Monolithically integrated 40GHz pulse source with >40nm wavelength tuning range

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Abstract: A monolithically integrated device combines 40 GHz dual mode-locked operation with the wide tuning range (>40nm) of sampled-grating DBR lasers, while further being integrated to an SOA and a potentially high-speed modulator.
OCIS codes: (250.5300) Photonic integrated devices; (140.3600) Lasers, tunable; (140.4050) Mode-locked lasers

1. Introduction

High-speed optical communications systems with transmission rates of 40 Gbps have been developed for future wavelength multiplexed high-capacity systems. One key enabling component, not previously demonstrated, is an integrated, wavelength-agile return-to-zero (RZ) optical pulse source. Although several integrated configurations have been reported in the literature to generate 40 GHz RZ pulse sources [1-3], none have been widely wavelength tunable. The topic of this paper is to demonstrate, for the first time, a single monolithically integrated device combining generation of spectrally compact RZ pulses with the wide tunability offered by an SG-DBR laser integrated with a semiconductor amplifier and an electroabsorption modulator. The modulator is at this stage not sufficiently fast for 40Gbps data encoding. However, MZ modulators integrated with widely tunable SG-DBR lasers, sufficiently fast for 40Gbps data encoding have recently been built and can be integrated with the dual-mode-locked laser.

In an extended perspective, this device would be well suited for integration to form a 40Gbps RZ transmitter. A conventional 40Gbps RZ transmitter typically consists of several optical and electrical components, including an optical source, two external modulators and drivers; one for pulse carving and one for encoding, and additional optical amplification, illustrated by Fig. 1a. The type of monolithically integrated device presented here has the potential to replace the majority of components in an RZ-transmitter, as indicated by Fig. 1b. This proposed transmitter would consist of a dual-mode-locked widely-tunable SG-DBR laser integrated with a semiconductor amplifier and a high-speed data encoder. Because the clock-reference is used only to synchronize the two modes, not to drive a modulator, the clock drive amplifier can in principle be eliminated.

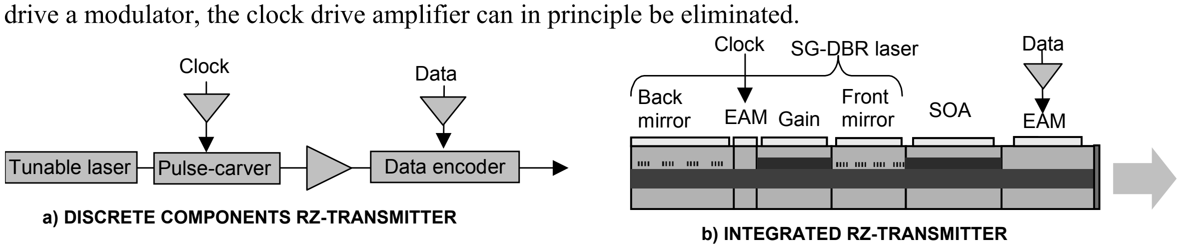

Fig. 1. a: Schematic of conventional wavelength tunable RZ optical transmitter. b: Schematic of proposed monolithically integrated RZ optical transmitter.

2. Experiment

The device used for this demonstration is the same as described in greater detail in reference [6]. It is based on a widely tunable sampled grating (SG) DBR laser with the structure shown in Fig 1b. The SG-DBR laser includes gain and phase sections positioned between two “sampled grating” distributed reflectors, sampled at different periods such that only one of their multiple reflection peaks can coincide at a time. An offset quantum-well structure provides a platform for integration of the laser with other active regions, such as detectors or semiconductor optical amplifiers (SOA), and passive regions, such as phase or amplitude modulators. Typical performance of an SG-DBR laser integrated to an SOA is more than 20mW fiber-coupled output power, lower than 2MHz linewidth, lower than

–140dB/Hz RIN and more than 40dB sidemode suppression ratio over more than 40nm wavelength tuning range. Also integrated in the device used in these experiments is an EA modulator designed for 2.5Gbps operation.

The sampled grating mirrors are designed so that only one single stable axial mode can be supported at a time. Mode-jumps between axial modes can be achieved by tuning the phase section, and at the mode boundary unstable operation is observed due to mode competition. By reverse biasing the phase section, it will take the function of an intracavity Franz-Keldysh modulator. Phase control must then be achieved by a combination of mirror and gain section tuning. A stable and synchronized dual-mode operation can be generated by modulating the phase section at the axial mode spacing frequency. Although the phase section has not been designed for efficient modulation at 40 GHz, the response is at the axial resonance sufficiently strong to correlate and stabilize the two lasing modes. In principle, if a high-speed modulator section is integrated in the laser, a much weaker drive signal can be used than for driving the equivalent external modulator, as only a small modulation is required to achieve mode synchronization.

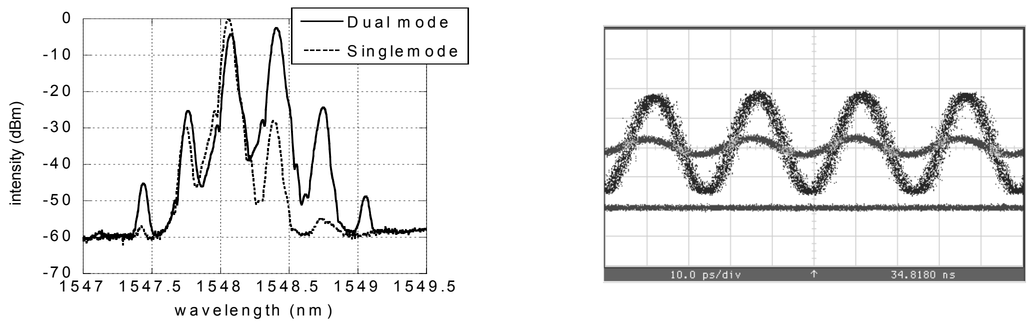

Fig. 2. a: Optical spectra for single and dual mode operation. b: Captured oscilloscope waveforms contrasting 40GHz dual-mode-locked and modulated single-mode SG-DBR laser operation.

3. Results

The optical spectra in Fig. 2a contrasts single and dual-mode operation under phase section modulation by a 19.3dBm signal. At single mode operation, weak modulation sidebands can be generated when the drive frequency matches the axial mode spacing; ~0.32nm. Adjusting the cavity round-trip phase, stable and synchronized dual-mode operation is observed. Figure 2b shows the comparison between the detected 40GHz waveforms generated under modulated single-mode and locked dual mode operation. The zero-level is also shown in the figure. At single-mode operation, a weak sinusoidal waveform was observed and it demonstrates that 40GHz optical pulses cannot be generated directly through strong modulation; while at locked dual-mode operation, a strong beat signal is obtained as a result of the heterodyne beat between the two locked modal frequencies. Based on the observed oscilloscope waveform, zero level, and the frequency roll-off of the 50GHz detector and 50GHz sampling oscilloscope used for detection, it is estimated that the actual extinction ratio is better than 10dB under dual-mode lasing.

The mode-beating can be synchronized over a 0.9GHz locking range, centered around 40.2GHz, corresponding to the cavity mode spacing of these devices, and illustrated by Fig. 3. At the boundaries of the locking range, a penalty in signal power was observed due to unbalanced mode amplitude. The 1-dB frequency range was on the order of 300MHz.

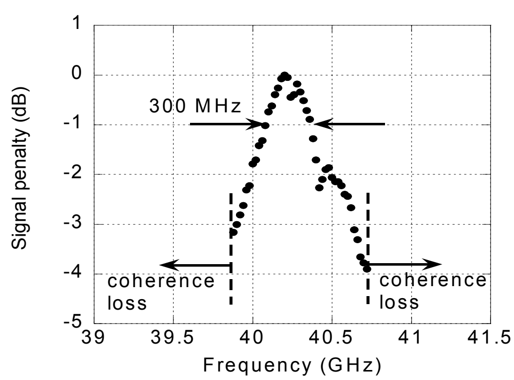

Fig. 3: Measured mode-locking range, where synchronized dual mode operation can be obtained. Also indicated is the 1-dB frequency range.

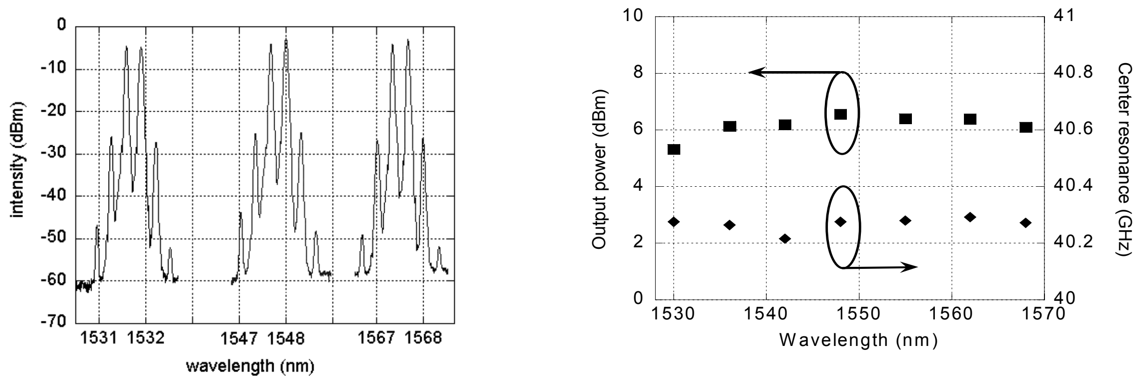

Fig. 4. a: Optical spectra taken through the tuning-range of the laser; low, center and high wavelength, illustrating a sidemode suppression ratio better than 20dB. (Res. bandwidth ~0.08nm). b: Fiber-coupled output power and center cavity resonance frequency over the wavelength tuning range of the laser.

Stable dual-mode lasing is obtained over the entire tuning-range of the laser; >40nm, illustrated by Fig. 3b, where dual-mode optical spectra at low, center and high wavelength are shown. The sidemode suppression ratio is at all wavelengths better than 20dB at a spectrum analyzer resolution bandwidth of ~0.08nm. The mode spacing remains well within the 1-dB lock-frequency range of Fig.3 over the wavelength tuning range of the laser, as shown in Fig. 4b, and is equally insensitive to chip operating temperature. The relative stability of generated modal beat frequency would allow the design of a widely-tunable dual-mode mode-locked laser for 40.0GHz or 42.7GHz applications. The fiber-coupled output power over the wavelength tuning range is consistent to that of single-mode operation and is also shown in Fig. 4b, where the gain section and SOA are kept at constant bias current.

4. Summary

In this paper we have demonstrated, for the first time, a single monolithically integrated device that combines generation of spectrally compact 40GHz pulses with wide wavelength tunability. This has been achieved by locking two axial modes of a widely-tunable SG-DBR laser to an external 40GHz reference used to modulate the reverse-biased phase section of the laser. The device is integrated with an SOA and an EAM that could potentially be designed sufficiently fast for data encoding, which would then be the realization of an integrated 40Gbps RZ transmitter. 40.2GHz pulse-generation is demonstrated with 0.9GHz locking range and uniform performance over the entire 40nm tuning range of the laser.

5. References

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