1 Research Activities on Photonic and Quantum Communications in NICT

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Communications technology has changed greatly since the invention of lasers and optical fibers. Today, information of all kinds is exchanged globally over the Internet in an instant. Broadband optical fiber connections are available even between access and backbone networks, with a rapidly increasing number of subscribers and correspondingly greater volumes of data. As content-distribution services and methods of electronic payment spread, demand will also increase for greater copyright protection and personal information security.

On the other hand, present optical communication networks primarily transmit information based on on-off modulation of light pulses, representing only a portion of the potential capacity of light. At the heart of these technologies are the principles of electromagnetism and optics established in the 19th century. With the accelerating development of information and communications technology, the limitations of this framework are becoming conspicuous. It is time we begin accelerating the exploitation and practical application of new communication principles if we are to promote the evolution of optical communication networks.

Our Optical and Quantum Communications Unit has been working toward the creation of an ultra-high-density light-wave communication technology that will ultimately control the wave nature of light, as well as quantum info-communications technology that will enable control of even the particle nature of light. Currently, however, links are missing between networking technology, light-wave control technology, and quantum-control technology, preventing integration of the three. The obstacle has also been highlighted as an obstruction to the technical application and commercialization of the outcomes of basic research. Nevertheless, NICT continues to apply diverse research and development promotion methods to foster a consistent workflow from the basics to technical applications and beyond. NICT has been taking full advantage of these methods to develop collaborative activities among industry, academia, and government.

In this special issue, we present an overall picture of the present field and the latest achievements in two separate chapters. First, regarding ultra-high-density light-wave communication, we discuss the technological achievements in high-speed, stable control of amplitude, frequency, and phase of the light wave. The discussion focuses mainly on NICT's unique device fabrication technology, optical non-linearity technology, and high-performance optical modulation technology. As for quantum info-communications, after we present an overview of the overall picture and discuss strategic problems in quantum info-communications technology—both in terms of increasing capacity and ensuring security—we report on quantum cryptography, quantum signal control and detection, and new quantum network technologies.

The new technologies based on light-wave control that we report upon here will form the foundations for a future ubiquitous broadband network offering transmission rates on the order of petabits (10^{15} bits) per second. Fur-

ther, with the incorporation of quantum cryptography technology, we can expect to see the implementation of robust information security. Quantum signal processing will then open the way to exabit (10^{18}-bit) and zettabit (10^{21}-bit) networks, while quantum repeater technology will increase the available distance. Consequently, photonic communications and quantum communications will coexist to form future information and communications networks offering the advantages of either or both, depending on physical restrictions and cost. We hope that readers will gain a sense of the exciting frontiers of research and development that NICT is now exploring in order to achieve these goals.

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Quantum Information Theory, Condensed Matter Theory

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High-Speed Lightwave Modulation