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Transmission of terahertz wave through one-dimensional photonic crystals containing single and multiple metallic defects

Source

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Abstract

We investigated numerically and experimentally the transmission of terahertz (THz) waves through single and multiple metallic defects created in a one-dimensional (1D) photonic crystal (PC) by inserting single metallic wires or arrays of parallel metallic wires into the air-gap defect of the 1D PC. The transmission properties of the metallic defect modes generated in the photonic bandgap (PBG) were characterized by using THz time-domain spectroscopy. For single metallic defects, it was found that the appearance the defect mode depends not only on the diameter of the metallic wires but also on the polarization of the THz wave. For transverse magnetic (TM) polarized waves whose electric fields are parallel to the metallic wires, the incident THz wave is generally split into two identical parts. In sharp contrast, the excitation of surface plasmon polaritons (SPPs) with enhanced field intensity is observed for transverse electric (TE) polarized waves whose electric fields are perpendicular to the metallic wires. In both cases, two resonant modes with reduced transmittance are observed in the PBG. While the resonant mode related to SPPs is found at the long-wavelength side of the original defect mode, the resonant mode without the excitation of SPPs appears at the short-wavelength side. Numerical simulation based on the finite-difference time-domain (FDTD) technique revealed that the electric field of SPPs is more tightly confined at the surface of the metallic wire when it is placed in the PC, implying that the confinement of a THz wave in the propagation direction will facilitate the localization of SPPs in the transverse direction. For two parallel metallic wires, the defect mode was found to depend on the separation between them. If they are widely separated, then the excitation of SPPs is similar to that observed in single metallic wires. However, the excitation of dipole-like SPPs does not occur for two closely packed metallic wires because of their large lateral size. It was also revealed that two parallel metallic wires with a small diameter and a narrow separation could be employed to achieve a significant enhancement, as large as 21.6, for the electric field in between them. More interestingly, the enhancement factor becomes larger when the confinement of the electric field in the propagation direction is increased. For an array of four widely separated wires whose lateral dimension is wider than the diameter of the THz beam, only one resonant mode is observed at the long-wavelength side of the original defect mode. The experimental observations are in good agreement with the simulation results based on the FDTD technique. The enhanced concentration of the electric field of SPPs at the surfaces of metallic defects may be useful for focusing and sensing of THz waves. (C) 2011 American Institute of Physics.