

# Abstract

In this thesis we sought to methodically confirm the quantum nature of the quantum dot, for which our mode of confirmation was not the usual entanglement, but rather in the detection of Rabi oscillations. Motivated by the statistical description of photons and the mechanism and structure behind the quantum dot. A rationale for expecting Rabi oscillations is developed, along with a theoretical understanding for Rabi oscillations which include a model used at present. Furthermore, we wished to fine tune this model, by including dampening mechanisms detailed by Huber et. al. in Coherence and Degree of Time-Bin Entanglement from Quantum Dots. The suggested Linblad Master Equation implemented in QuTiP using the master equation solver program. Ground, exciton, and biexciton populations modelled with dephasing present, all three populations oscillating about the 35% population probability. Quantum nature of the quantum dot confirmed, with considerations for further research suggested in the conclusion.

# Table of Contents

<u>Chapter 1 – Introduction</u> .....	1
<u>Chapter 2 – Experimental and Theoretical Context</u> .....	4
<u>2.1 What is Modelled - Rabi Oscillations</u> .....	4
<u>2.1.1 General Intuition</u> .....	4
<u>2.1.2 The Idealized Scenario</u> .....	8
<u>2.1.3 Approaching the Real World</u> .....	9
<u>2.2 Object Studied – The Photon</u> .....	11
<u>2.2.1 The Toy Model</u> .....	12
<u>2.3 Production of Object – The Quantum Dot</u> .....	15
<u>2.3.1 Quantum Dot Structure and Mechanism – Core-Shell Quantum Dot</u> .....	16
<u>2.3.2 Quantum Dot Used in Thesis</u> .....	20
<u>2.4 Lindblad Master Equation</u> .....	21
<u>Chapter 3 – Methodology, Findings, and Analysis</u> .....	25
<u>3.1 General Methodology</u> .....	25
<u>3.1.1. Motivation</u> .....	26
<u>3.1.2 General QuTiP Implementation</u> .....	28
<u>3.2 Implementation, Findings, and Analysis</u> .....	29
<u>3.2.1 Challenges</u> .....	29
<u>3.2.2 Results and their Analysis</u> .....	33
<u>Chapter 4 – Conclusions and Future Considerations</u> .....	35
<u>Acknowledgements</u> .....	38
<u>Bibliography</u> .....	39

# Table of Figures

<u>Figure 1 – 1.1 Spontaneous Parametric Down Conversion [17]</u> .....	2
<u>Figure 2 – 2.1.1 Two State System</u> .....	5
<u>Figure 3 – 2.2.1 Toy Model</u> .....	12
<u>Figure 4 – 2.2.2 Classifying light</u> .....	14
<u>Figure 5 – 2.2.3 Classifying Sub-Poissonian Light</u> .....	15
<u>Figure 6 – 2.3.1 Bandgap</u> .....	16
<u>Figure 7 – 2.3.2 Core-Shell Quantum Dot</u> .....	17
<u>Figure 8 – 2.3.3 Radiative Recombination</u> .....	17
<u>Figure 9 – 2.3.4 Biexciton-Exciton Cascade [1]</u> .....	17
<u>Figure 10 – 2.3.5 Reimer Group Quantum Dot [1]</u> .....	20
<u>Figure 11 – 2.4.1 Hilbert Spaces</u> .....	21
<u>Figure 12 – 3.1.1 Pennacchetti Experimental Data and Fit</u> .....	25
<u>Figure 13 – 3.2.1 Initial Curve</u> .....	32
<u>Figure 14 – 3.2.2.1-3 Results of Model (ground, exciton and biexciton respectively)</u> .....	34