PhD THESIS POSITION PROPOSAL
Design, modeling, fabrication and characterization of a Stirling micro-engine for energy harvesting and conversion.

Research unit/ Institution:
FEMTO-ST institute, 15 B avenue des Montboucons, 25030 BESANCON cedex (University of Bourgogne Franche-Comté, Ecole doctorale Sciences Pour l'Ingénieur et Microtechniques)

Keywords:
Micro-engine, Stirling, Microfabrication, Energy harvesting.

PhD supervisors & contacts:
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Funding/contract:
3 years contract, co-financing Labex ACTION/ Region

Scientific and material conditions:
Grant and fundings of the PhD on a Region project and a Labex ACTION project. Concerning the clean room process, the Femto-st institute benefits from a Micro/Nanotechnology center (MIMENTO) which belongs to the French national microfabrication network (RENATECH). MN2S and ENERGIE departments are equipped with test benches/setups and characterization equipment. Collaborations / interactions with other research institutes will occurred during the PhD.

Beginning of the PhD contract:
The first of October 2018 (10/01/2018) - A beginning before or after this date is possible

Deadline for application and documents to provide:
8th of June 2018. Applicants should submit a cover letter with details on research and teaching interests (teaching interest being not mandatory), a full curriculum vitae, names and contact information of one (or more) reference, certificates and copies of diplomas obtained and copies of transcripts of the Master's degree.

Profile and Required skills:
- Master II or engineer level/diploma
- Good knowledge in mechanics, fluidics, thermodynamics
- Bases in microfabrication process
- Knowledge in numerical simulation (COMSOL) would be appreciated
- Good English level required
- The candidate must be able to demonstrate autonomy and initiative

Context:
This project concerns the development of a micro-Stirling engine for energy harvesting (recovery of lost thermal energy and conversion into electrical energy, and vice versa). It is a collaborative project between the departments MN2S (MOEMS group) and ENERGY (THERMIE team) of the

FEMTO-ST institute and which is the result of a committed work with academic partners (University of Savoie and University of Sherbrooke-Canada) on the development of a miniaturized Stirling engine for energy recovery. The Stirling engine is based on a reversible cycle of isothermal compression and expansion of a gas (air), it allows to convert a thermal energy into mechanical energy (generated by the movement of the membranes), or on the contrary, by imposing a displacement to the membranes, to produce a thermal energy (cold). This makes the Stirling engine a relevant element in many fields, and especially for the valorization of thermal energy at low temperature level. If there are functional demonstrators at the macro (Femto-st: [1-2]) or mesoscopic scales, nothing exists at the microscopic one: international works on a miniature Stirling machine are only theoretical or numerical [3-5]. The miniaturization of such an energy system is of great interest since it can be deployed in many areas, making it a system that is relevant for multiple applications (for example, for on-board cooling systems for which congestion constraints are very strong).

Detailed presentation of the subject:

This phD thesis aims at the realization of a miniaturized Stirling engine by means of clean room technologies (available within the Femto-st institute). In the context of previous projects, some elements of the micro-Stirling engine have already been developed (hybrid membranes, micro-regenerators) [6-9]. In order to realize a complete machine, it will first be necessary to study the thermal and fluidic behaviors at the microscale by performing micro-test benches. At these scales, the mechanisms are still not well understood and there are almost no results on the subject in literature. So the results obtained on the micro-test setup will enable the optimization of the design of the machine to achieve. The use of innovative 3D machining tools (FEMTOprint) recently available in FEMTO-ST's MIMENTO technology center will enable innovative ultra-miniature geometries. The second part of the PhD work will consist of both thermal and fluidic characterization of the machine's performance. Emphasis will be put on energy recovery and conversion (thermal / electrical).

The expected results of this work will be potentially very innovative, especially since to date, no functional demonstrator at these scales exists: to obtain it would be a world first.

Promotion objectives:

The expected results being totally original, they must be valued, which will be done through oral communications (presentation of the results in national or international conferences), through publications in international peer-reviewed journals and through patents.

References:

[1] S. Bégot *et al.,* Stability analysis of free piston Stirling engines, The European Physical Journal Applied Physics, 2013.

[2] S. Djetel-Gothe *et al.,* A Stirling engine for automotive applications, IEEE VPPC, Belfort, France, 2017.

[3] N. Nakajima *et al.,* Study on microengines: miniaturing Stirling engines for actuators, Sensors and Actuators, 1989.

[4] D. Guo *et al.,* Modeling System Dynamics in a MEMS-Based Stirling Cooler, COMSOL conference, Boston, USA, 2011.

[5] L-L. Lemaire, Miniaturized Stirling Engines for Waste Heat Recovery, PhD thesis, McGill University, Canada, 2012.

[6] R. Chutani *et al.,* The design, fabrication and characterization of fluidic membranes for micro-engines , Journal of Micromechanics and Microengine, 2016.

[7] A. Diallo *et al.,* Hybrid Fluidic Membrane demonstration for a MEMS based Stirling engine, NAMIS School, Tokyo, Japan, 2016.

[8] E. Dellali *et al.,* Fabrication and CFD modeling of a Stirling engine microregenerator, The International Stirling Engine Conference (ISEC), Newcastle – UK, 24-26 August 2016.

[9] A. Diallo *et al.,* Study of dynamic response of silicone elastomer microfabricated hybrid membranes versus temperatures and aging time, PowerMEMS 2017, Nakazawa, Japan, 2017.