Kerr-lens mode-locked bidirectional dual-comb ring laser for broadband dual-comb spectroscopy: supplementary material

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Estimation of the difference in pulse repetition rate induced by the self-steepening effect

The degree of the timing shift induced by the self-steepening effect in Kerr-lens mode-locked Ti:Sapphire lasers has been characterized by a computer simulation in Ref. 1. In this reference, the authors present a model based on dispersion-managed mode-locking and the nonlinear Schrödinger equation with an additional term of the self-steepening effect and show their calculation of the timing shift due to the effect. Their laser cavity is a bow-tie ring-cavity with four mirrors, which is very similar to our laser except for the repetition rate (The repetition rate of their laser is 500 MHz while that of ours is 932 MHz). Fig. 4 in the reference shows the nonlinear timing shift (fs) as a function of the pulse energy (nJ) and its gradient 0.1 fs/nJ. Here we use this value for the following estimation.

Here we estimate the difference in pulse repetition rate in our system based on our experimental results. Since the pulse energies at the crystal in our laser cavity are estimated to be about 36 and 33 nJ (derived from the two output powers of 340 mW and 310 mW, the output coupler's coupling efficiency of 99%, and the repetition frequency of 932 MHz), the pulse energy difference is found to be 3 nJ. This leads to a timing difference of 0.3 fs, which corresponds to the difference in repetition rate of 260 Hz for the repetition rate of 932 MHz. This estimated value agrees well with our experimental observation. Therefore, we believe that the self-steepening effect accounts for this effect.

References

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