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Optical phonon lasing in double quantum dot fabricated in semiconductor substrate

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Quantum dots fabricated in semiconductor substrates are confinement structures of nanometer scale, in which the electron number is tunable one by one due to the Coulomb blockade. In the present study, we propose optical phonon lasing in a semiconductor double quantum dot (DQD), without the requirement of an additional cavity for phonons. We find that an electron in the DQD couples to only two phonon modes that act as a natural cavity due to the flat dispersion relation. The DQD is connected to external leads under a finite bias, which enables electric pumping similarly to a microlaser using superconducting quantum dot coupled to a photon cavity. We also take into account the natural decay of phonons due to lattice anharmonicity.

When the energy level spacing in the DQD is tuned to the phonon energy, the electron transport is accompanied by phonon emission. By analyzing the second-order autocorrelation function of phonons, we find a Poisson process of phonon emission, i.e., phonon lasing, when the electron tunneling between the DQD and leads is much faster than the phonon decay. On the other hand, anti-bunching of phonon emission occurs for slower tunneling. Both effects disappear by an effective thermalization via the Franck-Condon effect in a DQD fabricated in a suspended carbon nanotube with strong electron-phonon coupling. Our theory is also applicable to nanomechanical resonators. The results imply that a DQD could generate various quantum states of resonators.

Biography

Rin Okuyama completed his Ph.D. at Keio University in March 2013. He is a postdoctoral research fellow of the Japan Society of the Promotion of Science. He theoretically studies nonequilibrium phenomena in semiconductor nanodevices. His main work on phonon lasing was selected as "Papers of Editors' Choice" by Journal of the Physical Society of Japan.

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