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Plasmonic Modulator Based on Fano Resonance

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The field of plasmonics is continuously attracting research in the area of integrated photonics development, to highly integrate photonic components, devices and detectors in a single photonic chip, just as electronic chips containing many electronic components. The interesting properties that plasmonics offer include the electromagnetic fields enhancement and the confinement of the propagating surface plasmon polaritons to sub-100 nm size features at metal dielectric interfaces. Thereby, the field of plasmonics is very promising for minimizing the photonic components to smaller sizes that cannot be experienced using conventional optics and in particular the Silicon photonics industry. Many applications based on plasmonics are being increasingly developed and studied such as electromagnetic field enhancement for surface enhanced spectroscopy, wave guiding, sensing, modulation, switching, and photovoltaic applications.

We hereby propose a novel compact plasmonic resonator that can be utilized for different applications that depend on optical resonance phenomena in the Near Infrared spectral range, a very interesting range for a variety of applications, including sensing and modulation. The resonator structure consists of a gold layer which is etched to form a metal-insulator-metal wave guide and a rectangular cavity. The rectangular cavity and the wave guide are initially treated as a dielectric material. The strong reflectivity of gold at frequencies higher than the plasma frequency is the origin of the Fabry Perot resonator behavior of the rectangular cavity. The fano resonance was produced successfully and controlled by varying the rectangular cavity dimensions. The fano profile is generated in as the result of the redistribution of the electromagnetic field in the rectangular cavity as depicted by the plasmonic mode distribution in the resonator. The fano resonance is characterized by its sharp spectral line which attracts applications requiring sharp spectral line shapes such as sensing and modulation applications.

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Optical modulators are key components in the modern communication technology. The research trend on optical modulators aims at achieving compact designs, low power consumption and large bandwidth operation. Plasmonic modulators emerge as promising devices since they can have high modulation speeds and very compact designs.

The operation mechanism of our introduced plasmonic modulator is as follows: instead of a constant refractive index dielectric, an electro-optic polymer that has its refractive index is dependent on some controlled phenomena, is filled in the metal insulator metal waveguide and the rectangular cavity. Efficient modulation was achieved by changing the applied voltage (DC Signal) on the metal contacts which then changes the refractive index of the polymer, thereby shifting the resonant wavelength position in the resonator, leading to signal modulation. Our modulator is operational at the telecom wavelength 1.55 µm, thereby suitable for the modern communication technology.

Finite Difference Time Domain (FDTD) simulations were conducted to design the modulator structure and run the simulations experiments, and to study the resonance effects of the structure and optimize its response to the desired results, the most important results however are the efficient modulation of the optical energy at the wavelengths required in the modern communication technology, around 1.5 µm, all results were carried on using the commercially available Lumerical FDTD software.