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Compact Pulse Repetition Rate Multiplication Scheme
Using Micro Ring Resonator

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High repetition rate stable short pulse sources play an important role in high speed optical communication systems. Besides developing a short pulse laser with very high fundamental repetition rate, the high repetition rate pulse train can also be obtained using various optical multiplication techniques, based on a Fabry-Pérot filter [1] or a fiber Bragg grating [2], for example. A more stable system may be achievable using an integrated component for multiplication. In this paper, a silicon-on-insulator (SOI) micro ring resonator with free spectral range (FSR) of 40.9 GHz at 1550 nm is used as a filter to obtain a 40 GHz pulse train. This device is compact and offers stable filtering characteristics.

The experimental setup of the pulse rate multiplier is shown in Fig. 1 (a). A tunable mode-locked laser (TMLL) is used to generate a pulse train at desired central wavelength and repetition rate. In this experiment, the central wavelength is at 1550 nm and the repetition rate is adjusted to be one quarter of the FSR of the micro ring resonator. The extinction ratio of the ring resonator is 27 dB and the 3 dB bandwidth is 0.014 nm which corresponds to a quality factor of ~110000. The micro ring resonator is sensitive to polarization and has 24 dB insertion loss, at the resonances. The loss includes fiber to waveguide coupling loss and resonator loss. The polarization controller and EDFA are used to ensure quasi-transverse magnetic (TM) mode and sufficient signal power into the resonator.
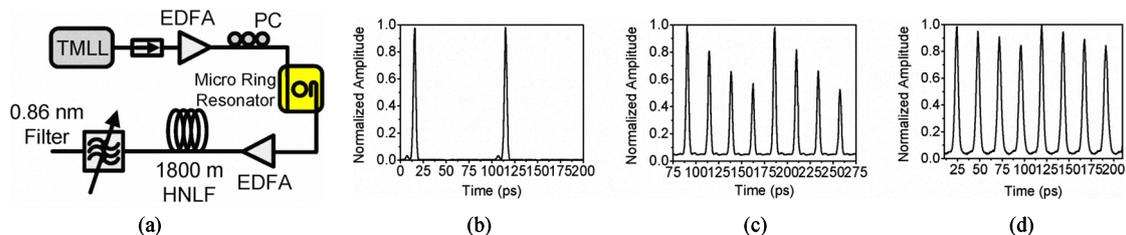

Fig. 1 (a) 40 GHz pulse multiplication setup (b) Original 10 GHz pulse train (c) 40 GHz pulse train before equalizer (d) Final 40 GHz pulse train after equalizer

The 10.29 GHz pulse train at 1550 nm from the TMLL (Fig. 1 (b)) with pulse width 2.98 ps is successfully multiplied to 41 GHz pulse train (Fig. 1 (c)) after the micro ring resonator. The pulse width is broadened to 3.12 ps, an increase smaller than 5%. However, the multiplied pulse train suffers from a variation of pulse power which can be seen from the temporal trace (Fig. 1 (c)). The amplitude modulation depth is about 3 dB. This is caused by the coupling loss between ring and waveguides and the roundtrip propagation loss in the ring. Therefore the amplitude modulation depth can be decreased by reducing the coupling ratio and improving in fabrication process. To obtain a homogeneous pulse train, an equalizer relying on spectral broadening and optical filtering [3] is added after the repetition rate multiplier (Fig.1 (a)). The multiplied pulse train is sent through 1800m highly non-linear fiber and a 0.86 nm FWHM narrow band pass filter. When the input average power into the equalizer is high enough (30 dBm), the variation in pulse power can be decreased. The amplitude modulation depth is reduced from 3 dB to 0.7 dB by use of the equalizer as shown in Fig. 1 (d). The pulse width is broadened to 4.21 ps due to the narrower spectrum induced by the band pass filter. By tuning the input signal repetition rate, it is also experimentally demonstrated that the micro ring resonator can tolerate about 50 MHz mismatch between one quarter of its FSR and the input signal repetition rate. This means that the scheme is tolerant towards changes in input frequency despite the fixed FSR offered by the ring resonator. Clean pulse trains can still be obtained, however the pulse width is broadened due to the mismatch filtering resulting in a narrower optical spectrum. In the tolerant range of the micro ring resonator, the equalizer works equally effectively. The optimum amplitude modulation depth is 0.7 dB at different input repetition rates in the range of 10.19 GHz - 10.29 GHz, around one quarter of the FSR of the micro ring resonator (10.23 GHz).

In conclusion, the scheme based on silicon-on-insulator micro ring resonator is compact and frequency tolerant and stable for pulse repetition rate multiplication.

References

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