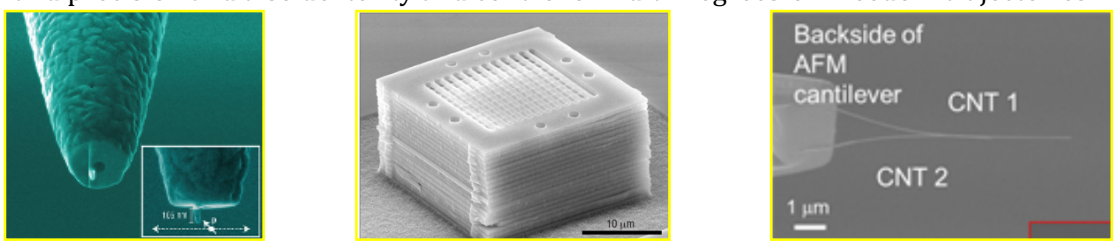
ULTRA-PRECISION ROBOTICS FOR NANOTECHNOLOGY APPLICATIONS

General context of the PhD. Thesis:

Nanotechnologies are increasingly growing from both industrial and scientific point of views. The recent emergence of many innovative materials and nano-objects with outstanding characteristics goes with the need to study and also to combine them to design more complex arrangements such as NEMS, nano-sensors or nano-optical devices. Among existing "characterization to manufacturing" techniques (self-assembly, chemical synthesis, electron beam lithography, mobile nanoparticules…), the use of nanorobotic platforms recently demonstrate extremely high interest through achieving, in an original way, nanomanipulation and nano-assembly tasks offering disruptive characterization and nanomanufacturing potential (Figure 1) **[Shi16][Lid16].** Nevertheless, these robots rely on tools initially developed for microscopy or microscale robotics purposes that have been derived for nanorobotics tasks. Then, intrinsic limitations induce numerous remaining issues to overcome the need of resolution and precision and also dexterity and control of multi-Degrees-of-Freedom trajectories.



(a) (b) (c)

Figure 1: Examples of complex nanodevices (a) optical nano-antenna at the end of a near-field fibre probe ***[Tam08]*** *(b) assembled nanophotonic crystal* ***[Aok03]*** *(c) AFM probe tip customized with two CNT* ***[Yan15].***

Main objectives of the works

The general objective of the PhD. Thesis is to propose an innovative way to perform complex tasks with high accuracy at the nanoscale through advanced robotics methods. Two complementary approaches will be investigated:

(1) The first approach will consist in investigating a new nanorobotics generation and will mainly consist in design and development steps. A proof-of-concept demonstrator using a parallel and compliant architecture including smart materials is expected to be developed during the PhD thesis. These works will notably be based on already achieved works, notably a patented parallel robot-architecture and smart material-based technologies and fabrication ones such as additive manufacturing or clean-room fabrication.

(2) The second approach will address control aspects especially to achieve complex multi-Degrees of Freedom (DoF) motions with ultra-precision (typically some tens of nanometers). New micro/nano-robot calibration and advanced control methods are clearly expected during the thesis. Experimental validation will be done on the micro-Robotex platform (please refer to the "surrounding of the PhD. thesis" section bellow) at first and on the newly developed proof-of-concept demonstrator mentioned in (1).

Several nanomanipulation and nano-assembly tasks will also be experimentally investigated on industrial use cases during the PhD. Thesis.

Surrounding of the PhD. thesis

The PhD. fellow will be part of the AS2M department[1] (Automatic Control and Micro-Mechatronic Systems) of the FEMTO-ST Institute. FEMTO-ST[2] is a joint research institute which is affiliated to four representative entities:

[1] http://www.femto-st.fr/fr/Departements-de-recherche/AS2M/Presentation/

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 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[3]. 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. Figure 2 shows an example of a 20µmx10µmx10µm (ou µm à la fin) house that has been assembled and fixed at the tip of an optical fibre (proof-of-concept realized for the industry exhibition Micronora 2016 to demonstrate the wide capability for optical fibber-tips functionalisation through robotics).

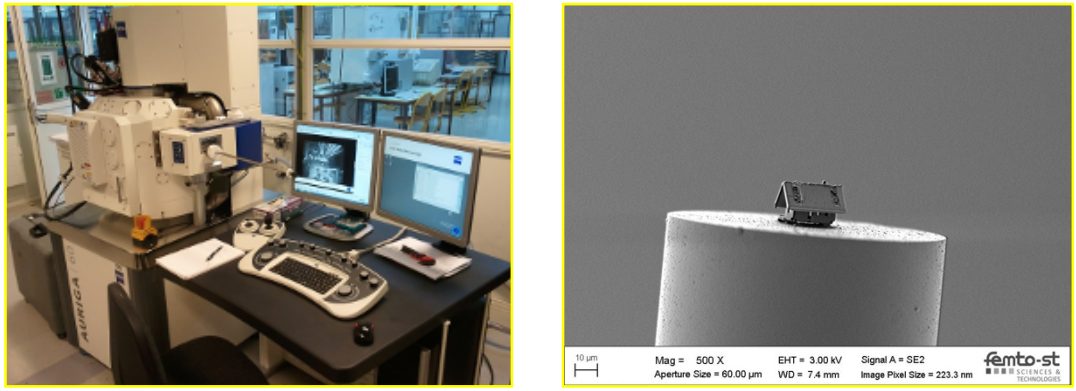


Figure 2: Illustration of MICRO-ROBOTEX abilities in handling and nano-assembly. The house is 20 µm in length, 10 µm in width. The walls have been made by folding 1µm-thick silica film.

Technical means available for the thesis:

MICROROBOTEX platform, computers, softwares (Matlab, Solidworks, Catia, Comsol Multiphysics), experimental set-up for research scale validation of results, funds for additional needs such as fabrication and participation to international conferences.

Requested skills

Profiles based on/or merging competencies of robotics with a high interest on experimentation will be considered with a great attention. Mechatronics, instrumentation, knowledge related to the micro and nanoscales as well as

[2] http://www.femto-st.fr/
[3] http://projects.femto-st.fr/microrobotex/fr

abilities for clean-room fabrication are skills that will also pay attention but will be also appreciated but will be considered as optional. The proposed thesis is for curious, inventive, dynamic applicants having a strong scientific background and a sense of communication in a collaborative and multidisciplinary environment.

Advisory team of the PhD:

Redwan Dahmouche - Associate professor
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Guillaume Laurent - Associate professor
CODE team[5] - Guillaume.Laurent@ens2m.fr - http://www.glaurent.free.fr/index.php

Cédric Clévy - Associate professor
CODE team5 – cclevy@femto-st.fr - https://sites.google.com/site/cedricclevy/home

Contract:

3 years' duration doctoral contract, The PhD thesis may start in September or October 2017.
Doctoral school SPIM (Engineering Sciences and Microtechnologies) - http://ed-spim.univ-fcomte.fr/
Additional activities such as teaching will be possible (to be discussed).

Application:

Please send your application documents (all in one PDF file) to Cédric Clévy (cclevy@femto-st.fr) including a detailed CV, motivation letter dedicated to the proposed position, marks and ranks you obtained during your master degree or engineering school and at least one contact person (typically your supervisor for a training period, master thesis or responsible of your master diploma).

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References:

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[Lid16] Liddle, J. Alexander, and Gregg M. Gallatin. "Nanomanufacturing: a perspective." ACS nano 10.3 (2016): 2995-3014.
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[Shi16] Shi C. et al. "Recent advances in nanorobotic manipulation inside scanning electron microscopes." Microsystems & Nanoengineering 2 (2016).
[Yan15] Yang Z. et al. (2015). Dual-MWCNT probe thermal sensor assembly and evaluation based on nanorobotic manipulation inside a field-emission-scanning electron microscope. Int. J. of Advanced Robotic Systems, 12.

[4] http://teams.femto-st.fr/minarob/
[5] http://teams.femto-st.fr/code/