Flexible and Highly Scalable LiDAR for an FMCW LiDAR PIC based on Grating Couplers

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Abstract -

In this paper three types of Silicon Photonics OPA architectures are proposed and investigated. Edge-fire optical phased array, that simplifies the design of the OPA. Second architecture is OPA with grating coupler antennas. Maximum steering angle for edge-fire OPA is ±44° ,FWHM is 0.10986°. For GC OPA steering angle is ±20° and FWHM=1.003116°. Third architecture is the Slanted Grating Coupler with a FOV of 100°.

1 Introduction

The development of the Photonic Integrated Circuits (PIC) make promising technologies become available. One of these promising technologies is the LiDAR onchip for high precision distance measurement [1]. The advantages of making the LiDAR onchip are the smaller footprint and the large scale fabrication capacity which leads to the reduction of manufacturing cost per system. In this paper, three types of OPAs where investigated: edge-fire emitters; emitters with grating coupler (GC) antennas and slanted grating coupler antennas. The schematics of system architectures are shown in Fig. 1. The systems have been simulated for the telecom wavelength for Silicon on Insulator platform.

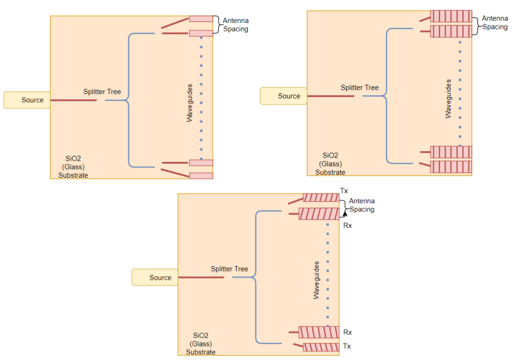

Figure 1. a) Edge-fre system; b) Grating Coupler System; c) Slanted Grating Coupler System

2 System description and simulation results

2.1 Edge-fire Optical Phased Array

One of the OPA architectures is to use waveguides. The light is coupled into the input grating coupler. A star coupler or MMI power splitting tree is used to evenly distribute the light into the waveguide channels [2]. This is shown in Fig. 1 (a). The advantage of this architecture is that the emitters can be substantially smaller than for example grating coupler, and can be spaced at $\lambda/2$ and hence achieving narrower FWHM. When spacing is greater than λ, the grating lobes will appear in the beam pattern and can limit the steering range [3]. Free steering range of the OPA is also determined by the antenna spacing Eq. 1.

$$FOV = 2\sin^{-1}\frac{\lambda}{2d} \tag{1}$$

Far field pattern from the edge-fire OPA is shown in Fig 2. The manufacturing errors in the emitters that add phase perturbation to far field pattern are also taken into account. [4]

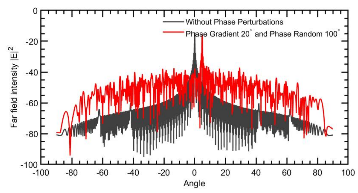

Figure 2. Simulated OPA far field pattern for edge-fire emitters; black) far field Intensity without random phase and phase gradient; red) far field with steering for random phase and a phase gradient of 20°.

2.2 Grating Coupler Antenna

The second architecture uses grating couplers (GCs) instead of the waveguides (Fig. 1 (b)). Due to the periodic structure of the GCs the light diffracts from the grating teeth (diffraction grating) and constructively interfere towards the direction of the propagation. The propagation angle can be changed by tuning the period of the grating teeth.

In Fig. 3 far field pattern a) and the steering capabilities b) of the proposed OPA are also being simulated for number of elements 1000.

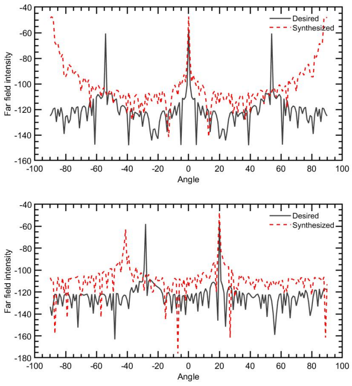

Figure 3. a) Farfield desired vs synthesised; b) Steering range.

2.3 Slanted Grating Coupler Antenna

The advantage to use GC antennas (Fig. 1 (c)) is that elements radiate into the zenith plane, providing an opportunity to make a compact model where transceiver and receiver parts of the LiDAR system can be used on one chip. One of these compact model concepts is to use slanted GCs. The schematic of the slanted GC is shown in Fig. 6. The concept relies on transmitting of multiple beams by slanting the grating. The radiation angle will be determined by the slant angle of the GC. The result shows that radiation angle can be shifted up to ±50º by slanting the gratings.

3 Conclusion

Three LiDAR transceiver designs have been investigated, edge-fire and with grating coupler antennas. The FWHM, phase perturbations, steering capabilities and far field patterns have been simulated and characterized for different numbers of emitters. For edge-fire OPA the maximum steering range is ±44° with FWHM of 0.10986° for 1500 number of channels. For GC OPA the simulated steering range is ±20° with FWHM of 1.003116° with 1000 GC antennas, with 50 grating teeth number 50. Resolution can be improved, by spacing the emitters close to each other, by increasing the number of channels, or increasing the grating teeth number on each individual GCs. Random phase distributions both for edge-fire OPA and GC OPA have been simulated. Slanted grating coupler architecture was discussed and the numerical results were

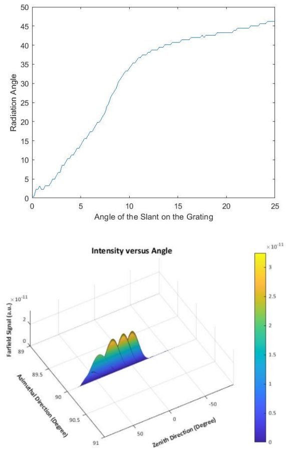

Figure 4. a) Slanted angle vs Radiation Angle; b) Farfield pattern from Slanted Grating Coupler.

shown for a FOV of 100 degrees. The future direction of the research is to fabricate and characterize the OPAs which performs the best and meets the industry requirements.

References

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