【Grant-in-Aid for Scientific Research (S)】

Science and Engineering (Interdisciplinary Science and Engineering)

Title of Project : New development of nonlinear photoelectronics based on terahertz strong field physics

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Research Project Number : 17H06124 Researcher Number : 90212034
Research Area : Optical Physics / Quantum Optics
Keyword : Nonlinear Optics, Strong Optical Field Physics, High-Harmonics Generation

【Purpose and Background of the Research】

Photoelectronics in a high frequency region exceeding 300 GHz is a leading research area where application development to the next generation high speed communication, nondestructive inspection, security, etc. is expected. There is a strong demand for new terahertz technology and science that support the basis of light sources and detectors.

In order to advance the photo electronics in the terahertz region dramatically, we study nonlinear optical effects in the mid-infrared ~ terahertz region using low-dimensional electronic material systems. In particular, we try to generate high-order harmonics for high-quality thin films of materials with Dirac electron systems such as graphene and single-layer two-dimensional materials such as MoS_2. We compare the results in material systems with different band dispersion and investigate whether nonlinear optical response can be explained by cooperation and competition between intraband process and interband process. We also elucidates the physical mechanism from the viewpoint of high intensity field physics.

【Research Methods】

To achieve the objectives, we will execute the following three research:

1. Optimization of high-order harmonics generation by clarifying the physical mechanism:

Experiments such as polarization dependence and crystal angle dependence of harmonic generation are systematically performed over a wide frequency range from the terahertz region to the infrared region, giving rise to the mechanism of the nonlinear optical effect. This will lead to the effective design guidelines for nonlinear optical devices.

2. Development of low dimensional materials and devices suitable for nonlinear optics:

We control defect density and Fermi surface in graphene and metal carbon nanotube and its device structure and optimize material system suitable for nonlinear optics in terahertz region.

3. Optimization of terahertz electromagnetic field by using metal structure and metal point contact:

We optimize the spatial electromagnetic field distribution in the nonlinear optical material by metal structures in order to effectively realize the nonlinear optical effect even for weak terahertz light. In addition, we consider the system of photo-induced STM as a nonlinear optical element with a metal point contact and search for novel nonlinear optical phenomena.

【Expected Research Achievements and Scientific Significance】

The main feature of this research is to pursue new theoretical basis of nonlinear optical phenomena caused by interaction between strong terahertz electric field and matter. We place the matter system in an extremely non-equilibrium state by applying a strong electric field of light that has not been searched so far. As a result, it is expected that new quantum effects. The theory that is ultimately constructed is directly linked to the development of future terahertz photonics and is also important from the viewpoint of securing the advantage of science and technology in our country.

【Publications Relevant to the Project】

- N. Yoshikawa, T. Tamaya, and K. Tanaka, "High-harmonic generation in graphene enhanced by elliptically polarized light excitation", Science 356, 736-738 (2017).
- T. Tamaya, A. Ishikawa, T. Ogawa, and K. Tanaka, "Diabatic Mechanisms of Higher-Order Harmonic Generation in Solid-State Materials under High-Intensity Electric Fields", Phys. Rev. Lett. 116, 016601 (2016).
- T. Kampfrath, K. Tanaka and K. A. Nelson, "Resonant and nonresonant control over matter and light by intense terahertz transients", Nature Photonics 7,680–690 (2013).

【Term of Project】 FY2017-2021

【Budget Allocation】 162,300 Thousand Yen

【Homepage Address and Other Contact Information】

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