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

Next-Generation Nano-Optics Using Fast Electrons（Next-Generation Nano-Optics Using Fast Electrons）

Head Investigator	Tokyo Institute of Technology, Department of Materials Science and Engineering, School of Materials and Chemical Technology, Associate Professor SANNOMIYA, Takumi　　Researcher Number:60610152
Research Area Information	Number of Research Area : 22B204　Project Period (FY) : 2022-2024 Keywords : TEM, quantum optics, cathodoluminescence, EELS

Purpose and Background of the Research

●Outline of the Research

Confinement of light in nanospaces*1, that is, control of the local density of states *2 of electromagnetic waves beyond the diffraction limit of light *3, is the key to realize nano-optical devices. Confining light energy to the nanoscale not only reduces the size of optical devices, but also enhances the interaction between matter and light. Improvements in the interaction between matter and light are expected to open up applications in energy conversion, luminescence enhancement, highly sensitive detection of viruses and antibodies, and ultrafast devices. For the development and exploitation of such nano-optical devices, there is an analysis method that measures the density of elementary excited states of light, electrons, and surface wave quasiparticles with a spatial resolution that far exceeds the diffraction limit of light, and directly correlates it with the structure. is necessary. On the other hand, measuring light at scales much smaller than the wavelength of light is not straightforward.

*1　nano: 1/billion

*2　local density of state:　number of containers to store particles within in a limited space and energy

*3　diffraction limit of light: c.a. Light wavelength　~ one billionth of Tokyo Skytree

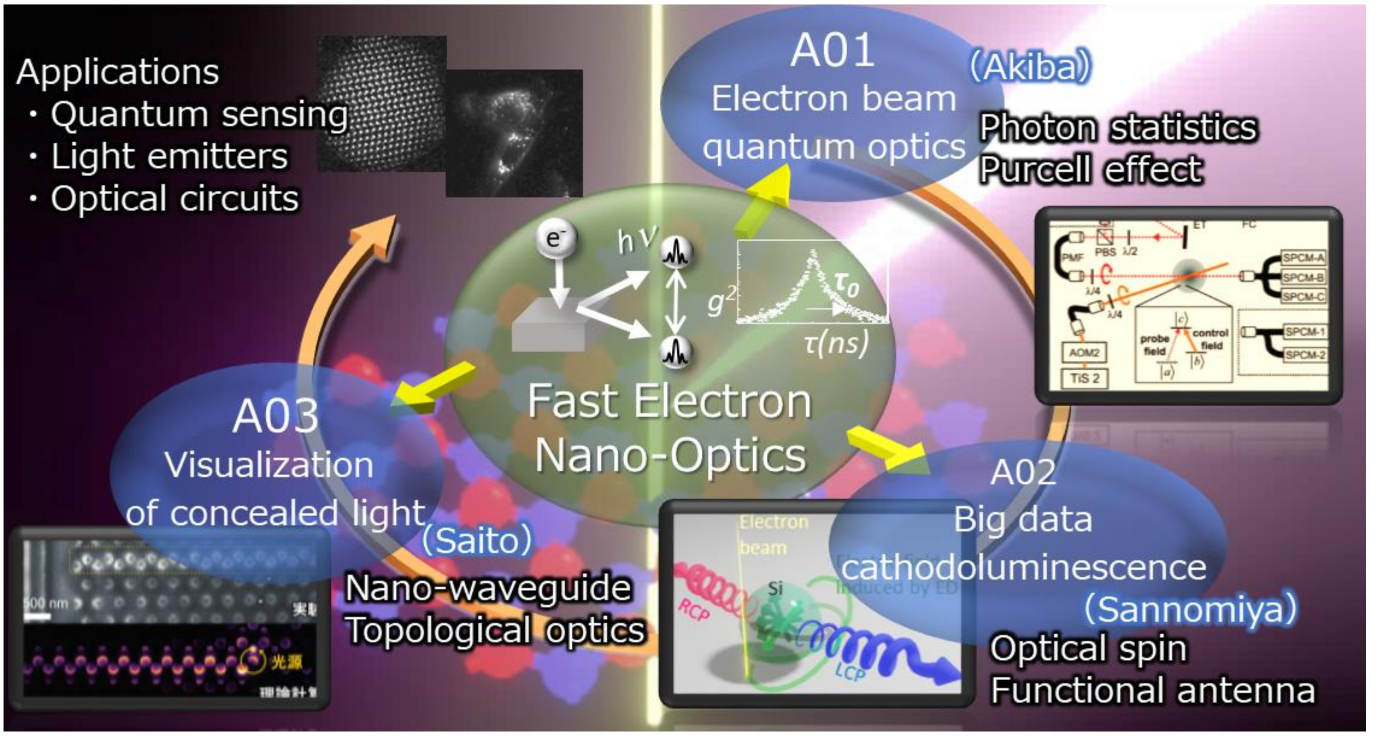

Figure 1. Concept of the research.

In this research, by using high-speed electrons, we will realize the measurement of "light" with super-resolution beyond the diffraction limit of light. As typified by electron microscopes, high-speed electron beams enable ultra-high-resolution imaging on a scale that cannot be achieved with light. Fast electrons accelerated to 10-70% of the speed of light also serve as optical probes with nanometer resolution. In this area research, top runners in optical measurement using high-speed electron beams will serve as representatives of each group, and will use quantum optical measurement, cathodoluminescence, and electron energy loss spectroscopy to measure momentum, which is important in energy conversion, and LEDs. Emission lifetime measurements, which are necessary for understanding carrier dynamics in light-emitting devices, will be performed. In addition to ultra-high resolution, multifaceted parameters such as "momentum", "energy", and "time" will be used to understand the expression mechanism of light functions and realize nano-light control.

Expected Research Achievements

We aim to improve the spatial resolution of the current nano-optical measurement by one or two orders of magnitude and realize multi-functional optical measurement, thereby creating a foundation for the development of next-generation optical circuits, optical energy conversion, and optical sensors. Ultra-high-resolution multi-functional optical measurement will bring out new information in a wide range of fields, elucidating of biological mechanisms and material analysis, in addition to device applications. The research team consists of three groups (themes).

- **Electron beam quantum optics**
  PI: Keiichirou AKIBA, Takasaki Advanced Radiation Research Institute, National Institutes for Quantum Science and Technology
  Member : Tatsuro YUGE, Department of Physics, Shizuoka University
- **Big-data cathodoluminescence**
  PI: Takumi SANNOMIYA, Department of Materials Science and Engineering, Tokyo Institute of Technology
- **Visualization of concealed light**
  PI: Hikaru SAITO, Department of Integrated Materials, Kyushu University

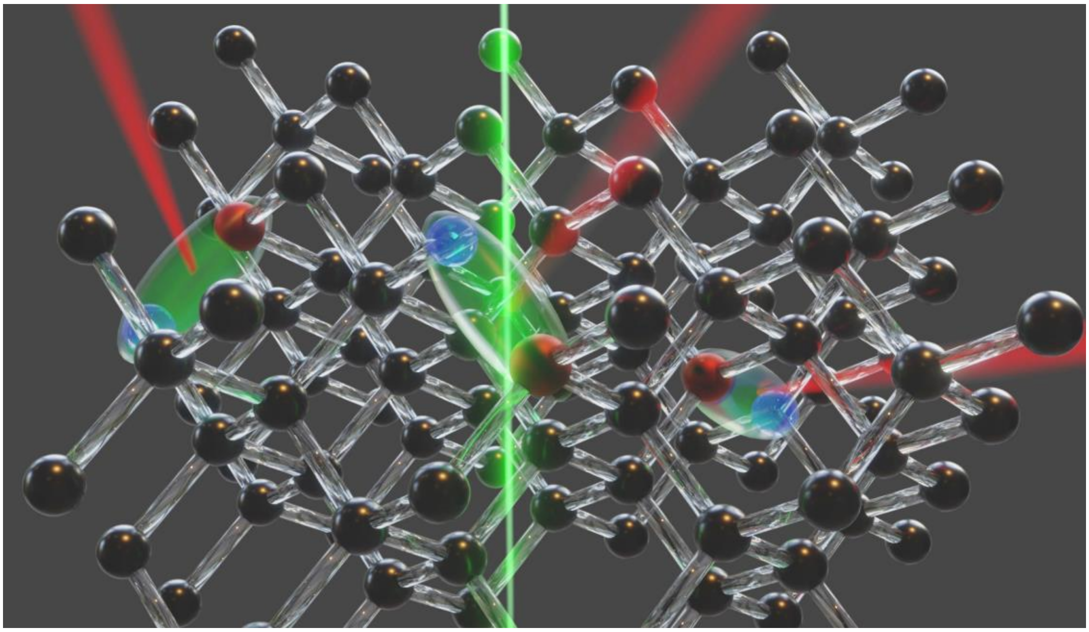

Figure 2. Illustration of cathodoluminescence (electron-beam excited luminescence) from nitrogen-vacancy defect centers in diamond.

Homepage Address, etc.	http://www.sannomiya.iem.titech.ac.jp/FENO