

**FREQUENCY RESOLVED ANGULAR MODULATION BEAM STEERING**

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**Introduction**

- Solid-state beam steering is the key component in various applications such as 3D sensing, imaging, and ranging, converging into emerging LiDAR technologies.
- Acousto-optic device based on Brillouin scattering of light by sound wave enables the continuous on-chip beam steering and large emission aperture.
- Acousto-optic beam steering (AOBS) automatically encodes the steering angle in the frequency shift of the steered light beam, achieving the frequency resolved angular modulation.

**Acousto-optic Beam Steering Operation Principles**

- The basic idea of AOBS is the guided optical wave deflected by a moving refractive index grating generated by the guided acoustic waves, where the phase-matching condition is applied, \( n_k \sin \theta = n_0 - \frac{2 \pi}{\lambda} \), as shown in the figures above. Grating couplers are used to couple the freespace light into the guided mode and interdigital transducers (IDT) are used to generate acoustic waves.
- As shown in the right figure, out-of-plane steering angle \( \theta \) can be also described as,
  \[
  \sin \theta = \frac{n_0 - n_0'}{n_0} \frac{\omega}{c} \frac{d}{L} = \frac{n_0 - n_0'}{n_0} \frac{\omega}{c} \frac{d}{L}
  \]
- Due to the energy conservation, the steered beam has an anti-Stoke frequency shift by the acoustic frequency \( \omega_a \), which relates its frequency \( \omega = \omega + \omega_a \) to the steering angle \( \theta \).

**Simulation and Optimization**

- COMSOL Multiphysics is used for the simulation and optimization of the guided optical mode, acoustic mode and AOBS efficiency.
- As shown below, the fundamental Rayleigh mode (R0) and high order transverse electric mode (T1) are applied to maximize the AO scattering efficiency.

**Device Characterization**

- Coupling efficiency of the input grating coupler is characterized by the transmission of a pair of opposite grating couplers.
- Transduction efficiency of the IDT from electromagnetic wave to acoustic wave, is characterized by the reflectance S11.

**Measurement Result**

- Measurement setup is shown in the following figure.
- We demonstrated an integrated frequency resolved angular modulation AOBS device fabricated on LN-on-insulator substrate.
- We achieved an AOBS efficiency as high as 0.1%, resulting in a 2μW output beam power. The steering angle range from -5 deg to 5 deg, with an angular resolution as small as 0.1 deg, resulting in 100 distinguished spots.

**Future Work and References**

- Improving efficiency to 10% by changing the AO material from LN to gallium phosphide, improving the optical grating coupler coupling efficiency and optimizing the IDT design.
- Finishing the LiDAR demonstration.

References:

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2. Qiyu Liu, Huan Li, Mo Li, “Electromechanical Brillouin scattering in integrated optomechanical waveguides”, Optica 6, 778 (2019)