Quantum devices in the ultra-strong light-matter coupling regime

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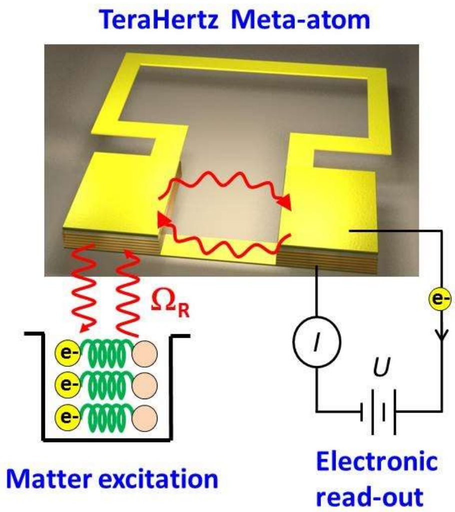
The absorption and emission of light in an optoelectronic device are often considered as *perturbative phenomena*, which are treated in a single-particle picture. When the light-matter coupling energy, $\hbar\Omega_R$, exceeds the dissipation rates of the system then the light-matter interaction is no longer a perturbative process, but instead energy is periodically exchanged with the microcavity at a frequency Ω_R. The system enters the *strong coupling regime*, where the cavity mode is split into two light-matter coupled (polariton) states separated by energy $2\hbar\Omega_R$. The last decade has seen the emergence of yet stronger interaction regime, where the coupling constant Ω_R becomes comparable to the frequency of the matter excitation, ω_m. This regime with Ω_R/ω_m~1 is known as "ultra-strong" light-matter coupling and sets new frontiers for cavity quantum electrodynamics [1]. This regime can be realized with quantum heterostructures that interact with far infrared photons (TeraHertz, λ = 30µm-300µm and Mid-Infrared, λ = 3µm-30µm domains) [2]. A very interesting topic is the possibility of observing the signatures of ultra-strong coupling in the electronic transport of devices such as infrared detectors [3] and tunnel junctions [4]. Such devices could enable the readout of the quantum properties of light in the MIR and THz frequencies, thus opening a new field of application for quantum technologies.



As an intern, the candidate will work in close collaboration with an experimented Ph.D student/post doc for the characterization of already fabricated devices. This activity will be followed by a PhD project, where the aim is to explore quantum devices operating in the ultra-strong light-matter coupling regime. We will study devices where semiconductor quantum wells are integrated into optical resonators featuring deep sub-wavelength electromagnetic confinement [5] (Figure). The Ph.D. student will actively participate in the conception and fabrication of the nano-devices, starting from 3D numerical modeling, through clean-room processing and optical characterization of the structures. She/he will acquire not only strong scientific expertise in solid state devices and quantum optics, but also in nanofabrication techniques.

[1] C. Ciuti, G. Bastard, and I. Carusotto, Phys. Rev. B **72**, 115303 (2005).
[2] Y. Todorov, et al., Phys. Rev. Lett. **105**, 196402 (2010).
[3] F. Pisani et al., Nature Comm. **14**, 3914 (2023).
[4] U. Iqbal, C. Mora, Y. Todorov, Phys. Rev. Research **6**, 033097 (2024).
[5] M. Jeannin et al. ACS Photonics **6**, (5) 1207-1215 (2019)