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Implementation of Spintronics in Plasmonsters for optimal power consumption (Spin Plasmonsters)

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Abstract— Plasmonster is a three terminal plasmonic device with transistor like properties. Plasmonsters possess the high data transmission rate of photonic devices while retaining the minuscule size of electronic devices. But one of the biggest challenges is the loss due to the imaginary component of the permittivity of the metals used in the construction of the device. Further, plasmonsters require pumping of power and the operation to be carried out at temperatures usually well below the room temperature. The utilization of electron spin in plasmonsters-spin plasmonsters is derivatively shown to reduce this imaginary permittivity thus improving the gain. Additionally, power pumping at room temperature can be achieved by the use of multiferroic bismuth ferrite in the electro-optic substrate of the plasmonster.

Index Terms— imaginary permittivity, light control, photonics, plasmons, plasmonster, spintronics

1 Introduction

SPINPLASMONICS is an area of nanotechnology combining spintronics and plasmonics.The use of quantum state of an electron's spin to switch a beam of terahertz light is the key to a new era of communication.

Plasmon is the quantum of Langmuir waves. Surface Plasmons find active application in plasmonic devices.Surface Plasmons are the coherent, collective, delocalized electron oscillations at the interface of a metal and a dielectric interacting very strongly with light. Plasmonics embodies the strongest points of photonic and electronic communication allowing high bandwidth and super fast transmission of data, all facilitated by a diminutive system. **The main disadvantage of plasmonics is that plasmons dissipate after only a few millimeters making it unsuitable to serve as a basis for computer chips which are a few centimeters across**

Spintronics utilizes the magnetic quantum properties of electrons i.e. the intrinsic spin of electrons, the associated magnetic moment and the fundamental electronic charge. **The power consumption of spintronic devices is lower than the conventional silicon devices since the energy needed to change the spin is lesser than the energy required to push the charges around**.These devices also exhibit the property of non-volatility meaning that memory is retained even when the chip is turned off leading to zero standby power consumption. **Dissipation less spin current could be made to flow even at room temperature making magnetization switching possible at room temperature.**

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Plasmonster is a machine that offers 'yes/no' multiple times to transfer information.This is performed using switches.Plasmonic switches pave the way for the computers to operate faster and store more. However, the main disadvantage is that plasmons are not sustained over long distance.Moreover, excitation of SPs is mostly performed using far-field optical techniques, which have resolution larger than plasmonic phenomenon. But for true nanoscale plasmonic studies, SPs point source with nanoscale dimensions and efficient excitation with nanoscale resolution are required.It also suffers from losses due to the electrical property of the substrate-complex permittivity.Further, pumping of power at low temperatures is required.

Solutions to mitigate the above said problems is obtained by introducing the concept of spintronics in plasmonster.Spinplasmonsters could serve as the core of an ultrafast signal-processing system, an advance that could revolutionize computing and make plasmonsters faster and useful. It can also provide solution for application requiring improvement to higher resolution.

2 Current Scenario

2.1 Plasmonster Model

A plasmonic transistor-plasmonster consists of an electro–optic substrate and a conductive layer placed on it. This first conductive layer and the electro-optic substrate are made of materials that are suitable for transmission of Surface Plasmons (SPs) along the interface. The conductive layer is provided with plurality of grooves with space between the first and second plurality of grooves for defining the source input grating and drain output grating for establishing the SPs.The plasmonic transistor can further include supplementary conductive layers placed on the electro-optic substrate. If these added layers are of diverse materials than the original conductive layer, a distinct additional interface is also formed. A means for varying the electro-optic substrate permittivity,

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such as a light source or voltage source, is connected to the electro-optic substrate. Selective manipulation of the varying means allows the user to selectively increase or decrease the substrate permittivity. Control of the substrate permittivity further allows the user to control SP propagation from the source input grating along the interface to the drain output grating to achieve a transistor-like effect for the SP.While the metals in the substrate provide the required negative electric permittivity for the sub wavelength confinement, they are also characterized by a significant imaginary component of the permittivity. Imaginary component of permittivity is directly related to absorption of photons. This absorption hinders long range plasmon propagation in waveguides and also serves as a significant impediment to metamaterial applications.

2.2 Plasmonster operation

To establish a surface Plasmon, a conductive layer is placed on an electro-optic substrate to form an interface. Light is coupled from the light source into the thin conductive layer to form SP which traverses along the interface in the direction of the arrow as shown in Fig.1. In the Fig.1. plurality of grooves are used in the conductive layer for the coupling of light. Alternatively, a high index prism can also be used for this purpose. Other means include mechanism such as establishing an aperture coupling.

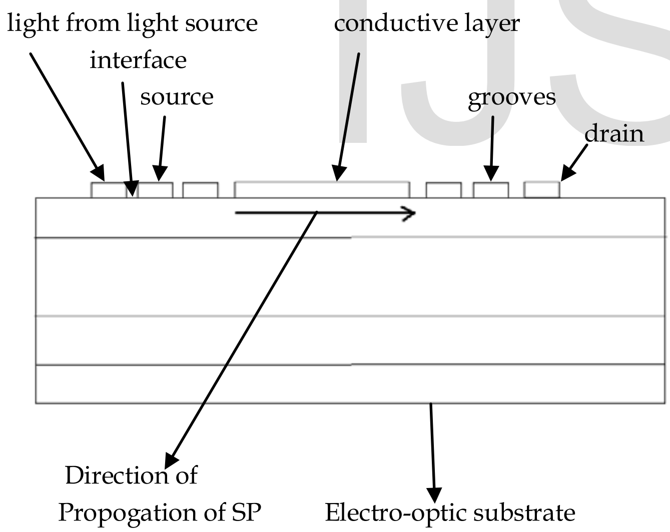

Fig. 1. Operation of Plasmonster

2.3 Defining of problem

Permittivity is the measure of resistance encountered while forming the electric field in the medium. Unfortunately, there exists an imaginary permittivity in the substrate resulting in the loss of energy due to which the SPs are unable to propagate for longer distances in the range of centimeters making it unsuitable for utilization in computer chips. Due to this dissipation of power, gain is also reduced. The present methods applied for improving the gain usually requires very low temperature.

3 Power Reduction Strategy:

Permittivity is a complex quantity consisting of real and imaginary parts. The imaginary part corresponds to absorption loss. The complex permittivity function is intimately connected to band structure. The primary quantity that characterizes the electronic structure of any material is the probability of photon absorption. Hence photon absorption is directly related to the imaginary component of the permittivity. Thus reducing the probability of photon absorption,imaginary permittivity is directly reduced.

Multi ferroic bismuth ferrite is used as the electro-optic substrate and gold as the conducting layer. Initially, the electrons in the substrate and the conducting metal are spinning in random directions.Before the incidence of light from light source for varying the permittivity of the substrate, a magnetic field is applied to spin polarize the electrons. This spin polarization of electrons drives some electrons from the substrate into the conducting layer (gold). This gives rise to a resistance termed as Anisotropic Magneto Resistance (AMR). This resistance controls the amount of light that is transmitted i.e. limits the number of photons propagating in unit time. This in turn decreases the probability of photon absorption, effectively reducing the imaginary permittivity. As the imaginary permittivity is reduced, the loss connected with it is also reduced thus improving the gain. Further by the use of multi ferroic bismuth ferrite, polarization of electrons is made possible at room temperature. So by the application of multi ferroic bismuth ferrite as substrate and spintronics the gain of the plasmonster is improved at room temperature.

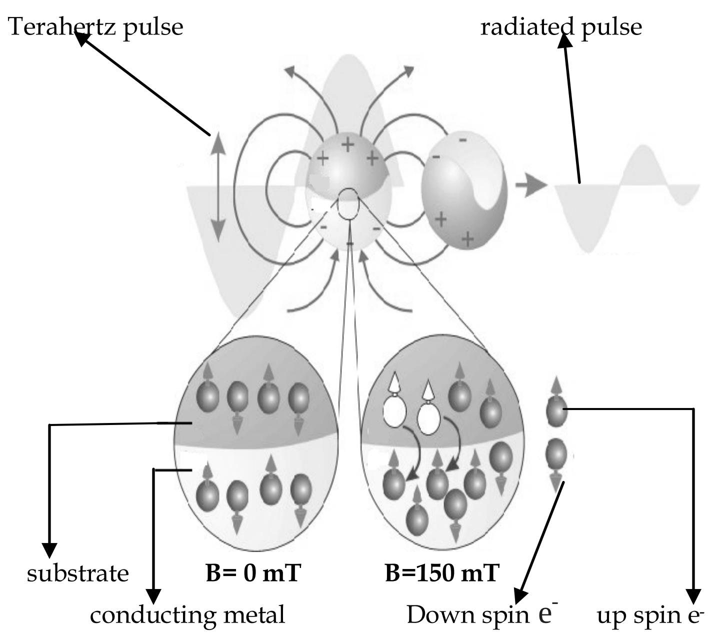

Fig. 2. Principle of Spin Plasmonics

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4 MATHEMATICAL PROOF:

Imaginary permittivity associated with loss component is directly proportional to probability of photon absorption

$\varepsilon \alpha p$.

Probability of photon absorption is proportional to the square of intensity of light incident

$p \alpha I^{2}$.

Intensity of any radiation is the number of photons (packets of energy) falling on a certain area, within some time interval. It is proportional to number (n) of photons and is inversely proportional to time (t) and area of cross-section 'A'.

$I \alpha n/(tA)$.

Each of these photons (assuming them monochromatic, of single wavelength and frequency v) has energy, E = hv with 'h' as constant. Then we have 'I' as,

$I = (nhv)/(tA)$.

Thus by reducing the amount of light (photons) transmitted i.e. for a constant time (t) and area (A), 'I' is reduced.

Since,

$I \alpha p^{1/2}$

as 'I' is reduced, probability of photon absorption (p) is reduced, which in turn reduces the imaginary component of permittivity responsible for loss. Hence the loss in the plasmonster is reduced.

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5 CONCLUSION

By the application of external magnetic field before the incidence of light, it is evident that the power loss in the plasmonster is controlled and practical application of spinplasmonsters is feasible.Thus the spin plasmonster will prove to be the building units of next generation processors with enormous speed in the range of terahertz and memory in the range of petabytes with minimum possible area. With cost effectiveness provided, it is assured that large scale production will definitely revolutionize the communication industry.

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