3-D photonic crystals make novel add-drop filters

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Researchers at the U.S. Department of Energy's Ames Laboratory have come up with a potentially perfect way to sort and distribute the massive amounts of data that travel daily over optical fibers to people throughout the world. The new technology, a three-dimensional photonic crystal add-drop filter, promises greatly enhanced transmission of multiple wavelength channels (wavelengths of light) traveling along the same optical fiber. The innovative filter is a significant achievement in the effort to develop all-optical transport networks that would eliminate electrical components from optical transmission links and guarantee virtually flawless data reception to end users of the Internet and other fiber-based telecommunications systems.

"There are up to 160 wavelength channels traveling through an optical fiber at the same time," said Rana Biswas, an Ames Laboratory physicist and one of the developers of the new add-drop filter. "That means a lot of dialogue is going on simultaneously." Biswas, who is also an Iowa State University adjunct associate professor of physics and astronomy and electrical and computer engineering, explained that as information is transported over these multiple channels, it's necessary to drop off individual wavelength channels at different points on the fiber. At the same time, it's essential to be able to add data streams into unfilled wavelength channels.

"When the data being transported in multiple frequency channels over an optical fiber comes to a receiving station, you want to be able to pick off just one of those frequencies and send it to an individual end user," said

Biswas. "That's where these 3-D photonic crystals come into play."

Biswas and his colleagues, Kai-Ming Ho, an Ames Laboratory senior physicist and an ISU Distinguished Professor of Liberal Arts and Sciences; Gary Tuttle, an ISU associate professor of electrical and computer engineering and a researcher at the university's Microelectronics Research Center; and Preeti Kohli, a former Iowa State Ph.D. student now at Micron in Manassas, Va. successfully demonstrated that 3-D photonic crystals could serve as add- drop filters, providing greatly enhanced data transmission.

To prove their concept, the researchers used a three-dimensional, microwave- scale photonic crystal constructed from layered alumina rods and containing a full bandgap - a wavelength range in which electromagnetic waves cannot transmit. Just as electronic bandgaps prevent electrons within a certain energy range from passing through a semiconductor, photonic crystals create photonic bandgaps that confine light of certain wavelengths.

The add-drop filter created by the Ames Laboratory team contains an entrance waveguide and an exit waveguide created by removing rod segments from the layered photonic crystal. A one-rod segment separates the two waveguides. (A waveguide is a system or material that can confine and direct electromagnetic waves.) A defect cavity is located one unit cell above the waveguide layer. The waveguides can communicate through the cavity, allowing a specific wavelength frequency to be selected from the input waveguide and transmitted to the output waveguide, excluding other input frequencies and resulting in near 100 percent efficiency for the drop frequencies.

The idea of using photonic crystals for add-drop filters is not new. Since the mid 1990s, many groups worldwide have been working to develop the technology with two-dimensional photonic crystals.

"It works," Biswas said, "but there is loss of some intensity to the end user because 2-D photonic crystals don't confine the light completely. For example, in a phone conversation, the voices would dim out. But with 3-D photonic crystal add-drop filters, the communication would be clear."

Although Biswas, Kohli, Tuttle and Ho have shown that 3-D photonic crystals would make highly efficient add-drop filters, there are still problems to address. Getting the size of the photonic crystals down to work at the wavelengths used for Internet communications - 1.5 microns - is the big challenge. The Ames Lab group now has some of these photonic crystals working in that range, but to make these controlled structures with one input, another output and a defect . that definitely takes some work. A future direction is to simplify the design of the add-drop filter by reducing the layers in the photonic crystal - perhaps having all the action happen in one layer.

Source: DOE's Ames Laboratory

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