Master 2 "Photonics, Complex and Quantum Systems (PhoCQS)": Research Training 2025-2026

Appel à sujet de stage recherche / Call for research training subject

Laboratory: PhLAM

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Collaborator(s):

Topic: Experiment/Theory

Master 2:

X Master 2 PhoCQS (GP-IKS)	□ Master 2 MME (GP-SCP)
X Option Complex and Quantum Systems	□ Option Condensed Matter
	□ Option Condensed Matter/Pharma
	□ Option Dilute Matter and Spectroscopy
	□ Option Atmospheric Sciences
	□ Option Modeling at the molecular & atomic scales
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Title: Direct detection of dark matter by precision molecular spectroscopy

Abstract: The mass of our Universe is composed in majority of Dark Matter (DM), an elusive object with faint interactions that prevented its direct detection. DM microscopic composition is not known that is a major problem Standard Model (SM) theory. Many experiments to search for DM or to constrain its couplings to the SM particles were conducted in energy ranges from 10^{-20} eV to 200 TeV. Below 1 eV, dark matter is represented in many theoretical models with a bosonic field oscillating classically at the corresponding Compton frequency. Coupling of this ultralight dark matter (UDM) to SM yields oscillations of fundamental constants (FC) that translate into oscillations of the frequencies of atomic, molecular, and optical cavity resonances, a spectacular phenomenon that, if discovered, will have huge consequences on the foundations and the applications of modern physics. The team at the PhLAM laboratory addresses direct detection of UDM by searching oscillating signals in laser absorption spectroscopy of acetylene transitions exploited as frequency references in the 1.5 µm spectral domain. Hamiltonian theory of polyatomic molecules was exploited for modelling sensitivity of molecular references to FC variations. The experiment exploits a laser from Paris Observatory with ultrastable frequency that is transmitted by the REFIMEVE network through phase-stabilized optical fibre links to a transportable spectrometer that is developed at PhLAM. The internship may address preparatory work in quantum physics concerning modelisation of the performances expected in linear absorption spectroscopy measurements. An experimental work may address low-noise optical detection, time-synchronized fast data acquisition, or real-time data exploitation in view of UDM detection. The work may be followed by a PhD project if appropriate funding is available, for example upon selection of the student by its *Ecole Doctorale*.

Key words: laser spectroscopy, photodetection, data acquisition and analysis