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An Optical Diode From Nonlinear Light Absorbers

An interesting study was taken up by Dr. Reji Philip of the Raman Research Institute, Bangalore, on a novel kind of optical diode, while he was working on a sabbatical in the research group of Prof. D.V.G.L.N. Rao of the physics department, University of Massachusetts, Boston.

In addition to Prof. Rao who heads the team, Dr. Chandra S. Yelleswarapu of the same department and Dr. M. Anija from the Raman Research Institute (presently at the Indian Institute of Science, Bangalore) also participated in the study. The study was motivated by the fact that passive devices that allow unidirectional propagation of an optical signal, i.e., passive optical diodes, are currently receiving much attention as an alternative to the conventional optical isolator, which is an active device based on linear polarizers and a magneto-optical Faraday rotator.

The research team investigated the transmission of optical pulses through structures in which the nonlinear absorption coefficient varied along the direction of beam propagation. A saturable absorber placed in tandem with a reverse saturable absorber is an example of such a device (the optical transmission increases in saturable absorbers, and decreases in reverse saturable absorbers, when the input light intensity is increased). Fabrication of such a structure is much easier compared to say, that of a photonic crystal.

Most optical diodes reported in literature are generally based on photonic crystals, which are dielectric or metallodielectric media, with a spatial periodicity in their refractive index. The other reported optical diodes include fluorescent dyes with a concentration gradient, absorbing multilayer systems, and second harmonic generators with a spatially varying wave vector mismatch.

As the basic transmission behavior of such a structure in mutually opposite directions was worked out from detailed numerical simulations, the team found out that the device showed a passive all-optical diode behavior. Experimental results confirmed that this principle worked for all light polarizations, has no phase-matching restrictions, and can be extended to a large number of available nonlinear media for possible applications.

With inputs from Usha Prasad, associate partner, PC Mediaworks, according to Dr. Philip, at the excitation wavelength of 532 nm used in the experiment (from an Nd:YAG laser), a commercial color glass filter showed strong saturable absorption, while a solution of the commercially available copper phthalocyanine (CuPc) powder showed reverse saturable absorption. When these media were placed in tandem, it resulted in an optical diode.

A structure of this kind has the advantage that it is all-optical and polarization independent, and it can withstand high optical intensities. Furthermore, its organization is extremely simple. The materials constituting the optical diode were individually subjected to high optical intensities several times, and no optical damage was observed.

There are a large number of optically nonlinear materials that can be used likewise, without involving any sophisticated fabrication process. By choosing highly nonlinear materials such as liquid crystals and optical fibers, it should be possible to operate the device at different wavelengths and at much lower laser intensity levels than presently used.

In conclusion, Prof. Rao and team studied the optical transmission of a medium characterized by an asymmetry in its longitudinal nonlinear absorption coefficient, and showed numerically and experimentally that a passive all-optical diode of high contrast can be realized in such structures.

Pradeep

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