THZ IMAGING SYSTEM BASED ON CW CLINOTRONS

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Terahertz (THz) radiation possesses several unique features, including the ability to penetrate a wide range of materials while being strongly absorbed by water molecules, as well as a non-ionizing effect on inspected objects due to the very low photon energy compared to X-rays. These properties make THz sources highly promising for applications in physics, biology, medicine, plasma diagnostics, radar and remote sensing, high-data-rate communications, security systems etc. THz radiation provides novel information about substances that cannot be obtained using conventional microwave or X-ray techniques. In particular, rotational transitions of many biological molecules lie in the frequency range of 0.1–1 THz, making THz radiation attractive for medical and biological applications, where X-ray, ultrasound, optical, and magnetic resonance methods are currently employed. Owing to wavelengths shorter than 1 mm, THz imaging offers high spatial resolution and has demonstrated potential for differentiating non-melanoma skin cancers from normal tissue [1]. The THz spectral region lies between the microwave and infrared bands, where the output power of available radiation sources drops significantly, a phenomenon commonly referred to as the “THz gap.” The most powerful THz sources are gyrotrons, which can generate megawatt-level output power at frequencies up to 200 GHz, while gyrotrons operating at the second cyclotron harmonic achieve output powers of several tens of watts at frequencies around 0.8 THz [2]. However, gyrotrons require bulky and expensive superconducting magnets and offer a limited frequency tuning range. Compact THz sources can be developed based on solid-state and vacuum electron device (VED) technologies. While modern solid-state devices provide insufficient output power for many practical applications, VEDs such as backward-wave oscillators (BWOs), clinotrons, orotrons, diffraction radiation oscillators (DROs), and extended-interaction oscillators (EIOs) are widely used in the millimeter-wave range. Although EIOs can deliver watt-level output power in the sub-THz range, their frequency tuning bandwidth is typically very narrow [3]. The clinotron is a powerful modification of the BWO, originally developed at the O. Ya. Usikov Institute for Radio Physics and Electronics of the National Academy of Sciences of Ukraine (Kharkiv, Ukraine) [4]. Compact clinotrons combine wide frequency tunability with output powers of up to 1.5 W at 200 GHz and up to 100 mW at 0.4 THz [5]. Experimental investigations of the output characteristics were performed using Schottky barrier diodes and interferometers, while precise spectral measurements were carried out using high-frequency harmonic mixers and a spectrum-analyzer-equipped oscilloscope. The developed high-voltage power supply units enable stepped-frequency operation based on a PID control algorithm, which is particularly suitable for three-dimensional THz imaging applications.

Keywords: THz radiation, clinotron, frequency tuning, THz imaging

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