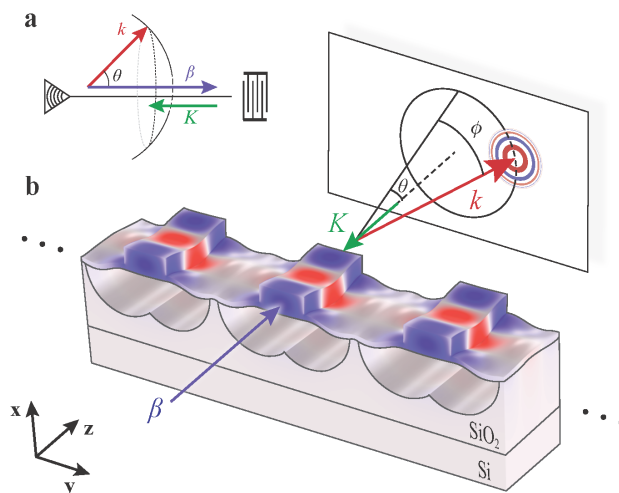


Docket #: S17-178

# 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, nonreciprocal 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 \(USA\)](#)

## **Innovators**

- Amir Safavi-Naeini
- Christopher Sarabalis
- Jeremy Witmer
- Patricio Arrangoiz-Arriola
- Raphael Van Laer

## **Licensing Contact**

### **Luis Mejia**

Senior Licensing Manager, Physical Sciences

[Email](#)