

INTERNSHIP PROPOSAL

Laboratory name: [IPCMS](#)

CNRS identification code: UMR 7504, CNRS and University of Strasbourg

Internship director's surname: **Avriller Rémi**

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Internship location: IPCMS, 23 Rue du Loess Bât 69, 67200 Strasbourg

Thesis possibility after internship: YES

Funding: YES Funding by IPCMS and Doctoral School

Condensed Matter Physics: YES

Soft Matter and Biological Physics: NO

Quantum Physics: YES

Theoretical Physics: YES

Strong Chiral Light-Matter Interactions in a Fabry-Perot Cavity

Chirality plays a central role in chemistry and biology, where molecules of opposite handedness can exhibit strikingly different biological and pharmacological activities despite having identical chemical compositions. Identifying and controlling molecular enantiomers is therefore of major importance. Light provides a natural probe of molecular handedness: chiral molecules interact differently with left- and right-circularly polarized light, giving rise to optical activity and circular dichroism, the foundations of chiroptical spectroscopy [1]. Cavity quantum electrodynamics [2] goes one step further by using confined electromagnetic fields to modify matter itself: Inside a cavity, molecular transitions can strongly couple to vacuum electric-field fluctuations, reshaping molecular properties without external illumination. Such coupling has been reported to enhance charge transport [3,4], alter chemical reaction rates [5,6], and modify intermolecular forces [7]. Extending these concepts to chiral molecules has recently attracted considerable interest. Chiral cavities, engineered to interact differently with opposite molecular handedness, could enhance weak chiroptical signals and open new routes toward enantioselective synthesis, a major challenge in the pharmaceutical industry.

This internship aims to develop a microscopic quantum model of chiral molecular ensembles strongly coupled to a Fabry-Perot cavity with engineered chiral mirrors [8]. Going beyond the electric-dipole approximation [9,10], the model will account for the spatial and polarization structure of the cavity field. Using quantum input-output theory [11], we will compute polarization-resolved transmission and reflection spectra. In close collaboration with the experimental group of Thomas Ebbesen and Cyriaque Genet in Strasbourg, **we will then address the inverse problem: Using the model to extract relevant microscopic light-matter coupling parameters from experimental cavity spectra.** The goal is to understand and optimize chiral light-matter interactions toward ultrasensitive chiroptical spectroscopy and cavity-controlled enantioselective chemistry. The candidate will join the [Mesoscopic Quantum Physics](#) team at IPCMS, working with **R. Avriller, D. Hagenmüller, and G. Weick**, and will benefit from the broader scientific environment of the TORNADO network (PEPR LUMA), which brings together 17 leading groups in chiral light-matter interactions.

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[5] J.A. Hutchison et al., *Angew. Chem. Int. Ed.* **51**, 1592 (2012)

[6] A. Thomas et al., *Science* **363**, 615 (2019)

[7] B. Xiang et al., *Science* **368**, 665 (2020)

[8] W. Wu et al., *Advanced Optical Materials* **11**, 2202831 (2023)

[9] L. Mauro et al., *Phys. Rev. A* **109**, 023528 (2024)

[10] E.U. Condon, *Rev. Mod. Phys.* **9**, 432 (1937)

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