Wavelength Hopping using Time Gating of a Chirped Supercontinuum

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ABSTRACT

We propose and demonstrate a new technique for realizing wavelength tuning that promises rapid response over a wide optical bandwidth. Wavelength tuning is obtained by varying the delay of the RF pulse that time-gates a linearly chirped Super Continuum (SC). Preliminary experiments demonstrating static tuning range of 90nm are reported.
Keywords: Tunable laser, Supercontinuum, Time gating

The ability to rapidly tune the frequency of a coherent optical source is desired in many existing and emerging fiber optic applications. Among these is Optical Code Division Multiple Access (OCDMA) where the hopping in time and in optical wavelength can be used to provide multiple access capability and/or added security [1][2].

Among the different approaches to tunable sources, Sampled Grating Distributed Bragg Reflector Lasers (SG-DBR) represents one of the most popular approaches. This stems from their ability to tune over a wide wavelength range and the relatively fast tuning speed which can be as low as a few nanoseconds [3]. Among the drawbacks of SG-DBR lasers are the inability to provide continuous tuning, the large output power variation under tuning, wavelength stabilization and complex calibration.

In this paper we propose and demonstrate a new approach for realizing a tunable source. Our approach makes use of the wavelength-to-time mapping, inherent in a linearly chirped Super Continuum (SC), followed by time gating to select the desired wavelength. Figure. 1 describes the proposed system. A linearly chirped SC (described below) provides the mapping of optical wavelength into time. Selecting a wavelength thus reduces to gating the SC in time domain using an optical modulator. The Dispersion Compensation Fiber (DCF) removes the chirp resulting in a transform-limited output pulse. The source is suitable for Return-to-Zero (RZ) optical communication. In the current experiment, the control signal is a short electrical pulse applied to an electro-optic Mach-Zehnder modulator. Wavelength tuning is achieved by varying the delay of the electrical pulse. The line width of the source is determined by the chirp rate and the temporal width of the gating signal. High speed switching can be achieved by using a fast-tunable delay circuit such as the one shown in the inset of Figure 1. The delay circuit consists of a series of 2x2 switches with binary weighted inter-stage delays. For a circuit consisting of N stages, 2^N distinct delays can be obtained. For a large tuning range, a long delay is desirable, however, the latency in such a circuit limits switching time. A pipelined delay architecture, shown in the inset, provides a combination of low latency and long time delays. Using conventional IC technology, sub nanosecond tuning times can readily be achieved.

Optical Devices for Fiber Communication IV, Michel J. F. Digonnet, Editor,
Proceedings of SPIE Vol. 4989 (2003) © 2003 SPIE · 0277-786X/03/$15.00

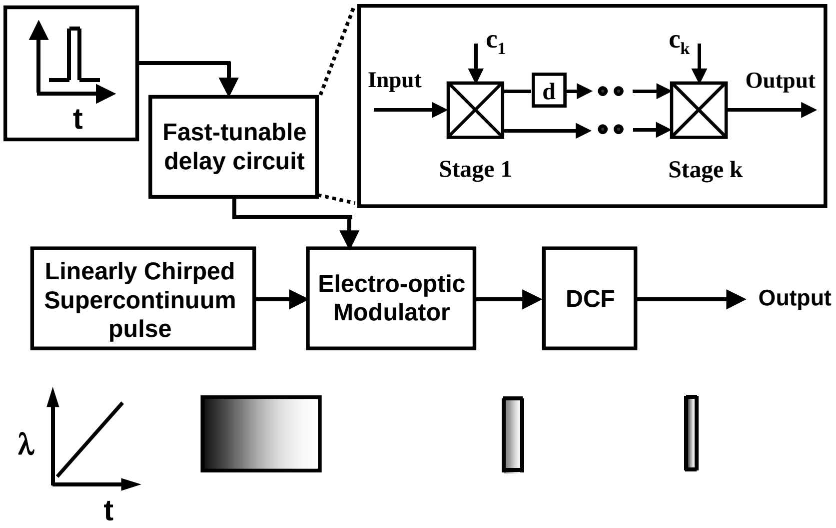

Figure 1: Block diagram for proposed tunable source.

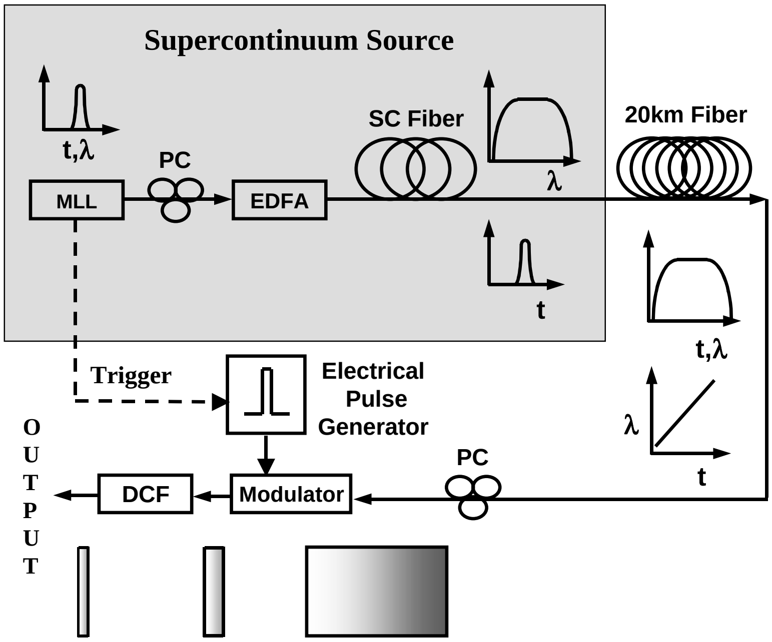

Figure 2: Proof-of-concept experiment setup.

Figure 2 describes the set up for a proof-of-concept experiment. The SC source consists of a passively mode locked fiber laser (MLL) with a repetition rate of 20MHz and an average output power of 1.8mW. The laser power is amplified to 25mW by the Erbium Doped Fiber Amplifier (EDFA). The high intensity pulses from the output of the EDFA are transmitted through the specially designed supercontinuum fiber [4][5]. The spectral output after the fiber is recorded using an optical spectrum analyzer (OSA). Since the supercontinuum generation is sensitive to the input polarization, a polarization controller is used to control the polarization of the light in the SC fiber to achieve a wide spectrum

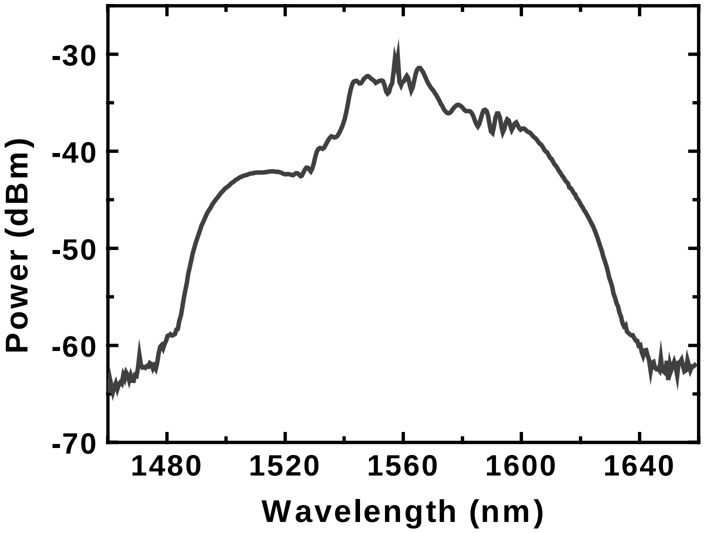

Figure 3: Measured spectrum of the optical supercontinuum.

The supercontinuum spectrum obtained from this set up is shown in Figure 3. The source typically produces a 1558nm-centered SC whose 12dB bandwidth is 120nm. The time-averaged output power of the SC source is 1.2mW. The light is then dispersed using a 20km, standard single-mode fiber (SMF28) to create the linear chirp. Electrical pulses with a temporal width of 380ps (FWHM), applied to the LiNbO3 intensity modulator, carve the linearly chirped spectrum. Spectral measurements of the output are performed using an Optical Spectrum Analyzer (OSA). The span of the supercontinuum over which the tuning is done is around 90nm, centered at 1560nm.

Figure 4 shows the optical spectrum obtained by varying the delay of the electrical pulse. The time-window of 380ps corresponds to a spectral-window of 1.11nm (FWHM). This corresponds to a dispersion coefficient of 18.44 ps/nm.km which is in good agreement with the expected value for SMF28. The power variation between different channels is due to the non-uniform power spectrum of the SC source. The average pulse extinction ratio is 20.5dB. The system exhibits a maximum Side-Mode Suppression Ratio (SMSR) of 21.86dBc and an average SMSR of 15dBc over a tuning bandwidth of 58nm. The peak power is limited by the non-optimized SC setup. With an optimized SC source, peak powers of 0dBm over 1nm bandwidth have been demonstrated [5]. The output power can further be increased using optical amplifiers.

Figure 5 shows the tuning behavior of the system. Linear tuning from 1518nm to 1613nm is observed when the delay varies linearly over 35ns, in good agreement with value based on the expected chirp rate. The linear relationship between output wavelength and time delay provides for easy and fast calibration of the tuning characteristic. The experiments are repeated using a 5.4km length of SMF28 for generating the linear chirp. As expected, in the case of the shorter fiber, the higher chirp rate manifests itself in a larger spectral width of 3.26nm.

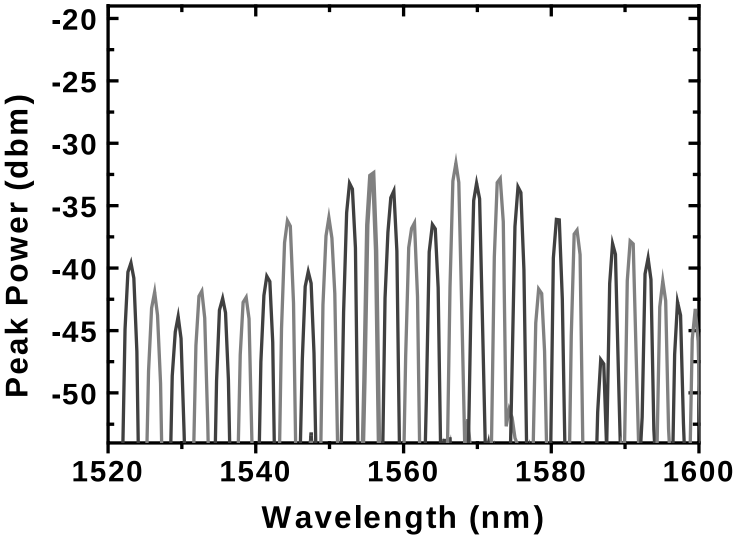

Figure 4: Wavelength tuning response observed using an optical spectrum analyzer. Resolution bandwidth was 0.08nm.

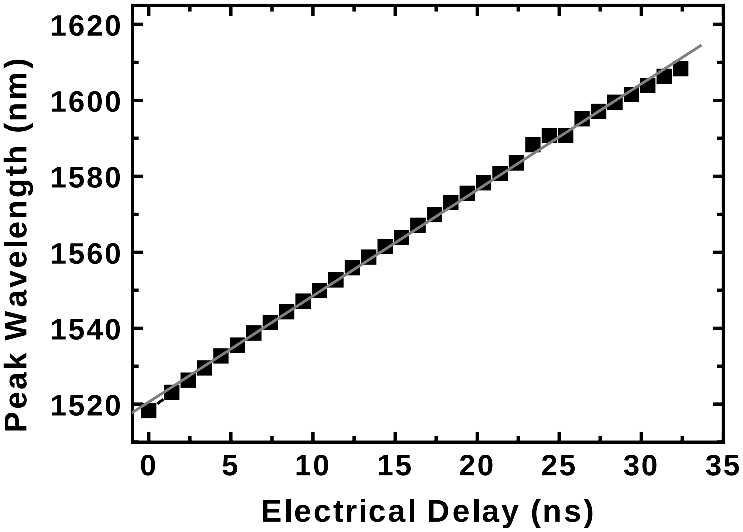

Figure 5: Center wavelength versus electrical delay when the 20.5km fiber is used.

In conclusion, we have presented a new tunable optical source which has the potential of providing fast tuning over a large bandwidth. The source can be constructed from commercially available components and provides linear tuning characteristics offering fast and easy calibration procedure.

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