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●テキサス大学研究チーム、「ノンリニア・ミラー」を発明

【University of Texas, 2014/07/02】

テキサス大学オースティン校工学部の研究チームは、新しいノンリニア・メタサーフェスを開発。同チームが「ノンリニア・ミラー」と呼ぶこの発明は、化学物質検出や爆発物検出、バイオメディカル研究など幅広い分野で応用可能なノンリニア・レーザー・システムの実現を後押しできる可能性を秘めている。

このメタマテリアルは、従来のノンリニア・マテリアルより数 100 万倍強い非線形光学応答性を持ち、人毛の 100 分の 1 の厚さの薄膜でレーザーポインター程度の強度の光を使って周波数変換できることが確認されている。

非線形光学応答は、新たな光源生成やレーザー診断、量子コンピューティングなどに用いられているが、自然素材ではこのような効果が起こりにくいため、検出可能な効果を励起するには強度の高い光と長い距離が必要とされている。

しかし、今回開発されたメタマテリアルは、これまでよりもはるかに強い非線形光学応答性を持っている。その基礎となっているのはインジウム、ガリウム、ヒ素の層、アルミ、インジウム、ヒ素の層を重ね合わせた薄膜で、この 1～12 ナノメートルの薄膜を 100 枚ほど重ねた上で、金と金のナノクロスを非対称に配列したものでサンドイッチにした構造を持っている。

（参考）本件報道記事

Researchers Invent 'Meta Mirror' to Help Advance Nonlinear Optical Systems

July 2, 2014

AUSTIN, Texas — Researchers at the Cockrell School of Engineering at The University of Texas at Austin have created a new nonlinear metasurface, or meta mirror, that could one day enable the miniaturization of laser systems.

The invention, called a "nonlinear mirror" by the researchers, could help advance nonlinear laser systems that are used for chemical sensing, explosives detection, biomedical research and potentially many other applications. The researchers' study will be published in the July 3 issue of Nature.

The metamaterials were created with nonlinear optical response a million times as strong as traditional nonlinear materials and demonstrated frequency conversion in films 100 times as thin as human hair using light intensity comparable with that of a laser pointer.

Nonlinear optical effects are widely used by engineers and scientists to generate new light frequencies, perform laser diagnostics and advance quantum computing. Due to the small extent of optical nonlinearity in naturally occurring materials, high light intensities and long propagation distances in nonlinear crystals are typically required to produce detectable nonlinear optical effects.

The research team led by UT Austin's Department of Electrical and Computer Engineering professors Mikhail Belkin and Andrea Alu, in collaboration with colleagues from the Technical University of Munich, has created thin-film nonlinear metamaterials with optical response many orders of magnitude larger than that of traditional nonlinear materials. The scientists demonstrated this functionality by realizing a 400-nanometer-thick nonlinear mirror that reflects radiation at twice the input light frequency. For the given input intensity and structure thickness, the new nonlinear metamaterial produces approximately 1 million times larger frequency-doubled output, compared with similar structures based on conventional materials.

"This work opens a new paradigm in nonlinear optics by exploiting the unique combination of exotic wave interaction in metamaterials and of quantum engineering in semiconductors," said Professor Andrea Alu.

The metamaterial at the basis of this unusual optical response consists of a sequence of thin layers made of indium, gallium and arsenic on the one hand and aluminum, indium and arsenic on the other. The researchers stacked approximately 100 of these layers, each between 1 nanometer and 12 nanometers thick, and sandwiched them between a layer of gold at the bottom and a pattern of asymmetric gold nanocrosses on top. The thin semiconductor layers confine electrons into desired quantum states, and gold nanocrosses resonate at input and output frequencies to enable the the nonlinear optical response of the mirror.

The realized mirror converts light from a wavelength of 8 micrometers to 4 micrometers; however, the structures can be tailored to work at other wavelengths, from near-infrared to mid-infrared to terahertz.

"Alongside frequency doubling, our structures may be designed for sum- or difference-frequency generation, as well as a variety of four-wave mixing processes," said UT Austin graduate student Jongwon Lee, the lead author on the paper.

"Our work unveils a pathway towards the development of ultrathin, highly nonlinear optical elements for efficient frequency conversion that will operate without stringent phase-matching constraints of bulk nonlinear crystals," said Professor Mikhail Belkin.

Belkin and Alu led a team of researchers that included electrical and computer engineering graduate students Jongwon Lee, Mykhailo Tymchenko and Feng Lu. Pai-Yen Chen and Christos Argyropoulos, who graduated from the Cockrell School in 2013, also contributed to the paper. The semiconductor material was grown at the Walter Schottky Institute, Technical University of Munich.

The research was funded by the National Science Foundation, the Air Force Office of Scientific Research and the Office of Naval Research, as well as the German Research Foundation.

The University of Texas at Austin is committed to transparency and disclosure of all potential conflicts of interest. All UT investigators involved with this research have filed their required financial disclosure forms with the university. Alu and Belkin have both received research funding for other projects from the National Science Foundation and other major public science foundations. Belkin has also received research funding for other projects from the companies Omega Optics, Anasys Instruments and Hamamatsu Photonics, and Alu from the AEgis Technologies Group. An alumnus and former doctoral student who worked on the project, Pai-Yen Chen, now works for Intellectual Ventures Inc.

Source: http://www.utexas.edu/news/2014/07/02/meta-mirror-engineering/

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