Federal University of São Carlos
Physics Department
Departamento de Física
UNIVERSIDADE FEDERAL DE SÃO CARLOS
ufscar

Semiconductor Nanostructure Group Optical Properties, Vibrational, Spin and Transport

Time Resolved Measurement System MUE: 2014/07375-2

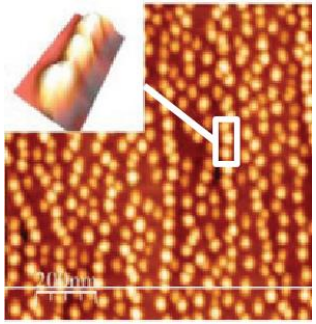
Young Investigator: 2013/18719-1
Electronic Carriers Dynamics in Semiconductor Nanostructures

Marcio Daldin Teodoro

www.nanostructures.df.ufscar

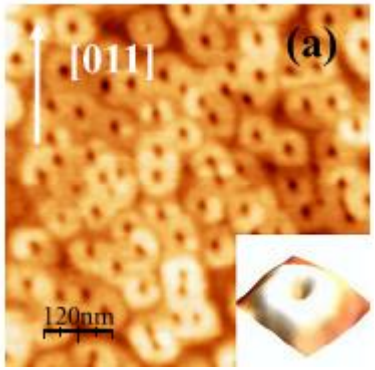
Semiconductor Nanostructures

Quantum Dots

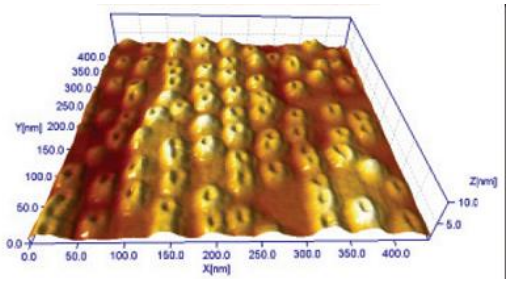


PRB **83**, 195307 (2011)
Appl. Phys. A **122**, 385 (2016)

Quantum Rings

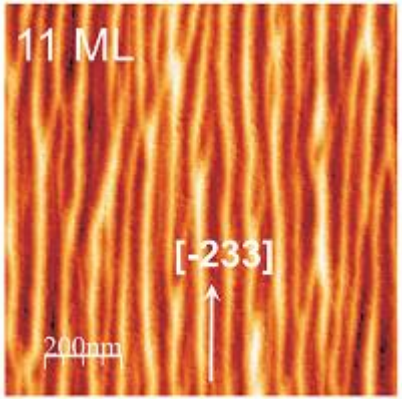


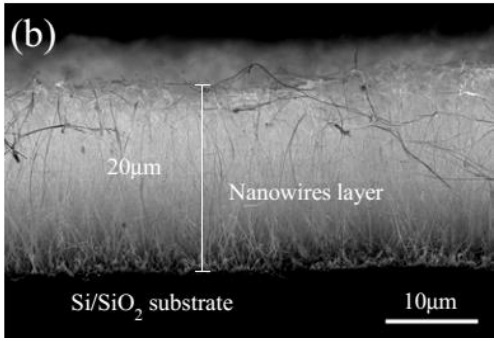
PRL **104**, 086401 (2010)



JAP **117**, 154307 (2015)
JAP **112**, 014319 (2012)

Quantum Wires





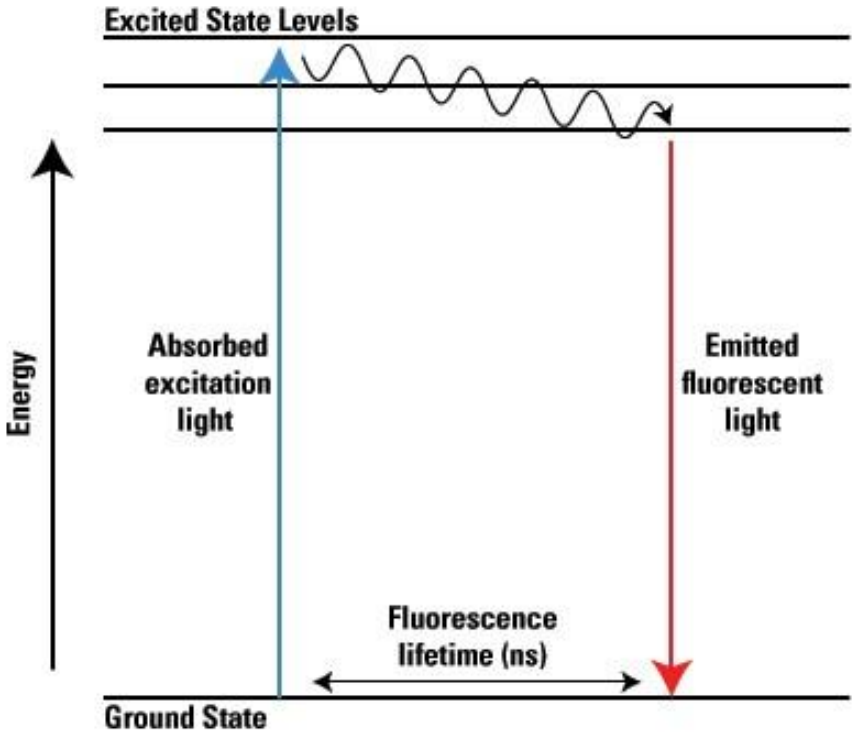
JAP **110**, 083714 (2011)
APL **97**, 262103 (2010)

Optical Techniques

Fluorescence / Photoluminesence, Raman, Absorption, Reflectivity...

Parameters:

Temperature, Laser Power, Polarization, Magnetic Field, Electric Field



https://www.thermofisher.com/br/en/home/life-science/protein-biology/protein-biology-learning-center/protein-biology-resource-library/pierce-protein-methods/fluorescent-probes.html

Time Resolved Techniques

It's all about time!

Applications: Material Science, biology, medical treatment...

How fast is the time decay?

Seconds, miliseconds, micro, nano, pico, femto?

10^{-3}s 10^{-6}s 10^{-9}s 10^{-12}s 10^{-15}s

Semicondutors Nanostructures

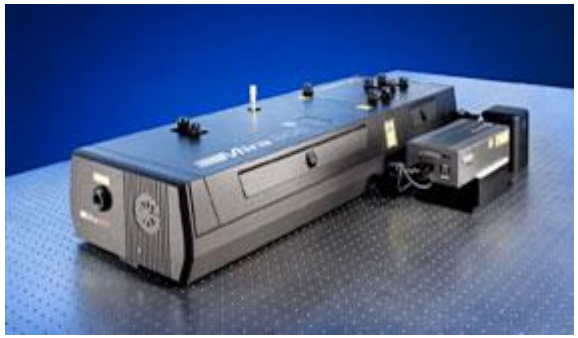
Time decay range: 100 ps – few ns

Temperature: 10 K – 300 K

Modular and Versatile

Experimental Setup: Fast pulsed laser + fast electronic + fast detector

Time Resolved Techniques Picosecond Resolution



Ti:Sapphire Lasers
Femtosecond/Picosecond – 100 fs – 2 os
Fixed Frequency ~ 80 MHz

Streak Cameras

TTS = 1 ps or 200 fs
High Sensitivity

www.hamamatsu.com

www.coherent.com

Fast Laser + Streak Camera → Time resolution~10 p

Alternatives!

Electronic Carriers Dynamics in Semiconductor Nanostructures

Available Systems in Brazil: Mostly sensitive in the Visible Region: 400-

Problems:

NIR: 900 – 1700 nm

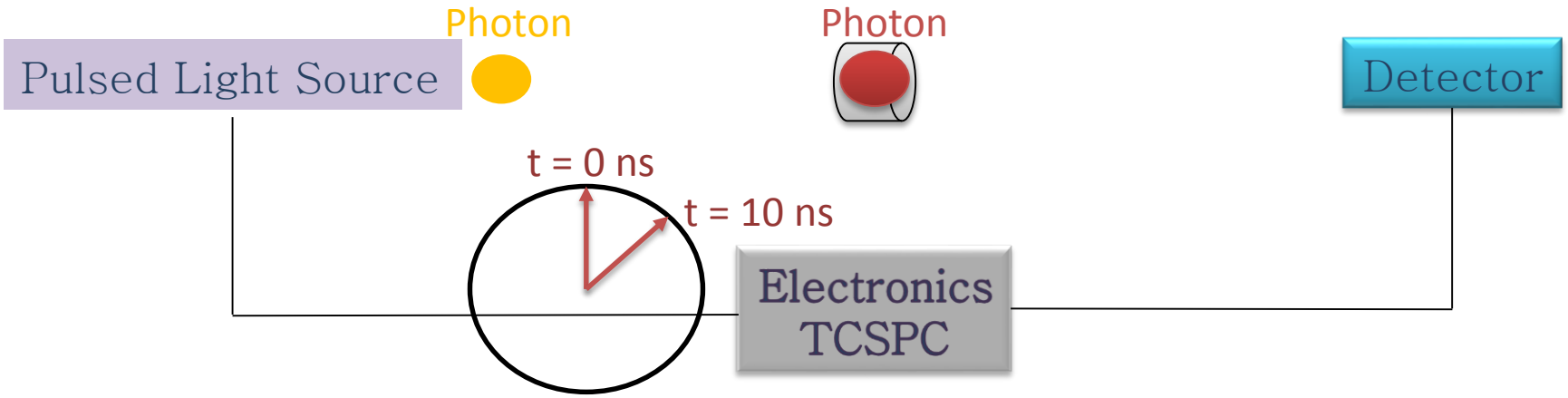
There is (almost) no commercial available system for low tempe

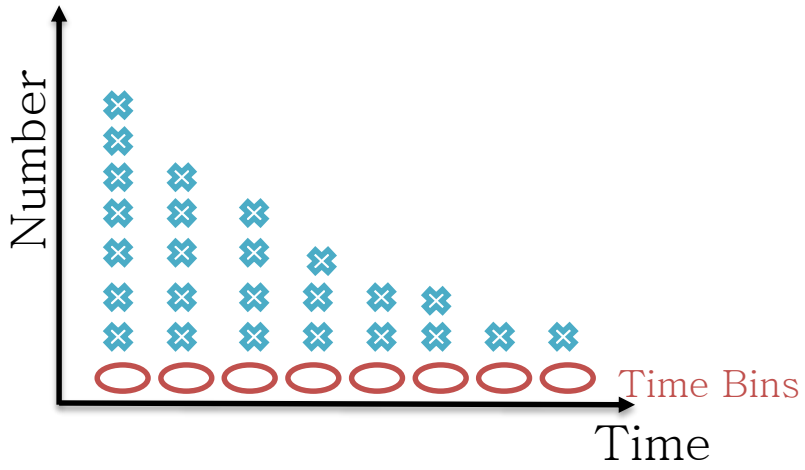
Solution:

One piece at a time

How to integrate all the components?

Time Correlated Single Photon Couting – TCSPC





$$I(t) = I_0 \exp\left(-{}^{t}/_{\tau}\right)$$

I_0 = Intensity at time zero

τ = lifetime

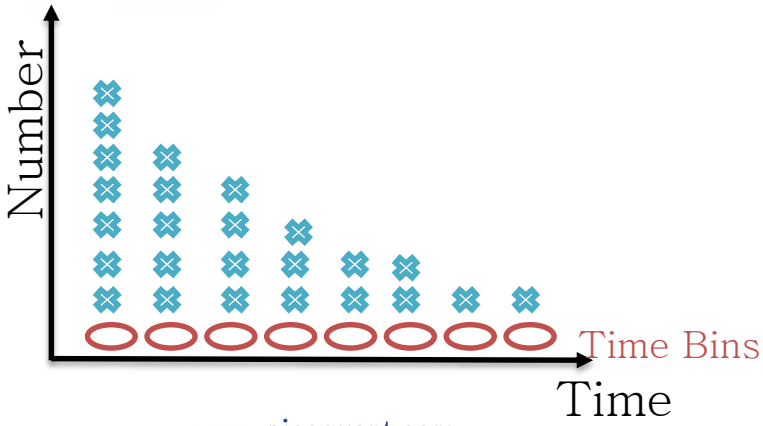
τ = 1/e = 37 %

How to install a customized TCSPC System

Diode Lasers

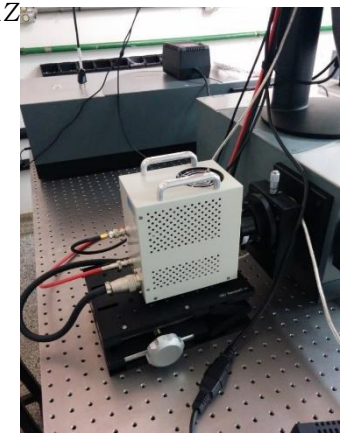
Wavelengths from UV – IR
Pulse width: 70 – 100 ps
Variable Frequency: 1 kHz – 80 MHz
Cheap

www.picoquant.com



www.picoquant.com

Detector



TTS = 400 ps
Darks Counts = 2 x 10^5 cps
Wavelength region: 950 – 1700 nm

www.hamamatsu.com

Internal Response Function (IRF)

$$\Delta t_m \approx \sqrt{\left(\Delta t_{exc}^2 + \Delta t_{det}^2 + \Delta t_{elect}^2 + \sum_i \Delta t_i^2 \right)}$$

Example:

$$\Delta t_{exc} = 70\ ps$$
$$\Delta t_{det} = 400\ ps$$
$$\Delta t_{elect} = 4\ ps$$

$\Delta t_m \approx 406$ ps

Divide this result per 5 and 10:

IRF ≈ 41 – 81 ps

Yong Investigator Project: Approved on March 2014

MUE: June 2014

FAPESP Investment:
MUE: U$ 97.800,99 + R$ 11.518,40
Y. I.: U$ 44,698,76
CAPES ~ U$ 85.000,00

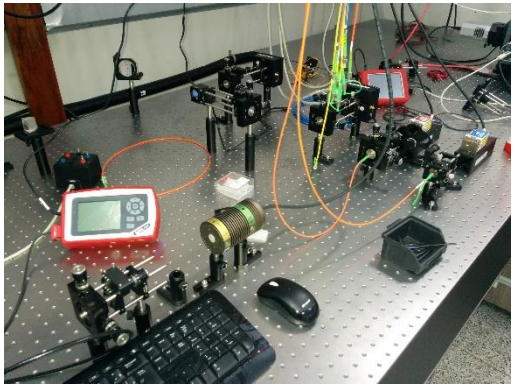
New Facilities inside the Physics Department

Room: 35 m^2

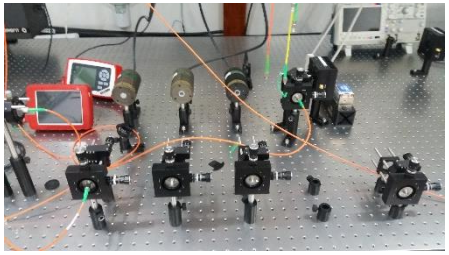
Starting a new Lab – March 2014

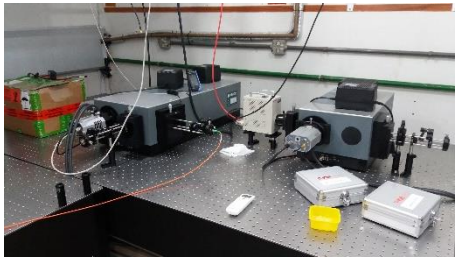
June – December 2014

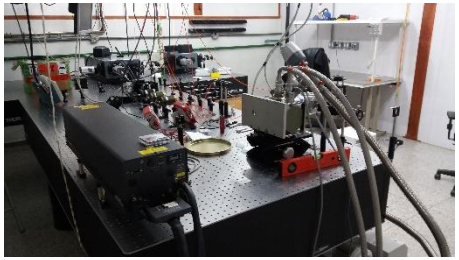
2015

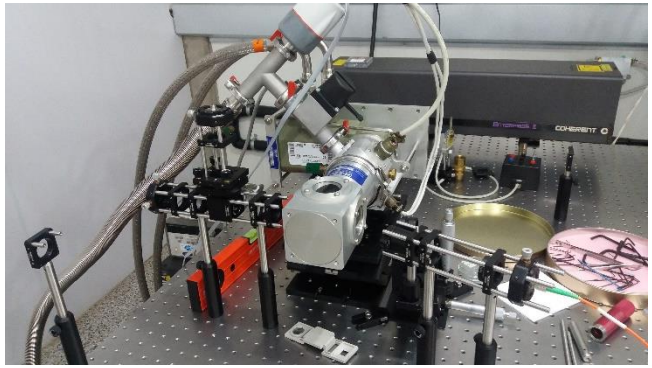


TODAY

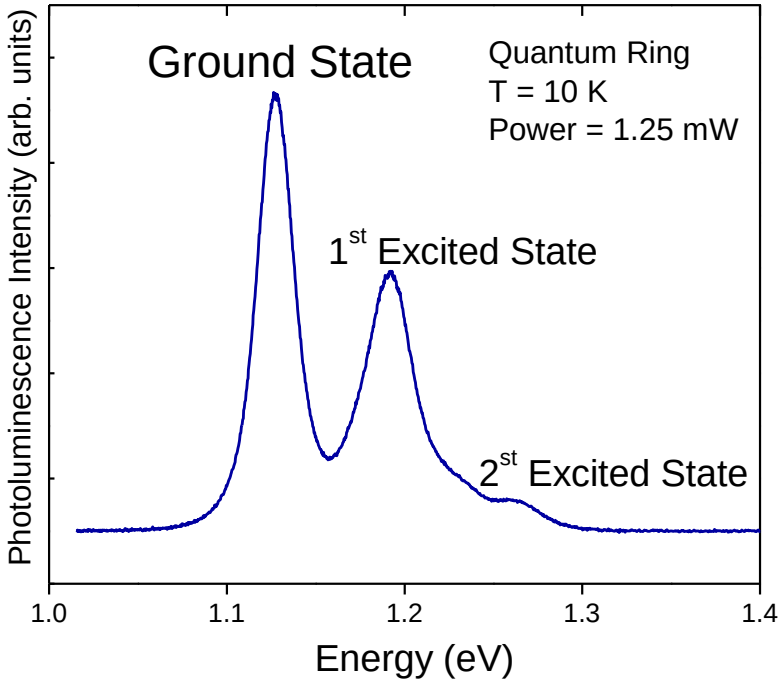


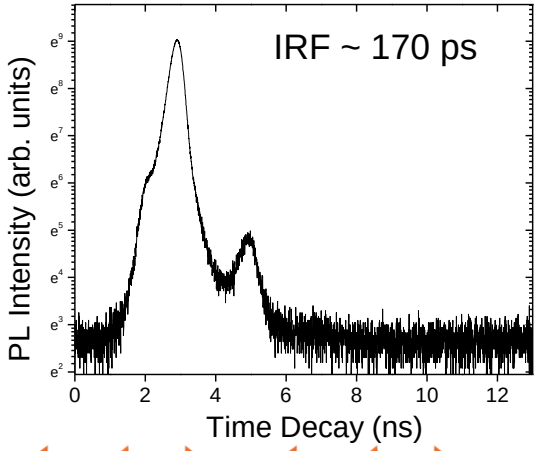


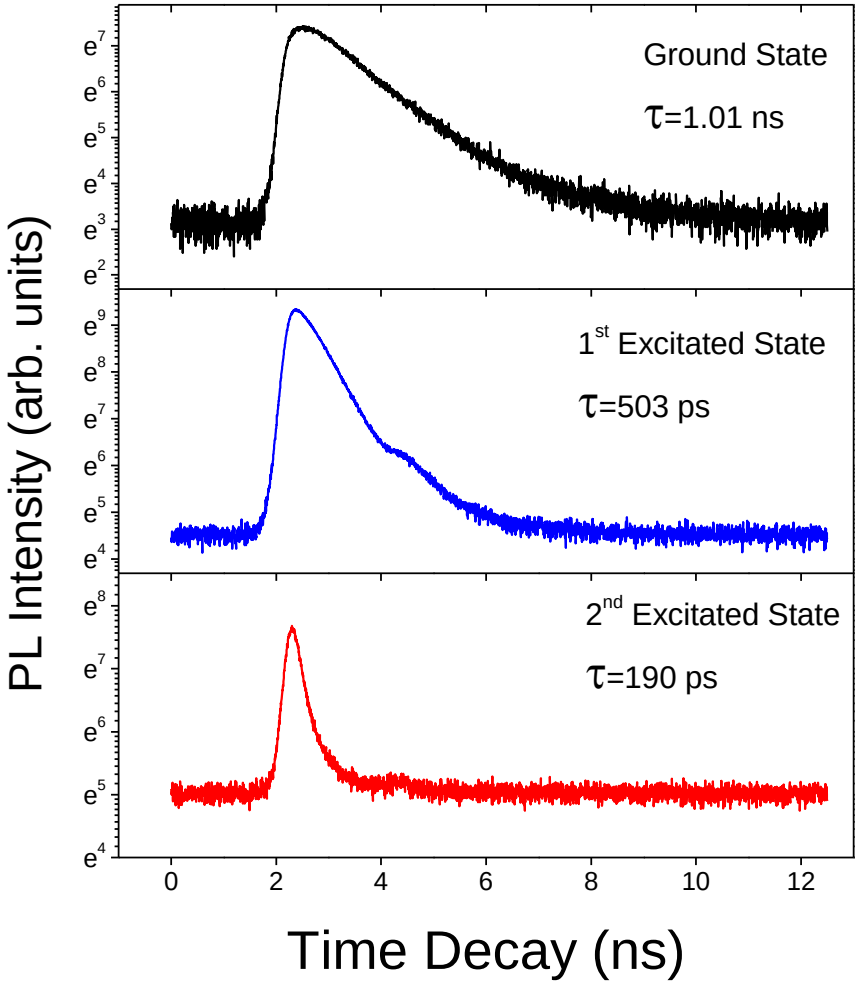




How fast is this system?







Publications

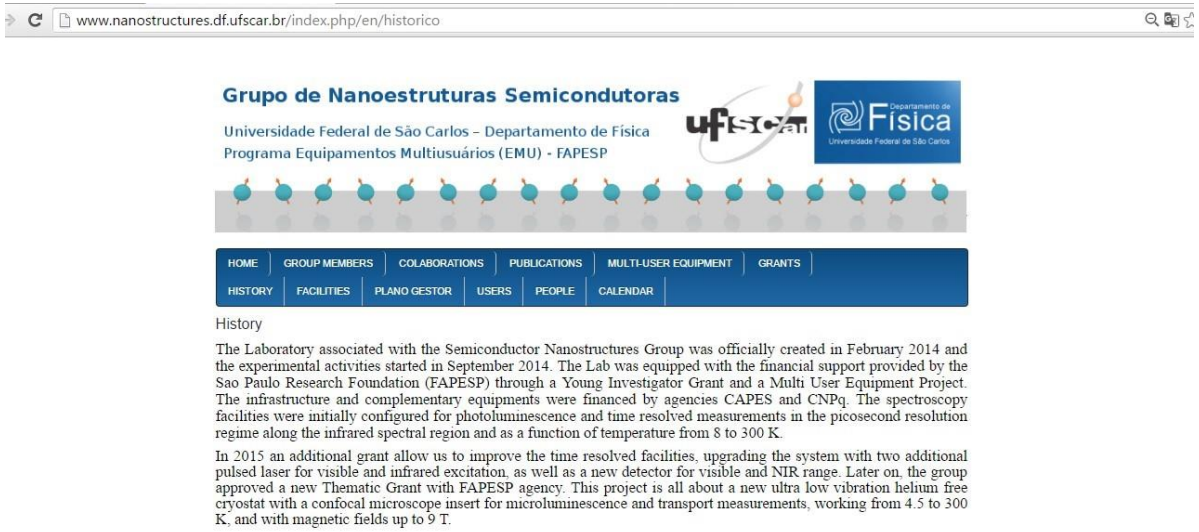
Journal of Applied Physics **119**, 094301 (2016).
Applied Physics A **122**, 385 (2016).
Journal of Applied Physics **117**, 154307 (2015).

External Users:
J. Phys.: Conden. Matter **28**, 175602 (2016).
J. Phys.: Conden. Matter **27**, 245601 (2015).

Users

University –
Researchers
UFSCar – 8
USP/São Carlos – 2
UNB – 1
UTFPR – 1
UFTM – 1
UFMS – 1
UFMG – 2

Visit us: www.nanostructures.df.ufscar.br

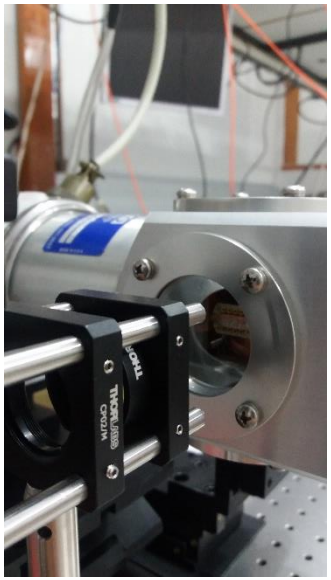


Visible LifeTime Measurements

Quantum Transport + Electroluminescence + TREL

Additional: U$ 28.254,107

Pulsed Blue Laser: 440 nm
Pulsed IR Laser: 1080 nm
Detector for visible range: 400-890 nm, TTS: 160 ps
Two new monocromators
F[illegible]olution < 100 ps



Temperature dependence: 10 k – 300 K
Time decay: NIR < 200 ps, VIS < 100 ps
Electric Field
Material Science, Physics, Chemistry
Biology? UV ligth and detection

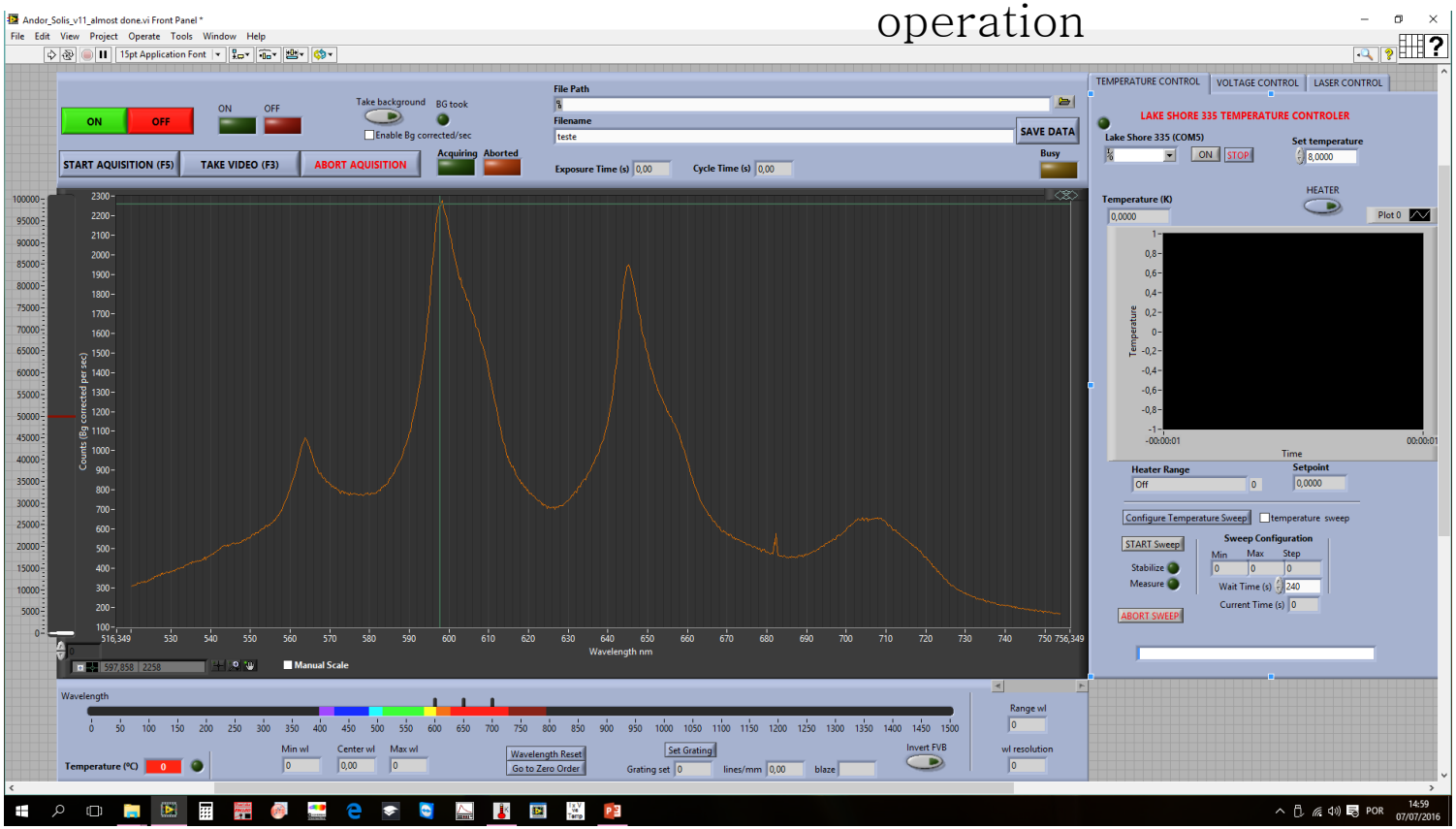
Multi-user Optical Lab: What can we do for you?

You can use as:

- External user
- Collaboration
- Free of charges

Goal:

- Simple optical alignment
- Lab operating 24/7
- Turnkey operation
- Set-and-forget type of operation



Soon: New MUE

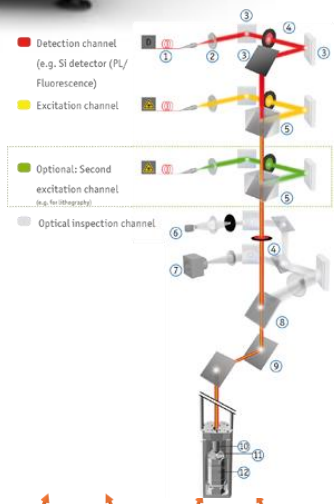
2015/13771-0: Ultra-low vibration cryostat with magnetic field and confocal microscope

Gilmar Eugenio Marques: Coordinator
A. J. Chiquito
E. Marega Jr.
J. P. Rino
L. K. Castelano
M. D. Teodoro
V. López-Richard
W. A. Junior
Y. A. Pusep

www.attocube.com

Temperature: 4.5 – 300 K
Magnetic Field: 9 T
Cooling: Cryo Free
Termal Stability: 25 mK
Vibration Level: 0.15 nm
Optical Performace: Diffraction limit
Techniques:

- Photoluminescence
- TRPL
- Transport
- Raman



We Were Born as a Multi-user Optical Lab

MUE - FAPESP

NIR Detector - Hamamatsu
75 cm Spectrometer - Andor
Objective Lens - Mitutoyo
Sourcemeter - Keithley
TCSPC - Picoquant
Laser 730 nm - PicoQuant
Cryostat - Janis
Vacuum pump - Edwards
Powermeter - Thorlabs
Optics
Visible Detector - Picoquant
Two lasers - Picoquant

YOUNG INVEST. - FAPESP

CAPES

50 cm Spectrometer - Andor
UV Si CCD - Andor
InGaAs diode array detector - Andor
Optical Table

THEMATIC - FAPESP

NIR - Si CCD - Andor
Two power meters - Thorlabs

MUE - FAPESP

Cryostat + supercond. 9 T - Attocube
Confocal Microscope - Attocube

CNPq

Lasers

TEAM