CPEC/NanoQuine

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[Quantum dots and advanced nano-photonics]

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Quantum Nano Devices, Nano Optoelectronics

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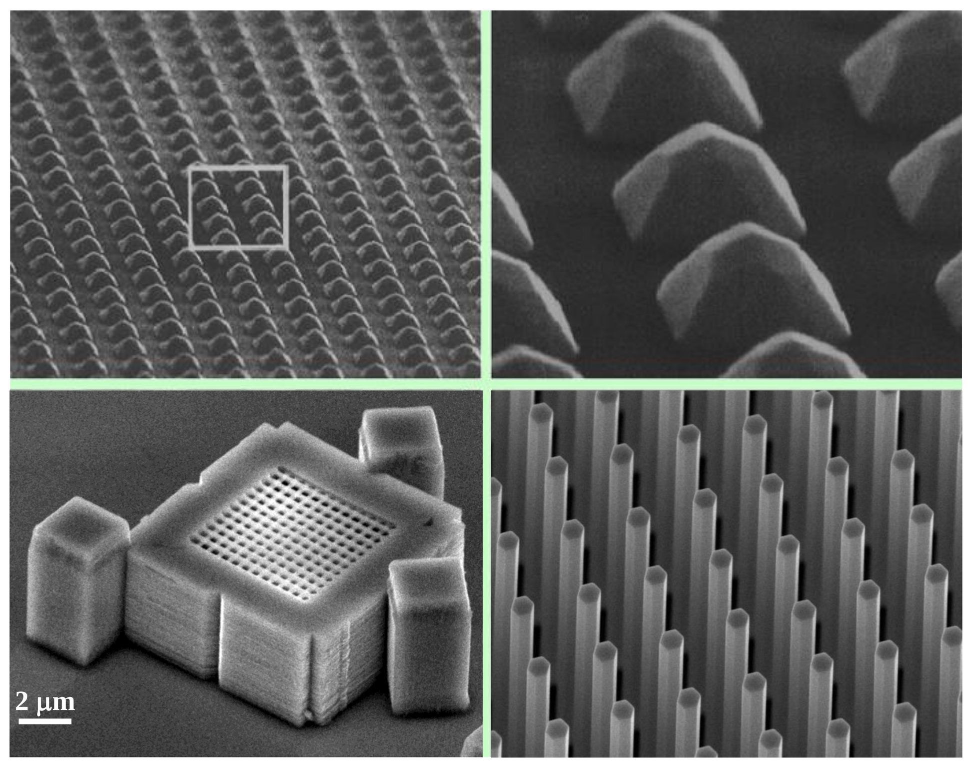
Since the first proposal of the quantum box (quantum dot) by Arakawa and Sakaki in 1982, we have been investigating quantum nanostructures and devices for future telecommunications applications. Our major subjects include: fabrication of semiconductor nanostructures such as quantum dots and photonic crystals, study of novel physics in such nanostructures, development of nano-photonic and quantum information devices, and basic research on future LSI-photonics convergence and IoT photonics. These are supported by large national projects, "Collaborative Research Center of Excellence for Nano-Quantum Information Electronics" by MEXT (FY2006-2015, a total of about JPY 6.2 billion), “Integrated Photonics-Electronics Convergence System Technology” in the framework of the Future Pioneering Program by METI (FY2012-2021, a total of about JPY 30 billion), and Grant-in-Aid for Specially promoted Research "Solid-state Quantum Electrodynamics in Quantum Dot-Nanocavity Multiply-Coupled Quantum Systems and Its Application to Novel Light Sources” by MEXT (FY2015-2019, a total of about JPY 4 billion).

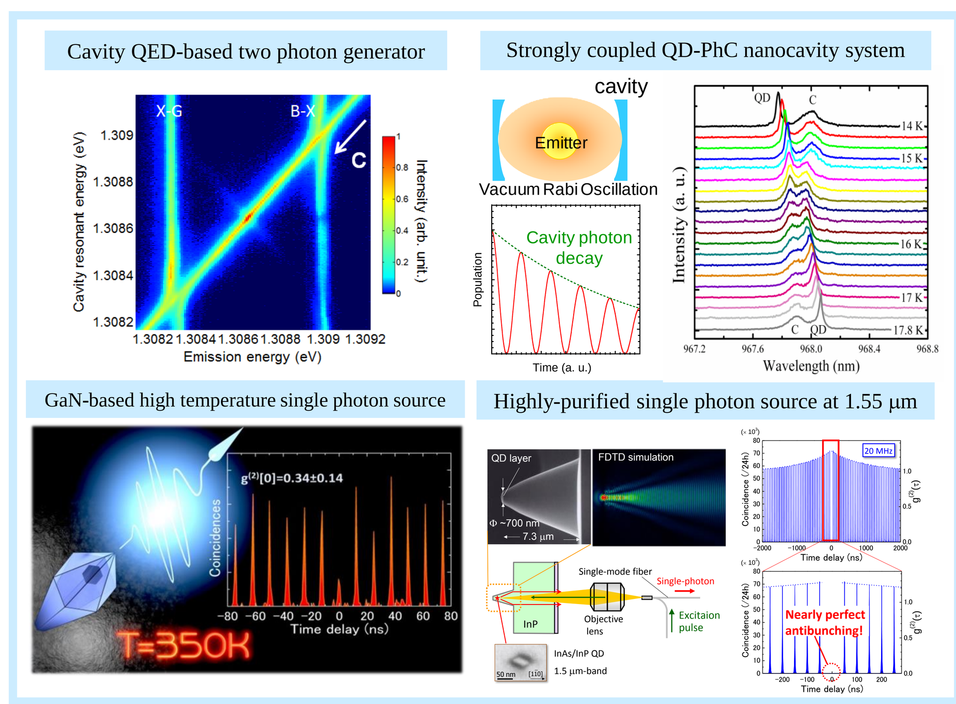
Fabrication of Nanostructures: Quantum Dots and Photonic Crystals

In order to create nanosystems which enable us to manipulate individual electrons or photons, we have been developing fabrication technologies for nanostructures such as quantum dots (QDs) or photonic crystals (PhCs) by employing metalorganic chemical vapor deposition, molecular beam epitaxy, or electron beam lithography. So far, we have demonstrated state-of-the-art InAs/GaAs or III-nitride QDs and nanowires for telecom and quantum information applications. In addition, we have developed fabrication technologies for 3D PhCs, leading to the world’s highest Q factor in a 3D PhC nanocavity, together with lasing therein. Furthermore, 3D PhC circuits integrating a nanocavity laser with waveguides have been successfully realized. We also succeeded in assembling 3D chiral PhC nanostructures for manipulating the spin angular momentum of photons.



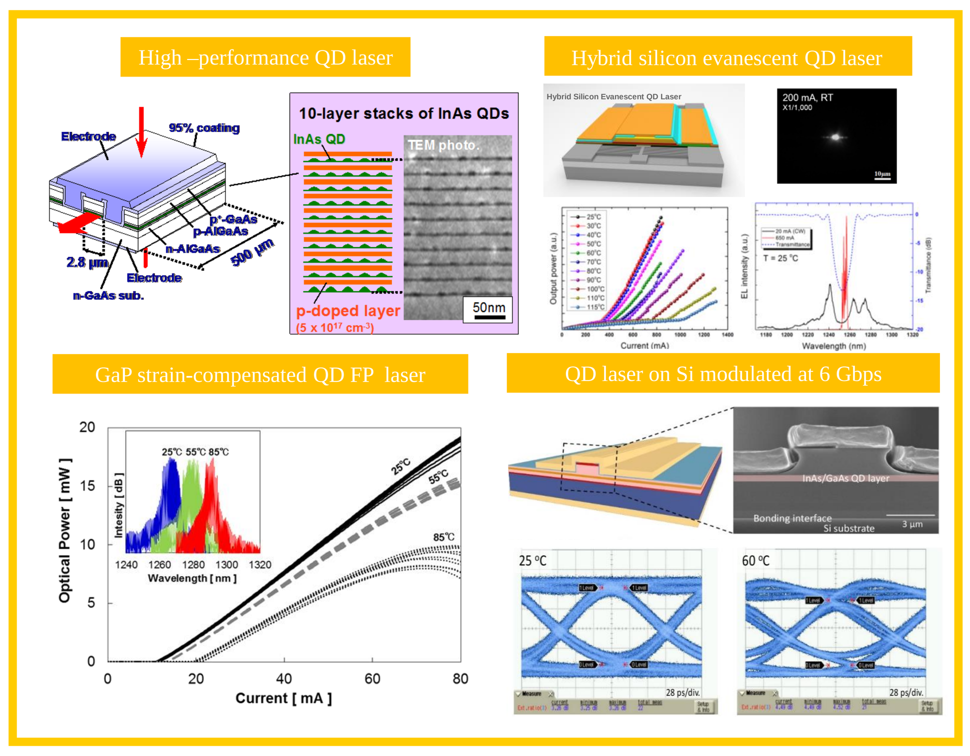
Optical Properties of Nanostructures and Basic Research on Quantum Information Devices

We have been studying electronic/optical properties of QDs, PhCs and their combined structures using various specially-tailored experimental techniques. In particular, our optical microscopes can access nanoscale individual QDs and their single photon emission, giving a technological foundation for exploring the cutting-edge nano/quantum world. Currently, we have demonstrated single photon emission from QDs in nanowires, ultrafast coherent control of QD excitons, and strong coupling in coupled QD-photonic crystal nanocavity systems. In addition, we have been strongly promoting basic research on quantum information devices, and so far demonstrated single photon LEDs and III-nitride-based single photon generators that can operate at 350K. Moreover, we have realized secure quantum key distribution over 100 km by developing high-performance single photon sources at 1.55 µm telecom-band and an efficient quantum key distribution system.



Development of Nano Optoelectronic Devices

Our research is directed toward advanced nano-photonic devices incorporating QDs or PhCs. In particular, by working in close collaboration with industry, we have developed high-quality QD lasers. Thermally stable 25 Gbps operation of FP lasers and 10 Gbps operation of DFB lasers have been successfully demonstrated. In addition, next-generation photonics-electronics convergence system technologies featuring high-efficiency light sources on silicon substrates are also under development. As one example, we have realized telecom-band 1.3 µm QD lasers on silicon substrates by employing wafer bonding techniques and have demonstrated their high-speed direct modulation. Also, we have succeeded in fabricating hybrid silicon evanescent QD lasers and QD lasers directly grown on Si(100) just substrates.



Development of Basic Technologies for IoT Photonics

For the purpose of realizing Internet of Things (IoT) by photonics, we are focusing on research and development of high-efficiency energy conversion devices, next-generation nanolasers, and integrated photonics-electronics convergence system technologies. Especially, fabrication technologies for high-performance QD solar cells have ben developed by using sophisticated crystal growth techniques, and the possibility of ultrahigh efficiency (75 %) multilevel intermediate band solar cells has been theoretically predicted. Also, high-quality PhC nanocavity-based single QD lasers and single QD-3D PhC nanocavity coupled system have been successfully realized.