Effect of Optical Force on Transmission of Plasmonic Bowtie Antenna

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We present a novel opto-mechanical antenna where strong optical force generated between the ends of the antenna can directly affect the optical transmission. Such devices are useful for sensing applications.

Optical force generated due to gradient of the electric field plays an important role in novel opto-mecahnical systems[1]. Further, the gradient field can be enhanced using surface plasmon polariton (SPP) and thus generated optical force can also be multiplied by many orders of magnitude[2]. We present a novel plasmonic bow-tie antenna design (Fig-1a) and show, how optical force can affect its transmission property. The optical force on the end beams of the bow-tie has been calculated using Maxwell's stress tensor method[3]. We used a 3D finite difference time domain (FDTD) method for all performed simulations. During simulation, the structure was illuminated using a planewave with an operating wavelength of 1550nm. The dielectric substrate has been chosen to be glass. We also considered the possible under-cut, generally formed during fabrication of such antenna using focused ion beam milling. The undercut is advantageous for our case as it helps the end beams of the antenna to be suspended and thus optical force can physical deflect it. The total optical force on each beam has been calculated with varying length of the antenna. The force was found to be attractive with two resonance peaks for varying antenna length between 10 to 1000nm (Fig. 1b). The first resonance peak was found to be at 175nm length of antenna and the second peak at 700nm. At first resonance peak, an optical force in the order of ~ 19pN/mW/um^2 can be achieved. We only considered the first resonance condition for all other performed simulations.

This generated optical force can impose a mechanical torque on the ends of the antenna and thus, can physically bend and bring them closer. This deformation is expected to cause changes in the antenna property. We calculated the change in optical force due to this deformation and found it to be negligible (not shown here). But, we found that it affects the near field intensity and far field transmission. Fig. 2c depicts the transmission of near field and far-field as a function of varying deflected angle of the antenna end. It shows that a deflection of ~ 16^o, can change the near field transmission by a factor ~ 3 and it is ~ 2 times for region 400nm above the top surface. The enhanced transmission is due to the proximity of the ends of the antenna. Fig. 2a and 2b show the electric field intensity profile for the antenna without and with deformation caused by the optical force. The map gives insight regarding the abrupt change in transmission due to generated surface plasmon resonance between deformed antenna ends. The majority of the field intensity, thus, gets concentrated to center in the contrary to the case without deformation where most of the field is concentrated to the ends of the antenna instead. These kinds of devices can be useful to manipulate the near and far field optical properties. Importantly the design is compact and can even be integrated with a light source as been shown experimentally in our previous work[4].

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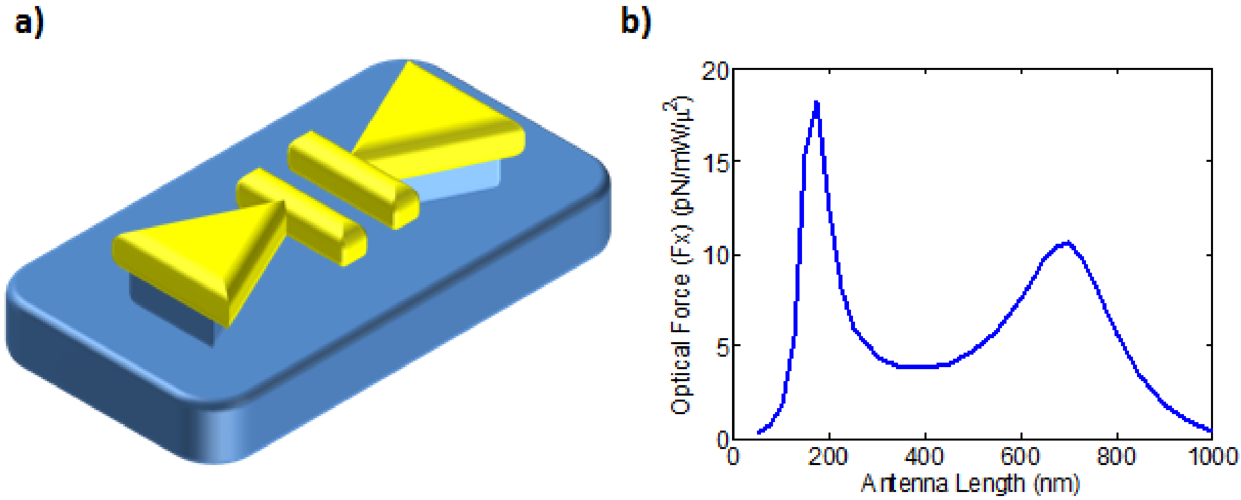

Figure 1 - a) Antenna structure used in FDTD simulation, b) Dependency of optical force on antenna length

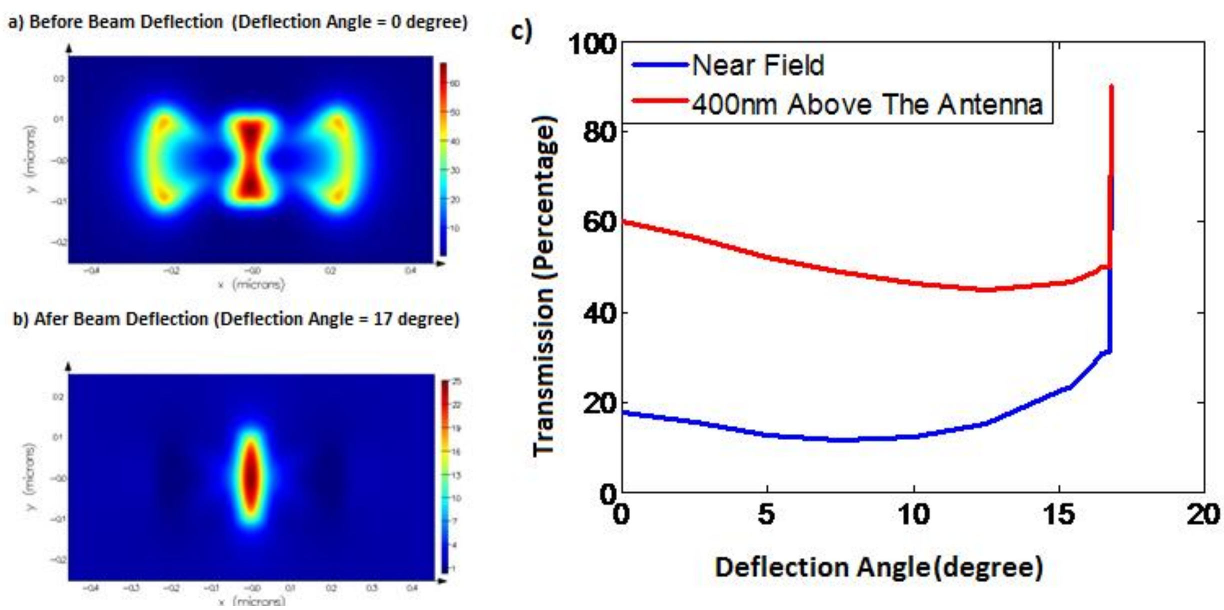

Figure 2 - Near-field intensity profiles for the case of a) without beam deflection and b) with beam deflection and two beams touch each other. c) Power transmission as a function of beam deflection angle

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