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# Analysis of Lorentz Beam Propagation at Critical Angle Using Accelerated Beam Propagation Method

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## Abstract 1

This work presents the analysis of the Lorentz light beam at a planar dielectric interface using accelerated beam propagation method (BPM). the FFT-BPM is implemented on a graphical processing unit (GPU) platform using CUDA-C program to decrease the execution time significantly. In this study, the interference between the incident and reflected beams is reported. Additionally, the angular spread of the refracted beam in the rare medium and its direction of propagation are considered. The non-specular shifts are also calculated using the FFT-BPM at sharp critical angle which is very difficult to examine using analytical methods.

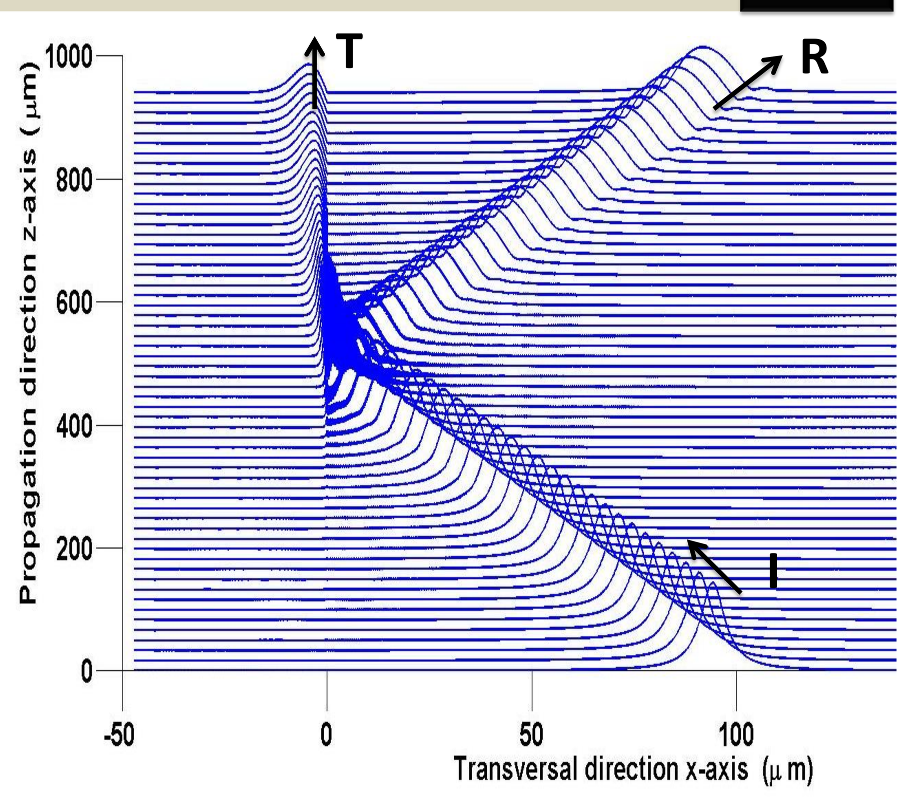


Fig. 1. the total field incident on a dielectric interface at critical angle.

## Design and Simulations 2

- The incident Lorantezian field takes the form:

$$E_i(x_i, z_i) = \frac{\exp(ik_1 z_i)}{1+(\frac{x_i}{w})^2} \qquad (1)$$

- The Lorentz light beam propagates at sharp critical angle of oblique incidence on a dielectric interface using FFT-BPM.
- The FFT-BPM measures the refractive indices changes in phase correction function, consequently, it doesn't faces any singularity problem during the calculations [1-5], and it gives the results at any incident angle.

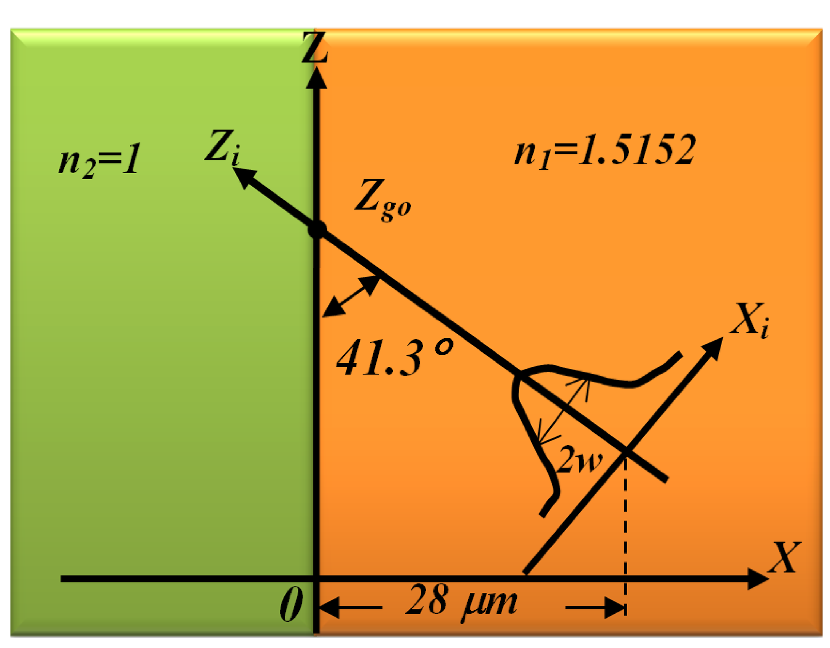


Fig. 2 shows the schematic diagram for the incident Lorentz field on a dielectric interface. The incident beam wavelength "λ" is equal to 1.33μm, and the beam waist w=20λ. The FFT-BPM result for the Lorentz fields (incident, reflected, and transmitted fields) can be evaluated from Fig. 1. The numerical results show that the lateral shift for the beam is equal to 5.45μm.

## BPM acceleration 3

- The BPM error depends on the square of the used step size Δz [6].
- In order to decrease the error, we need to increase the number of samples. However, software and hardware limitations are arisen.
- The time complexity of the BPM depends on quadratic-logarithmic, i.e. O (LN $\log_2$ N), where N and L are the number of samples in transversal direction x-axis and the number of steps in the propagation direction z-axis, respectively.
- However, the execution of the BPM on a CPU takes long time for higher values of N and L.

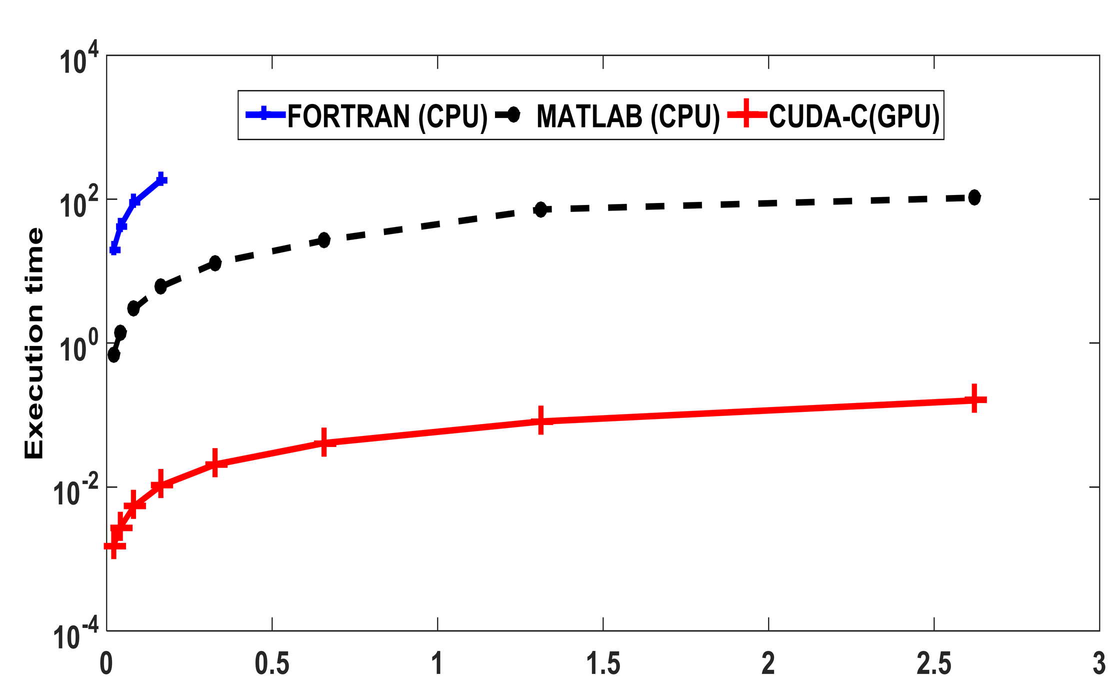


Fig. 3 depicts the execution time for the BPM running in modern central processing unit (CPU), where CPU specs is: 2.5 GHz, D processor, and 32 GB RAM, and the GPU device "Quadro-k2000".

- Therefore, the FFT-BPM is accelerated using a GPU, where the acceleration of BPM is highly needed in order to reduce the computation time.
- The reported BPM program is implemented using different programing languages: FORTRAN, MATLAB, and CUDA-C.

- We choose the same field parameters, where, Δx=0.35(λ/2)/$n_1$, Δz =0.01λ/($n_1$-n2) with the propagation distance of 82.5 μm.
- It is revealed from the fig. 3 that the execution time for the FORTRAN program is greater than that of the other programs.
- Additionally, the propagation step size Δz should be changed due to the allocated memory limitations of the FORTRAN language.
- However, the MTALAB based-BPM program can be run at different samples, without changing the steps size.

- The execution of the CUDA-C program on the GPU platform is faster.
- For comparison, at a number of samples of 0.16384x10[5], the MATLAB program is 30 times faster than the FORTRAN program on the same CPU.
- However, the GPU speeds the execution process up to 581 times faster than the MATLAB program and 17x10[3] times faster than the FORTRAN program.

## Numerical Results 4

- Figure 4 shows the BPM results for the incident, reflected and transmitted fields.
- The Gaussian field is incident at the critical angle.
- The field is spited into two fields; the first field is the refracted field which propagates in the rare medium and near to the interface. However, The second field is the reflected field in a denser medium.

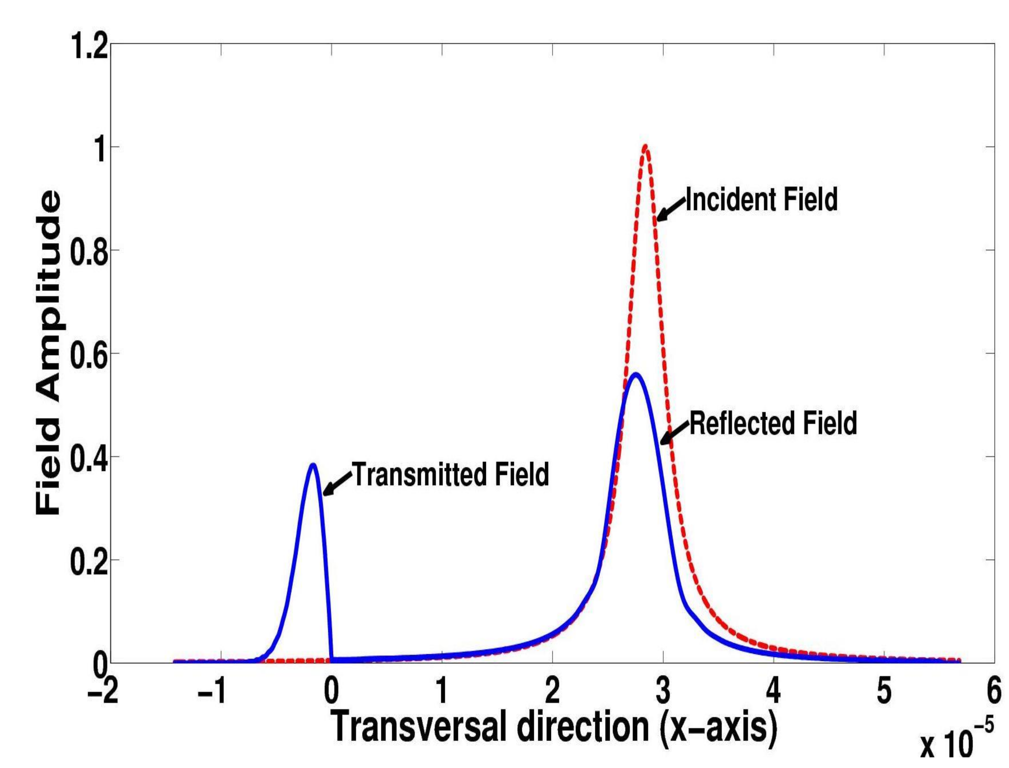


Fig. 4. The incident reflected, and transmitted fields.

## Conclusion 5

This analysis describes the Lorentz light beam interaction on a planar dielectric interface between two homogenous mediums. The BPM results are matched well with the theory of the non-specular phenomena of the electromagnetic field interaction on a dielectric interface. Accordingly, the BPM is the simplest numerical method to represent the interaction of the electromagnetic field at dielectric interface, which is simple in implementation and accurate in results. Hence, it can study the interaction of any type of fields (like Gaussian or Cauchy or others).

## References 6

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