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Generation of Highly Efficient Slow Light Using Specialty Optical Fiber — R&D for Practical Application of Ultra-Fast Communications —

Technology Attracting the Attention of Researchers Around the World

NICT is currently pursuing R&D of an optical packet network capable of high-speed transmission of packets directly as optical signals over a photonic network, a planned element of a future ultra-fast large-volume photonic network. One of the key technologies involved in this R&D lies in the photonic packet switch at the nodes within the photonic network. The photonic packet switches currently deployed adopt the light buffer, which makes use of the fiber delay line (FDL) of optical fibers to avoid collisions between optical packets arriving simultaneously from different paths. However, since the delay time cannot be changed continuously under this method, such light buffers can only offer fixed time lengths. Additionally, this method has the added disadvantage of requiring large buffer devices.

In contrast, it has been recognized that optical pulse propagation speed (group velocity) may be controlled by non-linearity within the medium that results in the generation of “slow light.” Accordingly, researchers from around the world have begun to focus on this approach as a solution to producing a compact light buffer in which delay time may be freely controlled. However, conventional methods using silica optical fibers require long fibers that extend over several kilometers, as well as the requirements of a high-power for excitation; the low efficiency in the generation of slow light has to date stood as the major obstacle to the use of this method.

Principle of Slow Light Generation

Using the non-linear phenomenon known as “induced Brillouin scattering,” which occurs when a high-intensity light beam is input to an optical fiber, it is possible to amplify a light pulse propagating in the opposite direction. When a pulse is abruptly amplified by this mechanism, the refractive index (n) of the optical fiber changes, resulting in a decrease in the propagation speed (group velocity, or vg) of the light pulse. The propagation time of an optical pulse within an optical fiber of length L is L/vg (which is equivalent to Lng/c, and where ng is the group refractive index and c is the speed of light), and since the amount of change in the refractive index depends on the intensity of the incident light (i.e., the excited light) causing Brillouin scattering, it is possible to change the propagation (and hence the delay) time within the optical fiber continuously by adjusting the incident light intensity (Fig. 1).

The Specialty Optical Fiber: As_2Se_3 Chalcogenide Fiber

The techniques for delaying an optical pulse by stimulated Brillouin scattering (a phenomenon known as “slow light”) has been demonstrated in the past using silica optical fibers. However, many problems remained to be solved prior to practical application of this technology (such as the optical-fiber lengths discussed above and the requisite intensity of the excited light beam), and so a specialized material that could be expected to yield a higher Brillouin amplification was investigated in preparation for the validation experiment. This material is the As_2Se_3 chalcogenide optical fiber (referred to below as the “chalcogenide fiber”), fabricated from compounds of arsenic and selenium.

Experiments and Results

The experiment was carried out using the chalcogenide fiber shown in Fig. 2, with the setup shown in Fig. 3. The light from the laser was split into two beams; one of the beams was amplified and used as the excited light for Brillouin amplification, and the other was used for generating the signal light pulse using a phase modulator and an intensity modulator. The two beams were then input to the chalcogenide fiber from opposite directions.

The results of the experiment showed that the propagation time of the signal light pulse passing though the fiber could be delayed by 37 nanoseconds (one nanosecond is one-billionth of a second), regardless of the fact that the chalcogenide fiber was only five meters long and that the mean power of the excited light was only 60 mW (Fig. 4). This indicates that light within the optical fiber was slowed to approximately half its normal speed; it was also confirmed that propagation time could be controlled freely by adjusting the intensity of the injected excited light. Furthermore, the efficiency of time delay generation per unit length and unit excitation power (ns/m/mW) was approximately 200 times higher than in conventional silica optical fibers.

Toward High-Efficiency, High-Performance Light Buffers

The results of the present experiment have contributed to significant progress in the practical application of the light buffer, an essential element in the realization of ultra-fast communications. Based on the success of the present R&D efforts, we hope to make steady progress in resolving the remaining technical issues, such as the fabrication of smaller-core optical fiber cores, improving the scattering efficiency of the materials, and expansion of bands.

Life and Technology

Q: It has been reported that the maturation of light buffer technology is essential for ultra-fast communications. How will the “slow light” generation technology developed in the present study contribute to achieving this goal?

A: Alongside an ever-increasing number of internet users in recent years, data formats have undergone a shift from text to voice and from images to video. In order to respond to the diverse demands that these shifts entail, we must develop a method for efficient, comprehensive, and error-free transmission of an increasing number of packets. This requires a solution to prevent collisions between packets at various points in the network. Slow-light technology can be a key solution to this, as it helps prevent collisions of optical packets at relay points within the photonic communication network by controlling the group velocity of light. In short, this essential technology will help ensure the safety and security of data transmissions.

Figure 1. Principle of slow light generation

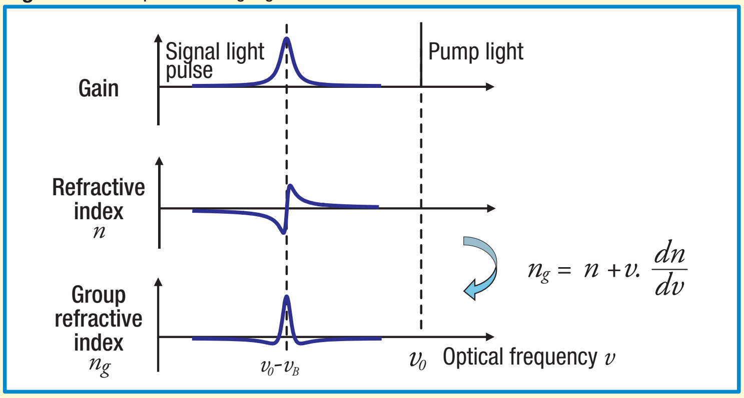


Figure 2. Chalcogenide fiber

Fiber diameter: 170 μm
Core diameter: 6 μm

Figure 3. Experimental setup used for As_2Se_3 slow light generation

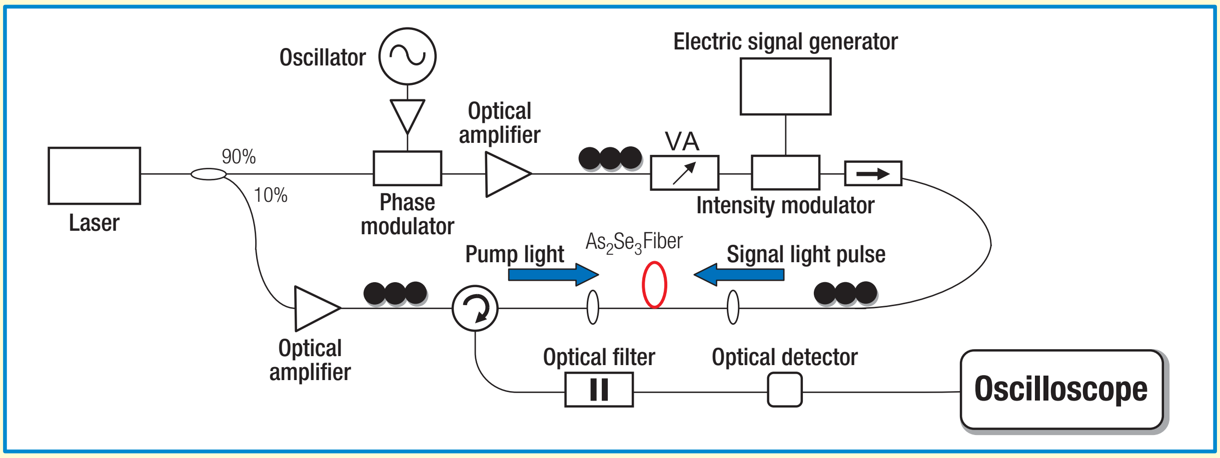
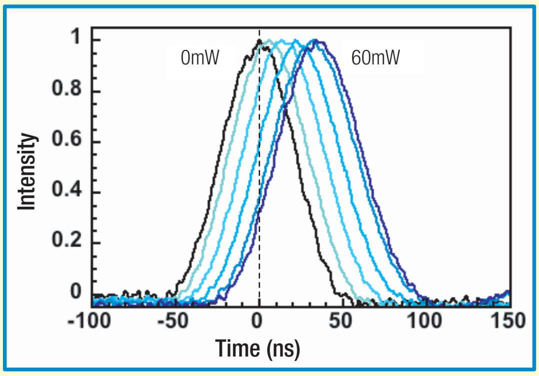


Figure 4. Characteristics of slow light generation
Shown here is the delay (Temporal domain) of the pulse waveform when the intensity of excited light is increased from 0 mW to 60 mW.



Researcher

Kazi Sarwar Abedin

Photonic Network Group
New Generation Network Research Center

After completing his doctoral course at the Tohoku University, Kazi Sarwar Abedin joined the Kansai Advanced Research Center (KARC) of the CRL (presently NICT) in 1997, where he continues to work to this day. He worked as a visiting scientist at the Massachusetts Institute of Technology, USA from 2000 to 2002. He is currently working on fiber lasers, non-linear fiber devices, and ultra-fast photonic signal processing technology.
Ph.D (Engineering).

This month's key concept

[Light Buffer Technology]

A photonic communication network requires a mechanism to prevent collisions by controlling optical packets arriving simultaneously and by assigning appropriate delay times to these packets. Devices that can store optical packets temporarily in this way are referred to as "light buffers." One method of light buffering is to prepare multiple delay lines having different physical lengths; switching between paths thus produces different delay times. However, this sort of method is incapable of providing continuous buffering, and also requires electronic control for the switching process. A compact light buffer device that can perform continuous adjustment of delay time will thus be essential in the realization of a next-generation ultra-fast communication network consisting entirely of optical-signal-processing technologies.

Development of a Japanese-Chinese Machine Translation System

Toward the Sharing and Use of Knowledge on a Global Scale

Today, thanks to progress in science and technology, the world can instantly share all sorts of information, and a variety of data collected from around the world now forms an increasingly significant part of daily life. Since much of this information is expressed in words, differences in languages—notably Japanese, English, and Chinese—can be an obstacle to the distribution and use of knowledge.

At NICT, we are aiming to overcome language barriers by creating a high-performance natural language processing technology, which will enable the processing of human language using computers. In the present study, we have embarked on a five-year project, starting this year, to develop a Japanese-Chinese translation system for scientific and technological papers, with the cooperation of the Japan Science and Technology Agency (JST), Kyoto University, the University of Tokyo, and Shizuoka University. Part of this research and development will be carried out as a study under the auspices of the "Special Coordination Funds for Promoting Science and Technology - Research and Development Program for Resolving Critical Issues," as "R&D for Japanese-Chinese and Chinese-Japanese language processing technology."

China, then Asia

While not as problematic among Western nations, the distribution of information in English is met with difficulty in Asia. We believe that, as an Asian nation, Japan has a responsibility to develop a machine translation system for Asian languages. As the first step in this endeavor, we have begun development of a machine translation system, mainly for scientific and technological materials for our Chinese counterparts, to keep pace with the significant progress we are seeing in various fields. NICT has carried out cooperative research projects with China, India, and other Southeast Asian nations, and in the future, we plan to expand the target languages of the system to include an even larger number of Asian languages. Figure 1 presents an outline of the system under development. The actual system is bi-directional and performs Japanese to Chinese as well as Chinese to Japanese translation.

Life and Technology

Q: How will the machine translation system benefit us?

A: Valuable scientific and technological information, currently circulating only inside China due to language barriers, will become easily accessible to researchers, engineers, and entrepreneurs in our country; this will very likely make way for the establishment of joint research projects and significant business opportunities. Further, providing Chinese researchers with access to papers on the latest Japan-led research and development in science and technology will contribute to overall progress in science and technology in China.

Moreover, the expansion of target languages to include other Asian languages will make it easier to search and view scientific and technological materials in the respective languages, promoting greater sharing of information among Asian countries.

Machine Translation System

In the past, the implementation of machine translation has adopted a range of approaches, including the transfer method and the intermediate language method (Fig. 2). In the conversion (transfer) method, the input text in the original language is first analyzed, and then the sentence structure is mapped out in accordance with the grammar of the original language. This sentence structure is then converted into that of the target language using conversion rules, to create a corresponding sentence. In the intermediate language method (pivot method), the input sentence undergoes a deeper analysis, and is converted into an expression described in an intermediate language that is not dependent on a specific language. The sentence in the target language is then created based on the structure of the intermediate expression. Since the intermediate language method carries out translation based on the identification of meaning, it allows for a more liberal translation and results in more natural phrasing. However, this demands that processing provide a deeper understanding of meaning, while at the same time handling massive volumes of information. On the other hand, the conversion method requires the description of a great number of conversion rules, which results in a proportional increase in the number of required rules when multiple languages are involved. Both methods involve compilation from various sources (grammatical rules, vocabulary lists, dictionaries, etc.), which must be performed manually, and the establishment of a coherent approach to this task of compilation is extremely difficult.

In contrast, it is believed that when a human performs translation, he or she is not strictly applying such knowledge, but is instead translating sentences through combinations of recollected phrases in the target language. Based on this hypothesis, Dr. Nagao (the current President of NICT), proposed an example-based machine translation in 1981, while serving as a professor at Kyoto University. At the time, computing capacity was insufficient to produce a practical system under this approach. However, rapid improvements in computer performance in recent years, in addition to the development of a method for judging similarity between examples (through reference to a database of grammatically analyzed sentences accumulated in the system; see Fig. 3) has now formed the foundation for the establishment of a practical example-based machine translation system.

In an example-based machine translation system, translation is executed based on the similarity between the input sentence and an example contained in a voluminous parallel corpus. This process demands a method of judging the similarity between the two—yet without the need to create a large collection of conversion rules. Furthermore, the quality of translation may be improved simply by adding examples to the database, and since the example translations will naturally reflect contextual differences in translations, these differences will also be reflected in the machine translation results.

Toward the Development of a Practical System

The goal of this project is to develop, within a period of five years, a practical machine translation system between the Japanese and Chinese languages focused on scientific and technological materials. In this endeavor we have adopted the example-based translation method, which provides a better reflection of linguistic structures. However, this method requires the accumulation of voluminous examples; accordingly, NICT is planning to develop a parallel corpus on the scale of 10 million sentences. The R&D of the basic technology will involve improving systems of analysis of the Japanese and Chinese languages. Further, we plan to modify example-based translation to accommodate the lengthy and complex sentences often seen in scientific and technological materials.

Even during the course of the project, we plan to publicize the language resources (such as the corpus) to the full extent possible, for research purposes. We will also work to publicize the contents and results of our research widely, as part of NICT's outreach activities.

Figure 1. Japanese-Chinese machine translation system

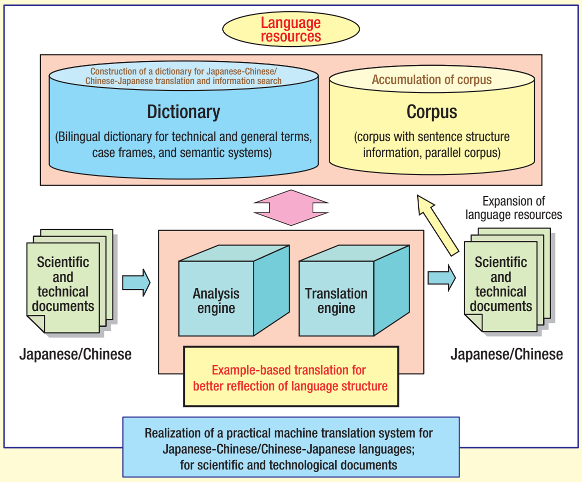
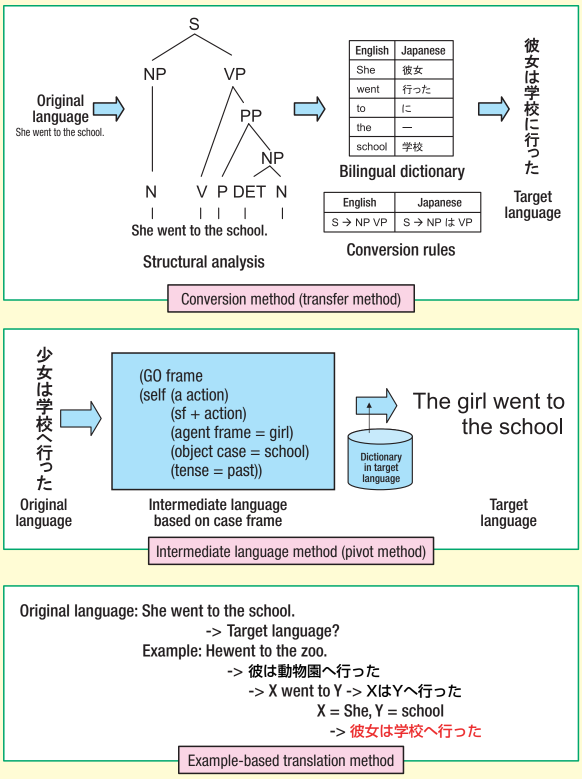


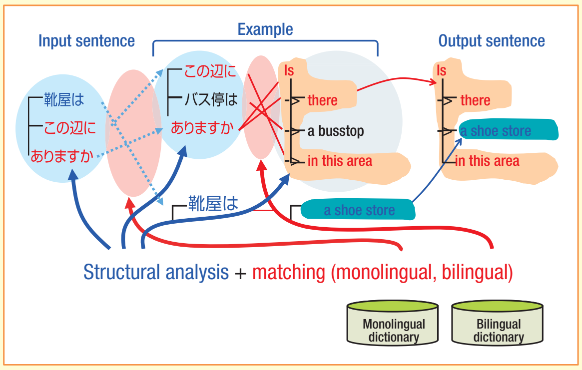
Figure 2. Methods of machine translation



Conclusion

The goal of science and technology is to provide a comfortable standard of living for everyone, regardless of individual ability or social status. Our goal is to help create an environment in which people everywhere can share information regardless of language barriers; we can accomplish this in part by giving computers the ability to process language. We hope that the present R&D into machine translation system will help us achieve this aim.

Figure 3. Example-based translation with improved reflection of language structure



Researcher

Hitoshi Isahara

Group Leader, Computational Linguistics Group
Knowledge Creating Communication Research Center

Isahara's interests lie in the study of translation and vocabulary. He joined the CRL (presently NICT) in 1995 and established a research group on natural language processing. He is also the president of the Asia-Pacific Association for Machine Translation.Ph.D (Engineering).

This month's key concept

[Machine Translation System]

A machine translation system (MT) is a computer program that automatically translates a sentence written in one language (the "original" language; for example, English) to another (the "target" language; for example, Japanese). Systems currently exist that not only translate sentences, but entire web pages as well (while retaining the format of the original page), as well as explain, with references, difficult words in a given document.
* Reference URL (list of systems)
http://www.aamt.info.japanese.mtsys-j.htm
http://www.aamt.info.japanese.mtweb-j.htm

[Corpus]

A corpus is a collection of sentences, such as all those appearing in newspaper articles over the course of an entire year. Corpuses may consist of collections of sentences in one language (a "monolingual corpus") such as Japanese, of sentences in multiple languages (a "parallel corpus"), or a mere collection of sentences, and may contain additional grammatical information (for example identifying parts of speech such as nouns and verbs). In this context NICT has created its "Kotonoba" website, where users can actually search and use the corpus.
*Reference URL
http://www.kotonoba.net~snj/cgi-bin/wiki/wiki.cgi

Report on Outreach Activities
Gunma Prefectural Takasaki High School

On July 27, 2006, NICT received students from Gunma Prefectural Takasaki High School for an educational tour conducted as a part of our overall outreach activities. Takasaki High School is one of the schools designated as an SSH (Super Science High School*), and has been associated with NICT on various occasions, through visits to NICT facilities and training courses. This visit was a part of the "Science Workshop" activities held by the high school during the summer vacation.

The visit started off with a brief introduction of NICT by Mr. Kurihara, Director of the Public Relations Office. He presented the roles and activities of NICT in a comprehensible and enjoyable manner, helping provide the students with a deeper understanding of the organization.

The students then listened to lectures on three themes and were led on a tour of the facilities. The lectures were given by Dr. Takahashi, Senior Researcher of the Environment Sensing and Network Group and a former student of Takasaki High School; Dr. Takizawa, whose unique career now finds him as the Group Leader of the Disaster Management and Mitigation Group; and Dr. Hori, Researcher in the Space Environment Group, whose lecture last year proved quite popular among the students. In addition to describing the details of their respective research activities, all three included unique stories about their particular experiences, and each was bombarded with questions from the students. It's fair to say that the answers they provided offered valuable food for thought as the students consider their future educational and professional courses.

Three themes were selected for the tour of the facilities—remote sensing, space communication, and Japan standard time–-and the students were guided through facilities that are normally closed to the public. Questions and answers were repeated at every site visited, and the students seemed extremely interested and listened attentively to the researchers. As a result, the tour significantly exceeded the time originally planned. Even after the entire program had been completed, the students asked additional questions; the educational tour was thus clearly an enjoyable and satisfying experience for all.

NICT actively will continue to promote these outreach activities for junior and senior high school students and to organize various events in accordance with each specific activity, with the aim of cultivating an interest and a passion for science and technology among these young successors to our pursuits.

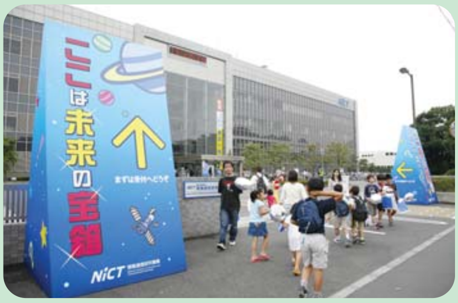
*** Super Science High School (SSH)**

High schools that specially focus on education in science, technology, and mathematics are designated as "Super Science High Schools" by the Ministry of Education, Culture, Sports, Science and Technology. Each of these schools is a cooperative partner in an R&D project to improve curricula in science and mathematics. As of FY 2006, 99 schools have been designated as SSHs.

NICT study tour of the SSH Gunma Prefectural Takasaki High School

Report on the 2006 Open House of NICT Facilities

The open house of NICT facilities held during the summer vacations of elementary and junior high schools in various regions ended as a huge success overall. We would like to thank all of our guests for visiting our facilities and look forward to your joining us again next year.



Koganei Headquarters: July 21–22, 4,240 visitors

Knowledge Creating Communication Research Center: July 29, 840 visitors

Kashima Space Research Center: July 29, 1,669 visitors

Okinawa Subtropical Environment Remote-Sensing Center: July 23, 379 visitors

Kobe Advanced Research Center: July 29, 668 visitors

Theme for the 2006 Open House of the NICT Facilities

Introduction of NICT's Newly Appointed Vice Presidents

NICT has appointed three new vice presidents, and we have asked them to discuss their plans and hopes.

Vice President of General Affairs: Mr. Eiichi Tanaka
Appointed on July 21, 2006

Some believe in a universal principle behind the individual specific phenomena that occur everyday. In Buddhism, the former would be referred to as "ri" (or "reason") and the latter, "ji" ("incident"). Even in the course of NICT's highly scientific and technological research and development, we must not forget to bear both aspects in mind.

The term "riji" ("vice president") refers to a person who has acquired the understanding of the two components, and is therefore suited for entrustment with the management of an organization. From this perspective, I must admit to feeling somewhat unqualified, but I hope that I will maintain this level of understanding as my goal, even if it remains beyond my reach. In any case I will be extremely grateful for any support and understanding I may receive.

Vice President of the Strategic Planning: Mr. Shuichi Inada
Appointed on July 21, 2006

The role of NICT is expanding, as many private businesses are retreating from R&D activities that are not directly linked to profits. Against this backdrop, and given the unlikelihood of an increase in our budgets, it is clear that further reforms and changes are required if we are to deliver more results and heighten our public image.

We must define clear missions and concentrate our energies, working effectively to link the results of our various research activities with publicity of NICT's achievements, as well as to maximize the job satisfaction of our researchers and staff, to ensure optimal performance of the entire organization. Let's work together to make a contribution as we continue our pioneering efforts in ICT.

Vice President of Research: Dr. Yuichi Matsushima
Appointed April 1, 2006

Beginning in April of this year, NICT has embarked on its second middle-term plan as an incorporated administrative agency. We have passed the stage of organizational reforms and initial steps, and I believe the time has come for us aggressively to explore the horizons of universal communication, with the integration of our information and communication technologies.

I believe that it is important to pursue daring, foresighted, and balanced research projects, based on what NICT ought to do in order to contribute to society, as well as based on what NICT alone can do. I will ensure that the results of our latest research are continuously disseminated throughout the world, and will devote my efforts to creating an organization capable of attracting the best minds on the planet.

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