Cavity-Less 40 GHz Pulse Source Tunable Over 95 nm

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Abstract *We demonstrate a widely tunable 40GHz pulse source using linear pulse compression in a cavity less structure. The source is characterized with pulsewidth of 2.2ps and SNR exceeding 30 dB is achieved over 95nm.*

Introduction

Optical pulse sources have a wide range of applications including optical time division multiplexing (OTDM) and optical sampling, among others[1-7]. Pulse sources based on mode-locked fiber lasers require complex and costly phase locking arrangement to maintain stability[1]. Consequently, there is a significant interest in construction of cavity-less tunable short pulse sources. Cavity-less pulse sources have previously been demonstrated based on several approaches including optical modulators, chirped pulses with dispersion, or self-phase modulation and dispersive compression[2-7]. A major advantage of a cavity-less pulse generation is that the timing jitter will be determined only by the RF-source rather than by the actively controlled cavity. While many schemes rely on chirp induced through nonlinear effects followed by dispersion, these approaches require high power optical amplifiers to elicit nonlinear effects. On the other hand, pulse shaping with modulators eliminates the need for high power optical amplifiers while offering precise control on the pulse generation. For applications such as OTDM or all-optical sampling[6,7], widely tunable pulse sources covering both C- and L-bands are of significant interest. However, most presented tunable sources are limited to single EDFA band[1-4].

In this paper we present an achromatic 40 GHz pulse source covering both C- and L-band. The source is based on the generation of chirped pulses by a concatenation of a Mach-Zehnder and a phase modulator, followed by compression in a dispersive medium. While the compression of modulator generated chirped pulses in dispersive media is a known phenomemon[5,6], seamless wavelength tunability is obtained for the first time, through the use of a highly dispersive fiber with flat dispersion over the C and L-bands. We show that high quality 2.2 ps pulses with 40 GHz repetition rate can be generated over 95 nm with high fidelity maintained over the entire tuning range.

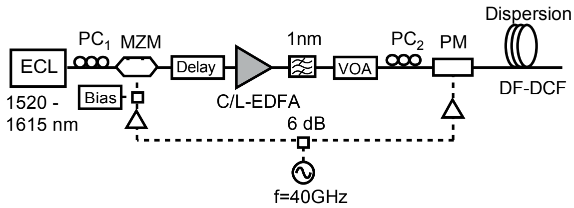

Fig. 1: Experimental setup.

Principle of widely tunable pulse source

The chirped pulses were generated by concatenating a Mach-Zehnder amplitude modulator and a Lithium Niobate phase modulator, both driven by a 40 GHz sinusoidal wave. The Mach-Zehnder modulator (MZM) carved pulses which were slightly compressed using a bias setting below the quadrature point and the pulses were subsequently frequency chirped in the superseding phase modulator. The chirped pulses were finally compressed by dispersion in an optical fiber. If standard single mode fiber (SMF) was used as the dispersive element, accumulated dispersion would differ with wavelength due to the finite dispersion slope over C- and L-bands. Consequently, the optimal fiber length for pulse compression will change with wavelength. To address this issue, a highly dispersive fiber with close to zero dispersion slope was used in the pulse compression stage. Consequently a single fiber segment was used to achieve constant pulse compression independent of wavelength. For our experiment we selected a segment of dispersion-flattened dispersion compensating fiber (DF-DCF), which had high but almost constant dispersion over C- and L-bands which is ideal for pulse compression.

It should be noted that the pulse source offers extra flexibility as the width and shape of the generated pulses can be controlled by the bias and amplitude of the MZM, the phase between the MZM and the PM, the amplitude of the PM and the total accumulated dispersion, i.e. the length of fiber used.

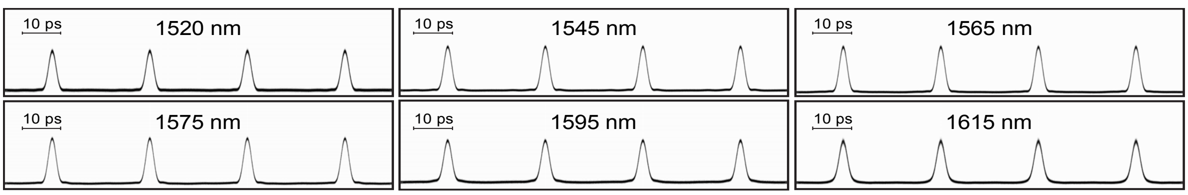

Fig. 2: Oscilloscope traces of pulses captured over 95 nm with C- and L-band optical sampling oscilloscopes.

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Experiment

The experimental setup is shown in Fig. 1. The RF-source was a 67 GHz low phase noise signal synthesizer, which was operated at 40 GHz. The synthesizer output was divided with a 6-dB power splitter in order to drive both modulators. The RF-signal power was then amplified by two driver amplifiers. In order to attain large frequency chirp in the PM, a high power microwave amplifier, having an output power over 1W, was used to supply the RF signal to PM with voltage swing over $2V_\pi$ at 40 GHz. A widely tunable external cavity laser (ECL) was used as a light source, which was fed into a 40 Gb/s bandwidth MZM. The input polarization was carefully controlled by a polarization controller (PC_1). The MZM was biased below the quadrature point giving a small initial pulse compression to 9 ps. The timing of the output from the MZM was controlled by a tunable optical delay before the signal was amplified with a low power C/L-band Erbium doped fiber amplifier (C/L-EDFA). The EDFA was used in order to compensate for the loss in the MZM, PM and fiber. A tunable 1 nm optical bandpass was used to reject the amplified spontaneous emission (ASE) and the output power of the EDFA was controlled by a variable optical attenuator (VOA). The polarization of the input to the PM was controlled with PC_2. The generated chirped pulses were out from the PM was subsequently launched into 12.4 m of DF-DCF which had an average accumulated dispersion of -3.5 ps/nm, over the whole tuning range, for pulse compression.

Thanks to the cavity-less nature of the proposed pulse source, wavelength change can be achieved simply by changing the emission wavelength of ECL, followed by adjustment on the optical delay. Note that adjustment on optical delay is needed only due to long fiber length in EDFA used, which incurs significant group delay change against wavelength. In principle such adjustment can be eliminated by using short-fiber EDFA or dispersion-managed EDFA. The wavelength was scanned from 1520 nm to 1615 nm, with the MZM bias kept constant.

Results

The measured results of the tunable pulse source are shown in Figs. 2-4. Oscilloscope traces captured with C- and L-band 500 GHz bandwidth optical sampling oscilloscopes are shown in Fig. 2, for different wavelength positions. The pulse form and quality was maintained over the wavelength tuning range. Superimposed spectra are plotted in Fig. 3 showing the wide tunability and constant spectral output of the pulse source over 95 nm. The measured average pulsewidth was 2.2 ps with a standard deviation of 0.07 ps over the tuning range (Fig. 4). The average time-bandwidth product, which corresponds to an average bandwidth of 1.9 nm, was calculated to be 0.52 implying a close to the transform limited (Gaussian pulse) operation. The quality of the generated pulses was evaluated through signal to noise ratio (SNR), Fig. 4, and extinction ratio (ER) measurements. High quality pulses with a SNR over 30 dB and ER over 20 dB were retrieved over the whole 95 nm with negligible fluctuations. We note that a further improvement in SNR is possible by optimization of powers inside the device.

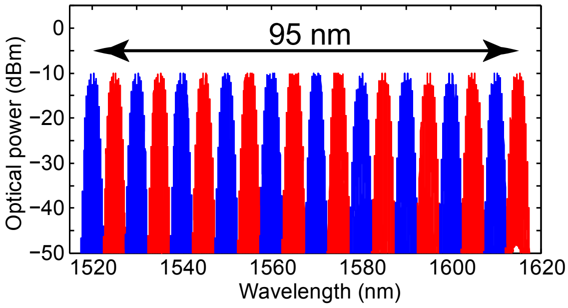

Fig. 3: Spectra of the pulse source tuned over 95 nm.

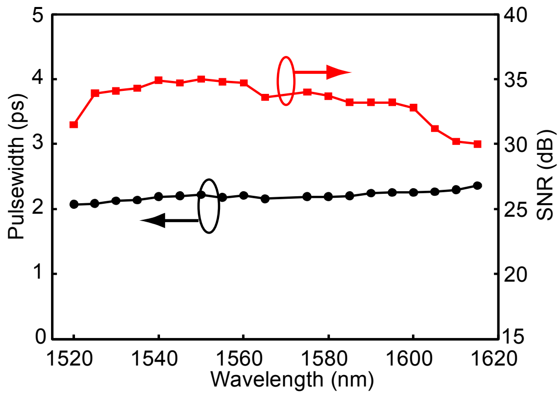

Fig. 4: The measured pulsewidth and SNR of the pulses as function of wavelength.

Conclusions

We have presented the experimental demonstration of widely tunable RF-driven 40 GHz pulse source. A tuning range of 95 nm with maintained pulse width of 2.2 ps and SNR over 30 dB was obtained. Seamless tunability was achieved by the use of dispersion-flattened dispersion compensating fiber as the dispersive medium, which has high and constant dispersion over C- and L-bands.

Acknowledgement

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