Concepts of dressed photon science and technology

Motoichi Ohtsu
Graduate School of Engineering, the University of Tokyo,
2-11-16 Yayoi, Bunkyo-ku, Tokyo 113-8656, Japan,
also with Nanophotonics Research Center, The University of Tokyo,
2-11-16 Yayoi, Bunkyo-ku, Tokyo 113-8656, Japan,
E-mail: ohtsu@ee.t.u-tokyo.ac.jp

Dressed photon (DP) science and technology exploits the electromagnetic field localized in nanometric space. This fields has been named optical near-fields due to its non-propagating features. The principles and concepts of DP science and technology are quite different from those of conventional wave-optical technology encompassing photonic crystals, plasmonics, metamaterials, silicon photonics, and quantum-dot photonic devices. This is because these devices use propagating light even though the materials or particles used may be nanometer-sized. The theoretical picture of DP has been proposed to describe the electromagnetic interactions between nanometric particles located in close proximity to each other. The DP is a virtual cloud of photons that always exists around an illuminated nanometric particle. Independently of the real photon (, i.e., conventional propagating scattered light), a virtual photon is emitted from the electron, and this photon can be re-absorbed within a short duration. Since the virtual photon remains in the proximity of the electron, it can couple with the electron in a unique manner. This coupled state (DP) is a quasi-particle from the standpoint of photon energy transfer.

The DP has been theoretically described by assuming a multipolar quantum electrodynamic Hamiltonian in a Coulomb gauge in a finite nano-system [1]. The creation and annihilation operators of the DP are expressed as the sum of the operators of the real photon and an electron–hole pair. A real nanometric material is composed not only of electrons but also of a crystal lattice. In this case, after a DP is generated on an illuminated nanometric particle, its energy can be exchanged with the crystal lattice. By this exchange, the crystal lattice can excite the vibration mode coherently, creating a multi-mode coherent phonon state. As a result, the DP and the coherent phonon can form a coupled state (dressed-photon – phonon: DPP) [2]. This coupled state is a quasi-particle and is generated only when the particle size is small enough to excite the crystal lattice vibration coherently.

Three examples for application to energy conversion will be reviewed: (1) Up-conversion of optical energy [3]. (2) Conversion from optical to electrical energy [4]. (3) Conversion from electrical to optical energy by taking a LED as an example. Novel LED [5] and a laser[6] will be demonstrated by using indirect transition-type semiconductors (Si, SiC, and GaP), which are fabricated and operated by DPP.

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Motoichi Ohtsu received the Dr. E. degrees in electronics engineering from the Tokyo Institute of Technology, Tokyo in 1978. He was appointed a Research Associate, an Associate professor, a Professor at the Tokyo Institute of Technology. From 1986 to 1987, while on leave from the Tokyo Institute of Technology, he joined the Crawford Hill Laboratory, AT&T Bell Laboratories, Holmdel, NJ. In 2004, he moved to the University of Tokyo as a professor. He has been the leader of several Japanese national projects for academia-industry collaborations. He has written over 509 papers and received 83 patents. He is the author, co-author, and editor of 62 books, including 27 in English In 2000, he was appointed as the President of the IEEE LEOS Japan Chapter. From 2000, he is an executive director of the Japan Society of Applied Physics. He is a Fellow of the Optical Society of America, and a Fellow of the Japan Society of Applied Physics. He is also a Tandem Member of the Science Council of Japan. He has been awarded 14 prizes from academic institutions, including the Issac Koga Gold Medal of URSI in 1984, the Japan IBM Science Award in 1988, two awards from the Japan Society of Applied Physics in 1982 and 1990, the Inoue Science Foundation Award in 1999, the Japan Royal Medal with a Purple Ribbon from the Japanese Government in 2004, H. Inoue Award from JST in 2005, the Distinguished Achievement Award from the IEICE of Japan in 2007, Julius Springer Prize for Applied Physics in 2009, and Fuji-Sankei Business Eye Award in 2012.