INTERNSHIP PROPOSAL

Laboratory name: Laboratoire de physique de la matière condensée
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Internship location: Ecole polytechnique, Route de Saclay 91120 Palaiseau

Thesis possibility after internship: YES
Funding: YES If YES, which type of funding: ED

Disorder and charge dynamics in nitride semiconductor heterostructures: new experimental tools for more efficient devices.

Summary of thesis project: Today, nitride semiconductor quantum heterostructures used in light-emitting diodes (LEDs) are able to efficiently produce blue photons [Feezell2018]. The so-called wall-plug efficiency (WPE, defined as the ratio of the output optical power to the input electrical power) is close to 90 % in this wavelength range, but falls drastically as emission wavelength increases, dropping to only a few percent in the red. For this reason, red-emitting LEDs use phosphide-based technologies while a so-called "green gap" exists where no commercial, high WPE LEDs are available. As a consequence, in today's commercial lighting devices, white light is produced by coupling green and red emitting phosphors to blue LEDs which decreases the overall WPE. Producers of nitride LEDs are thus actively searching for ways to ameliorate WPE of green- and red-emitting LEDs for (white) lighting applications enabling important energy savings, and for the economic advantages that come with the use of a single nitride-based technology.

The physical origin of the efficiency decrease with increasing emission wavelength of nitride LEDs is not identified. However, crystalline disorder is thought to play a significant role, both for high WPE in blue-emitting LEDs, as well as for recent observations of high WPE in green- and orange-emitting LEDs [Zhang2022]. Examples of disorder include nanometre-scale compositional alloy disorder in InGaN quantum wells (which are the active parts of LEDs) due to the random placement of the group III atoms (In and Ga) during growth of the structure, as well larger scale disorder such as V-pit defects (typical scale 100 – 300 nm). We propose an internship, and subsequent thesis, aimed at studying the opto-electronic consequences of these types of disorder using novel experiment tools developed at Ecole polytechnique. These include scanning tunnelling luminescence microscopy [Hahn2018, Alyabyeva2023, Sauty2023] which combines the spatial resolution of STM with the spectral resolution of optical spectroscopy, low energy photo-emission [Sauty2022] and high resolution photoluminescence and photoluminescence excitation spectroscopy. These tools are unique in that they are used to study fundamental physical processes affecting electron dynamics in operational devices, including commercial LEDs. As such, our goal is to provide physical insights that will help to design the high efficiency light emitters of tomorrow.

[Alyabyeva2023] N. Alyabyeva et al., Phys. Stat. Sol. (b) **260**, 2370013 (2023)
[Feezell2018] D.F. Feezell et al., CR Physique **19**, 113 (2018)
[Hahn2018] W. Hahn et al., Phys. Rev. B 98, 045305 (2018)
[Sauty2023] M. Sauty et al., Phys. Stat. Sol. (b) **260**, 2200365 (2023)
[Sauty2022] M. Sauty et al., Phys. Rev. Lett. **129**, 216602 (2022)
[Zhang2022] S. Zhang et al., Phot. Res. **8**, 1671 (2020)

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