2008-2011 PhD PROJECT TITLE:

Infrared absorption microscopy of a single quantum dot

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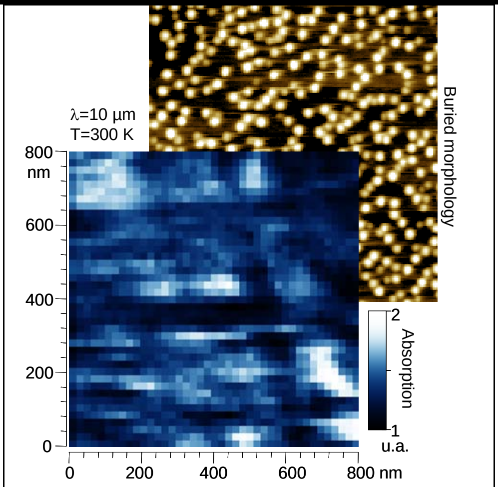

Figure : Absorption microscopy at λ=9,6 µm and behind typical morphology of buried quantum dots.

Self-assembled semiconductor quantum dots are model nanostructures both for solid state physics and at the core of promising devices such as single photon sources or telecommunication lasers. A new exploration field has recently emerged concerning the optical properties of these quantum dots at the single nano-object level in the midinfrared spectral range (λ~10 µm).[1] This spectral region is essentially unexplored so far on single quantum dots. This wavelength range corresponds to the optical manipulation of a confined electron in particular between discrete levels of the conduction band. The three dimensional confinement at the nanometer scale leads to specific and useful optical and dynamics properties governed by the coupling of confined charge carriers to the quantum vibration modes of the surrounding crystal (i.e. phonons). This PhD thesis project will make the most of this particular coupling to measure and analyze the absorption of a single quantum dot.

The core of the PhD project will be based on a original, fruitful and recently developed microscopy technique.[1] The absorption measurement if of photo-thermal-acoustic type and couples an atomic force microscope (AFM) with a pulsed laser excitation. Instead of detecting absorbed photons as in a standard transmission experiment, one seeks the detection of phonons emitted by the quantum dot and the subsequent local deformation as an alternative signature of the absorption. In this experiment the AFM tip plays the role of an ultrasensitive localized microphone and the laser plays the role of the optical pump. This approach offers high sensitivity with detection of absorptions as low as 10^{-9}, a largely sub-wavelength spatial resolution (60 nm i.e. λ/170), enabling to optically address the nanostructures individually, and a spectral resolution only limited by the spectral width of the used laser. For the first time one can probe the inter-sub-level electronic structure of a single quantum dot.

In the midinfrared the PhD project will imply a close collaboration with the team of the CLIO free electron laser (large scale facility at Orsay). In the near infrared the candidate will use the daily available laser pulsed sources in the team, as well as helium cryogenic equipments. The inter-sub-level and interband absorption of single self-assembled InAs/GaAs quantum dots will be spectrally and spatially resolved and analyzed. The absorption will be compared the ensemble linear spectroscopy performed on a large number of quantum dots and compared to the three dimensional calculation of their optical properties (energy, polarizations, oscillator strength). A new experimental research direction will be developed by considering quantum dots as natural acoustic and thermal nanosources emitting locally phonon wave packets.

[1] J. Houel, S. Sauvage, P. Boucaud *et al.*, Physical Review Letters **99**, 217404 (2007).

Keywords: Quantum dots, semiconductors, infrared absorption

Used techniques: Near- and mid-infrared optics and pulsed lasers, atomic force microscope, Fourier transform spectroscopy, numerical simulations, helium cryogenics

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