Rigorous modeling of dispersive, reflective, and polarization prisms

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The prism belongs to an important group of optical components in optical systems design. It is not only capable for separate uses, but also can be embedded into complicated and sophisticated devices as a component, such as spectroscopy, microscopy, and laser systems. We discuss a fast and rigorous modeling approach to treat with prism simulations. Based on electromagnetic concepts the effects of different surfaces and the propagation inside prism are considered, respectively. The appropriate handling and dynamic adaptation of coordinate systems for describing the modeling as well as the light itself turns out to be crucial for this approach. By using this method, we simulate three types of prisms: dispersive prism, reflective prism and polarization beam splitter.

1 Introduction

Nowadays various modeling approaches enable the modeling of optical prism. In this paper we choose the most efficient and accurate three modeling approaches: ray tracing, geometric field tracing and diffractive field tracing. Ray tracing concept is really well-known, in the following firstly we present how to implement prism simulation by field tracing approach [1]. Then with the help of some practical simulation tests, the comparison and analysis of these three approaches will be respectively given.

2 Prism simulation by field tracing approach

In this section, the strategy of prism simulation by field tracing is demonstrated. As an example, a simple dispersive prism system is shown in Fig. 1. According to field tracing concept, this system can be divided into five small pieces, which are corresponding to propagation process or interface process:

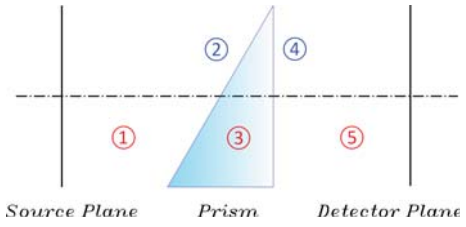

Fig. 1 *Illustration of a dispersive prism system.*

1. Propagation from source plane to first surface of prism (propagation process)

2. Field pass though the first surface of prism (interface process)

3. Propagation inside prism, from first surface to second surface of prism (propagation process)

4. Field pass though the second surface of prism (interface process)

5. Propagation from second surface to detector plane (propagation process)

Until now, the modeling of prism system is simplified into the simulation of two processes, propagation process and interface process. In detailed, for different processes we can apply different field tracing techniques:

Propagation process:

(1) Geometric field tracing: geometric propagation operator

(2) Diffractive field tracing: SPW operator [2] + field rotation operator

Interface process:

(1) Geometric field tracing: geometric interface operator

(2) Diffractive field tracing: diffractive interface operator

3 Simulation and results

In this section, with different modeling approaches we test three kinds of prisms: disperive prism, reflective prism and polarization prism.

3.1 Dispersive prism

In disperive prism test we use truncate plane wave as input field. Fig. 2 shows the simulation result by ray tacing approach. Then in order to compare geometric field tracing and diffractive field tracing, we prepare two kinds of truncate plane wave as input field, Fig. 3 and Fig. 4.

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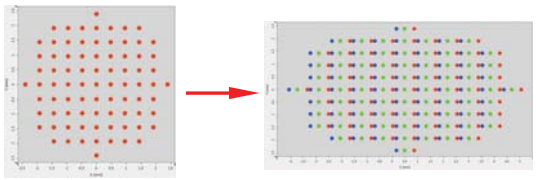


(a) Dot diagram on source plane (b) Dot diagram on detector plane

Fig. 2 *Dispersive prism simulation by ray tracing*

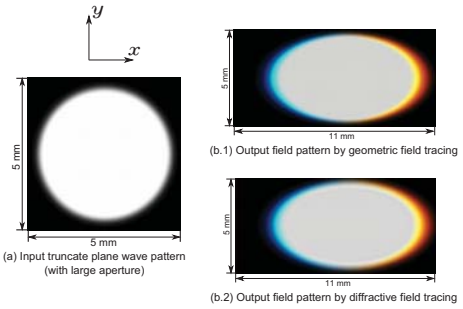


Fig. 3 *Dispersive prism simulation by field tracing. Test 1, truncate plane wave with large aperture*

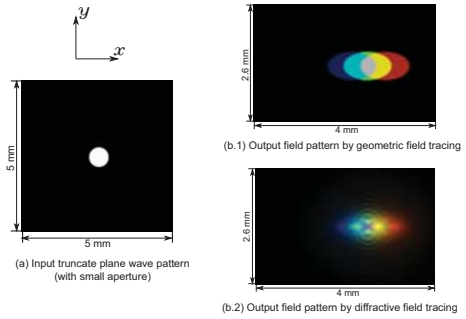
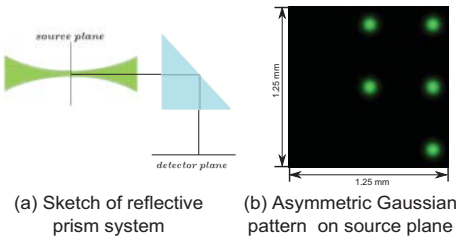


Fig. 4 *Dispersive prism simulation by field tracing. Test 2, truncate plane wave with small aperture*

With ray tracing we can't get any field information. Then in large aperture truncate plane wave test, geometric field tracing has same performance as diffractive field tracing. Finally, when the diffraction effect is very strong which can't be neglected, only diffractive field tracing provide accurate result.

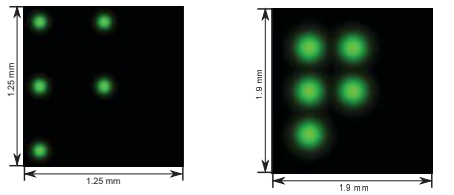
3.2 Reflective prism



(a) Sketch of reflective prism system (b) Asymmetric Gaussian pattern on source plane

Fig. 5 *Sketch of reflective prism system and input field pattern*

In reflective prism test, we use asymmetric Gaussian beams pattern as input and simulate the system by both geometric field tracing and diffractive field tracing.



(a) Output pattern by geometric field tradcing (b) Output pattern by diffractive field tradcing

Fig. 6 *Simulation results of reflective prism*

Fig 6 shows simulation results of reflective prism. Due to the reflection inside prism, mirrored output patterns are obtained. Comparing the results by both approaches, we can find geometric field tracing can't handle the diffraction effect in propagation process.

3.3 Polarization prism

At the end, we simulate the polarization prism. This type of prism is used to seperate different polarized field. In this task, we used interface operator to model a multi-layer coating, whose transmitance is 0 for TM mode and about 99 % for TE mode. In Fig. 7 we show the simulation results.

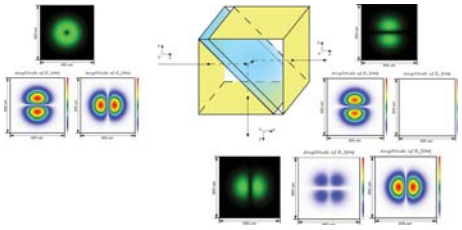


Fig. 7 *Simulation of polarization prism*

4 Conclusion

In this paper, we discuss three simulation approaches for the modeling of optical prisms. With famous ray tracing approach, we can obtain enough information of ray: position, direction and optical path length(OPL). However, there is no more field information. So if the users expect more information of field, they must consider to use field tracing approaches. In detailed, if the diffraction effect is predominated in optical process, only diffractive field tracing can be used for rigorous modeling of optical prism.

References

[1] F. Wyrowski and M. Kuhn, "Introduction to field tracing," Journal of Modern Optics **58**(5-6), 449–466 (2011).

[2] D. Asoubar, S. Zhang, F. Wyrowski, and M. Kuhn, "Efficient semi-analytical propagation techniques for electromagnetic fields," J. Opt. Soc. Am. A **31**(3), 591–602 (2014).