Focal Plane Array systems for « semiconductor nanostructures » optical properties research

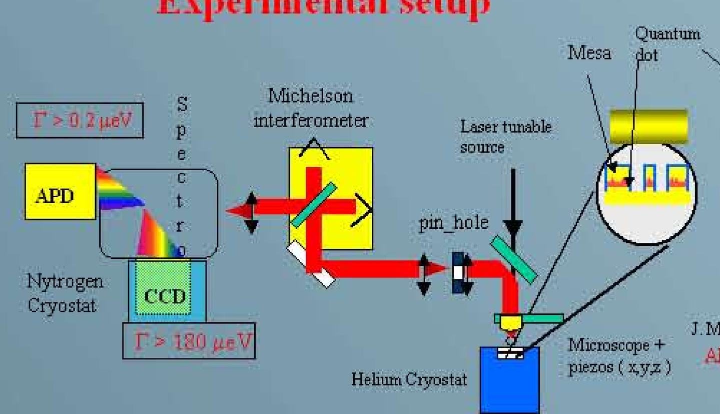
D.Darson, P.Morfin, A.Denis, G.Cassabois, J.Tignon, C.Voisin, Ph.Roussignol, J.M.Berroir

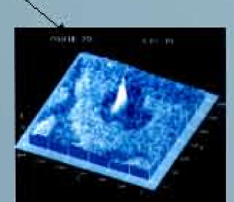
LPA (Laboratoire Pierre Aigrain) -Ecole Normale Supérieure - 24 rue Lhomond 75231 Paris Cedex 05

In LPA of ENS Paris, we study, among other things, physical properties of Semiconductor Nanostructures. Many of these properties are in the optical domain and until 2002 we used only monochromator system with APD (avalanche photodiode) and spectrometer. But this kind of system took too much time to record a full spectrum and we couldn't make long integration for each wavelength. So we started to develop our own CCD detector systems for their « low noise », flexibility of use, speed, resolution etc…..

A CCD system to study decoherence in InAs/GaAs quantum dot

Experimental setup

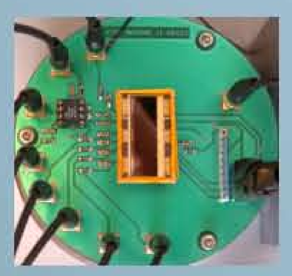




J. M. Gérard *et al.*, J. Cryst. Growth **150**, 351 (1995)

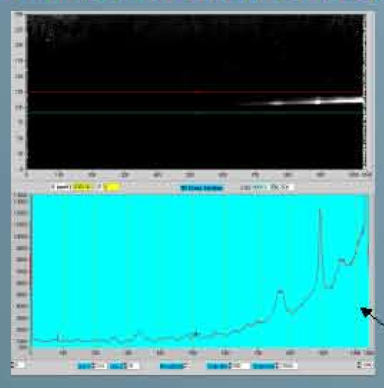
AFM image of InAs/GaAs quantum dot
Areal density~10^3 µm^{-2}

C. Kammerer *et al.*, Appl. Phys. Lett. **81**, 2737 (2002)



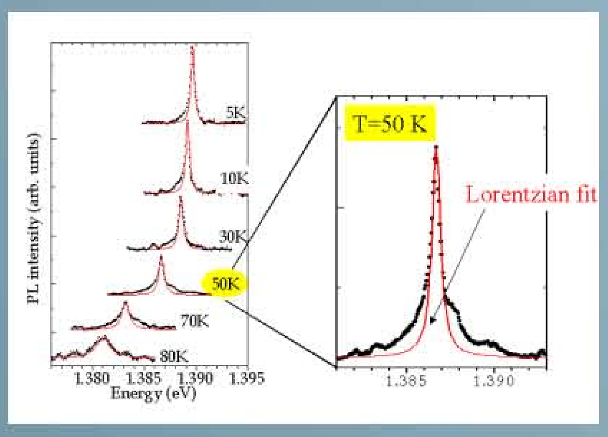
CCD30-11 back illuminated and its nitrogen cryostat
- CDS readout
- 10 e^- readout noise
- Readout frequency : 100 kHz
- 16 bits

Non Lorentzian emission line

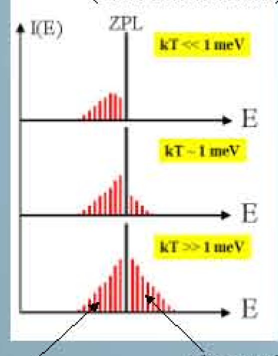


Non Lorentzian emission line

Exposure time : 300s , wavelength band : 780nm-820nm



(Zero Phonon Line)



Emission effect phonon lines

Absorption effect phonon lines

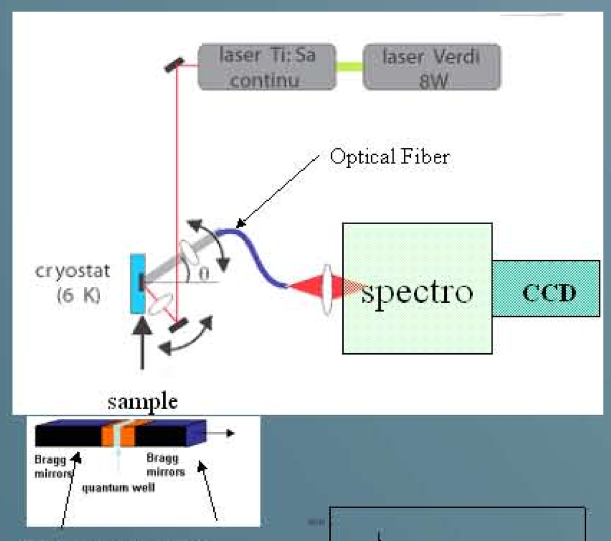
A new version to continue study of InAs/GaAs nanostructures

- CDS readout, oversampling in near future
- $<6e^-$ readout noise with CDS
- Readout frequency :
  - 100 kHz for low noise
  - 1 MHz, high frame rate for tuning the experimental set up
- 16 bits

- All clocks and bias are digitally tunable.
- All properties of clocks are independently tunable : frequency, level (high and low), rise time and fall time.
- Controller optimized for our CCD30-11 BI device. Easy to configure for a 42-10 and minimum modification for a 42-40 or higher.

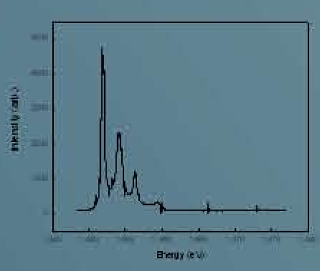
A CCD system for Semiconductor MicroCavity Research…

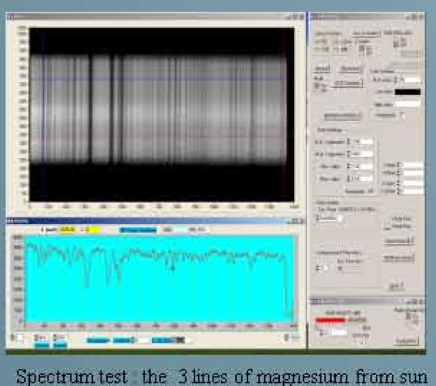
Experimental Set-up



Fabry Perot cavity

Photoluminescence detection.
Excitation angle=0°
Detection angle=0°
Excitation power=130 mW
Temperature= 6 K



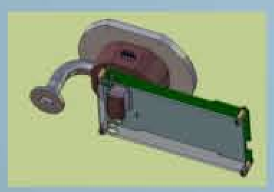


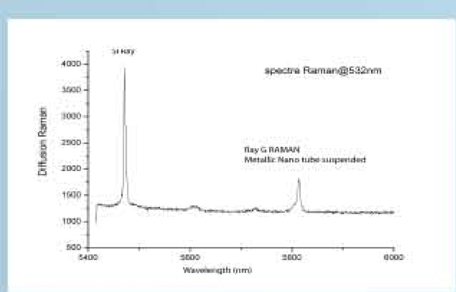
Spectrum test : the 3 lines of magnesium from sun

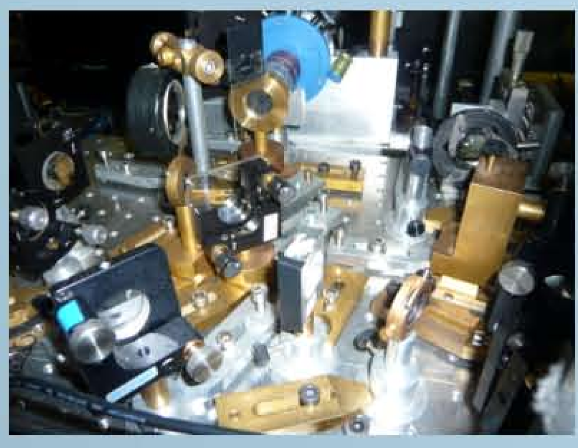
ICX285AL from Sony
1360*1024 effective pixels
5 fps with 1360*256 pixels resolution
1/2000 s to 1000 s exposure time
CDS readout
Readout noise $< 30\ e^-$
14 bits
Peltier cooling system
Direct USB2 link

… three years of evolution and finaly :

- ICX285AL from Sony
- 1360*1024 effective pixels
- 10 fps with 1360*256 pixels resolution, 1fps at full resolution
- 1/2000s to 3600s exposure time
- CDS readout
- Readout noise $< 6\ e^-$
- 14 bits
- Peltier cooling system regulated –40°C
- Dark current <0.08 e^-/s
- Direct USB2 link







Last system was installed on an experimental set-up for study of the carbon nanotubes photoluminescence. Single-nano-object spectroscopy is performed by « micro-photoluminescence » measurements in the far field of a confocal geometry. The same microscope objective is used to focuse the excitation beam on the sample and to collect the photoluminescence signal.

NOSIRIS

NOSIRIS (Nano Objects Short Infra Red Imaging System) was built for the carbon nanotubes photoluminescence detection up to 2µm (and above for other nano-objects, for instance graphene). We used, in this camera, an InSb CRC 744 FPA (256x256) from Raytheon.

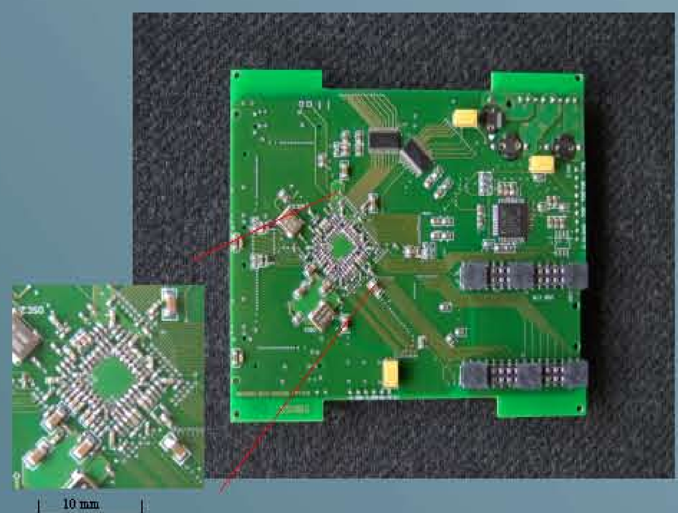
Cryostat and its Controller

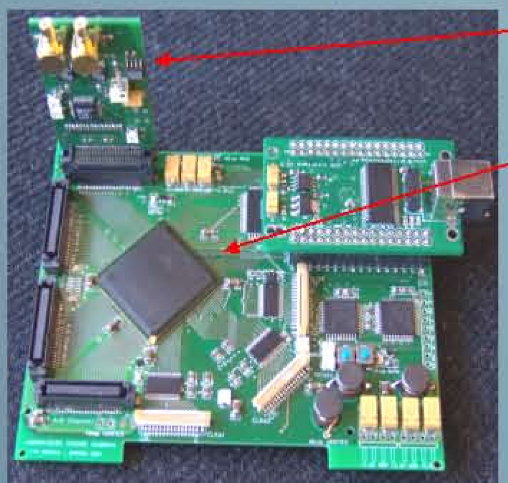
- Cryostat fully studied, designed and tested in the laboratory.
- Liquid He cryostat with a guard of liquid N2.
- Autonomy of 12 hours in normal use.
- 77K heat shield on which preamplifiers and all connections are fixed to thermalize.
- Cold Finger (receiving the detector) mounted on a liquid He exchanger with a heating element.
- Temperature controlled between 15 and 40K with 0.1K accuracy.

- Controller of the cryostat fully studied and built in the laboratory.
- Monitors and displays system parameters including He level and the cold finger's temperature.
- Shutdowns the camera if necessary.
- PID control of the cold finger's temperature.

IR-FPA Controller

- **Electronics fully studied, designed and tested in the laboratory.**
- **Preamplifiers (using OPA350) were built and validated at 77K.**
- **4 to 6 layers PCBs with many buried vias (PCB with the VirtexII).**
- **New bias generator and programmable DC power supplies were created for all analog devices. These bias and DC supplies are very low noise (<20nV/Hz$^{1/2}$), high precision (10µV) and large range (+/- 10V).**





One of the four ADC card.

VIRTEX II XC2V3000
- Manages the clocks and the acquisition of four 16 bits channels.
- Performs real-time processing (Fowler sampling or FUR sampling etc …)
- Communications with the control PC through two USB2 ports.