Electron Musical Chairs: The Rabi Oscillation

(QuTIP Edition)

by

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# Chapter 1 –

# Introduction

Of the multiple modes proposed for quantum computation; one of the first was quantum optics. It is a natural choice for candidacy due the photon’s high mobility and durability. That is to say that it weakly interacts with its environment. However, despite this, it is because of these strengths that it also lacks. It is difficult to achieve successful photon-photon interactions, when the photons are highly mobile and will withstand external interactions. This has another consequence, in that it is difficult to create nonlinear gates, especially when most optical tools are linear in nature. To remedy this, through the combined efforts of Knill, Laflamme, and Milburn; the KLM/linear optical quantum computing (LOQC) was born; and it seeks to make optical quantum computing a reality.

The KLM/LOQC protocol outlines three distinct criteria that must be attained in order to have a successful optical system:

1. Heralded single photon sources with strict mode and bandwidth characteristics

A heralded photon source is able to generate entangled pairs of photons. This solves the difficulty of creating entanglement reactions between photons.

1. High-efficiency number resolving single photon detectors

The exact method is not outlined, but the detector counts the number of photons incident on the detector. Upon measurement, the photon is destroyed, as such any state information is not discernable.

1. Construction of complicated optical circuits exhibiting both classical and quantum interference effects

We will be addressing the first of three criteria in this thesis. While we have achieved a heralded source in spontaneous parametric down conversion (SPDC). Is it possible for us to do better?

(Throw in a picture) Before we continue, I wish to outline the basic premise behind SPDC. This non-linear optical tool takes in a single photon input, incident upon a crystal, and outputs entangled photon pairs. Beta-barium borate, lithium niobate, or potassium dihydrogen phosphate crystals are used as crystals to split the incident photon. The sum of the momenta and energies of the photon pairs total to the initial momentum and energy of the incident photon, which follows in accordance with conservation laws. The resultant output photons are not only identical, but also entangled. While this phenomenon is fascinating, this is not the main focus for this thesis.

SPDC is the most popular entangled photon source, however, is this source deterministic? That is to say, can we produce photons on demand? This will be discussed in detail later on in the thesis but suffice it to say that it is not a deterministic source. While it can be guaranteed if a photon is produced that the entangled pair is present, producing these outputs occurs with an efficiency of 4 outputs for every 106 input photons (source). Alternative deterministic sources are considered, the most promising of which is the quantum dot, details of which will follow in this thesis.

A method for verifying the quantum nature of a system is in the detection of Rabi oscillations. In this thesis, we will confirm the quantum nature of the quantum dot by demonstrating the presence of Rabi oscillations. This is done by contrasting a previous method used in the analysis of the detection of Rabi oscillation against an alternative which will consider environmental effects that may contribute to the dampening of the system.

However before this, we must understand the experimental conditions required to replicate this event. An account considering the object measured – the photon, how the object is produced – the quantum dot, and the experimental setup – the double unbalanced Mach-Zehnder interferometer will be provided in chapter two. In the third chapter, we will consider the theoretical background behind Rabi oscillations as well as the analytic method used to generate results – the Linblad Master Equation. Finally in the fourth and fifth chapters there will be a discussion of what was done with detailed findings and resulting conclusions. Coupled with the information from the thesis for PHYS 437 A, I hope that I will be able to demonstrate the viability of this new model. It is my sincere hope that you will learn, as much as I have, so without further ado, onto chapter two.

(Does this need further elaboration with respect to the quantum dot?)

# Chapter 2 –

# Experimental Background

2.1 Object Measured – The Photon

2.2 Production of Object – The Quantum Dot

2.3 Experimental Technique Used – The Double Unbalanced Mach-Zehnder Interferometer

# Chapter 3 –

# Theoretical Background

3.1 Rabi Oscillations

Intuitively expect once electrons are excited by laser that that was the end of the story, however what actually happens is an oscillatory excitation and de-excitation of the electron that is dependent on the pulse length of the laser.

3.2 Lindblad Master Equation

# Chapter 4 –

# Findings and Analysis

# Chapter 5 –

# Conclusions and Future Considerations