

Series No. 97-06

**PHYSICS, BIG SCIENCE, AND MODERN  
INDUSTRIALIZATION IN KOREA**

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This article is one in a series of occasional papers published by the Center for Science, Trade, and Technology Policy of George Mason University and the Science and Technology Policy Institute of Korea as part of their U.S.-Korea Science and Technology Cooperation Program. This article is drawn from Prof. Kwun's presentation at the U.S.-Korea Forum on Fusion Science and Technology held on February 18-19, 1997 in Tysons Corner, VA.

STEPI-GMU/CSTP Occasional Paper 97-06

## **Introduction**

This article is on the role of basic science, especially physics and big science projects, in the modern industrialization process. As a physicist representing the Korean Physical Society, I would like to provide background on scientific as well as policy issues related to fusion research by reviewing the historical role of physics in Korea. I will present my views on bridging the gap between basic science research, such as fusion, and advanced technology, including industrial technology, which is pivotal to the success of big science projects like KSTAR (Korea Superconducting Tokamak Advanced Research).

It is widely accepted that physics in advanced countries such as the United States, the European Union, and Japan has played an important role in the development of high technology by providing scientific discoveries and technological innovations. A question that arises then is “how has physics in Korea contributed to the development of high technology and industry?” This is a difficult question because the growth of the physics community, and industrialization in general, are not necessarily interdependent.

To understand modern industrialization in Korea, one has to refer to the history of science and technology in Korea. During Korea’s 5000 year history there have been many important inventions such as metal typography—which occurred long before Gutenberg. The first rain-gauge, “Chok-Wo-Ki,” was invented 200 years earlier than in the West. These inventions did not come about systematically, but rather spontaneously by a few geniuses. The reason for this is that Korea, until the early 20th century, did not have a modern educational system to study or to learn science. The first physics or science higher education began in 1915 at Yonsei Junior College which was

established by foreign missionaries. Moreover, the Korean people had only limited opportunities to study natural sciences or engineering during the Japanese occupation.

### **The Role of Physics in Korea**

The development of science in Korea did not start until 1945 when Korea was liberated from Japan. At that time, there were only two Ph.D. degree holders and less than 20 B.S. degree holders in physics in Korea. After liberation from colonial occupation, the Korean government reorganized several junior colleges and established Seoul National University in 1946. When the small physics department was opened later that year, only a few students wanted to major in physics. The department produced its first four graduates in 1947. After the establishment of Seoul National University, many other universities began to spring up. Unfortunately though, the Korean War started in 1950 and the groundwork that had been laid had to be set aside. Students were scattered around the country and normal education could not be conducted again until the war ended in 1953.

After the war, the Korean government reconstructed physics programs with the help of U.S. government aid programs. Research apparatus and facilities were developed by graduate students using military surplus material. A small MNR and cyclotron were built by graduate students. I was on hand to witness those difficult days. Many Korean graduates with B.S. degrees went abroad, especially to the United States, to advance their study in various science fields. Many of them got their Ph.D. degrees and return to Korea as professors. At that time, most science students were majoring in engineering rather than natural science, and physics was not a popular course of study. However, physicists like myself tried hard to persuade high school graduates that the study of physics was important not only to their own future, but also that of Korea's. Because of these efforts, physics became popular, and in 1970 excellent students began entering the physics departments of various universities.

Today, the physics department of most universities is very prestigious. Therefore, when companies want to recruit new employees, graduates with majors in physics are held in high esteem,

even though their job assignments may not be related to their physics education. Highly qualified physicists, therefore, are entering the modern industrialization process in Korea and their physics background contributes to the development of high technology and industry by providing creative ideas and competent analytical capability.

Along with the rapid economic growth in the 1980s and 1990s, the physics community in Korea was also growing. Membership in the Korean Physical Society is presently about 5000 members, up from 37 when it was established in 1952. The Korean physics community has contributed to industry by supplying excellent and competent graduates. The Korean physics community is comparatively young. Physicists in their 30s make up the largest group in the Korean Physical Society.

### **Physics Contributing to Industrialization**

I would like now to give my perspective on how the Korean physics community is contributing to the industrialization process in Korea. This is important because the role of the Korean physics community is very different from its counterparts in advanced countries.

Korea has experienced rapid and sustained economic growth for the last 30 years. As a relatively small country with a large population, Korea has come to realize that in order to survive it must look beyond its borders to find ways to utilize its human resources to the maximum. The key to Korea's success is to develop creative scientific and innovative technological minds so that technological know-how for industrialization and high technology development can be accumulated.

Korea began to pursue an outward-looking, open economic policy in the 1960s and has seen its economy grow at an average annual rate of eight percent in real terms since then. Today, the Korean economy is the 11th largest in the world, and Korea is the 12th largest exporting country in the world. Over the same period, per capita GNP rose from \$87 in 1962 to over \$10,000 in 1996. However, during the 1960s and 1970s, the economic growth depended mainly on cheap labor in

labor-intensive industries and on acquiring technical know-how from advanced countries. The role of science, therefore, was limited to strengthening scientific and technical education, to developing technological infrastructure, and to promoting the importation of foreign technology.

In the late 1970s, the Korean government adopted a strategy to expand into the heavy and chemical industries. In line with this strategy, science and technology education also aimed at strengthening engineering relevant to the heavy and chemical industries and promoting R&D to meet industrial needs. It was during this period that government-supported research institutes were established.

In the 1980s, Korean industrial policy was re-directed from labor-intensive to technology-intensive industries such as electronics and machinery. During this period, the government launched several national R&D projects aimed at strengthening indigenous R&D and private industries started to establish their own research laboratories to meet the growing need for technology.

### **Basic Science Research In Korea**

The rapid growth and modern industrialization continued into the early 1990s. The Korean goal of joining the ranks of advanced industrialized countries now seems within reach in the next decade. However, experts in science and technology as well as economics recognize that the growth paradigm for the development stage will not apply for the future of Korean industry and economy. From 1996, the slow down in economic growth and the deepening of the Korean trade deficit has caused alarm. Koreans realize that improving national and industrial competitiveness will require changing science and technology policy toward creativeness and innovation, rather than promoting imported know-how. The government, therefore, has initiated a movement to promote basic science research and has placed special emphasis on the training of creative scientists and high-caliber engineering manpower to meet the new challenges. There is now a national consensus that advancement of science and technology is a prerequisite to becoming an advanced country by the 21st century.

The Korean government continues to provide various support and incentives to accelerate industrial technology innovation as well as basic science research in hopes of overcoming recent economic difficulties and to lead technology-based industries into the 21st century. The basic science community of Korea will have to play a greater role in helping to achieve national goals.

There have been several successful efforts to promote basic science research in Korea. Similar to many developing countries, basic research in Korea is principally carried out by universities. Due to the efforts of the Ministry of Education and the Ministry of Science and Technology to promote basic science in Korea, there has been significant growth in R&D expenditures and an increase in the number of published papers in basic science in recent years. Relative to that of advanced countries, however, the level of basic science research in Korea is far lower than industrial technology research.

Despite the fact that progress in basic science research in Korea is sluggish, there are some examples of successful programs and newly endowed programs that are worth mentioning.

In 1977, the Korean Science and Engineering Foundation (KOSEF) was established and it has played a major role in supporting basic research in Korea. Among KOSEF's programs, the establishment of Science Research Centers (SRC) and Engineering Research Centers (ERC) has been one of the most significant accomplishments in terms of improving the basic research capability of Korea. The SRCs and ERCs foster cooperation among academia, industries, and national laboratories, thereby networking dispersed research manpower at universities and reinforcing international competitiveness through science innovation. This program was started in 1990 with six SRCs and seven ERCs and has grown to 17 and 21 respectively. Excellence is maintained by a competitive selection process. The selection ratio is less than ten percent. The center of excellence program has proven to be an extremely effective way to improve the quality of university research and it is expected to continue to serve as the driving force for basic research in Korea.

There are two new programs for promoting basic science in Korea that are worth mentioning. They are the Asia-Pacific Center for Theoretical Physics and the Korea Institute of Advanced

Science. These institutes, which were established in 1996, are expected to play an important role in enabling domestic research organizations to conduct joint research with distinguished physicists of other nations. This could be another milestone in Korea's efforts to increase the level of physics research in Korea.

### **Big Sciences in Korea**

From the 1960s to the late 1980s, limited R&D resources prevented Korea from promoting big science projects. But in the late 1980s, there was rapid growth in R&D expenditures from the government as well as the private sector. The need for advanced technology development triggered a science and technology policy which emphasized basic research. This in turn initiated the first physics-oriented, big science project in Korea. The project was the development of a 2 GeV-class, third generation synchrotron radiation source, the Pohang Light Source (PLS). The project was initiated by Pohang Iron and Steel Company (POSCO) and Pohang University of Science and Technology (POSTECH) in 1988. The cost of the PLS project was approximately \$200 million and was completed in 1994.

PLS, which is running at 2.0 GeV electron energy and has stored current of more than 300 MA, has served as a national users facility for domestic and international users since September 1995. PLS made a big impact on scientific and industrial researchers in Korea. By providing a powerful new research tool in a diverse field of science and technology, the primary impact of PLS in Korea is already evident.

The impact of the PLS project on the science and technology in Korea was felt even during the construction phase. For the successful construction of a large-scale advanced device, Korean physicists had to collaborate with engineers in the industrial sector. Participation of advanced industrial companies to build accurate magnets, ultra-high vacuum systems, and other advanced systems, made a big impact on industrial technology and gave birth to some high technology

companies. This type of interaction between physicists, engineers, and industrialists suggests a new role for the physics community by contributing to the industrialization of Korea into the 21st century.

After successful collaboration on the PLS project, the second physics-oriented, big science project in Korea was launched in late 1995. It is now known as the Korean National Fusion Project (KNFP) and is based on the advanced superconducting KSTAR tokamak. Even though the long-term goal of the KSTAR project is fusion energy development, the immediate goal is successful construction of a large-scale device by employing the best technology, such as large-scale superconducting magnets, high-temperature materials, and cryogenic systems. Even after construction of the KSTAR device, investigating advanced fusion issues will be a more powerful driver of the project than fusion energy development.

### **A New Paradigm for Cooperation**

I would like to focus on the new paradigm of interaction between physicists, engineers, and industrial partners in Korea using the KSTAR project as an example. The KSTAR project requires even greater participation of world-class, advanced companies to develop even more complex industrial technologies than was required during the PLS project. Also, the experimental nature of KSTAR tokamak requires a new degree of flexibility for machine operation than other large-scale devices or reactors, so the involvement of physicists in the design and development phase is more important than with any other big science project. Therefore, the idea of Korean physicists collaborating with engineers in big science projects will be enforced as the project progresses. Through their interaction, the physics community in Korea will contribute to innovation in industry and the development of high-technology for future use. For the physics community, this interaction process could cultivate the industrial infrastructures for new advanced manufacturing capacity in Korean industry. This infrastructure can be tapped then when physicists seek to convert their new ideas into experimental devices.

The other important impact of big science projects in Korea is the increased awareness of the need for internationalization of Korean science and technology. With world-class, physics-oriented big science facilities, the interaction of Korean scientists with the world community is easier, wider, and deeper. The PLS project, design, and construction induced strong collaboration with the United States, China, and Japan. Moreover, the international utilization of this world-class facility has opened up further international collaboration.

The international character of the KSTAR project is even more pronounced. Korean institutions and many U.S. institutions are already collaborating on the design of the KSTAR tokamak. Results of fusion research on existing devices are shared to enable better design of devices, and the results of developmental work on superconducting tokamaks are also shared.

The KSTAR tokamak will be open to the world fusion community for collaboration when it opens in the year 2002. This facility will be one of the best fusion research facilities in the first decade of the 21st century until the International Thermonuclear Experimental Reactor (ITER) is operational. For this reason, the globalization and internationalization of science and technology in Korea will be accelerated with the advent of the KSTAR project.

I sincerely hope that the KSTAR project will be completed with the strong collaboration of the international science community so that a new milestone of Korean science efforts can be achieved.

## **Conclusion**

We are in the midst of tremendous change, the outcome of which is still unknown and can not be comprehended. However, the current changes convey to us several important indications regarding our future socio-economic development. One is that the socio-economic development of the new century will be lead by knowledge-based industries, and thus the role of science, including

physics, will be more important than it has ever been. The second indication is that national boundaries no longer constrain human activities, including scientific ones.

To bridge the gap between physics and industrial development we have to produce the highest quality graduates who can develop new high technologies for industry. Also, new physics research results should directly contribute to high technology so that they can help promote industrial development.

In conclusion, the history of scientific progress in advanced countries is known and understood. However, the progress of science, including physics, in Korea is very different from that of the United States. This article has reviewed the progress of science in Korea using the role of physics in the modern industrialization process as an example. I hope this review helps readers to better understand the historical background of the Korean physics community and will assist in further cooperation among scientists and engineers from around the world.