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Design of Plasmonic Waveguides for a High Sensitivity Photodetector

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Abstract: A photodetector composed of plasmonic waveguides and nano niobium wires inside an optical fiber is designed for developing photonic technology. The plasmonic waveguide model is investigated for concentrating electromagnetic energy in a niobium nano wire as a high sensitivity photodetector.

1. Introduction

For developing photonic technology, a photodetector composed of plasmonic waveguides and niobium nano wires inside an optical fiber has attracted attention [1][2]. In this paper, we design and discuss the novel photodetector which is able to concentrate and absorb the electromagnetic energy inside the niobium nano wire.

2. Computational methods

To compute electromagnetic fields in a dispersive medium, the FDTD method with the ADE method [3] is applied. In computational analysis, the smallest cell size is $0.5\times0.5\times30.0$ nm^3 and the absorbing boundary condition is the CPML. The plasmonic waveguide with the niobium nano wire in SiO_2 is illustrated in Figure 1. We select the parameters of the plasmonic waveguide such as the thickness h = 16 nm, width w = 5 μm, and length ℓ = 30 μm. The incident light is a Gaussian beam propagating in the negative z-direction as shown in Figure 2 and the wavelength is 1550 nm. The materials of the waveguide and nano wire are gold and niobium expressed by the Drude model[4], respectively.

3. Numerical results

Figure 3 shows distribution of the electric field intensity when the metal stripe is considered as the plasmonic waveguide. We can confirm that strong electric field intensity is obtained around the metal stripe.

Figure 4 shows the normalized energy through the area S which is on the x-y plane at z = 26μm. The electromagnetic energy is evaluated by

$$W(S) = \int_t \int_S |\mathbf{E}\times\mathbf{H}| dS\, dt \,. \qquad (1)$$

The horizontal axis means the electromagnetic energy normalized by the energy of the incident light.

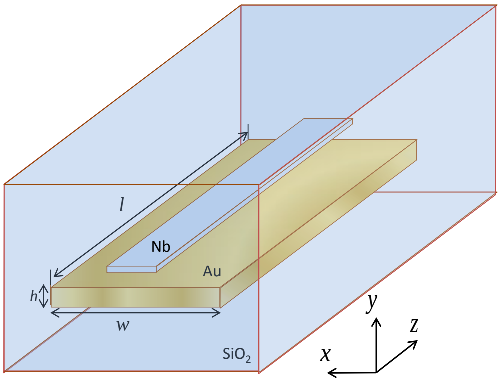

Figure 1. Plasmonic waveguide with the Nb wire.

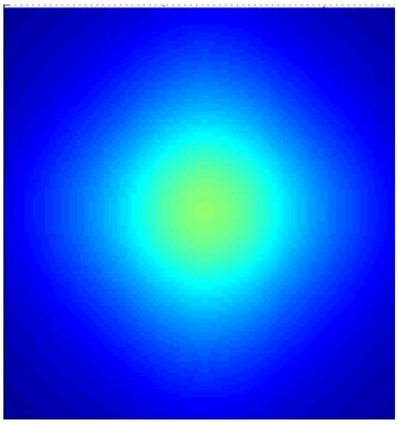

Figure 2. Distribution of the electric field intensity without the metal stripe.

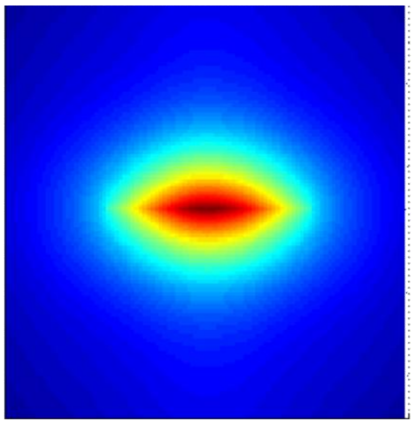

Figure 3. Distribution of the electric field intensity with the metal stripe.

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The vertical axis means the area size which corresponds to the percentage of the electromagnetic energy in the horizontal axis. It is shown that the higher electromagnetic energy is obtained in a smaller area when the metal stripe is placed inside the optical fiber.

Figure 5 shows distribution of the electric field intensity on the *x*-*y* plane at *z* = 26 μm. The distribution near the niobium nano wire is constant without the metal stripe as shown in Figure 4 (a). When the metal stripe is placed inside the optical fiber, the enhanced electric field intensity is observed near the metal stripe as shown in Figure 5 (b).

Table 1 shows the electromagnetic energy in the niobium nano wire. The internal normalized energy is 0.42μ in the niobium nano wire without the metal stripe. When the metal stripe is placed, the internal normalized energy is 1.25μ in the niobium nano wire. The electromagnetic energy in niobium nano wire is absorbed three times.

4. Conclusions

We discussed a photodetector which was able to concentrate and absorb electromagnetic energy and absorb energy inside the niobium nano wire. In the case of a metal stripe placed inside the optical fiber, we can confirm that the strong electric field intensity is concentrated around the metal stripe. The internal energy ratio of the niobium nano wire is increased about triple.

5. Acknowledgments

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6. References

[1] L. Chen, T. Zhang, X. Li, and W. Huang : Opt. Express, Vol.20, No.18, pp.20535-20544, 2012.

[2] Y. Sekiguchi, S. Ohnuki, G. Fujii, and S.Inoue : IEICE Society Conference 2012, C-15-16, September 11-14, 2012, Toyama University, Toyama.

[3] T. Yamaguchi, and T. Hinata : Opt. Express, Vol.15, No.18, pp11481-11491, 2007.

[4] A. D. Rakić, A. B. Djurišic, J. M. Elazar, and M. L.Majewski : Opt., Vol.37, No.22, pp.5271-5283, 1998.

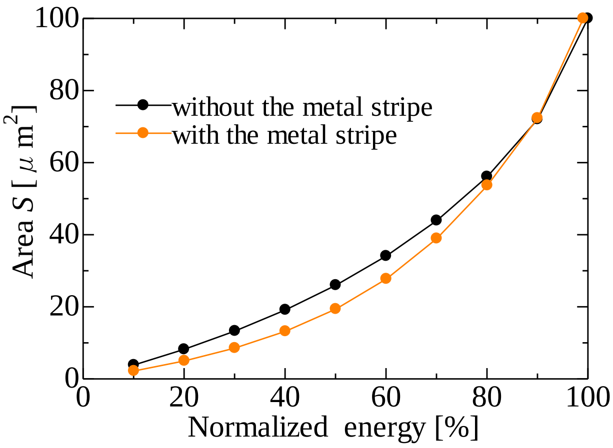
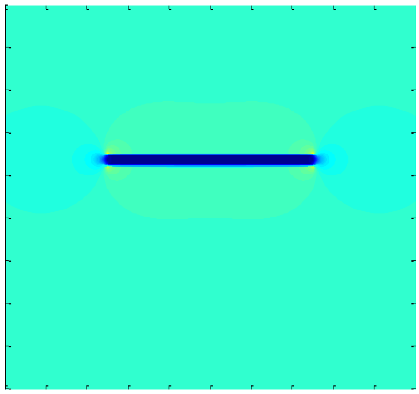
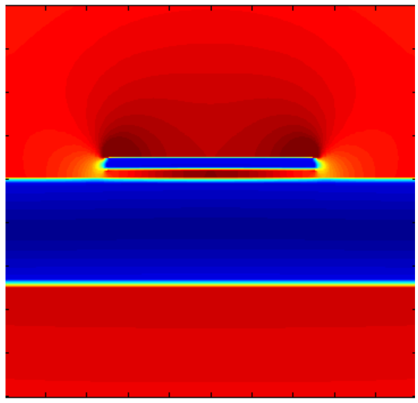


Figure 4. Concentration rate of energy.



(a)Without the metal stripe.



(b) With the metal stripe.

Figure 5. Distribution of the electric field intensity.

Table 1. Energy in Nb nano wire.

	Normalized Energy	Energy ratio
Nb wire	0.42e-006	1.00
Nb wire with Au stripe	1.25e-006	2.98