Quantum cascade detectors operating in the strong light-matter coupling regime.

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Infrared detectors operating in the mid-IR spectral range (3µm-20µm) find applications in the field of spectroscopy, space observation, free space telecommunication and imaging. Detectors based on intersubband (ISB) transitions are of major interest for both applicative and fundamental aspects, as they feature high sensitivity and high speed. Usually operated in the weak light-matter coupling regime, quantum cascade detectors (QCD) [1], photo-voltaic counterparts of quantum well infrared detectors (QWIP), provide also an interesting playground to study fundamental aspects of the strong light-matter coupling regime.

Over the past decade, there have been continuous research efforts to develop MIR and THz emitters based on ISB polaritons, quasi particles arising from the strong light-matter coupling between an ISB transition and a photonic micro-cavity mode, as they are predicted to have improved functionalities with respect to current sources [2,3]. However, efficient electrical injection of polaritonic devices is a major challenge, with few experimental demonstrations present in the literature [4]. The reason is that most of the electrons injected from an electronic reservoir into a polaritonic system tunnel into dark states [2].

To get insightful information on the transport mechanisms underlying the tunnel coupling process, it is of interest to study the inverse process [5]: the extraction of an electrical current from a polaritonic reservoir, i.e. a detection process. We investigate the photo-response of MIR QCDs (λ = 10µm) operating in the strong light-matter coupling regime ($2\Omega \approx 10$ meV). This is particularly relevant, as it allows to study the process of *resonant* current extraction from a polaritonic state into an electric state. By measuring the optical absorption and the photocurrent (Fig. 1(a)), we are able to experimentally retrieve an effective (polariton) extraction efficiency. We develop an intuitive, semi-classical formalism based on the coupled modes theory (CMT) which quantitatively reproduces both the optical and electrical device characteristics. The excellent agreement between the experimental data and our simplified transport model confirms previous reports on QWIP detectors operating in the strong-coupling regime [5]. We also show that the current extraction involves electronic tunnelling from the polaritonic state to the extractor state, and thus that the dark electronic states do not contribute to the photocurrent (Fig. 1(b) and (c)).

These results highlights the potential of QCDs to study ISB-polaritonic systems, and establish an intuitive picture of the polaritonic extraction. They constitute a step towards a better understanding of the resonant electrical injection of carriers into a polaritonic state for efficient ISB polaritonic emitters.

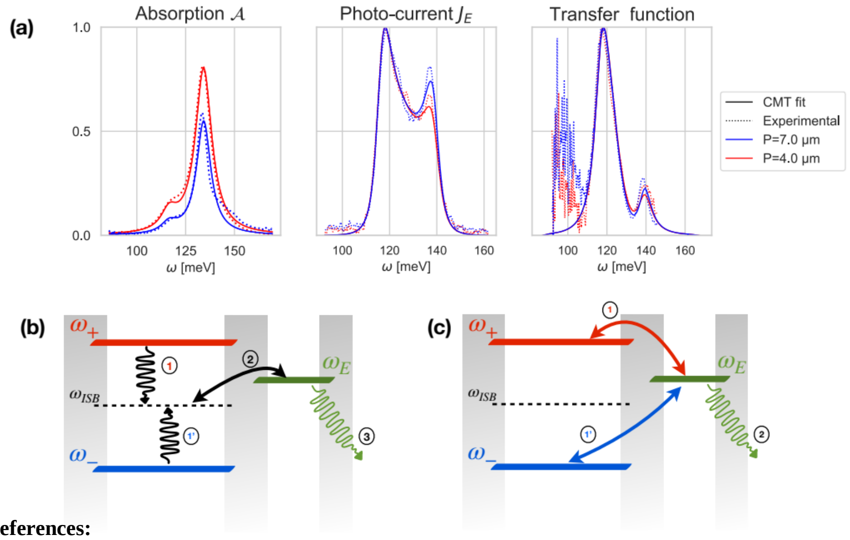

Fig. 1: (a) Left and center: absorption and normalized photo-current, and CMT fit. Right : polaritonic transfer function deduced from the measurements. Two possible extraction scheme : (b) Intrasubband dominated transport : polaritons collapse into the dark states before extraction. (c) Tunnelling through polaritonic states:

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