école doctorale **sciences pour l'ingénieur et microtechniques**

Titre de la thèse : Études théoriques et expérimentales des modes intrinsèques localisés dans des réseaux périodiques sous excitation paramétrique - Application au piégeage ou à la récupération de l'énergie vibratoire

Thesis title: Theoretical and Experimental Investigations of Intrinsic Localized Modes in parametrically excited periodic lattices – Application to Vibration Energy Trapping or Harvesting

Host Laboratory: Femto-St Institute, UMR 6174, Department of Applied Mechanics

PhD thesis Specialty: Mechanical Engineering

Keywords: Energy harvesting, Nonlinear dynamics, Intrinsic localized modes

1. BACKGROUND

The nonlinear physics of discrete systems has received enormous developments in recent years. In particular, a lot of attention has been paid to the Intrinsic Localized Modes (ILMs), or discrete breathers (DBs) [1]. ILM key features are nonlinearity [2] and discreteness [3] and unlike Anderson localization [4], ILMs are not externally imposed rather due to intrinsic nonlinearity. These localized excitations have been observed in a wide variety of different systems [5-7]. Although breathers are just very particular solutions of nonlinear systems, the fact that they appear spontaneously and persist in numerical simulations with a fairly long lifetime suggest that they must play an important role in the dynamics of nonlinear systems.

The remarkable property of ILMs [8-11] is their exceptional stability against disturbances (Figure 1). They are also able to occur spontaneously in a non-autonomous physical system even if the initial excitation does not exactly correspond to an ILM. Actually, if a system has characteristics that allow the existence of solitons, then an intense excitation will potentially lead to their creation. Therefore, solitons play a fundamental role in the properties of energy transport for a variety of fields such as optics, acoustics and hydraulics.

2. PROJECT (RESEARCH) AIMS

The principal goal of this thesis consists in the numerical and experimental investigations of ILMs (mono solitons and multi-solitons) creation in periodic nonlinear structures such as granular chains [12] and pendulum arrays [13]. The proposed structures will be designed based on a developed model for the prediction of the collective dynamics of nonlinear magnetically coupled beams under parametric excitation. An experimental set-up will be developed and will serve as a validation tool for the model in order to identify the energetic paths, which can be used for energy trapping (VET) useful for passive vibration control in vibroacoustics problems or energy harvesting (VEH) useful for autonomous sensors network.

Once created, the stability of ILMs will be analyzed with respect to the damping and the excitation amplitude. These investigations may serve to overcome the dissipation phenomena within designed periodic structures, which is considered as **a first challenge**. The **second challenge** will be the realization of an innovative Vibration Energy Harvester (VEH) [14-15] based on ILMs in parametrically excited nonlinear periodic structures and considering the electromechanical coupling (Figure2) as well as the integration of an adequate nonlinear circuit.

3. METHODOLOGY & EXPECTED OUTCOMES

The methodology for the project involves numerical modeling, system design and manufacturing as well as feedback from experiments. Numerical simulations based on perturbation methods and Schrödinger equations under different excitations will been performed in order to predict ILMs in nonlinear periodic structures. Based on the obtained results, an experimental VEH proof-of-concept will be designed and characterized for validation and model calibration.

The expected outcomes for this thesis are as follows:

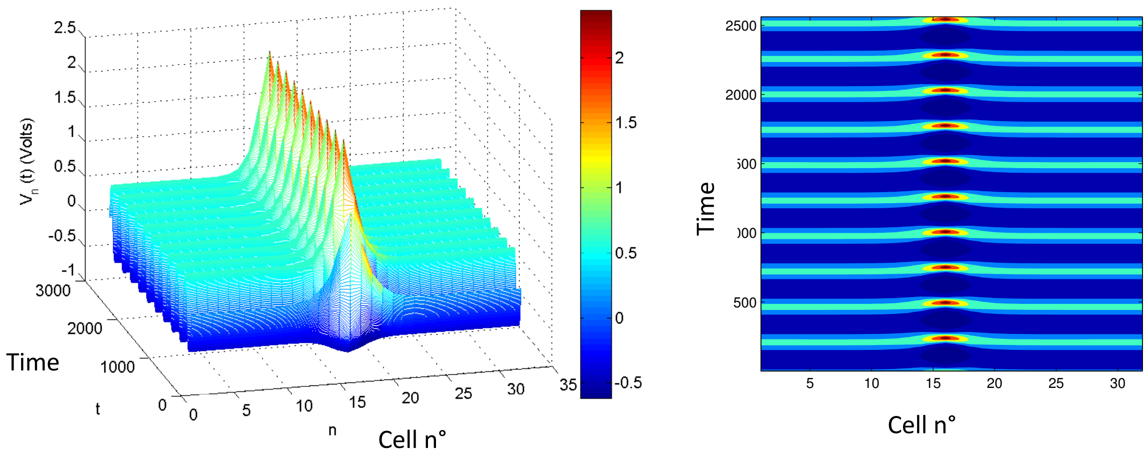

Figure 1: Space-time profile of the soliton in a periodic lattice

Task1. Derivation of: **(i)** a nonlinear model for a parametrically excited periodic lattice leading to the well-known nonlinear Schrödinger equation; **(ii)** the required conditions (nonlinearity, imperfection, initial condition, damping, etc.) to create solitons in two configurations: mono-breathers and multi-breathers.
Task2. Advanced numerical simulations (online, off-line approaches) to generate the stability chart.
Task3. Proof of concept based on a magnetically coupled periodic structure. It consists in a lattice of weakly coupled beams with specific boundary conditions.
Task4. Numerical simulations on the multiphysics model and experimental validation of the proposed concept for vibration energy trapping and harvesting.
Task5. Modeling and design of a dedicated nonlinear circuit which will be integrated in the VEH proof-of-concept.

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4. REQUIRED SKILLS/TOOLS

According to the objectives and methodology for this project, the following skills/tools are required:

- ✓ The candidate should be proficient in common programming, especially in Matlab coding.
- ✓ The candidate should also have strong mathematical background and modeling skills.
- ✓ The student should be proficient in nonlinear dynamics and Multiphysics modelling.

Preferred selection criteria:
- Quality of the application
- Oral interview of the candidate

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Application deadline: **May 20, 2022**
Start date: 01.10.2022 - Duration: 3 years
Salary (gross salary): 1975€ /month

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Applicants are invited to submit their application to the PhD supervisors.

Application must contain the following documents:
- CV (possibly with list of publications)
- Provide detailed explanation justifying your choice for this PhD project
- Short summary of the master's thesis (including certificate of grades and ranking)
- At least 1 reference letter with contact details