A Compact Integrated Plasmonic Modulator

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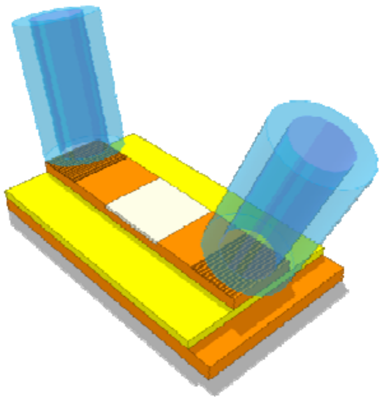
We describe an integrated plasmonic modulator with a compact and simple structure: current through a short and thin metallic layer, with plasmonic modes on both surfaces, can switch the light through a silicon waveguide underneath.

The combination of the silicon photonics platform with the plasmonics field offers many device opportunities, for example in the areas of optical information processing and sensing. Silicon photonics exploits the mature technology base of CMOS processes, which led to the demonstration of many passive and active devices, based on low-loss, high index contrast photonic wires and cavities. On the other hand, one of the many plasmonic subjects under examination is the use of very confined and sensitive surface waves. Here we study an integrated plasmonic modulator, which combines elements of both fields.

The structure is shown in the figure below, with input and output grating couplers included. It is an adaptation of a device currently under study for biosensing applications [1]. Essentially it simply consists of a thin metal film on top of a silicon waveguide. The waveguide regions without metal film support a single TM waveguide mode. The region with the film guides two independent plasmonic modes, one on the top surface, and one on the bottom surface. These two modes are excited from the silicon waveguide mode, they propagate independently to the other side, and there they recouple to the silicon mode. The phase difference between the plasmonic modes at the end determines how much is coupled to the output. We can modulate this phase difference by changing the temperature. In addition, we add a polymer on top of the structure so that the plasmonic modes sense a different sign of index change with respect to temperature. Note that the temperature change can be induced by a current through the metal layer itself, so that it serves both optical and electrical functions. There has already been interest in these kinds of structures [2,3,4]. In our case, however the interference principle is novel, and makes it possible to realize a more compact structure.

The device is theoretically analyzed using rigorous optical and thermal models. For the optical calculations we use the eigenmode expansion method, specifically adapted for plasmonic modes. Optimal designs have been calculated and a first manufacturing round was initiated. The simulations result in the following target parameters: a silver film with thickness 20nm and length 4μm, deposited on top of a 210nm thick silicon layer. This results numerically in 8dB insertion loss and a modulation extinction ratio of 23dB. The insertion loss mainly stems from the coupling mismatch between the silicon and the plasmonic modes. Our first manufactured structures deviated too far from the desired values, as microscopy shows. Further experiments are under way.



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