From Science to Innovative Core Technology

Hideaki Takayanagi
Director of NTT Basic Research Laboratories

NTT Basic Research Laboratories (BRL) was established in 1998 when the former BRL was divided into two: NTT Communication Science Laboratories and NTT BRL. Ever since then, we have been focusing on basic research in the area of hardware. Our goals are to: 1) discover novel principles and invent novel concepts in the field of network technology to overcome the present limitations in speed, capacity, and size and 2) pioneer basic technology that will become a frontier for future business. Our two most promising projects are quantum information processing and the nano-bio project.

The main research in quantum information processing is on quantum computers and quantum cryptography. The quantum computer, which is based on the principles of quantum mechanics, unfortunately has a negative image as something that could crack public key cryptography. However, it has good potential for developing superior algorithms as valuable as Shor's algorithm, which would lead to various applications. Taking advantage of our ability to run projects ranging from small to huge, NTT BRL has engaged in research on quantum bits using solid-state components utilizing both superconductors and semiconductors. We have achieved world-class success in quantum oscillation measurement and single-shot readout. However, we are still at the initial stage, operating with only 1 or 2 quantum bits, so it is likely to take another 15 to 20 years to actually make the so-called "dream computer." On the other hand, quantum cryptography can be put to use much faster, in 5 to 10 years. Therefore, we are currently accelerating research in this field using single photons.

The nano-bio project is based on the fusion of neuroscience with bio-molecular science and nanotechnology. Analysis of the nano-scale conformational change of receptor protein corresponding to signal transduction is one of the themes. A hybrid of molecular and protein-based devices that could be operated with a bio-informational architecture could be the basis of novel devices in the future. This interdisciplinary research is extremely promising for creating a new field of science and new knowledge. Nano-bio science could be a key to understanding mysterious biological phenomena and developing new technologies that lead to a novel, innovative social life in the future.

While promoting these two projects, we are also implementing exploratory research in the following fields: quantum correlation within low-dimensional electron systems, systems that use the spin of individual electrons as an information carrier, material design that uses quantum dots as building blocks, electrical properties of carbon nano-tubes, and MEMS (microelectromechanical systems) related to superconductivity. As we research these topics, it is essential to judge whether or not they will bear fruit in the future, so good communication between researchers and managers is vital.

Alongside such exploratory research, we are putting efforts into creating innovative technology. For instance, in the field of diamond semiconductors, whose ability to handle high power and high-frequency waves should enable them to perform various applications, we have succeeded in operating a diamond transistor at 80 GHz by developing technology to produce diamond thin films of high quality. Moreover, we recently developed three-dimensional electron beam exposure technology and created the world's smallest globe, 30 µm in diameter. This exposure technology is expected to lead to the development of nano-bio devices. In addition, we are engaged in research on single-electron devices, which have extremely low power consumption, photonic crystals for use as active optical circuits, and optical devices using wide-bandgap semiconductor materials. We see these as innovative technologies that will overcome the limitations of the present network.

To maintain fruitful research activities we believe it is essential to have an open research policy. We not only keep in close touch with other NTT Laboratories, but also run various scientific exchange programs with institutes inside and outside Japan. We have been working on quantum dots and quantum bits together with Delft University and Stanford University for years. Nano-bio research with the University of Tokyo has also been producing promising results. In addition, we are undertaking nearly 100 projects with others on both the group and individual levels, and these have all been mutually beneficial. Moreover, we hold International Symposiums, Summer Schools, and International Advisory Board Meetings to disseminate our research information worldwide and to encourage greater understanding of it.