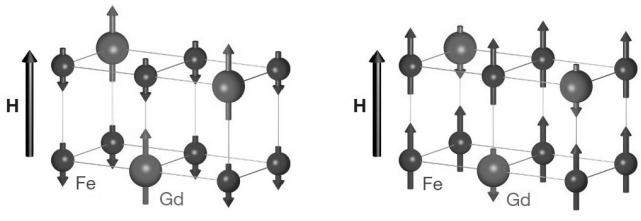
Toward a Healthy Future

Almost three years have passed since we started our project "Nanotechnology Excellence, Nihon University — Nanomaterial-based Photonic, Quantum and Bio Technologies —" in the strategic research scheme of our university, "Nihon University *N.* research project."

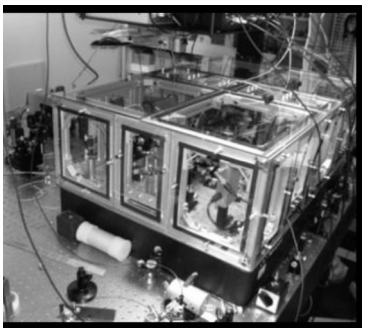
The purpose of our project is to contribute to find solutions for three big issues — (1) cancer, which accounts for a third of deaths in Japan, (2) shortage of fossil fuel and increase in the atmospheric CO_2 concentration, and (3) dire need of massive and secure information processing — for a healthy future comes true. Despite the apparent diversity of these issues, views from nanoscience and nanotechnologies may allow a common approach from different but relevant fields. Our approach to these issues is on the basis of nanomaterials, particularly from the viewpoints of quantum mechanical interactions of matter with light. This interdisciplinary endeavor is being made through collaboration among practitioners in science, engineering, and medicine from five Colleges of Nihon University.

The first year saw some excellent achievements, such as one in the area of super-high speed recording, which was covered as research topics in several journal articles, and another on the analysis of genetic network, which was published in *Nature*. The most notable in the second year is the research on quantum information by Inoue et al. Three major achievements are that: (1) the highest rate of 2.8 kilobit in the entanglement distribution at the telecommunication wavelength to date, (2) the detection efficiency of 98.4% with their photon-number resolving detector, the highest for an optical photon detector, and (3) the fabrication of the first superconducting nanowire single photon detector using niobium film. Some of these works have been published in *Nature Photonics*, and led to the successful awarding of the Strategic Information and Communications R&D Promotion Program (SCOPE) funded by the Ministry of Internal Affairs and Communications.

The research in the information technologies and related science have continued to develop in the third year. The highest rate (24 kbit/s) and the longest distance (100 km) quantum information transfer were achieved using the highest-rate single-photon detector and the most sensitive photon-number resolving detector, which were developed by Inoue and co-workers (Inoue et al., *Phys. Rev. Lett.* 2011, 106 250503). These works were covered in technology-related newspapers and publications. Behaviors of spins in a magnetic material in a femto second regime were revealed for the first time (Tsukamoto, Itoh et al. *Nature* 2011, 472, 205). Yet another new result has just been accepted for publication in *Nature Communications*.



Nature **2011**, *472*, 205.



Quantum receiver

In the energy area, greener alternatives are being researched that maximizing the use of solar energy as an energy source and hydrogen as an energy storage material. A unique finding is that placing a

hydrogen-storage alloy in a container in which cyanobactria is producing hydrogen is a method not only for efficiently collecting hydrogen produced; but also the amount of hydrogen produced increases (Patent Application, 2011-124597). Solid oxide fuel cell consists of three phases: fuel electrode, electrolyte, and air electrode. The optimized material for each of these phases has been developed: a material for the fuel electrode, which is stable under high temperatures and reductive conditions, a material as the electrolyte with a high proton conductivity and excellent sintering characteristics, and an electrolyte material with a large surface area and a suitable porosity (The best presentation award was given to Sugimoto from the Ceramic Society of Japan). We are now ready to construct a model fuel cell using these materials.

In the medical area, our research on pyrrole-imidazole polyamides, a class of synthetic compounds that can be tailor made to selectively recognize the base sequence in DNA, cover over a whole range from the synthesis and chemical characterization to in vitro and in vivo studies. Exemplary results obtained this year are (1) an efficient synthesis of cyclic PI polyamides, (2) efficient suppression of p57KIP2 gene in relation to peripatetic cancer, (3) lead polyamides selected for inhibition of TGF-β1, (4) conjugate between SAHA, a HDAC inhibitor, and PI polyamides for targeting specific subsets of genes in cancer. Research environments are being strengthened to further the researches into practival drugs. Collaboration agreements were made with the pharmaceutical department of Itahashi Hospital for the preparation of ointments of PI polyamides as well as with the Central Institute for Experimental Animals for the application of PI polyamides on marmosets.

Another interesting finding is that some derivatives of sensitizing compounds used in PDT are effective not only with visible light irradiation but also with X-ray irradiation. This is a finding that would potentially widen the scope of PDT, which currently limited to tumors close to the body surface due to the limited transmittance of visible light through body tissue.

A paper by Matsumoto et al. was selected as the paper of the year by The Japanese Journal of Therapeutic Drug Monitoring.

Training younger generation researchers is another important objective of our project. Nine post-doctoral fellows and 3 research assistants are working with financial support from the Project. Good news is that 4 students who presented their works as part of the Project were awarded excellent presentation prizes in academic meetings.

We are trying to make our research visible with various channels. Developments made in the field of quantum information technology were covered in Japanese industry papers and magazines. For publication within the university, three review articles by member researchers were published in a University journal and are now available free on line in J-Stage (see Topics in our website).

We are doing our best, through our research, to create a center of excellence in the field of nanoscience and nanotechnology, which will hopefully be recognized as such in the scientific communities academic and industrial, domestic and international, in two years when the Project will have been completed.

Joe Otsuki, Principal Investigator, January 25, 2012.