Generation of Extremely Short Pulses from Self-Hybrid Mode-Locking of Semiconductor Lasers

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Short-pulse generation from mode-locked semiconductor lasers is attractive for its wide applications in optical processing [1], medical and biological imaging [2], optical communication [3] and so on. Mode-locked semiconductor lasers are particularly attractive due to their compactness and low cost. Passive mode-locking methods usually generate shorter pulses than active mode-locking ones, but with worse timing jitter [4]. Hybrid mode-locking, combining active mode-locking and passive mode-locking, thus has both advantages of generating very short pulses and low timing jitter. However, it usually requires an additional section of saturable absorber. Therefore, hybrid mode-locking is relatively difficult and complex compared to other methods. In this work, we report that pulses as short as 1-2 ps can be generated with novel self-hybrid mode-locking technique. With suitable bias and RF modulation depth, this scheme has the action of saturable absorption self-provided by the gain region of a conventional semiconductor laser amplifier (SLA). Therefore, multiple sections are no longer needed and the hybrid mode-locking can be achieved.

The novelty of self-hybrid mode-locking is that the RF modulation frequency is the half or sub-harmonic of the pulse repetition frequency corresponding to the external cavity. Therefore, the pulses pass through the gain medium alternatively at the gain peak and the gain valley of the modulation. The gain peak provides the mechanism of active mode-locking, while the gain valley provides the effect of saturable absorption. Compared to other sub-harmonic mode-locking techniques [5], [6], the RF modulation here is very deep so that, at the modulation valley, the semiconductor gain is nearly reverse-biased and functions like a saturable absorber.

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Fig. 1 shows the simple cavity configuration for self-hybrid mode-locking in the experiment. The arms at the two sides of the gain medium do not have to be equal, giving the flexibility of adding optical components for intra-cavity dispersion compensation. The modulation frequency for self-hybrid mode-locking is not high, in the order of sub-GHz range. The mode-locked pulses can be less than 2 ps.

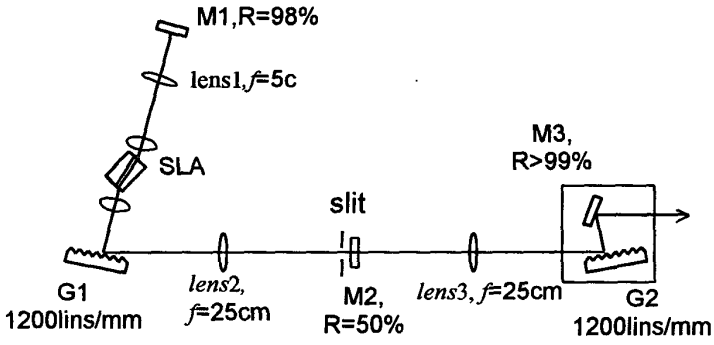

Fig. 1 Schematic of cavity configuration for self-hybrid mode-locking

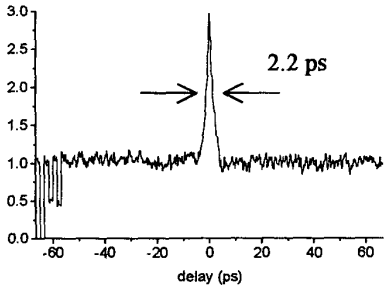

Fig. 2 auto-correlation trace

Fig. 2 shows the auto-correlation trace of the mode-locked pulses. The saturable-absorption effect at the modulation valley gives additional pulse-shortening mechanism in the self-hybrid mode-locking, so extremely short pulses can be generated. For active mode-locking with modulation at this frequency of 394.3 MHz, such short pulses cannot be generated. Fig.2 also shows that no secondary pulses are generated from this technique. The corresponding spectral width is 10 Å and the time-bandwidth product is 0.68. The details of the self-hybrid mode-locking conditions will be discussed.

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