Docket #: S24-212

Photon spin processor for on-chip classical and quantum information systems

Researchers in the Dionne lab (D-Lab) at Stanford University have designed an on-chip, optical spin processor for classical and quantum information systems. The D-Lab chip-size spin processor efficiently generates one-handed circular polarized light regardless of excitation sources (e.g. light or electrical excitation), and detects both the circular polarization state and intensity of an incoming light at the same time.

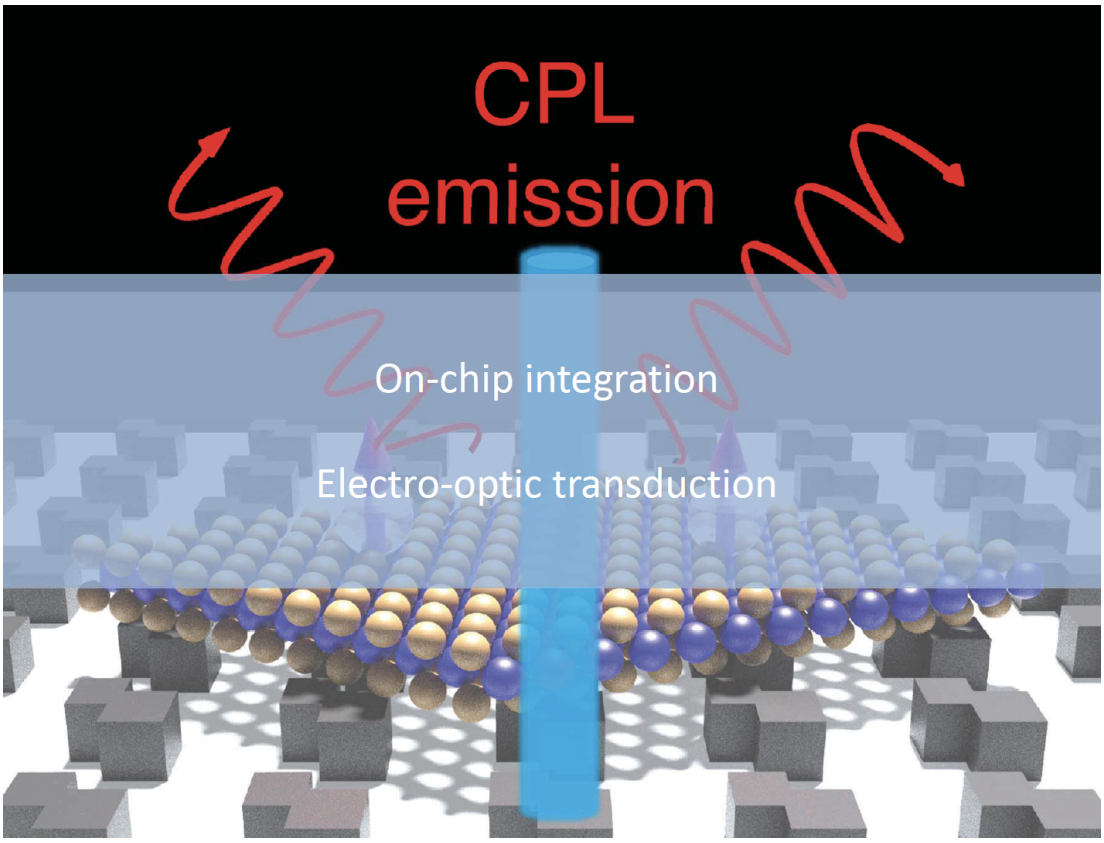

Figure 1 Photon Spin Processor for On-Chip Classical and Quantum Information Systems

(Image courtesy the D-Lab)

The integrated nanophotonic platform (figure 1) includes a high-quality-factor (high-Q) chiral Si metasurface integrated with a light-emitting or absorbing thin-film. The high-Q chiral metasurface is made of periodically arranged silicon "meta-atoms" with a subwavelength thickness (i.e. 220 nm), Q over 2400, and a nearly 100-fold near-field electric field enhancement for one-handed circularly polarized light over the other. To demonstrate the photon spin processor for classical and quantum light sources, the D-Lab integrated the Si metasurface with a monolayer crystal $MoSe_2$, transition metal dichalcogenide (TMDC) film. The resulting processor, free of bulky birefringent crystals, can generate valley-selective emission at room temperature with a user-defined chirality. Importantly, the light emitter can be photoexcited or electrically excited. Compact chiral light generation for both classical and quantum systems can greatly improve multiplexing of data streams, increase speeds, lower latency, and increase data volume.

Stage of Development – Proof of Concept Prototype
Ongoing development includes expanding the number of spin processor pixels per chip, integrating the spin processor chip with an electrical circuit board, and packaging a prototype electro-optic device.

Applications

- **Quantum computing**:
  - Chiral quantum light sources for increased encoding capacity and multiplex operations
  - On-chip sensors within photonic ICs for quantum states initialization, manipulation, and readout
- **Ultracompact classical chiral light sources** and 2D sensors for:
  - **Chiral sensing** and **circular dichroism spectroscopy**
  - **Enantiomers separation** crucial to pharmaceuticals development and manufacturing
  - **Photodynamic therapy** and **optogenetics**
- **Optics-free chiral light detector** to simultaneously measure circular polarization state and intensity (without birefringent crystals or photodiodes)

Advantages

- **High performance**
  - **Multiplexing capability** - A single chip (1 cm2) can encompass over 4000 processors (or pixels) with uniform or different functionalities
  - **High spin selectivity** - Integrated with a light-emitting or absorbing thin film, the metasurface reaches nearly 100% selectivity of one-handed circular polarization over the other
  - **High spectral resolution**
- **CMOS compatible fabrication**
- **Highly compatible with transparent conducting films** (e.g. indium tin oxide and graphene).
- **Scalable production** – Competing chiral TiO2 metasurfaces require precise control of TiO_2 slant etch angle
- **Robust** – Competing technologies like chiral perovskite thin films degrade
- **Readily integrable** with standard electro-optic device architectures, with no need for a camera for chiral imaging

Publications

- Pan, Feng, et al. Room-temperature valley-selective emission in Si-MoSe2 heterostructures enabled by high-quality-factor chiroptical cavities. *arXiv Physics* 2024.

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