Generation of Terahertz Radiation with Optical Heterodyne by Nanoantenna-Coupled Tunneling Devices

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The terahertz technology has been intensively studied for its diverse applications spanning from imaging, non-destructive inspection, remote sensing, high-speed communication, to astronomy and studies of fundamental physics. Despite its huge potential in many areas, the practice of THz technology is restricted by a suitable and efficient radiation source, which falls between the electronics and photonics areas of research (P. Y. Chen and A. Alù, Nanotechnology, 24, 455202, 2013). We propose here a new nanoantenna-coupled THz photomixer based on the optical heterodyne down-conversion (photomixing). The sharp edge of nanobowtie antennas and the sub-microscopic vacuum gap provide a low tunneling-barrier and ballistic transport properties for electrons near the Fermi level, leading to low threshold voltage and large quantum tunneling current. The subwavelength nanobowtie geometry also makes this tunneling device an efficient optical nanoantenna, which couples two frequency-offset lasers and localize light within the deeply subwavelength nanogap, thereby enhancing significantly the heterodyne efficiency. The ac current generated by the heterodyning two laser frequencies will feed the THz antenna, which radiates the THz power into the free space. As a result, the nanobowties play a dual role of shunted nanodiodes and nanoantenannas, thus ensuring a low-bias-voltage operation and strong optical field localization that lead to the efficient heterodyne down-conversion.

Further, by shrinking the vacuum gap to a few nanometers, the THz generation may be dramatically boosted due to the increased importance of the second-order quantum conductivity, which results from the photon-assisted quantum tunneling. Our theoretical results show that this nanoantenna-coupled, vacuum-packaged photomixer may realize a practical THz source, with a robust and potentially high-power operation (~mW) at high temperature and harsh environments, being of particular interest to space, military and security applications. In this talk, we will present both the theoretical results and the preliminary experimental data of this nanoantenna device, which may pave the way towards the cost-effective, high power-output, and robust THz sources for various aerospace and environment-hard applications.