Dependence of the generation efficiency of air-plasma based ultrabroadband coherent infrared pulses on the thickness of optical components

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1. Introduction

In the last JAPS-OSA Joint symposia, we reported the enhancement of the generation efficiency of ultrabroadband coherent infrared pulses from air plasma driven by hollow fiber compressed two-color 10 fs pulses, by controlling the polarization of two-color pulses using a dual waveplate [1]. However, the mechanism of the enhancement has not been fully understood; the simple analysis taking only the group delay dispersion of the βBBO crystal and the dual wave plate indicates two-color pulses do not overlap at all at the focal point where plasma is formed. In the present paper, we report the result of a systematic study on the dependence of the generation efficiency on the thickness of optical components and nonlinear crystals employed for the air plasma based infrared pulse generation.

2. Experiments

The details of the experimental setup are described in elsewhere [2]. In the present experiments, we tested two half wave plates placed before generating second harmonic pulses (thickness; 43 μm and 1 mm), three βBBO crystals for second harmonic generation (thickness; 100, 300, and 500 μm), four αBBO crystals for time adjustment (thickness; 100, 200, 300, and 500 μm) including the case without using αBBO. Bounce times of chirped mirrors were tuned so that pump pulses were the shortest at the position of plasma generation when using the 1-mm thick half wave plate, so that pump pulses were negatively chirped when using the thinner half wave plate. We systematically altered the thickness of each component, and measured the spectrum of the ultrabroadband coherent infrared pulses using a monochromator attached with a liquid nitrogen cooled HgCdTe detector.

3. Results and conclusion

Figure 1(a) shows a typical spectrum of ultrabroadband infrared pulses with a flat structure. In Fig. 1 (b) we plot the intensity at 150 THz (2 μm) as a function of the thickness of αBBO crystals for each thickness of βBBO crystals. The spectral shape was not altered by changing the thickness of optical components and nonlinear crystals. Hence the dependence is qualitatively equal at every frequency position. In the cases of βBBO with thicknesses of 100 and 300 μm, the intensity was the largest when we did not inserted αBBO, namely zero thickness, and the intensity steeply decreased by inserting αBBO. With increasing thickness of αBBO, the intensity kept on gradually decreasing when using 100-μm thick βBBO. However, the intensity increased to the maximum at 300 μm and decreased again in the case of 300-μm thick βBBO. Contrary to the cases, the intensity reached a gentle maximum at 300-μm when using 500-μm thick βBBO, where the signal was more intense than the case without αBBO. We obtained similar results also in the case of negatively chirped pump pulses. Summarizing these results, we found the signal intensity becomes the maximum when βBBO is thicker than αBBO by 100−200 μm although it is a local maximum in the case of 300-μm thick βBBO. Also we found the most intense signal is given by the case of 100−μm thick βBBO without αBBO, where propagation time difference of two-color pulses after βBBO and the dual waveplate is approximately 30 fs.

To elucidating the mechanism, first, the negative group delay dispersion in plasma is requisite for the overlapping of two-color pulses [3]. Second, the minor dependence on the thickness of αBBO crystals is consistent with the minor pump chirp dependence of the signal intensity which we found previously.

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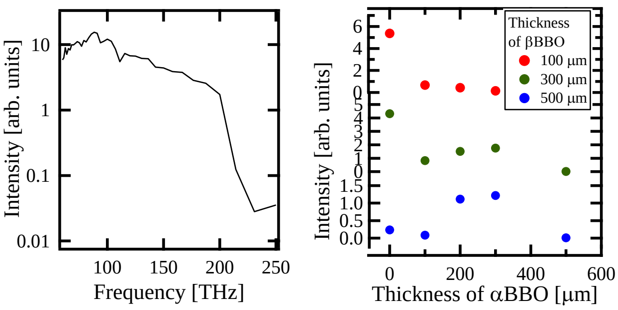

Fig. 1 (a) Typical spectrum of the ultrabroadband coherent infrared pulses. (b) Dependence of the intensity at 150 THz on the thicknesses of αBBO and βBBO crystals.

References

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