Nanostructures in Semiconductor Photonic Devices

N.R. Das

Institute of Radio Physics and Electronics, Univ., of Calcutta, 92 Acharya P.C. Road, Kolkata, India

The novelty in most of the modern high performance electronic and photonic devices is attributed to the characteristic behaviour of semiconductor nanostructures. Thanks to the advancement of technology of growth and lithography, in recent times there has been a tremendous interest on nanostructures among researchers and technologists. In this talk, principle, performance and applications of semiconductor nanostructures in photonic devices are discussed. Semiconductor photonics devices include Light Emitting Diodes (LEDs), LASERs, optical amplifiers, optoelectronic modulators, photodetectors, etc.. When light is absorbed by the semiconductor, carriers may go to a higher state. This absorption causes an electron to move from valence band to conduction band, creating electron-hole pairs in this process. The reverse process, where electrons and holes recombine radiatively, gives rise to emission of light. Such transitions involving valence band and conduction band are called interband transitions. In semiconductor nanostructures, the energy levels are quantized (forming subbands) because of the carrier confinement in one or more directions. So, the transition between two subbands may also occur and is known as inter-subband transition. The energy for such transition is usually in the mid or long infra-red regions. Because of the quantized energy states and the discrete nature of density of states, the nanostructure–based devices show novelty in their behaviour. For example, Quantum Well (QW) LEDs are important for their high speed and better linearity. Quantum Dot (QD) LEDs are attractive for their portability, flexibility, etc. in addition to tunability of nano-LEDs. Nanostructure lasers have shown significant reduction in threshold current density. Of special mention is exploiting the inter-subband transition in semiconductor nanostructures. This transition can be radiative transitions irrespective of whether it is a direct-gap or an indirect-gap semiconductor. Terahertz emission is reported using SiGe-based quantum cascade laser, though SiGe is an indirect band-gap semiconductor. Quantum Well Infra-Red (QWIP) photodetector also utilizes inter-subband transition for detection of medium- and long-wave infra-red radiation. QWIP has already been commercially used in Camera. Other applications include night vision, defense, weather monitoring, medical, astronomy, food industry, etc. In the talk, prospect of Quantum Dot Infra-Red Photodetector (QDIP) as future devices is also indicated.