The Fundamentals of Quantum Dots for Advanced Photonics

Yasuhiko Arakawa
Institute for Nano Quantum Information Electronics, The University of Tokyo
4-6-1 Komaba, Meguro-ku, Tokyo 153-8505 Japan
arakawa@iis.u-tokyo.ac.jp

ABSTRACT

Since semiconductor quantum dots (QDs) were first proposed in 1982, they have been intensively studied for both fundamental solid-state physics and advanced device applications. The quantum-confinement of electrons in QDs has enabled the realization of high-performance quantum lasers, high-sensitivity quantum dot infrared detectors, and advanced non-classical light sources. Moreover, embedding a single quantum dot inside a photonic nanocavity has provided a new platform for studying solid-state cavity quantum electronics (cavity-QED).

In this lecture, I will introduce some of the fundamentals of QD structures, mainly related to light-matter interaction. The first part is devoted to basic electronic and optical properties, including electronic states, electron spin, optical transition with selection rules, and optical gain. The phonon assisted relaxation of electron between the QD discrete energy states with respect to so-called the phonon bottleneck will also be discussed.

In the second part, the fundamentals of semiconductor quantum optics including cavity QED are described. In particular, I will discuss both the strong and weak light-matter coupling regimes with QDs embedded in photonic nanocavities. The two regimes lead to the cavity polariton and enhanced Purcell effect in stimulated emission/spontaneous emission, respectively.

In the final part of the lecture, I will review recent progress in quantum dot photonics technologies, such as epitaxial growth of III-Arsenide QDs on silicon for lasers, realization of QD-based nano-lasers, and single photon sources based on III-Nitride nanowire-QDs operating above room temperature.

BIOGRAPHY

Yasuhiko Arakawa received the B.E., M.E., and Ph.D. degrees in electronics and electrical engineering from the University of Tokyo, Tokyo, Japan, in 1975, 1977, and 1980, respectively. In 1980, he joined The University of Tokyo as an Assistant Professor and became a Full Professor in 1993. He is currently a Specially-Appointed Professor of the Institute for Nano Quantum Information Electronics, The University of Tokyo, and also Professor Emeritus of The University of Tokyo. His major research interests include physics, growth, and photonics application of quantum dots.

He received numerous awards including ISCS Quantum Devices Award in 2002, Leo Esaki Award in 2004, IEEE/LEOS William Streifer Award in 2004, the Fujiwara Award in 2007, the Prime Minister Award in 2007, the Medal with Purple Ribbon in 2009, IEEE David Sarnoff Award in 2009, the C&C Award in 2010, ISCS Heinrich Welker Award in 2011, OSA Nick Holonyak Jr. Award in 2011, JSAP Isamu Akasaki Award in 2012, Japan Academy Prize in 2017, and IEEE Jun-ichi Nishizawa Medal in 2019. IN 2017, he was elected as a Foreign Member of the US National Academy of Engineering (NAE). He is a Life Fellow of IEEE and Fellows of OSA, JSAP, and IEICE.