Generation of Coherent cw-Terahertz Radiation Using a Tunable Dual-Wavelength External Cavity Laser Diode

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A tunable dual-wavelength external cavity laser diode (2-λ-ECL) was used to generate tunable coherent cw-terahertz (THz) radiation by photomixing. We demonstrated that the frequency of the emitted THz radiation corresponded to the difference frequency between the two modes of the diode laser. The tunable 2-λ-ECL, due to its compact design and ease of optical alignment, is a promising laser source for the generation of tunable cw-THz radiation by photomixing.

KEYWORDS: tunable dual-wavelength external cavity laser diode, tunable cw-THz radiation, LTG-GaAs, photomixing
and 10 dB for the minimum and maximum separation, respectively.

The output of the 2-λ-ECL was focused on the biased electrode gap of a 1-mm-long dipole photoconductive antenna with a set of collimating and focusing optics. The photoconductive antenna (AuGe/Ni/Au) was fabricated on the LTG-GaAs layer. The LTG-GaAs has a short (sub-ps) photocarrier lifetime, a high photocarrier mobility (200 cm²V⁻¹s⁻¹), and a high DC breakdown field that is larger than 5×10⁵ V/cm. These properties of the LTG-GaAs are desirable to use as a substrate of a photomixer to emit THz radiation. A hemispherical silicon lens with a diameter of 3 mm is attached to the backside of the GaAs substrate of the antenna device in order to reduce the reflection loss at the air-substrate interface and to increase the radiation collection efficiency. The cw-THz radiation emitted from the dipole antenna is linearly polarized in the dipole direction. The THz radiation was first collimated with a parabolic mirror, then passed through a Martin-Puplett polarizing interferometer and was finally focused onto a 4.2 K InSb hot-electron bolometer with another parabolic mirror to detect the THz radiation power and spectrum, as shown in Fig. 1.

Figure 3 shows an output power of the cw-THz radiation as a function of the difference wavelength between the two modes. An optical spectrum analyzer was used to monitor the difference wavelength (corresponding to the frequency of the detected THz radiation) of the two modes. A trend of decreasing THz radiation power with increasing radiation frequency is evident in Fig. 3. This can be explained as follows. It is well known that the photoconductive antenna has a tendency to suppress the power emission at high frequencies because of the photocarrier lifetime of the LTG-GaAs and photomixer antenna RC time constant, where R is the radiation impedance and C is the electrode capacitance. We used a 1-mm-long antenna with a resonance frequency of 120 GHz, at which the antenna emitted the highest radiation power. The radiation power of the antenna falls in frequency regions lower and higher than 120 GHz. Furthermore, the sensitivity of the InSb bolometer is roughly inversely proportional to the detection frequency. The sensitivity of the bolometer used in our experiment is two times higher at 250 GHz than that at 1 THz, and the cutoff frequency is almost 2 THz. Therefore, we cannot measure radiation power above 1.75 THz with a good signal-to-noise ratio using the InSb bolometer. For these reasons, we observed THz radiation power which decreased with increasing radiation frequency as can be seen in Fig. 3. The radiation power from the antenna was estimated to be about 2 nW at 250 GHz.

To further investigate the properties of cw-THz radiation from the antenna, we fixed the difference wavelength of the tunable two-mode diode laser operating at 0.58 nm (250 GHz), and measured the radiation frequency using a Martin-Puplett polarizing interferometer. The polarization of the THz radiation through the silicon hemispherical substrate lens is oriented to pass through the wire-grid polarizer at the input port of the Martin-Puplett polarizing interferometer. The interference signal at the output port was measured with an InSb hot-electron bolometer cooled to 4.2 K. The laser beam is chopped at 200 Hz and the modulated signal voltage from the bolometer is detected with a lock-in amplifier. Figure 4(a) shows the interference signal of the radiation. Figure 4(b) shows the Fast Fourier Transform (FFT) of the interferogram (a). The radiation frequency was 250 GHz, corresponding to the wavelength difference of 0.58 nm. The emission of radiation with the same frequency as the beat frequency of the tunable 2-λ-ECL indicates that the radiation originates from the photocurrent modulated by the tunable 2-λ-ECL. The spectral resolution of the interferometer, which is limited by the maximum path difference of the scanning mirror (5 cm), is approximately 6 GHz. Therefore, we could measure the linewidth of the radiation directly. However, in the previous work we showed that the linewidth of the beat frequency of the two modes in the same laser cavity was narrower than that of individual laser modes. This is because a large part of the frequency fluctuations of the two laser modes was canceled out due to the two-mode oscillation in the same cavity. It was established that the linewidth of the cw-THz radiation generated by the photomixing method was almost the same as the beat linewidth of the two excitation lasers. We suggest that the tunable two-mode operation diode laser using as the excitation source can generate a stable and compact tunable cw-THz radiation. We are currently studying the stabilizer of the tunable two-mode operation diode laser in order to gener-
ate more stable cw-THz radiation. Improvement in the spectral purity of the THz radiation is expected by achieving the frequency stabilization of the laser.\textsuperscript{16} The laser output can be increased by techniques such as injection locking.

In summary, tunable coherent cw-THz radiation is generated by exciting the photoconductive antenna fabricated on an LTG-GaAs layer using a tunable dual-wavelength external cavity laser diode (2-\textlambda-ECL). The system is simpler and more compact than that using two independent lasers. Our results indicate that the tunable 2-\textlambda-ECL is a promising laser source for photomixing, which will enable us to build a stable and compact tunable coherent cw-THz radiation source.

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