

My Gratitude for the Kakenhi Program, Which Supported My Inventive Proposals

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Creation of Ultra-low Power-consumption Semiconductor Membrane Photonic Integrated Circuits toward On-chip Optical Interconnections (Grant-in-Aid for Scientific Research [S])

In April 1982, I was blessed with the opportunity to study abroad at Bell Laboratories in the United States as a post-doctorate researcher, only a year after being hired as a research associate at Tokyo Institute of Technology's School of Engineering. Therefore, my first application to the Kakenhi program as a principal investigator took place in fiscal 1984 under the Grant-in-Aid for Encouragement of Young Scientists category (1 million yen). I was also fortunate to participate in Kakenhi-supported research conducted by my mentor Dr. Yasuharu Suematsu, the former president of Tokyo Institute of Technology, as well as in projects in which professors in related fields had applied as principal investigator for Grants-in-Aid for Special Project Research and for Scientific Research on Priority Areas, as a co-investigator. As I was therefore, in practice, receiving slightly more support than my Grant-in-Aid for Encouragement of Young Scientists alone, it was not until fiscal 1989 that my first major applications as principal investigator were accepted under the General Scientific Research (B) and Developmental Scientific Research (B) categories. Even now, I cannot forget the joy I felt at having two applications accepted at once, totaling more than 10 million yen in research expenses per year and allowing me to purchase the research equipment and supplies I had applied for.

Now that resources such as the Database of Grants-in-Aid for Scientific Research and the website "research-er.jp" allow us to review past Kakenhi data, including the research projects applied for, the co-investigators, and the allocation of research funds, I am reminded once again of the extensive support I have received throughout my career

under a range of research projects. Since I began operating my own laboratory in fiscal 1991, there have been two cases in which the Kakenhi applications I submitted as principal investigator were rejected. Although this was a major source of stress at the time, during this period I was able to receive research support under the JSPS Research for the Future Program (FY1996–2000) and one of the JST Strategic Basic Research Programs (CREST; FY2002–2006), which allowed me to continue the research activities already underway in my laboratory. Laboratories which conduct experiments, such as mine, incur a significant cost for consumable supplies. As such, it is a fact of life that as researchers we are unable to make any meaningful progress on the operating expenses allocated to us by our universities alone. The stagnation of Japan's economy from the 1990s onwards has compounded this situation, and even in the field of engineering we were able to solicit little in the way of joint research or donations from corporations. Public research grants such as those funded by the Ministry of Education, Culture, Sports, Science and Technology and JSPS were therefore the lifeline that allowed us to continue our research activities.

From fiscal 2002 to 2006, I served as principal investigator of Photonic Nano-Device Integration Engineering on the 21st Century Center of Excellence (COE) Program. The primary aim of this program was to develop and provide research support to doctoral students and young researchers. However, as its annual budget (150–200 million yen) was cut significantly from original plans (300 million yen per year.), we had to operate under the policy of not allocating funding to myself and my project members. This made me worried whether the program might be a major disappointment to our members. In the end, this 21st Century COE Program and its successor Global COE Program paved the way to providing support to doctoral students in the form of research assistant expenses and travel expenses to participate in international conferences. Today, the program provides support to doctoral students at a university-wide level, something which I consider a major achievement.

Looking back over my involvement with the Kakenhi program, during the two-year period from April 1988 to March 1990, I served as a senior scientific research specialist at the then Ministry of Education, Science, Sports and Culture and through attending Kakenhi Screening Committee meetings and participating in onsite studies for large grants, I often witnessed the struggles faced by the administrative staff who support the Kakenhi system. Approximately 20 years later I received the honor of being appointed senior program officer (engineering sciences) at the JSPS Research Center for Science

Systems over a three-year period from April 2010 to March 2013. Almost once every week we would gather at the Research Center to select candidates for the Screening Committee, or engage in debate on topics such as the mission of the Kakenhi program or how to reform the screening system. These meetings provided the opportunity to listen to a variety of valuable opinions, not only from those in the engineering field but also from specialists in fields such as science, medicine, and the humanities—an experience for which I am truly grateful.

The request to contribute to this issue of the Kakenhi Essay Series was somewhat of a bolt from the blue. But I discovered that Dr. Hiroyuki Ohno, the president of Tokyo University of Agriculture and Technology, and who had formerly served as senior scientific research specialist at the Ministry of Education, Science, Sports and Culture and senior program officer (engineering sciences) at the JSPS Research Center for Science Systems at the same time as myself, had already contributed an essay to issue No. 90 (July 2016). Like Dr. Ohno, while I was not expecting to be selected to write an essay, it was an offer that if presented, I felt I could not refuse.

Forty-one years have quickly passed since 1976, when I began my research career as a thesis student in the Suematsu Laboratory. From this time through to the mid-1980s, I primarily devoted my research to the study of long-wavelength (1.5–1.6 μm) semiconductor lasers for optical fiber communication. During the 1990s through to the early 2000s, I worked to develop quantum well structure lasers and quantum wire lasers to achieve higher performance and conducted research into nanofabrication techniques. These long-wavelength semiconductor lasers started to be applied in optical fiber communications on a global scale from the 1990s onward, reflecting the vitality of Japanese companies at the time. Then I came to believe that as a university researcher, it was necessary to propose the “seed” for a more fundamental field of research. I recalled the words of Dr. Saburo Nagakura during my time as a senior scientific research specialist at the Ministry of Education, Science, Sports and Culture, which were to the effect of, “Do not be swayed by popularity or trends in research—when applying for grants, go as far as to deliberately avoid topics that other researchers are studying.” At the time, my own efforts to secure research funding were not always successful, and I was perhaps not so willing to accept this advice at face value. However, through the research we conducted as part of JST’s CREST Program (Functional Optical Devices Using Low Dimensional Quantum Structures [2002–2006]) we were able to establish a research platform for the fabrication of nanostructures, such as quantum wires and

quantum nanostructures, and for their application in optical devices. This development led to a major shift in my research direction toward my proposed Grant-in-Aid for Exploratory Research in the 2000s (Study of Active Optical Devices Employing Thin-Film Semiconductors/Polymer Composites [2001–2002]), and from this I successfully applied for funding under the Grant-in-Aid for Scientific Research (A) and Grant-in-Aid for Specially Promoted Research (InP-based membrane-type optical and electronic devices for broadband intra-chip/inter-chip interconnection in Si-LSI circuits [2007–2011]) categories. This research was a completely different direction from the semiconductor lasers used in optical fiber communications, which relay repeaterless transmission signals over a distance of 100 kilometers. Of the metal wiring layers on an LSI chip, if, through our exploratory research, we were able to utilize optical wiring instead of global wiring which consumes large volumes of energy, this could potentially reduce the overall energy consumption of the LSI chip as well as achieve higher transmission speeds. While, on one hand, the transmission distance of 1–2 centimeters was extremely short, we needed to reduce energy consumption to one-in-several-hundredths that of semiconductor lasers used in optical fiber communication. Although we were unable to achieve the desired research results in the time span proposed, during the subsequent three years working under the Grant-in-Aid for Scientific Research (A) we made significant progress in developing the fundamental manufacturing technology, while under the Grant-in-Aid for Scientific Research (S) that was accepted in fiscal 2015 (2015–2018; my final Kakenhi application before retirement) we are now close to developing a semiconductor laser with the properties we envisioned under our original plan. During the remaining research period, the key task will be addressing how to integrate this low power consumption semiconductor laser with a high-speed photodetector to realize a low power consumption signal transmission method that can replace electric wiring on LSI chips.

During test research conducted at the research planning stage, in which the actual elements are created in order to indicate the ultimate performance capability of the proposed elements and systems, it is common to face a range of difficult challenges, and I have personally encountered many instances in which we were unable to obtain the desired results as planned. The fact that I have been able to continue my research over a long time span despite such setbacks is, I believe, a testament to the Kakenhi program's excellence as a research support system. In recent years, the operating funds allocated to universities are in decline, and it is therefore important for universities to obtain a wide range of research funding, including from sources such as corporate donations, in

addition to public research funds. However, I believe that the Kakenhi system, which grants individual researchers relative freedom to pursue inventive, open-minded research projects, is essential for maintaining the vitality of Japanese science in the future.