PL-2.4

Terahertz Spectroscopy as an Effective Tool of Experimental Nanophysics

Boris Gorshunov
Moscow Institute of Physics and Technology (National research university), Dolgoprudny, Russia

Since the development of coherent source (backward-wave oscillators based) [1-3] and, later, pulsed time-domain [4] terahertz spectroscopy techniques, the so-called “terahertz gap” or “spectroscopic gap” (0.1 – 10 THz) of the electromagnetic spectrum has been completely mastered. This paved the way for solving many fundamental and applied problems, the solution of which experienced enormous difficulties due to the lack of reliable experimental data on the electromagnetic properties of objects in the given frequency band. Nowadays, the powerful arsenal of terahertz spectroscopy available to researchers and developers is actively used in various fields of natural, material and applied sciences (see, e.g., [5] and references therein), and corresponding techniques and approaches are described in detail in many reviews and books (e.g., [6,7] and references therein). The laboratory of terahertz spectroscopy at the Moscow institute of physics and technology is equipped with a unique set of spectroscopic equipment that allows to conduct fundamental and applied research in various fields of condensed matter physics. The experiments can be carried out starting from sub-Hertz frequencies up to ultraviolet, and at liquid helium up to room temperatures. Such a wide frequency interval allows for most in-depth studies of a wide variety of phenomena. At the same time, it is terahertz frequencies (quantum energies from fractions of meV to several meV) that are often key for understanding the microscopic nature of exotic properties that materials acquire when their size is reduced to nanoscale and which they do not possess in their “regular” macroscopic state. This happens when the “samples” dimensions become comparable to the spatial parameters that characterize their physical properties, such as correlation lengths of collective interactions, mean free paths of charge carriers, etc. Understanding the nature of emerging phases is of great fundamental and technological interest but is presently still at its infancy. The talk provides a review of latest and recent results obtained by our group using terahertz spectroscopy on a number of nano-structured materials and systems that are most popular and most widely studied in recent years: carbon nanotubes, graphene, endofullerenes, nano-confined water molecules and ultra-porous aerogalnite aero-GaN. Physical properties of the materials are discussed from both, fundamental and technological viewpoints.

References

1. A.A.Volkov, Yu.G.Goncharov, G.V.Kozlov, S.P.Lebedev, A.M.Prokhorov. Dielectric measurements in the submillimeter wavelength region. Infrared Phys., **25** 369 (1985).
2. A.A.Volkov, G.V.Kozlov, A.M.Prokhorov. Progress in submillimeter spectroscopy of solid state. Infrared Phys. **29** 747 (1989).
3. G.Kozlov, A.Volkov. Coherent source submillimeter wave spectroscopy. Topics in Applied Physics vol.74. Millimeter and submillimeter spectroscopy of solids. Ed. G.Gruner. Springer, 1998.
4. S.E.Ralph and D.Grischkowsky, THz spectroscopy and source characterization by optoelectronic interferometry, Appl. Phys. Lett. **60** 1070 (1992).
5. J. Neu and Ch. A. Schmuttenmaer. Tutorial: An introduction to terahertz time domain spectroscopy (THz-TDS). Journal of Applied Physics **124** 231101 (2018).
6. B.Gorshunov, A.Volkov, I.Spektor, A.Prokhorov, A.Mukhin, M.Dressel, S.Uchida, A.Loidl. Terahertz BWO-spectroscopy. Int. J. of Infrared and Millimeter Waves, **26** 1217 (2005); B.P.Gorshunov, A.A.Volkov, A.S.Prokhorov, I.E.Spektor. Methods of Terahertz–Subterahertz BWO Spectroscopy of Conducting Materials. Physics of the Solid State, **50** 2001 (2008).
7. P.H.Siegel. Terahertz technology. IEEE Trans. Microwave Theory Tech. **50** 910 (2002).