2D tunable graded index prism beam steering device based on nematic liquid crystals

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INTRODUCTION

Liquid crystal devices are being used in many non-display applications in order to construct small devices controlled by low voltage electronics without mechanical components.

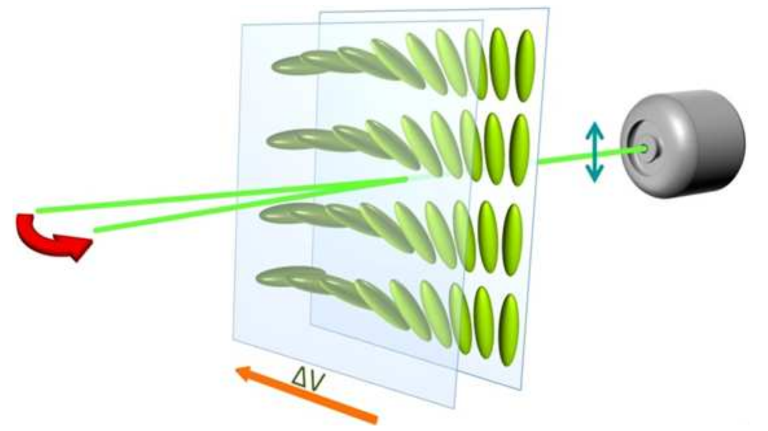

Fig 1: Liquid crystal graded profile and laser beam deviation

In this work, we present a novel liquid crystal device for laser beam steering. In this device the orientation of the liquid crystal molecules can be controlled. A change in the liquid crystal orientation results in a change of the refractive index. When a laser beam passes through the device, the beam will be deviated (Fig.1) and the device works a prism.

The main difference between this device and a prism is that in the device the orientation profile of the liquid crystal molecules can be modified so that the laser beam can be deviated a required angle: the device is tuneable.

1. THE DEVICE

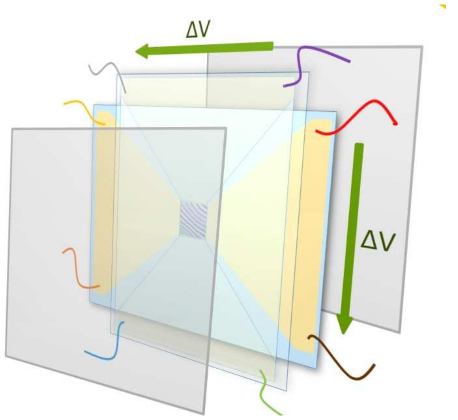

Fig 2: Scheme of the finished device

1.1 Manufacturing

The device consists of two patterned Indium-Tin Oxide (ITO) coated glass plates assembled in a sandwich-like cell filled with a nematic liquid crystal.

The pattern is made up of high density (in the order of hundreds) transparent conductive ITO electrodes. The high resolution area is covered with a high resistivity coating (PEDOT), so interference problems are avoided.

Antiparallel homogeneous alignment is conditioned with rubbed nylon. Several cell thicknesses where tested.

Although large steering angles can be obtained when thickness is high, the performance of the device becomes slower. The choosen cell thickness was 30µm, where good steering angles are obtained as well as good rise times. Thicker cells were also tested (60 and 150µm).

Aligning the switching plane with the polarization plane of the incoming laser light, the LC orientation profile will deviate the laser beam towards the desired direction (Fig 2).

1.2 Performance

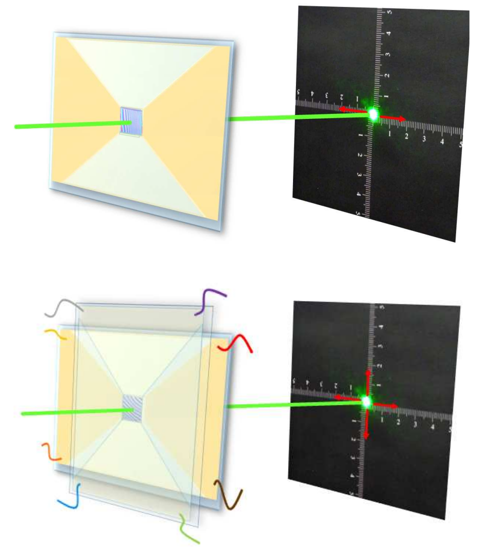

Fig 3: The device using a single glass plate (top), two glass plates (bottom).

A voltage gradient on the substrates generates a graded switching profile in the LC across the cell, and hence a graded refractive index profile.

The profile becomes visible by placing the sample between crossed polarizers and visualizing the pattern interference colors. Liquid crystal orientation profiles are seen between crossed polarizers (at ±45º).

In the laser beam steering setup only one polarizer is employed. The position of the ground voltage can be shifted along the plate so that the prism can be shaped differently, therefore obtaining a range of deviation angles.

If the device is manufactured with one patterned electrode and a backplane, it shows a beam deflection across one axis.

When two glass plates are patterned and aligned perpendicularly to each other, the beam steering may work in 2D (Fig 3).

2. 2D LASER BEAM STEERING RESULTS

A range of different voltage gradients will result in a set of colored interference patterns to the device (Fig 4). When applying a gradient in a horizontal direction, a pattern of vertical bands will become visible and the laser beam will be deviated in the horizontal and vice versa.

Fig 4. shows the different patterns that were obtained. Measured angles for the 30 µm working devices are about $\gamma \approx 0.25^{\circ}$ for each direction, i.e. $\gamma \approx 0.5^{\circ}$ in the whole range. 150 µm thick device are able to steer larger angles: $\gamma \approx 0.9^{\circ}$ for each direction, i.e. $\gamma \approx 1.8^{\circ}$ in the whole range.

One of the most appealing features of this device is that not only the laser beam can be deviated in horizontal or vertical directions but also that combining several voltage gradients different diagonal patterns can be also obtained. The figure also shows the laser beam deviations depending on the voltage gradient applied in each case.

An improvement for the future would be modifying the pixelated structure, that will also allow for adding more electrodes which would make the switching profile tunable, which means the device could be employed as a lens as well.

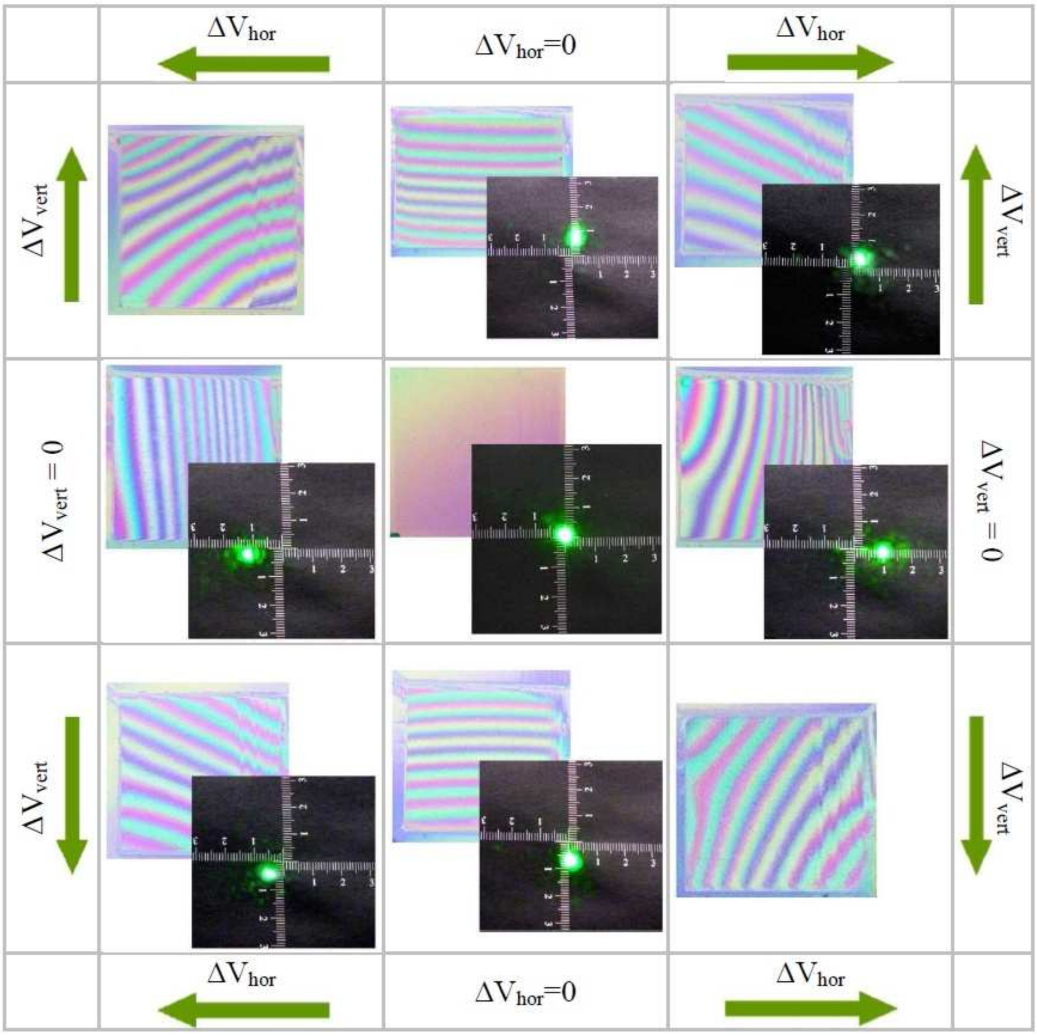

Fig 4: Liquid crystal orientation profiles and laser beam deviations for a 30 µm thick device

3. APPLICATIONS

The device offers a high accurate control of the laser beam angle in two dimensions with low voltages (~10 V). Since it is an analog device, the maximum angular resolution achievable is only limited by the electronics. It has the great advantage of being all-electro-optical instead of the mechanical FSM, frequently used for fine pointing.

The device will also allow the addition of a tunable lens function, so that the beam-divergence control can be integrated with the fine pointing, being the system a fully non-mechanical one. Such a device has a great potential in space applications and will be demonstrated within this project to test its capability within an actual free-space communication system or also an adapted device to be employed in a sun tracking system for solar cells in the solar energy industry.

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