Antenna-Coupled Microcavity-Enhanced THz Photodetector

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In the mid- and far-infrared spectral region (5μm < λ < 200μm), the performances of quantum detectors are intrinsically limited by the small energy of the electronic transition involved in photon absorption. Electrons can be thermally excited, even at low temperature, to the upper state of the transition inducing a dark current that deters the noise properties of detectors. To overcome this problem is essential therefore to conceive detector schemes in which for the same amount of photons harvested the dark current is reduced. In this abstract we show that by judicious use of metallic antennas in a sub-wavelength configuration it is possible to obtain a strong reduction of the dark current in a Quantum Well Infrared Photodetectors (QWIP) [1, 2], while maintaining a high level of photocurrent [3].

Intersubband electro-optical devices, such as Quantum Cascade Lasers (QCL) [4] and Quantum Well Infrared Photodetectors (QWIP) have been actively developed for the past twenty years. For QWIP's, the optimization of the active region itself is now well understood [2], however, the efficient light in-coupling remains an issue due to the rather restricting selection rule for the light-absorption of intersubband transitions [2]. In this context, novel photonic architectures, such as photonic crystals [5] or double-metal microcavities [6] have been recently proposed in order to increase the light in-coupling efficiency.

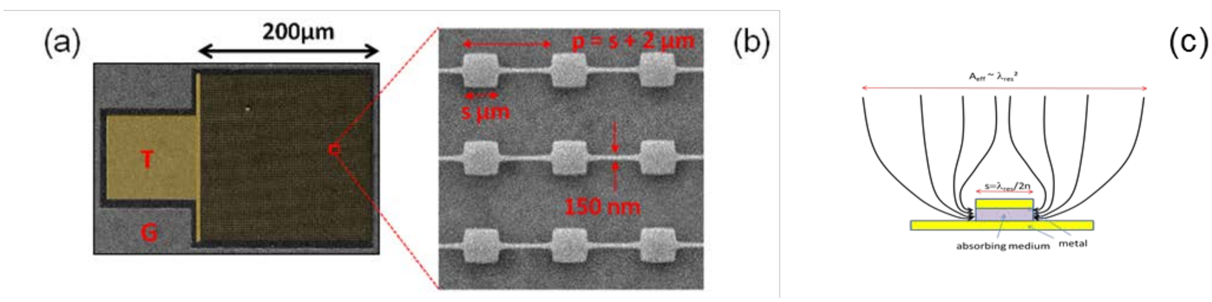

Fig. 1: (a) SEM picture of the device (top view). (b) Details of the subwavelength structure. (c) Schematic of the electric field harvested by the metallic patches on an area much bigger than the pixel surface.

The structures that we employ are inspired from our recent research on the ultra-strong light-matter coupling regime and consist of electrically connected patch antennas (Fig 1.). These plasmonic antennas not only collect photons from the free space, but also act as microcavities where photodetection takes place. We have indeed observed that the photo-response of the device is strongly enhanced when the microcavity becomes resonant with the intersubband resonance, as shown in Fig. 2.

However, our investigation shows that this design not only allows to increases the coupling of incident photons, but also brings an improvement on the intrinsic detector performances, such as the BLIP (Background-Limited Infrared Performance) temperature. Indeed, this design has the particularity that photons are absorbed in an effective area much smaller than the illuminated spot size. As the detector dark current is proportional to the device area, in our design the dark current is reduced as comparison to the photo-generated current. This reduction has a direct impact on the BLIP temperature that rises from 72 K for conventional QWIP operating at 9 μm [2], to 86 K. These results therefore illustrate how the concept of antenna-coupled microcavity can be applied successfully to enhance the performances of infrared opto-electronic devices.

Recently we have applied our concept to very long wavelength detectors (λ ~ 100μm) [7] with very encouraging results, that will be presented at the workshop.

The microcavity-coupled geometry reported here brings, therefore, important degrees of freedom in the design of intresubband detectors, as it allows for an efficient light funneling into the active region. With proper design of patch microcavity arrays, it is possible to bring the system in the critical coupling regime where all incident photons could be absorbed in the structure [6].

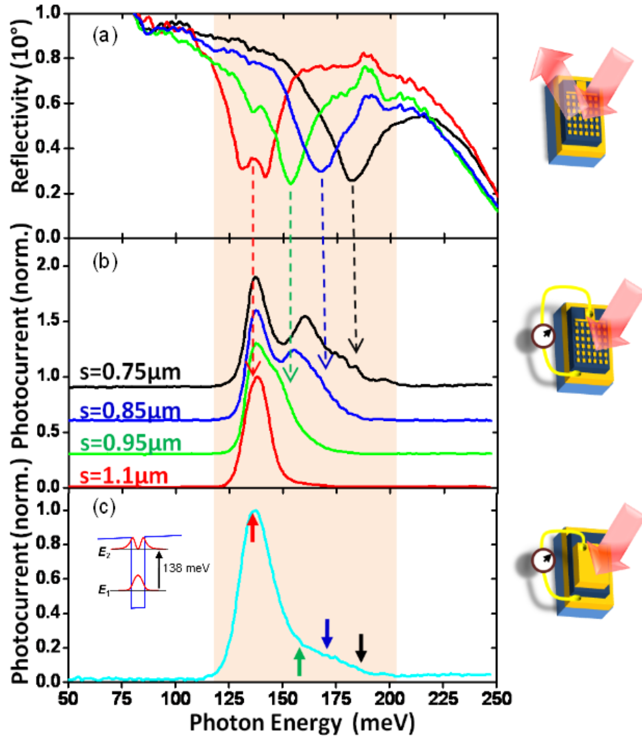

Fig. 2 (a) Reflectivity of the device of grating dimension s=0.75, 0.85, 0.95 and 1.1µm at 77K. (b) Spectral photocurrent response of the devices. (c) Spectral photocurrent response of the double metal mesa of dimension 200x200 µm^2.

References:

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