Optical Clock Repetition Rate Multiplier

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Abstract

We present a novel technique for the repetition frequency multiplication of a short pulse clock laser. We demonstrate up to 6 times rate multiplication and up to 34.68 GHz clock repetition frequency.

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Summary

The rapidly maturing technologies of high performance, active and passive opto-electronic devices has helped to spurn an intense interest in several research groups for the development of ultra-high speed, all-optical logic circuits [1]. One essential subsystem for ultra high speed, optical logic circuits is a high repetition frequency optical clock source. A number of short pulse, high repetition rate laser sources have been demonstrated for this purpose [2,3], but they almost always have to rely on high frequency microwave sources to provide the drive signal or narrow frequency linewidth and stabilised DFB laser sources and sophisticated compression techniques. In the present communication, we report a short pulse, high repetition rate laser source that is capable of producing 15 ps pulse trains, at a repetition frequency of up to 34.68 GHz. The principle of its operation relies on a master-slave oscillator arrangement. In this instance the master oscillator is provided by a 5.78 GHz gain switched DFB, to which a fiber ring laser is synchronised. This arrangement of obtaining the high repetition rate optical clock signal presents two significant advantages. (a) The high repetition frequency optical clock requires a low frequence and therefore less expensive rf signal generator. (b) The low repetition frequency rf and optical signal may be used as the universal reference signal of all the high repetition frequency optical clocks in the optical logic circuit. In this way data may be introduced into the logic circuit at a low rate, so that it is compatible with commercially available modulators.

The basis of the concept on which repetition rate multiplication is achieved in our laser source relies on two key observations. The first is that the fast saturation of a semiconductor optical amplifier (SOA) by an externally introduced picosecond optical pulse, may be used for gain modulation in a fiber ring laser and the generation of stable picosecond pulse trains from such a system [4]. The second observation is that by using this technique to mode-lock a fiber ring laser, it is possible to tune the frequency f_{ext}, of the externally introduced pulse train to $f_{ext}=(N+1/n)\delta f_{ring}$, and to obtain an output pulse train at a frequency nf_{ext}. In this equation N and δf_{ring} is the order of harmonic mode-locking and fundamental frequency of the ring laser and

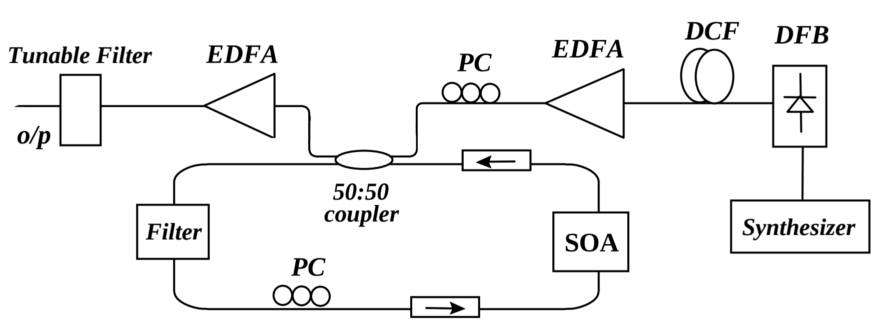

Figure 1. Experimental setup

n is an integer number. This method for repetition rate multiplication is only possible, if the gain modulation in the laser cavity is provided by a saturable amplifier so as not to present loss at any time.

Figure 1 shows the experimental layout. All the components used in the cavity are pigtailed with standard single mode fiber. Gain was provided from a 500 μm InGaAsP/InP ridge waveguide SOA. The waveguide facets were angled at 10^{o} and were antireflection coated. The SOA had a peak gain at 1535 nm and could provide 23 dB small signal gain at 250 mA dc drive current. Faraday isolators were used at the input and output of the SOA to ensure unidirectional oscillation in the ring cavity. After the SOA, a 3 dB fused optical fiber coupler was used to insert the externally introduced signal and to obtain the output from the source. A tunable filter with 5 nm bandwidth was used for wavelength selection. As the SOA exhibited a 2 dB gain dependence, a polarization controller was introduced at its input port. The total length of the ring cavity was 14.6 m corresponding to 13.9 MHz fundamantal frequency. The external signal was provided from a gain switched DFB laser at 1548.9 nm, which was compressed in dispersion compensating fiber to produce 12 ps pulses at 5.78 GHz. The output of the DFB laser was amplified in an EDFA and its polarization state was controlled for optimum performance before entry into the ring.

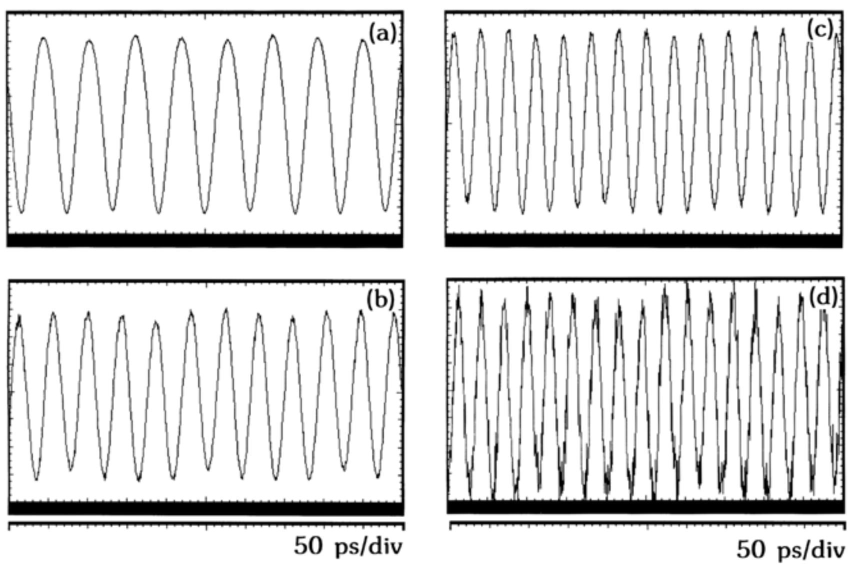

Figure 2. Output pulse trains at (a) 17.34 GHz, (b) 23.12 GHz, (c) 28.9 GHz and (d) 34.68 GHz

With the synthesizer source of the DFB adjusted to a harmonic of the fundamental of the ring cavity (approx. 5.7 GHz) and the EDFA adjusted to provide 800 μW into the cavity, the ring laser breaks into stable, mode-locked operation at this frequency. By changing the driving frequency in the synthesizer source by 13.9/n MHz and n varying from 2 to 6, the laser produces pulse trains at 11.56 GHz, 17.34 GHz, 23.12 GHz, 28.9 GHz and 34.68 GHz. Figure 2 shows the output pulse trains at (a) 17.34 GHz, (b) 23.12 GHz, (c) 28.9 GHz and (d) 34.68 GHz monitored on a 40 GHz sampling oscilloscope. Figure 3 shows the corresponding second harmonic autocorrelation traces obtained at (a) 17.34 GHz (b) 34.68 GHz. The pulse widths obtained from the fiber ring laser were approximately 15 ps for all repetition frequencies and the output power was about 60 μW.

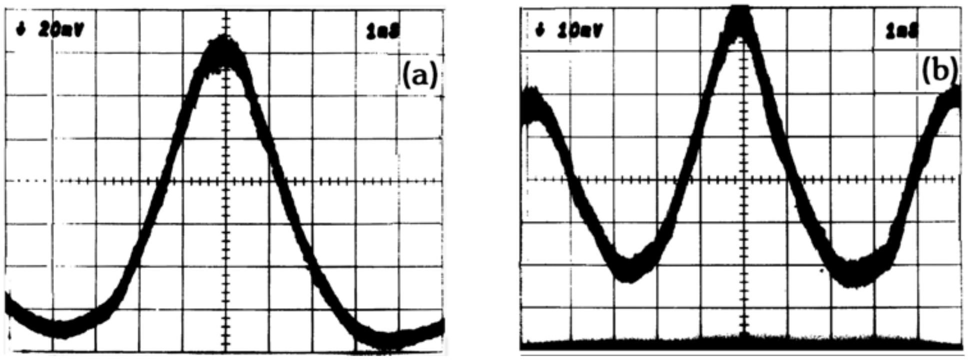

Figure 3. Second harmonic autocorrelation traces obtained at (a) 17.34 GHz (b) 34.68 GHz. The time base in the traces corresponds to 5.88 ps.

The process by which the ring oscillator mode-locks in the presence of the external pulsed signal relies on the fast saturation of the SOA. The mode-locked pulse experiences a sharp loss edge at its trailing edge because of the external pulse. As such it forms just ahead of the external pulse, at the point where the recovery of the SOA is maximum. The circulating mode-locked pulse has to rely on the recovery of the SOA for gain and as the fiber laser is tuned to increasingly higher harmonics of the external signal, the output pulse train develops a small modulation at the frequency of the external signal. This however may be eliminated at the high frequencies by using an SOA with low recovery time, or external driving frequency of a higher rate.

We have also examined multiplication factors obtained from even lower external frequencies. It has been possible to obtain up to 23.75 GHz output pule trains from 1.25 GHz external input, corresponding to a factor of 17 frequency multiplication.

We have demonstrated a novel technique for the multiplication of optical clock signal to high repetition frequencies, that is compatible with clock requirements for optical logic circuits. We have demonstrated up to 6 times multiplication factors and up to 34.7 GHz clock frequency.

References

1. N.S. Patel, K.L. Hall and K.A. Rauschenbach, '100 Gb/s Bitwise Logic', Optics Letters 23, pp. 1271-1273, 1998.
2. E.A Swanson, S.R. Chinn, K.Hall, K.A. Rauschenbach, R.S. Bondurant and J.W. Miller, '100-GHz Soliton Pulse Train Generation using Soliton Compression of Two Phase Site Bands from a Single DFB Laser', IEEE Photonic Technology Letters 6, pp. 1194-1196, 1994.
3. S.V. Chernikov, J.R. Taylor and R. Kashyap, 'Integrated All Optical Fiber Source Multigigahertz Soliton Pulse Train', Electronic Letters 29, pp. 1788-1789, 1993.
4. T. Papakyriakopoulos, A. Hatziefremidis, T. Houbavlis and H. Avramopoulos, '10 GHz Mode-Locked Ring Laser with External Optical Modulation of a Semiconductor Optical Amplifier', accepted for presentation at Optical Fiber Communication Conference, San Diego, 1999.