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Characteristics of Intensity and Generation Time of Localized Circularly Polarized Light for All-Optical Magnetic Recording

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Abstract: All-optical magnetic recording with circularly polarized light has attracted attention for developing ultra-high speed recording. Plasmonic antennas have been designed to localize the circularly polarized light for higher density magnetic recording. In this paper, we investigate the relation between the intensity and the generation time of localized circularly polarized light.

1. Introduction

For high speed and high density magnetic recording, all-optical magnetic recording with localized circularly polarized light has attracted attention[1-3]. It is necessary to study the generation time of the localized circularly polarized light for faster recording. In this paper, we investigate the relation between the intensity and the generation time of localized circularly polarized light in terms of the Stokes parameters[4].

2. Computational methods

The ADE-FDTD method[5] is applied to simulate the near-field light of dispersive media expressed by the Drude model[6]. In this computation, the finite difference equation for the electromagnetic fields and polarization current are expressed as follows:

$$\mathbf{H}^{n+1/2} = \mathbf{H}^{n-1/2} - \frac{\Delta t}{\mu_0}\left(\nabla \times \mathbf{E}^n\right), \quad (1)$$

$$\mathbf{E}^{n+1} = C_1 \mathbf{E}^n + C_2\left[\nabla \times \mathbf{H}^{n+1/2} - \frac{1}{2}\sum_{l=0}^{K}\left\{(1+\alpha_l)\mathbf{J}_l^n - \gamma_l \mathbf{P}_l^n\right\}\right], \quad (2)$$

$$\mathbf{J}_l^{n+1} = \alpha_l \mathbf{J}_l^n + \beta_l\left(\mathbf{E}^{n+1} + \mathbf{E}^n\right) - \gamma_l \mathbf{P}_l^n, \quad (3)$$

$$\mathbf{P}_l^{n+1} = \mathbf{P}_l^n + \frac{\Delta t}{2}\left(\mathbf{J}_l^{n+1} + \mathbf{J}_l^n\right). \quad (4)$$

The three dimensional mesh size $1.0\times1.0\times1.0$ nm^3 and the time increment 1.9×10^{-18} s are used. Figure 1 shows the plasmonic cross antenna model with bit-patterned media. Materials of the antenna and the recording media are gold and cobalt. The particle parameters are selected for realizing 2 Tbit/inch^2 recording density. The incident light is assumed to be a linearly polarized sinusoidal plane wave propagating in the negative *z*-direction. The amplitude of the electric field is 1.0 V/m and the wavelength is 780 nm. Here, θ is an angle formed by the *x*-axis and the electric field component of the incident light on the *x*-*y* plane. The observation point is at the center of the target particle.

3. Numerical results

We analyze the plasmonic cross antenna with bit-patterned media to determine the *x*-length and *y*-length of this antenna shown in Figure 1. The characteristics of this antenna are investigated to produce the phase difference between the *x* and *y* components of the electric fields.

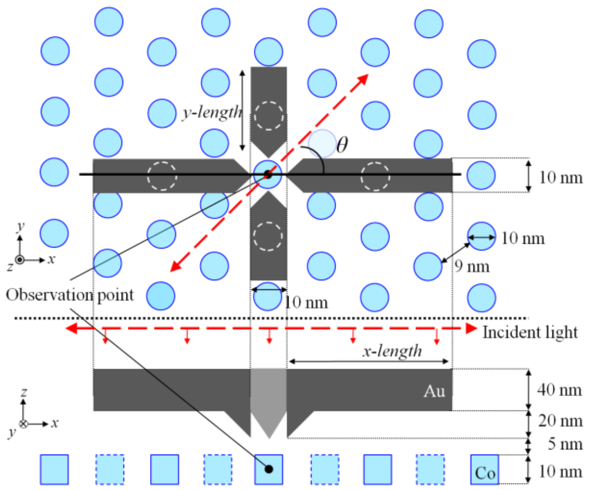

Figure 1. Plasmonic cross antenna model with bit-patterned media.

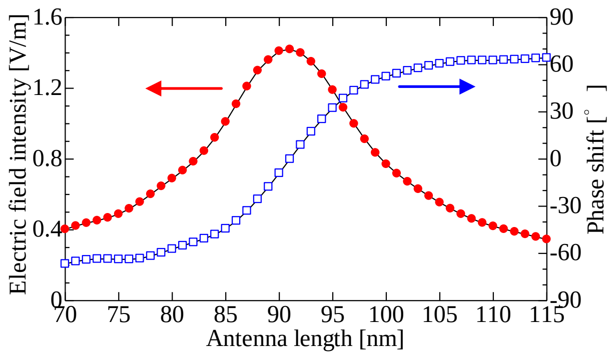

Figure 2. Characteristics of the electric field intensity and phase shift at the observation point.

Figure 2 shows the characteristics of the electric field intensity and the phase shift at the observation point. To investigate the characteristics of the electric field in one direction, the *x*-length is varied from 70 to 115 nm, the *y*-length is constant, and the angle θ is 0 deg to examine the electric field intensity. The phase shift is assumed to be 0 degree for which the intensity becomes the maximum.

Considering the characteristics described in Figure 2, we can select some combinations of the *x*-length and *y*-length for which the difference of the phase shift becomes 90 deg. One of such combinations is 98 and 85 nm to generate the localized circularly polarized light from a linearly polarized light.

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Here, we consider the Stokes parameters which represent the total intensity enhancement I and the degree of circular polarization C' as follows:

$$I = \langle E_x^2(t) \rangle + \langle E_y^2(t) \rangle + \langle E_z^2(t) \rangle, \quad (5)$$

$$C' = 2\langle E_x(t) E_y(t) \sin(\delta_x - \delta_y) \rangle / I. \quad (6)$$

The intensity and the generation time of the localized circularly polarized light are evaluated by using these parameters.

Figure 3 shows the Lissajous curve at the observation point when the x-length = 98 nm, the y-length = 85 nm, and the angle $\theta = 41.7°$. A clockwise circularly polarized light is generated from a linearly polarized light. The intensity I becomes 0.96 $(V/m)^2$ in steady state. Figure 4 shows the time response of the E_x and E_y in the same conditions as in Figure 3. It takes 21.0 fs to achieve that the circularity C' becomes over 90 %.

Figure 5 shows the Lissajous curve at the observation point when the x-length = 94 nm, the y-length = 71 nm, and the angle $\theta = 41.7°$. A clockwise circularly polarized light is generated. The intensity I becomes 0.32 $(V/m)^2$ in steady state. Figure 6 shows the time response of the E_x and E_y in the same conditions as in Figure 3. It takes 18.2 fs to achieve that the circularity C' becomes over 90 %.

4. Conclusions

Plasmonic antennas to generate the localized circularly polarized light are analyzed for all-optical magnetic recording. We investigate that the characteristics of the localized circularly polarized light are different by changing the combination of the antenna lengths. When we select the combination of the highest intensity, the generation time becomes the longest.

5. Acknowledgments

This work was partly supported by Grant-in-Aid for Scientific Research (C) (22560349), CASIO Science Promotion Foundation, and Nihon University Strategic Projects for Academic Research.

6. References

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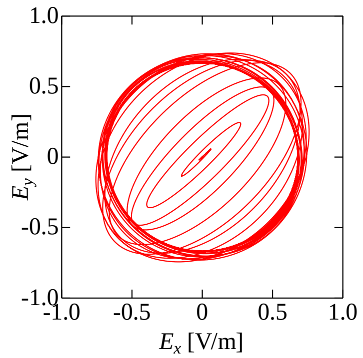

Figure 3. Lissajous curve for x-length = 98 nm, y-length = 85 nm, and $\theta = 41.7°$

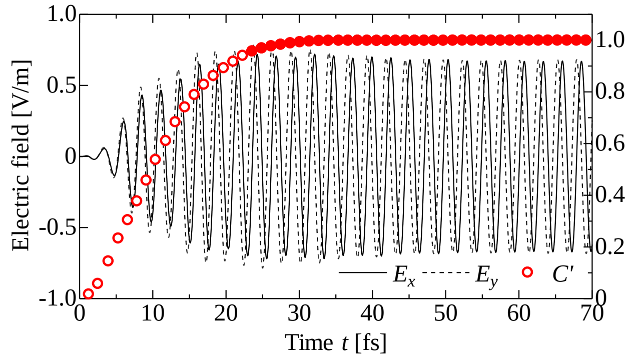

Figure 4. Time response of the electric fields for x-length = 98 nm, y-length = 85 nm, and $\theta = 41.7°$

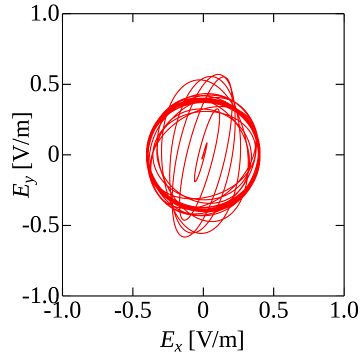

Figure 5. Lissajous curve for x-length = 94 nm, y-length = 71 nm, and $\theta = 71.7°$

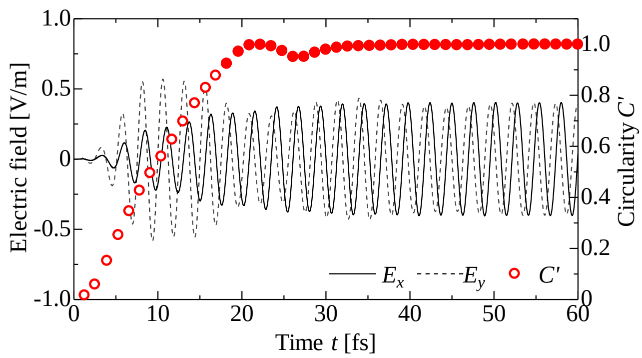

Figure 6. Time response of the electric fields for x-length = 94 nm, y-length = 71 nm, and $\theta = 71.7°$