HORIBA JOBIN YVON

Photoluminescence of InGaAs/GaAs Quantum Dots

Introduction

InGaAs/GaAs and InAs/GaAs quantum dot (QD) molecules have been identified as suitable candidates for various applications in the Terahertz range by using their intraband carrier transitions. These applications include remote sensing of chemical and biological agents, infrared counter measures, laser radar, pollution monitoring, molecular and solid-state spectroscopy, and noninvasive medical diagnostics. By adjusting the quantum dot size, shape, and composition, the atomic-like optical and electronic properties of the QDs can be optimized for specific applications.

Temperature dependent photoluminescence spectroscopy (PL) is a powerful optical method used for characterizing materials. It can be used to identify defects and impurities in Silicon and group III-V element semiconductors, and determine semiconductor bandgaps. Temperature dependent PL measurements are particularly useful in characterizing materials containing Quantum Dots and Quantum Wells, and assist in optimization of specific characteristics of the InGaAs/GaAs QD molecules described above. Typically, one of two types of cryostat are used: a cryostat requiring liquid nitrogen and/or liquid helium, or a closed cycle cryostat in which a cryogenic liquid is included as part of the cooling system. The cooled sample is excited by a laser, and the PL emission is coupled to a spectrometer via an optical interface.

Experiment

InGaAs/GaAs QD molecules were grown by MBE on GaAs (001) substrates. The samples were mounted on the cold finger of a He-flow optical cryostat (Janis, Model ST-100), and coupled to a HORIBA Jobin Yvon iHR320 spectrometer via a Low-Temperature Cryostat Interface. The samples were excited with a 532 nm Coherent Verdi V5 diode laser (Coherent Mira laser shown in Figure 1). The PL detection system consisted of a chopper, lock-in amplifier and InGaAs photodiode.

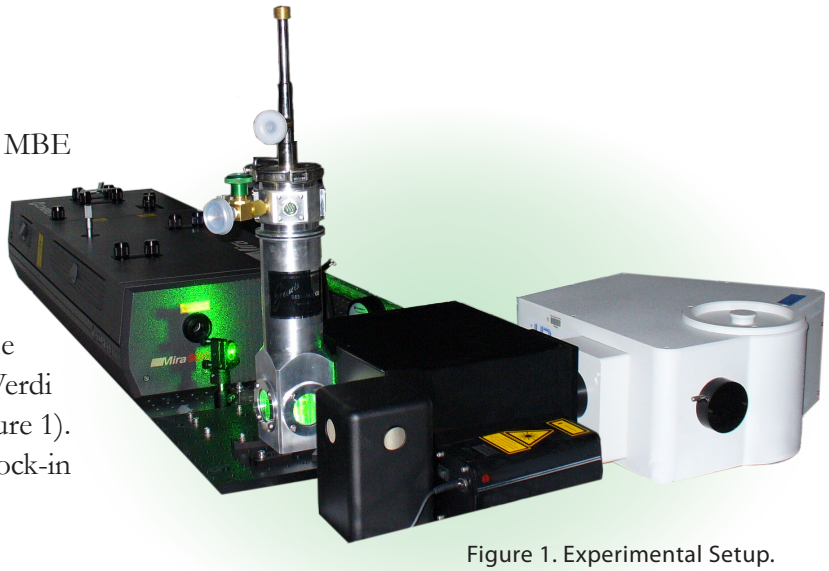

Figure 1. Experimental Setup.

Results

Figure 2 shows PL spectra of typical InGaAs/GaAs quantum dots, measured at temperatures between 5 K and 200 K. In photoluminescence spectroscopy, a material absorbs light, creating an electron hole pair; an electron from the valence band jumps to the conduction band leaving a hole in the valence band. The photon emitted upon recombination corresponds to the energy difference between the valence and conduction bands (bandgap), and is hence lower in energy than the excitation photon, so that the luminescence is red-shifted with respect to the excitation light. At low temperatures, the peak is quite sharp. As the sample temperature increases, the peak broadens and shifts to lower energy. This red shift indicates bandgap shrinkage as a function of temperature, which is typical for such materials. The decrease in peak intensity indicates that electrons escape from the QD via non-radiative processes, such as interactions with the wetting material or barrier materials (in the sample matrix) where non-radiative recombination occurs.

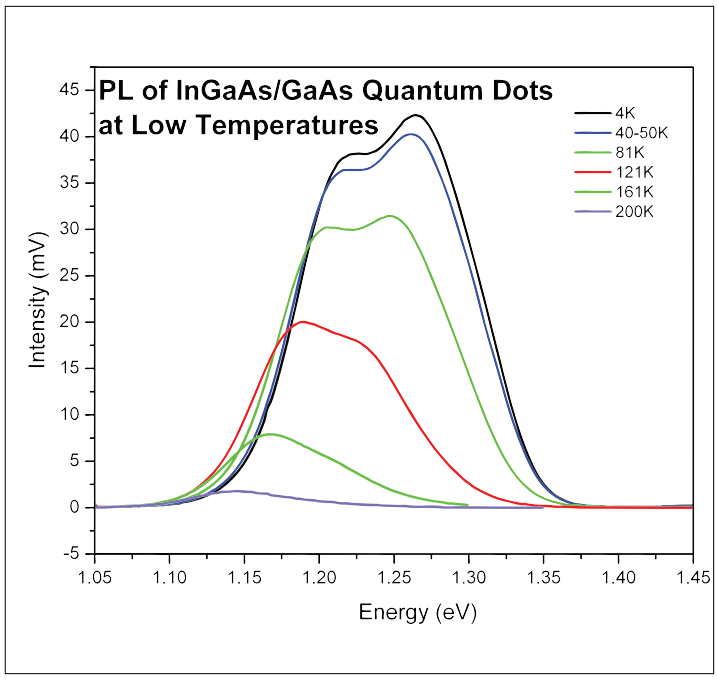

Figure 2. PL spectra of InGaAs/GaAs quantum dots from 5 K to 200 K.

System Components

In order to measure photoluminescence of semiconductors, there are various requirements: (a) a stable, powerful monochromatic light source, (b) optics to focus light on the sample, (c) a sample holder, (d) collection optics, (e) a spectrometer and (f) a detector for spectral analysis. The Low Temperature PL Optical Interface from HORIBA Jobin Yvon provides a stable collection optics system, designed to collect the maximum amount of light from the sample inside either type of cryostat, and couple it efficiently into the spectrometer. Benefits of the system include:

- Easy collection of light from sample in cryostat
- Reflective optics for maximum light collection
- Compatible with M-Series, iHR320/550 and Triax550 spectrometers
- Mounts directly on spectrometer entrance slit
- Easy optical adjustment
- Adjustable height
- Compatible with Janis models ST-100, CS100/202, ARS CS202-x1ss (shown with Janis ST-100 system)
- Input f/1.5, output f/7.5
- Optical axis 102.5 mm above base
- Notch filter holder included (standard 1” filter)
- Optional automated filter wheel for 13 mm filters, GPIB or RS-232 control
- Optional mounting hardware for cryostat

HORIBA Jobin Yvon Components	Part Number
Low Temperature PL Optical Interface	ACC-CRYO-IHR
iHR320 Imaging Spectrometer 2 entrance and 2 exit slits	iHR320
Optical Chopper	ACH-C
Lock-in Amplifier	SR810
Solid state detector interface	1427B
Cryogenic InGaAs photodiode	DSS-IGA020L
SynerJY Spectroscopy Software	CSW-SYNERJY

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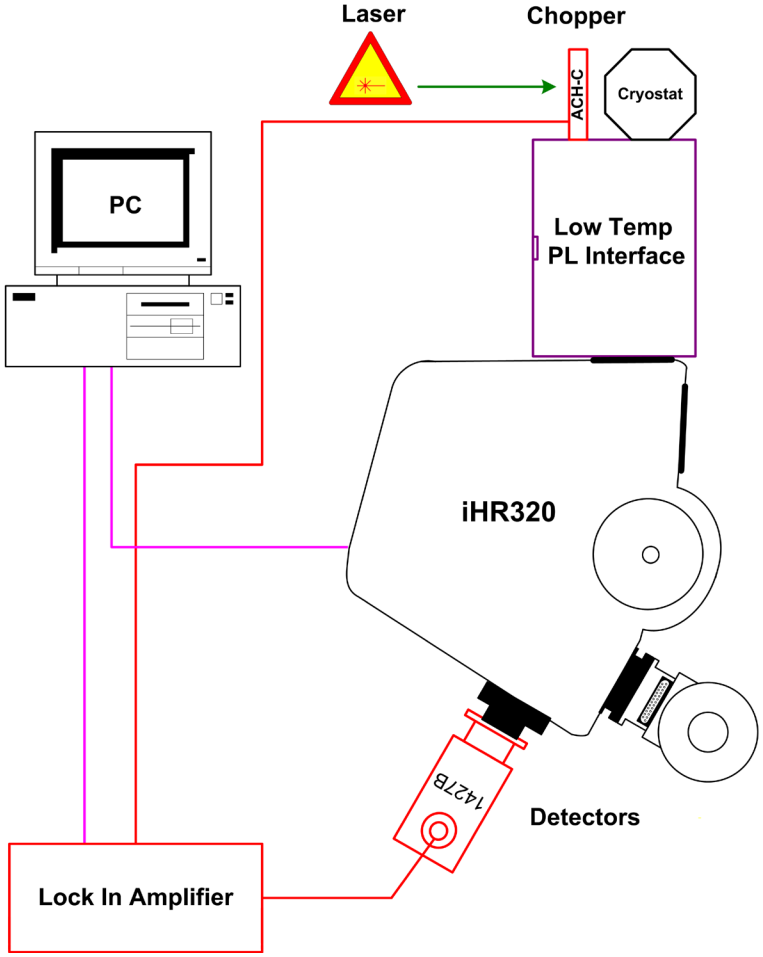

Figure 3. Schematic Drawing of the Experimental Setup.