FUNDAMENTAL SYMMETRY AND POLARIZATION CONTROL

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Recent developments in ultra-short pulsed laser technologies have enabled ultrafast optical manipulation of low-energy excitations in solids, for example, phonons and magnons. In particular, Raman-induced nonlinear optical processes offer an attractive opportunity of ultra-fast control without heating. In coherent scattering on the low-energy excitations, the conservation laws of energy, momentum and angular momentum determine the frequency, wave vector, and polarization of the scattered photons, respectively [1]. In particular, the latter implies that angular momentum of the electromagnetic field ($\boldsymbol{J}^{EM}$), collective excitations ($\boldsymbol{J}^{ex}$), and the crystalline lattice ($\boldsymbol{J}^{c}$) satisfy the following relationship: $\boldsymbol{J}^{EM}+\boldsymbol{J}^{ex}+\boldsymbol{J}^{c}=0$. When light propagates in the medium along a continuous rotational axis Z, J_z^{c} is a conserved quantity and thus $J_z^{EM}+J_z^{ex}$ is also conserved. In contrast, when light propagates along a threefold rotational axis, the crystal quasi angular momentum is conserved and thus $J_z^{EM}+J_z^{ex}$ can be changed in the process of the light scattering by $3N\hbar$, where N is an integer. Such an analogue of the Umklapp process [1] is known for decades in nonlinear optics. It determines in particular the polarization selection rules in the second-harmonic generation[2] and parametric down-conversion [3]. However, until now a little attention has been paid to implications of the discrete rotational symmetry for the coherent control of low-energy excitations.

We have recently demonstrated that the angular momentum conservation enables optical manipulation of magnetization vector in multi-domain antiferromagnetic NiO. The [111] axis of this crystal is effectively threefold because all the domains contribute to the optical process coherently. We observed magnetic dipole terahertz radiation, which originates from the magnetization oscillations induced by linearly polarized femtosecond laser pulses. The relationship between the polarization azimuths of the incident light beam and generated terahertz wave can be excellently interpreted in terms of the angular momentum conservation [4]. In addition, we achieved control of magnetic oscillations by employing polarization-twisted double pulse excitation [5]. The angular momentum conservation manifests itself also in terahertz radiation via optical rectification in a ZnTe single crystal when the excitation beam propagates along its threefold [111] axis. By the vectorial pulse shaping, we select *envelope helicity* [6] of the excitation femtosecond pulse and control the helicity of the terahertz radiation.

[1] N. Bloembergen, J. Opt. Soc. Am. **70** 1429 (1980).
[2] H. J. Simon and N. Bloembergen, Phys. Rev. **171**, 1104 (1968).
[3] J. Visser, E. R. Eliel, and G. Nienhuis, Phys. Rev. A **66**, 033814 (2002).
[4] T. Higuchi, N. Kanda, H. Tamaru, and M. Kuwata-Gonokami, Phys. Rev. Lett. **106**, 047401 (2011).
[5] N. Kanda, T. Higuchi, H. Shimizu, K. Konishi, K. Yoshioka, and M. Kuwata-Gonokami, Nature Commun. 2, 362 (2011).
[6] T. Higuchi, H. Tamaru, and M. Kuwata-Gonokami, submitted.