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Photo-mixing of chirped ultra-short optical pulses at 1 μm for the generation of broadband long THz pulses

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Located between microwaves and infrared, the terahertz (THz) frequencies find various applications in recent technologies, notably in non-destructive imaging and telecommunications [1]. The method commonly used for their generation and detection is based on the conversion of infrared ultra-short pulses into THz waves by exciting photoconductive (PC) antennas. While being an efficient process offering a high dynamic range, the ultra-short optical pulse duration and high peak power bring some limitations, particularly for integrating devices toward a high-power level of optical excitation. Here, we present a novel method for photo-mixing generation in PCs using long chirped pulses to reduce peak power, thereby producing broadband, long-duration THz radiation. This approach offers new opportunities for temporal spectroscopy and the development of integrated devices.

The photo-mixing process principle consists of producing a beat note at the THz frequencies by overlapping two optical chirped pulses with a relative delay. This beat note exciting the PC antenna results in the emission of THz radiation at the beating frequency. By tailoring the optical excitation with an appropriate chirp rate, it becomes possible to control the shape and the frequency-to-time distribution of the generated THz wave, allowing for the production of both narrowband and broadband long THz pulses [2]. Indeed, this method is commonly used with two identical delayed chirped pulses, which typically create a narrowband radiation. However, the bandwidth is significantly enhanced when the two chirps are different. In our approach, we used two pulses with opposite chirp. A volume Bragg grating is seeded on both sides to linearly chirp two optical pulses at 1030nm from 70 fs to 93 ps with a rate of ± 6.2 ps/nm. The superimposition of the two pulses provides a temporally evolving beat note, which is subsequently converted in THz radiation when applied in the PC antenna. We achieved the emission of a 12 ps THz pulse with a 1 THz bandwidth and a 90 GHz/ps distribution (Figure 1 a. b. and c.). The evolution of the peak to peak electric field in function of optical power is shown in figure 1 d. for narrowband and broadband emission. Notably, the saturation of broadband emission occurs at a lower optical power (2.7 mW) than that of narrowband emission (8.6 mW). The achievable THz electric field is thus reduced by a factor of 4 between the two cases.

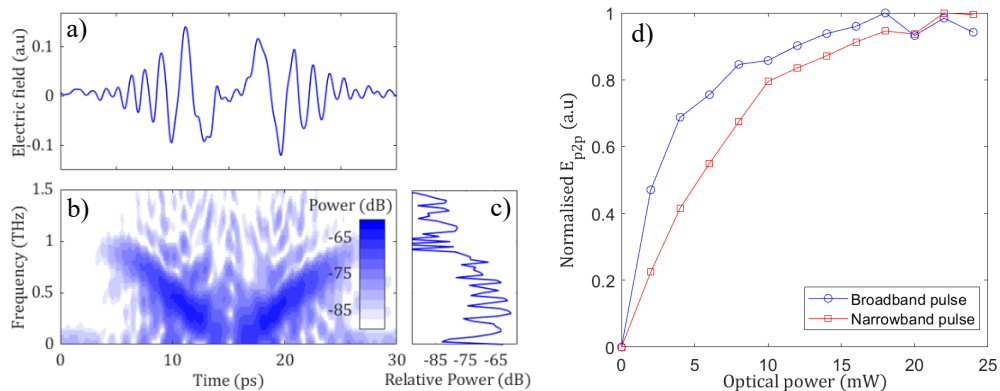


Fig. 1 (a.) Electric field emitted by a long pulse with opposite chirps with its corresponding (c.) spectrum and (b.) spectrogram in the logarithmic scale. The optical power and voltage are at 15mW and 25V. (d.) Normalised Electric field peak to peak of narrowband (red) and broadband (blue) THz emission in function of optical power.

This new approach on THz generation, by employing stretched optical pulses, allows higher optical power excitation in an integrated power demultiplier and will lead to stronger THz emission processes when attached to an array of antennas [3]. In addition, the frequency-to-time distribution of the THz pulse could be applied for time-domain detection in spectroscopy techniques, similar to the linearly frequency-modulated continuous wave (FMCW) detection [4].

References

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35-word abstract :

We demonstrate the generation of 1 THz broadband long THz pulses using a novel technique based on photo-mixing of chirped optical pulses, extending emission possibilities of photo-conductive antennas as well as their integration in devices.