Design and Simulation of the Fourier Transform Beam Propagation Method in Different Optical Waveguides

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Abstract. Fundamentals of optical waveguides is a needed resource for any researcher, concerned in optics and communications engineering. Interested by designing or actively running with optical gadgets have to have a company hold close of the standards of light wave propagation. This paper presents an FFT Beam Propagation Method Models for optical waveguides. The technique is based on the use of the Propagation of a Gaussian pulse by a waveguide with a rectangular, triangular optical waveguides and free space the cases of straight and bent optical waveguides are successively considered.

1. Introduction
Multiplexing and de-multiplexing of optical alerts. Passive waveguides, electro-optic components, transmitters, receivers, and using bodily technology is included into one chip exploitation planate technology, like electronics. Though the operation of conductor devices is properly researched and understood, their express overall performance depends on several parameters—geometry, wavelength and preliminary discipline distribution, cloth expertise, and electro-optic driving situations. These parameters have to be optimized earlier than fabricating a device. With large-scale optoelectronic circuits, correct modeling is main as a result of the various sources had to fabricate a chip. [1] Optical conductor style depends on simulating the propagation of light indicators, conductor modes, mode coupling, and loss and benefit. One part of the entry data defines the conductor device with the aid of its pure mathematics, fabrication parameters, and cloth constants. It’s first-rate to go into the conductor records exploitation code with a venture layout with the intention to conjointly manage fabrication parameters. Every other part of access record is for configuring numerical calculations. Preferably, access structures conceal or restrict the main points of the numerical calculation. But, due to conductor modeling usually uses diffused numerical algorithms, you want to be at domestic with a few elements of the underlying numeric. Waveguides location unit the building blocks of photonic circuits. [2] The width of a waveguide (consistent or variable) is characterized as opposite to the manner along the waveguide focus. the bar engendering technique (BPM) is an estimation approach of reenacting proliferation of light in regularly moving wave-guides [3] largely similar to purported explanatory condition (pe) approach in submerged acoustics. Each bpm and the pe have been first provided within the 1970s. On the point after a wave engenders alongside a waveguide of a huge separation (larger contrasted and wavelength), thorough numerical reenactment is tough. [4] BPM to depend upon for estimated differential situations that are likewise named the limited simulations. Those restricted models consist of simply a primary request subordinate within the moveable z (of waveguide pivot. The "underlying" esteem issue fixes no longer consist of time [5]. They may be received via applying reasonable approximations to the rectangular root administrator. after a confined version is gotten, regardless of the whole thing one needs to fathom it by using discretizing the variable z. [5], [6] the exactness for BPM can remain additionally superior, within the event that you
utilize the vitality monitoring one-way display or the unmarried-diffuse one-manner display. The beam propagation approach relies upon at the gradually differing envelope estimation and is off base for the demonstrating of discretely or first of all fluctuating systems. essential utilization is additionally flawed for the showing of systems wherein light proliferates in huge scope of points and for gadgets with excessive refractive-list differentiate, generally discovered as an instance in silicon photonics. propelled utilization, be that as it may, relieve an element of these regulations enabling bpm to be utilized to exactly show a massive lot of these cases, which include numerous silicon photonics structures. There are numerous simulation gear that put in force bpm methods. Popular profitable gear had been industrialized through rsoft layout and optiwave schemes. [7, 8, 9].

2. Beam Propagation Method in different Optical Waveguides

The BPM is the close to extensively used generation method because of modeling built-in or fiber-optic photonic devices, but close business software program software due to the fact positive modeling is based totally approximately it. There are numerous motives due to the fact the recognition on bpm; probable the nearly big animal to that amount that is conceptually sincere, permitting fast implementation about the primary method. this conceptual simplicity additionally advantages the person over a bpm-primarily based modeling tool as a whole lot properly as tons the implementer, seeing that a draw close about the consequences then proper usage of the device be able stand without a hassle grasped with the aid of a no expert amongst numerical methods. BPM is typically formulated as a lot a solution in conformity with Helmholtz equation [10, 11].

\[
(\nabla^2 + k_0^2 n^2) \psi = 0
\]  

(1)

With the field:

\[
E(x, y, z, t) = \psi(x, y) \exp(-j\omega t).
\]  

(2)

The spatial dependence explains as:

\[
\psi(x, y) = A(x, y) \exp(jk_0 \nu y),
\]

(3)

When applied the envelope A (x, y) subsequent a slowly varying estimate,

\[
\frac{\partial^2 A(x, y)}{\partial y^2} = 0
\]

(4)

Now the explanation when exchanged to the Helmholtz equation:

\[
\left[ \frac{\partial^2}{\partial x^2} + k_0^2 (n^2 - \nu^2) \right] A(x, y) = \pm 2j k_0 \nu \frac{\partial A_k(x, y)}{\partial y}
\]

(5)

with the intention to compute the sphere in any respect points of space for all times, we handiest vital to calculate the feature a(x,y) for all space, and then we're talented to reconstruct ψ (x,y) due to the fact that the solution is for the time-harmonic Helmholtz equation, we simplest essential to compute it over one term. We will consider the fields along the propagation direction, or the pass segment waveguide modes. FFT is a complicated system, and its particulars are typically left to the ones that explain in such results. This phase defines the overall process of the FFT however skirts a vital difficulty: using complicated numbers. If you have a history in complicated mathematics, you be able to read along the lines to apprehend the real nature of the procedure. An FFT calculates the DFT and produces exactly the equal end result as assessing the dft which means immediately; the maximum significant distinction is that an fft is much quicker. (Inside the presence of spherical-off mistakes, many fft methods are too much extra particular than assessing the DFT which means at once, as deliberated beneath.) Let x0... xn−1 be complicated numbers. The dft is described via the method [11].
The technique of spatial domain can calculate a sphere at the following stage (inside the propagation course) via resolving a linear calculation, at the same time as the approaches of the spectral domain use the influential ahead/inverse DFT procedures. Spectral area strategies have the benefit of constancy even in the lifestyles of nonlinearity, despite the fact that spatial area strategies can possibly become mathematically unbalanced. [12]

3. Results

In this part, the presentation of the BPM mode solver is analyzed in three aspects, including the precision for numerous sampling intervals in transverse and longitudinal direction, the dependability of the technique for dissimilar early values of the active refractive index and dissimilar waveguide widths the all simulations done by Matlab Software 2016 [13].

A. BPM in free space

Generates a Gaussian pulse and propagates it from 0 to 1000 um

![Gaussian pulse Original Ae^{-(x/8)^2}](image)

**Figure 1.** Gaussian pulse Original in BPM in free space
Figure 2. Magnitude of Propagated Gaussian in BPM in free space

B. Propagation of in a triangular waveguide

Figure 3. Gaussian pulse Original in BPM in a triangular waveguide
Figure 4. Refractive index in a triangular waveguide

Figure 5. Wave vector $K_X$ in a triangular waveguide
Figure 6. Attenuation of the Signal in a triangular waveguide

Figure 7. Magnitude of Propagated Gaussian Pulses in Triangular Waveguide
C. Propagation of in a Rectangular waveguide

Figure 8. Gaussian pulse Original in BPM in a Rectangular waveguide

Figure 9. Refractive index in a Rectangular waveguide
Figure 10. Wave vector $K_X$ in a Rectangular waveguide

Figure 11. Attenuation of the Signal in a Rectangular waveguide
Figure 12. Magnitude of Propagated Gaussian Pulses in Rectangular Waveguide

Figure 13. Contour Graph in Rectangular Waveguide
D. Mach-Zender

Figure 14. Contour Graph in Mach-Zender

Figure 15. Contour Graph in Branch-Zender
4. Conclusions

On this paper, a beam propagation method using a finite distinction estimate is studied in assessment with that the use of Fast Fourier transformation. From the look at, it’s far located that the calculation time for the simulation in FD-BPM is 66% instances much less than that of FFT-BPM. Also, FD-BPM is plenty extra stable with recognize to propagation step length, δ z, and variety of grid factors n variations. For comparable accuracy, one necessities a whole lot smaller propagation step sizes in the FFT-BPM than the FD-BPM. This designates that blended with the CPU time development in line with step FD-BPM may be tons additional efficient than FFT-BPM. As extra test at the accuracy of all processes, from previous examination we can accomplish that our optical diffraction grating fabricated by a double–ion exchange method is additional proficient as an optical waveguide diffraction device and verified to have numerous applications in optics. The Fourier Transform method showed useful for propagating Gaussian beams. For early waist radii that were close to or larger than one wavelength there was good promise between these two approaches and the paraxial approximation. So, for beams of with initial beam radii within this range it is a valid approximation that saves reduces computational cost. Though, agreement between the FFT method and FDTD method and the paraxial approximation begin to breakdown for narrow initial waist radii. For beams with early beam radii of less than a wavelength both approaches demonstrate valuable for modeling Gaussian beam propagation. The FFT technique is less computationally demanding than FDTD so for beams propagating in free space it is a much more proficient technique. Though, the FDTD technique permits complete design of the computational domain. If the Gaussian beam is incident on any surface the FDTD technique is chosen.

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