Near-Field Pattern Images of a Cylindrical Plasma Column

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***Abstract*—This paper demonstrates abilities of plasma columns to reflect and transmit radiation, and excitation of surface plasmons is also shown. Images of near-field patterns are obtained based on analytical eigenfunction-series solution.**

***Index Terms*—Numerical simulation, plasmas, plasmons, time domain analysis.**

STRONG INTEREST in the electromagnetic wave propagation and scattering in the presence of plasma objects is due to the wide range of potential applications of such study. Tuning of resonant characteristics of microdisk resonators by free-carrier plasma injections can be used in active switches or tunable filters [1]. Transient phenomena in plasma lead to the possibility of the frequency upshifting and the generation of waves [2], [3]. Using resonators composed of negative-permittivity materials such as plasma can form the basis of effective small-size antenna elements [4]. Plasmonic covers near their plasma resonance can make the object nearly invisible to an external observer [5].

Plasma is used in the light-modulated photoinduced method for the development of a nonmechanical millimeter-wave scanning technique [6]. A plasma–dielectric sandwich structure can be used as a tunable bandpass filter in the microwave range [7]. Here, the center frequency of the passband and also the bandwidth can be electrically tuned by varying the electron density of the plasma that can be controlled by a voltage applied across the plasma electrodes. Plasma-based lenses with properties adjusted electronically by varying in time the density of plasma offer an alternative to existing electronic beam steering systems [8].

Suitable columns of plasma can be used in the design of both transmitting and receiving antennas [9] with very broad frequency range and tunability that allows switching it on and off very fast. The main advantage of a plasma antenna over the conventional antennas is due to the possibility to control antenna parameters by tuning plasma properties. It has been shown experimentally that arrays of vertical plasma antennas produce more directive radiation patterns than a single plasma antenna [10]. Therefore, accurate modeling of process in plasma is of great importance.

We consider a 2-D cylindrical plasma column of infinite extent with a radius denoted by R which is filled by cold homogeneous plasma with frequency ω_p. The ambient medium is a vacuum characterized by material parameters (ε_0, μ_0), where ε_0 is the free-space permittivity and μ_0 is the free-space permeability. Electromagnetic field in the column is excited by a TE polarized plane wave with ω being the angular frequency and $\lambda = 2\pi/\omega\sqrt{\varepsilon_0\mu_0}$ being the free-space wavelength. The analytical eigenfunction-series solution is constructed [3] based on the Mie formalism. The simulation data for the images were generated using MatLab and present the absolute value of the total magnetic field distribution inside as well outside the cylinder for different values of parameters.

At frequencies below the plasma frequency, the plasma is a good reflector. Fig. 1(1) shows this property and corresponds to the case when $\omega_p/\omega = 1.1$ and $\lambda = 0.2\pi R$. Fig. 1(2) shows the field for $\omega_p/\omega = 0.5$ and $\lambda = 0.1\pi R$. Here, the incident wave frequency is greater than the plasma frequency, and consequently, the column is transparent for radiation. It is seen a clear beam formation in the opposite side of the column. Moreover, two very narrow and intensive lateral beams are observable. The excitation of surface plasmon resonance modes is shown in Fig. 1(3) and (4). For both of them, $\omega_p/\omega = 2$; $\lambda = 0.4\pi R$ in Fig. 1(3), and $\lambda = 0.2\pi R$ in Fig. 1(4). The number of lobes increases with decreasing wavelength.

In conclusion, the images have shown the ability of plasma to reflect and transmit radiation. Images of surface plasmons have been presented.

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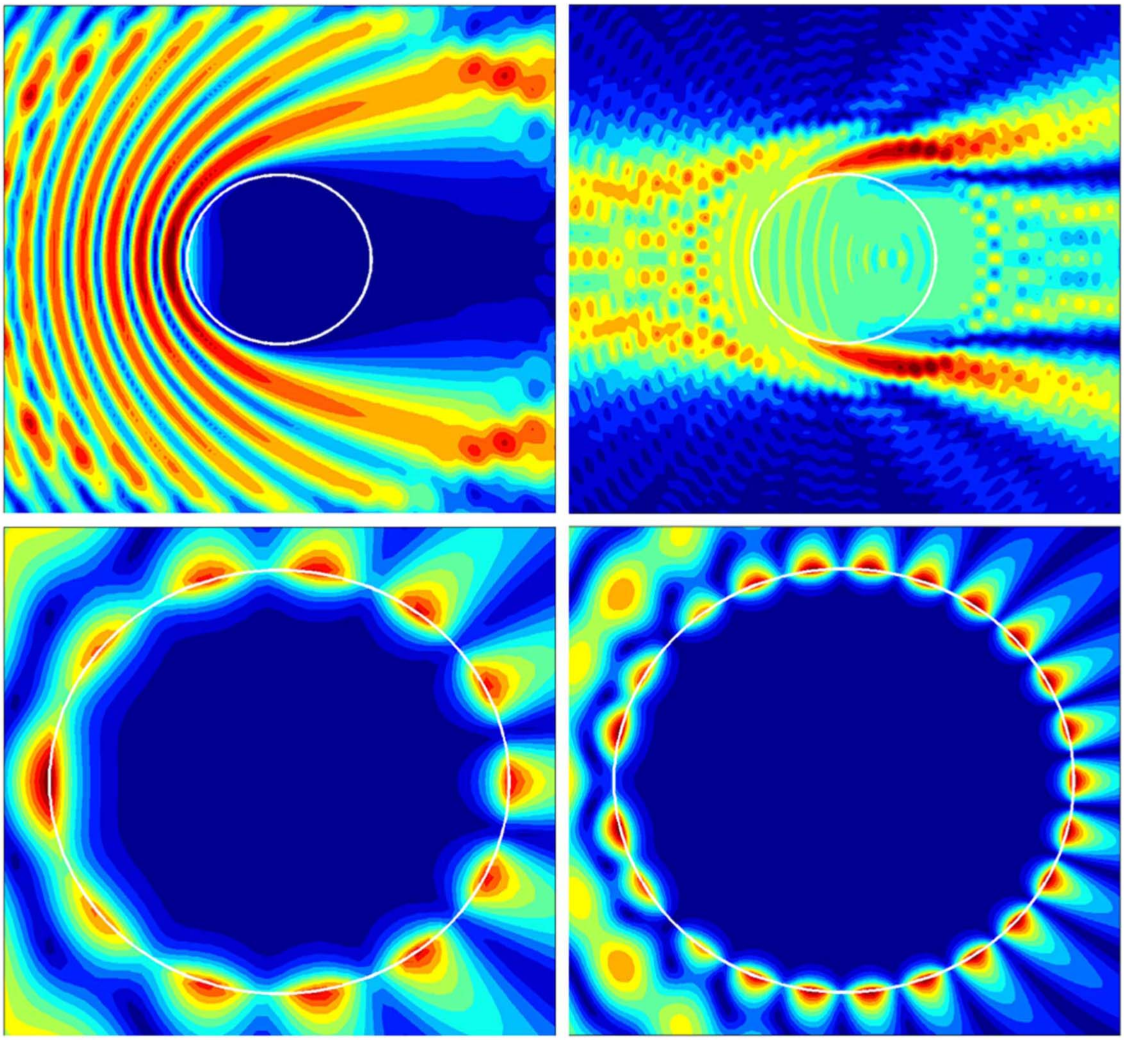

Fig. 1. Spatial distribution of the absolute value of magnetic field. (1) $\omega_p/\omega = 1.1$ and $\lambda = 0.2\pi R$. (2) $\omega_p/\omega = 0.5$ and $\lambda = 0.1\pi R$. (3) $\omega_p/\omega = 2$ and $\lambda = 0.4\pi R$. (4) $\omega_p/\omega = 2$ and $\lambda = 0.2\pi R$.

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