INTERNSHIP PROPOSAL

Laboratory name: Laboratoire de physique de l'Ecole Normale Supérieure (LPENS)
CNRS identification code: UMR8023
PhD directors: Carlo Sirtori (LPENS) & Baptiste Chomet (LPENS)
e-mail: carlo.sirtori@ens.fr, baptiste.chomet@phys.ens.fr

Phased Arrays of Quantum Cascade Nano-Lasers

Quantum Cascade Lasers (QCLs)[1] have revolutionised the generation of coherent light in the mid-infrared and terahertz spectral ranges, enabling transformative applications in molecular spectroscopy, environmental sensing, medical diagnostics, and free-space communications[2]. Their electrically pumped architecture and material flexibility make them uniquely suited for on-chip integration. However, despite remarkable advances in epitaxial design and thermal management, conventional QCLs remain constrained by two persistent challenges: i) the difficulty of achieving low current laser threshold; ii) the difficulty of achieving reconfigurable far-field with good beam directionality.

The aim of this project is the realisation of a mid-infrared optoelectronic light source embedded in a photonic structure based on an array of metal–dielectric–metal microcavities that can be electrically injected[3]. The small microcavities area and their arrangement in sparse arrays enable operation at very low currents, limiting power consumption and improving thermal dissipation. The array of cavities forms a metamaterial which provides efficient surface emission in the free space through an antenna effect. This metamaterial array induces a mechanism of radiative loss suppression, similar to bound states in the continuum (BICs)[4], giving rise to optical modes with high quality factors. This metal–dielectric architecture, allows direct electrical injection and wavefront engineering. Moreover, it opens the way towards compact, low power consumption highly directional light sources with their wavefront engineered for beam steering or remote focusing.

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References

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