

Federal University of São Carlos  
Physics Department



**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

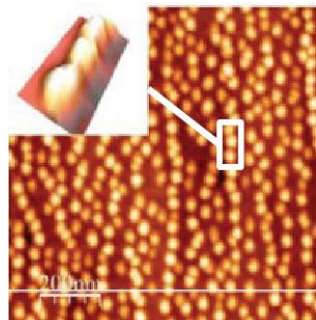
[www.nanostructures.df.ufscar](http://www.nanostructures.df.ufscar)



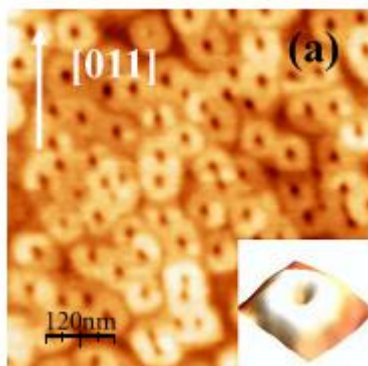
# Semiconductor Nanostructures

## Quantum Rings

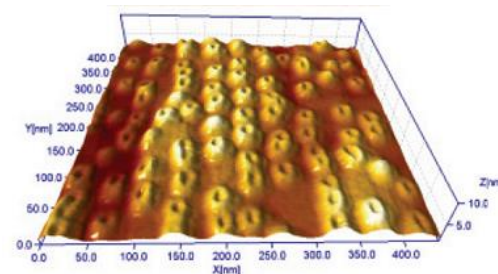
### Quantum Dots



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

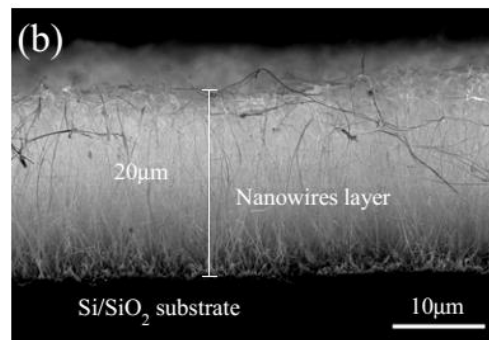
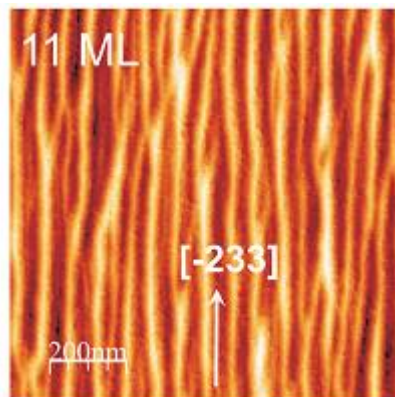


PRL **104**, 086401 (2010)



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

## Quantum Wires

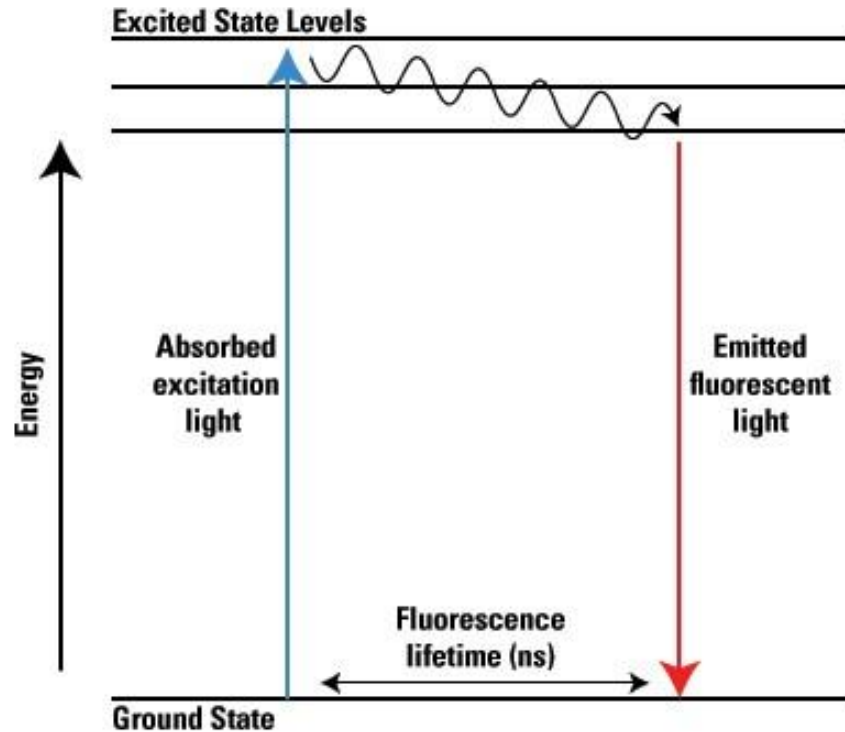


JAP **110**, 083714 (2011)  
APL **97**, 262103 (2010)



# Optical Techniques

Fluorescence / Photoluminescence, Raman, Absorption,  
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?

$10^{-3}\text{s}$      $10^{-6}\text{s}$      $10^{-9}\text{s}$      $10^{-12}\text{s}$      $10^{-15}\text{s}$

Semiconductors Nanostructures

Time decay range: 100 ps – few ns

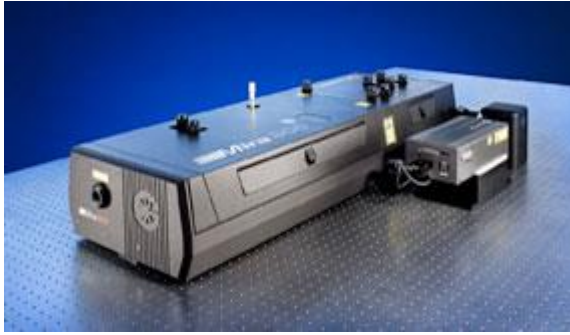
Temperature: 10 K – 300 K

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 ps

Fixed Frequency ~ 80 MHz



[www.coherent.com](http://www.coherent.com)



## Streak Cameras

TTS = 1 ps or 200 fs

High Sensitivity

[www.hamamatsu.com](http://www.hamamatsu.com)

Fast Laser + Streak Camera → Time resolution ~ 10 ps



# 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 temper

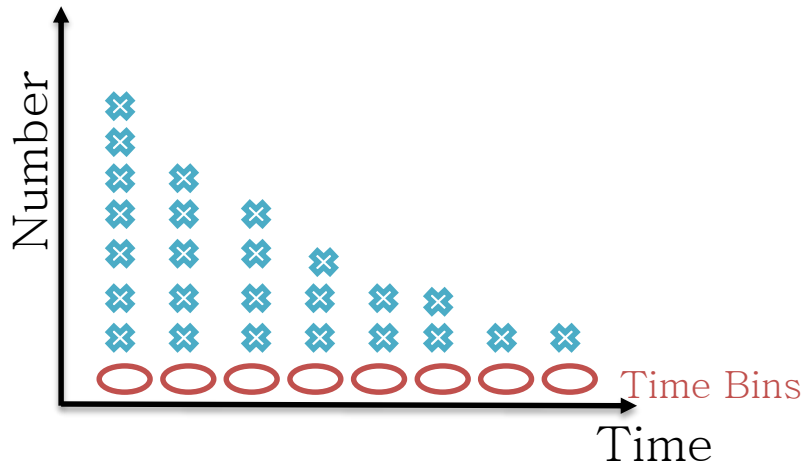
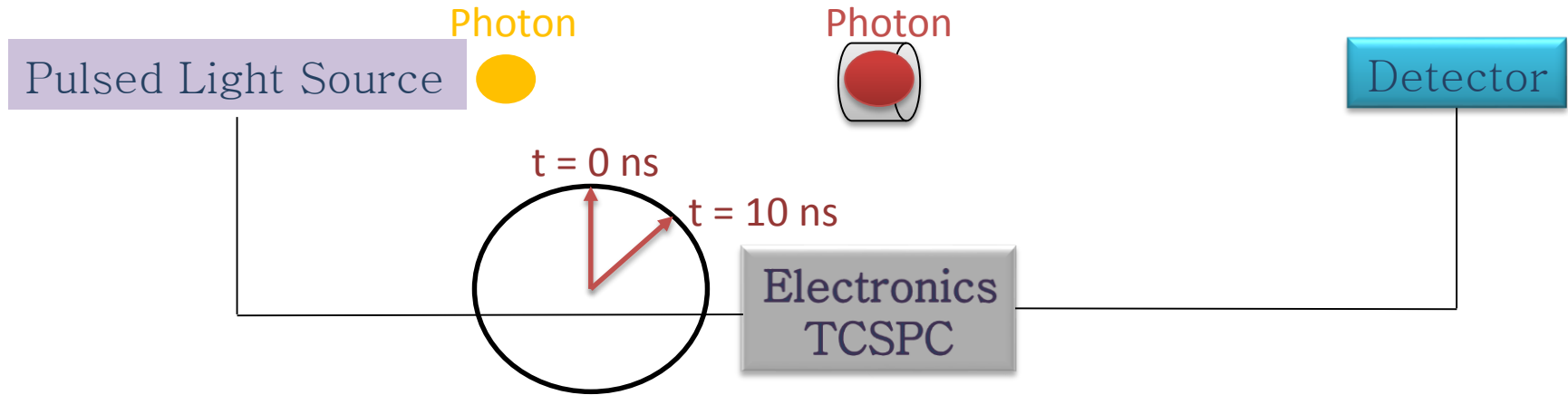
Solution:

One piece at a time

How to integrate all the components?



# Time Correlated Single Photon Counting - TCSPC

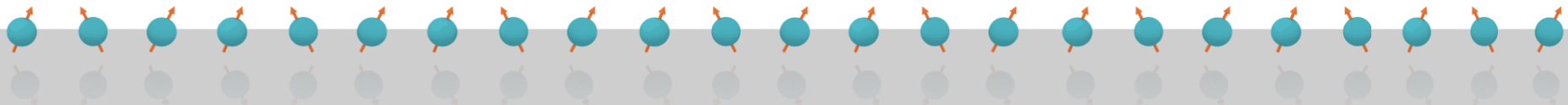


$$I(t) = I_0 \exp(-t/\tau)$$

$I_0$  = Intensity at time zero

$\tau$  = lifetime

$\tau = 1/e = 37 \%$



# How to install a customized TCSPC System

## Diode Lasers

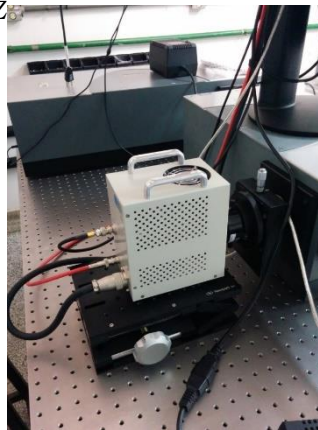


Wavelengths from UV – IR  
Pulse width: 70 – 100 ps  
Variable Frequency: 1 kHz – 80 MHz  
Cheap

[www.picoquant.com](http://www.picoquant.com)

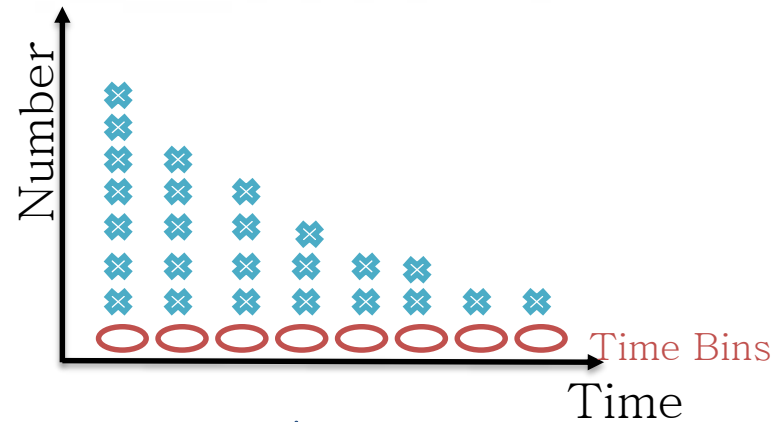


## Detector

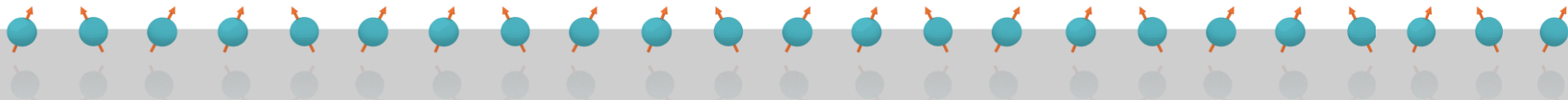


TTS = 400 ps  
Darks Counts =  $2 \times 10^5$  cps  
Wavelength region: 950 – 1700 nm

[www.hamamatsu.com](http://www.hamamatsu.com)



[www.picoquant.com](http://www.picoquant.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:

$$\Delta t_{exc} = 70 \text{ ps}$$

$$\Delta t_{det} = 400 \text{ ps}$$

$$\Delta t_{elect} = 4 \text{ ps}$$

$$\Delta t_m \approx 406 \text{ ps}$$

Divide this result per 5 and 10:

$$\text{IRF} \approx 41 - 81 \text{ ps}$$



# 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

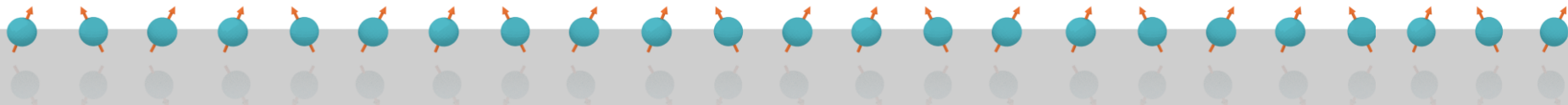
CAPES ~ U\$ 85.000,00

New Facilities inside the Physics Department

Room: 35 m<sup>2</sup>



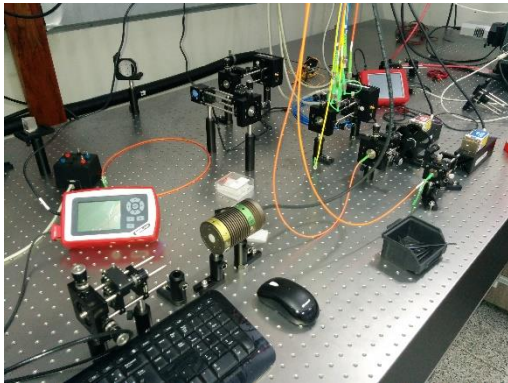
# Starting a new Lab – March 2014



# June – December 2014

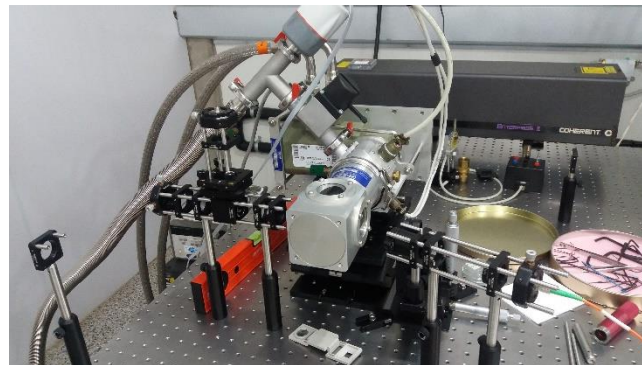
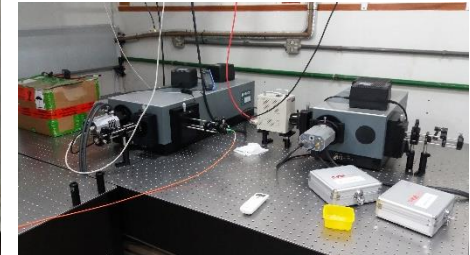
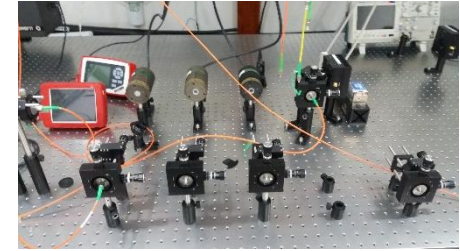


# 2015

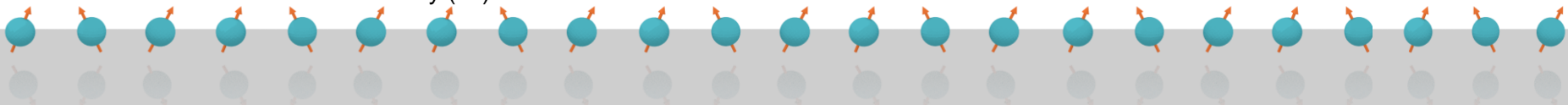
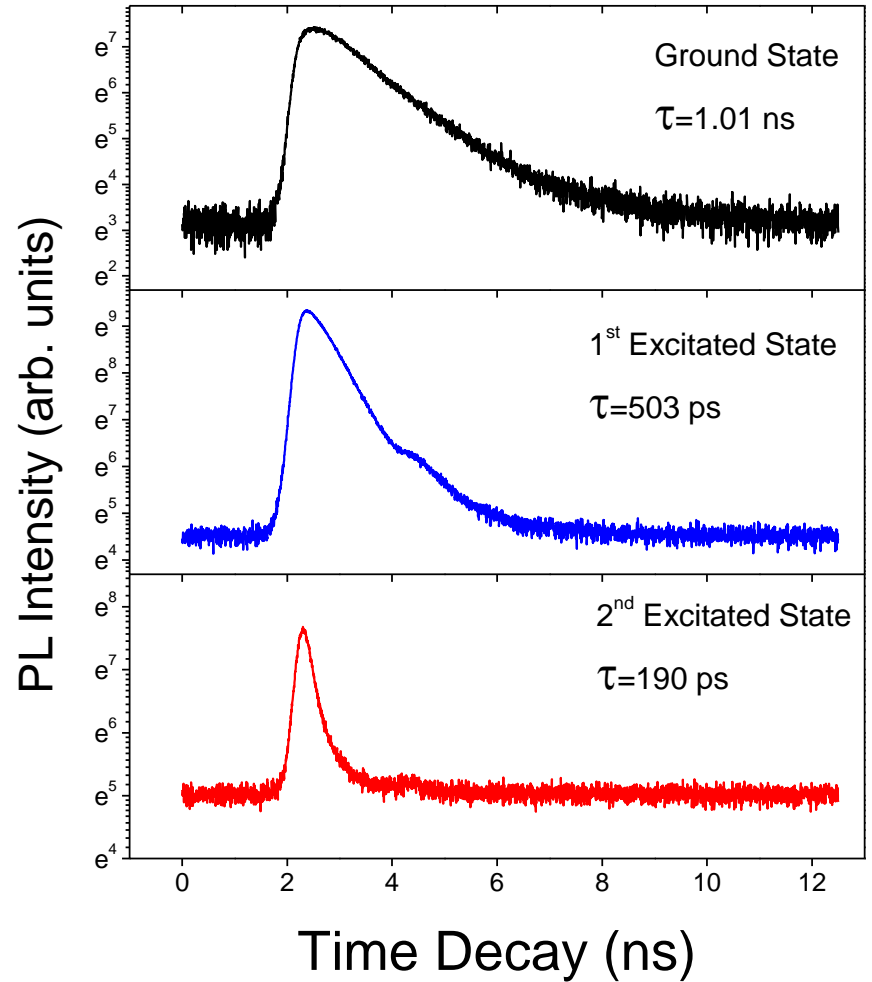
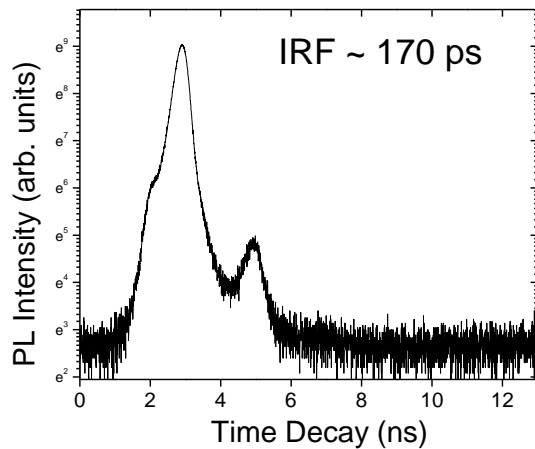
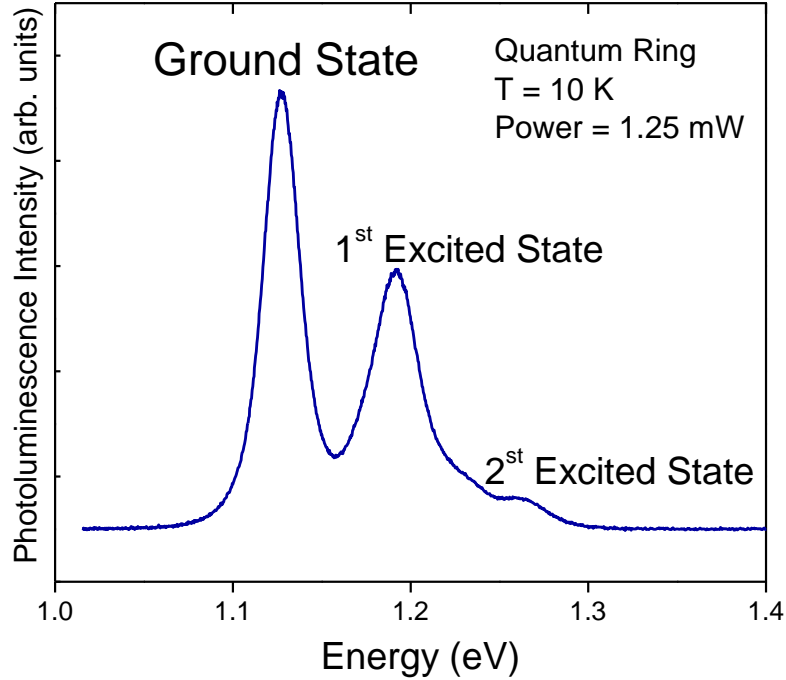




# TODAY



# 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

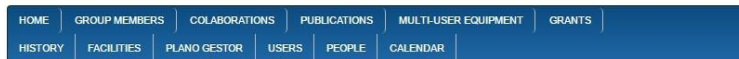
UFMG – 2

Visit us: [www.nanostructures.df.ufscar.br](http://www.nanostructures.df.ufscar.br)



## Grupo de Nanoestruturas Semicondutoras

Universidade Federal de São Carlos – Departamento de Física  
Programa Equipamentos Multiusuários (EMU) - FAPESP



### History

The Laboratory associated with the Semiconductor Nanostructures Group was officially created in February 2014 and the experimental activities started in September 2014. The Lab was equipped with the financial support provided by the Sao Paulo Research Foundation (FAPESP) through a Young Investigator Grant and a Multi User Equipment Project. The infrastructure and complementary equipments were financed by agencies CAPES and CNPq. The spectroscopy facilities were initially configured for photoluminescence and time resolved measurements in the picosecond resolution regime along the infrared spectral region and as a function of temperature from 8 to 300 K.

In 2015 an additional grant allow us to improve the time resolved facilities, upgrading the system with two additional pulsed laser for visible and infrared excitation, as well as a new detector for visible and NIR range. Later on, the group approved a new Thematic Grant with FAPESP agency. This project is all about a new ultra low vibration helium free cryostat with a confocal microscope insert for microluminescence and transport measurements, working from 4.5 to 300 K, and with magnetic fields up to 9 T.



# Visible LifeTime Measurements

Additional: U\$ 28.254,107

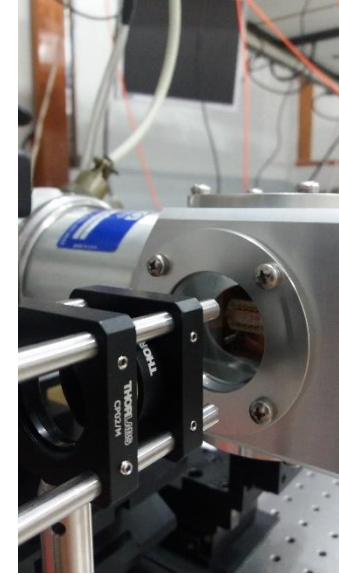
Pulsed Blue Laser: 440 nm

Pulsed IR Laser: 1080 nm

Detector for visible range: 400–890 nm, TTS:  
160 ps

Two new monocromators

Fluorescence lifetime resolution < 100 ps



# Quantum Transport + Electroluminescence + TREL

Temperature dependence: 10 k – 300 K

Time decay: NIR < 200 ps, VIS < 100 ps

Electric Field

Material Science, Physics, Chemistry

Biology? UV light and detection





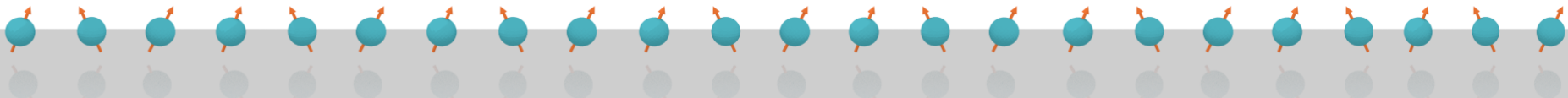
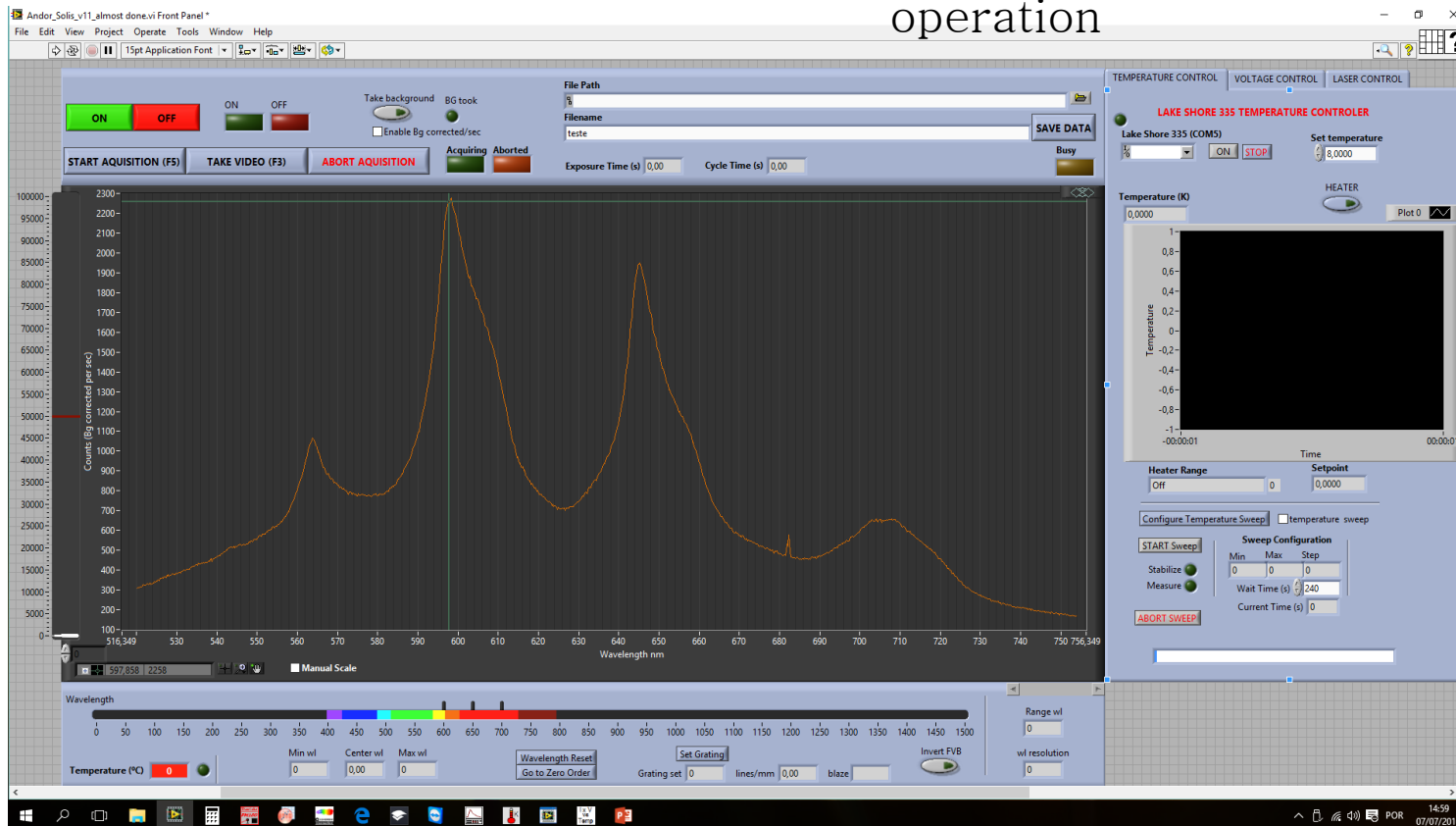
# Multi-user Optical Lab: What can we do for you?

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

Temperature: 4.5 – 300 K

Magnetic Field: 9 T

Cooling: Cryo Free

Thermal Stability: 25 mK

Vibration Level: 0.15 nm

Optical Performance: Diffraction limit

Techniques:

Photoluminescence

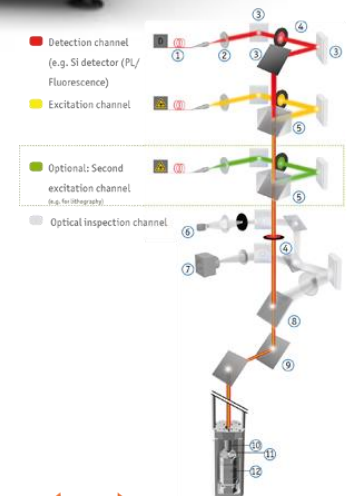
TRPL

Transport

Raman



[www.attocube.com](http://www.attocube.com)



# We Were Born as a Multi-user Optical Lab

## MUE – FAPESP

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

## 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

