Design and Characterization of MOEMS Optical Tweezers

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Abstract

Optics is playing important role in communication and material study. Currently studies on sub-micron sized particle concentrate more on understanding Physics and Engineering at single particle level for single electron devices. For such studies non-contact diagnostics methods such as Optical Tweezers would be the best option.

Optical tweezers are based on the the gradient and scattering forces, in which gradient force is more critical as compared to scattering force. On the other hand, diffraction limitation constraints focus of the laser beam smaller than the wavelength. In order to over come the diffraction limitation we suggest a novel method.

When light falls on the metal it excites the electron inside it and make them free. Free electrons inside the metal can move freely and they make a cloud. This cloud is called surface plasmon polariton (SPP). When this cloud is moving in an harmonic frequency it satisfies the resonance condition called surface plasmon resonance (SPR). For the generation of SPR, Otto and Krestchmann configurations are used. We use Krestchmann configuration, where a thin nano metal film is deposited over a dielectric substrate.

Negative permittivity of metal layerprovides negative energy vector for metallic medium, so it provides energy conservation and momentum conservation is associated with the bending of light, which is fulfilled by phase matching. A Mie particle trapped in an optical tweezers is held stable by two forces, viz, scattering force and gradient force. The scattering force acts along the direction of incident light, while gradient force acts along the direction of gradient intensity. A Gaussian beam such as from a laser source is necessary for generating such forces on the particle. For Rayleigh particles (particle size is smaller than wavelength) the thermal forces dominates over the optical pressure. Current optical tweezers are not capable of overcoming thermal force since it is very high in the case of smaller particles.

In SPR, light is launched from one port of the device and the controlled output is taken from the other port of the device, which can be vary by using control parameter inside the system, so at the other port we are getting controlled light output. Its aperture is possible in the sub-wavelength size, since light is traveling inside the boundary between metal and dielectric. So it can be decoupled from any small size, also less than wavelength size so that we can overcome

diffraction limitation.

We have simulated metal dielectric waveguide of dimension 4x4x1mm^3. A metal film of area 4x4mm^2 and a thickness of 50nm is deposited over dielectric, which is used to excite SPR on the metal dielectric interface. Appropriate holes at pre-calculated region generates a very sharp electric field gradient. Optical pressure due to the SPR are harvested to trap sub-micron sized Rayleigh particles inside the metallic traps. It is estimated that a force of the order of 2pN are generated by such trap, which is the optimal force required for trapping sub-micron size particle.

The results are discussed in Figure caption.

Reference

H. Nishihara, M. Haruna, T. Suhara,``Optical integrated circuits" McGraw-Hill, New Delhi 1989.
T.-J. Wang, C.-W. Tu, and F.-K. Liu, `Integrated-Optic Surface-Plasmon-Resonance Biosensor Using Gold Nanoparticles by Bipolarization Detection' IEEE J. Sel. Topica in Quan. Electron., 11, 2, (2005).
J. C. A. Castro, A. S. C. Beltran, `Surface Plasmon Resonance of a Few Particles Linear Arrays', Journal of Electromagnetic Analysis and Applications, 3, 458-464, 2011.
J.R. Martijn, et al. "Hybrid Silicon Photonic Integrated Circuit Technology" J. Quan. Electron, 19, 223, 2013.
http://optical-waveguides-modeling.net/mode-solvers.jsp-Finite-Element Method
http://www.comsol.com/outlines.html

Figures used in the abstract

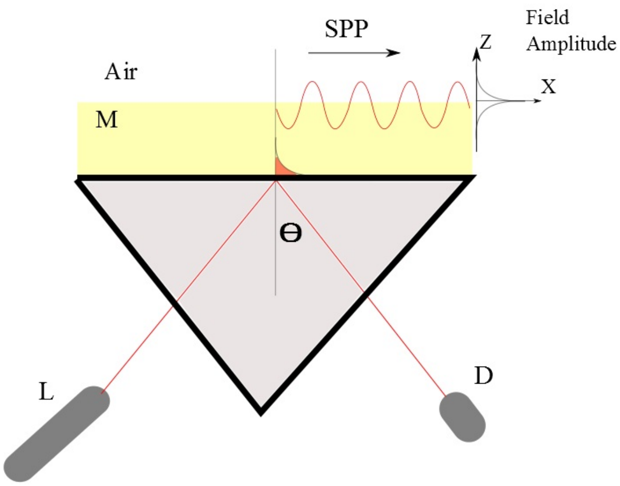

Figure 1: Schematic of Krestchamann Configuration used in the experimental setup. There is no air-gap between dielectric-metal interface.

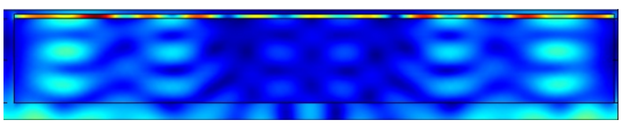

Figure 2: Study of SPR generation at Gold-glass interface. A nanolayer (50nm) of Au is coated over glass substracte. SPR are excited at the interface.

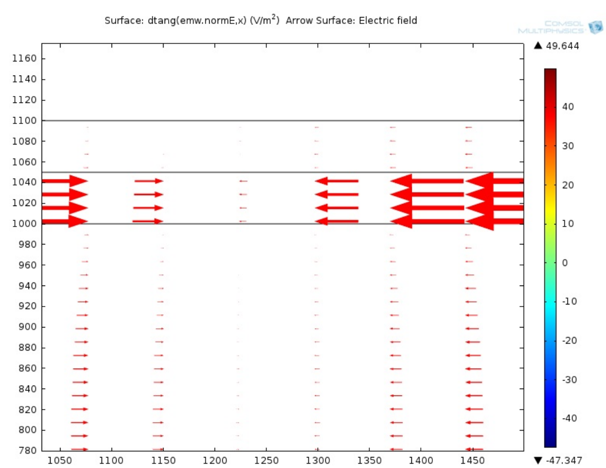

Figure 3: The rsultant force vector acting on the sub-micron size particles at the interface. The forces are compensated at ~ 1225um.

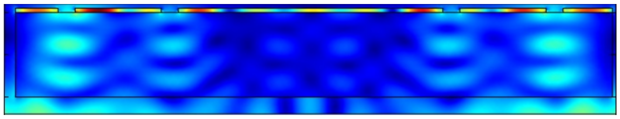

Figure 4: The design micro-optical tweezers setup. The low or zero optical pressure are shownas cyan color, wheresub-micron sized particles could be trapped.