

Proposition d'un Projet de Recherche en Laboratoire

Titre : Dynamic two-step phase transitions in an ensemble of coupled Kapitza pendulums

Laboratoire d'accueil : Laboratoire des Solides Irradiés (LSI, Ecole Polytechnique)

Résumé : A passive pendulum represents one of the basic model systems in physics. An active, periodically driven pendulum displays a much richer physics resulting in parametric instabilities (Mathieu equation, 1868) or forming new equilibrium states (a pendulum pointing up) existing only under conditions of strong periodic driving (Kapitza pendulum, 1951). Collective behavior of coupled passive pendulums displays a fascinating phenomenon of spontaneous synchronization also known as synchronization of metronoms (J. Pantaleone, Am. J. Phys. 70 (2002)), which can be seen as a special case of a phenomenological but very general Kuramoto model describing synchronization phase transitions (Y. Kuramoto, Lecture Notes in Physics 39, 420 (1975)).

Surprisingly, recent experiments dedicated to the cooperative (superradiant) quantum light emission from femtosecond-laser excited perovskite thin films (M. Biliroglu et al., Nature Phot. 16, 324 (2022)) indicate that the collective vibration-assisted synchronization phenomenon between optical dipoles is at the origin of superradiance, which can be interpreted as a sequence of two sub-sequent phase transitions.

The main objective of this PRL will be to develop a phenomenological model of coupled Kapitza pendulums to mimic a two-step transition in a nonlinear but fully classical system. The first step of pendulum synchronization is expected to modify, through cooperative coupling, the stability criterion of individual pendulums making their initially stable upper state unstable for all of them. In the second step all unstable pendulums should drop in a collective manner.

A two-step capacity of a student to (i) write a system of coupled differential equations from scratch, based on an intuitive mechanical model, and (ii) solve them numerically to explore the «phase diagram» is a strong prerequisite to succeed in this exploratory PRL-project.

Mots clés : nonlinear equations, nonlinear dynamics, synchronization, theory of phase transitions

Nature : theoretical and numerical

Accueil d'un binôme possible : Non

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