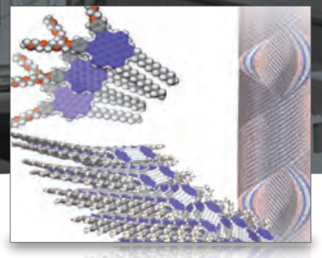
Emergent Matter Science

The Science of Emergent Matter

"Emergence" refers to the phenomenon in which a number of elements that are brought together gain properties that could not be predicted from the individual elements. For example, when a large number of electrons become strongly correlated, they can give rise to extremely strong electrical and magnetic action that could not be predicted from the actions of a single electron. Additionally, by linking together a large number of molecules, it is possible to create materials with new functionalities that were not possessed by the individual molecules. In this way, when particles such as electrons or molecules gather together, they can give rise to surprising materials and functions that could not be predicted simply as an aggregation of the original constituent elements. The science that attempts to elucidate the principles of emergent phenomena and create new materials and functions based on these principles is known as emergent matter science.

Strong Correlation Physics

A strongly correlated electron system is a state in which vast numbers of electrons mutually interact. By leveraging and controlling the movements of these electrons, it is possible to fabricate materials that have powerful energy properties, such as very low consumption, minimal electricity loss, and a high conversion ratio.



Supramolecular Chemistry

Supramolecular assemblies are complexes made of molecules which have novel functions that their individual molecules do not. By synthesizing molecules and assembling them regularly, such architectures with new function can be designed.

Quantum Information Electronics

Quanta are the smallest unit of matter-like mass, and can behave both like waves and particles. By developing technologies to control the quantum state, it is possible to create quantum computers and quantum devices that process information extremely securely and with extremely low energy consumption.

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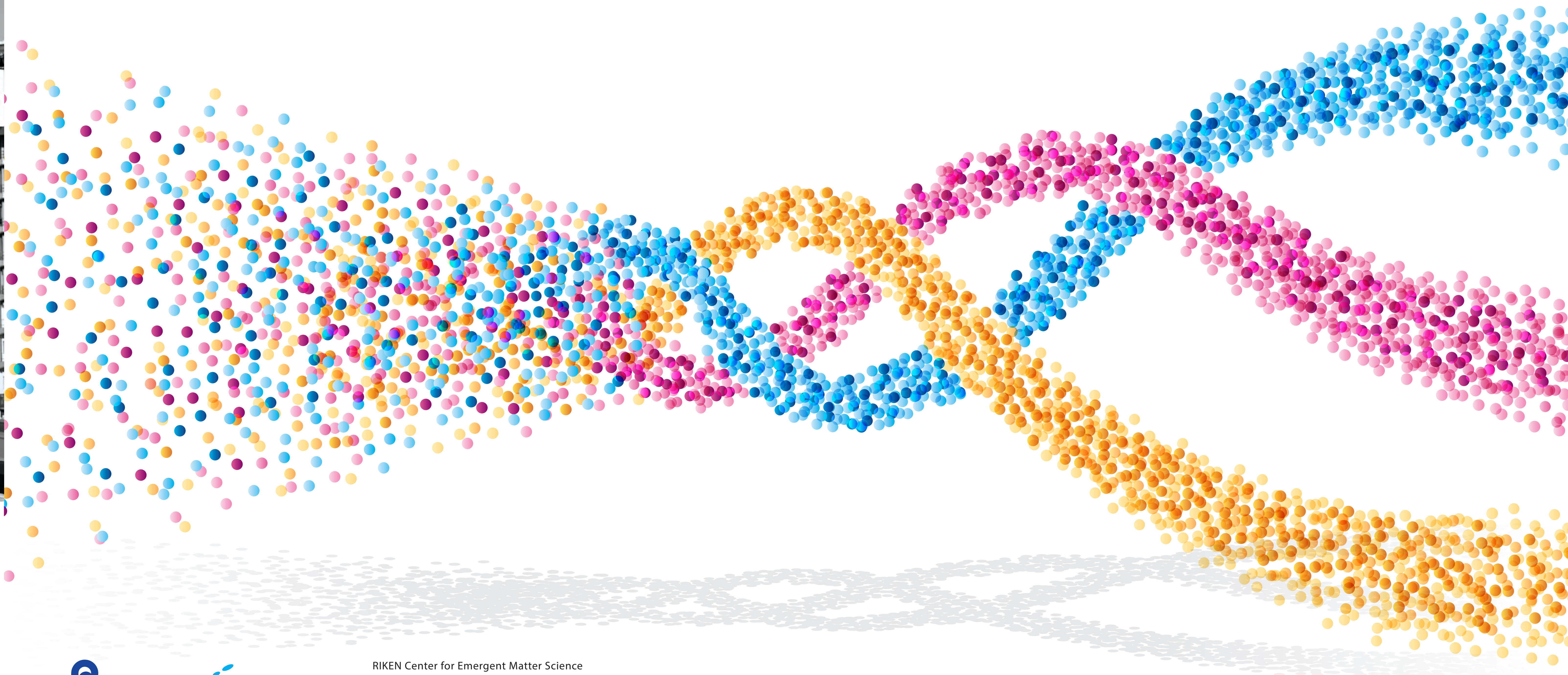
CEMS RIKEN Center for Emergent Matter Science



RIKEN CEMS

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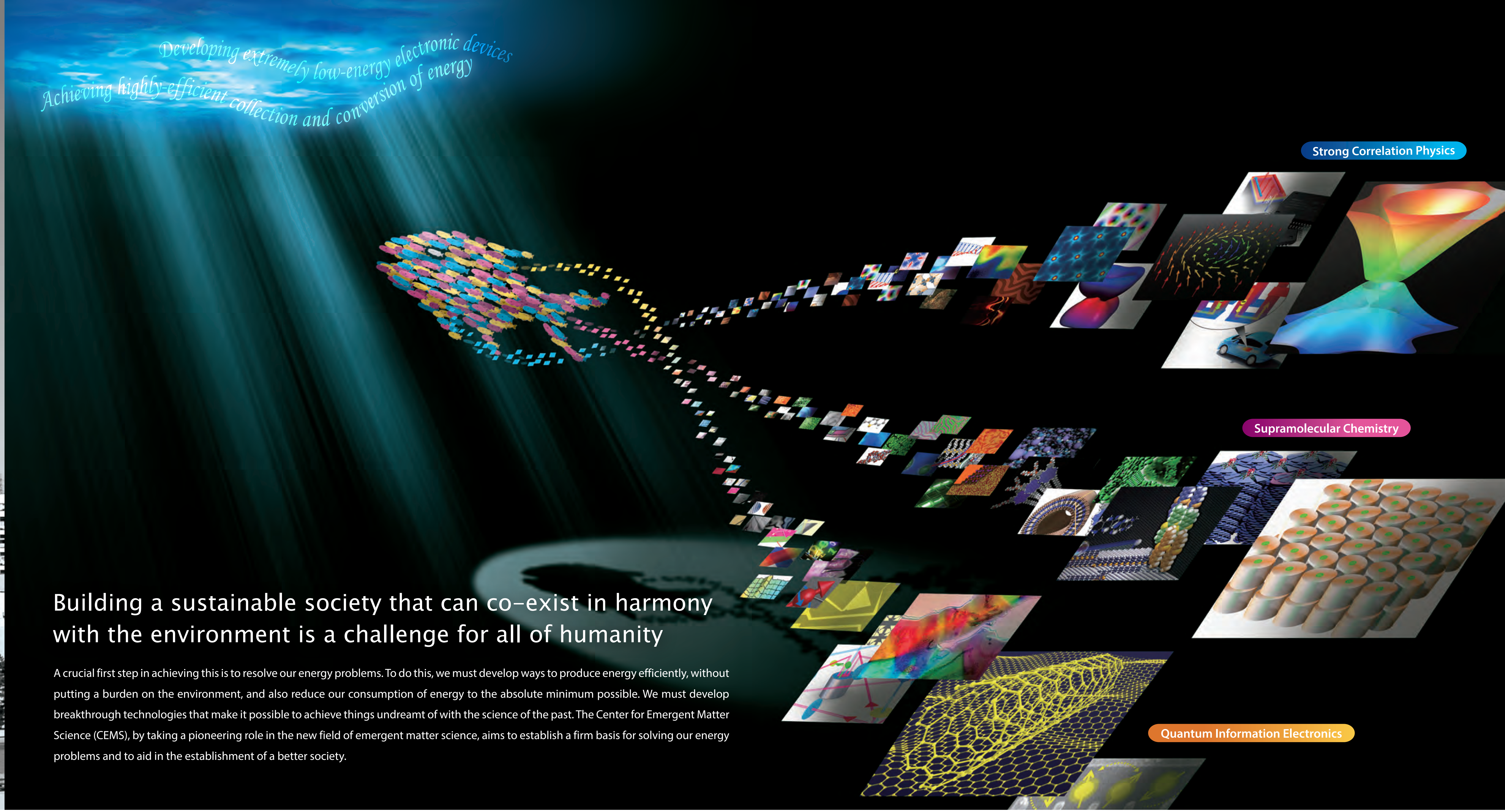


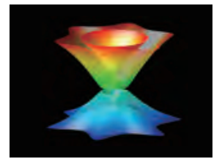
Building a sustainable society that can co-exist in harmony with the environment is a challenge for all of humanity

A crucial first step in achieving this is to resolve our energy problems. To do this, we must develop ways to produce energy efficiently, without putting a burden on the environment, and also reduce our consumption of energy to the absolute minimum possible. We must develop breakthrough technologies that make it possible to achieve things undreamt of with the science of the past. The Center for Emergent Matter Science (CEMS), by taking a pioneering role in the new field of emergent matter science, aims to establish a firm basis for solving our energy problems and to aid in the establishment of a better society.

The Center for Emergent Matter Science (CEMS) brings together leading scientists in three areas—physics, chemistry, and electronics—to elaborate the principles of emergent phenomena and to open the path to potential applications

CEMS carries out research in three areas: strong correlation physics, supramolecular chemistry, and quantum information electronics. It incorporates more than 200 researchers from around the world, organized into approximately 30 research groups and teams. There are other leading centers around the world working in each of the three individual disciplines covered by CEMS, but nowhere in the world is there a center that brings the three together in one place. In order to create a sustainable society that can co-exist with the natural environment, cooperation among the fields of physics, chemistry, and electronics is critical. Bringing these three areas together allows "emergent phenomena" to take place within the center's research as well, making possible breakthroughs in research that could not be predicted from the outset.

Strong Correlation Physics



Topological currents

Electrons within a solid create beautiful geometrical patterns in momentum space. This is related to electron functions such as topological currents, where there is no energy loss.

Strongly correlated electronics

Strongly correlated electrons can quickly change between metal and insulator with tiny stimuli. This can be used for non-volatile memory (ReRAM) with high speed/density and low energy loss.

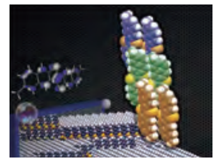
Thermoelectric conversion

By controlling strongly correlated electrons, it is possible to create materials that efficiently convert heat to electricity and vice versa.

Supramolecular Chemistry

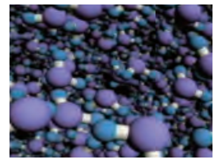
Optical actuators

Polymers incorporating parts that transform in response to light are regularly ordered, allowing the development of functional materials for efficient light-to-mechanical energy conversion.



Supramolecular photovoltaics

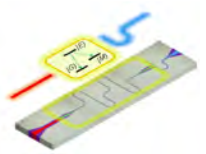
The efficiency of organic thin film solar cells is improved by creation of organic semiconducting polymers using fused polycyclic aromatics with high mobility carriers (electrons and holes).



Aquaplastics

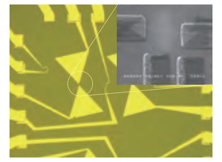
Aquamaterials, which are plastics and rubbers composed almost entirely of water, are being further developed into materials that have a minimal environmental load.

Quantum Information Electronics



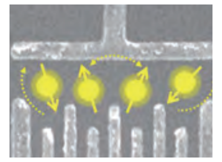
Coherent computers

Quantum-state controls in integrated superconducting circuits, consisting of qubits, resonators, waveguides, etc., enable quantum information processing and ultimate low-noise signal detection.



Quantum devices

By using carbon nanotubes, it is possible to build extremely small devices that maximize quantum effects, such as double quantum dot devices.



Quantum computers

By constructing qubit circuits formed from the electron spin of semiconducting quantum dots, it is possible to conduct logical calculations with quantum manipulation and error correction.