Simulation of mode deflection and reshaping in lithium niobate planar waveguide with serrated array electrodes

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***Abstract*—In this paper, we establish a lithium niobate (LN) thin film planar waveguide model with serrated array electrode configuration to reshape the optical mode. The refractive index profile of the waveguide can be slightly electro-optically manipulated, so the optical beam can be deflected and reshaped in the transmitted direction of waveguide. When the beam deflection can be modulated via the high speed electro-optic effect of LN, the temporally and spatially beam smoothing can be potentially achieved for the application of inertial confinement fusion system.**

I. Introduction

One of the vital requirements in ultrahigh power laser drivers used for inertial confinement fusion (ICF) system is beam smoothing in the target surface. Nowadays, the widely utilized technology is smoothing by spectral dispersion (SSD) [1]. However, when a broadband light source is produced by sinusoidal frequency-modulation, the beam smoothing effect of SSD is not obvious. Various methods and proposals have been suggested for optical mode deflection to surmount this issue [1, 2]. In this paper, we propose a novel theoretical model to demonstrate the deflection and reshaping of optical mode. An optical planar waveguide with serrated array electrodes configuration is inserted to connect the end-fire of the light source, which can play the role as SSD. The optical waveguide is made of electro-optic material: lithium niobate (LN) thin film. 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.

II. Theory Analysis

A. Optical planar waveguides of lithium niobate

Lithium niobate is extensively used materials in optical communication, as it possesses large electro-optic coefficient. Fig. 1 is a LN planar waveguide with metal electrode [3]. The thickness of the LN thin film is about 0.6μm, and the orientation is z-cut. A metal electrode layer (Au) between the SiO_2 layer and the LN substrate is inserted by deposition. An electric field can be applied on the LN thin film between this metal electrode layer and a top electrode layer. SiO_2 can act as optical insulation layer. This structure is used to produce high-speed modulators or high-efficiency electro-optic tunable nonlinear optical devices or ferroelectric memories.

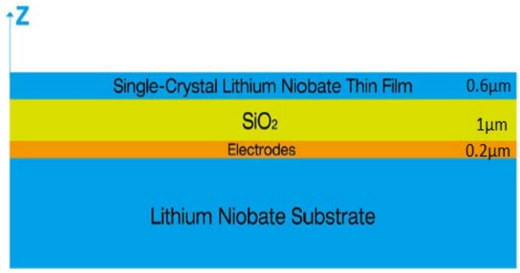

Fig. 1. LN planar waveguide with metal electrode

B. The scheme of waveguide

The scheme is mainly composed by a LN planar waveguide as displayed in Fig. 2. Through the electro-optic effect of the LN waveguide, the beam deflection and reshaping in the transmitted direction can be achieved through the refractive index shaping. The refractive index distribution can be manipulated slightly via the electrodes configuration. In this paper, the electrode configuration is serrated array.

III. Model and Simulated Results

Fig. 2 is the waveguide model. The operating wavelength λ is of 1.064μm, the width of the planar waveguide is 50μm, the thickness and the refractive index of LN substrate are 1μm and 2.156 respectively, the electrode layer between SiO_2 layer and LN substrate is set as ground, and the thickness of the electrode layer is of 0.2μm, the thickness and the refractive index of SiO_2 layer are 1μm and 1.40 respectively, the thickness and the refractive index of LN thin film are 0.6μm and 2.156 respectively. In fig. 2, a metal (Au) serrated array with 25 periods is imprinted in the top electrode layer, the lateral extend of serrated array is 50μm, the longitudinal pitch of a serrated pattern is 60μm. An electric field can be applied on the LN thin film between the ground electrode layer and the top electrode layer.

The refractive index profile of in LN waveguide bellow the serrated array can be changed through the electro-optic effect. With applying different operating voltages to the top electrode layer, it can cause different refractive index profiles, which acts as prism array for refractive index distribution of LN planar waveguide to deflect the optical beam, and it makes different optical mode profiles in the end-fire of waveguide as Fig. 3.

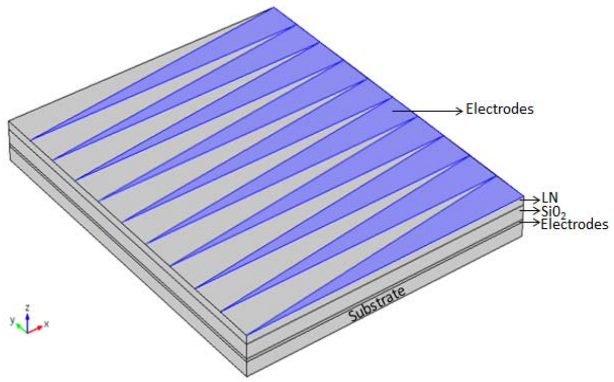

Fig. 2. Theoretical waveguide model with serrated array electrodes

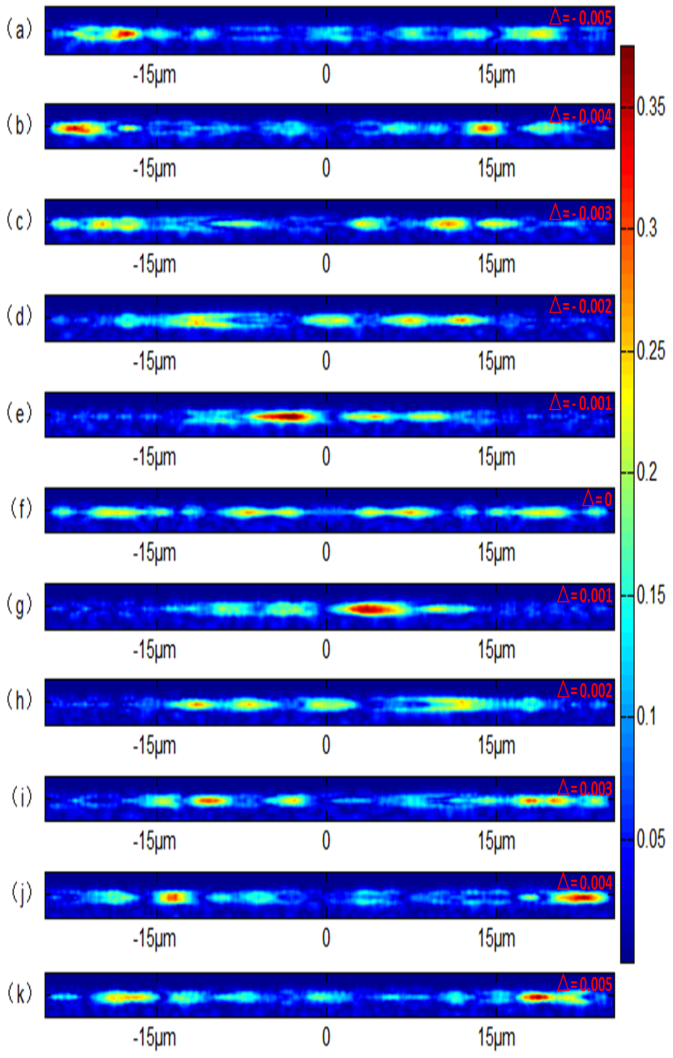

Fig. 3. Optical mode profile in output of LN waveguide when refractive index changes (a) -0.005; (b) -0.004; (c) -0.003; (d) -0.002; (e) -0.001; (f) 0 (no applied voltage); (g) 0.001; (h) 0.002; (i) 0.003; (j) 0.004; (k) 0.005.

The algorithm we use is beam propagation method (BPM) which embedded in the simulation software Rsoft [4]. BPM is the widely used propagation technique for modeling integrated and fiber-optic photonic devices.

Fig. 3(f) represents the optical mode profile before applying a voltage to the serrated array electrodes, and the refractive index profile is constant. Fig. 3(a), (b), (c), (d), (e), (g), (h), (i), (k) represent the optical mode profiles in the end-fire of waveguide. The difference between them is that different refractive index profile of LN waveguide bellow serrated array can be realized. Fig. 3(a), (b), (c), (d), (e), (g), (h), (i), (k) represent the optical mode profile when the refractive index of LN waveguide bellow the serrated array changes -0.005, -0.004, -0.003, -0.002, -0.001, 0.001, 0.002, 0.003, 0.004 and 0.005 respectively.

According to the simulation results, the different refractive index manipulation of LN planar waveguide can make the optical beam have different reshaping. Since in this configuration, the distanced electrodes is less than 2μm, the high speed electro-optic effect of LN waveguide is more important and sensible, hence, this makes the driving voltage of mode deflection and reshaping lower, 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 different refractive index manipulation of LN planar waveguide can make the optical beam have different reshaping. The beam deflection scale depends on the difference of refractive index distribution which can be manipulated through the electro-optic effect of a LN planar waveguide with serrated array electrode configuration. The simulation results can be exploited to the beam smoothing for the application of ICF system.

Acknowledgment

This work is supported by the National Natural Science Foundation of China (No. 61177075; No. 61008057; No. 11004086; No. 61475066; No. 61405075), the National Major Special Project of China (22104001), the Fundamental Research Funds for the Central Universities of China (No. 21614313; No. 21613325; No. 21613405); and the Natural Science Foundation of Guangdong (No. 2014A030313377).

References

[1] S. Skupsky, R. W. Short, T. Kessler, et al. “Improved laser-beam uniformity using the angular dispersion of frequency-modulated light”, J. Appl. Phys., vol. 66, pp. 3456-3462, 1989

[2] S. Zhou, Z. Lin, X. Jiang, “Beam smoothing by lens array with spectral dispersion”, Optics communications, vol. 272, pp. 186-191, 2007

[3] http://www.nanoln.com/product/lnoi-with-metal-electrode-ii

[4] RSoft Design Group, lnc. BeamPROP 8.2, Ossining, NY 10562 USA, 2010