INTERNSHIP PROPOSAL

(One page maximum)

Laboratory name: Laboratoire de physique de l'Ecole Normale Supérieure (LPENS)
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Thesis possibility after internship: YES
Funding: YES If YES, which type of funding: ANR

Photon emission from optical phonons in semiconductor nanostructures

Can lattice vibrations be converted directly into photons? This PhD project aims to address this fundamental question by investigating the radiative emission of non-equilibrium optical phonons in electrically injected semiconductor nanostructures.
In polar crystals, infrared-active optical phonons carry macroscopic polarization fields that couple strongly to electromagnetic radiation, giving rise to a strong photon absorption within the Reststrahlen band [1]. In spite of such strong absorption, the opposite process, the radiative decay of optical phonons into photons, has never been directly demonstrated in solid-state systems. Their energy is generally assumed to relax predominantly through anharmonic decay into acoustic phonons, on picosecond timescales [2].
We propose to investigate the condition that makes the radiative emission a measurable relaxation pathway by combining two ingredients: the generation of large non-equilibrium optical phonon populations and the enhancement of their radiative coupling through engineered photonic structures [3,4]. The understanding of this phenomenon would establish a new pathway for converting lattice excitations into electromagnetic radiation, thus light, with potential applications in the mid- and far-infrared spectral ranges.
The non-equilibrium population of longitudinal optical (LO) phonons will be generated in a specifically conceived device enabling electrically driven intersubband transitions in quantum wells. To enhance the radiative emission of optical phonons, the device will be inserted into metal–dielectric–metal metamaterial cavities providing strong electromagnetic confinement in a subwavelength dielectric layer. Finally, the energy of the modes will be engineered to overlap with the phonon emission frequencies, improving photon extraction.
The semiconductor heterostructures will be grown at C2N and processed and characterized at LPENS. Their electro-optical properties will be investigated through transmission, reflectivity and electroluminescence measurements.
The PhD thesis is financed by an ANR project.

References

[1] K. H. M. Born, Dynamical theory of crystal lattices. Oxford: Clarendon Press, 1998.
[2] J.Ziman, Electrons and Phonons. Oxford University, 2001.
[3] G. Cassabois, G. Fugallo, et al, Phys. Rev. Res., vol. 4, no. 3, p. L032040, Sep. 2022, doi: 10.1103/PhysRevResearch.4.L032040.
[4] B. Askenazi, et al., New Journal of Physics 16, 043029 (2014)

Please, indicate which speciality(ies) seem(s) to be more adapted to the subject:

Condensed Matter Physics: YES Soft Matter and Biological Physics: NO
Quantum Physics: YES Theoretical Physics: NO