Research areas in the Strategic Objectives "Pioneering next-generation photonics through the discovery and application of novel optical functions and properties"

6.2.9 Fully-controlled photons and their proactive usage for new era creation (FRONTIER)

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Overview

It is said that light has no intrinsic limitations. The object of this research area is to test and attempt to overcome limitations using light. More specifically, the research area targets (1) research attempting to create new uses for light that can meet a variety of future demands of society in such areas as the environment, energy, manufacturing, telecommunications, and medical care; (2) research using phenomena that appears through the presence and mediation of light to break down walls of conventional fields, such as physics, chemistry, biology and engineering, and bring about great innovation; (3) research for establishing more universal principles and phenomena from the perspective of optical science through high-energy density physics, high field photon science, and studies on the properties of matter under extreme conditions; and (4) research for thoroughly investigating light sources and light-sensing, measuring, and imaging functions needed to implement the above items (1) - (3) and to make such functions available for new applications.

This research area will take a cross-disciplinary approach by actively exchanging information with researchers in other science/technology fields peripherally related to optical sciences and is aimed at producing new perspectives and ideas in advanced research on fields that treat diverse and complex phenomena.

Research Supervisor's Policy on Call for Application, Selection, and Management of the Research Area

Optical science has seen remarkable progress in recent years in the performance of light sources that provide new perspectives in a wide range of fields and serve as a major driving force for the development of new fields. Light is said to have essentially no intrinsic limitations. The goal of this research area is to explore boundaries by thoroughly investigating the essential character of light in all of its properties. We will conduct researches that tackle important issues in a variety of fields in an effort to tear down walls between disciplines by actively utilizing and applying these properties of light.

Examples of research targets

The following are some specific examples of research that fall within the scope of this research area, but is not intended to be restricting.

(1) A study on light-mediated biology, organisms, and medical applications in general, including active functional expressions that transcend imaging

Since creatures on earth were born and raised under light, light has a noninvasive property to organisms and cells while simultaneously possessing a wondrous energy that applies a needed stimulus to living things. Consequently, applications for optics and photonics in bio-science, life-science, and medical science will likely increase in importance. Through the introduction of such ground-breaking technologies as super-resolution optical microscopes and fluorescent protein in recent years, this study is expected to have an immense impact on society, as in the direct observation of activity in living cells. We also anticipate applications for optical sciences in elucidating the mechanisms of more basic physiological phenomena.

(2) A study on devices that apply nanophotonics to produce new functions, and their specific applications

Progress in advanced technological development in the field of nanophotonics has revealed many new properties. The truth is that many hurdles remain in the way of connecting this field to actual applications in society. However, just as research has unveiled new properties of light, progress in research is anticipated to lead to more practical applications for nanophotonics.

(3) A study on physical properties under extreme conditions, light-atom interactions of ultra cold atoms and space-time measurements with optical lattice clocks, and so on.

The physics of ultracold atoms prepared via laser cooling is not only important for verifying basic principles of physical properties, but has also been used to create ultraprecise clocks with optical lattices. Now we can perform measurements to prove that time does not pass at the same rate everywhere in space, which is beginning to open up a whole new world of possibilities. Since ultraprecise frequency control and space-time measurements using light enable us to study fundamental principles of physics through a micro-macro connection, as in gravitational wave astronomy, there is promise for research studies under new concepts.

(4) High-energy physics and its underlying new optical sciences for studying interactions with new matter produced from high energy density and high-intensity electric fields

It has been theoretically predicted that concentrating light to ultrahigh intensity will cause a vacuum to break down into matter. The path to proving this theory involves research on particle acceleration and gamma ray conversion under vacuum through nonlinear, relativistic optics, pulse compression with plasma photonics devices, and plasma interactions with light at extreme conditions. While this research includes many problems

that cannot readily be resolved, making an attempt at resolving the issues may lead to the development of advanced technologies that could impact other fields. Research on the creation of materials having new properties, even new materials generated using high temperature and high density, and on transitional states that are far more diverse than those at room temperature may provide a key opportunity to gain new knowledge in condensed matter physics.

Philosophy on research proposals

The quintessence of research is to challenge the limits of science and technology identified to that point and to attempt to understand and expand the true nature of science and technology by investigating these limits. If research that studies theoretical limits is called pure science, then research on utilizing highly developed technologies to demonstrate a required performance while satisfying the identified limits and developing viable technologies and devices that are beneficial to society may be called "limit-exploring research." Ceaselessly challenging the limits in this way to expand horizons is my goal for this research area.

The research examples given above are all at a stage in which they have begun to show potential. By challenging these issues in earnest, we will likely reveal things that have not been seen before. For this reason, there is great value in grappling with research that challenges limits. Since you are all likely on the cutting edge of research involving light, any proposals in fields outside those in the above examples that go beyond the scope of the research supervisor's concept will be whole-heartedly accepted if they are new and important. In any case, when submitting a proposal I would like the applicant to express a strong passion for implementing their concept. At the same time, I expect the research proposals to be supported by a self-awareness that their study could lead to important research in the long-term.

Exchange and collaboration with other fields

The 20th century is universally regarded as the Electronics Age because there were great technological advances particularly in the field, which led to the creation of a new phase of society and new industries. Based on this case, revolutionary achievements in advanced research must trigger a rippling effect to other fields. Photonics has been considered as a field possessing such promise. In fact, the technology has produced fruits in optical communications when photonics or optics was merged with electronics, but there is much more work to do in order to expand applications into other fields. By resolving these issues, the technology has greater influence on other fields and lead to a paradigm shift in photonics itself.

In light of this, the call for proposals for this research area will give importance to proposals for greatly expanding research through exchange and collaboration with other fields, and we intend to encourage this attitude during implementation of the research because advanced research in fields handling diverse and complex subject matters can also produce new perspectives and ideas when researchers in different fields actively collaborate.

Further, the more complex the subject matter, the more important it is to use sound techniques. When superior methods and techniques developed in one field are applied to another, one can anticipate ground-breaking results. For this research area, we are anticipating the participation of researchers from different fields that all deal with light. In addition to the strong passion mentioned earlier, I expect researchers to establish their own positions on research that includes constructively adopting new techniques and perspectives learned through exchange and collaboration with those in other fields, and encourage them to be mindful of unexpected developments.

Exploring the limits of research requires that one possess clear objectives. It could be said that all researchers are challenging their own limits. Even when the goal seems monumental, one can explore paths that close in on the limits so that the goal does not remain a perpetually unattainable one. Take a broad view of your research from your own perspective and not that of others and work hard toward your goal while gauging the distance between the goal and the limits. As the research supervisor, I will endeavor to provide suitable advice and guidance to direct individual research tasks and will encourage collaboration with researchers in other fields while simultaneously striving to train research personnel that can flourish in the coming era.

Both briefing sessions will be conducted according to the schedule of the listed below for the CREST "Advanced core technology for creation and practical utilization of innovative properties and functions based upon optics and photonics" and PRESTO "Fully-controlled photons and their proactive usage for new era creation" research areas. We hope to see many interested parties in attendance.

Date & Time	Venue
April 26 (Wed) 13:30-16:00	<Kanto-Area> TKP Ichigaya Conference Center 3F, Hall 3C. 8 Ichigaya-Hachimanchō, Shinjuku-ku, Tokyo 162-0844 Japan
April 27 (Thu) 13:30-16:00	<Kansai-Area> Campus Plaza Kyoto, 4F Lecture Room 3. Nishino-Toin-dori Shiokoji Sagaru, Shimogyo-ku, Kyoto 600-8216 Japan

For more information, please visit the following site: http://senryaku.jst.go.jp/teian-en.html.