FY2017

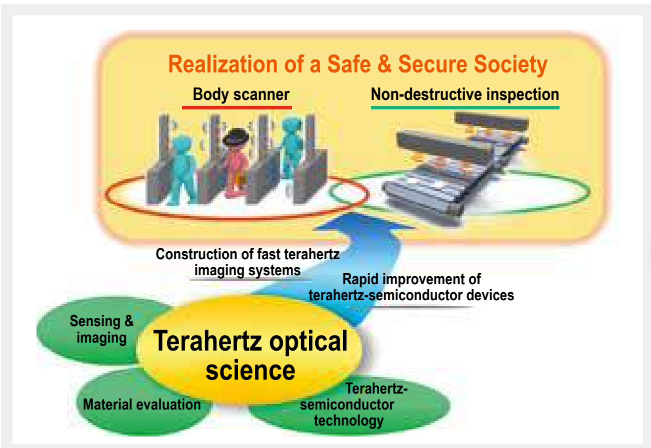
Terahertz Optical Science and Technology in Semiconductors

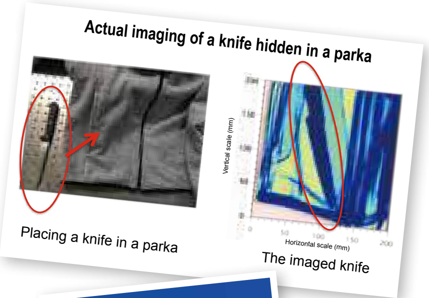
Developing a high-intensity terahertz pulse light source that allows observation of living cells

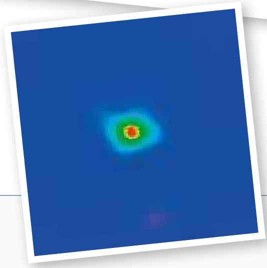
Terahertz (THz) light is the electromagnetic wave range at the boundary between radio waves and light. It has been called an unexplored electromagnetic region because of the difficulty with which it is generated, controlled, and detected. However, recent technological innovations have triggered higher expectations for its commercialization. In the CREST project, we have developed the world's highest intensity THz pulse light source, with a peak electric field of 1 MV/cm or more, using 100 femtoseconds pulsed lasers and lithium niobate crystals. We are able to amplify the number of free electrons responsible for electrical conduction in the semiconductor some 1000 times by simply irradiating the semiconductor with this THz light for a mere trillionth of a second. In addition, we were able to discover a variety of extremely non-linear optical responses. Moreover, by developing a novel THz near field microscopic apparatus that takes advantage of the characteristics of this light source, we have achieved real-time observation with video rates and spatial resolutions of less than a hundredth of the wavelength limit, succeeding in the observation of living cells as well.

Construction of a high-resolution, high-speed, safe terahertz imaging system

In addition to the development of the THz light source and detector, issues to be addressed in the ACCEL project include systemization. While the THz light source has seen rapid development, the output levels are still insufficient. We will expand light-laser-excitation terahertz technology into terahertz-semiconductor technology, constructing a basic imaging system using semiconductor sources and detectors. With the increases in output power and imaging speed gained by making arrays and modules of semiconductor light sources and with the sensitivity improvement gained by adding phase detection technology to detectors, we will use conversion to arrays and modules for high-speed imaging and construct a basic terahertz imaging system composed of a light source, detector, optimized low-loss optical system, control system, and analysis software to make possible equipment such as body scanners and non-destructive inspection systems that are even higher-resolution, faster, and safer than the existing technologies. This will enhance the security of public places such as transport facilities and improve the safety of products manufactured at factories or other locations, leading to a safer and more secure society.







Terahertz (THz) light

This is a special light/electromagnetic wave that falls in the region between millimeter waves and infrared light, with the characteristic of both radio waves and light. It passes through media such as cloth, paper, plastics, and wood, but not water or metal. It generally has an oscillation frequency of 300 GHz to 10 THz, which is the region that provides much information about molecular structures and kinetic states, including molecular vibration and rotation, molecular interaction, and the lattice vibration of solids.

Research Director

Koichiro Tanaka

Professor, Graduate School of Science, Kyoto University

Out of an interest in fundamental physics, I previously conducted research using THz light as a tool to investigate the excitation mode of electrons and molecules in semiconductors. I started out by using existing equipment for measurement, but the light source intensity was weak, and I became unsatisfied with the measurement method as well. This motivated me to continue pursuing world leading research, with the goal of developing a light source and creating a measurement apparatus. Now I have succeeded in developing the underlying technology necessary to apply imaging technology using THz light to society.

In this ACCEL project, we will drastically improve the performance of individual elements based on semiconductors, reconstructing the THz light system in order to satisfy every one of those long-unmet industrial expectations, bringing about a real-time, reliable, and safe imaging system.

I have already drawn multiple road maps to success. My aim is the creation of innovations that will allow this technology to become common and contribute to society as soon as possible.

I am convinced I can succeed in paving the way to a new phase by going back to the first principles of physics, thinking independently, and reconstructing them from scratch.

Program Manager

Ryoichi Fukasawa

ACCEL Program Manager, Japan Science and Technology Agency

When I was carrying out corporate research on THz technology, Professor Tanaka and I succeeded in developing a compact THz sensing system that was revolutionary at that time. Later, I founded an R&D-type venture company and continued development towards putting THz light technology to practical use, such as establishing non-destructive inspection equipment utilizing THz light. These days, the industry has increasing and varying demands for the ability to image objects more precisely and more finely, so I am constantly strongly reminded of the need for a THz light technology that allows us visualize objects that were invisible using existing light technology. THz light technology has made some impressive advances in recent years, but there are still obstacles preventing the wide adoption of this technology in society. To solve these problems, we need to accomplish breakthroughs such as downsizing and reducing costs by carrying out semiconductor-focused research in this ACCEL project.

To open up the path towards full-scale application of THz light technology, we shall move this project ahead with the goal of promoting participation from industry and expanding applications.

I am engaged in this project with the conviction that this is a once-in-a-lifetime opportunity, fulfilling the dreams of many researchers and others who have been involved with this THz technology.

Technology development towards industrial application of terahertz light aimed at helping achieving a safe and secure society.

PROFILE KOICHIRO TANAKA

1990: Ph.D. (Science), Kyoto University; after working at the Institute for Solid State Physics at The University of Tokyo and other institutes, started work at Kyoto University in 1997; 2004: Professor, Kyoto University; 2008: Adjunct PI, Professor, iCeMS, Kyoto University; 2014: Professor in Graduate School of Science and concurrently appointed to iCeMS. Field of expertise: Optical physics.

PROFILE RYOICHI FUKASAWA

1989: Ph.D. (Physics), Niigata University. Joined Japan Spectroscopic Corporation; after working for Tochigi Nikon Corporation and others, founded Spectra Design Ltd. in 2004, and has been president of the company since 2008. Involved in R&D in terahertz engineering for many years, and engaged in a range of work that includes starting a new business for non-destructive inspection systems.