Antenna-coupled quantum devices for detection and emission of mid-infrared and terahertz waves

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Intersubband (ISB) transitions in a semiconductor quantum well (QW) superlattice (mainly n-type doped GaAs/AlGaAs) have been investigated in the past 20 years to conceive devices working in the all infrared range[1]: two famous examples are quantum cascade lasers (QCL)[2] and quantum well infrared photodetectors (QWIP)[3]. The interest to study the mid-infrared (few micron wavelengths) relies on the two atmospheric windows (3-5µm and 8-10µm) which allow spectroscopy and thermal imaging applications; terahertz optoelectronics (hundred micron wavelengths) at the same time has huge potential in different domains, from sensitive and non-invasive scan for security check, materials characterization, to biological studies and space exploration[4].

Novel concepts on the detection side will be shown as antenna-coupled and circuit-coupled microcavity arrays[5,6] (see figure 1) to improve light-coupling and strongly reduce electrical noise in quantum ISB photodetectors, with a direct impact on the thermal performances of the devices: the ability to collect photons from an area much larger than device itself results in the room temperature operation of 9µm sensors which are normally cooled down at liquid nitrogen temperature (figure 2 - left): this is due to an electromagnetic field enhancement thanks to the antenna-effect. The plasmonic architecture of subwavelength resonators become crucial at terahertz frequencies as well (figure 2 - right), given the very low working temperature (~ liquid helium) of performant optoelectronic devices.

Finally, innovative optomechanical resonators and superradiant plasmonic emitters[7] will be exposed as alternative concept to detect and emit infrared light.

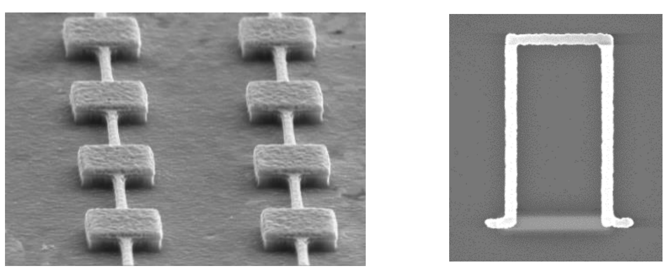

Figure 1: patch-antennae array (left) and LC-circuit resonator (right) for infrared and terahertz devices

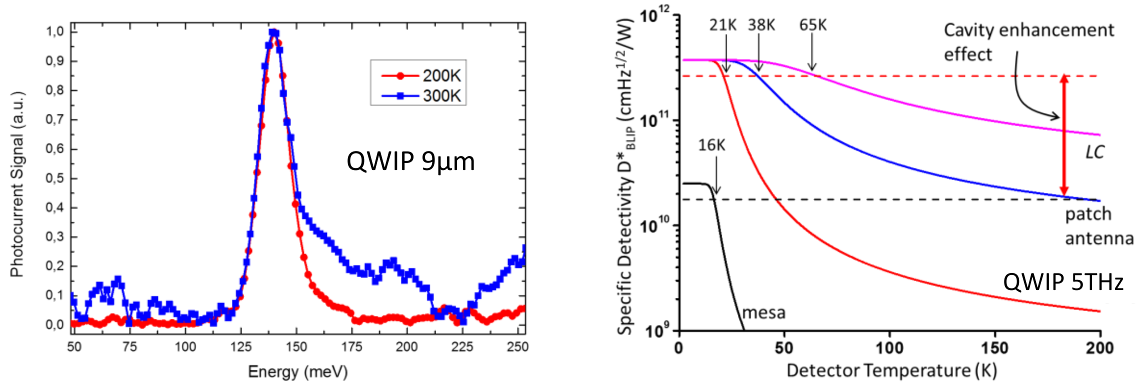

Figure 2: (left) Room-temperature photocurrent spectrum of a quantum well infrared detector at 9µm in patch antenna geometry, compared to the signal at 200K (right) specific detectivity D* as a function of the temperature, for a quantum well infrared detector at 5THz (60µm) with different photonics architectures: the microcavity concept allows to enhance the performances of the device

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