Subwavelength Focusing of GHz Radiation by 2D Metamaterials Demonstrated

Metamaterials, or "left-handed" materials, are artificial structures that exhibit negative permittivity (ε) and permeability (μ) for certain frequencies of electromagnetic waves. This property can be utilized for focusing electromagnetic radiation through negative refraction. In particular, a material with $\varepsilon = -1$ and $\mu = -1$ has been predicted to focus light beyond the diffraction limit. In the March 15 issue of *Optics Letters* (p. 814), I. Bulu and co-workers at Bilkent University in Ankara, Turkey, have reported subwavelength focusing of GHz radiation by metamaterials based on a labyrinth structure.

The labyrinth structure was obtained by modifying the split-ring resonator structure commonly used in metamaterial systems. It has four concentric rings, 0.15 mm thick, with two slits on each ring. The unit cell consists of two thin substrates of dimensions 8.8 mm × 8.8 mm oriented at 90° with respect to each other. Standard printed circuit board manufacturing methods are used to print the copper labyrinth structure on one side of the substrate and copper wire stripes, 2.5 mm wide, on the other side. The copper thickness was 0.05 mm. The whole sample has length, width, and height of 68, five- and 20-unit cells, respectively. Calculations show that this metamaterial system exhibits a negative refractive index for frequencies ranging from 6.1 GHz to 6.4 GHz, with $n = -1$ at around 6.3 GHz.

Using monopole antennas as source and receiver, the researchers measured the electric-field intensity over an area of 100 mm × 200 mm on the output face of the metamaterial. Examination of intensity profiles at 6.3 GHz along the horizontal and vertical directions of the output face revealed that radiation from the source can be focused to a spot size as small as $\lambda/4$. The researchers said that this demonstration of subwavelength focusing of electromagnetic waves by metamaterials in free space may find useful applications in the field of imaging.

TUSHAR PRASAD

Slow Light Efficiently Coupled Along Bends in Photonic Crystal Waveguide

Photonic crystals are periodic dielectric structures capable of manipulating light propagation in a variety of novel ways. Unlike conventional optical fibers, waveguides based on photonic crystals can channel light efficiently around very sharp bends and are considered to be the routing devices for the next generation of integrated optics. Straight photonic crystal waveguides allow all waveguide modes to transmit. However, light at wavelengths close to the onset of the waveguiding mode—that is, in the regime of a very large group velocity dispersion that could be consistent with a greatly reduced group velocity (slow light)—does not transmit through photonic crystal waveguides with bends. In the March 15 issue of *Optics Letters* (p. 745), S. Assefa and co-workers at IBM T.J. Watson Research Center in Yorktown Heights, N.Y., have shown that light transmission at wavelengths commensurate with slow light can be improved by optimized design of the photonic crystal waveguide bend.

Using conventional semiconductor processing technology, two-dimensional photonic crystals (lattice constant a = 437 nm) with a triangular lattice of holes (radius $r = 0.23a$) were fabricated on silicon-on-insulator wafers. Waveguides were created by removing a row of holes along the Γ–K direction, and up to 20 bends were incorporated into the whole waveguide structure by cascading straight waveguides at 60° with respect to each other. Transmission measurements estimate the loss per bend to be very low but also reveal that the long-wavelength cutoff is blueshifted by about 30 nm with respect to a straight waveguide. That blueshift