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BISTABILITY OF NONLINEAR SURFACE POLARITONS IN CONDUCTING ANTIFERROMAGNETS

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ABSTRACT

The paper deals with the theoretical investigation of the hysteresis effects and bistability states arising from the excitation of the s-polarized surface polaritons (SP) with the attenuated total reflection (ATR) technique at the nonlinearly conducting antiferromagnet boundary. We emphasize the analysis of influence of the electron plasma frequency on the conditions of bistability appearance. It is found that there exists a critical value of the plasma frequency at which the bistabiliy vanishes.

INTRODUCTION

Today the investigations of semimagnetic semiconductors attract many efforts [1-3]. This interest is stipulated by the fact that semimagnetic semiconductors possess magnetic and electron subsystems, which influence on each other. Semimagnetic semiconductors in the phase of antiferromagnetic ordering are of great interest from the viewpoint of millimeter and submillimeter wave applications. This phase is interesting because the antiferromagnetic resonance frequency of semimagnetic semiconductor lies exactly in this waveband. It can be used for both noncontact diagnostics of parameters of semimagnetic semiconductors and for the creation of radically new devices of semiconductor microelectronics.

As known, surface polaritons (SP) can exist in conducting antiferromagnets [4,5]. The propagation of large amplitude SP (nonlinear SP) results in a number of new features, which are concerned with the dependence of the dielectric permittivity of semimagnetic semiconductor on the electric field intensity [6]. For nonlinear SPs the dependence of their spectra on the electric field intensity at the media interface and the monotonic and non-monotonic character of the decaying electromagnetic field in the nonlinear medium are typical.

The present paper deals with the theoretical investigation of the hysteresis effects and bistability states arising from the excitation of nonlinear SP with the attenuated total reflection (ATR) technique at a nonlinear conducting antiferromagnet boundary. As conducting antiferromagnets, we use semimagnetic semiconductors in the phase of antiferromagnetic ordering. We place emphasis on the investigation of the influence of the electron plasma frequency on the conditions of bistability appearance.

THE PROBLEM STATEMENT

We assume that a semimagnetic semiconductor is in the phase of antiferromagnetic ordering and can be simulated by an easy-axis two-sublattice conducting

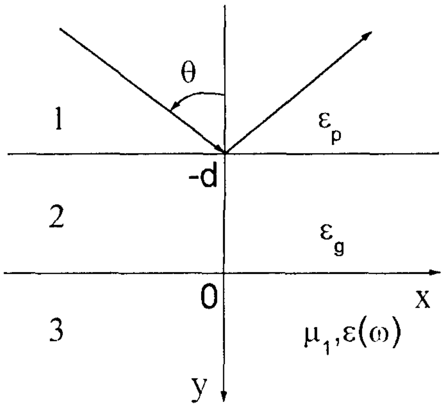

Fig.1. The geometry of the problem.

antiferromagnet with a magnetic permeability μ_1 [4,5]. Fig.1 shows the geometry of problem. Media 1 and 2 are the dielectrics with the dielectric permittivities ε_p and ε_g respectively. Medium 3 is a semimagnetic semi-conductor. We suppose that $\varepsilon_p > \varepsilon_g$ and the external wave, which is incident at the boundary, $y = -d$, propagates at an angle θ exceeding the angle of total external reflection. The easy axis of the antiferromagnet (the z-axis) is directed along the media interface. We shall consider s-polarized nonlinear SP ($E_x = E_y = H_z = 0$), the wave vector $\vec{k}$ of which is directed along the x-axis. The antiferromagnet dielectric constant $\varepsilon(\omega)$ is supposed to depend on the electric field intensity $|E_z|^2$ and has the form $\varepsilon(\omega) = \varepsilon_{(0)}(\omega) + \delta|E_z|^2$, where $\varepsilon_{(0)}(\omega)$ is the linear part of the dielectric constant, δ is the nonlinearity parameter, ω is the nonlinear SP frequency.

We have shown previously that on the antiferromagnet-dielectric boundary there exist the nonlinear SPs with both monotonic and non-monotonic decay of the electromagnetic field in the nonlinear medium [6]. The frequency ω of the nonlinear SP is found to depend on the value of $\Omega_p = \omega_p / \omega_r$, where ω_p and ω_r are the electron plasma frequency and antiferromagnet resonance frequency, respectively.

In this paper we have found a reflection coefficient R of the external wave which is incident at the boundary $y = -d$. We have revealed the bistability states in the dependence of R on the intensity of the incident wave. It has turned out that the appearance of the bistability depends also on the value of Ω_p. It has been found that there exists the critical value Ω_{pc}, at which the bistabiliy vanishes. The dependence of Ω_{pc} on the value of dimensionless frequency $\Omega = \omega / \omega_r$ has been investigated.

NUMERICAL RESULTS

Fig.2 shows the dependence of the reflection coefficient R (left coordinate axis, solid lines) and the reflected wave intensity I_r (right coordinate axis, dashed lines) on the incident wave intensity I_i for the nonlinear SP with a monotonic decay of the electric

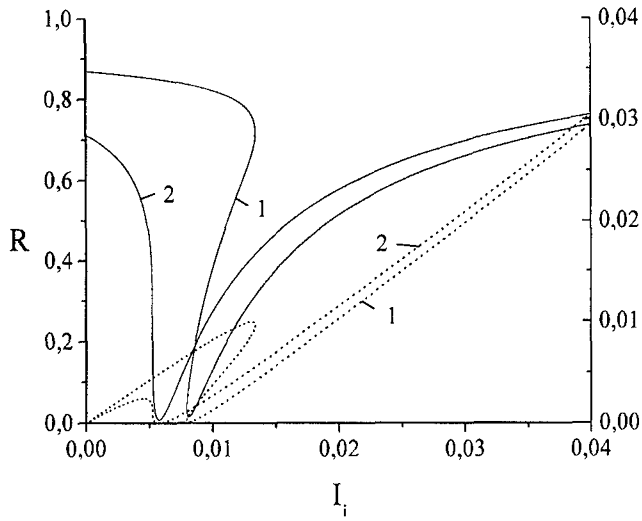

Fig.2

field at $\Omega = 1{,}004\omega_r$, $d = 0{,}8c/\omega_r$, $\nu = 0{,}01\omega_r$, $\Gamma = 0{,}0001\omega_r$ for two values of Ω_p: 1 - $\Omega_p = 0{,}5$; 2 - $\Omega_p = \Omega_{pc} = 0{,}641$. ($c$ is the velocity of light, d is the dielectric-gap thickness, ν and Γ are the energy loss parameters in electronic and magnetic subsystems of the semimagnetic semiconductors, respectively) The intensity of the reflected and incident waves are given in the units of $|\mathrm{E}_{\max}|^2$, $\mathrm{E}_{\max} = (c\alpha_{s0}/\omega)\sqrt{2/|\mu_1\delta|}$ is the amplitude of the nonlinear SP, $\alpha_{s0}^2 = k^2 - \omega^2\mu_1\varepsilon_{(0)}/c^2$. It is evident from Fig.2 that at $\Omega_p = \Omega_{pc}$ (curves 2) the bistability of the reflection coefficient of the nonlinear SP vanishes.

CONCLUSIONS

To conclude, it should be emphasized that bistability states arising from an SP excitation on a nonlinear conducting antiferromagnet boundary can be used for the creation of the memory elements in microwaves. Besides, switching devices having parameters depending on the electron concentration in the conducting antiferromagnet can be developed.

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