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SUMMARY OF CHANGES

Dear Editor and Referees:

Thanks for your time and efforts for considering our manuscript. We appreciate the referee's helpful and instructive comments/questions to improve our manuscript. Based on these comments and suggestions, we have addressed their concerns point by point and made a careful revision to our manuscript. The main changes are summarized as follows:

(1) The title has been changed to "Broadband terahertz detection by laser plasma with balanced optical bias".

(2) The statements in the abstract and the conclusion have been modified to "Compared to the conventional optical bias detection scheme".

(3) Fig. 4 has been replotted and we reorganized the caption to increase the clarity.

(4) We add a new reference (Opt. Lett. 34, 1213-1215, 2009) in the revision to supply the necessary information on how the SNR is calculated.

(5) The English overall has been checked and some errors were corrected. Some sentences were reformulated for clarity.

All comments are addressed in detail below.

Yours sincerely,

Xu Sun, Zhi-Hui Lyu, Hai-Zhong Wu, Cong-Sen Meng, Dong-Wen Zhang, Zhi-Zhong Lu, Xiao-Wei Wang, Zeng-Xiu Zhao, and Jian-Min Yuan

Response to Review 2

This article presents a novel approach to perform coherent balanced terahertz detection using the interaction of an emitted terahertz field with an optical LO through the third order non-linearity of a gaseous plasma excited by pump. The article also analyzes the dependencies of the detection technique on the temporal delay between emitted terahertz field and the optical LO. The results are very interesting, and they are also well presented. The degree of technical sophistication is quite high. I recommend acceptance after the following minor corrections.

Q1. In line 7, the word 'spectroscoy' should be replaced by 'spectroscopy'.

A1. Thank you to point to the mistype.

Q2. In the sentence written within lines 21-22 some articles are missing. I think the sentence should read: "It converts the THz wave to the second harmonic of the laser pulse employing the third-order non-linearity".

A2. Thank you to correct the grammar mistakes.

Q3. The beginning of the sentence within lines 24-25 doesn't make much sense. I recommend that the authors change it to something like: "Early implementations of the LO were obtained by means of…".

A3. Thank you to improve the readability of our manuscript.

Q4. In line 26, I recommend that the authors specify that the threshold requirement is about an optical threshold, i.e. that the a very high amount of laser power is required for that technique to work.

A4. We reorganize the sentence as "As the supercontinuum in air plasma requires a very high amount of laser power and cannot be independently controlled both in terms of polarization, phase and bias intensity, an alternating-polarity bias …"

Q5. In line 58, I recommend substituting the word 'repress' by 'reduce'.

A5. Thanks for your correction.

Q6. In lines 82-83, spaces are missing between numerical values and units. Also, 10 um should be replaced by 10 μm.

A6. Thank you to point out the mistypes.

Q7. In line 89, I think the authors meant ‘dichroic mirror’ and not ‘bichromatic mirror’.

A7. Thanks for your correction.

Q8. In line 91, the article ‘the’ before ‘optical biased LO intensity’ is missing.

A8. Thanks for your careful correction.

Q9. In line 111, the word ‘widthes’ should be replaced by the word ‘widths’.

A9. Thank you to correct the mistake.

Q10. In line 155, the verb ‘varies’ should be replaced by the noun ‘variations’.

A10. We corrected it as “Due to the variation of the phase of TISH with the probe delay, …”.

Q11. I also recommend that the authors explain in more detail a few technical points to improve even more the quality of the article: How was the difference signal between the two PMTs obtained? What electronic device did they use? A 180° hybrid coupler? What bandwidth it had?

A11. We used two home-made I-V converters to transform the current outputs of the PMTs to voltage signals. The differential voltage output of the lock-in amplifier SR830 was recorded by the Matlab program. The bandwidth of the I-V converters was designed to be several kHz since the repetition frequency of the femtosecond laser pulses was 1 kHz.

Q12. The authors should explain in more detail how the time-synchronization between the two cross-polarization pulses is achieved utilizing the difference of group velocities in the fast and slow axis directions of the BBO crystal. Did they change of the angle incidence? Did they rotate the crystal? What would happen if this synchronization is not done?

A12. Following your suggestion, we add a sentence to explain the temporal overlap between fundamental and second-harmonic pulses. It reads “The birefringence in alpha-BBO is exploited to temporally delay the 2ω bias envelope relative to TISH in the experiment.” We change the incident angle of the dichroic mirror to control the intensity of the fundamental pulses as shown in Fig. 1. The phase delay between TISH and residual fundamental probe beams can be finely controlled with dispersion by rotating the fused silica wafer as well as the dichroic mirror. The temporal overlap

between TISH and biased 2ω is achieved by the birefringence in alpha-BBO and can be adjusted by inserting a pair of wedges (not shown in Fig. 1). The interference between TISH and biased 2ω would be weak if their envelopes are not well synchronized.

Q13. The authors should explain why they used the jitter of the signal as the noise floor for the SNR calculation. Normally, the noise floor is the signal level at which the signal cannot be distinguished anymore. Why didn't they use this usual definition for the noise?

A13. We followed Mira Naftaly's article (Methodologies for determining the dynamic ranges and signal-to-noise ratios of terahertz time-domain spectrometers, Opt. Lett. 34, 1213-1215, 2009) to calculate SNR in Fig. 2(b). Due to the limited number of our experimental measurements, we use half of the signal jitter to replace the standard deviation of the signal for simplicity. We add this reference in the revision to supply the necessary information.

Q14. The authors should specify the integration time they used to obtain the plots in Figure 2.

A14. We add the sentence in the revised manuscript as "The integration time of the lock-in amplifier is set to be 100 ms in the experiment."

Q15. The time-domain signals plot in Fig. 4(b) do not seem to match. The time-domain signal with higher temporal resolution has a lot of noise after -0.1 ps while the time-domain signal exhibiting a longer delay does not seem to exhibit the same noise. Also, the slopes seem to be different.

A15. Thank you to help us to clarify the presentation of Fig. 4. We replotted Fig. 4 and reorganized the caption to increase the clarity. The orange THz waveform in Fig. 4(b) shares the same ticks of the y-axis in Fig. 4(a), which is the zoom in on blue THz waveform in the yellow time slot.

Q16. The authors should specify how they chose the spectrum that they used as reference to obtain the scaling factor in Fig. 5(b).

A16. We specified the way to obtain the scaling factor in the revised manuscript. Under a certain phase between TISH and controlled optical bias, the THz waveform as well as spectrum was measured and chosen as the reference. We measured THz spectra by scanning the controllable phase and normalized to the reference spectrum to obtain

the frequency-dependent scaling factor, which can be regarded as the maximal drift of the baseline in the broadband THz time-domain spectrometer.

Q17. The authors should be aware that although their system does not require an electrical bias to operate, it is not compact compared to other existing systems such as the ones implemented using photoconductive antennas. In particular, their system requires a lot of free-space optical components that are not required by photoconductive systems. Therefore, I suggest that the authors modify their statements about this in the Abstract and in the Conclusion.

A17. Following your suggestion, we modified the title and the statements in the abstract and in the conclusion.