

Terahertz Emitters Based on Quasi-One-Dimensional Carbon Nanostructures

R. R. Hartmann⁽¹⁾, V. A. Saroka^(2,3), and M. E. Portnoi*^(4,5)
(1) De La Salle University, 0922 Manila, Philippines
(2) Norwegian University of Science and Technology, NO-7491, Trondheim, Norway
(3) Institute for Nuclear Problems, Belarusian State University, 220030 Minsk, Belarus
(4) University of Exeter, Exeter EX4 4QL, United Kingdom; e-mail: <u>m.e.portnoi@exeter.ac.uk</u>
(5) ITMO University, St. Petersburg 197101, Russia

Creating reliable, portable, tunable sources and detectors of terahertz (THz) radiation is one of the most challenging tasks of contemporary applied physics. One of the recent trends in bridging the so-called THz gap is to use carbon-based nanostructures [1]. Several schemes utilizing the unique electronic properties of carbon nanotubes (CNTs) and graphene nanoribbons for THz application were brought forward by our group [2-5]. These schemes include THz generation by hot electrons in quasi-metallic CNTs, frequency multiplication in chiral-nanotube-based superlattices controlled by a transverse electric field, and tunable THz radiation detection and optically-pumped emission in metallic CNTs in a strong magnetic field. In the current presentation, we focus on direct interband dipole transitions in narrow-gap quasi-one-dimensional carbon-based nanostructures.

We show that the curvature effects in quasi-metallic single-walled CNTs and edge effects in gapless graphene nanoribbons not only open bang gaps, which are typically in the THz range, but also result in giant enhancement of the probability of optical transitions across these gaps with a sharp decrease in transition probability away from the band gap edge. A similar effect occurs in an armchair CNT with a band gap opened and controlled by a magnetic field applied along the nanotube axis [4]. There is a direct correspondence between armchair graphene nanoribbons and zigzag CNTs [5]. The described sharp photon-energy dependence of the transition matrix element together with the van Hove singularity at the band gap edge of the considered quasi-one-dimensional systems make them promising candidates for active elements of coherent THz radiation emitters. Inversion of population can be achieved by either excitation at optical frequencies or injection of carriers in biased nanostructures. An additional THz emission frequency control can be provided by a gate-induced p-n junction.

Another promising nanocarbon system for THz generation is an array of ultimate one-dimensional carbon nanostructures – carbynes (also known as linear acetylenic or polyynic carbons) which allows fully analytical treatment within the nearest-neighbor tight-binding model. A prominent feature of finite-length carbynes is the presence of optically-active edge states. For long enough (over 18 atoms) carbyne chains, the energy separation between the HOMO and LUMO edge states corresponds to the THz frequency range.

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