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NANOALLOY ANTENNA FOR OPTICAL COMMUNICATION

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Abstract. In this paper a different nano material i.e. nickel-aluminium(Ni-Al) alloy is presented for optical communication. Generally gold and silver as nanoparticale are used for optical antenna due to their optical properties, but they seem to be more costly than these materials and limits the use of optical antennas for general purpose. Optical antennas are the new advent of technology, which makes the antennas to operate at optical frequency and makes the optical communication possible at nanoscale, which was limited to micro scale. Hence, optical antennas will bring a revolutionary change in technology.

Keywords: optical antennas, nanoscale, communication.

I. Introduction

From the very beginning gold nanoparticle has been used for Optical antennas which limit their use for general purpose due to its increasing cost. Basically, Optical antennas are specially designed nano antennas for optical communication. As at optical frequency, losses are high, so normal antennas cannot serve the purpose. Therefore, it created the basic requirement of antennas for optical communication. Optical antennas are devices that enable the control and manipulation of optical fields at the nanometer scale, and hold promise for enhancing the performance and efficiency of photo detection, light emission and sensing. Although many of the properties and parameters of optical antennas are similar to their radio wave and microwave counterparts, they have important differences resulting from their small size and the resonant properties of metal nanostructures. The objective of optical antenna design is equivalent to that of classical antenna design: to optimize the energy transfer between a localized source or receiver and the free-radiation field. In certain recent studies, however, the term 'optical antenna' has clearly been stretched beyond its common definition in radio wave technology. An antenna is not simply a resonator or a strong scatterer. Instead, it is defined by its function, namely as a transducer between free radiation and localized energy. Its efficiency is defined by the degree of localization and the magnitude of transuded energy. The term 'antenna' is used in a wide range of contexts, such as for tent posts, the beams of sailing boats or insect whiskers. The electro-magnetic antenna, originally referred to as an 'aerial', is a transducer between electromagnetic waves and electric currents, and generally operates in the radiofrequency regime. In analogy with the electromagnetic antenna, we define the optical antenna as a device that converts freely propagating optical radiation into localized energy, and vice versa[1] into the optical frequency regime. The introduction of the antenna concept into the optical frequency regime will lead to new technological applications, such as enhancing absorption cross-sections and quantum yields in photovoltaic, releasing energy efficiently from nanoscale light-emitting devices, boosting the efficiency of photochemical or photo physical detectors, and improving spatial resolution in optical microscopy. The absence of optical antennas in technological applications is primarily associated with their small scale. Antennas have characteristic dimensions of the order of a wavelength of light, demanding fabrication accuracies better than 10 nm. The fabrication of optical antenna structures is an emerging opportunity for novel optoelectronic devices. Nanotechnology is defined as the application of scientific knowledge to control and utilize matter at the nanometer scale (about 1–100 nm). At this scale size related properties and phenomena can emerge[2,3] .Because diffraction limits the confinement of propagating radiation to roughly half a wavelength, the length scales over which optical fields can be manipulated traditionally lie outside the size range of interest to nanotechnology. It is often possible to spatially separate the nanoscale building blocks and to study their physical and chemical properties by using standard spectroscopic techniques [4, 10]. However; their properties can change once they are embedded in a macroscopic structure because of interactions between the building blocks and with the environment. In fact, one of the most interesting aspects of nanoscale systems involves properties dominated by collective phenomena, which can bring about a large response to a small stimulus in some cases. To understand optical fields in such complex nanoscale structures, challenging obstacles in detection and control must be overcome. Optical antennas help surpass the diffraction limit, making it possible to manipulate, control, and visualize optical fields on the nanometer scale. The introduction of the antenna concept into the optical frequency regime will provide access to new technological applications [5-6]. Optical antennas will likely be employed to enhance absorption cross sections and quantum yields in photovoltaic, to release energy efficiently from nanoscale light-emitting devices, to boost the efficiency of photochemical or photo physical detectors, and to increase spatial resolution in optical microscopy. The field of optical antennas is in its infancy, and new studies and developments are evolving at a rapid pace.

II. History

The concept of the optical antenna has its roots in near-field optics [7]. In 1928, Edward Synge proposed the use of a colloidal gold particle for localizing optical radiation on a sample surface and thereby surpassing the diffraction limit in optical imaging[8]. Then, in 1985, John Wessel proposed for the first time that a gold particle could function as an antenna[9]. The first experimental demonstrations of this followed in 1995 by Dieter Pohl and Ulrich Fischer, who used a gold-coated polystyrene particle20. In the following years, optical antennas in the form of sharply pointed metal tips were used in near-field microscopy and spectroscopy [10]. These experiments gave birth to what is today known as ‘tip-enhanced near-field optical microscopy’. It should be noted that antennas were used as whisker (Schottky) diodes for the detection and mixing of infrared radiation in as early as 1968[11–13]. These studies continued, and since then various infrared antenna geometries have been systematically investigated [14,15].

Bow-tie antennas were proposed as near-field optical probes in 1997, and initial proof-of-principle experiments have been performed in the microwave regime [16]. In follow-up experiments, bow-tie antennas were fabricated on the tips of atomic force microscopes [17]. After establishing the analogy between near-field optical probes and optical antennas, antenna structures were grown on the end faces of aperture-type near-field probes (also known as tip-on-aperture probes)[12,18]. Following these developments, several groups set out to explore various geometries of antenna, both experimentally and theoretically. As an example, Fig. 2 shows various antenna configurations fabricated by focused ion-beam milling and electron-beam lithography.

Surface Plasmon resonances make optical antennas particularly efficient at selected frequencies — an attribute that also holds promise for biological sensing and detection [19–20].

III. Main thrust of the paper

Although optical antennas are strongly analogous to their radio frequency (RF) and microwave counterparts, there are crucial differences in their physical properties and scaling behavior. Most of these differences arise because metals are not perfect conductors at optical frequencies, but are strongly correlated plasmas described as a free electron gas. Optical antennas are also not typically powered by galvanic transmission lines; instead, localized oscillators are brought close to the feed point of the antennas, and electronic oscillations are driven capacitive. Moreover, optical antennas can take various unusual forms (e.g., tips or nanoparticles), and their properties may be strongly shape- and material dependent due to surface Plasmon resonances. Typically, an optical antenna interacts with a receiver or transmitter in the form of a discrete quantum system, such as an atom, molecule, or ion. Because the antenna enhances the interaction between the receiver or transmitter and the radiation field, it may control the light-matter interaction on the level of a single quantum system. On the one hand, the presence of the antenna modifies the properties of the quantum system, such as its transition rates and, in the case of a strong interaction, even the energy-level structure. On the other hand, the properties of the antenna depend on the properties of the receiver/transmitter. Thus, the two must be regarded as a coupled system.

Since gold and silver has been used for optical antennas due to their optical properties, it’s now the time to have different approach towards the selection of material. Metal nanoparticles interact strongly with visible and infrared photons due to the excitation of localized surface plasmons (LSPs)[22,23]. LSPs are a result of coherent oscillations of conduction electrons, and can be excited in some metals by UV, visible or NIR photons. The strongest optical interaction occurs at a resonance, with the resonance condition being a function of the nanoparticle size, shape, and type of metal, as well as the local dielectric environment[24] Once excited an LSP can decay radiatively, resulting in scattering, or nonradiatively, resulting in absorption. The sum of absorption and scattering is known as extinction, and the extinction peak occurs at the resonant wavelength of the LSP. The strong, tunable optical properties of metal nanoparticles have lead to a wide range of applications, ranging from biosensing [25,26] to photovoltaic’s[27] Various physical characteristics of electro less nickel coatings, such as hardness, wear resistance, coating uniformity, and corrosion resistances, as Well as the ability to plate non-conductive surfaces make this a coating of choice for many engineering applications Electro less nickel coatings compliment aluminum's inherent characteristics by adding hardness, wear resistance, corrosion protection, and solderability. Therefore nickel aluminum would work best as nanoparticles for optical antenna. First of all, various energy parameters of this alloy is checked with respect to the time, such as potential, kinetic and total energy.

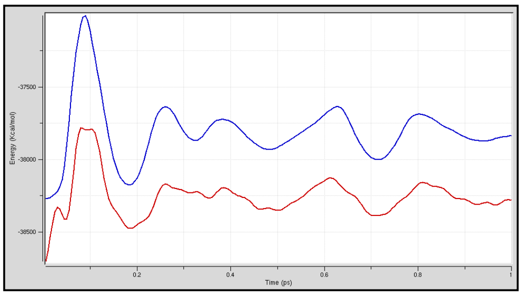

Fig.1. Plot of total energy(blue curve) and potential energy(red curve) against time

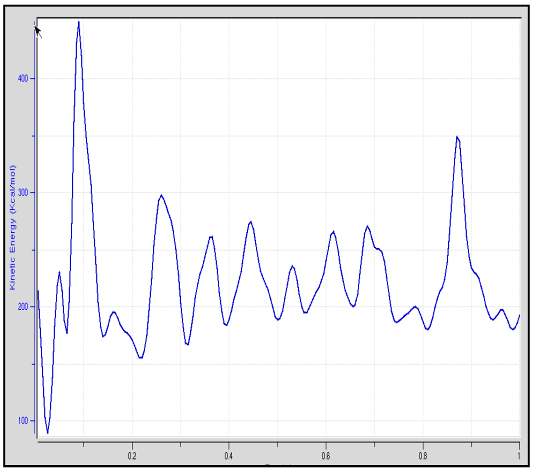

Fig.2 Plot of kinetic energy against time

From the various plot of energy graph its being very clear that energy of Ni-Al alloy is high initially and it decreases as time increases. Now next step for antenna at nanoscale is to find the electric field enhancement.

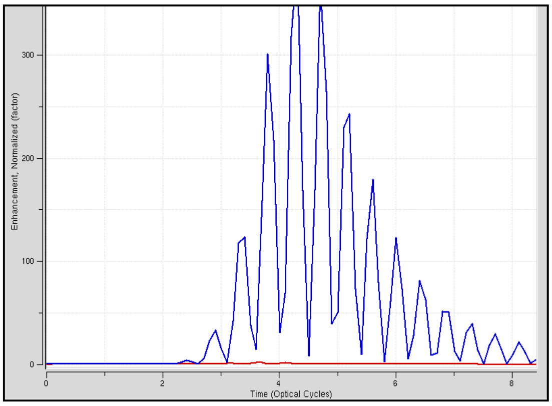

Fig.3. Plot of normalized enhancement against time

From the above figure it’s clear that if aluminum nickel alloy is used as nanoparticle for antenna , then its enhancement is low initially and increases with respect to time till a certain point, known as a peak point and then again decreases .Also its energy parameters decrease with time which limits it use as a material for antenna .

IV. Conclusion

The study of optical antennas is still in its infancy. While some properties directly derive from classical antenna theory, the direct downscaling of antenna designs into the optical regime is not possible because radiation penetrates into metals and gives rise to plasma oscillations. In general, an optical antenna is designed to increase the interaction area of a local absorber or emitter with free radiation, thereby making the light–matter interaction more efficient. To reduce the cost of gold optical antenna, various parameters of aluminum nickel alloy was discussed. Though cheaper and stronger than gold and silver, its enhancement and energy parameters decrease as time increases. So it can be used as a material for optical antenna but its shape must be chosen in such a way that it increases the enhancement efficiency of an antenna.

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