*** 北米連携センター定期報告***

2014 年 11 月 17 日

<u>●ペンシルベニア大学、ナノスケールで光波を効率的に光波をミックスする技術を開発</u>

【University of Pennsylvania, 2014/11/17】

コンピュータ・コンポーネントの小型化、高速化で将来は光学システムが現在の電気システムに取って代わる可能性もあるが、現時点では 2 つの入力を 1 つの出力にまとめるという演算の基本を光で実行するには必要とするスペース、光源ともに大きすぎる。

しかし、ペンシルベニア大学の研究チームが開発したナノワイヤ・システムは、2 本の光波から異なる周波数を持つ 3 本目の光波を生むもの。

光キャビティを用いることで出力の強度を増幅することも可能で、今後光学コンピューティング実現の道を開く可能性を有している。

今回の研究結果は、「Nature Communications」誌上で発表された。

2 本の光波を 1 本にまとめる「非線形」素材の量と光源を縮小するためには、硫化カドミウム製のナノワイヤを通過する光波の強度を増幅する必要があるが、研究チームはナノワイヤの一部を銀幕で覆い、エコー・チャンバーのように動作させることでこれを実現している。

この研究には、米陸軍研究所、国立衛生研究所、空軍科学研究局が補助金を交付している。

（参考）本件報道記事

Penn Engineers Efficiently 'Mix' Light at the Nanoscale

Date:
November 17, 2014
Source:
University of Pennsylvania
Summary:

Researchers have engineered a nanowire system that could pave the way for photonic computing, combining two light waves to produce a third with a different frequency and using an optical cavity to amplify the intensity of the output to a usable level.

Light emitted from the underside of the cavity. The dotted outline represents the orientation of the cadmium sulfide nanowire.

Credit: Image courtesy of University of Pennsylvania
[Click to enlarge image]

The race to make computer components smaller and faster and use less power is pushing the limits of the properties of electrons in a material. Photonic systems could eventually replace electronic ones, but the fundamentals of computation, mixing two inputs into a single output, currently require too much space and power when done with light.

Researchers at the University of Pennsylvania have engineered a nanowire system that could pave the way for this ability, combining two light waves to produce a third with a different frequency and using an optical cavity to amplify the intensity of the output to a usable level.

The study was led by Ritesh Agarwal, professor of materials science and engineering in Penn's School of Engineering and Applied Science, and Ming-Liang Ren, a post-doctoral researcher in his lab. Other members of the Agarwal lab, Wenjing Liu, Carlos O. Aspetti and Liaoxin Sun, contributed to the study.

It was published in Nature Communications.

Current computer systems represent bits of information -- the 1's and 0's of binary code -- with electricity. Circuit elements, such as transistors, operate on these electric signals, producing outputs that are dependent on their inputs.

"Mixing two input signals to get a new output is the basis of computation," Agarwal said. "It's easy to do with electric signals, but it's not easy to do with light, as light waves don't normally interact with one another."

The difficulty inherent in "mixing" light may seem counterintuitive, given the gamut of colors on TV or computer screen that are produced solely by combinations of red, green and blue pixels. The yellows, oranges and purples those displays make, however, are a trick of perception, not of physics. Red and blue light are simply experienced simultaneously, rather than combined into a single purple wavelength.

So-called "nonlinear" materials are capable of this kind of mixing, but even the best candidates in this category are not yet viable for computational applications due to high power and large volume constraints.

"A nonlinear material, such a cadmium sulfide, can change the frequency, and thus the color, of light that passes through it," Ren said, "but you need a powerful laser, and, even so, the material needs to be a many micrometers and even up to millimeters thick. That doesn't work for a computer chip."

To reduce the volume of the material and the power of the light needed to do useful signal mixing, the researchers needed a way to amplify the intensity of a light wave as it passed through a cadmium sulfide nanowire.

The researchers achieved this through a clever bit of optical engineering: partially wrapping the nanowire in a silver shell that acts like an echo chamber. Agarwal's group had employed a similar design before in an effort to create photonic devices that could switch on and off very rapidly. This quality relied on a phenomenon known as surface plasmon resonance, but, by changing the polarization of the light as it entered the nanowire, the researchers were able to better confine it to the frequency-altering, nonlinear part of the device: the nanowire core.

"By engineering the structure so that light is mostly contained within the cadmium sulfide rather than at the interface between it and the silver shell, we can maximize the intensity while generating the second harmonic," Ren said.

Like a second harmonic played on a guitar string, this meant doubling the frequency of the light wave. Information in a photonic computer system could be encoded in a wave's frequency, or the number of oscillations it makes in a second. Being able to manipulate that quality in one wave with another allows for the fundamentals of computer logic.

"We want to show we can sum two frequencies of light,"Agarwal said, "so we simplified the experiment. By taking one frequency and adding it to itself, you get double the frequency in the end. Ultimately, we want to be able to tune the light to whatever frequency is needed, which can be done by altering the size of the nanowire and the shell."

Most important, however, was that this frequency mixing was possible on the nanoscale with very high efficiency. The researchers' optical cavity was able to increase the output wave's intensity by more than a thousand times.

"The frequency-changing efficiency of cadmium sulfide is intrinsic to the material, but it depends on the volume of the material the wave passes through," Agarwal said. "By adding the silver shell, we can significantly decrease the volume needed to get a usable signal and push the device size into the nanoscale."

The research was supported by the U.S. Army Research Office, National Institutes of Health and Air Force Office of Scientific Research.

Source:
http://www.upenn.edu/pennnews/news/penn-engineers-efficiently-mix-light-nanoscale

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