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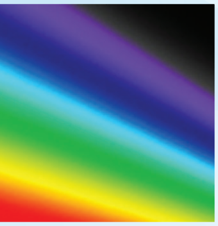
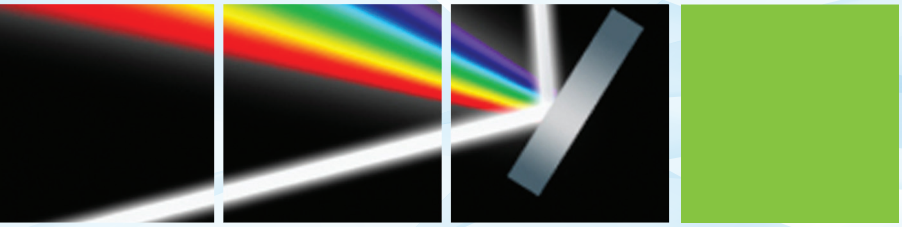


Photoluminescence of InGaAs/GaAs Quantum Dots

OSD-109

ELEMENTAL ANALYSIS
FLUORESCENCE
GRATINGS & OEM SPECTROMETERS
OPTICAL COMPONENTS
FORENSICS
PARTICLE CHARACTERIZATION
RAMAN
SPECTROSCOPIC ELLIPSOMETRY
SPR IMAGING



Near-IR luminescence of solid-state materials

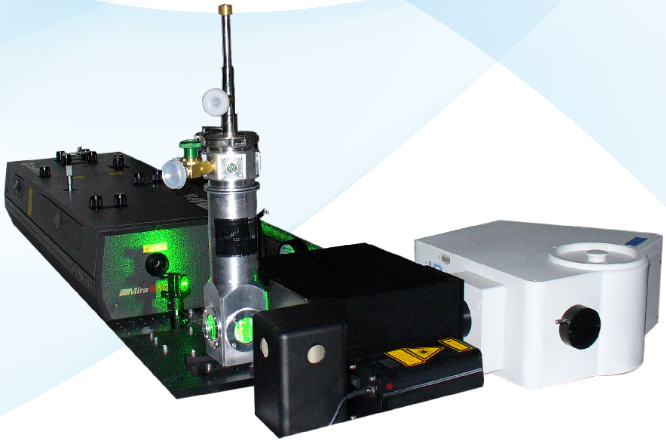
Introduction

InGaAs/GaAs and InAs/GaAs quantum dots (QDs) 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 countermeasures, laser radar, pollution monitoring, molecular and solid-state spectroscopy, and noninvasive medical diagnostics. By adjusting the size, shape, and composition of QDs, 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 semiconductors, and determine semiconductor bandgaps. Temperature-dependent PL measurements are particularly useful in characterizing materials containing QDs and quantum wells, and assist in optimization of specific characteristics of the InGaAs/GaAs QDs described above. Typically, one of two types of cryostat is 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 cryogenic sample is excited by a laser, and the PL emission is coupled to a spectrometer via an optical interface.

Experiment

InGaAs/GaAs QDs were grown by molecular-beam epitaxy 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 Scientific iHR320 spectrometer via a Low-Temperature Cryostat Interface. The samples were excited with a 532 nm Verdi V5 diode laser; a chopper, lock-in amplifier, and InGaAs photodiode were used to detect the PL signal.



Results

Figure 2 shows the PL spectra of a typical InGaAs/GaAs QD, measured at temperatures between 5 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.

JOBIN YVON
Technology

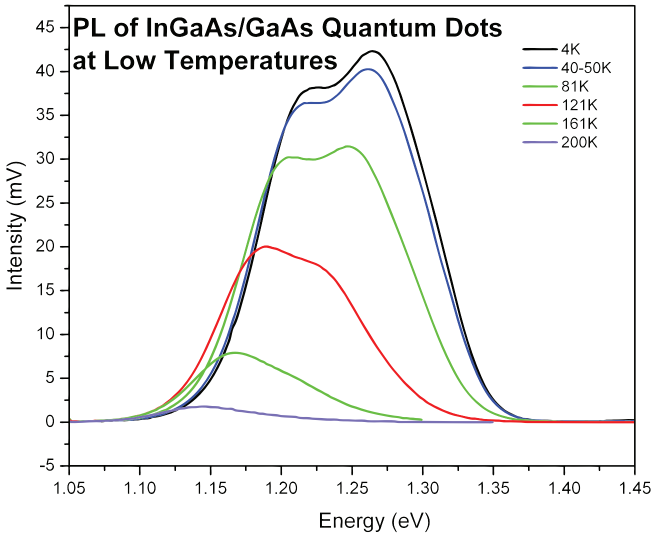


Figure 2. PL spectra of InGaAs/GaAs quantum dots from 5 K to 200 K.

System components

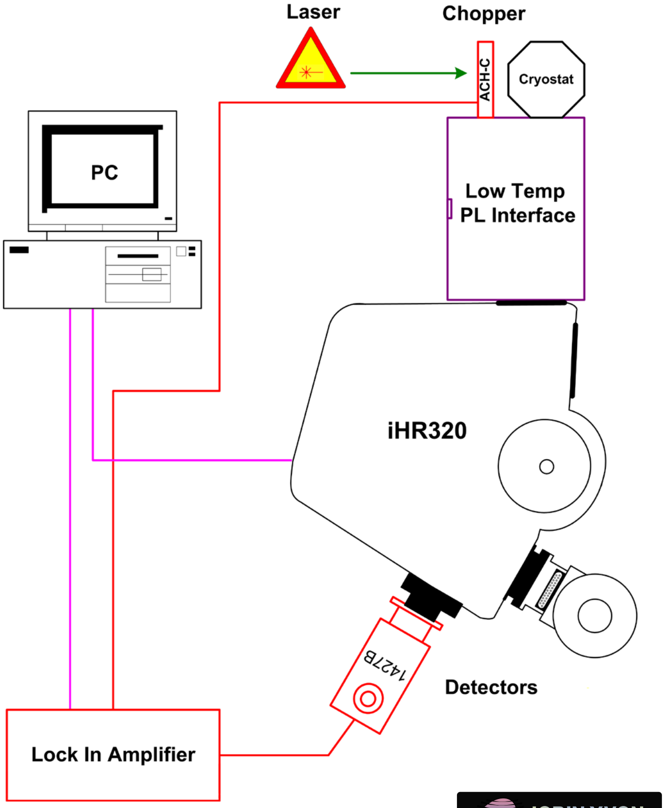
In order to measure photoluminescence of semiconductors, there are various requirements: (a) a stable, powerful monochromatic light source, (b) optics to focus light on the sample, (c) sample holder, (d) collection optics, (e) monochromator, and (f) detector for spectral analysis. The Low Temperature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

- Easy collection of light from sample in cryostat
- Reflective optics for maximum light collection
- Compatible with M-series, iHR320 and TRIAX550 monochromators
- Mounts directly on monochromator slit
- Easy optical adjustment
- Adjustable height
- Compatible with Janis models ST-100, CS100/202, ARS CS202-x1ss
- Shown above with iHR320 and 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 Scientific components	Part number
Low-temperature PL Optical Interface	23332xxx
Imaging Spectrometer, two entrances, two exits	iHR320
Optical chopper	ACH-C
Lock-in amplifier	SR810
Solid-state detector interface	1427B
Cryogenic InGaAs photodiode	DSS-IGA020L
SynerJY® spectroscopy software	CSW-SYNERJY

Acknowledgements

The experimental work was conducted by Professor V. G. Stoleru and A. Pancholi at the Department of Materials Science and Engineering, University of Delaware, written in collaboration with Dr. Linda M. Casson, Senior Applications Scientist, HORIBA Scientific, Optical Spectroscopy Division, in Edison, New Jersey.



info.sci@horiba.com **www.horiba.com/scientific**

USA: +1 732 494 8660
UK: +44 (0)20 8204 8142
China: +86 (0)21 6289 6060
France: +33 (0)1 69 74 72 00
Italy: +39 2 5760 3050
Brazil: +55 (0)11 5545 1500
Germany: +49 (0)89 4623 17-0
Japan: +81 (0)3 6206 4721
Other: +33 (0)1 69 74 72 00