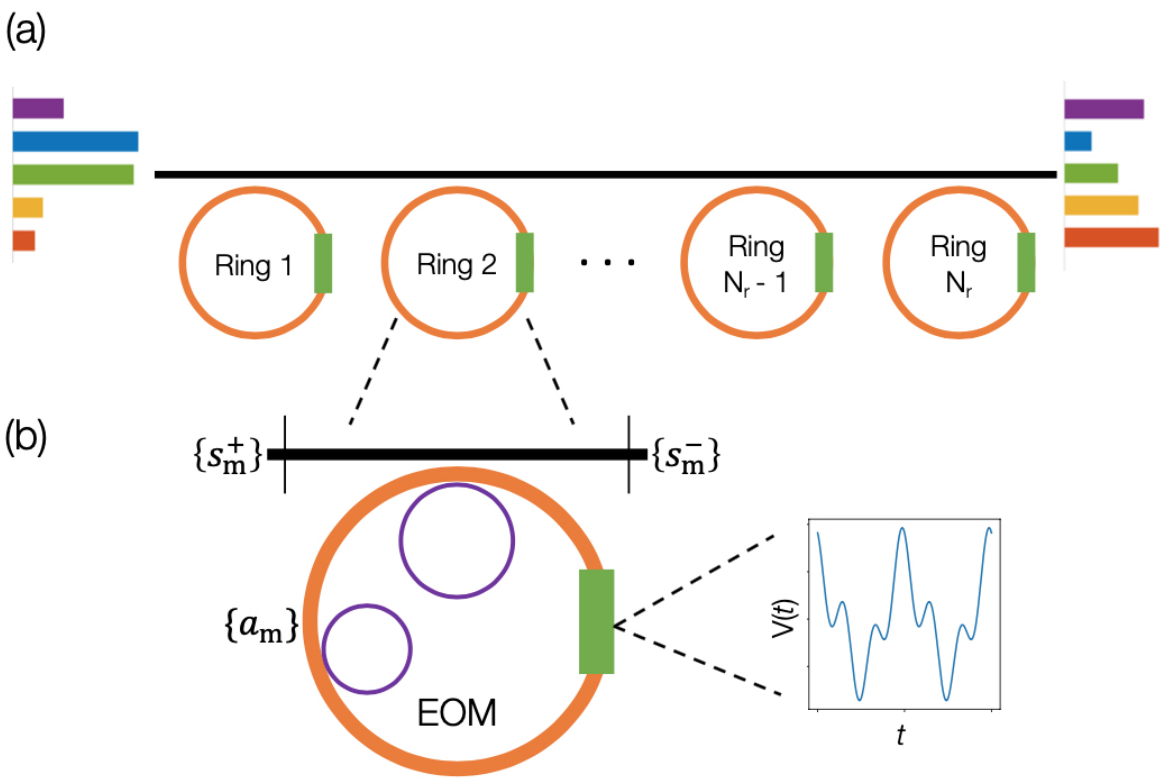
Docket #: S20-249

Frequency-domain arbitrary linear transformations for photons

Stanford researchers in The Fan Group have developed an optical device that can fine tune the color of each photon in a stream of light. Existing methods simply reroute photons of a particular frequency, but do not actually change the photons frequencies. The Fan Group device, comprised of an external waveguide coupled to an array of dynamically modulated rings with electro-optic modulators (figure 1), changes the frequencies of each individual photon in a stream of light so that the output stream is a mixture of any desired colors. The photon frequencies are used as information channels for arbitrary linear transformations. The energy efficient device has a compact footprint, uses commercially available optical components, is easy to scale up matrix-vector multiplications to larger matrices, and configure for arbitrary unitary transformations (quantum computing), and non-unitary transformations (deep learning). The approach can be used to develop photonic chips that can perform complex mathematical operations in real time, and transform digital communications, AI, deep learning, and quantum computing.



Schematic of the Frequency Changing & Tuning Photonic Device
(Image Courtesy The Fan Group)

(a) The external waveguide (black) is coupled to an array of dynamically modulated rings (orange) with electro-optic modulators (EOMs shown in green). The system transforms the incoming spectrum on the left to the outgoing spectrum depicted on the right. (b) A detailed view of a single ring.

Stage of Development - Proof of Concept

Applications

- **Optical neural network** development for **AI**.
- **Photonic chips** and hardware for **machine learning** and **quantum computing**.
- **Photonic chips** and hardware for **signal processing** and **communications**.

Advantages

- **Energy efficient** with a **compact** footprint.
- **Accurate** control of frequencies and portions, **spectral shaping of light** – actually changes photons frequencies instead of rerouting photons of a certain frequency.
- **Simple design** with **commercially available** optical components makes it easier to scale up for more complex computing.
- **Scalable and configurable** integrated photonic architectures for classical and quantum domains.

Publications

- Buddhiraju, Siddharth, Avik Dutt, Momchil Minkov, Ian AD Williamson, and Shanhui Fan. "Arbitrary linear transformations for photons in the frequency synthetic dimension." *Nature communications* 12, no. 1 (2021): 1-9. https://doi-org.stanford.idm.oclc.org/10.1038/s41467-021-22670-7
- Myers, Andrew. "With new optical device, Stanford engineers can fine tune the color of light." Stanford News, 23 April 2021.

Patents

- Published Application: WO2022047378
- Published Application: 20230324607
- Issued: 12,710,587 (USA)

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