Grant-in-Aid for Transformative Research Areas (A) 2022-2027
Revolution ofChiral Materials Science using Helical Light Fields

NEWS LETTER VOL 2

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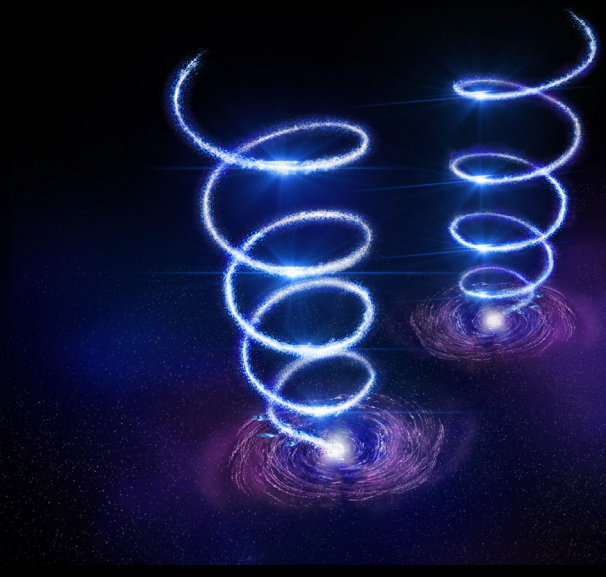


Message

Eiji Yashima

Nagoya University, Graduate School of Engineering

I first learned about the existence of optical vortices and the ability to freely manipulate left- and right-handedness of them, during Professor Omatsu's invited lecture at the Molecular Chirality Symposium held at Chiba University in May 2018. I remember being very surprised by the generation of macroscopic chiral fibers twisted in one direction upon irradiation with an optical vortex, and the subsequent formation of crystalline structures rich in one enantiomer from dynamic racemic mixtures. At that time, we were exploring the possibility of inducing and retaining a single-handed helicity in synthetic polymers, envisioning the use of weak physical chiral forces such as circularly polarized light, magnetic fields, stirring, and torsion. I felt that the physical chiral force of light vortices could serve as a remarkably innovative and potent tool for inducing one-handed helicity. With the establishment of the Transformative Research Area termed "Revolution of Chiral Materials Science using Helical Light Fields," I eagerly anticipate the creation of new light (optical vortices) possessing strong chirality beyond circular polarization. This promises to open up unexplored avenues in chiral science that were previously unattainable with circularly polarized light, leading to the discovery of unexpected chiral phenomena.

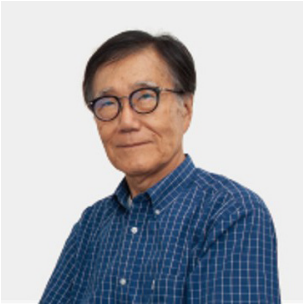
Toyohiko Yatagai

Utsunomiya University, The Center for Optical Research and Education

I have been involved in the study of optical engineering, particularly wave optics. I have maintained an interest in applications such as magneto-optical effects and optical rotation as part of polarization phenomena. Specifically, I have conducted research on holography using polarization-sensitive organic materials and holographic memory. I have also attempted analysis on the formation of three-dimensional polarization lattices using mutually orthogonal circularly polarized light and the anisotropy of materials. However, I have not satisfied with these macroscopic approaches. I have for a long time believed that it is necessary to reconsider how to form desired chiral structures within materials and how to analyze them to link them to practical applications at their root.

This Transformative Research Area "Revolution of Chiral Materials Science using Helical Light Fields" is an ambitious research project that brings together experts from a wide range of disciplines including physics, chemistry, biology, engineering, etc., to tackle the scientific ordering of chiral structures in materials through light. I am hopeful that my long-held aspirations will soon be realized with this initiative.

Message



Hiroshi Masuhara

National Yang Ming Chiao Tung University

In the past, it was common to distinguish between basic research (science) and applied research (technology), but by the 1960s, science and technology came to be seen as inseparable. I entered the doctoral program at Osaka University's newly established Faculty of Engineering Science, which symbolized that era. Subsequently, I came to believe that it is more appropriate to refer to basic and applied researches as exploratory and realization researches. Recently, the situation has changed dramatically, with a paradigm shift in science and technology centered around semiconductors and AI. Both basic and exploratory researches have been overshadowed, and research that is useful today and contributes to SDGs tomorrow is now highly valued. Also in Taiwan, where I have spent over 15 years after retiring from Osaka University, and in Belgium, where I am engaged in collaborative research, this trend is very strong. While Japan has been criticized for lagging behind and experiencing a "lost 20 years," it may be possible to see that Japan has finally reached an environment where its uniqueness can be demonstrated. Every time I meet with members of Transformative Research Areas and PRESTO (SAKIGAKE) projects, I am deeply moved by this sentiment. Particularly, "Revolution of Chiral Materials Science using Helical Light Fields" emerges as a field that showcases unique perspectives, innovative methodologies, and integrates optical, physical, and material sciences. Its further development is highly anticipated. I hope it becomes a representative example of Japan's research originality.

Tohru Suemoto

The University of Electro-Communications

In recent years, there has been growing attention on light with orbital angular momentum, known as "optical vortices." Initially, I wondered about its practical utility. However, upon attractive phenomena like the formation of screw-like structures when optical vortices interact with matter, or the creation of spiral structures resembling ropes when passing through photo-curable resins, it becomes undeniable that these phenomena hold significant potential. While supporting the research conducted by the Omatsu Group from the sidelines, it is indeed gratifying to see that a systematic effort to develop this field, involving theorists and biologists, was adopted as an "Transformative Research Areas". Nowadays, there has been a tendency to overly prioritize research results published in journals like Nature and Science. However, I completely agree with the idea that it is crucial to shed light on truly innovative research, even if it hasn't been recognized by everyone worldwide yet. From this project, which brims with excitement due to the active involvement of young researchers, I eagerly anticipate the emergence of groundbreaking and creative outcomes that will astonish the world.

Composition of Publicly Offered Researches

In the fiscal year 2023, 21 researchers were recruited to participate in the project as Publicly Offered Researchers. These Publicly Offered Research positions were selected with a focus on three key aspects: complementing planned research to strengthen the field, conducting expansion research in "Chemistry of Chiral Order," "Engineering of Spirals," and "Physics of Vortices," and broadening the ideals of this field.

Group A

- Study of chirality-dependent optical forces enabled by spin-orbital angular momentum conversion in the nonlinear optical trapping of VO_2 particles

  Principal Investigator Pin Christophe
  Hokkaido University, Research Institute for Electronic Science

- Theory of topological-light driven nonequilibrium dynamics of vortex generation in magnets and superconductors

  Principal Investigator Masahiro Sato
  Chiba University, Graduate School of Engineering

- Molecular Theories in Chiral Materials Science

  Principal Investigator Hirofumi Sato
  Kyoto University, Graduate School of Engineering

- Experimental and theoretical studies on the interaction of high-energy UV vortex synchrotron radiation with biomolecules

  Principal Investigator Koichi Matsuo
  Hiroshima University, Hiroshima Synchrotron Radiation Center

- Interaction of light vortices and electrons explored in quantum Hall regime

  Principal Investigator Kenichi Oto
  Chiba University, Graduate School of Science

- Simulation study on the correlation between local asymmetry and macroscopic chirality in fundamental processes of optical-vortex and plasma interaction

  Principal Investigator Hiroaki Nakamura
  National Institute for Fusion Science, Helical Research Division

Composition of Publicly Offered Researches

Group B

- Topological structures induced by transverse spin angular momentum of surface plasmon polaritons

  Principal Investigator Atsushi Kubo
  University of Tsukuba, Institute of Pure and Applied Sciences

- Integrated system of HS-AFM and optical vortex for high spatio-temporal resolution observation of chiral ordering

  Principal Investigator Takayuki Umakoshi
  Osaka University, Graduate School of Engineering

- High resolution observation of chirality by photo-induced force microscopy and elucidation of light helix and molecular interaction

  Principal Investigator Yasuhiro Sugawara
  Osaka University, Graduate School of Engineering

- Visualization of nano-optical chiral fields generated by helical light

  Principal Investigator Kohei Imura
  Waseda University, Faculty of Science and Engineering

- Development of single-chip optical chiral light sources

  Principal Investigator Kyoko Kitamura
  Kyoto Institute of Technology, Faculty of Electrical Engineering and Electronics

- Optical Vortex Tweezers using Nanostructured Semiconductors and their applications to Chiral Chemistry

  Principal Investigator Yasuyuki Tsuboi
  Osaka Metropolitan University, Graduate School of Science

- Chiro-thermo-optical reaction fields at the nanometer scale

  Principal Investigator Kenji Setoura
  Kobe City College of Technology

Composition of Publicly Offered Researches

Group C

- Development of Nanomaterials with Photoregulated Helicity

  Principal Investigator Ryojun Toyoda
  Tohoku University, Graduate School of Science

- Chiral Nucleation in Metaspace with Enhanced Helical Near-Field Co-Created by Electric and Magnetic Field

  Principal Investigator Hiromasa Niinomi
  Tohoku University, Institute of Multidisciplinary Research for Advanced Materials

- Creation of magnetic skyrmions by helicity of light

  Principal Investigator Tomoyuki Yokouchi
  The University of Tokyo, Graduate School of Arts and Sciences

- Theory for fluid control and chiral ordering with helical light field

  Principal Investigator Mamoru Tamura
  Osaka University, Graduate School of Engineering Science

- Chirality-selective nucleation and crystal growth induced by chiral vortex beam

  Principal Investigator Ryusei Oketani
  Osaka University, Graduate School of Engineering Science

- Exploring chiral edge mode and geometric universality in active matter by optical vortex manipulation

  Principal Investigator Yusuke Maeda
  Kyushu University, Graduate School of Science

- Photochemical chiral growth of metal colloids using helicity of light

  Principal Investigator Koichiro Saito
  AIST: Electronics and Manufacturing

- Molecular assembling of phenylalanine derivatives by chiral optical forces

  Principal Investigator Kenichi Yuyama
  Osaka Metropolitan University, Graduate School of Science

Workshop participation report

Hikaru Yoneji (Osaka University, Graduate School of Engineering Science D3)

On February 21st and 22nd, 2023, a mini-workshop on "Spirality of Light" and "Optical Pressure" was held at the North Terrace Campus of the University of Adelaide in Australia. The workshop was organized by Transformative Research Areas (A) "Chiral Optical Materials Science," and Scientific Research on Innovative Areas "Optical Pressure Nano Material Manipulation." Professor Kishan Dholakia from University of Adelaide hosted the workshop, which featured 18 oral presentations (8 invited talks), and poster presentations. The program also included sessions on international collaborative research and interdisciplinary research, where leading researchers in chiral optics, nanophotonics, and plasmonics engaged in lively discussions throughout the event. I participated in the poster session and received valuable feedback and insights during the workshop.

Due to the impact of the COVID-19 pandemic, it had been a while since I traveled abroad, but thanks to the warm climate and hospitality of Australia, I truly enjoyed the experience. The only disappointment was that the flight scheduled for departure was canceled due to inclement weather, resulting in one less day in Australia. It was quite a rushed schedule, and initially anxious about whether we would arrive safely. However, once we arrived, we had a very fulfilling time. I am grateful to all the participants from both fields of "Chiral Optical Materials Science" and "Optical Pressure Nano Material Manipulation," as well as to Professor Dholakia and everyone at the University of Adelaide, for giving me the opportunity to participate in such a workshop and for supporting my travel expenses.

Event report

Workshop “Chiral Light and Chiral Materials”

On March 1st, 2023 (Thu), a workshop titled "Chiral Light and Chiral Materials" was held at Toyonaka Campus of Osaka University in a onsite and online hybrid format. The workshop was organized by this Transformative Research Areas in collaboration with Center for Novel Science Initiatives (CNSI) of National Institutes of Natural Sciences (NINS). As a part of activities of Department of Frontier Photonic Sciences in CNSI, the workshop aimed to provide researchers who are not experts in the research field of chiral optical properties with opportunities to gain new ideas, and focused not only on cutting-edge research but also on the fundamental knowledge underlying it.

In addition to our members including Professor Omatsu, Professor Yoshihiko Togawa from Osaka Metropolitan University gave a presentation titled "Chirality and Spin: Perspectives from Materials Science," sharing the latest research findings. Furthermore, Professor Eiji Yashima from Nagoya University, who is a member of evaluation committee, delivered a special lecture on "Creation of Helical Polymers and Future Challenges: Towards the Creation of Helical Polymers Guided by the Spiral Nature of Light." The workshop saw participation of approximately 60 attendees, onsite + online, fostering lively discussions and Q&A sessions with the speakers.

Event Report

International conference OMC2023

Takashige Omatsu (Chiba University, Molecular Chirality Research Center)

From April 19th to 21st, 2023, the international conference "Optical Manipulation and Structured Materials Conference 2023 (OMC2023)" was held as one of the specialized conferences at OPIC International Conference at the Pacifico Yokohama Convention Center. The conference chairs were Takashi Omatsu (Chiba University), Kishan Dholakia (University of Adelaide), and Sile Nic Chormaic (OIST). There were a total of 85 registered participants (59 domestic and 26 international).

Submissions were received from various regions including Asia, Europe, the United States, and Australia, resulting in 61 papers (including 10 invited talks, 47 contributed talks, and 4 posters) presented at the conference.

Optical manipulation has evolved as a technique for manipulating micro-objects, including cells. With recent advancements in microfabrication and laser control technologies, optical manipulation has evolved into a new field of chiral material science that incorporates the spiral nature of light, such as angular momentum of light and circularly polarized near-fields. The various research were reported on involvement of the spiral nature of light and chiral material science, such as generation of optical vortices in nano-spaces using micro-metal antennas and control of chiral structures in materials using angular momentum of light.

Throughout the conference, the venue was bustling with about 70-80% of the seats occupied, indicating a very lively atmosphere with active discussions taking place. Particularly, during the plenary and invited lectures, the venue was almost at full. Participants' evaluations of the contributed talks were positive, with many repeat attendees.

Excluding the invited talks, the presentation titled "Inverse design finds chiral nanogap antennas" by Atsushi Taguchi (Hokkaido University) was selected for Best Paper Award. This research focuses on the optimal design of chiral optical fields in nano-gap antennas and holds the potential to significantly contribute to the advancement of this Research Area. This year marks the 10th anniversary of OMC. As a special event, optical society presidents from countries around the Pacific gathered for a panel discussion on strategies for fostering young researchers. It was agreed upon to organize special sessions led by young researchers and students during the OMC conference next year.

Press Releases, Awards, etc.

- A paper by Yoshito Tanaka (Tokyo University: present address Hokkaido University) of planning team A01 was published in ACS Photonics. https://pubs.acs.org/doi/full/10.1021/acsphotonics.2c01136
- A paper by Hiromi Okamoto (Institute of Molecular Science) of planning team B01 was published in Nature. https://www.nature.com/articles/s41586-022-05589-x
- A paper by Takashige Omatsu (Chiba University) and Teruki Sugiyama (National Yang Ming Chiao Tung University) of planning team C01 was published in Optica. https://doi.org/10.1364/OPTICA.478042
- Atsushi Taguchi (Hokkaido University) of planning team B02, received the OMC Best Paper Award at The 10th Optical Manipulation and Structured Materials Conference (OMC2023).

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Chair : Takashige Omatsu, Chiba University