Angular momentum manipulation in hybrid plasmonic waveguides

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Abstract-Manipulating spin angular momentum (SAM) and orbit angular momentum (OAM) are promising techniques for boosting the capacitance of telecommunications. Conventional optical elements like polarizers and phase plates, or recently developed metallic antennas have been proposed to manage light beam in free space. Here, we propose a simple method to generate angular momentum in hybrid plasmonic waveguides, leading to compact devices and on chip signal processing capability. Both polarization rotation and OAM are demonstrated in sub-10μm waveguides.

Spin and orbit angular moments are intrinsic properties of light beam, which can be used to improve the capacitance of telecommunications. For this application, we prefer compact devices and on-chip manipulating capability. Various polarization rotators have been proposed in a SOI platform for SAM handling. However, they are either hundreds of microns in length or difficult for fabrication [1]. For OAM, spiral phase plate or photonic crystal fiber have been proposed [2], which are also bulky and complex. In this paper, we demonstrate efficient polarization rotation and OAM generation in hybrid plasmonic waveguide. This device includes asymmetrical cross section for mode hybridization and can be simply realized by oblique deposition process. Operating at the telecommunication wavelength of 1.55 μm, polarization conversion efficiency of 99.7% can be achieved in a sub-10 μm device with an insertion loss of 2.2 dB. Furthermore, OAM is generated in a waveguide in a sub-5 μm waveguide.

In our device, input and output waveguides are silicon waveguides on a SOI wafer as shown in Figure 3. In the middle, there is a hybrid plasmonic waveguide consisting of silicon core and oxide/metal coating layer [3] with well confined guiding modes in the oxide layer. The asymmetrical structure with coatings only at top and one sidewall induces the mode splitting of the input TE or TM mode into the two intrinsic mode 1 and mode 2 in the hybrid plasmonic waveguide (Figure 1), which have a rotation of their light axes compared to the TE or TM modes [4]. Due to the large birefringence in hybrid plasmonic waveguide, a phase delay is accumulated between mode 1 and 2 along the propagation. By optimizing the phase delay and the coupling between the hybrid plasmonic waveguide and the input/output waveguide, we can have a nearly complete (>99%) transfer of polarization state in a sub-10 μm devices (Figure 2). The simple structure and fabrication process make it very promising for photonics integration. Furthermore, when the device length was shorten to 4.7 μm as shown in Figure 3, a clear first order OAM is observed in the guiding mode in the output waveguide. The OAM is generated in such an asymmetrical plasmonic waveguide as the input TE mode has no OAM. Compared to the recently proposed method based on directional couplers [5], our devices are much more compact and efficient.

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Figure 1. Schematic cross section of plasmonic waveguide PR and magnetic field profiles of hybrid mode 1 and 2 at $W_{\text{Si}} = H_{\text{Si}} = 310$ nm, $W_{\text{SiO}_2} = H_{\text{SiO}_2} = 50$ nm, $W_{\text{Ag}} = H_{\text{Ag}} = 80$ nm.

Figure 2. Transverse electric field distributions in the x-z plane at the center of Si core for TM (a)-(b) and TE (c)-(d) polarization input. $L = 9.7$ $\mu$m.

Figure 3. Schematic of plasmonic waveguide based OAM generator. Longitudinal electric field distributions in the x-y plane at the input and output of plasmonic waveguide. $L = 4.7$ $\mu$m.

REFERENCES