Mode defletion in lithium niobate waveguide via elecctro-optic effect and its application for beam smoothing

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***Abstract*—In this paper, we establish a straight waveguide model which is made of electro-optic material: lithium niobate. The refractive index profile of the waveguide can be slightly electro-optically manipulated, so that the optical mode can be deflected and reshaped in the transmitted direction of waveguide. When the mode deflection can be modulated via the high speed electro-optic effect, the temporally and spatially beam smoothing can be potentially achieved for the application of inertial confinement fusion system.**

I. INTRODUCTION

One of the key requirements in high power laser drivers used for inertial confinement fusion (ICF) system is beam smoothing in the target surface. Nowadays, the widely used technology is smoothing by spectral dispersion (SSD) [1]. The light source is a broadband light which is produced by electro-optic phase modulation and dispersed by grating [2]. The light beam will dither in a small range, and the light spot will quickly move in the focal plane. So it produces a beam smoothing effect in the average time. However, when a broadband light source is produced by sinusoidal frequency-modulation, the beam smoothing effect of smoothing by spectral dispersion is not obvious. Various methods and proposals have been suggested to surmount this issues [1,2]. In this paper, we propose a novel theoretical model to demonstrate the mode deflection. An optical waveguide is inserted to connect the end-fire of the light source which can replace the role of SSD. The optical waveguide is made of electro-optic material: lithium niobate (LN). The high-speed electro-optic modulation causes that the intensity profile of output light is modulated by a high speed, so the light beam will be deflected to realize beam smoothing in the target surface of ICF system.

II. THEORY ANALYSIS

A. The scheme of waveguide

The scheme is composed by a LN waveguide which was installed to replace the SSD as displayed in Fig. 1. Through the electro-optic effect of the LN waveguide, the mode deflection in the transmitted direction can be achieved through the refractive index shaping. The refractive index distribution can be manipulated slightly via the electrodes configuration, for instance, the asymmetric or interdigital electrodes structures.

B. Optical waveguides of lithium niobate

Lithium niobate is extensively used materials in optical communication, as it possesses large electro-optic coefficient. The most popular approaches to fabricate the LN optical waveguide are annealed proton exchange (APE) or ion doped method such as titanium in-diffusion [3].

III. MODEL AND SIMULATED RESULTS

Fig. 1 is the waveguide model. The operating wavelength λ is of 1.064μm, the width of substrate and refractive index of LN substrate are 75μm and 2.156 respectively, the width of waveguide is of 7μm, the height of waveguide and substrate are both of 2.5μm, and the waveguide and substrate length are both of 1cm. The first 0.5cm is used for the coupling between the light source and the LN waveguide, the remaining 0.5cm which is installed laterally with asymmetric electrodes structure can slightly reshape the refractive index distribution as shown in Fig. 2, Fig. 3 and Fig. 4. The refractive index of APE waveguide is of 2.161 in the first part of the waveguide. The remaining part of the waveguide has three different kinds of refractive index profiles. Fig. 2 shows the constant refractive index profile which signifies the straight APE waveguide has no electrodes installed, Fig. 3 and Fig. 4 show that the refractive index profile can be linearly changed and parabolically changed respectively through the electro-optic effect of LN waveguide with specific electrodes configurations.

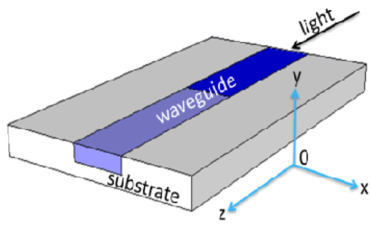

Fig. 1. Theoretical waveguide model

The algorithm we use is beam propagation method (BPM) which embedded in the simulation software Rsoft. BPM is the widely used propagation technique for modeling integrated and fiber-optic photonic devices.

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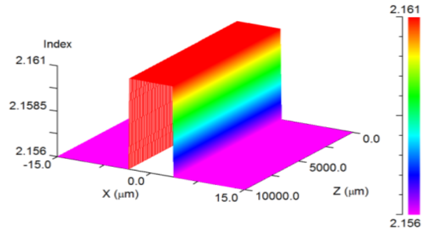

Fig. 2. Constant refractive index profile

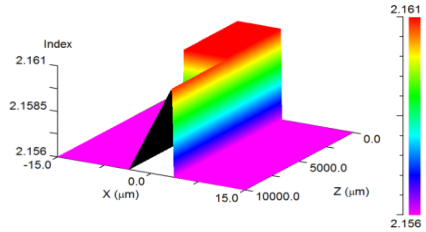

Fig. 3. Refractive index profile linearly changes.

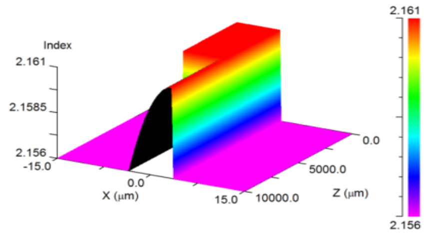

Fig. 4. Refractive index profile parabolically changes.

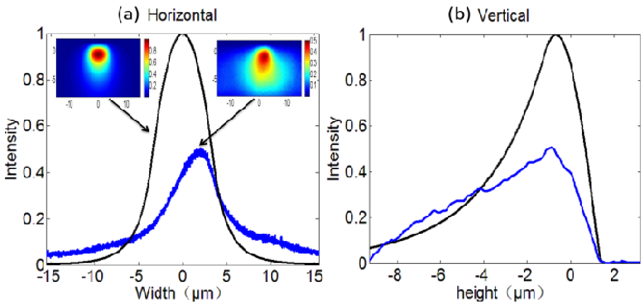

Fig. 5. (a) Optical mode profile and its horizontal cross setion with refractive index changes linearly. (b) Vertical cross setion of optical mode with refractive index changes linearly.

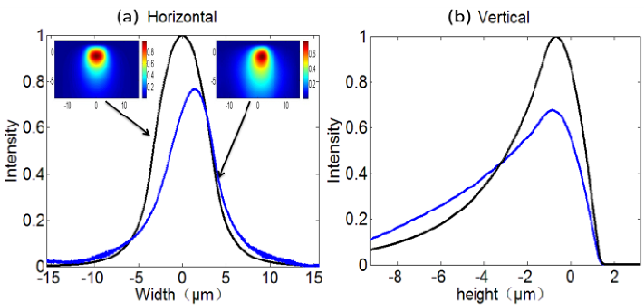

Fig. 6. (a) Optical mode profile and its horizontal cross setion with refractive index changes parabolically. (b) Vertical cross setion of optical mode with refractive index changes parabolically.

Fig. 5(a) represents the horizontal cross section of the optical mode in the end-fire of waveguide with refractive index distribution as Fig. 3, the insets represent the profile of the optical mode. The blue line and the black line correspond to the Fig. 3 with refractive index linearly changed and Fig. 2 with constant refractive index respectively. A horizontal mode deflection of ~2µm is obtained. Fig. 5(b) represents the vertical cross section of optical mode. The difference between them is that a vertical deflection of 0.28µm can be realized. Similarly, Fig. 6(a) represents the horizontal cross section of the optical mode as the refractive index changes according to Fig. 4. A horizontal mode deflection of ~1.49µm and a vertical deflection of 0.15µm are obtained. According to the simulation results, the slight different refractive index manipulation of LN waveguide can deflect the optical mode profile both in horizontal and vertical direction. These mode deflections can be modulated by the high speed electro-optic effect, the beam smoothing in average time can be potentially achieved for the application in ICF system.

IV. Conclusions

In summarize, through the simulated results, we observe that the slight linearly and parabolically change of refractive index distribution of the LN waveguide can deflect the optical mode both in horizontal and vertical direction, the mode deflection scale depends on the shape and the difference of refractive index distribution which can be manipulated through the electro-optic effect of a LN waveguide with specific electrode configuration. The simulation results can be exploited to the beam smoothing for the application of ICF system.

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