Measurement of the spectral brightness under nonlinear-optical terahertz wave detection

G. Kh. Kitaeva, P. V. Yakunin, V. V. Kornienko, A. N. Penin
Faculty of Physics
Lomonosov Moscow State University
Moscow, Russia
gkitaeva@physics.msu.ru

Abstract—A new method of self-calibrated measurement of the terahertz wave spectral brightness in the course of nonlinear-optical detection is discussed and an experimental proof for its theoretical background is demonstrated.

Keywords—terahertz wave detection; brightness; nonlinear-optical crystal; spontaneous parametric down-conversion

Based on parametric conversion of terahertz frequencies into the visible or near-infrared ranges, the non-linear optical methods of the terahertz wave (THz) detection are well-known mostly due to the electro-optical sampling technique, which is frequently used in the THz time-domain spectroscopy systems. This commonly used detection method provides a remarkable possibility to measure the spectral distribution of short THz pulses, generated under femtosecond laser pumping, without any spectral-selection device. Taking advantage of another approach, the quasi-CW nonlinear-optical terahertz detectors have been proposed, based on up-conversion of terahertz frequency to the optical range in nonlinear optical crystals pumped by laser pulses of nanosecond duration [1,2]. This method is suitable for an incoherent detection of THz wave intensity distributions and is free of any restrictions imposed by the mode of the THz wave generation.

At the same time, the problems of absolute measurements of terahertz radiation parameters, such as field amplitude, radiation power, spectral brightness, remain as not solved properly. This trouble is character not only for the non-linear optical group of methods, but still for other detection methods in the THz range. Recently, while studying the non-linear schemes for detection of continuous-wave and nanosecond-pulsed THz radiation (Fig.1), we have shown, that the sensitivity of such schemes can be calibrated using the modified Klyshko method for absolute measurement of spectral brightness [3]. The general idea of Klyshko method was to use the effective spectral brightness of zero vacuum fluctuations under spontaneous parametric down-conversion (SPDC) of laser radiation as an optical brightness standard. Comparison between the radiation spectral brightness (radiance) with this standard is made when the radiation under measurement is involved into the down-conversion process at an idler frequency and produces the frequency-shifted signal at the same frequency as SPDC. We show that the radiance calibration procedure has to be modified when the idler frequency is shifted to the terahertz frequency range. The specificity of the terahertz range requires to take into account not only quantum fluctuations of the parametric frequency converter, but also the classical thermal fluctuations, which have a comparable spectral brightness in the THz range [4-6]. A method for measurement of the incident terahertz wave brightness and a procedure for absolute calibration of the thermal-fluctuations brightness are proposed, based on the same detection scheme and non-linear optic signals generated in the Stokes and anti-Stokes optical ranges.