Transmissive Polymer Network Liquid Crystal Phased Array antenna at Short-wave Infrared Band

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Abstract—**The polymer network liquid crystal (PNLC) with fast response time and large phase modulation is attractive for many photonic applications, such as free space optical communication system and laser radar system. Except for the beam steering precision and optical beam steering range, the response time is one of the key parameters of the free space optical communication system. In this paper, the transmissive polymer network liquid crystal optical phased array antenna (PNLC-OPAA) at short-wave infrared band is designed, fabricated, and demonstrated. The beam steering ability and the response time of this transmissive polymer network liquid crystal optical phased array antenna is tested with 1064nm laser. The experiment results show that the response time of the transmissive polymer network liquid crystal optical phased array antenna is less than 800μs with $V_{2\pi}$ voltages lower than 40V.**

I. INTRODUCTION

Liquid crystal optical phased array antenna（LC-OPAA）can be used to form and steer the laser beam of the free space optical communication system and laser radar system. With the rapid development of the free space optical communication technology, the free space optical communication system needs to use non-mechanical devices with less inertial and higher optical beam steering precision, such as optical phased array antenna. In the developing free space optical communication network, the free space optical communication link also needs to solve the multiple access technologies with optical phased array antenna [1]-[3].

In the paper [3], the Air Force Research Laboratory reported the space-time division multiple access network with LC-OPAA in the free space laser communication to lower the cost, size, weight, and the power consumption of per user in 2012. Paper [3] designed and built an experimental terminal with LC-OPAA, and the demonstrating results show that the response time of the LC-OPAA is a very important parameter for the free space communication system. Among various LC technologies explored such as ferroelectric LC, dual frequency liquid crystal (DFLC), and polymer network liquid crystal (PNLC), PNLC technology is attractive for many photonic applications because of its fast response time and large phase modulation[5][6]. Under the support of the Air Force Research Laboratory, Paper [5] reported a low voltage sub-millisecond response PNLC spatial light modulator by employing a large dielectric anisotropy in 2014. In the paper [7], we reported the LC-OPAA with the nematic liquid crystal E7[7]. The response time of the OPAA is higher than 10ms, which does not satisfy the needs of the response time in the free space optical communication system. In this paper, we design and fabricate the transmissive OPAA with PNLC (named as PNLC-OPAA) for Short-wave infrared band optical communication systems. We also demonstrate the beam steering ability of the PNLC- OPAA with Nd:YAG 1.06um laser, and measured the response time of the PNLC-OPAA.

II. DESIGN AND FABRICATION

The general conceptual sketch of the PNLC-OPAA with two conductive layers is shown in figure 1. The upper conductive layer is lithographically transparent and conductive stripe electrodes with indium-tin-oxide (ITO) on glass. The lower conductive glass-based layer is common ITO electrodes on glass. Between the two conductive layers, the polymer network liquid crystal is filled as the medium of phase modulation. And the PNLC cell is maintained with a few of spherical plastic spacers.

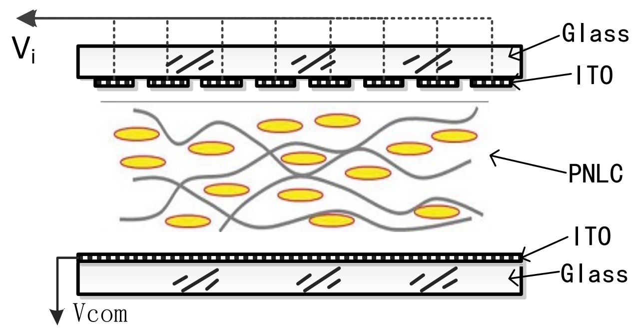

Figure 1. The conceptual sketch of PNLC-OPAA

According to the reported results in the papers [4]-[6], the response time of PNLC-OPAA is related to the strong anchoring effect of polymer network. We studied the response time of the PNLC-OPAA with different LC hosts under different $V_{2\pi}$ voltages and working temperatures at short-wave infrared band. By choosing proper LC host, controlling voltage and specific curing temperature, we fabricate the PNLC-OPAA at Short-wave Infrared Band according to the conceptual sketch of the PNLC-OPAA and the beam forming methods in paper [3]. The module of the PNLC-OPAA is shown in figure 2. The PNLC-OPAA is driven by a COG(chip on glass) driver with 8-bit input and hundreds of output channels.

III. EXPERIMENT RESULTS AND DISCUSSIONS

In order to demonstrate and measure the performance of the PNLC-OPAA, an experiment with two one-dimensional PNLC-OPAAs is setup. And the diagram of the PNLC-OPAA experimental setup is shown in figure. 2. The Nd:YAG laser sends out the single mode 1064nm laser beam, and the beam is polarized by a PBS polarizer, where the direction of optical axis of PNLC-OPA device is parallel to the polarizer. The polarized

1064nm laser beam is phase modulated by two one-dimension PNLC-OPAAs. The output laser beams of the PNLC-OPAAs can be observed by a high resolution charge-coupled device CCD that is perfectly aligned on the focal plane of a front Fourier lens. The CCD is connected with a computer that displays the detected beams by CCD and controls the voltages of the PNLC-OPAAs. Figure 3 shows the laser beam phase controlled by the PNLC-OPAAs on the CCD. The experimental results show that the PNLC-OPAA with proper LC host and controlling voltages can steer the laser beam with high precision. The beam steering precision of the PNLC-OPAAs is evaluated experimentally to be better than 2 urad.

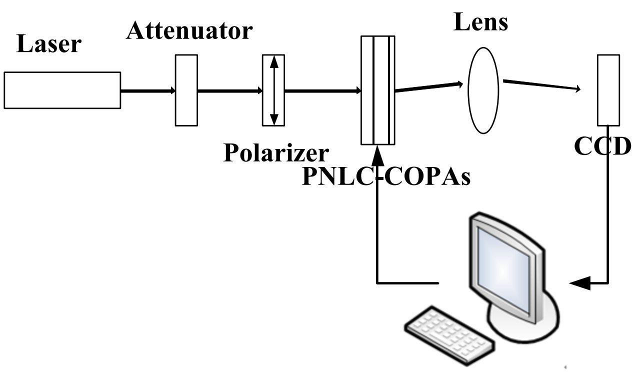

Figure 2. Diagram of experimental setup of LC OPAA

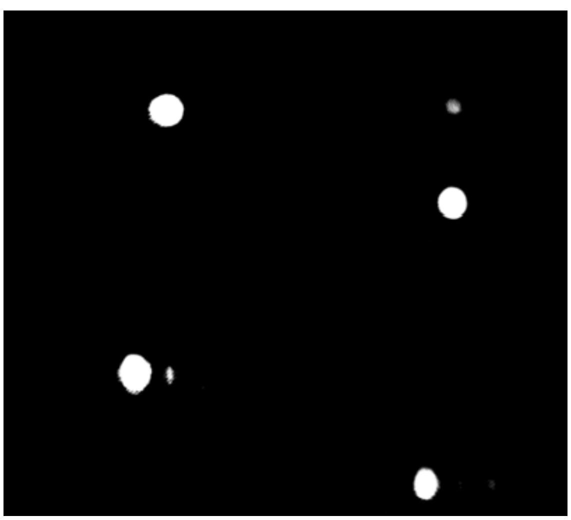

Figure 3. the detected beams phase controlled by the LC-OPAAs on CCD

We also measure the response time of the transmissive PNLC-OPAA replacing the CCD with a photoelectric detector connected with an oscillograph. The response time is measured by the oscillograph. The measured optical decay time is lower than 400 μs and the rise time is lower than 800μs with $V_{2\pi}$ voltages lower than 40V. By optical power meter, the measured optical scattering loss is about 3%. Except for beam steering precision, the experiment response time and optical scattering loss are good agreement with the reported results shown in the paper [4]. The demonstration results also show that the response time and scattering loss can be reduced by selecting the proper LC host, reducing the curing temperature, and reduce the thickness of glass cell, which are good agreement with the newly reported PNLC technologies.

IV. SUMMARY

In this paper, a novel transmissive PNLC-OPAA at short-wave infrared band is designed, fabricated and demonstrated. The demonstrating and measuring results show that the PNLC-OPAA not only has the fast response time, but also phase modulating and steering the optical beams with high precision. The studied PNLC-OPAA in this paper can provide a useful guideline for the optical antenna and no-mechanical acquisition, pointing and tracking subsystem of the free space communication system with OPPA.

V. ACKNOWLEDGMENTS

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