Out-of-plane Focussing Polarization Control Grating Couplers for Photonic-Spintronic Integration

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We demonstrate the first out-of-plane 2D focusing grating coupler (FGC), designed for compact photonic-spintronic integration allowing full polarization control of the emitted light. The couplers are designed for a standard 220 nm-SOI platform and fabricated with 193 nm UV lithography. These couplers can find applicability as polarization (de)multiplexers, optical layer couplers or to realize optically enabled spintronic memory based on helicity dependent all-optical switching (AOS)[1,2].

In contrast to out-of-plane 1D FGCs [3], 2D designs allow additional polarization control of the emitted light. Here, in particular, we aim to illuminate optically switchable spintronic memory elements [1]. The binary state of the memory element can be changed depending on the handedness of the incident light within a given energy range [2]. The devices are designed with a 10x10 µm footprint, which presents out-of-plane 2D FGCs with the smallest footprint published so far. To achieve focusing, the phase matching conditions are numerically solved and produce the well known photonic crystal array of 2D FGCs [4].

We evaluate the focusing characteristics experimentally by spatially scanning with a lensed fiber at multiple distances. The scan profile measures the mode overlap, which infers an approximated mode profile. The extracted effective focal spot area (A_{FWHM}) and corresponding coupling efficiency are exemplarily shown in Fig. 1a. The measurements determine the focal spot location at the fiber position of 4 µm and an effective focal spot area of 3.1 µm^2. This corresponds well to the simulated focal spot area of 3.3 µm^2.

Furthermore, we thermally introduce a relative phase shift between the two optical inputs of the 2D FGC to demonstrate their full polarization control capabilities. The polarization state is analysed by means of a polarization controller. In a first approach we achieve full 2π phase tunability with a thermal waveguide phase modulator. The polarization state is normalized and plotted for illustration on the Poincaré sphere (cf. Fig. 1b). As anticipated, this confirms that we can continuously change the state of polarization by tuning the relative phase delay of the two inputs. A second polarization control scheme relies on ring resonators (cf Fig. 1c). The ring modulator (FSR = 14.2 nm, FWHM=0.6 nm, λ_{res} = 1543.8 nm, $\kappa = 0.4$) exhibits a continuous phase shift of 2π, whereas a more abrupt phase change of π can be observed crossing the resonance as shown in Fig. 1 d). An abrupt phase change is characteristic for critical coupling [5] and poses a promising path to extremely fast and energy-efficient polarization state switching. In conclusion, we demonstrated compact out-of-plane 2D FGCs and verified their polarization controlling capabilities with different modulation schemes. Showing that these devices provide a suitable solution for photonic layer coupling and spintronic integration.

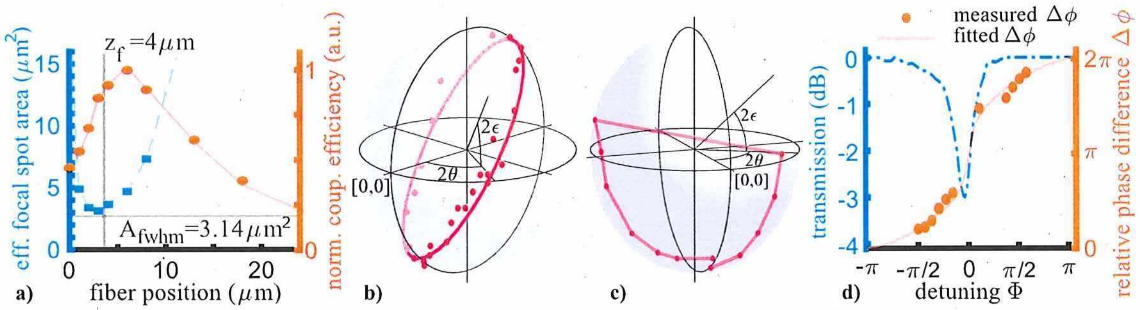

Fig. 1 a) Experimental characterization of the focusing properties of the out-of-plane 2D FGCs. b) Measured polarization states produced by thermal phase tuning and fitted tunability of the polarization state illustrated on the Poincaré sphere. c) Measured polarization states produced by a ring modulator illustrated on the Poincaré sphere. d) Transmission spectrum and extracted phase difference $\Delta\phi$ across the ring resonance over the detuning Φ.

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