Application of Microphotoluminescence Spectroscopy to Study Semiconductor Quantum Well Disorder.

by

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The final copy of this thesis has been examined by the signatories, and we find that both the content and the form meet acceptable presentation standards of scholarly work in the above mentioned discipline.

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Manufacturing processes unintentionally introduce fluctuations in the width of semiconductor quantum wells. These fluctuations subtly modulate the optical emission energies of exitons confined within the quantum well layer. It is therefore imperative to quantify these width fluctuations so their effect on exiton confinement potentials can be accounted for in ultrafast spectroscopic studies of semiconductor quantum wells. The use of micro-photoluminescence spectroscopy makes quantifying this disorder possible. I present microphotoluminesence spectroscopy work taken in pursuit of an Honors' thesis.

Dedication

To my friends on the playground.

Acknowledgements

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Chapter 1

Introduction

Semiconductor nanostructures provide uniquely manipulable platforms for probing quantum interactions between light and matter in a highly controllable environment. These structures typically require the ability to manipulate semiconductor growth on the nanometer scale. As a consequence, manufacturing such materials is a complex and involved process. However, due to the unique physical properties of valence electrons within the crystalline latice, describing the physics of semiconductor nanostructures is relatively simple [CITE davies]. Therefore, within the broader context of atomic and molecular optics, materials physics, and ultrafast spectroscopy, semiconductor nanostructures form the basis of deeper study into many-body physics in the quantum-mechanical regime.

Band theory, broadly construed, describes how electrons behave as atoms group together to form various materials. As this introduction is not meant to be a rigorous description of condensed matter physics, a brief sketch of band theory will be sufficient to explain the importance of semiconductor nanostructures. When a large number of atoms coalesce, the discrete energy states of electrons relative to their host atoms smear into 'bands' of allowed energies electrons can occupy in the atomic superstructure. In this limit, two distinct energy bands form: the valence band (lower electron energies) and the conduction band (higher electron energies). Electrons occupying the valence band are confined to the atomic superstructure, whereas electrons within the conduction band energies may roam around the superstructure. The difference between these two energies in a material is known as its 'bandgap'. In semiconductors, the bandgap is relatively small, and thus one

can photo-excite an electron from the valence band to the conduction band. Electronic confinement happens when one takes a semiconductor material of lower bandgap and surrounds it with a semiconductor of higher bandgap on the length scale of the electronic wavefunction. The confinement dimensionality (generally one, but sometimes two or three), width, and energetic depth are all free parameters in this process. Because of this parametric freedom, everything simple confinement schemes to complicated structural configurations have proven to be very useful for creating electronic and opto-electronic devices CITE SOMBODY. In addition, semiconductor nanostructures form the basis for photonic quantum information devices CITE SOMBODY.

For our purposes, we will be discussing semiconductor quantum wells (QWs). These nanostructures are layers of relatively low bandgap material (GaAs in our case) sandwiched between layers of higher bandgap (AlGaAs). If one excites an electron within the confined layer, that electron will be confined to move about in two dimensions. Furthermore, that electron will be weakly bound to the vacancy (or 'hole') it left in its parent atom. This electron-hole pair constitute a quasiparticle known as an exciton, the importance of which will be expanded upon later. Excitons confined within QWs can be treated theoretically using a simple particle-in-a-box quantum mechanical picture, making QWs useful devices for studying the subtleties of lights' interaction with matter.