【Grant-in-Aid for Transformative Research Areas（A）】

Evolution of Chiral Materials Science using Helical Light Fields

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Research Area Information	Number of Research Area : 22A204　Project Period (FY) : 2022-2026 Keywords : Optical Vortex, Nearfield Optics, Chirality, Materials Science

Purpose and Background of the Research

●Outline of the Research

An object is chiral if it cannot be superimposed onto its mirror image. Chiral objects have the same chemical and physical properties as their mirror images but different optical responses to circularly polarized light (e.g. circular dichroism), and they play universally important roles in materials science. Chiral objects, including physical matter and phenomena, chemical composites and even biomaterials, possess typically helical structures, such as spirals and vortices on a nano/macro-scale.

This research area aims to freely manipulate a myriad of nanomaterials using helical light fields to establish exotic micro- to macro-scale chiral structures with multifunctional properties. Further, we pioneer innovative materials sciences and advanced materials technologies, such as chemistry with chiral light fields, engineering with light induced helices, and physics in vortices, by employing this structured matter.

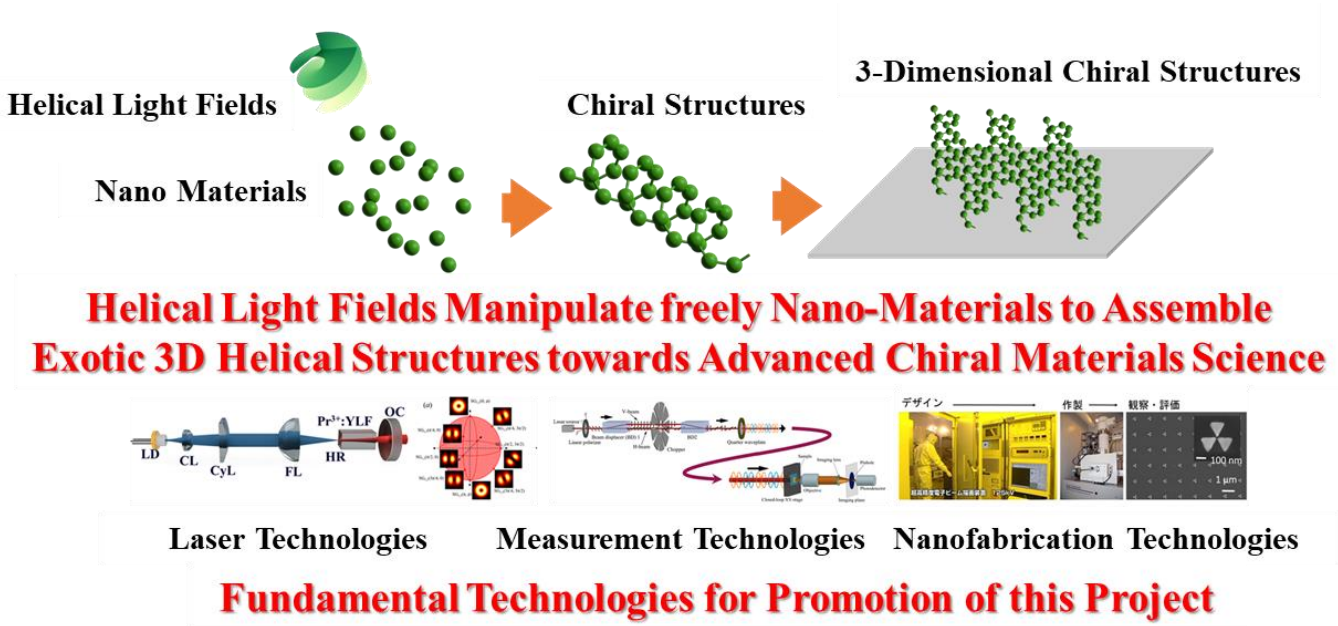

Figure 1. Project Concept

●Helical Light Fields

Circularly polarized light carries spin angular momentum (SAM), s, owing to its helical electric field. However, it is difficult to control the enantioselectivity of the irradiated nano- or molecular-scale materials even when employing high-intensity circularly polarized light field. This is due to the intrinsically weak interactions between submicron-scale helicity of light and nanoscale materials.

In 1992, Allen et al. theoretically proposed that helical light fields, such as optical vortices, carry orbital angular momentum (OAM), as a consequence of its associated helical wavefront and on-axis phase singularity. The OAM is characterized by a topological charge ℓ, which can be properly selected in the region of 0~infinity. Beyond the conventional circularly polarized light, optical vortices thus offer the exotic light-matter interaction to create helical structures.

Furthermore, advanced nanofabrication technologies have made remarkable progress in structured devices, such as plasmonic metamaterials. These devices produce the circularly polarized light with enhanced chirality to offer the novel interaction between and materials at the nano/micrometer-scale.

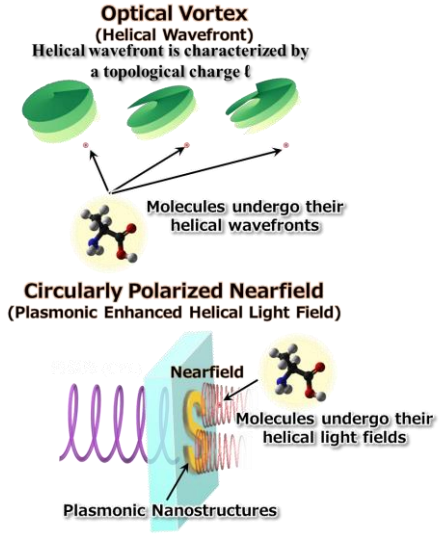

Figure 2. Helical Light Fields

Expected Research Achievements

●Impact & Innovation

This project consists of fundamentals of helical-light induced chiral materials science, direct observations of helical-light induced chiral materials, and demonstrations of helical-light induced chiral materials science and technology, and it will aim for the following three goals.

(1)Chemistry with chiral light fields: e.g. chiral crystallization at ultimate chiral bias.
(2)Engineering with light induced helices: e.g. biomimetics with light-induced helices.
(3)Physics in vortices: e.g. creation, annihilation and manipulation of quantum vortices and skyrmions.

Going beyond the conventional chiral materials science and technology, this project enables the establishment of interdisciplinary research areas based on interaction between helical light fields and materials.

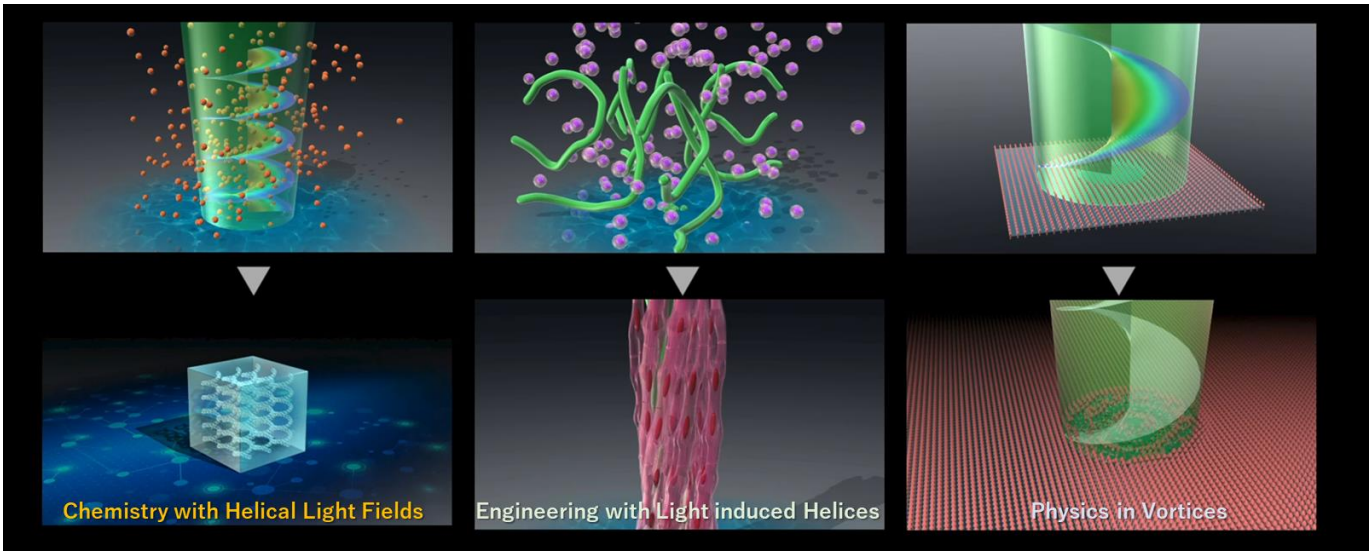

Figure 3. Innovation and Prospectives

●Career Developments

This project aims for the developments of cutting-edge and global skills for early careered researchers and students by organizing a myriad of programs, such as training workshops, international academic exchange, research colloquiums and young researchers' collaborative projects.

Homepage Address, etc.	https://www.light-chiral-materials-science.jp/