Chapter 1

Introduction

1.1 Introduction to Down-conversion

1.1.1 Theory

Many nonlinear crystals exhibit a phenomenon known as spontaneous parametric down-conversion (SPDC). In this process, the electric field of an incoming photon is absorbed by atoms of the crystal. The nonlinear properties of the crystal cause the re-emission to take the form of multiple photons. [1] These "daughter" photons have lower frequencies than the original, or "pump" photon. Conservation of energy requires that the frequencies of the daughter photons must add up to the frequency of the pump. In addition, the trajectories of the daughter photons are governed by conservation of momentum. [2] From these laws, the multiplicity, frequency, and location of down-converted photons can be predicted mathematically in a process known as phase matching.

The special names given to the daughter photons come from common practices when studying SPDC. Generally, a first photon, called the "signal" photon, is detected. Once researchers know the presence of the signal photon, they look for its corresponding "idler" photon. The detection of both signal and idler photons is called a "coincidence." [1]

[Rough] There are two types of SPDC. In Type I down-conversion, the indexes of refraction are the same on both the ordinary and extraordinary axes. Signal and idler photons propagate in opposite directions along a single cone. In Type II down-conversion, however, the ordinary and extraordinary indexes of refraction differ. This causes the signal and idler photons to propagate in separate cones. These cones are offset equal distances from where the single cone would appear. [3] These cones are shown in figures **??** and **??**.

[Rough-More] Because of the restraints phase matching puts on the daughter photons, they are highly correlated in many parameters such as frequency, geometry, polarization, and emission time.

1.1.2 Applications

[Rough] The rare correlation properties of daughter photons from SPDC lead to many varied applications. Most of these applications stem from the high level of entanglement between the daughter photons. The daughter photons are often used to test Bell's inequalities. [3] Since the correlation between the photons is so high, the Bell's inequalities are pushed to their limits. SPDC also has important applications in quantum cryptography. [1] After the signal photon has has been detected, the idler photon can be isolated and used for encryption without detecting and thereby destroying it. Applications in quantum teleportation have also been considered. [1] The entanglement of the daughter photons and the simple process of SPDC provide many possibly convenient experiments to test these and other basic laws of quantum information and quantum mechanics. [2]

1.2 Computational Modeling

1.2.1 Purpose of Modeling

[Rough-More] In order to study the process of SPDC and its daughter photons, researchers must know the location of daughter photons to be isolated and observed.

[Rough-More] The conditions for phase matching are very sensitive to a number of parameters.

1.2.2 PhaseMatch Model

Etc.