論文の内容の要旨

Optical physics with topological lightwaves

(トポロジカル光波による光物性)

氏名 藤田　浩之

Optical physics is a study of light-matter interaction. In the past decades, controlling electric and magnetic properties of matters with laser beams has been actively explored in the broad region of condensed matter physics supported by the developments in laser technologies. In this thesis, we discuss how optical physics can be even more promising with the help of topological lightwaves, also known as structured lights or singular lights. Topological lightwaves such as optical vortex and cylindrical vector beam are characterized by their topologically nontrivial spatial profiles, and their applications like microscopes and tweezers have been intensively studied in the field of optics in the name of singular optics. However, their applications for optical physics have been lacking. In this thesis, we propose several novel ways of controlling electromagnetic properties of matters with topological lightwaves.

Our analysis based on the (stochastic) Landau-Lifshitz-Gilbert equation revealed that optical vortices are potentially useful for ultrafast magnetism, namely optical control of magnetic textures. We show that the characteristic spatial profile and the orbital angular momentum of optical vortices provide a way of controlling the spin texture of (chiral) magnets in an unconventional way. We can exploit the chiral nature of optical vortices to design spin waves and generate topological magnetic defects. The ring-shaped intensity distribution of

optical vortices enables us to systematically generate a family of topological defects such as skyrmions and skyrmioniums in chiral ferro- and antiferromagnets.

The unique focusing property of cylindrical vector beams allows us to control electric and magnetic fields applied to a target independently if the target is sufficiently smaller than the wavelength of the beams. At terahertz or far-infrared frequencies, where various interesting phenomena of solid-state-physics take place, this situation is easily realized. Hence, cylindrical vector beams potentially have a substantial impact on condensed-matter physics [and (bio-) chemistry]. We propose various applications of cylindrical vector beams for condensed-matter uses; nonequilibrium extension of magnetic oscillation measurements applicable to magnetic metals, novel magnetic field spectroscopy for conductors and dielectrics, imaging and control of circulating edge currents in topological materials, and Floquet engineering of nonequilibrium states of matters.

From condensed-matter physics to biochemistry, topological lightwaves would make significant contributions by shedding a new light on optical properties of atoms, molecules, and solids. A new research field of ``singular optical physics'' would emerge at the intersection of optical physics and singular optics, deepening our understanding of optical properties of matters.