"Photonics and Quantum Technology for Society 5.0" Creating a cyber-physical system (CPS) that sharpens Japan's industrial competitiveness

Which are the key technologies for a cyber-physical system (CPS), societal infrastructure for realizing Society 5.0? Which parties will be involved in establishing CPS? "Photonics and Quantum Technology for Society 5.0," a project of the Cross-ministerial Strategic Innovation Promotion Program (SIP) promoted under the auspices of the Cabinet Office, is endeavoring to answer these questions with a view to creating CPS that will sharpen Japan's industrial competitiveness.

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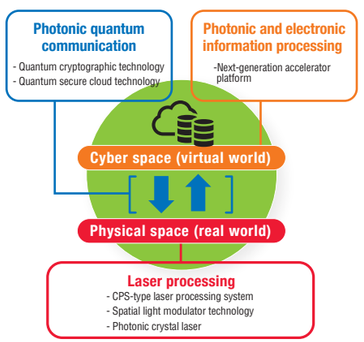
Laying the foundation in Japan for platform creators in the era of Society 5.0. That is the significance of "Photonics and Quantum Technology for Society 5.0," a five-year SIP project launched in 2018.

CPS for Society 5.0 cannot be realized without renewing the core technologies for societal infrastructure. Whereas present-day information platforms for social media and websites only handle data generated in cyberspace, CPS primarily handles data continuously generated in physical space. Reflecting the multitude of diverse natural and social phenomena, the volume of data in physical space increases exponentially. So, says Program Director NISHIDA Naoto, "It's impossible to realize CPS simply by enhancing the performance of conventional computers and networks. It's indispensable to transition to technology based on a new paradigm."

This project aims to realize CPS that will sharpen the global competitiveness of Japanese industry by integrating the country's prowess in photonics and quantum technology research. Of the technological elements constituting CPS, the project focuses on three R&D themes—laser processing, photonic quantum communication, and photonic and electronic information processing—in pursuit of strongly desired technological innovation.

Establishing CPS (Cyber Physical System)



Contribute to establishing a network-type manufacturing system that leads to a qualitative change in productivity

The challenge of demonstrating practical implementation of CPS in society, starting with a tough task of laser processing

With regard to laser processing for which data gathered in physical space are handled, the project aims to build a CPS-type laser processing system.

The steep rise in demand for laser processing machines, which already account for 20 to 25% of the machine tool market, is expected to continue. But since the principles underlying laser processing have yet to be fully elucidated, it proceeds by trial and error. Determining the processing conditions is both time- and labor-intensive.

Laser processing technology itself is not the objective of this project. The aim is to digitize the phenomena during laser processing and demonstrate that CPS is applicable to laser processing.

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Deputy Program Director YASUI Koji says, "Implementation of CPS to laser processing is a tough task to which researchers could devote their entire lives. In the 'cyber' part, modeling of processing phenomena is the issue. In the 'physical' part, the challenges include system simplification by use of a photonic crystal surface emitting laser diode and the use of a modulation device for feedback control. Resolving these complicated issues at manufacturing sites is a precondition for the practical implementation of CPS in society. We intend to show that these issues can be resolved by pooling the expertise of leading universities, research institutions, and the private sector."

Once these issues are resolved, it will be possible to apply CPS widely to meet sharply rising market needs for processing composites and other hard-to-process materials such as glass. Practical application of CPS to laser processing and cutting, which is considered to be a particularly tough challenge, will trigger great expansion of the CPS application field leading to the emergence of Society 5.0.

Quantum secure cloud system Targeting the ultimate security technology

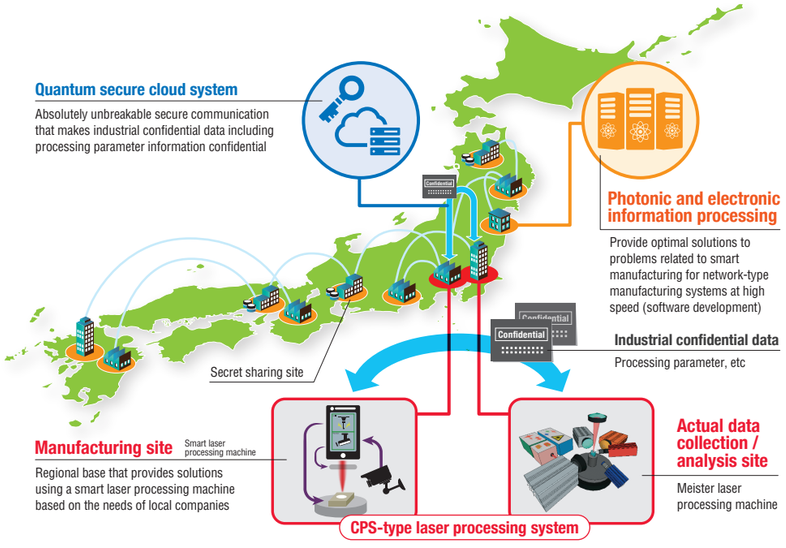
Expertise at manufacturing sites digitized through implementation of CPS would present an attractive target for hackers because of its high commercial value. Since these digital data embody the sources of a company's competitiveness, confidentiality must be ensured over the long term as data leakage might compromise the company's competitiveness, possibly jeopardizing its continued existence.

Hence, there is an urgent need to fundamentally revamp security technology. In particular, the rise of quantum computing may make public-key cryptography, long the cornerstone of security infrastructure, decipherable.

Quantum cryptography is attracting attention as an alternative to public-key cryptography. Public-key cryptography uses hard-to-solve mathematical problems. Although they are difficult to decode at present, this may well change as a consequence of technological progress. On the other hand, quantum cryptography, which is based on the laws of physics, is the only cryptographic technology whose security is assured regardless of technological advances.

This project aims to develop ultra-long-term quantum cryptographic technology to support CPS. For this purpose, the power of quantum cryptography must be harnessed to safeguard stored digital data. In a quantum secure cloud system, source data would be processed into multiple random data, which would be transmitted to multiple remote storage servers for dispersed storage.

Deputy Program Director SASAKI Masahide says, "Our aim is to establish a security system that would cause hackers to throw in the towel, thus opening the way to implementation of the system throughout society."



Photonic and electronic information processing Paving the way toward utilization of CPS to solve familiar hard problems

Photonic and electronic information processing is for elucidating in cyberspace various phenomena that occur in physical space. In regard to photonic and electronic information processing, by using quantum computing the project aims to achieve practical solutions of problems that existing computers cannot handle.

Numerous problems remain unsolved even in the contemporary world despite the progress of computer science. For example, the traveling salesman problem is a typical hard problem that requires an unrealistically long time to reach a solution even for a supercomputer. Problems involving combinational optimization arise frequently in drug discovery, development of new materials, reduction of traffic congestion, and optimal control of a robot manipulator, to cite but a few familiar examples. For solving problems in physical space, CPS requires effective methods.

Capitalizing on innovative computational resources, such as quantum annealers, digital annealers, and quantum-gate computers, the project aims to develop a next-generation accelerator platform for achieving total high-speed optimization.

"Many companies have sensed the potential of quantum computers but can scarcely imagine how to utilize them. With photonic and electronic information processing, we want to pave the way for their utilization," emphasizes NISHIDA.

The project aims to build a model system that can be used as the foundation for applying CPS to manufacturing, which companies can test without constraints and introduce. It is envisaged that the project will lead to outcomes that will sharpen Japan's competitive advantage.

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