Chapter 5

Conclusion

Wave effects that occur when the magnitude of the wavelength is comparable to the dimension of the beam were only explainable by wave optics. Geometrical optics, which is simple under the approximation when terms containing wavelength are neglected, fails to describe these effects. Descriptions of wave effects i.e. diffraction, interference and diffraction grating involves solution by Kirchhoff or Fourier integral based on Huygens' principle.

In order to investigate these effects without involving Kirchhoff or Fourier integral, the generalized eikonal formalism has been employed to describe these phenomena. The generalized eikonal formalism was able to give an account of wave effects through point by point tracing of the amplitude and phase of the beams much as was in geometrical optics. Its ability to produce diffraction effects by tracing a finite Gaussian beam as it propagates, has accuracy of the order of 10^{-5} of relative error.

The magnitude of the accuracy in relative error was due to the application of the implicit method to the algorithm. The program, at first, was based on the forward time centred-space scheme and it was found that this algorithm was not stable. To overcome the instability problem, an implicit scheme was then applied to the algorithm. It shows an improvement in stability when compared to the previous program that only uses the forward time centred-space scheme. It also shows an improvement in accuracy by an order of relative error when compared with the program based on a moving grid[5].

However, the computation time increases and this is one of the compromises that are required to obtain higher accuracy. An obvious disadvantage that exists with this scheme is the loss of accuracy when the gradient of the beam increases. This may be further improved by using higher order schemes.

The generalized eikonal formalism was further applied to investigate the interference effect. It was established that the generalized eikonal equation as a nonlinear equation was able to linearly superpose two beams. The linearly superposed beams have accuracy in the order of 10^{-3} in relative error at 4m compared to the results of interference obtained by using Fresnel integral.

As the interference effect by generalized eikonal formalism was established, the interference pattern dependence on various parameters, i.e. the distance of observation from the initial plane, the separation on the beams and the different values of sigma were investigated. First, when z is large enough, the position of the first minimum is linearly proportional to z. Then, the variation of the beams separation shows a corresponding shifting in the minima position. As the beams were brought closer together, the minimum shifted away from the origin as expected. It is found that the location of the minimum is proportional to z and inversely proportional to the separation of the beams initially at far field.

However, the inability of the pattern to have minima with zero amplitude was attributed to the initial conditions applied. When compared to Young's two-slit experiment, the beam waist used to generate this effect is very much larger. The wave function used was of finite Gaussian beams where as in Young's experiment, the two slits produce two point sources. Furthermore, the two point sources in Young's experiment produced from infinite point source before they interfere. It was observed, however, that the minimum tends to zero when the beam waist has been reduced.

Observations of the interference of three and five slits have also been carried out as an extension to interference effect. From all the results obtained, it has been found that the energy from different beams will redistribute when they interact with the neighbouring beams. This can be seen from the ray tracing of all these effects. Ray tracing was possible due to the definition of the localized index of refraction by generalized eikonal equation and the equation of continuity. The path of the energy flow was altered at the localized points.

In conclusion, the generalized eikonal formalism is accurate in describing wave effects giving it an advantage over the wave theory with its ability to do ray tracing of wave phenomena in linear, non-linear and inhomogeneous media. It can serve as an alternative method to wave theory for solving wave phenomena. At the same time it is able to describe such phenomena with a simple ray trace method.