Chapter 1

Introduction

1.1: Introduction

Geometrical optics is a branch of optics that is characterized by the assumption that the wavelength of light is small in magnitude when compared to the dimensions of an optical system. This model describes the light source as a continuous stream of energy that propagates along a ray that obeys three empirical laws i.e., the law of rectilinear propagation, the law of refraction and the law of reflection. These laws can be derived from Maxwell's equations based on the short wavelength approximation i.e. $\lambda_0 \to 0$. Geometrical optics gives good explanation to most of the classical optical problems, where this approximation is true. However, this approximation is not valid when the magnitude of the dimensions of the optical components or the beam is comparable to the wavelength such as in Young's experiment. Then, the beam exhibits effects such as diffraction and interference, which can only be explained by wave theory. These wave properties can be derived based on the Kirchhoff and Fourier integrals. However, these approaches cannot be easily applied to inhomogeneous and non-linear media.

A simpler alternative is to generalise the eikonal equation, which serves as the basic equation of ray optics, by keeping the higher order terms. This generalized eikonal equation has been shown in a few recent studies at the University of Malaya[1, 2, 3] to be able to describe wave phenomena using simple ray tracing method.

Wave phenomena that were only explainable through wave optics can now be described using simple ray tracing method by utilizing the generalized eikonal equation.

The effects on a beam as it passes through a slit and propagates forward can be traced by using the generalized eikonal equation and the equation of continuity. Since these rays coincide with the direction of the Poynting vector, these phenomena can now be understood in the picture of energy redistribution due to changes of self-reactive forces for a spatially finite electromagnetic wave.

Two beams of the same nature, when superimposed give rise to interference effects. Using the ray tracing method, the optical trajectories of the beam can give a better understanding of the redistribution of the energy leading to the formation of fringes when the rays are brought close together. This simple method of including wave effects in optical phenomena can be extended to include diffraction grating, where a number of beams are set to interfere with each other.

1.2: Objective

The objective of this study is to utilize the method mentioned above to study some of the optical phenomena that was previously explained by the wave theory. The optical phenomena investigated include interference of two beams and also the interference of multiple slits. By retaining the simple geometrical concepts, these phenomena can be constructed by using the generalized eikonal equation together with the equation of continuity.

To achieve the purpose above, a numerical scheme for solving the generalized eikonal equation and the continuity equation was constructed. This is carried out by comparing various numerical schemes available and the possibility of adopting such schemes to the equations used in this study.

1.4: Outline of the Thesis

This thesis is separated into five chapters. The first chapter introduces the subject under discussion. In the second chapter, the literature review will give a more in depth description of this subject. It will go through the derivation and the method applied to obtain the generalized eikonal equation. The wave effects that are to be investigated i.e. diffraction and interference would be included in this chapter.

The third chapter discusses the numerical methods and the schemes that are proposed for this study. It also takes into consideration the suitability of each proposed scheme and their justifications. A computational program is then built based on the final choice of a suitable scheme.

The results generated from the computational program are presented in chapter four. It covers the above mentioned wave phenomena and the accuracy of the results are compared to those obtained using the Fresnel integral.

Lastly, discussions and conclusions of this study are presented in chapter five.