Curriculum Vitae

Name	:	**Amlan Mukherjee**
Date of birth (age)	:	28.04.1985 (29 yrs)
Nationality (sex)	:	Indian (Male)
Marital status	:	Married, no children
Present position	:	Research Scholar
Address for correspondence	:	Dept. of Condensed Matter Physics and Material Science Tata Institute of Fundamental Research (TIFR) Homi Bhabha Road, Mumbai-400005, INDIA Tel: +91-22-22782261 Fax: +91-22-22804610 Email: amlan@tifr.res.in Web: www.tifr.res.in/∼amlan/

Academic qualifications
- 2007: B.Sc. (Physics) Banaras Hindu University, India
- 2010: M.Sc. (Physics) TIFR, India
- 2014 (expected): Ph.D. (Physics) TIFR, India
  Thesis title : Optical spectroscopic studies on semiconductor nanostructures

Awards/Scholarships
- Gold medal in National Graduate Physics Examination-2006 (ranked in top 5)
- Amongst top 1% in National Graduate Physics Examination-2005
- Selected for National Initiative on Undergraduate Science at the Homi Bhabha Center for Science Education, 2005
- Research scholarship from TIFR on the basis of a national selection test, 2007
- National Rank 31 in Joint Entrance Screening Test for admissions to integrated M.Sc.-Ph.D. programs at national research institutes in India, 2007
- National Rank 44 in Joint Admission test for M.Sc. programs at Indian Institutes of Technology, 2007
- National Rank 55 in National Eligibility Test for Council for Scientific and Industrial Research graduate studies scholarship, 2010

Research interests
- Optical spectroscopy of solids
- Physics of semiconductors and their nano-structures
- Opto-electronic devices
- Solid state quantum optics and nanophotonics

Research skills and experience
- Built a setup for polarization sensitive optical spectroscopy measurements with high spatial resolution ($\sim 1.2\ \mu$m) at temperatures down to 4.5 K.
- Extensively used techniques such as micro-photoluminescence, photo-luminescence excitation, Reflectance, micro-Raman and modulation techniques such as Photo-reflectance spectroscopy.
- Experienced in working with high vacuum systems, cryogenic measurements, sensitive electrical signal detection techniques including Lock-in measurements and CCD data readouts.
- Instrumentation, data acquisition and control using LabView.
- Thin film deposition by spin-coating and thermal evaporation.
- Programming language and software proficiency : Mathematica, FORTRAN, C/C++, Origin, Sigmaplot and LaTex.
- Computational experience: (i) First principles simulation of spectral lineshapes, (ii) use of Transfer Matrix method for determining optical response of multilayered systems, (iii) calculation of electronic band structure of quantum wells, quantum dots under the effective-mass envelope-wavefunction approximation and (iv) band structure of bulk III-V semiconductors using the $\mathbf{k}\cdot\mathbf{p}$ formalism.
- I have presented my work at conferences in India and abroad including the ICSNN-2012 in Dresden.

Language proficiency
- I write and speak English fluently. English has been the medium of instruction for me since junior school onwards. I am also fluent in Bangla (mother tongue) and Hindi.

Summary of Doctoral research work

My Ph.D. Thesis work involved the study of electronic band structure (EBS) related physics of semiconductor nanostructures using optical spectroscopic techniques. My initial assignment was to build experimental setups and data acquisition/control systems for spectroscopic measurements. We built a low-temperature micro-photoluminescence(PL)/Raman setup using a long-working-distance objective as the main element of the microscope arrangement, which was then coupled to a 0.55m focal length monochromator with an attached Si-CCD. A spatial resolution of ~ 1.2 μm was achieved, with the sample cooled down to 4.5 K using a continuous flow He-cryostat. We also designed a novel photoreflectance (PR) spectroscopy arrangement using two detectors, where the S/N ratio could be dramatically improved.[**2**] Using these and other spectroscopy setups [**6**] we studied specific problems related to semiconductor nanostructures in 1D (quantum well), 2D (nano-wire) and 3D (quantum dot), which are described below.

GaAs/AlGaAs Quantum Well (QW): In this study [**4**] we determined the origins of additional distinct spectral features on the high energy side of the first confined heavy-hole and light-hole exciton transitions in high resolution PR spectra of GaAs/AlGaAs single QWs. We also measured photoluminescence excitation (PLE) spectra which showed broadened step-like features around these energies. A detailed lineshape analysis of the PR and PLE spectral features, including first principles simulations, was performed to understand the origins of these additional PR spectral features. They were shown to arise primarily from inhomogeneously broadened first excited state transition of the excitons, rather than from a change in the joint density of states at the exciton continuum edge. The analysis suggested that such features are more likely in the case of excitons confined in 2D, as compared to 3D excitons in bulk material. Apart from its importance for post-growth characterization, identification of these additional PR features enabled direct estimation of the exciton binding energy.

GaAs Nano-Wire (NW): GaAs does not form in wurtzite (WZ) crystal structure in bulk. WZ form is found only when GaAs NWs are made. Adjacent zinc-blende (ZB) and WZ section in GaAs NWs can be used to make novel quantum structures and devices, but there continues to be disagreement on the EBS parameters of WZ-GaAs. We performed polarized and spatially resolved PL measurements [**7**] on single GaAs NWs. We observed that from some regions along the NW length there was strongly polarized emission relative to the NW axis. The anisotropy was found to depend on the excitation intensity. The strongly polarized emission at high energies is identified as arising from predominantly WZ regions of the nanowire. The excitation intensity dependence of the emission polarization characteristics supports type-II alignment of the WZ-ZB sections, with the valance band of WZ above that of ZB. The measured transition energies and polarization characteristics were analysed by comparison with EBS calculations based on the $\mathbf{k}\cdot\mathbf{p}$ formalism to obtain the low temperature bandgap of wurtzite GaAs and the crystal field splitting parameter.

CdSe-ZnS core-shell Quantum Dot (QD): We studied two problems associated with such QDs whose average core diameters ranged from 2.6 nm to 7.2 nm. The first [**3**] was that the larger dots show a threshold phenomenon wherein for excitation photon energy greater than a value E_{th}, the PLE and absorption (Abs) spectra diverge abruptly. Beyond E_{th} the PLE signal tends to decrease while Abs continues to increase. These results were compared with EBS calculations based on a spherical core-shell potential model under the effective-mass approximation. We found that E_{th} matches with the minimum photon energy required to create holes with energy equal to the core-shell potential energy barrier for holes. These holes, more exposed to shell surface defects, are likely to be lost through non-radiative pathways hereby reducing the luminescence throughput. These results are important for the choice of pump excitation energy in application of such QDs for luminescence imaging of biological tissues.

In the other study [**5**] we tried to understand the difference between the measured and the calculated Abs spectra of these QDs at photon energies ~ 1 eV above the effective bandgap. We performed a special polarized PLE measurements in order to eliminate spurious spectral features and independently verify the Abs spectra. A calculation that accounts for strongly allowed interband transitions cannot reproduce the measured relatively higher Abs at high energies. The calculated electron and hole envelope wavefunctions show asymmetry due to the core-shell structure. It leads to normally symmetry-disallowed transitions acquiring a weak oscillator strength, with their numbers and strength increasing with energy. We provided a phenomenological model that invoked normally disallowed transitions and showed that it reproduces the measured Abs spectra at high energies quite well. The oscillator strength scaling factor for such transitions was found to increase with decrease in QD size, consistent with expectations.

Publications in journals

[**1**] "Distorted wurtzite unit cells: Determination of lattice parameters of nonpolar a-plane AlGaN and estimation of solid phase Al content", Masihhur R. Laskar, Tapas Ganguli, A. A. Rahman, *Amlan Mukherjee*, Nirupam Hatui, M. R. Gokhale and Arnab Bhattacharya
J. Appl. Phys. <u>109</u>, 013107 (2011)

[**2**] "Improved sensitivity of photoreflectance measurements with a combination of dual detection and electronic compensation", *Amlan Mukherjee*, Sandip Ghosh and Vasam Sugunakar
Rev. Sci. Instrum. <u>83</u>, 046105 (2012)

[**3**] "Optimum excitation photon energy for CdSe-ZnS core-shell quantum dot based luminescence imaging", *Amlan Mukherjee* and Sandip Ghosh
J. Phys. D. Appl. Phys. <u>45</u>, 195103 (2012)

[**4**] "Origin of additional spectral features in modulated reflectance spectra of 2-dimensional semiconductor systems", *Amlan Mukherjee* and Sandip Ghosh
J. Appl. Phys. <u>115</u>, 123503 (2014)

[**5**] "Absorption spectra of CdSe-ZnS core-shell quantum dots at high photon energies : experiment and modelling", *Amlan Mukherjee* and Sandip Ghosh **(manuscript submitted, under review)**

[**6**] "Angle of incidence averaging in reflectance measurements with optical microscopes", Nihit Saigal, *Amlan Mukherjee*, Vasam Sugunakar and Sandip Ghosh **(manuscript submitted, under review)**

[**7**] "Band parameters of wurtzite GaAs from polarized micro-photoluminescence study of single nanowires", *Amlan Mukherjee*, Sandip Ghosh, Uwe Jahn and Holger T. Grahn **(manuscript under preparation)**

(Soft copies of my main publications are attached separately as a zipped file)

Conference/Workshops and presentations

(i) *ICTP (Trieste) Advanced Workshop on Spin and Charge Properties of Low Dimentional Systems*, Sibiu, Romania, June 2009

(ii) *SERC School on Nano-Optics, Department of Science and Technology*, Hamirpur, India, October 2010

(iii) "Emission and excitation studies on CdSe-ZnS core-shell quantum dots used as luminescent tags for imaging biological samples" (poster), *Amlan Mukherjee* and Sandip Ghosh, **28th Photonics Conference**, Guwahati, India, December 2010

(iv) "Photoreflectance lineshape due to Exciton continuum edge in Quantum Wells" (poster), *Amlan Mukherjee* and Sandip Ghosh, **29th Internat. Conf. on Superlattices, Nanostructures, and Nanodevices, ICSNN-12**, Dresden, Germany, July 2012

(v) "Pump photon energy dependent quantum efficiency of CdSe-ZnS core-shell quantum dot luminescent tags for imaging biological samples" (poster), *Amlan Mukherjee* and Sandip Ghosh, **11th Internat. Conf. on Physics of Light-Matter Coupling in Nanostructures**, Berlin, Germany, April 2011 (accepted, could not attend due to funding constraints)

(vi) "Polarized micro-photoluminescence study of GaAs single nanowires" (poster), *Amlan Mukherjee*, Sandip Ghosh, Steffen Breuer, Lutz Geelhaar, Uwe Jahn and Holger T. Grahn, **13th Internat. Conf. on Optics of Excitons in Confined Systems**, Rome, Italy, September 2013 (accepted, could not attend due to funding constraints)