Generation of high repetition rate (>100 GHz) ultrastable pulse trains from a coherent optical beat-signal through non-linear compression using a high SBS-threshold fiber

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Abstract: A stable beat-signal produced by two comb-phase-locked CW lasers separated by >100 GHz is nonlinearly compressed in a high SBS-threshold highly nonlinear fibre.

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1. Introduction

The generation of high repetition rate (e.g., 160 GHz) pulse trains through four-wave-mixing (FWM) temporal compression of a dual-frequency beat signal has been shown to produce transform-limited pedestal-free signals [1]. Such pulses may be of interest in many fields including telecommunications, THz generation, and metrology. This technique relies on two key stages: (i) the production of the beat signal and (ii) non-linear temporal compression in a highly non-linear fiber (HNLF). To date beat signal generation at rates far beyond those accessible by RF-electronics (>>40 GHz) has been through the mixing of two independent narrow linewidth lasers (e.g., [1,2]). Obviously, this approach leads to significant timing jitter on the pulses generated over a timescale inversely proportional to the linewidth of the seed lasers used. Furthermore, Stimulated Brillouin Scattering (SBS) in the HNLF is usually a limiting factor within these schemes since in order to obtain low-jitter pulses, two very narrow linewidth continuous-wave (CW) lasers are used as the seed. Keeping the seed power below the SBS threshold means that little if any compression can be achieved and phase modulating the seed signals to overcome the SBS [1] introduces undesirable timing jitter and/or carrier phase variation.

Here, we propose and experimentally demonstrate a technique that mitigates both issues previously discussed. It is based on (i) stable injection-locking of two semiconductor lasers (with a frequency separation corresponding to the desired repetition rate) to an optical comb generated using ~10-GHz drive electronics which suppresses signal timing jitter and (ii) a new alumino-silicate HNLF with a significantly higher SBS threshold as compared to other types of HNLF allowing significant pulse compression ratios without active SBS suppression.

2. Experimental Setup and Results

A fiber Fabry-Perot like laser (the Rock laser from NPhotonics with a 3dB linewidth below 10 kHz) is fed onto a 10-GHz spaced optical frequency comb generator (OFCG, OptoComb Inc., Japan), which is based on the resonant driving of a phase modulator placed inside a high-finesse Fabry-Perot cavity, thereby allowing broadband comb generation (over several THz) [3]. The comb was subsequently demultiplexed using a 100-GHz arrayed waveguide grating (AWG) and used to injection-lock two descrete mode semiconductor lasers (Eblana Photonics, Ireland) at different wavelengths via a circulator, see Fig.1. The narrow-bandwidth filtering properties of the AWG helped to improve the optical signal to noise ratio (OSNR) to the >70 dB level. These two, now properly phase-locked CW signals, with a power level of 3 dBm per wavelength, were then amplified up to about 32 dBm and launched into a 300-m-long alumino-silicate HNLF (OFS, Denmark) to generate new frequency components via FWM. The nonlinear coefficient, dispersion, dispersion-slope and loss of the HNLF at 1550 nm are: 6.8 $W^{-1}km^{-1}$, -0.8 ps/nm·km, 0.0085 ps/nm^2/km and 15 dB/km respectively. Finally, a few tens of metres of single mode fibre (SMF-28) were used to temporally compress the pulses.

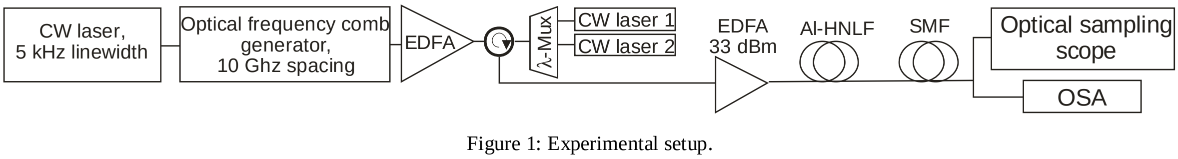

Figure 1: Experimental setup.

The signal in the time and spectral domains at different points along the system are shown in Figs. 2 and 3, respectively, when the frequency spacing between the two injection-locked lasers was 100, 160, and 200 GHz, respectively. The frequency spacing was controlled (in 10 GHz steps) by varying the operational temperature of the injected lasers. In practice, significantly higher frequency spacing could be achieved simply by a different choice of the two CW laser wavelengths. The temporal waveform was measured using an optical sampling oscilloscope (EXFO Inc.), which was electrically triggered by the OFCG clock. The temporal intensity profile of the two combined CW lasers corresponds to a sine wave at a repetition rate given by the CW spacing with pulses of a full width at half maximum (FWHM) corresponding to half of the signal period. The pulses were then launched into the HNLF to generate new spectral components via FWM and were then compressed using a few tens of metres of SMF-28 with a dispersion of 17 ps/nm·km. Pulse compression down to 2.1 ps (100 GHz), 1.4 ps (160 GHz) and 1 ps (200 GHz) was achieved, see Fig. 3, giving compression factors ranging from 1.7 to 2.5. Assuming Gaussian pulse shape, the corresponding time-bandwidth product was ~ 0.5.

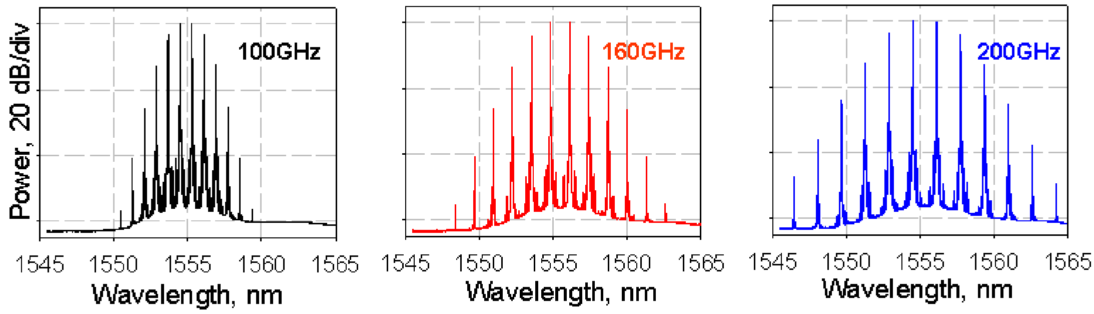

Figure 2 Output spectral traces at 100GHz, 160GHz and 200GHz spacing.

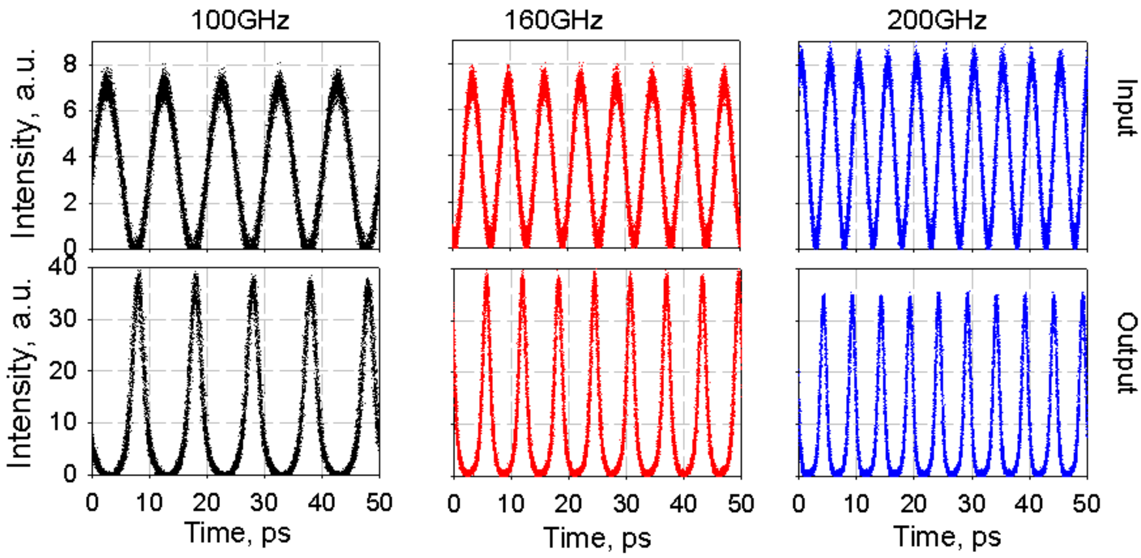

Figure 3 Measured temporal traces at 100, 160, and 200 GHz spacing at the input of the HNLF (first row) and at the system output (lower row) when 52, 36, and 20 m of SMF were used respectively. Optical sampling oscilloscope temporal resolution is 800 fs.

4. Conclusions

We generated short high repetition rate pulses using two phase-locked CW lasers and a HNLF with a high SBS threshold followed by a dispersive element for nonlinear compression. Although only repetition rates up to 200 GHz were experimentally demonstrated, higher values of up to 3 THz can be envisaged and obtained simply by using a different CW-laser frequency spacing.

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5. References

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