Nara Institute of Science and Technology

Takayuki Yanagida
Professor, Division of Materials Science, Nara Institute of Science and Technology

NARA INSTITUTE OF SCIENCE AND TECHNOLOGY

Nara Institute of Science and Technology (NAIST) was officially established in 1991, making NAIST one of the newest national universities in Japan. NAIST is in Nara prefecture and is close to Nara city. Approximately 1,300 years ago, Nara was the first capital city of Japan and consequently there are many ancient temples in Nara. NAIST is also close to two famous cities in Japan; specifically, to Osaka and Kyoto. Osaka is Japan's second largest city and Kyoto is a familiar city for tourists from all over the world. These two cities can be accessed from NAIST within one hour by train or car. For international visitors, there is one accessible airport, namely Kansai International Airport. From this airport, there is a direct bus to a close station of NAIST (Tomigaoka Station), which makes accessibility from abroad convenient. In addition to Kansai International Airport, Osaka International Airport has many domestic lines to most Japanese cities.

NAIST is oriented toward research and the education of graduate students. In typical years, NAIST has approximately 700 master's degree and 350 doctoral degree students. Among these one thousand students, typically 20~30% of these students are international students.

NAIST has three divisions: information science, biological science, and materials science. In 1993, the first master's degree students were enrolled in information science, and then in 1994 the division of biological science began enrollment. The division of materials science started enrolling graduate students in 1998. In addition to these three divisions, we have several research centers focusing on specific research themes, i.e., the Research and Education Center for Genetic Information; the Research and Education Center for Materials Science; and the Data Science Center.

Figure 1 represents the number of publications where the authors were affiliated with NAIST, since the establishment of the university. In the past five years, there has been a continuous increase in the number of publications; when compared to five years ago, the number of publications increased 36%. Our university has typically two hundred instructors (professors, associate professors, and assistant professors) and, most recently, there were approximately 2.5 papers/year for every one instructor at NAIST. This rate of publication is a top-level achievement for universities in Japan. Unfortunately, as a general tendency, the number of publications in Japan has continuously decreased in the last 20 years due to decreases in Japan's national research budget; NAIST, however, has shown great levels of performance despite this difficult situation. Because our university is solely a graduate school, the instructors are relatively free from classroom lectures as compared to typical universities, where there are teaching requirements for the undergraduate courses. The lighter teaching load is one of the reasons for NAIST's top performance in publications.

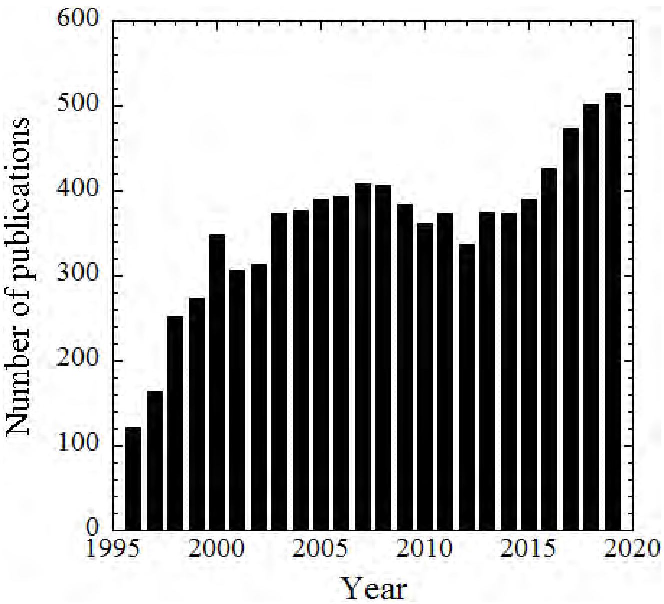

Fig. 1: Publications with authors affiliated with NAIST. Data taken from Scival.

EDUCATIONAL PROGRAMS

At NAIST, instructors (professors, associate professors and assistant professors) belong to one of NAIST's three divisions, in information science, biological science or materials science. Similarly, the laboratories also belong to these three divisions. Students, however, can be part of seven programs. The seven programs have three base programs: information science and engineering, biological science and engineering, and materials science and engineering. In addition to these three base programs, NAIST offers four interdisciplinary programs: computational biology (information + biological science), intelligent cyber-physical systems (information + materials science), bionanotechnology (biological and materials science) and data science (information + biological + materials science). Students can select one of the seven programs, and they can attend lectures offered in each program. For example, if a student selects the materials science and engineering program, that student can take lectures in physics and chemistry. If a student selects bionanotechnology, lectures in physics, chemistry and biology are offered. Typical master's degree students take 20 subjects (one subject with one credit with 8 classroom lectures) relating to their research topic. The situation for doctoral candidates is almost the same, but the number of classroom lectures is limited because the doctoral students need to concentrate on their own research. A schematic drawing of the relationship between the divisions and programs is shown in Figure 2.

Classroom lectures are critically important in most universities with undergraduates students; however, as NAIST is solely a graduate school, education in the laboratory (for thesis research) is the most important. In NAIST, each laboratory can select which programs they join, and students can join the laboratory that is associated with the preferable program of each student. As a maximum, one laboratory can join four programs (one base program and three interdisciplinary programs), while some laboratories offer one program as a minimum. In recent years, interdisciplinary research has become ever more important, and NAIST's educational programs are structured to maximize the strengths of interdisciplinary studies.

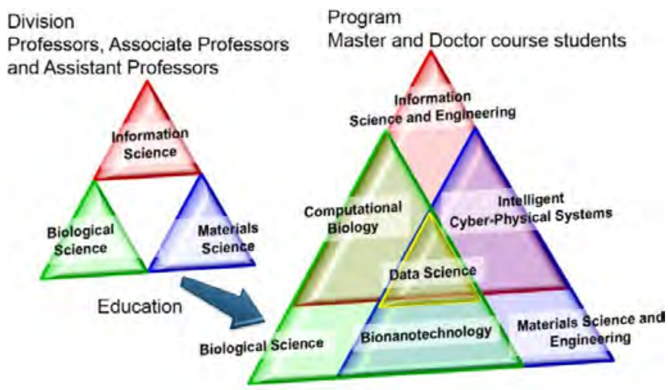

Fig. 2: Divisions and programs of NAIST.

DIVISION OF MATERIALS SCIENCE

Given that this article is published in the *Association of Asia Pacific Physical Societies Bulletin (AB)*, we can assume that our readers will have an interest in physics; thus the rest of the article will focus on the Division of Materials Science. The Division of Materials Science has some buildings where experimental and lecture rooms exist, as shown in Figure 3. There are two main buildings, and the first and second floors of both buildings are mainly lecture rooms. Laboratories are in the upper floors and typically each laboratory has a size of $\sim$400 m^2. This amount of laboratory space is large, as compared to typical Japanese universities.

Fig. 3: Division of Materials Science, NAIST.

The Division of Materials Science consists of mainly two parts, physics and chemistry, as shown in Figure 4. Physics is then subdivided into two subgroups: physics and electronics. The laboratories in the physics group focus mostly on solid state physics, and those in the electronics group study applied physics. Chemistry is also divided into two subgroups: chemistry and chemical biology. There are sixteen key laboratories in the division, and five collaborative laboratories. The latter laboratories are operated by researchers outside of the university, such as private companies and national institutes, and in this way, students can have opportunities to learn research topics associated with those companies and national institutes.

The research topics of the physics laboratories will be described in the following section.

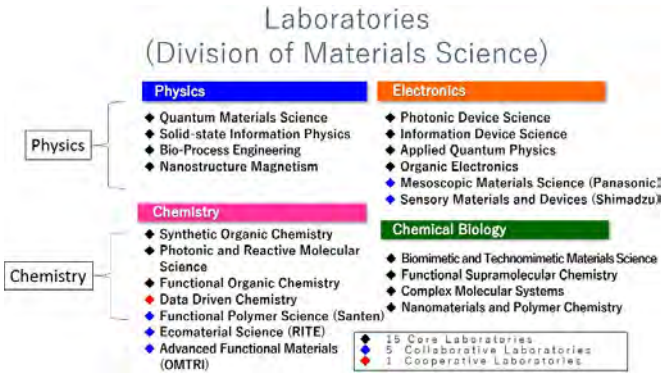

Fig. 4: Laboratories in the Division of Materials Science.

In the physics subgroup, there are four laboratories. Generally, most of the laboratories in the physics group are assigned to the faculty of science in common universities. The Quantum Materials Science Laboratory investigates luminescent materials and luminescent physics, and their main research topics are organic lasers, exciton polaritons, and quantum dots. In particular, they focus on quantum size effects, ranging from the synthesis of samples to the evaluation of physical properties of synthesized samples. In their research of organic lasers, they use thiophene and phenylene crystals, and by tuning the amount of chemical bonds and their order, they can control the emission wavelength (color) of the laser. This is a typical quantum size effect of actual materials. In addition to developing a new laser, they also study quantum coherence in lasers, which could be applied for future quantum computing.

The Solid-State Information Physics Laboratory is one of the most authoritative groups for structural analysis in Japan. They observe atomic and electronic structures of functional materials to clarify the origin of functionalities. They can reconstruct 3D nano-scale images of materials, and they can draw photoelectron holography and electron diffraction tomography images under deep collaborations with synchrotron facilities. In addition to the development of an original analysis technique, they have joined a project regarding new observation devices, using holography of functional materials such as phosphors. Recently, they have focused on dopants in functional materials. A low percentage of dopants are added to mother (host) materials and those dopants govern functionalities of materials. They are interested in understanding the function addition by dopants.

The Bio-Process Engineering Laboratory would not normally be classified in general physics if one would strictly focus on their research topic. Their main objective is to observe and control biological phenomena by lasers, and such research is generally classified under applied physics. Historically, however, laser laboratories at NAIST have been assigned to the physics group and for this reason, the Bio-Process Engineering Laboratory is in the physics group. Using lasers, they manipulate very small cells and, owing to their high-level techniques, they have joined some large national projects.

The Nanostructure Magnetism Laboratory studies magnetic materials and their magnetic properties, using X-rays. The main objective of the division is to study optical nano-science. Optical properties are mostly caused by electromagnetic interactions between photons and materials, and magnetic properties deeply relate to optical properties because the root of these phenomena is electrons. The main research topics of this group are induced magnetism of non-magnetic layer conduction electrons, the element selective vector magnetization process, and surface magnetism of exchange bias film and the development of novel measurement techniques for magnetic properties by synchrotron radiation.

In contrast to the physics subgroup, the electronics subgroup is assigned in faculty of engineering in most universities, and compatible department will be applied physics or electrical and electronic engineering. There are four key laboratories in this subgroup, and the main aim of these laboratories is the development of new devices for practical applications. Consequently, most of the laboratories in this group have collaborations with companies.

The Photonic Science Device Laboratory studies photonic devices for biological applications. One of the famous topics of this group is artificial vision. They have investigated an electronical device that can stimulate retinas by using electricity, and by using some technologies of the LSI (large scale integration) fabrication process, they successfully confirmed the concept in a mouse. They embedded an LSI-based electronic device outside a retina, and artificial vision could be realized by outer stimulation. In addition to the development of such a device offering a function to patients, they have continuously studied new devices to observe functions in the brain. In order to observe any signals in the brain, imagers with very high spatial resolution are required. In such experiments, they give a drug containing luminescent molecules to mice, and they observe functions of the brain by luminescence from the drug. The typical device size is less than 1 mm, and very high resolution can be achieved by those devices. Similarly, with luminescent molecule-based drug delivery, they have developed a very small LED to stimulate the brain using light. Some cells react to light illumination, and we can observe a response of the brain under illumination. These are the main topics of the Photonic Science Device Laboratory, and there are many other projects based on optical devices that are running in this group with some collaborative companies.

The Information Device Science Laboratory studies conventional semiconductor devices. One of the main topics is the development of a thin film transistor (TFT) for displays and other applications. Recently, they have studied IGZO (In-Ga-Zn oxide) for transparent electrodes for future monitors. Solar cells are also a main topic. They have developed some observation techniques regarding the degradation of Si-based solar cells, using cathode luminescence. In addition to studies on conventional Si-based solar cells, they study new semiconductors for solar cells, and one example is organic-inorganic layered perovskite. For future electric power supplies, the suppression of energy loss is a critical problem. The Information Device Science Laboratory investigates new power devices in order to resolve this problem, and a GaN-based power device has been studied. Semiconductor devices are a major industry in Japan and as the Information Device Science Group is one of the top groups in this field in Japan, many collaborations are done with companies.

The Applied Quantum Physics Laboratory's main topic is the development of new ionizing radiation detectors, with a particular focus on phosphor-based radiation detectors, including scintillation detectors and phosphor-based dosimeters. This group has succeeded to practicalize some materials and instrumentations, such as GAGG scintillators (Furukawa), $LiCaAlF_6$ scintillators (Tokuyama Corp.), Tl/Bi co-doped CsI scintillators (Nihon Kessho Kogaku), SrI_2 scintillators (Oxide Corp.), a pulse X-ray streak camera system and an afterglow characterization system (both by Hamamatsu Photonics K. K.). Based on these industrial successes, many collaborations are being done with companies. In addition to their achievements in practical applications, a noticeable achievement of this group is their number of publications in one year. Typically, 60~70 papers are published in this group in a year, and their share of publications affiliated with NAIST, each year, is typically 15%. To the best of my knowledge, this is the top amount in Japan, in terms of the number

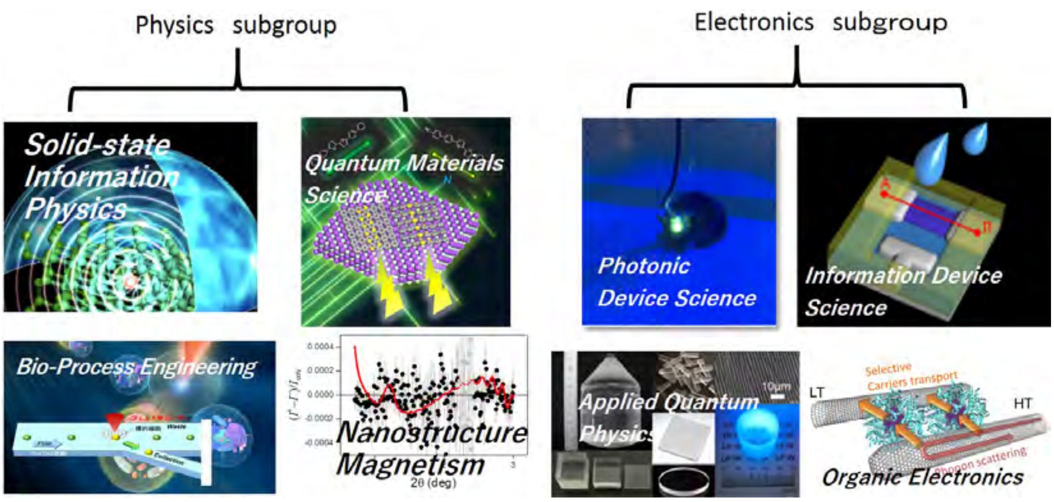

Fig. 5: Laboratories in the Physics Group.

of publications affiliated with one laboratory. In terms of our current status, the laboratory has already published more than 90 papers as of 2020 Sept.

The above three laboratories study devices consisting mainly of inorganic materials. The Organic Electronics Laboratory conducts research on devices consisting of organic materials. They have two main topics. One topic is to create thermoelectric devices using organic materials for power generation of wearable devices, such as clothing-embedded devices. For such wearable devices, flexibility is the most important function, and organic materials will be the best means to achieve that flexibility. The other topic is the creation of plastic solar cells. Although they are less efficient than Si-based solar cells, the environmental affinity and relative cost of plastic solar cells make them superior to Si-based solar cells.

Figure 5 shows the laboratories of the physics group. As explained earlier, NAIST has four subgroups in physics and four subgroups in electronics as key laboratories, and the balance of the laboratories is very good, from a science and engineering viewpoint. In addition to the eight laboratories described earlier, there are two laboratories by the companies Shimadzu Corp. and Panasonic Corp., respectively.

NAIST is an extremely unique and vibrant university in Japan. More information about NAIST can be found on our website: http://www.naist.jp/en/

Takayuki Yanagida was born in Japan in 1978. In 2002, he received a BS degree from the Faculty of Science at the University of Tokyo, Japan, and MS and PhD degrees in physics from the University of Tokyo in 2004 and 2007, respectively. He worked at Tohoku University from Apr. 2007 to 2012, and at Kyushu Institute of Technology from Sept. 2012 to Mar. 2015. In 2015, he became a professor at Nara Institute of Science and Technology. He has received a total of 17 awards. In 2014, he received the Young Scientist Award from the Ministry of Education, Culture, Sports, Science and Technology of Japan. In 2017, he received the JSPS (Japan Society for the Promotion of Science) Prize. He is on the editorial board of the *Journal of Materials Science: Materials in Electronics and Sensors and Materials*. His research interests include the synthesis and evaluation of scintillation and dosimeter materials, and the development of radiation detector devices using those materials.