Review Article

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Optical Beam Influenced Visibility Including Dual Photonic Crystals

Abstract

We propose a plasmonic graphene structure by depositing two layers of graphene mixed with a thin layer of gold within a silicon lattice. Using the finite-difference time-domain method (FDTD), we study the optical response of the system and observe that the design achieves dual-tunable electromagnetically induced transparency (EIT)-like effects at terahertz frequencies. The EIT-like effect arises from the destructive interference between the light mode of the graphene layer and the dark mode of the gold layer. The EIT-like phenomenon can be tuned by the Fermi level associated with the applied voltage. The results show that the group delay of the present structure reaches 0.62 ps in the terahertz band, the group index exceeds 1200, the maximum delay bandwidth product is 0.972, and the EIT-like peak frequency propagation is up to 0.89. is exposure. This indicates that the slow light performance of the device is excellent. The proposed structure may have promising applications in slow-light devices.

Keywords: Grating • graphene • EIT-like • subwavelength structures

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Introduction

Electronically induced transparency (EIT) is a quantum interference phenomenon that produces strong scattering within the transparency window, resulting in slowed lighting effects and enhanced nonlinear magnetization. We first observed and proposed EIT, but the extreme conditions for achieving quantum EIT limit its development and application [1]. To overcome the limitations of conventional His EIT conditions, researchers studied his EIT-like phenomena in other systems such as: H. Plasma-induced transparency (PIT) is of great interest to researchers. In 2009, Chinese researchers. Publication of research showing that the interaction of dipole and quadrupole patterns in metals provides transparency in Nature Materials. We proposed a planar metamaterial structure with open resonant rings in combination with metal strips to achieve an EIT-like effect [2]. same year. Numerical simulations proposed a metasurface consisting of two identical and orthogonal double-ended half-ring metallic resonators to achieve a polarization-independent EIT-like effect [3]. By introducing an FP resonator into a guided-mode dielectric resonant system, we have achieved an EIT-like effect with a high quality factor [4]. In general, effects like EIT can be excited in two ways. One is due to destructive interference generation between bright and dark modes and the other is due to resonant excitation of trapped modes in planar metamaterials based on structural symmetry breaking. To our knowledge, EIT-like effects have been achieved in some nanostructures, but EIT-like effects are modulated by careful tuning of structural parameters, which limits the applicability of the devices [5]. Graphene, a material with a two-dimensional honeycomb lattice structure, is of great interest in optoelectronic applications due to its high electron mobility and unique doping ability. Investigating its material properties, it was found that graphene has optical properties similar to those of noble metals in the terahertz band and can excite surface plasmas at specific wavelengths. Still, it has some unrivaled advantages over precious metals. For example, the low light absorption results in low resistive losses over a wide frequency range, and the Fermi level in graphene can be artificially controlled by electronic or chemical doping, thus directly tuning the chemical potential. .Adjust the applied voltage without changing the micro-nano model. This excellent tunability and low-loss characteristics make it potentially valuable for applications such as photoelectric detection and light modulation. In addition to tuning by doping and applied voltage, graphene can be tuned by changing other parameters. For example, conductivity and charge carrier concentration are modulated electrically. This tunability is used to further control THz transmission, group delay, and EIT response. It was confirmed by naming and so on that the absorption behavior of srr can be suppressed by increasing the resistivity of the graphene ink [6]. Michael et al. It was suggested that tuning the dielectric thickness between the graphene layers could also change the photoelectric effect. Based on this property, many researchers have applied graphene to design nanostructures in recent years, proposing many tunable devices like his EIT [7]. For example, the proposed graphene substructure. With the chemical potential set to 0.8 eV, the design has a group delay of 0.15 ps and a group exponent of 200 [8].

A planar terahertz-like EIT metamaterial composed of a single-layer graphene microring cavity and a single-layer graphene microstrip cavity has a group delay of 1.49 ps and a group refractive index of 400 due to the thickness studied [9]. In the same year,Demonstrating an EIT-like metasurface that can be used as a refractive index sensor, Tang et al. demonstrated, using ultrafast optically pumped THz probe spectroscopy, a graphene-like EIT metasurface with polarization-controlling features with polarization group delays in the x and y directions reaching 0.06 ps and 0.08 ps, respectively.We have studied negative terahertz photoconductivity phenomena based on photoexcited graphene structures. The device can achieve 18.8% modulation depth at 200 mW pump power [10].showed interesting optoelectronic switching effects and nonlinear gain transfer based on the array structure. Apparently, graphene turned out to be a promising material for EIT-like systems due to its remarkable properties. In this work, his bilayer of graphene and a thin layer of gold were deposited on a silicon lattice to achieve his EIT-like effect tunable at terahertz wavelengths. In the proposed structure, the top and bottom graphene layers are directly excited by the incident light and act as optical modes, whereas the middle gold layer cannot be directly excited and a local strong the gold layer is considered dark mode due to its resonance effect [11]. Destructive interference between bright and dark modes resulted in plasma-induced transparency. A finite-difference time-domain method (FDTD) was used to analyze the transmission characteristics in detail. The results show that the present structure can achieve a double EIT-like phenomenon. The proposed design can achieve a group delay greater than 0.6 ps and reaches a maximum group index of 1240. The peak transmission exceeds 0.89 in the 1-10 THz range [12]. These advantages, including large group delay, high group index, large delay bandwidth product, high transmission efficiency and excellent tuning effect, make the proposed structure a good candidate for slow-light devices [13].

Structure and Theoretical Model

A unit of the designed periodic structure is a schematic diagram of a three-dimensional structure, and (b) is a cross-sectional view thereof. The design consists of two layers of graphene and one of his layers of gold embedded in a silicon lattice. More specifically, the top graphene layer passes through the air grid and is intercalated into the silicon grid at both ends, the middle Au layer is intercalated only in the center of the dielectric silicon, and the bottom graphene layer is intercalated through the air grid. but not the ends inserted into the silicon lattice. By epitaxially growing graphene layers, the chemical potential of graphene in the structure can be tuned by applying a voltage [14]. We assume that the device extends semi-infinitely along the positive y-direction and the graphene layers are separately epitaxialized in the negative y-direction and connected to the electrodes. The structural parameters of the proposed design are: period P = 1000 nm, height H = 150 nm, upper graphene layer width w1 = 920 nm, middle gold layer width w2 = 300 nm, underlying graphene layer w3 = 700 nm, h1 = 25 nm, h2 = 50 nm, h3 = 50 nm, h4 = 25 nm, central thin gold layer thickness h = 16 nm. For the terahertz range at room temperature, we use a Drude-like model to characterize the electrical conductivity of graphene [15].

Results and Discussion

For comparison, we numerically study the transmission spectra of a silicon grid with three material layers (solid black line), top layer graphene only (red dashed line), middle layer thin film gold (blue dashed line), and bottom layer graphene only. (green dashed line) when the graphene chemical potential is set to 0.6 eV. It can be seen that both the top and bottom graphene layers are directly coupled to the incident light, acting as bright modes, and the middle gold layer is not directly coupled to light, but acts as a dark mode. The solid black line is the transmission spectrum obtained from the device when all three layers of graphene and gold are present. It can be seen that destructive interference between two bright states and one dark state produces two EIT-like emission peaks. not only the transmission curve, but also the reflection and absorption curves. It can be seen that this structure has three reflection peaks and the absorption rate is more prominent at two frequency points, mainly due to the absorption loss caused by gold. According to the transmission characteristics, the peak transmission of the two EIT-like transmission peaks is greater than 0.6, and the peak transmission of the frequency transfer can be 0.89. Considering the light absorption of each graphene layer and gold thin layer during disorder, the light transmission of this structure is good. show a decrease in the electric field spectrum 3and 7.0 THz, respectively) when the top and bottom graphene layers are alone, where the electric field is greatly increased at both ends of the graphene. If only the middle gold layer is present, the electric field. Without a significant electric field amplification effect in the entire simulation band, the figure introduces the electric field diagram of the device with a frequency of 3.3 THz. This further illustrates that the top and bottom graphene can be efficiently excited by incident light and act as bright modes, while the middle thin gold layer cannot be efficiently excited by incident light and acts as a dark state.

To investigate the tunability of the device, we examine the transmission and reflection spectra of the device for different chemical potentials. From the figure, we can see that the transmission and reflection spectra of the device shift to higher frequencies as the chemical potential increases from 0.6 eV to 0.7 eV. To more clearly observe the change of each inflection point of the transmission spectrum, we show the change trends of three dips and two peaks of the transmission spectrum. Here dip1, dip2 and dip3 are defined as the three transmission peaks described from lower frequencies to Peak1 and Peak2 from lower frequencies to higher frequencies. It can be seen that the frequencies of the three dips and the two peaks are approximately linearly related to the chemical potential, indicating that the peaks are more sensitive to changes in the chemical potential. Fig. 2 shows the correspondence between the applied voltage and the chemical potential of graphene. To illustrate the process of determining the effects on structural parameters, transmission spectra and group delay spectra of varying the width of the top and bottom graphene layers. Therefore, increasing the width of the top graph has little effect on the peak value and position of the first transmission peak, while the peak value of the second transmission peak changes with increasing width of the graph. You can see that it increases. The time-lapse spectrum shows that the maximum group delay first increases and then decreases as the width of the upper graph increases. Since the purpose of this design is to obtain a device structure with high group delay, this design has potential application value in the slow light effect, so the upper graph width is determined as the value of the maximum group delay point, i.e. will be h, 920 nm. Under conditions where the width of the upper graphene layer does not change (that is, the optimal value chosen is 920 nm), the transmission and group delay spectra show a change in the width of the lower graphene layer. We found that changing the width of the underlying graphene had a significant effect on the peak value and position of the second transmission peak, and that the group delay spectrum also first increased and then decreased as the width of the underlying graphene increased. increase. The width of the underlying graphene is fixed at 700 nm to obtain high group delay. Finally, we investigate the effect of the polarization state of the incident light on the EIT-like effects of this structure. Change in transmission efficiency with polarization angle of incident light. It can be seen that when the TM polarization gradually changes to TE polarization in the frequency range of 1 to 10 Hz, the transmission efficiency decreases as the polarization angle increases. When the polarization angle reaches approximately 75°, the entire transmission spectrum is effectively zero. At the same time, the group delay and group refractive index gradually decrease as the phase change becomes smaller and smaller. Both the group retardation and the group refractive index are nearly zero when the TM wave is completely converted to a TE wave. The EIT effect essentially vanishes. We find that in the range 1–10 THz, the device is relatively sensitive to the polarization mode of the incident light, and TE-polarized waves cannot pass through highly transmissive structures.

Conclusions

In summary, we propose and numerically demonstrate a dynamically tunable EIT-like device in the terahertz range. The proposed structure is made of two layers of graphene, one layer of gold film, and a silicon grating. The two layers of graphene can strongly couple to the incident electromagnetic wave under the excitation of the periodic grating. The layers of graphene and gold operating in bright and dark modes, respectively, coupled with each other to produce two EIT-like transmission peaks. The spectral resonance position can be tuned by adjusting the chemical potential of graphene. The device utilizes a skinny thickness to achieve a large group delay while maintaining high transmittance. The slow light effect of the design is superior to most known similar structures. The maximum group delay reaches 0.62 ps, the group refractive index is 1240, the delay-bandwidth product reaches 0.972, and the maximum peak transmittance exceeds 0.89. The proposed structure has good prospects for applications in the fields of slow light, switching, and communication.

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