A Lidar System Based on Integrated Lens Assisted Two-dimensional Beam Steering

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Abstract: A Lidar system based on lens assisted two-dimensional beam steering at 1550nm is demonstrated. The Lidar has 19m measurement distance and 4×4 scanning points, indicating the potential of integrated beam steering technology for Lidar applications.

In recent years, light detection and ranging (Lidar) technologies have played a significant role in sensing, autonomous driving, three-dimensional mapping, etc. In a Lidar system, optical beam steering is a key function for distance measurement and angle scanning. Conventional beam steering by mechanically scanning a mirror has limited scanning speed and is vulnerable to environmental perturbation. Therefore, many solid-state beam steering technologies have emerged, among which optical phased arrays (OPAs) have aroused great interest and Lidar based on integrated OPA device has been reported [1]. Meanwhile, lens assisted integrated beam steering technology has also been paid wide attention because it allows much less number of control signals, lower power consumption and digital control, compared to the OPA devices with the same number of antennas emitters [2]. A lens assisted beam steering device consists of an integrated 1xN switch, N emitters and a lens. Incident light is guided to one emitter by the 1xN switch and emitted to the free space. The light in the free space is then collimated and steered by the lens to propagate to different direction. Although a few works of lens assisted beam steering have been reported, a Lidar system based on this technology has not been demonstrated yet.

In this work, we demonstrate a Lidar system based on lens assisted beam steering technology at 1550nm. The Lidar has 19m measurement distance, 4×4 scanning points and 1.05° scanning angle. The system can be easily scaled to more scanning points and larger scanning angle. This proof-of-concept work indicates the potential of lens assisted beam steering technology for solid-state Lidar applications.

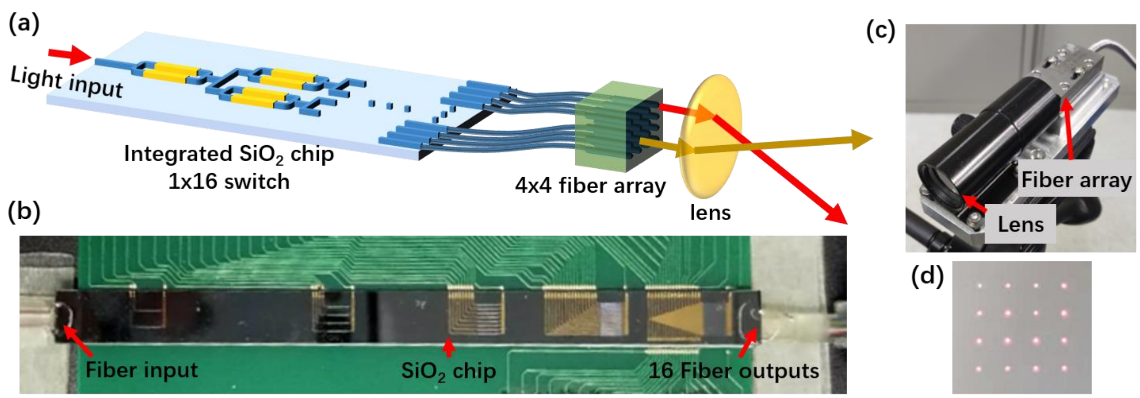

Fig. 1. (a) Beam steering device. (b) Photo of SiO_2 chip as 1×16 switch. (c) Photo of packaged fiber array and lens. (d) Output red light spots on a white paper for illustration.

The structural setup of the beam steering device is shown in Fig. 1(a). The device consists of an integrated SiO_2 1×16 switch chip, a 4×4 fiber array and a lens. The SiO_2 1×16 switch chip is made of cascaded 1×2 Mach-Zehnder interferometer (MZI) switches. It is fabricated by standard planar lightwave circuit (PLC) technology. The 16 outputs of the chip are connected to 4×4 fiber array to convert the 1D waveguide array to 2D array. This fiber array can also be replaced by an integrated chip with 3D waveguides. The lens has a focal length of ~40 mm. The fiber array has a spacing of 0.25 mm between two adjacent fibers. So the beam steering step is 0.35° and the total steering angle is 1.05°. Fig. 1(b) and 1(c) show the photos of SiO_2 chip and packaged fiber array and lens, respectively. The lens is sealed in a lens tube to isolate the scattering light. Fig. 1(d) shows the output red light spots on a white paper when a red laser is injected to the beam steering device. This figure is for illustration purpose and the device is designed for operation at 1550 nm.

The experimental setup of Lidar system is shown in Fig. 2(a). The whole Lidar system is based on co-axial time-of-flight (ToF) design. A pulsed fiber laser is connected to the beam steering device through a fiber circulator. The pulses from the laser have a repetition rate of 20 kHz and a peak power of ~1.7 kW. The laser pulses are emitted to the free space by the beam steering device. The returning light after reaching a target (a white A4 paper) is also collected by the beam steering device. Then the returning light is extracted by the same circulator and enters an acoustic-optic modulator (AOM) and an amplified photodetector. The interface of uncoated fiber array and air will result in a 4% reflection. The peak power of the reflected pulses is high enough to saturate the amplified photodetector. Therefore, a synchronized notch pulse (negative pulse) is generated by the AOM to suppress the reflected pulses. Fig. 2(b) shows a typical output waveform of the photodetector when a target is placed at 10.5 m distance. The 100-ns wide AOM suppression window and suppressed reflected pulse (by fiber/air interface) can be clearly seen. This suppressed pulse is also utilized as a time reference. The returning pulse from the target is marked by an arrow in the figure. The DC background is the amplified spontaneous emission (ASE) noise from the laser. Fig. 2(c) summarizes the measured time delays of the returning pulses with respect to different target distances. The linear relation can be clearly seen. The maximum measured target distance is 19.5 m.

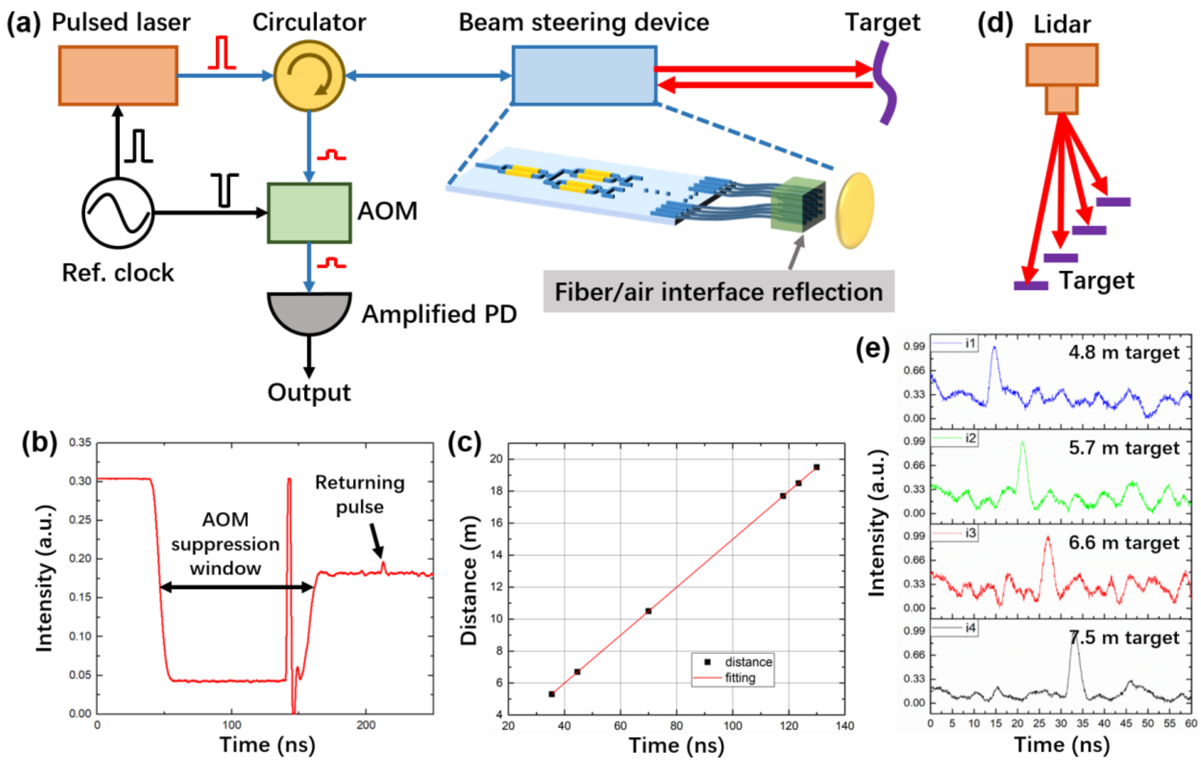

Fig. 2. (a) Setup of Lidar system. (b) Typical output waveform of the photodetector. (c) Time delays of returning pulses with respect to target distances. (d) Setup for Lidar scanning test. (e) Four returning pulses at four different target distances and angles.

Furthermore, in order to verify the beam steering function of the Lidar system, four targets are placed horizontally in the distance from 4.8 m to 7.5 m with an interval of ~0.9 m, as illustrated in Fig. 2(d). By switching the laser pulses to different emitters on the SiO_2 1×16 switch chip, different steering angles are achieved. The measured returning pulses are shown in Fig. 2(e). Similar experiment is also performed when the four targets are placed vertically, which confirms the 2D beam steering function of the Lidar system.

In conclusion, a solid-state Lidar system is demonstrated at 1550nm. The Lidar system is based on a lens assisted 2D beam steering device consisted of a SiO_2 switch chip, a fiber array for 1D to 2D conversion and a lens. The Lidar has a maximum measurement distance of 19.5 m, 4×4 scanning points and a scanning angle of 1.05°. The scanning points and angle can be easily scaled to large number. The fiber array can also be replaced by an integrated chip with 3D waveguides. This work proves the potential of lens assisted 2D beam steering for Lidar applications and paves the way for a fully integrated Lidar system.

[1] C. V. Poulton, A. Yaacobi, D. B. Cole, et al., "Coherent solid-state LIDAR with silicon photonic optical phased arrays," Opt. Lett. 42, 4091-4094 (2017).
[2] Chao Li, Xianyi Cao, Kan Wu, et al., "Lens-based integrated 2D beam-steering device with defocusing approach and broadband pulse operation for Lidar application," Opt. Express 27, 32970-32983 (2019).