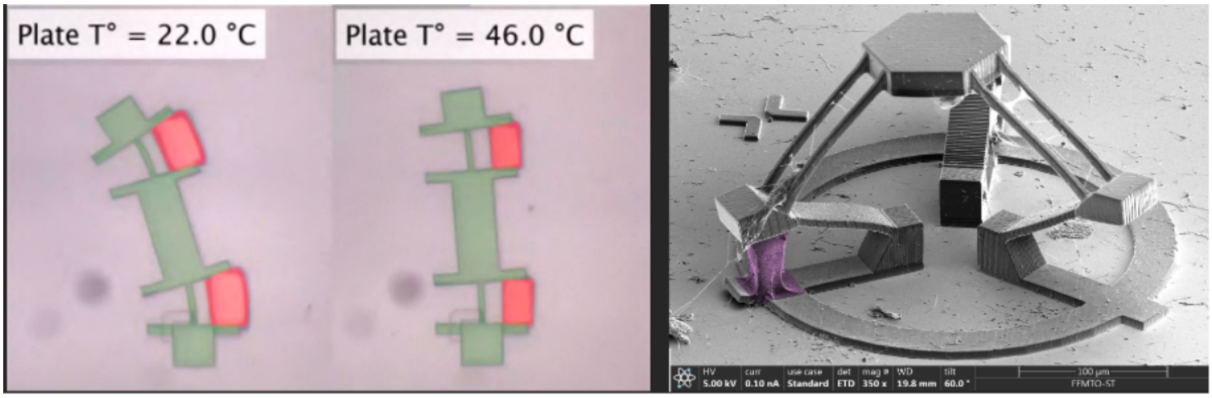

Figure 1: (left) A 100µm long micromechatronic bi-material structure combining two actuators (in red) and a passive mechanical motion transformation structure (in green) [SBC25], (right) Parallel microrobot combining an actuator (in purple) and a mechanical motion

Objectives of the PhD thesis: Building on these unique proof-of-concepts, the main objectives of this thesis are to propose original designs based on 4D-priting for various microrobots types—that is, robots incorporating multiple actuators and a passive mechanical structure. Several robotic architectures will be studied, starting with basic building blocks, as well as serial and parallel robots. The integration of these robots at the tip of a multi-core optical fiber will be of key interest to enable the localized and multi-DoF (Degrees of Freedom) actuation in very tiny workspaces. Indeed, part of the work will involve doping the actuators with metal particles (to absorb energy from a laser beam), which will allow for the selective heating of each actuator. Key influential parameters of the laser/matter interaction will be studied such as the wavelength, power, etc. The thesis will include proposing designs, finite element simulation of their behavior (multiphysics simulation such as COMSOL Multiphysics mainly), 3D printing of several robots, and characterizing their performance using an existing experimental platform that will need to be adapted and improved for this purpose. The experimental work will require, in particular, familiarity with and mastery of all the tools on the dedicated test bench (control of positioning axes, image acquisition, etc.). The ultimate goal of the thesis will be to build the first sub-millimeter-scale robots and demonstrate their potential through illustrative videos and experimental data quantifying their performance (working range, repeatability, path and trajectory tracking, execution of a manipulation task, etc.). This last objective will thus include modelling of the behavior and control.

Main steps of the PhD thesis:

1. Literature review for the familiarization with internal technical reports, external process recently published in the literature and the overall scientific positioning of the works in the state-of-the-art;

2. Design, modelling and fabrication* of initial prototypes and familiarization with the experimental platform** for their characterization; This step will consist in proposing kinematic architectures, to model their behavior (different methods will be investigated that are Finite Element modelling, data and physics based) and to fabricate them

3. Characterization and control of robots with complex movements (3D) to validate their operating principles, to quantify their performance but also to demonstrate their interest on practical applications such as micro-assembly, manipulation or characterization scenarios.

* The main part of the work will deal with 4D printing. A Technical support will be available to assist with prototype fabrication for first iterations then to come to a full autonomy on the Nanoscribe GT2 machine.

** a first experimental platform has recently been developed and will be re-used at the beginning of the thesis. The PhD candidate will be responsible for further developing this experimental platform.

Working environment

As the works are in collaboration between FEMTO-ST and Roberval research institutes, the PhD candidate will be a full member of the Department of Automation and Micro-Mechatronic Systems (AS2M) at the FEMTO-ST Institute in Besançon, France and of the Roverval laboratory located in Compiègne. The candidate will conduct her/his research at FEMTO-ST/Besançon and may be required to make a few short stays to Roberval/Compiègne.

FEMTO-ST is a multidisciplinary research institute comprising 7 research departments. The AS2M (Automatic control and Micro-Mechatronic Systems) department, which specializes in microrobotics and micro-mechatronics, is internationally renowned for its more than 20 years of expertise in micromanipulation, miniature robotics, flexible robotics, advanced automation, optics and applied mechanics. The PhD candidate will be part of the ROMOCO team (Robotics, Modeling and Command) of AS2M and will have close collaboration with engineers and researchers, notably within the CMNR (Centre de Micro et de Nano Robotique) and will have full access to the MIMENTO platform if required (platform part of the national Renatech network). The PhD candidate will also be part of the M2EI (Mecatronics, Energy, Electricity and Integration) research team of the Roverval laboratory from UTC and will have full access to the microrobotic platform. This research team has more than 20 years of experience in the design, modeling and characterization of mini-robots and micro-sensors. The candidate will be encouraged to participate in current ongoing national and international collaborations or to initiate one if so desired. The PhD student will also have access to all equipment part of the TIRREX platform on micro-nanorobotics (national network of robotic platforms of excellence) located in the AS2M department.

Deliverables

Several deliverables will be expected from the PhD thesis this will be the form of:

- The writing of reports: to formalize research advancements regularly, a yearly thesis report as well as the thesis manuscript,
- The dissemination of the works/results: by publishing in international journals in robotics and mechatronics, by attending international conferences and workshops at the international, national and regional levels and by presenting the thesis/research thematics during visits, and
- The sharing of experience with people in the group.

Profil demandé / Applicant profile

We are seeking a highly motivated, a team player, an open mind, and result-oriented candidate. The candidates are expected to have the following skills:

- Master degree in mechanical, mechatronics, robotics engineering or equivalent with distinction and covering both methodological/theoretical and experimental aspects.
- Strong background in modelling of multi-physical systems, control, robotics, soft materials, and manufacturing (micromachining).
- Familiar with Matlab, Python or C++, CAD software and Finite Element Methods.
- Interest/experience on experimental investigations/validations.
- Additional skills on computer vision and optics (lasers) might be appreciated

Candidates must be fluent in English. French would be an advantage but not necessary.

Funding & contract: PEPR MINIRO "Robotique miniature"

The works (PhD thesis and all related costs) will be funded by the PEPR MINIRO ("Miniature robotics") project. This is a new national project to deploy "miniature robotics" through a network of excellence comprising the 9 research institutes contributing to this field. The project started on Dec. 2025 and will last for more than 6 years. This is a very fruitful working environment that will allow the PhD student to develop her/his thesis project and research through a collaborative network at a national and international level.

Beginning of the contract: 1st October 2026

Gross monthly salary: 2100€. The position is fully funded position for a 3 years duration. Additional teaching activities might be available in case of interest. The contract will be established by University Marie and Louis Pasteur.

Thesis Supervisor: Cédric CLÉVY, Professor, Université Marie et Louis Pasteur, FEMTO-ST, UMR CNRS 6174
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Thesis co-supervisors: Laurent PETIT, Associate Professor, Université de Technologie de Compiègne, Laboratoire Roberval, laurent.petit@utc.fr

Application: Applicants are invited to submit their application to the PhD supervisors, including a CV, a cover letter, transcripts from master's program or engineering degree and one reference letter in a single PDF. If you have significant work experience (more than one year, excluding internships), you may submit a document (no more than two pages) detailing aspects of your professional background that you believe are relevant to your application. The selection process is ongoing and will last until the position is filled.

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