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39 - Sorting of Free-Space Spatial Modes of Light with Integrated Optics

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Generating and sorting spatial modes of light is a recurring obstacle to using multiple transverse modes for both classical and quantum free-space optical communication. The Hermite-Gaussian (HG) modes provide a complete propagation-invariant set of basis states, but they cannot be transformed or sorted with common optical elements. Current implementations of free-space mode sorting thus suffer from limited efficiency, high losses, or complex experimental realization. In contrast, the manipulation of transverse modes in integrated optical waveguides is enabled by the inherently non-degenerate properties of these different modes and recent advances in nanophotonic fabrication. The similarity between the HG modes in free space and the transverse modes in a multi-mode (MM) rectangular waveguide allows for coupling between these two platforms using a simple microscope objective.

Here, we extend previous work in on-chip manipulation of spatial modes of light in two ways. First, we couple the light in and out of the integrated device, which allows sorting of free-space modes. Second, we sort modes with non-zero transverse mode index in the vertical direction, forming a 2-D array of transverse modes. We sequentially outcouple the different transverse modes from the MM waveguide by evanescently coupling a series of single-mode (SM) waveguides with transverse dimensions tailored to resonance with a particular mode of the MM waveguide. Light in the resonant transverse mode is efficiently coupled to the SM waveguide, while the remainder of the modes continue propagating in the MM waveguide unaffected. This approach will enable fast, efficient, and complete control over the spatial structure of light both on-chip and in free space.

Primary authors: Dr BRAVERMAN, Boris; Mr SKERJANC, Alexander; Dr RESHEF, Orad; Dr UPHAM, Jeremy; Prof. BOYD, Robert W.

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