CAS Research Instrumentation Initiative

Time-Resolved Single Photon Counting and Low Temperature Photoluminescence Systems

Instrument Capabilities and Usage Policy

I. Time-Resolved Single Photon Counting (TCSP) system

Location: Room MN 107, Department of Physics and Materials Science

The TCSPC system includes two very sensitive detectors (PDM photodiodes with 30 ps time resolution, single photon sensitivity), a reference photodiode (TDA 200), and an electronic timing box (Picoharp 300, 4 ps time resolution).

Pictures of components of the TCSPC module:

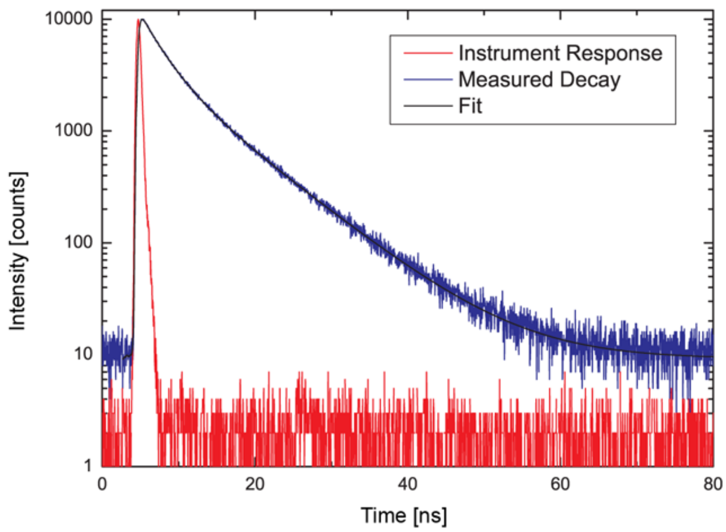
PicoHarp 300 Single Photon Avalanche Diode (PMD) Trigger Diode (TDA)

This TCSP system offers a powerful capability to the optical study of the broad areas of physics, materials science, chemistry, and biology. Specifically, this system offers possibilities to study the temporal dynamics, photon statistic and ultrafast optical, electronic processes that occur in novel nanomaterials (including nanocrystals, semiconductor nanowires and rods, 2-dimensional dichalcogenides), organic materials (such as organic dyes or photochromic molecules) and ultrafast optical processes in nanophotonic and plasmonic nanostructures. Several specific capabilities are:

- Time-Resolved Fluorescence
- Phosphorescence Lifetime Measurement
- Fluorescence Correlation Spectroscopy (FCS)
- Fluorescence Lifetime Correlation Spectroscopy (FLCS)
- Foerster Resonance Energy Transfer (FRET)
- Fluorescence Anisotropy (Polarization)
- Time-Resolved Photoluminescence (TRPL)
- Single Molecule Spectroscopy
- Fluorescence Upconversion

- Antibunching
- Coincidence Correlation
- Quantum Entanglement
- Quantum Information Processing
- Time response characterization of optoelectronic devices

An example of fluorescent decay curve resulted from the TCSPC setup is shown the Figure below.



A simple example of a fluorescent decay curve resulted from a TCSPC measurement of L-tryptophane dissolved in water (Image of Picoquant)

II. <u>Low Temperature Photoluminescence System</u>

Location: Room MN 107, Department of Physics and Materials Science

The main component of the low temperature photoluminescence system is a closed-cycle cryostat (Janis Model CCS-100-XG-M). The cryostat has a horizontal extension making it ideal for optical microscopy experiments at low temperature. The extension is roughly 1.5” tall to allow them to fit in many optical microscopes. In addition, the horizontal extension allows the sample to be positioned very close to the top window, an essential feature for short focal length microscope objectives. This horizontal extension also allows for easy sample changes; simply remove the horizontal extension top plate and radiation shield plate to access the sample area.

A picture of the closed-cycle cryostat (Image of Janis Inc.)

Some main features of the closed-cycle cryostat:

- Temperature range: ~8 K - 300 K (at sample mount)
- Initial cooldown time: < 2 hours to 10 K
- Vibrations at sample less than 15 nm during operation
- Horizontal vacuum shroud extension with top and bottom quartz windows
- Sample holder with a heater and temperature sensor.
- Vacuum shroud with electrical feedthroughs, evacuation, and safety pressure relief valves.
- Exchange gas vibration isolation with flexible rubber bellows connecting cold head to cryostat.
- Power requirements: Single Phase: 50 Hz: 200, 220, 230/240 V.

The low temperature closed-cycle cryostat described above can be used in conjunction with a state-of-the-art spectroscopic system developed at the Department of Physics and Materials Science, featuring:

High Spectral Resolution (0.01 nm resolution)

- Spectrometer*:* Horiba Jobin Yvon iHR550 f/6.4 high resolution spectrometer with three gratings, 150, 600 and 1200 grooves/mm optimized for UV-visible wavelength, on a single turret.
- Detector: Horiba Jobin Yvon Synapse Back-Illuminated with QE up to 95% in the visible frequency. 2048x512 pixels (13.5 mm/pixel), thermoelectrically cooled at -80oC.

Home built optical Bright/Dark field microscopes (sub-micron resolution)

- 150X, 0.9NA Bright/Dark field microscope objective together with nano-positioning linear stage (Newport NPXY400SG), 400 micrometer travel range, and 4 nm resolution will allow optical characterizations of single nanostructures.

Polarization Optics

- Sets of Newport and Thorlabs polarizers and wave-plates allow us to measure various optical signals with different polarizations and frequencies.

Time-correlated single photon counting setup (30 ps timing resolution overall)

- PDM APD (Micro Photon Devices) single photon detector: allows optical measurements with single photon sensitivity.
- Picoharp 300 (Picoquant) counting module: allows fast-timing measurements down to 4 ps time resolution.

Laser for excitation: large tuning ranges, high power

- Coherent Chameleon Ultra II hands-free ultrafast Ti:Sapphire laser provides femtosecond pulses with tuning more than 400nm, from 680nm to 1080nm and peak power >3.5 W (at 800 nm) all in one box. Fully automated for the ultimate ease-of-use the Chameleon Ultra II is operated either via a simple menu-driven interface located on the power supply or via an external computer.
- Harmonix Second Harmonic Generation which converts the wavelengths of the Chameleon ULTRA II (680-1080 nm) to 340-540 nm range.

CW Laser for PL and Raman

- CW narrow band-width 488 nm laser ideal for Raman measurements. This can also be used for luminescent measurements.

Usage Policy

For user access from outside of the Department Physics and Materials Science, no special arrangement is needed. Users will first need to contact appropriate personnel (Presently, Dr. Hoang, email tbhoang@memphis is responsible for maintaining of the system) for available time slots. The system can be used together with other spectroscopic equipment in the Nanophotonics Laboratory as mentioned above, including an ultrafast laser, high spectral, temporal and spatial resolution setups and other polarization optics. To this end, the users are required to have some basic training regarding the laser safety and operations, and uses of spectroscopic equipment.

A fee structure is established for use of above facilities for both internal and external users. The fee structure is determined with reference to Integrated Microscopic Center (IMC) on campus as shown below. For those faculty who contributed their own research funds to the purchase of facilities in the Nanophotonic Lab, their contributed funds will be considered as prepaid user fees for future service. The recovered cost will go towards regular maintenance, contract service, and consumable items.

All rates hourly. Fees are charged in whole hour increments with the minimum charge of 1 hour.

Instrument	Internal User Rates	External User, Non-Profit Organization Rates	External User, For Profit Organization Rates
Nanophotonics Lab	$50	$80	$100
Technical Assistance	$50	$80	$120