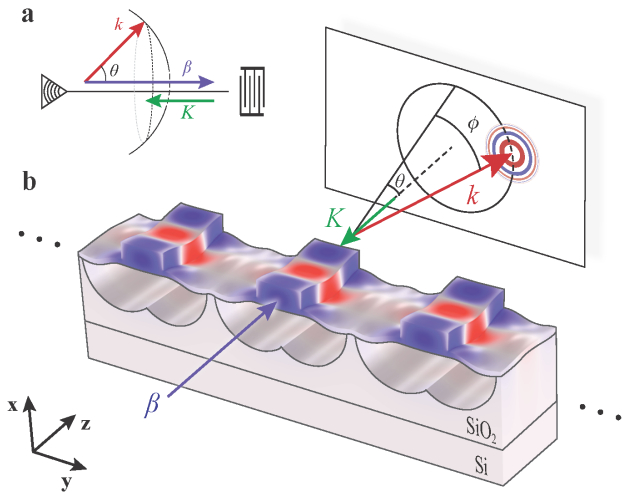
Docket #: S17-178

Low cost, power efficient, scalable beam steering for photonic circuits

Engineers in Prof. Amir Safavi-Naeini's laboratory have developed an inexpensive, on-chip optomechanical system that harnesses sound waves to form and direct a beam in free-space, achieving high resolution, millimeter-scale apertures with low mechanical drive power (hundreds of microwatts per antenna). Conventional two-dimensional mechanical beam deflection systems are large, heavy, slow and expensive, while the current alternative on-chip optical phased arrays (OPAs) cannot steer monochromatic light. This new, compact on-chip optomechanical antenna (OMA) employs acoustic waves (sound) as a naturally tunable grating to scatter light, thereby independently forming and steering beams of different colors with ultra-low cost and power requirements. These rapidly reconfigurable OMAs can be fabricated with standard microelectronics processes on a silicon-on-insulator chip and can be readily incorporated into current silicon photonics components as well as integrated electronics. This agile, scalable beam steering system could enable a host of imaging, display, communication, targeting, guidance and navigation technologies.



Optomechanical antenna arrays.*a, A mechanical wave scatters a guided optical wave to steer a beam through a range of angles b, micron-scale antennas with guided optical and guided mechanical modes form a beam in the far-field directed into a designated angle. c, antennas are incorporated into a phased-array driven by a single piezoelectric transducer.*

Stage of Research
The inventors have designed the silicon photonic system with photonic waveguides that achieves 44? field of view with 880 resolvable spots by sweeping the mechanical wavelength with about a milliwatt of mechanical power. The beam direction, beam shape and the number of beams can be quickly reconfigured using mechanical waves as nonreciprocal, active gratings.

Applications

- **On-chip photonic circuits** - optomechanical antenna arrays perform two-dimensional laser beam steering for imaging, targeting, guidance, navigation and autonomy, with end-user applications such as:
    - light detection and ranging (LIDAR)
    - sensing for autonomous vehicles and robotics
    - 3D color scanning
    - holographic displays
    - light-field imaging
    - optical interconnects
    - optical wireless communication

Advantages

- **Low cost** - on-chip arrays are much less expensive than traditional mechanical beam deflection systems
- **Achromatic** - an optomechanical antenna array steers a beam of monochromatic light in two dimensions across a large range of optical wavelengths (color and direction are linked in previous optical phased-arrays)
- **Power efficient** - an optomechanical antenna array is expected to perform beam steering for millimeter-scale aperture with only hundreds of microwatts of mechanical power

- **Compact** - drastically reduced size and weight compared to the bulky motors and mirrors that make up current beam steering systems
- **Fast steering** - a beam can be redirected on the order of 200 nanoseconds (the amount of time it takes acoustic waves to propagate across the aperture)
- **High bandwidth transmission** - information can be transmitted on a beam with 40 GHz of bandwidth per optical channel, wavelength-multiplexed optical channels can be steered independently
- **High SNR** - the active, nonrecriprocal steering mechanism provides built-in heterodyning which rejects noise and lowers the optical power needed for detection
- **High bandwidth detection** - monochromatic light can be sent to many angles and received simultaneously, each beam producing a distinguishable, low-noise microwave tone on an integrated photodetector
- **Scalable:**
    - the number of phase-shifters in OMA devices scales as the number of antennae, or the width of the array
    - very simple extension to multiple simultaneous beams (>100 beams) by enabling wavelength multiplexing and optically broadband operation for both steering and detection
- **Compatible with mass manufacturing**

Publications

- Optomechanical antennas for on-chip beam-steering Christopher Sarabalis, Raphaël Van Laer, Amir H. Safavi-Naeini, submitted - (October 11, 2017), arXiv:1710.04197

Patents

- Published Application: WO2019135787
- Published Application: 20200192184
- Published Application: 20210341814
- Issued: 11,029,578 (USA)
- Issued: 11,520,213 (USA)

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