Design and Optimization of Tip Slotted Bow-Tie Optical Antenna

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1. Introduction

In recent times, optical antenna have found many applications in area of optical microscopy, optical tweezers, thermal imaging and solar energy harvesting. Optical antenna is a device which converts the energy of free propagating electromagnetic waves into localised energy. The optical antennas are generally made of rare metals, such as gold or silver, rested over the Silica glass. When light of certain frequency is incident on it, localised plasmons are formed at the metal-dielectric interface. As a result, charge accumulating at the edges generates high electric field at the feed point of the antenna. In this work, analysis and performance of gold bow-tie optical antenna with a V-shape slot is investigated.

2. Design and Analysis

The optical antenna is a sectoral bow-tie type which has a slot on its tip which is rested on a silica glass substrate (permittivity of ε_r = 2.09). The schematic of the device is shown in Fig.1. The optical antenna arms are made of Gold. The dielectric constant of gold is obtained from Drude model. The 3D numerical simulation of the proposed design has been done using commercial COMSOL Multiphysics, which works on finite element method. The antenna structure is illuminated in normal direction to the plane with a unity (1V/m) electric field magnitude and a linear polarisation along the antenna axis. The structure is optimized in terms of antenna length, thickness of antenna, width and length of the slot to monitor the performance of the antenna in the mid-IR wavelength region. Through simulation, it is found that antenna resonates at multiple wavelengths between 8 µm to 15 µm. The first resonant wavelength is at ~9 µm whereas the second and third resonant wavelengths are 10.6 µm and 12.8 µm, respectively, as shown in Fig. 2 and Fig. 3. For optical antenna of length and thickness of 4.5µm and 375 nm, high electric field intensity is obtained in the gap.

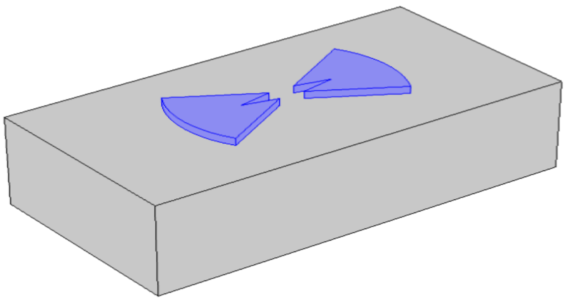

Fig.1. Tip slotted gold bow tie optical antenna placed over Silica

Because of the slot at the antenna tip, multiple resonances occur. In Fig. 3, the transmission characteristic of the designed antenna is plotted, which shows a maximum transmission depth of −12.98 dB at 12.8 µm wavelength and greater than −10 dB at ~ 9 µm.

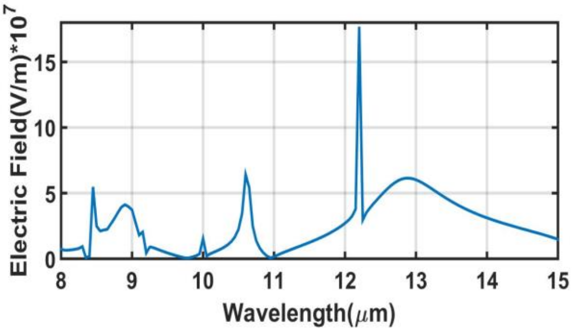

Fig.2. Electric field for optimized parameter of bow-tie optical antenna

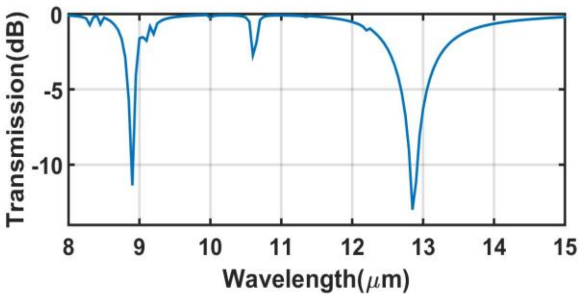

Fig.3. Transmission characteristic of the optimized optical antenna

3. Conclusion

The designed optical antenna works in mid–IR range of 8 µm to 15 µm which can be used for near-field optical microscopy, IR detection and solar energy harvesting. It is observed that because of the slot, higher-order resonances occur at the optimized length of 4.5 µm and thickness 375 nm. Slot is also further optimized for length and width Maximum electric field intensity of 61.35 V/µm and transmittance of -12.98 dB is obtained at the wavelength of 12.8 µm.

References

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