Chapter 1 INTRODUCTION

1-1 Background

Photonic crystals are a class of photonic materials that use periodic structures to create photonic band gaps. The periodic structures are periodic changes in the dielectric constant. Photonic band gaps were first predicted in 1987 by two physicists, Eli Yablonovitch[1] and Sajeev John[2], working independently. This phenomenon has the similar influence on the propagation of light as atomic crystalline potentials gave on electrons. A crystal is composed of atoms or molecules with periodic arrangement, and an electron "feels" a periodic potential as it propagates though it. The conduction properties of the crystal are given by the geometry of the crystal. In particular, the lattice might introduce gaps into the energy band structure of the crystal, so that electrons with certain energies can't propagate through the crystal in certain directions. The phenomenon of the light in a photonic crystal is similar to the discussion above, and the using of the word "photonic" indicated the ability of a photonic crystal to well control the photon. Therefore, we can design and construct photonic crystals with photonic band gaps, which can prevent light with specified energies (frequencies) from propagating through it in certain directions. Similar to electronic dopants, we can introduce the disorder into the periodic structure to give rise to localized electromagnetic states: linear waveguide and point-like cavities.

The propagation of the electromagnetic wave in the periodic media was first studied by Lord Rayleigh in 1887, in connection with the peculiar reflective properties of a crystalline mineral with period "twinning" planes. These correspond to one-dimensional photonic crystals, and he identified the existence of a narrow band gap which forbids the light to propagate through the planes and that this band gap is angle-dependent. A similar effect is responsible for many other iridescent colors in nature, such as butterfly wings and abalone shells.

1-2 Motivation

Over the past decade a considerable number of studies have been made [3-7]. Many savants believe that the photonic crystal bring us a possible solution and unlimited visions of creating large-scale photonic integrated circuits in the future. Large numbers of reports focusing on the design of photonic crystal devices have been published in the last few years. Since the design of the photonic crystal devices needs the properties of the photonic crystal, we want to develop a program to calculate those properties. There are several methods to analysis the photonic crystal: plane waves expansion method [8-9], finite-difference time-domain (FDTD) method [10-11].

In this thesis, we develop a program of FDTD method to calculate the properties of photonic crystal. There are several primary reasons for the expansion of interest in FDTD and related computational solution approaches for Maxwell's equations:

1. FDTD use no linear algebra. Being a fully explicit computation, FDTD avoids the difficulties with linear algebra that limit the size of frequency-domain integral-equation and finite-element electromagnetic models to generally fewer than 10^6 electromagnetic field unknowns.
2. FDTD id accurate and robust. The sources of error in FDTD calculations are well understood, and can be bounded to permit accurate models for a very large variety of electromagnetic wave interaction problems.

3. FDTD treats impulsive behavior naturally. Being a time-domain technique, FDTD directly calculates the impulse response of an electromagnetic system. Therefore, a single FDTD simulation can provide either ultra wideband temporal waveforms or the sinusoidal steady-state response at any frequency with the excitation spectrum.
4. FDTD treats nonlinear behavior naturally. Being a time-domain technique, FDTD directly calculates the nonlinear response of an electromagnetic system.
5. FDTD is a systematic approach. With FDTD specifying a new structure to be modeled is reduced to a problem of mesh generation rather than the potentially complex reformulation of an integral equation. For example, FDTD requires no calculation of structure-dependent Green's functions.
6. Computer visualization capabilities are increasing rapidly. While this trend positively influences all numerical techniques, it is of particular advantage to FDTD methods which generate time-marched arrays of field quantities suitable for use in color videos to illustrate the field dynamics.

Besides developing the program, we also want use this program to design a type of photonic crystal device: "band pass filter". We want to design a 1.55 μm filter. Since the infrared is the mostly used in the optical communication.

1-3 Thesis Outline

In chapter one, we introduce the brief concept of photonic crystal. In chapter two, we drive equations of the FDTD method briefly. In chapter three, we present several properties of photonic crystal calculated from our program, and we also discuss the behavior of the electromagnetic wave in a phonic crystal. And then we focus on the design of a band pass filter with 1.55 μm . We conclude our results in chapter five.