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Absorption Improvement and EM Spectroscopy in Photodetector based on Plasmonic Effect by Introducing Sio2 Layer and Ag Nano Particles

Omid Davarpanahi, Hasan Rasooli & Sayyed Salar Hosseini

Rajshahi University of Engineering and Technology

Abstract- We have a light detector structure based on plasmonic effects for maximum light absorption at a wavelength of 820 nm have suggested and the two-stage absorption rate to have increased considerably compared to the previous ones. Firstly, by placing layers of glass between gold and the semiconductor GaAs is Grating and secondly embedding silver nanoparticles in the metal Grating gold. With the implementation of each stage can be seen to increase light absorption in the detector in this structure we proposed for the first time we've done it both ways, to intensify the absorption coefficient is 25.83.

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Omid Davarpanahi [α], Hasan Rasooli [σ] & Sayyed Salar Hosseini [ρ]

Abstract- We have a light detector structure based on plasmonic effects for maximum light absorption at a wavelength of 820 nm have suggested and the two-stage absorption rate to have increased considerably compared to the previous ones. Firstly, by placing layers of glass between gold and the semiconductor GaAs is Grating and secondly embedding silver nanoparticles in the metal Grating gold. With the implementation of each stage can be seen to increase light absorption in the detector in this structure we proposed for the first time we've done it both ways, to intensify the absorption coefficient is 25.83.

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I. Introduction

Today, the network of data transmission Such as the fitting of Types of the high-speed chip, Internet and telephone communication has created incentives to build and use light detectors. study of the structure of Light metal-semiconductor-metal detectors-from the early 1970s began[1]. The surface plasmon resonance in the context of the emergence and realization of sub-wavelength aperture to improve the absorption of light. In recent decades a number of experimental work and theory research to study ultra-light transmission through The reviews ultra-light transmission by sub-wavelength aperture is done.[2] Nano grating nano-under-wavelength light creates a robust response and for potential trapping the light in the semiconductor area. Interconnect metal - semiconductor-metal detector electrodes led to a significant increase in bandwidth and reduce the dark current in the detector LED p-i-n structures that have the same active region, is. [3] Detectors plasmonic nano-scale response time due to the distance between the electrodes is about a few tens of picoseconds to the transportation of products from the metal connection is limited. In addition, reducing the distance the electrodes will lead to a reduction in the active region and the decrease in sensitivity. [4] Surface plasmons, which are electromagnetic waves along a metal are released. Properties of their interaction with light, causing surface polariton plasmon waves and create features by which we can photonic components with dimensions much smaller than what has been achieved to build. [5] study and understanding of the plasmons, are widely idea of what began in the 1950s after the article was. These studies also cast a frequent flashpoint of the surface plasmons in thin metal Filter trick of the light scattering of particles of nano metal was done in the early 1970s. Find the improved transmission of light through periodic array of holes with dimensions smaller than the wavelength plasmons in metal films drew much attention. [6]

Author α: Engineering degree and the M.Sc degree in electrical engineering from the "Tabriz" University of Islamic Azad University (Tabriz Branch), Tabriz, Iran. e-mail: o_davarpanahi@nigc-dist8.ir
Author σ: Department of Electrical engineering, Islamic Azad University-Tabriz, Iran. e-mail: h_rasooli@iaut.ac.ir
Auhtor ρ: MSc. degrees in electrical engineering from the Islamic Azad University, Tabriz Science and Research Branch, Tabriz, east azerbaijan, Iran. e-mail: stu.salarhosseini@iaut.ac.ir

a) *The structure design*

Metal-semiconductor-metal detector structure usually consists of three separate parts, including:

A) metal grating, b) sub-wavelength aperture and f) substrate

Is as shown in Figure 1.

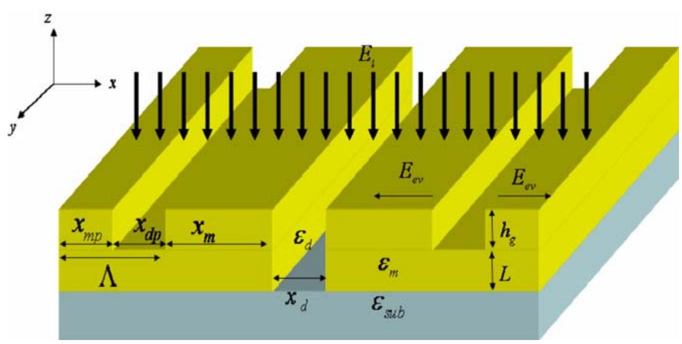

Fig. 1: Structure of the metal detector with diffraction, sub-wavelength aperture and substrate provided by tan and et

Part A metal grating that includes a good conductor and the x axis is parallel grooves. Dimensions has been optimized light wavelength surface plasmon polariton is designed to be coupled along the axis x prompt. Surface plasmon polariton wave vector with a period Λ for metal grating in Equation 1, we see that in 1991 was used by Soole. [1]

$$k_{sp} = \frac{\omega}{c} sin\theta \pm j\frac{2\pi}{\Lambda} = \frac{\omega}{c}\sqrt{\frac{\varepsilon'_m \varepsilon_d}{\varepsilon'_m + \varepsilon_d}} \quad (1)$$

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In relation (1), ω the angular frequency, θ the angle of the incoming light, c is the speed of light in vacuum and permittivity factor in the metal in the form of equation (2) is defined. In reference [1] is mentioned.

$$\varepsilon_m = \varepsilon'_m + i\varepsilon''_m \qquad (2)$$

ε_d is the air permittivity used. Each groove surface plasmon polariton E_{spp} metal grating by electric field excitation and emission during both positive and negative x-axis location will be done. Surface plasmon polariton wave intensity decreases exponentially with propagation distance and depth is a factor that is proportional to permittivity material. [7] The amplification factor of attraction for "normalized power transition metal grating detector on "normalized power no = structure transition metal grating as in reference [7] are used, we define. The surface plasmon polariton by restrictions on slots (not the center) to release the sub-wavelength aperture triggered a wave of surface plasmon polariton light input (which is presented in Figure (1) with E_i) interference (coupling) is.] 2] the total surface plasmon polariton increase optical transmission through sub-wavelength aperture is. In fact, metal grating as collector or lens focused wave in the resonant frequency of the acts. Highly dependent increase in light transmission parameters such as frequency grating x_m and thick metal grating is h_g.[7]

Coupled surface plasmon polariton wave E_{spp} of the incoming wave E_i hybrid transmission t_{12} and it've shown in Figure (2).

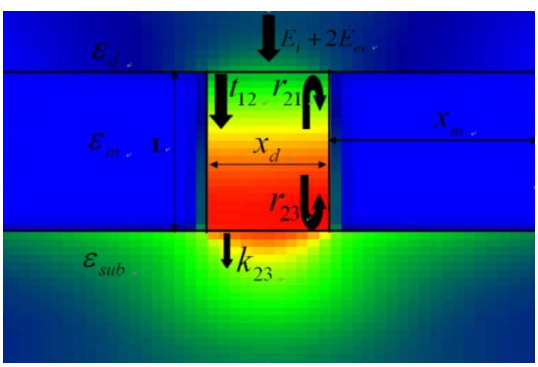

Fig. 2: Modified model of attract high above based the Fabry–Perot model-based presented in reference [8] red zone (where r_{23} located) has a high energy intensity and energy intensity is less water locations

Using semi-analytical calculation Fabry–Perot [8] and formalism expansion mode [2] Green tensor analysis [9] In reference [7] is calculated; When the sub-wavelength aperture width x_d is much smaller than the wavelength of emission λ_0, increase light transmission and improve absorption in semiconductors absorb light transmission caused by metal grating can be achieved. A more accurate model improved light transmission through sub-wavelength aperture as well as by Sturman and et [10] described. Modify the parameters of (1) changes in the semiconductor light transmission is desired wavelength. So we improved the best parameters [7] use.

b) The simulation desired model

In this article we improve absorption in three stages as follows absorbance at a wavelength of 820 nm have the amplification factor, we speak to all three structures. Finite difference time domain simulation models expressed are using.

1. plasmonic optical detector structure with gold grating and gallium arsenide substrate.

We design gold metal grating (Au) and the substrate of gallium arsenide (GaAs) consider. Gold permittivity rate ε_m of Drude-Lorentz model worked in the reference [11] and the coefficient of permittivity substrate (gallium arsenide) ε_sub real value was assumed to be 12.25. The imaginary part for infrared wavelengths were ignored. [12]

Fig. 3-A: proposed framework for gold grating and gallium arsenide substrate detector

In this model, the (3-a) by setting the parameter can be reached absorb light in the desired wavelength, the absorption rate for the model in Figure (3-b) shown is equal to 0.16.

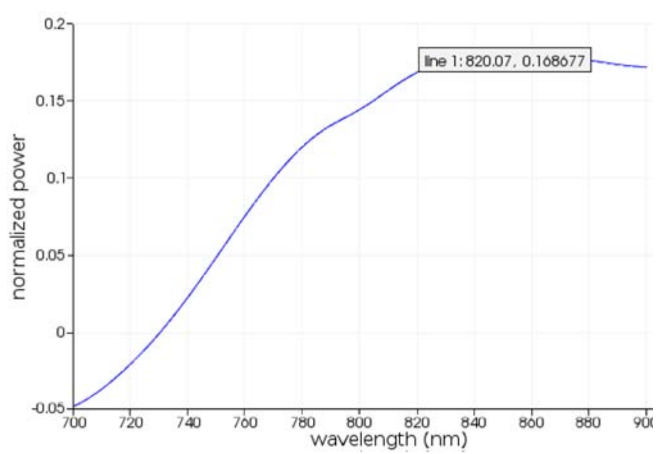

Fig. 3-b: the normalized power absorbance detector with gold grating and gallium arsenide substrate

2. plasmonic optical detector structure with gold grating and substrate layers of glass between gold grating and gallium arsenide substrate

The idea of putting layers of glass (SiO2) between gold grating and substrate gallium arsenide (under sub-wavelength aperture) of the E-plain Tee is a split in the microwave, is used [13] The detector is also used by Jamalpur et al. was. [14] performance glass substrate which is an insulator for the rejection of electron-hole pairs in the semiconductor to metallic connection. To sum carriers on both sides of the gold structure can be used vertically. In this structure, the absorption rate was 0.24. Figure 4 shows a structure in the form of (4-B) absorption at a wavelength of 820 nm curve we see.

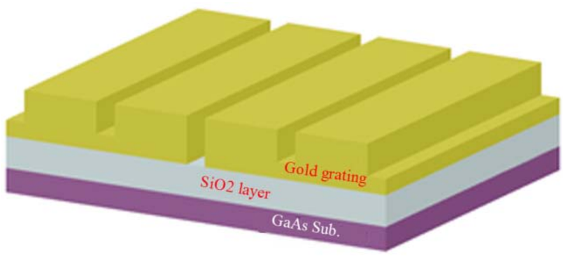

Fig. 4 –A: our proposal model for detector with substrate layers of glass between gold grating and gallium arsenide substrate

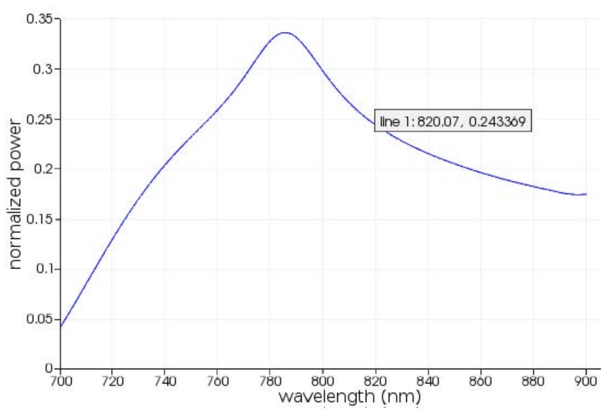

Fig. 4-b: power normalized absorbance detector with substrate layers of glass between gold grating and gallium arsenide substrate

3. plasmonic optical detector structure with silver nanoparticles on glass substrates, between gold grating and gallium arsenide substrate

Our silver nanoparticles under sub-wavelength aperture (in place of glass layer) placed. This is similar to gallium arsenide substrate and intermediate layer of germanium. [15] Due to the high refractive index semiconductor base frequency must be chosen too small metallic nanoparticles. It features some difficult and sensitive process with a common manufacturing techniques. In this structure, the absorption rate was 0.31. Figure 5 shows a structure in the form of (5-b) absorption at a wavelength of 820 nm curve we see.

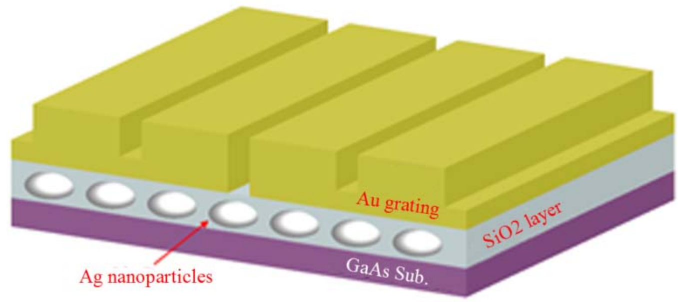

Fig. 5-A: Our proposed model for plasmonic optical detector with silver nanoparticles on glass layer, between gold grating and gallium arsenide substrate

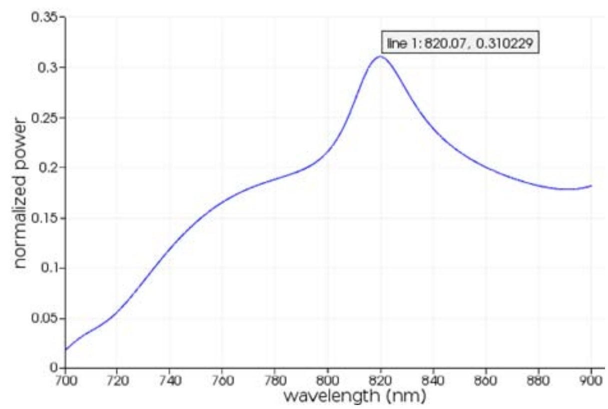

Fig. 5 (b): normalized power absorption optical detector plasmonic with silver nanoparticles on glass layer, between gold grating and gallium arsenide substrate

c) *Data of models*

In this paper, results of the three proposed structure your previous jobs on the graph (1) We compare the amplification factor of attraction for "normalized power transition detector with metal grating" on "normalized power without transition metal grating " in [7] is used to optimize and use our sub-contractor relations.

$$AEF = \frac{P_{npt,g}}{P_{npt}} \tag{3}$$

Explaining the relation (3) is as follows: Absorption Enhancement Factor as the ratio of: the normalized power transmittance of the metal-grating MSM photo detector to the normalized power transmittance of an MSM photo detector structure without a metal grating.

This relationship is expressed for the results of three structures and substrate in the denominator we can use as a reference gallium arsenide. Normalized power transmission substrate gallium arsenide (without metal grating) in the form (6) is shown at a wavelength of 820 nm is equal to 0.012.

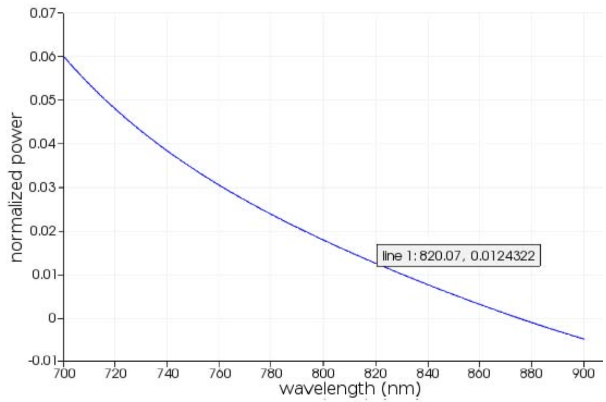

Fig. 6: normalized power transmission gallium arsenide substrate (without metal grating)

4. EM Model

we have established that by performing finite element EM computation to the following expression, the absorption QE, labeled as η, of any detector geometry can be predicted [16]:

$$\eta = \frac{n\alpha}{AE_0^2}\int_V |E_z(\vec{r})|^2 d^3r \qquad (4)$$

where n is the material refractive index of the detector material, α is the absorption coefficient for vertically polarized light, A is the detector area, E0 is the incident electric field from the air, V is the detector active volume, Ez is the self-consistent vertical electric field. Equation (4) states that QE can be calculated from the volume integral of |Ez |2 in the presence of a finite α. Since E0 and Ez are linearly proportional to each other, E0 can be set arbitrarily, and the only input parameter in (1) is the wavelength-dependent α(λ), which can be calculated based on the material layer structure [17]. For a known α(λ), there will be no more free parameters, and the value of η(λ) is uniquely and unambiguously determined. To solve Ez numerically, we use a commercial finite element solver. In addition to η, we also define another quantity, the external QE or ηext , which is QE × pixel area fill factor (≡A/Apitch).

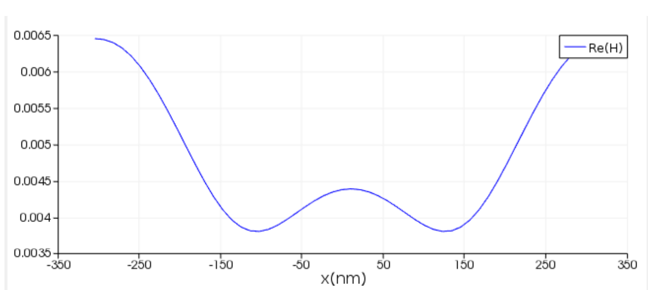

Fig. 7-a: Plot of EM spectroscopy in linear type

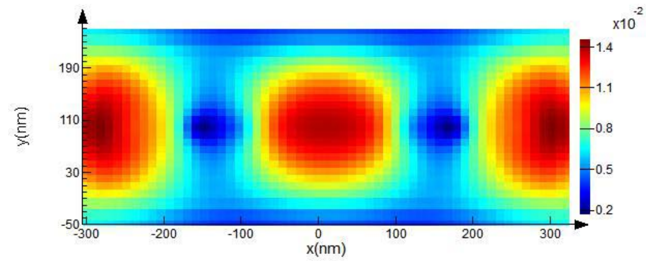

figure 7-b: plot of EM spectroscopy in surface type

Results 1-3 of plasmonic optical detector structure with gold grating and infrastructure in relation gallium arsenide (2), we have:

$$AEF = \frac{0.168}{0.012} = 14 \qquad (5)$$

Which represents an increase absorption due to grating adjusting parameters compared with similar structure. Results of the 2-3 structure plasmonic optical detector with gallium arsenide layers of glass between Gold grating and substrate in equation (2), we have:

$$AEF = \frac{0.243}{0.012} = 20.25 \qquad (6)$$

Results 3-3 of plasmonic optical detector structure with silver nanoparticles on glass substrates, gallium arsenide between Gold grating and infrastructure in equation (2) we have:

$$AEF = \frac{0.31}{0.012} = 25.83 \qquad (7)$$

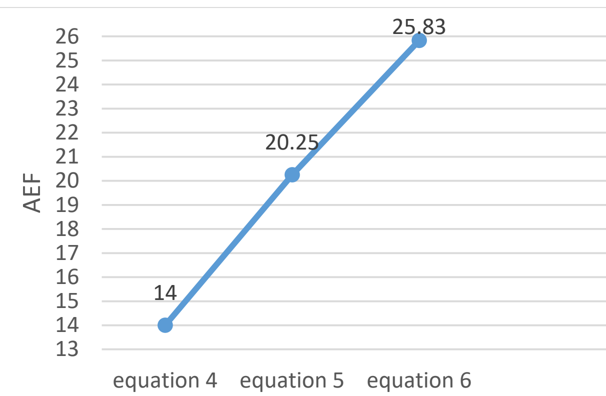

Chart: increased absorption on three structures proposed

II. Simulation Setup

The 3D - plasmonic optical detector structure shown in Fig. 5(a) was simulated using the FDTD software package developed by Lumerical. For the FDTD simulation, we used a mesh size 10nm. This high-resolution sampling yielded convergent solutions at reasonable computation times. A periodic boundary condition was assumed along the y-direction for an incident light wave propagated along the normal direction. perfectly matched layer (PML) boundary condition was assumed along the y-direction to accurately simulate the absorption of the light reflected from the bottom as well as light transmitted from the top boundaries of the simulated plasmonic optical detector structure.

III. Conclusion

In this article we construct the optical detection based on plasmonic effects by improving the detection parameters for maximum light absorption at a wavelength of 820 nm have suggested. We improved amplification factor of attraction even for the initial state, including gold and base gallium arsenide grating was obtained as a result of adjusting parameters grating compared with a similar structure and was 14 times. The coefficient of resonant absorption by adding layers of glass between gold grating and base the amount of gallium arsenide 20.25 for the glass came up with. Then proceeded to put silver nanoparticles on glass substrates that absorb amplification factor increased to 25.83. Compared with previous work Jamalpur and colleagues [14] in 2015 which attracted about 15 have reached the amplification factor, we have increased every neighborhood we have our final difference is the structure of 10.83.

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