Master thesis/Internship proposal

Crystalline membranes for quantum optomechanics

Laboratory :

Université PSL - Chimie ParisTech, Institut de Recherche de Chimie Paris (IRCP),
Crystals and Quantum State Dynamics group (CQSD)
11 Rue Pierre et Marie Curie, 75005 Paris

Project :

The goal of the project is to develop a novel platform for quantum photonics using crystalline oxide nanomaterials. CQSD has recently synthesized state-of-the-art rare-earth ion-doped nanomaterials, including nanocrystals and thin films with unique coherent properties in optical and spin domains [1,2]. To fully exploit the potential of this platform for quantum information processing for implementing integrated single photon sources and optical quantum memories, it is required to demonstrate the integration capabilities of these materials [3]. This project will emphasize the design and fabrication of membranes and their nanostructuring for realizing optomechanical interfaces with rare-earth ions [4].

Rare-earth ions exhibit highly effective coupling with the strain in their crystalline matrix, which makes the optomechanical interface with this system unique. In addition, long optical coherence times of rare-earth ions make reaching a strong coupling regime with nanomechanical structures possible. While this is widely exploited in the microwave regime by coupling the mechanical mode with a spin degree of freedom, it is still to be realized in the optical domain. To fully exploit the developed platform, it is necessary to realize an optomechanical interface with rare-earth ions based on thin film membranes.

The student's tasks will include:

- Acquire the fabrication and synthesis skills required to realise thin film membranes.
- Perform optical characterization of integrated nanostructures at cryogenic temperature.
- Characterize integrated rare-earth ions coupled to nanostructures.
- Perform numerical simulations (finite difference time domain or finite elements) of the devices.

[1] D. Serrano, J. Karlsson, A. Fossati, A. Ferrier, and P. Goldner, Nat. Commun. **9**, 2127 (2018).
[2] N. Harada, A. Ferrier, D. Serrano, M. Persechino, E. Briand, R. Bachelet, I. Vickridge, J.-J. Ganem, P. Goldner, and A. Tallaire, J. Appl. Phys. **128**, 055304 (2020).
[3] T. Zhong and P. Goldner, Nanophotonics **8**, 2003 (2019).
[4] R. Ohta, G. Lelu, X. Xu, T. Inaba, K. Hitachi, Y. Taniyasu, H. Sanada, A. Ishizawa, T. Tawara, K. Oguri, H. Yamaguchi, and H. Okamoto, Phys. Rev. Lett. **132**, 036904 (2024).

Who are we looking for? :

The candidate is expected to have:
- Background in optics, solid-state physics, or optoelectronics, including experimental skills
- Basic knowledge of quantum physics and quantum information
- Interest in nanofabrication and experimental work
- Ability to work independently and in daily collaboration with the international research team

About us :

Institut de Recherche de Chimie Paris (IRCP) is one of the leading CNRS chemistry laboratories in the Paris region. The group "Crystals and Quantum State Dynamics" (cqsd.fr) is internationally recognized for developing rare-earth ion-doped materials for applications in quantum technologies. Our team has extensive experience in the design, growth, and characterization of bulk, thin films, and nanoscale crystals, as well as diamond films containing color centers for applications in photonics and quantum sensing.

We offer creative and stimulating working conditions in a dynamic and international research environment, with access to a wide range of cutting-edge experimental techniques, including high-resolution coherent spectroscopy and structural analysis, and nanofabrication facilities.

Project responsible :

Please send applications to Alexey TIRANOV (alexey.tiranov@chimieparistech.psl.eu)