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Integration of a Metasurface with a Photonic Chip Enables Free-Space Light Projection with Arbitrary Polarization

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Photonic systems being integrated with mechanical, biological, and chemical systems, where phase, intensity, and polarization of light radiation are well-controlled, pave the way for chip-scale optical materials spectroscopy [1], molecular and atomic physics [2], and optical manipulation [3]. A photonic extreme mode converter (EMC), that we have recently realized, emits a ≈ 200 μm wide collimated Gaussian beam from a single-mode waveguide (WG) into free-space [4,5]. The radiated linearly polarized beam stays collimated over several millimeters with low diffraction. Here we demonstrate integration of the developed EMC with a planar metasurface (MS), enabling efficient conversion of light from a single-mode photonic waveguide into free-space with arbitrarily-defined spatially-dependent wavefront and polarization state. In our design, 780 nm light is converted from an on-chip photonic mode to a free-space mode via 3 consecutive stages (Fig. 1a): (i) a WG mode expansion into a slab mode via evanescent coupling, slab mode projection to a linear polarized 2D Gaussian beam using an apodised grating, and then light focusing and polarization conversion from linear to elliptical processed by a flat MS.

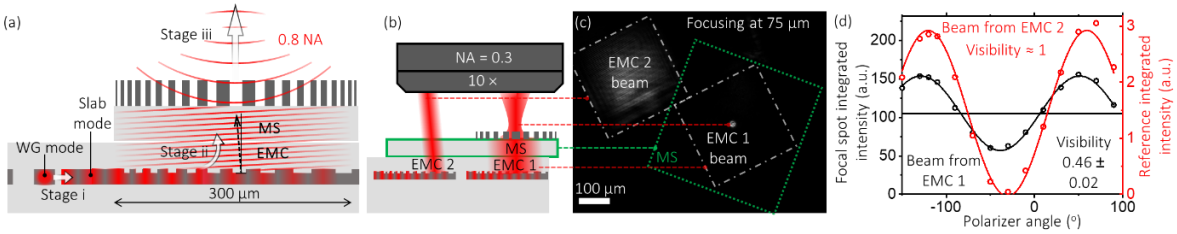

Figure 1. A photonic platform and characterization of free-space light. (a) Device operation. (b) Experimental apparatus. (c) An optical image showing free-space MS-processed and reference beams. (d) Light intensity of free-space reference (red) and MS-processed (black) radiation vs. polarizer orientation.

To test the performance of our photonic platform, we collect light processed by a MS and linear polarized radiation from a similar EMC 2 within the same field of view (Fig. 1 b,c). Polarization of both beams is estimated based on light transmission vs. polarizer orientation and shows an elliptical polarized beam modified by a MS (Fig. 1d). Analysis of the focal spot acquired using 100× objective (NA = 0.9) reveals the symmetric and aberration-free shape with 445 nm full width at half maximum based on a Gaussian fit.

To conclude, we have developed an integrated photonic platform made of a planar MS and an EMC, that radiates free space light with well-controlled light properties. Our device opens new avenues for miniaturized atomic sensors with essential need for atomic vapor interacting with circular polarized focusing light beams.

References

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