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An ICT Device Technology for the Future
— A High-Performance Device Using the New "Dendrimer" Material —

Future Demands of Communication Systems

As info-communication technologies advance to meet the demands of the coming age of a borderless and ubiquitous society, research and development of plastic communication devices is actively underway. As optical communications become a household technology and demands increase for optical technologies for electronic appliances and mobile electronic devices, plastics are coming into focus as new flexible materials that will allow for low-cost mass production of such devices. Recent progress in technologies in the use of plastics has expanded the area of application from simple optical guiding devices to devices with high-precision fine structures and high-performance electro-optic properties. In order to respond to the need for novel mobile devices that will allow access to needed information at any time and place, we must develop thin, lightweight, flexible devices offering high performance and low power consumption. Furthermore, to develop devices that will permit people to enjoy seamless info-communication services, we must first overcome the challenges inherent in developing low-load, environmentally friendly designs and energy-saving technologies. NICT believes that the answer to the above demands lies in molecular device technology. In this report, we will introduce research and development of high-performance photonic material technologies.

Pioneering the Future with Nano-Scale Technologies

With time, plastics have evolved into advanced materials offering superior properties such as lightness, strength, and flexibility, and plastic products have entered into our daily lives in various forms and with innovative designs. Indeed, plastic is coming to be recognized as a nearly ubiquitous material. Plastics are called as "polymer molecules." Recent R&D efforts in the production of high-performance plastics have enabled their transformation into a completely new material that transmits light and records information. Some example applications using such new properties include flexible displays, holographic memory, and molecular transistors. These new properties are expected to render these plastics useful in info-communication systems when used as elements for mobile devices, large-volume memory, and processors with low power consumption. The basic properties of these materials are controlled by the electro-optical functions of the individual molecules; thus, development of basic molecular materials and elemental technology that make the most of these electro-optical functions will form an extremely important focus in the R&D stages of our endeavor.

The basic research at NICT will be aimed at the development of polymer device applications in the info-communication field. Research conducted to date has focused deep into basic areas such as studies on the detailed molecular structures involved. The result was the production of a high-performance material designated a "dendrimer." As shown in the figure for the Keyword of the Month, the dendrimer encapsulated a fluorescent unit at the center of its molecular structure. By enclosing the functional unit inside a dendrimer having a diameter of several nanometers, a fluorescent efficiency of nearly 100% may be achieved. Furthermore, the molecule offers wide applications, and allows control of light from the visible to the near-infrared range.

Towards Versatile Human Sensing

The creation of new materials such as that described above having high-performance optical properties has expanded the range of applications in the info-communication field. It is now possible to emit light and perform signal conversion and processing using plastic devices. The dendrimer has superior properties that allow the processing of the plastic devices with precision. Furthermore, device structures can be created with high precision through a surprisingly simple process. With the present efforts, we are also developing a fabrication technology for fine-structured polymer devices using laser processing. We modified a conventional optical microscope system for polymer device fabrication as shown in Figure 1. With this relatively simple assembly, we have succeeded in producing polymer micro-structures with high precision by making use of the optical functionality of molecules. Presently, this instrument is capable of creating prototypes of finely structured elements featuring polymer line with a linewidth of 100 nanometers. Unlike the semiconductor lithography method, the present technology does not require multiple steps within a clean room, and so we expect the current method to find use in a wide range of applications, due to its simplicity and the facility

Life and Technology

Q: How could future electronic devices be affected by the results of R&D on plastic communication devices?

A: Studies are now underway to replace the metal electronic materials that have been used in batteries, condensers, and antistatic films with newly developed plastics that conduct electricity. Applications such as display elements that make use of the clear luminescent properties of molecules and transistors with integrated circuits on flexible substrates that can be shaped are under development. These devices have a range of superior properties: lightweight, portable, low power consumption. They are thus expected to find wide application in mobile products and ubiquitous sensors. Since plastic elements can be mass-produced by heat molding or the inkjet-print method, these elements offer the advantages of being cost-efficient and environmentally friendly. Presently, high-performance plastic elements are under development for various applications—both in terms of common household products and for micro-scale parts too small to be seen with the naked eye.

of high-precision fabrication.

An optical diffraction grating—a representative example of an optical element—requires high-precision periodic structures on the order of several hundred nanometers. This level of precision can be provided through our polymer processing technique. Figure 2 shows a plastic laser element produced using dendrimer. This device is designed so that the properties of the laser may be adjusted by integrating the polymer narrow-line at high density, thereby enabling control of the generation and transmission of light from the visible to the near-infrared bands. Further, we are beginning to investigate a number of sensor applications that make use of the high-performance sensing properties of molecules and high-precision element-processing technology, with a view to the development of so-called "human sensing" technologies.

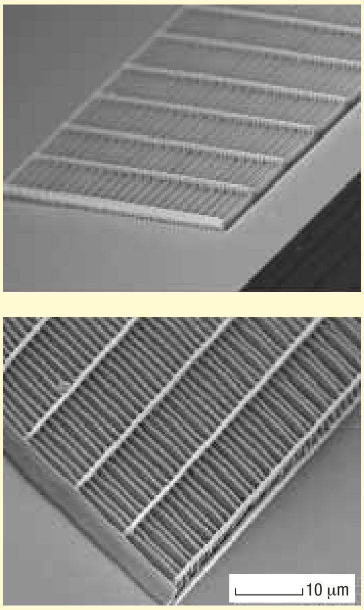
Bringing Molecular Device Technologies Nearer to Our Daily Lives

As stated above in this section, device technologies that make use of the high-performance properties of molecules offer superior qualities such as high functionality, low cost, and low power consumption, as required to satisfy the demands of technologies for a ubiquitous society. In the future, we hope to promote further developments in molecular device technologies and to contribute to the development of "soft-device" technologies, which will bring info-communication services even nearer to the common user, as well as to pursue the environmental and energy-conservation issues we expect to face in the future of info-communication technologies.

Figure 1

A Photo of polymer-element fabrication instrument. This instrument with simple configurations is capable of creating high-precision polymer-elements on the order of 100 nanometers.

Figure 2



Photos of polymer laser elements produced (the lower is a close-up). Since the element can be applied to plastic substrates during fabrication, we anticipate that it will have a wide range of applications including sensor technologies.

Researcher

Shiyoshi Yokoyama

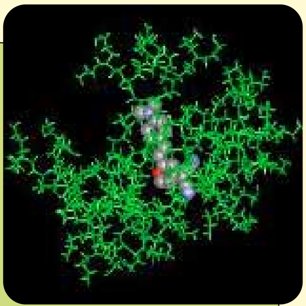
Group leader of the Nano ICT Group
Kobe Advanced ICT Research Center

After completing a graduate course, joined the CRL (presently NICT) in 1995, where he currently remains. Conducts research on non-linear optical properties of molecular materials, luminescent elements, and device technology. Took up swimming two years ago, and his goal is to swim 150 km per year. Doctor of engineering.

This month's key concept

[Dendrimer]

Dendrimers are large molecules that have branching chains radiating from the center, creating a structure resembling a tree or sphere. This molecular structure was named after the Greek word "dendron," meaning tree. Unlike a normal chain polymer, a dendrimer spreads out in radial directions by regular repetition of branching of the unit from the core, ultimately forming a tree-like sphere. This property has become a focus of research in the biotechnology and pharmaceutical fields. As in fractal forms, the branching is referred to as "generation 1," "generation 2," and so on. It can be synthesized a generation at a time, thus allowing high degrees of freedom in the design of its structure. The dendrimer developed at NICT (see figure) is a "fluorescent" polymer that can be used in advanced applications such as plastic light sources and lasers. It has also been found to offer superior fine-processing properties that will serve as important elements in molecular nanotechnology-based technology of optical-device fabrication.



The picture shows the molecular structure of a dendrimer. The dendrimer has a spherical shape with a diameter of several nanometers and a single luminescent pigment bonded to its core. This dendrimer displays a fluorescent efficiency of nearly 100%.

NICT Succeeds in the World's First Optical Communication between an Optical Ground Station and a Low-Orbiting Satellite

— Aiming to Establish the Basic Technologies for a Next-Generation Space Communication Network —

The Arrival of the Age of the Photonic Network

The popularization of ADSL and optic-fiber networks in recent years has made high-speed Internet environments available to the common household. In the future, the speeds offered by ground-based communication lines are expected to increase, and a network completely interconnected by optical fibers will undoubtedly arrive. The application of such info-communication technologies based on light will without question be extended to space communication networks, and so it is believed that in the future, the day will arrive when space/ground communications will be linked by optical networks that use light as the medium. The basic technologies for such optical communication systems have been established in an optical communication experiment using the "Optical Inter-orbit Communications Engineering Test Satellite (OICETS)," or Kirari.

Optical Communication Experiment Between the Kirari Satellite and an Optical Ground Station

An optical communication experiment employing Kirari and an optical ground station was conducted in a joint project between the Japan Aerospace Exploration Agency (JAXA) and NICT. The development of the Kirari satellite began at JAXA in 1993 and was completed in 2001, after eight years of research and development. The author also worked at JAXA during the four-and-a-half years from July 1999 to November 2003, participating in the development of the main mission instrument, LUCE (Laser-Utilizing Communications Equipment), designed for inter-satellite optical communications. The Kirari satellite was launched from Kazakhstan in August 2005 and was successfully deployed to a sun-synchronous orbit at an altitude of 610 km and inclination angle of 97.8°.

In December of the same year, the world's first bi-directional inter-satellite optical communication experiment between Kirari and the stationary satellite ARTEMIS of the European Space Agency (ESA) was successfully carried out. Since the optical antenna of Kirari normally points upward from a stationary orbit, it cannot be directed in the earthward direction. However, even in space, the Kirari has a function for orienting its attitude, and so the optical antenna may effectively be pointed towards the ground station. Using this function, an optical communication experiment between the ground and this low-orbiting satellite was conducted from the roof of the space optical communication ground station in Koganei, Tokyo (referred to below as the "NICT optical ground station") in March and May of 2006.

The Optical Communication Experiment — Expanding the Fields of Application

The general scheme of the experiment is presented in Fig. 2. A command is sent to Kirari by JAXA, and the settings and controls are made such that the satellite operates as planned at the start of the experiment. At the NICT optical ground station, satellite tracking is initiated when the satellite enters the visible range with an elevation angle greater than 15 degrees, and bi-directional laser communication is performed. Unlike a geostationary satellite, low-orbiting satellites travel at an orbital speed of approximately 7 km/s and have a high apparent speed, making satellite tracking of Kirari difficult. Furthermore, an optical ground station experiment is susceptible to the effects of atmospheric fluctuations, which result in variations in received signal intensity. This has a negative effect on both tracking and communication. To suppress this effect and to stabilize the communication link, four beams were synthesized and transmitted from the NICT optical ground station, as shown in Fig. 3. This has a similar effect as when using a diversity antenna, and it can be seen from Fig. 4 that variations in signal intensity were sufficiently reduced. With respect to the quality of communication, large error bits are observed for the 2-Mbps uplink, while the bit error rate measured for the 50 Mbps downlink is approximately 10-5. Thus, by using an error-correcting code (ECC), it becomes possible to transmit the large volumes of data collected by the satellite to the ground station. Further, in the present experiment the effect of atmospheric fluctuation on the optical communication link between a low-orbiting satellite and ground station has been measured for the first time, and this success is expected to be valuable not only for its academic significance, but also for optical communications using the space between buildings scattered over urban areas, free-air communication with objects in flight such as airplanes, and optical wireless communications on the ground.

Life and Technology

Q: How will society in general be affected by the establishment of an optical network that includes satellites traveling at high speeds in space?

A: In the news only recently, there was a report of an increase in volcanic activity at Mt. Merapi, in the central region of Java, Indonesia. The sudden occurrence of a volcanic ash flow from Merapi resulted in unfortunate deaths in the region. Satellites are especially useful during natural disasters such as volcanic eruptions, earthquakes, and wind and flood damage. They not only provide a tool for communication, but can also be used to monitor vast areas on the ground at high resolution, and this information can then be sent to the ground. However, the volumes of such high-resolution image data are massive, and there are limits to the amount of data that may be transmitted by conventional satellite-ground-station links that use radio waves. Thus, demands are growing for the early establishment of an optical network technology that will allow large volumes of data collected by satellite observation to be transmitted to the ground in a short period of time. By developing more technologies such as that introduced above, it will be possible to construct a reliable system for transmitting high-resolution images acquired by satellite observation of the Earth's surface, and it will most certainly contribute to the establishment of a safer and more secure society in the near future.

Technology for Safety and Security in Society

Optical communication links that have been validated in space to date include a ground/geostationary satellite link using the Engineering Test Satellite VI (ETS-VI), a geostationary-satellite/low-orbiting-satellite link using Kirari, and the ground/low-orbiting satellite link in the present experiment. This last link has completed the set necessary for constructing an all-optical communication network in the near-Earth environment from the ground to satellites. By applying ground-based optic-fiber technology to space communications, it becomes possible to increase transmission speed further, and thus, we have come one step closer to realizing an ultra-high-speed optical communication network in space. Furthermore, these validation experiments in space have demonstrated the high quality of Japanese products to the world, and we believe that this will work to our advantage in the future when the demand for space communications grows. In addition to the optical communication experiment with Kirari, NICT plans to seek out the opportunity to launch a small satellite in order to perform validation in space of a small, orbiting optical communication terminal. These technologies should allow the transmission of large volumes of data from various environments and disaster-monitoring systems collected by Earth-observation satellites; these technologies are thus expected to contribute greatly to establishing the foundations of a safe and secure society.

As a concluding note, I would like to thank all those at JAXA and NICT for their steadfast cooperation during the present experiment.

Researcher

Morio Toyoshima

Space Communications Group
New Generation Wireless Communications Research Center

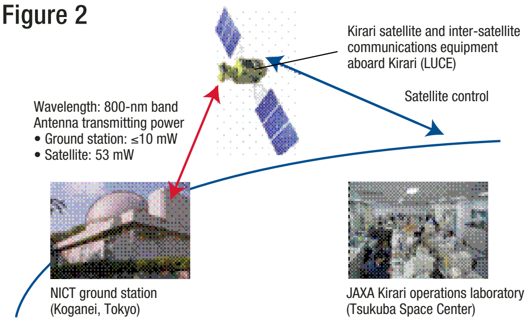
Joined the Communications Research Laboratory (presently NICT) in 1994. Performs optical communication experiments using the ETS-VI satellite. Was temporarily transferred to JAXA, followed by research abroad at the Vienna University of Technology. Presently takes part in the *Kirari* optical communication experiment and conducts research on optical-wave propagation and atmospheric fluctuations in free-air optical communications. Hobbies include tennis and running marathons, and he has a taste for locally brewed beers. Doctor of engineering.

Figure 1

Inter-satellite communications equipment aboard Kirari (LUCE)

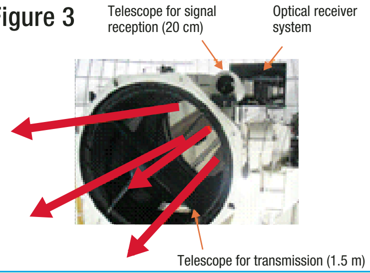
Courtesy of JAXA

Figure 2



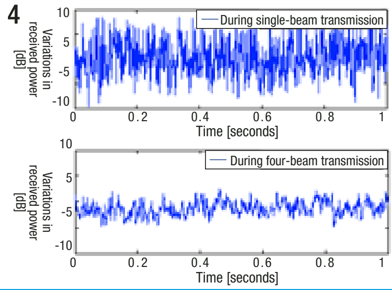
General scheme of the optical communications experiment using *Kirari* and the NICT optical ground station

Figure 3



Configuration of the NICT optical ground station

Figure 4



Variations in signal intensities caused by atmospheric fluctuations received at Kirari

This month's key concept

[Optical Inter-orbit Communications Engineering Test Satellite (OICETS) or *Kirari*]

Kirari (or OICETS) is an engineering test satellite launched into space by a Dnepr rocket from the Baikonur Cosmodrome of the Republic of Kazakhstan on August 24, 2005 with the main goal of performing a validation experiment with the Advanced Relay and Technology Mission Satellite (ARTEMIS) of the European Space Agency (ESA). Optical communication between ground stations and low-orbiting satellites such as *Kirari* are affected by atmospheric signal attenuation and atmospheric fluctuations; thus, large variations in received signal intensity occur as a result. The transmission of a laser beam in the precise direction of the ground stations, while the satellite is in high-speed orbits such as *Kirari*'s, involves extremely high-level technologies. As discussed in the section above, NICT and JAXA have successfully performed an optical communication experiment linking *Kirari* and an optical ground station. This is the first experiment in the world to have succeeded in establishing optical communications between an optical ground station and a low-orbiting satellite such as this, and this success has demonstrated the high level of Japanese technology. In the future, in addition to continued inter-satellite optical communication experiments using *Kirari* and ARTEMIS, NICT will also continue conducting satellite-ground communication experiments using *Kirari* and ground stations owned by institutions such as the NICT and the German Aerospace Center (DLR), in order to confirm the performance of optical inter-satellite communication instruments in space and to evaluate the effects of the atmosphere.

* At 10:13 (JST) on June 7, 2006, an optical communications experiment was conducted using a laser beam between Kirari (OICETS) and the ground station owned by the German Aerospace Center (DLR) in Wessling, Bayern, Germany, and communication was successfully established for a period of three minutes.

The 1st Wireless Technology Park (WTP2006)

Wataru Chujo, Research Manager, Project Promotion Office, New Generation Wireless Communications Research Center

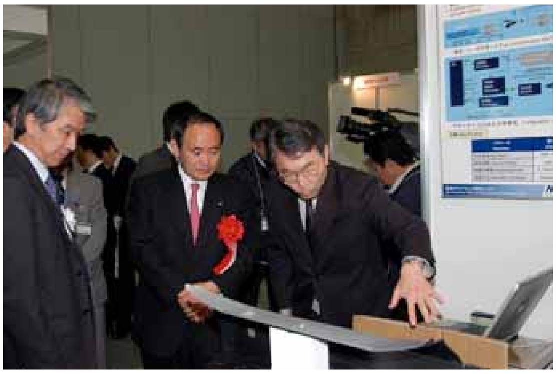
The 1st Wireless Technology Park (WTP2006) was held at Pacifico Yokohama on April 27–28, 2006, which was the largest exhibition of a series of industry/academia/government collaborations in R&D of wireless communication technologies, organized by National Institute of Information and Communications Technology (NICT) jointly with the YRP R&D Promotion Committee and the YRP Academia Collaboration Network. The WTP2006 represented a synthesis of the three events held up to the previous year: the "YRP Symposium on Cooperation between Industry, Academia, and Government in Mobile Telecommunications," the "Next Generation Wireless Technology Showcase," and the "Asia Wireless Summit." The programs of the WTP2006 were organized mainly by the New Generation Wireless Communications Research Center at NICT, with the aims of strengthening the competitiveness of Japanese wireless communications technology on the global market, to promote R&D of information and communications technology throughout the world, and to promote the activities of venture businesses in the field.

Unlike the former events, the WTP2006 was specialist-oriented; however, almost 50 organizations including domestic and foreign research institutions, electronic communication businesses, and vendors exhibited the newest results of their R&D activities in wireless communications technology. The NICT exhibited 15 R&D outcomes, mainly from the New Generation Wireless Communications Research Center, on software defined radio terminal, next-generation mobile networks, etc. The exhibition lasted for two days and 4,700 people attended. The attendants came from Japan and from all over the globe, including a legislative delegation from the upper house of the French parliament and a party from the Industrial Technology Research Institute (ITRI) of Taiwan. Furthermore, on the opening day, we were honored by a visit from Mr. Suga, the Senior Vice-Minister for Internal Affairs and Communications.

In addition, forums and special sessions on themes of immense interest were given by the forerunners in their respective areas, such as the establishment of a global standard for wireless communications and the launch of businesses for commercializing the latest wireless technologies. Moreover, 18 major universities in the wireless communications field in Japan participated in academic sessions and presented their latest results, sharing information on technology transfer in a specially reserved stand.

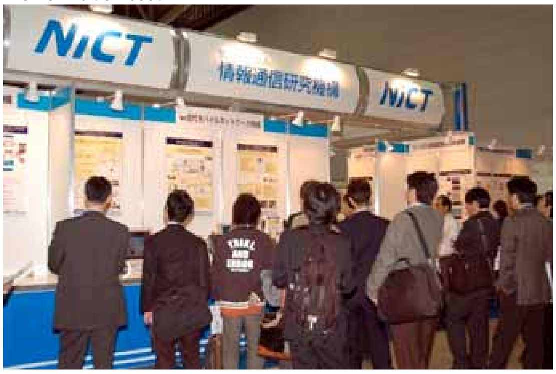
The New Generation Wireless Communications Research Center will continue to carry out R&D in the field of wireless communications and will continue to cooperate with various institutes to organize events on wireless communications technology and related R&D efforts. The success of the WTP2006 will certainly fuel and motivate the WTP2007 next year, so that it will be even more successful than the first.

Visit by Mr. Suga, Senior Vice-Minister for Internal Affairs and Communications

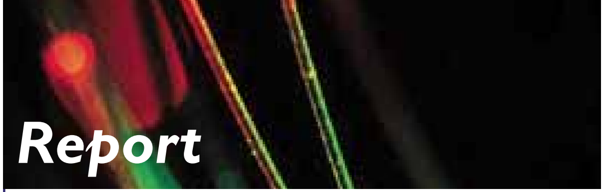


Visit by a legislative delegation from the upper house of the French parliament

NICT exhibition booth



The 1st Wireless Technology Park (WTP2006)
Date: Thurs., April 27–Fri., April 28, 2006
Venue: Pacifico Yokohama
Sponsors: National Institute of Information and Communications Technology, YRP R&D Promotion Committee, and YRP Academia Collaboration Network



Report on the "Symposium for New Challenges at NICT"

Yukiko Ohno, Coordination Office, General Affairs Department

The "Symposium for New Challenges at NICT" was held on June 13, 2006 on the 14th floor of the Keidanren Kaikan (Chiyoda-ku, Otemachi). The present symposium was organized to mark the launch of the 2nd Middle-Term Plan of NICT and to introduce to those outside NICT the research projects that will be promoted under the new organizational system. At the seminar, talks were given on the directions that NICT's efforts will take under the 2nd Middle-Term Plan and the outlines of the priority research areas that are to be pursued to fulfill our goals.

The symposium consisted of two sessions: the first presented summaries of NICT's new policies and priority research areas, and the second was allotted to a panel discussion which three experts from outside NICT were invited to join.

Session 1: High Interest in the "Knowledge Creation Project"

After our guest, Mr. Matsumoto, the Councilor for General Technical Affairs, addressed those assembled, Vice President Mr. Kawauchi described the policies of NICT as it embarks on its 2nd Middle-Term Plan for the coming five years, to help the audience get a general picture of the reinvigorated NICT. This was followed by presentations on "New Generation Network Technology," "Universal Communications Technology," and "Info-Communication Technology for Safety and Security," followed by talks given by the executive directors of the research centers (and/or departments), Dr. Kubota, Dr. Matsuyama, Dr. Shinoda, and Dr. Ueno on their respective "Collaborative Research Promotion Projects," represented by commissioned research and R&D promotion fund projects. It appeared from the atmosphere there felt through questions and answers after the presentations, etc. that the audience were most interested in the "Knowledge Creation Project," in the Universal Communications Area.

Session 2: Leaping Forward

Three panelists were invited from different fields—Ms. Tomoe Kiyosada, Senior Science and Technology Policy Analyst of SRI International; Mr. Mario Tokoro of Sony Computer Science Laboratory Inc.; and Prof. Masaru Kitsuregawa of the Institute of Industrial Science, University of Tokyo—to the discussions on the "Expectations for a Reinvigorated NICT." President Dr. Nagao of NICT also joined in the discussions, with active exchanges among all participants. Ms. Kiyosada introduced the exciting state of information accumulation in the U.S., Mr. Tokoro presented his opinions on the basic research that ought to be undertaken by businesses and public institutions, and Prof. Kitsuregawa expressed his alarm at the state of modern society, one inundated by massive volumes of information. The presentations and opinions given by the panelists displayed their warmhearted support and the great expectations they have for the role that NICT can fulfill in the future. In response, President Dr. Nagao stated his renewed determination to focus continued efforts on expanding the integration of R&D activities at NICT.

We are grateful to the nearly 400 attendants who took the time to come to the symposium in spite of the bad weather, and to all those whose cooperation made the symposium a success.

Opening speech by the organizer (President Dr. Nagao)

Scene from the conference room

Scene from the panel discussion

"Symposium for New Challenges at NICT"
— The Creation of a Universal Communications Society —
Date: Tues, June 13, 2006
Venue: 14th floor of the Keidanren Kaikan
(Chiyoda-ku, Otemachi)

Information

Experience NICT Now!
Open House of the NICT Facility for FY 2006 (free admission)

NICT will hold its annual open house of its facilities to share the results and activities of our research activities and R&D efforts with the local community. We offer our warm welcome, and are sure that all will find something to enjoy, from elementary school students to junior high school students to parents. We look forward to seeing you at the open house.

Address of facility for open house

http://www2.nict.go.jp/p/p463/event/2006kokai/index.html

■ **Koganei Headquarters**
Date: Fri., July 21–Sat., Jul. 22, 2006

■ **Knowledge Creating Communication Research Center (Keihana)**
Date: Sat., July 29, 2006

■ **Okinawa Subtropical Environment Remote-Sensing Center**
Date: Sun., July 23, 2006

■ **Kashima Space Research Center**
Date: Sat., July 29, 2006

■ **Kobe Advanced ICT Research Center**
Date: Sat., July 29, 2006

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