Conference Report

Report of ICSOS2009

National Institute of Information and Communications Technology (NICT)

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1. Abstract

The International Conference on Space Optical Systems and Applications 2009 (ICSOS2009) was held in Miraikan (National Museum of Emerging Science and Innovation; see Fig. 1) from February 4 to 6, 2009. This conference had the following objectives: (1) to provide a forum for discussion on the realization and demonstration of space optical technologies including terrestrial optical and terahertz frequency technologies that are already used or applicable in the future and (2) to build a community regarding these fields. This conference was organized by the National Institute of Information and Communications Technology (NICT) in Japan. This report describes the results of the ICSOS2009.

Fig. 1. Photograph of Miraikan (National Museum of Emerging Science and Innovation)

2. Main technical topics

The ICSOS2009 deals with the optical technologies relating to space applications. The technical topics are listed as follows:

- **Systems and applications:**
  - present and future laser communication systems and scenarios
  - laser communication technologies for next-generation applications
  - space-based and terrestrial-based optical systems
  - novel optical systems for laser beams
  - small satellite systems for laser communications
  - space lidar systems
  - imaging systems
- **Devices, components, and subsystems:**
  - novel optical devices for space-based applications
  - optoelectronic subsystems and components
  - laboratory demonstration hardware
- **Basic link technology:**
  - atmospheric propagation, transmission effects, and compensation techniques
  - modulation formats for space-based systems
  - trade-offs between optical and microwave (RF) systems
  - new mm-wave/THz communication devices and systems
  - quantum optical communication and

cryptography

- standardization.

As shown above, this conference includes the wide spectra on the optical technologies.

Table 1. ICSOS2009 program

Time Table

1st Day

Time	Session
8:30	Registration open
9:30	Opening session
10:10	Coffee break
10:20	Plenary session I
11:50	Lunch
13:00	Plenary session II
14:00	Coffee break
14:10	Space laser communications technology
15:50	Poster session
17:00	1st day end

2nd Day

Time	Session
8:30	Registration open
9:00	Developments in laboratory
10:00	Coffee break
10:10	Experimental demonstration
11:20	Coffee break
11:30	Quantum technology for space applications
12:20	Lunch
13:30	Novel optical devices
15:20	Coffee break
15:30	Space lidar technology
16:40	Awards ceremony
16:50	Concluding remarks
17:00	2nd day end

3rd Day

Technical Tour
We are planning the technical tour from around the venue to National Institute of Information and Communications Technology (NICT).
After that, we will go sightseeing in Tokyo (Asakusa, Akihabara, etc.).

3. Participants at the conference

The ICSOS2009 was the first conference held this year; however, it can be considered as the third conference in Japan since the International Workshop on Optical Space Communication (IWOSC) held in 1990 at ATR and the CRL International Topical Workshop on Space Laser Communications held in 1997 organized by CRL (currently NICT). The ICSOS2009 was held for three days from February 4 to 6, 2009. The program time table is shown in Table 1. The first day included the two plenary sessions: the oral session and the poster session. The oral sessions were held on the second day. The technical tour was conducted on the third day. There were 87 people (including one press) who were registered in this event. Further, the researchers came from 9 countries (Austria, Switzerland, Germany, England, Netherlands, USA, Morocco, France, and Japan), and there were 42 high-quality papers presented in the conference. The presentations included 26 oral presentations (10 invited) and 16 poster presentations.

4. Opening session

The general chairperson, Prof. Takano, addressed the opening session (Fig. 2). He mentioned about the previous laser communications experiments on the GOPEX, the SILEX, and the OICETS programs. Then, he described about the future applications of not only optical waves but also THz, X-ray, and THz waves for communications. Further, he also pointed out that optical technologies will be able to assist in protecting the Earth's environment, saving energy, and avoiding economic crisis. The Space Fundamental Law in Japan may bring about greater flexibility in space organizations and activities. Thus, the optical observation and communications technologies are quite important and this conference will play an important role on such issues.

The vice president of the NICT, Dr. Ohmori, made the opening statement and he acknowledged all the participants and contributions from all the speakers.

There was also the welcome speech from the president of Miraikan, Dr. Mohri, who is an astronaut. He showed a video of the Earth seen from space taken by a high definition camera in the space shuttle; further, he mentioned that the technologies discussed in this conference hoped to contribute to the future (Fig. 3).

Fig. 2. Opening statement from the general chairperson, Prof. Takano.

Fig. 3. Welcome speech from the president of Miraikan, Dr. Mohri, who is an astronaut.

The co-vice chairperson, Mr. Nakamura, of Japan Aerospace Exploration Agency (JAXA), mentioned about the Japanese activities taking place in JAXA and their importance. Mr. Okano, the director of Space Communications Policy Division, Ministry of Internal Affairs and Communications (MIC), gave his welcome speech, and he mentioned that optical technologies are making progress and being applied in the space system area.

5. Plenary sessions

First, Dr. Iida discussed about the importance of using ultra high speed communication links. He assumed a human community in Mars and considered using Web 2.0. If the amount of information data produced in one year (in 2002) is assumed to be 5 exabytes (10^{18}) and the growth rate of +30% in the information data occurs per year until 2050, then he predicted that the amount of information data will be 1.47 yottabytes (10^{24}), and the surface web must be transferred from Earth to Mars at 8 Gbps. He concluded that the use of optical communications would become inevitable in the future.

Dr. Lange of TESAT presented the results of the fastest communication link in the world between German TerraSAR-X and US NFIRE at 5.6 Gbps. He mentioned about the ground-to-TerraSAR-X link experiment and the optical link was maintained under cloudy conditions. The TESAT terminal is supposed to be used in TanDEM-X and Alphabus satellites in the future.

Prof. Seeds from University College London introduced the coherent communication by using the Optical Injection Phase Lock Loop (OIPLL) and a piezoelectric fiber stretcher. The receiver can demodulate amplitude shift keying (ASK) and phase shift keying (PSK). He also introduced the generation of terahertz waves by using the OIPLL mixer technology.

Dr. Hemmati introduced the research and development of deep space laser communications conducted in NASA's Jet Propulsion Laboratory (JPL). He mentioned that the data rate would be improved by 30 Gbps until 2020 by using conventional laser technologies. This corresponds to the data rate of 1

Gbps from Mars.

Dr. Perdigues of European Space Agency (ESA) presented the European activities on space laser communications. Sentinel satellites are built for the Global Monitoring of Environment and Security (GMES) in European Union (EU). The measured data from these Earth observation satellites will be transmitted via the European Data Relay Satellite System (EDRS) that consists of three GEO satellites. Each satellite will have one optical terminal with a 600-Mbps class data link.

Dr. Thomas of the US Naval Research Laboratory (NRL) reported the 16.2-km laser communication link over the Chesapeake Bay. The propagation data will be used for establishing the standard propagation model over the sea. The ship-to-ship laser communication experiment was demonstrated by using a very small battery-powered modulating retroreflector (MRR) array as part of the Trident Warrior 2008 campaign.

Fig. 4. Oral presentation room.

Fig. 5. Poster presentation room.

Mr. Kunimori discussed the research and development of the digital coherent receiver and the portable telescope system. Dr. Yamakawa of Japan Aerospace Exploration Agency (JAXA) introduced the role of data relay in JAXA and provided an overview of the Optical Inter-orbit Communications Engineering Test Satellite (OICETS). JAXA started the feasibility study of a BPSK-homodyne modulation/demodulation system and is currently developing the BBM model. The system realizes a huge data rate link up to 2.5 Gbps with small and light-weighted (approximately 30 kg) terminals. The feasibility will be confirmed until 2010 through the development of the BBM. JAXA's target is to develop the next-generation inter-orbit optical communication system between GEO and LEO satellites, which will be deliverable and operable in mid-2014.

6. Technical sessions

There were many active discussions during the oral presentations (Fig. 4) and poster presentations (Fig. 5). Space laser communications and optical devices including terahertz, laser power transmissions, quantum communications, gravitational wave detections, and lidars were presented. Main subjects are introduced in the next section.

(1) Space laser communications and their application technologies

Dr. Perlot of German Aerospace Agency (DLR) discussed the effect of the atmospheric turbulence at the limb of the Earth. If one can predict the atmospheric turbulence as a function of the link altitude, his/her results can be useful for high altitude platform systems (HAPSs).

Mr. Aoyanagi from Hokkaido Institute of Technology discussed the research and development of the laser communication terminal for the Earth observation microsatellite "TAIKI." The laser communication terminal can transmit the measured data at 100 Mbps. Its power consumption is 1.5 W and its mass is 3 kg. His paper was awarded at the reception (Fig. 6) by the chairperson of the technical program committee, Dr. Suzuki (Fig. 7), as the Best Student Paper Award, which was held at the Grand Pacific Le Daiba Hotel.

Fig. 6. Reception.

Fig. 7. Best Student Paper Award.

Mr. Ikebe of NEC Corporation mentioned about the future data relay by laser communications at various locations in space. Mr. Kodeki of Mitsubishi Electric Corporation discussed the development of a fine steering mirror for ground-to-satellite laser communications.

Dr. Kudielka of Oerlikon Space reported the inter-island demonstration of pulse position modulation (PPM) conducted in Tenerife, Spain, at a distance of 144 km.

Mr. Shimayabu of Hokkaido University presented an application of phase conjugation techniques for inter-satellite laser communications. If one uses the double phase conjugate mirror with a multiplication factor of over 8, 10-Gbps laser communications will be possible over distances of 100 km.

Dr. Takayama of the NICT presented the portable optical telescope system with a 20 cm diameter. This terminal will be useful for site diversity in the future. Dr. Shoji proposed the electro-magnetic environment transmission over the IP-based network protocol. This idea will create the remote electro-magnetic environment applicable for radio astronomy and Ground-Based-Beam-Forming (GBBF).

(2) Space verification of OICETS

Mr. Abe of Spacelink presented the fast steering

mirror that used four piezoelectric actuators and operated at several kHz. Mr. Takenaka of the University of Electro Communications reported the fiber coupling test in the OICETS-to-ground laser communication link by using the fast steering mirror developed by Spacelink.

Mr. Tanaka of Nippon Control System discussed the development of the real-time LDPC decoder based on Field Programmable Gate Array (FPGA). Mr. Kadoike of Nagoya Institute of Technology developed the LDPC codes applicable for ground-to-OICETS laser communications links. These designed LDPC codes were tested in real ground-to-OICETS laser communications links.

(3) Terrestrial laser technology

Mr. Bekkali of Waseda University presented the 1-km free-space laser communication result using 2-GHz W-CDMA, ISDB-T, and WLAN signals with Radio on Fiber (RoF) technology. Dr. Higashino of Osaka University reported the optimum link design of four different wireless signals transmitted over the Density Wavelength Division Multiplexing (DWDM) Radio on Free Space Optics (RoFSO). Mr. Kim of Osaka University also presented the temporal autocorrelation function and the spectrum model based on the experiment over the 1-km laser propagation path. He also derived the statistical scintillation model and the throughput by shadowing.

Mr. Kawamoto of Osaka University presented the multiple access system by the space and time division multiple access using the optical receiver array and reported the throughput characteristics.

(4) Components and novel devices

Mr. Morimoto of Nippon Control System presented the digital coherent receiver circuit that could demodulate the 6-Gbps optical BPSK signal on real time. This electrical circuit consists of the high speed analogue-digital converter (ADC) and the digital circuit based on FPGA.

Mr. Koyama of the NICT reported the development of the Erbium Doped Fiber Amplifier (EDFA) for space qualification. The target output power of the EDFA is about 2 W at a wavelength of 1.5 μm. He plans to conduct the space qualification tests such as the vibration test and the thermal vacuum test.

Prof. Tsumura of Tsumura Research Institute presented the modulating corner cube reflector using the piezo actuator.

Prof. Watanabe's group of Shizuoka University presented the memory using the optically reconfigurable gate array based on the VLSI technology. They used the hologram technology; therefore, their memory was tolerant to the single event latch up (SEP) under the radiation environment. They presented the reconfigurable characteristics by laser and the characteristics of the three-order redundant system.

Dr. Munemasa of JAXA proposed the optical antenna for collimating the laser diode based on Micro Electro Mechanical Systems (MEMS). He developed a small Fresnel lens based on MEMS and compared the characteristics between the theory and the measurement.

(5) Quantum technology

Dr. Ursin of Vienna University presented the quantum key distribution (QKD) mission onboard the International Space Station (ISS) called Space-Quest. The Space-Quest will be launched in around 2015 and it will be the first verification of the entanglement over a distance of 1000 km. Dr. Toyoshima reported the transportable QKD terminals. The QKD experiment was performed between two buildings separated at a distance of 70 m. The quantum key rate of 98.1 kbps

was achieved and the polarization rotation tracking mechanism was also implemented in this system.

For quantum communications, Dr. Takeoka of the NICT reported the experimental parameters for the ultimate BPSK optical receiver that can beat the Shannon capacity limit.

(6) Science missions

Dr. Kawamura of National Astronomical Observatory of Japan presented the Japanese DECi-hertz Interferometer Gravitational wave Observatory (DECIGO). This mission will develop the future Japanese space gravitational wave antenna, which consists of three drag-free satellites connected by the laser link. The goal of DECIGO is to derive (1) the characterization of dark energy, (2) the formation mechanism of super-massive black holes at the center of galaxies, and 3) the verification and characterization of inflation.

Dr. Wada of Riken introduced the development of the space lidar for the JEM-EUSO mission to measure high energy particles using the Earth's atmosphere. The lidar was designed at the third harmonic wavelength of the Nd:YAG laser at 355 nm, which corresponds to the optical fluorescent and Cherenkov light. The lidar can measure the height of clouds with a 30-cm resolution.

(7) Laser power transmission

Dr. Summerer of ESA proposed the wireless power transmission by using a laser. There is a plan to send 1-GW power transmission by using the Nd:YAG laser, which is pumped by the solar power in JAXA. ESA has started the feasibility study on the solar power transmission with the industry since 2002. The power transmission to the Moon is suitable among the near Earth and deep space applications and ESA is now studying the 6-kW power transmission system by using a 1.5 m telescope with the EADS Astrium.

(8) Optical design technology

Mr. Enokuchi of Genesia Corporation reported the optimum system design for space use including the mechanical and thermal characteristics in optical systems. Their design methods were used for the collimator onboard the "Hinode" satellite and the multispectral aurora camera onboard the "Reimei" satellite.

Dr. Miyamura of Tokyo University proposed the adaptive optics based on the spatial light modulator for the space imaging mission. He proposed the neural network to compensate for the wavefront deformation and he presented the simulation result.

(9) Lidar technology

Dr. Araki of National Astronomical Observatory of Japan presented the result of the global topographic map of the Moon with a spatial resolution less than 0.5° by using the laser altimeter (LALT) onboard the Japanese lunar explorer KAGUYA (SELENE). Dr. Mizuno of JAXA reported the lidar onboard the HAYABUSA spacecraft. He presented the ranging results of the ranging and the received optical powers against the small asteroid Itokawa.

Dr. Mizutani of the NICT presented the coherent Dopplar lidar for CO_2 and wind measurements. The CO_2 is taken as the index of the green house effect and the concentration of CO_2 can be measured by the spectra at different absorption lines. He measured the wind velocity at a distance of 10 km and the concentration of CO_2 at a distance of 1 km.

As shown above, there were novel and wide spectra field presentations. Toward the end of the sessions, the co-vice chairperson, Dr. Kadowaki, delivered his closing remarks and he hoped to establish much better relationship between the researchers and to achieve a

much better improvement in technologies in the future; The NICT wants to play a role in promoting these technologies. Thus, this conference was a great success and was successfully closed.

7. Technical tour

The technical tour was conducted at the NICT on the third day in the morning. The participants visited the Japan standard time, satellite communications, satellite laser communications, and quantum communications groups. Figure 8 shows a snapshot of their visit at the NICT optical ground station. There were really active and constructive discussions that took place during the tour. In addition, some participants wanted to remain at the NICT for further discussions on their research objectives. Such discussions will contribute to the collaborative relationship and the research agreements in the future.

In the afternoon, the participants were taken sightseeing around Tokyo. The participants visited the emperor castle and Asakusa. They got onboard the Yakatabune at night. The Yakatabune was really the appropriate choice for learning the customs in Tokyo. The participants enjoyed the entire technical tour.

Fig. 8. Technical tour at NICT optical ground station.

8. Summary

The International Conference on Space Optical Systems and Applications 2009 (ICSOS2009) was held in Miraikan, and it is confirmed again that there are many areas for optical technologies for space use and optical technologies are required for science and engineering application fields. The researchers in optical communications, optical observations, lidar technologies, quantum technologies, optical power transmissions, and related novel optical devices must have much stronger relationship among the crossing fields including intermediate and derivative technologies, which contribute to the profound progress for space developments. The successive collaboration such as this will develop the foundation for a new international project in this field.

The reflection point to the future ICSOS will be to get more international papers from the Asia-Pacific region. This will help to form the community in the Asia-Pacific region.

The future ICSOS is planned to be conducted routinely every 1~2 years. Dr. Mohri, who is an astronaut, commented that the real international conference would be held in international countries. The next ICSOS will be held at the U.S. organized by NASA JPL. The detailed information will be announced according to the progress of the preparation. The successive help and advices from the participants and readers are highly appreciated.

If you have any information about the ICSOS, please let me know at morio(at)nict.go.jp.

Acknowledgments

Toward the end of this report, I would like to express my sincere gratitude to all the participants, the organizing and technical program committee members, and the related staffs who supported the conference.

As an appreciation, I have included their photograph taken at the ICSOS reception (Fig. 9).

Fig. 9. Photograph of the participants.