LiDAR Beamsteering by Digitally Switched MEMS Gratings on a Silicon Photonics Platform

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Abstract: A new method for solid-state beamsteering using MEMS grating switches integrated on a Si-PIC has been demonstrated. This method provides fast random access switching, simple digital control, extremely low side-lobes, and is scalable to large arrays, large apertures, and long ranges.

OCIS codes: (250.5300) Photonic integrated circuits; (230.4685) Optical microelectromechanical devices; (280.3640) Lidar

1. Introduction

There has been significant interest in methods for solid-state beamsteering for LiDAR applications, and other applications such as optical communication and remote sensing. Two technologies that have received much of this interest are MEMS mirrors and optical phased-arrays (OPA). However, both of these technologies have significant shortcomings. For example, MEMS mirrors are limited in aperture size and scanning speed, and OPAs are very challenging to implement due to the large number of active, analog phase controllers required. Described and demonstrated here is an alternative method for solid-state beamsteering. All-digital control makes this method simpler to implement than an OPA, and is compatible with large optical apertures and fast random access scanning. The method is based on a silicon photonic integrated circuit (Si-PIC) with a new type of MEMS switch.

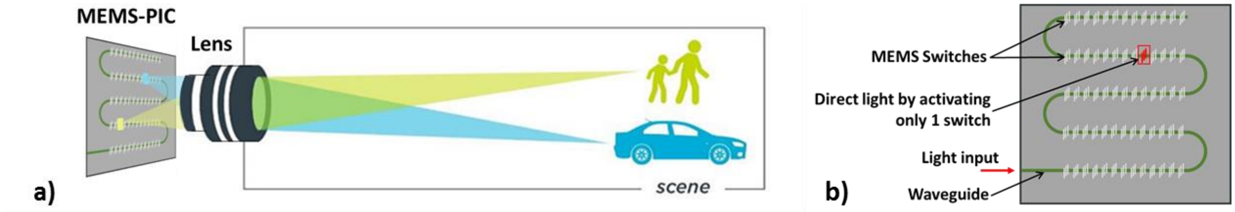

Fig. 1. a) Overview of the beam scanning method. Note that the two beams shown are sequential and not illuminated at the same time. b) An overview of the MEMS-PIC device.

2. Design Description

An overview of the method is shown in Fig. 1. The MEMS-PIC is placed in the focal plane of a lens in typical camera configuration. A laser source is coupled to the MEMS-PIC which directs the light around and out of the MEMS-PIC through a series of switches. After emerging from the MEMS-PIC, the lens focuses the light onto the scene. The direction of the beam out of the lens corresponds to the spot on the MEMS-PIC from which the light emerged [1]. Note that the device can also function similarly, in reverse, to work as a receiver. (Also note, that unlike an OPA, light is only emerging from one location on the chip, and the phase of the light does not matter).

Fig 1b shows how the MEMS-PIC works in more detail. In the current implementation, light follows a serpentine path around the chip. This path is implemented in a silicon nitride waveguide. Along the path are MEMS switchable gratings, that either allow light to pass, or eject light from the waveguide. This grating switch is an essential part of the technology, because its compact size allows a high density of pixels when compared to other types of switches [1] [2]. These other types of switches could, in the future, be added to partition the chip into separate selectable paths, to enable large arrays without prohibitively long path lengths.

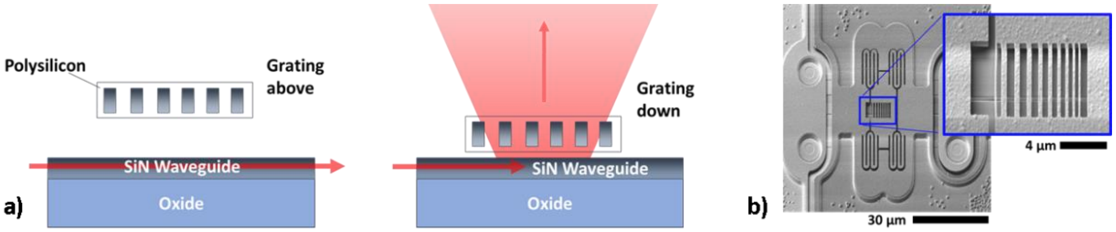

Fig. 2. a) Sketch of mechanism of the MEMS grating switch. b) SEM image of a completed grating switch.

Fig. 2a shows a sketch detailing the function of the grating switch. In the off position, the grating switch is suspended above the waveguide, with enough gap that the light in the waveguide does not interact with the grating. In the on position, the grating is pulled-down, such that the grating interacts with the evanescent field of the waveguide. Physical stops assure the grating is in the correct position relative to the waveguide. Gratings with efficiencies of 80% have been designed, fabricated, and tested. The binary operation of this switch, assures reliable operation of the switch with simple digital control.

Fig. 3. a) Image of light emitted from grating switch when the first switch in the path is on, and b) when the 70th switch in the path is on. Even at this high gain setting, with the camera clearly saturating, there is no background visible on this scale. c) LiDAR data of donut test object and the wall beyond it. The field of view is approximately 1°.

3. Test Device and Results

For a proof-of-concept demonstration, a small scale array of 10 x 10 elements was fabricated. This array was designed for operation at wavelengths near 1550 nm, but it is possible to implement an array that operates at shorter wavelengths, such as 905 nm, with the same materials. Fig. 2b shows a SEM image of a completed grating switch. Figs. 3a and 3b shows a microscope image of the light emerging from the first grating switch and another grating switch when actuated. There are some differences in brightness due to waveguide propagation losses, but both switches provide strong signal, and no background signal is visible in these images. Greater than 30 dB of difference has been measured between the intensity of light from the grating when on, compared to the brightest spot from randomly scattered light from the waveguide when all gratings are off. Although switching speeds have not yet been characterized, switching speeds of 1 µs should be possible based both on resonant frequency measurements, and results in somewhat similar devices [2].

A LiDAR demonstration was completed with this array as the transmitter and a lens focusing onto a single single-photon avalanche diode (SPAD) as the receiver. This bistatic arrangement with a single small detector limits the receiver aperture to a very small size (~1.3 mm diameter). Fig. 3c shows the point-cloud data from a donut shaped target at a range of 12.5 m, and the wall beyond the target at 15 m. A future system could operate at 905 nm, to use one of a number of detector array technologies currently available, (SPAD or SiPM, for example). Other possible receiver options are a monostatic arrangement or using a second similar chip and lens for the receiver. This second set of receiver options are ideally suited for coherent or FMCW LiDAR systems. Any of these options will allow a much larger receiver aperture, which will enable a larger field of view, and will increase the range possible beyond 200 m.

References

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