Chasing rainbows

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Engineers working in optical communications bear more than a passing resemblance to dreamers chasing rainbows. They may not wish literally to capture all the colors of the spectrum, but they do seek to control the rate at which light from across the spectrum moves through optical circuits.

This pursuit is daunting when those circuits contain dimensions measured in nanometers.

At the nanoscale, says Qiaoqiang Gan, a Ph.D. candidate in electrical engineering at Lehigh University in Bethlehem, Pa., engineers hoping to integrate optical structures with electronic chips face a dilemma.

Light waves transmit data with greater speed and control than do electrical signals, which are hindered by the mobility of the electrons in semiconducting materials.

But light is more difficult to control at the nanoscale because of natural limits on its diffraction, or ability to resolve.

"There is a mismatch between nanoelectronics and nanophotonics," says Gan. "Because of the diffraction limit of light, optical circuits are now much larger than their electronic counterparts. This poses an obstacle to the integration of optical structures with electrical devices.

"For that reason, the dream now among photonics researchers is to make optical structures as small as possible and integrate them with electrical devices."

Gan and his colleagues have made a major contribution towards this effort by developing a relatively simple structure that can slow down or even stop light waves over a wide portion of the light spectrum.

On Friday, June 27, they published an article describing their progress in *Physical Review Letters* (PRL), a publication of the American Physical Society. PRL is one of the most influential international journals devoted to basic physics.

The article, titled "Ultrawide-Bandwidth Slow-Light System Based on THz Plasmonic Graded Metallic Grating Structures," is coauthored by Gan, Zhan Fu, Yujie Ding and Filbert Bartoli. Fu is a Ph.D. candidate in electrical engineering, Ding is a professor of electrical and computer engineering, and Bartoli is professor and department chair of electrical and computer engineering. Bartoli is Gan's adviser, while Ding advises Fu.

The structure developed by his team, says Gan, has the unique ability to arrest the progress of terahertz (THz) light waves at multiple locations on the structure's surface and also at different frequencies.

"Previous researchers have reported the ability to slow down one single wavelength at one narrow bandwidth," says Gan. "We've succeeded in actually stopping THz waves at different positions for different frequencies.

"Our next goal is to develop structures that extend this capability to the near infrared and visible ranges of the spectrum, where optical communications signals are transferred."

The Lehigh researchers report in PRL that their key innovation is a "metallic grating structure with graded depths, whose dispersion curves and cutoff frequencies are different at different locations."

In appearance, this grate resembles the pipes of a pipe organ arranged side by side and decreasing gradually in length from one end of the assembly to the other.

The degree of grade in the metal grate can be "tuned," says Gan, by altering the temperature and modifying the physical features on the surface of the structure.

Likewise, he says, temperature and surface structure can also be adjusted to trigger the release of the light signals after they have been slowed or trapped.

"The separation between the adjacent localized frequencies can be tuned freely by changing the grade of the grating depths," Gan says. "And the propagation characteristics of the trapped surface modes can be controlled by the surface geometry."

By "opening a door to the control of light waves on a chip," says Bartoli, the new Lehigh grating structure could help scientists and engineers reduce the size of optical structures so they can be integrated at the nanoscale with electronic devices.

"Our grating structure can also be scaled to telecommunications frequencies for future possible applications in integrated optical and nano-photonic circuits," he says.

"This might even help us realize such novel applications as a spectrometer integrated on a chip for chemical diagnostics, spectroscopy and signal processing applications."

Gan, who holds an M.S. in electrical engineering from the Chinese Academy of Sciences in Beijing and a B.S. in materials science and engineering from Fudan University in Shanghai, has used computer modeling to develop and test the grating structure. He will begin soon to work with Ding to conduct physical experiments. Ding has made significant progress in generating THz radiation.

It was after reading an article by another researcher in the field that Gan and Fu came up with the idea of developing graded grating structures to trap and slow light waves.

"The other researcher was attempting to use a cylindrical structure to focus light waves into a subwavelength scale for a THz scanning microscope," he says. "We simplified the cylinder to a grating structure and realized that incoming light waves would be trapped at various points across the grade."

Source: Lehigh University

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