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GENERATION OF 40 GHz CW SOLITON TRAINS USING MULTISOLITON COMPRESSION AND TRANSFORMATION IN A DISPERSION VARYING FIBER.

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ABSTRACT

We experimentally demonstrated 40 GHz optical double-frequency beat-signal to soliton train transformation employing a novel technique based on multisoliton compression effect in a dispersion varying optical fibers. The quality of the generated pulses was approved by the following propagation in a fiber with the constant dispersion.

Recent achievements in the experiments on data transmission with ultra-high repetition rates as high as 100 GBit/s [1] have led to necessarity of the development of new sources, alternative to conventional e.g. gain-switched DFBs and mode locked fiber lasers. The sources generated high-frequency pulse trains with the repetition rates from 20-40 GHz to more then 200 GHz are thus of great practical interest.

The transformation of a dual-frequency signal into a train of solitons is the promising technique to reach the high-frequency range [2,5,7]. The repetition rates of about 70-200 GHz have been obtained experimentally by the adiabatically transformation of the sinusoidal beating signal in Dispersion Decreasing Fiber (DDF) [3,4]. Unfortunately, impractically long length of DDF (> 10 km) are required to extend the techniques to repetition rates below 60 GHz and the basic technique is therefore of little interest for current telecommunication applications. Spectral enrichment of the beat signal inn Dispersion Shifted Fiber (DSF) prior to propagation in DDFs has been shown to lead to the generation of slightly lower repetition rates [5]. It has also been shown theoretically that an even greater length reduction can be obtained by compressing the initial beat signal through multisoliton compression prior to propagation in a DDF enabling 40 GHz soliton train generation [6]. In this paper we demonstrate that a simple combination of spectral enrichment in DSF and multisoliton compression in standard fiber prior to propagation in a DDF can be used to generate a high quality 40

GHz soliton train. The technique should be capable of extension down to 30 GHz. Note that 32 GHz soliton trains have been generated from a beat signal by using multisoliton effects in a nonlinear loop mirror [7]. However, this particular technique suffers from acute environmental instability and requires additional (linear) chirp compensation at the system output - undesirable properties for any practical sources.

The experimental configuration is illustrated in Fig.1. The outputs from two, pig-tailed, single frequency DFB lasers (DFB 1 and DFB 2) were combined using a 3dB coupler to create a beat- signal. The lasers emitted at wavelengths around 1550 nm. The temperature of the laser diodes could be independently tuned and the laser wavelength separation set between 0 and 2 nm. The beat- signal was amplified in a two stage 1064 nm pumped, erbium- ytterbium doped fiber amplifier incorporating an in - line band pass filter. Upto 200 mW of amplified power was available at the isolated EDFA output. The amplified beat - signal was passed through 1km of DSF (D = 0.5 ps/nm/km) where four-wave mixing leads to side-band generation at -15 dB relative to the signal input level. The signal is then passed through 1km of standard fiber (D = 16 ps/nm/km) where it undergoes multisoliton compression by a factor of 1.5 - 2 before entering the DDF. The DDF had a length 3.5 km and a loss of 1dB/km. The dispersion at 1550 nm varied along the fiber length from 11 ps/nm/km at the input to 0.8 ps/nm/km at the output. On its own the DDF was suitable for the generation of 80-90 GHz pulse trains. The total system loss from DSF input to DDF output was 5.6 dB.

The behavior of the system was investigated for a wide range of frequency separations and pump powers and the optimum performance determined. Due to the multisoliton compression stage high quality pulses could only be obtained around a relatively narrow repetition rate resonance 37 - 43 GHz determined by the standard fiber length and beat-signal power. The source does not exhibit the broadband repetition rate tunability of the basic adiabatic DDF technique [4]. Optimum system performance was obtained at a wavelength separation of 0.318 nm (R = 40 GHz) repetition rate and an input beat-signal power of 135 mW. An autocorrelation trace and optical spectrum of the trains so obtained are shown in Fig.2 where we see that we have obtained a 40 GHz train of 3.4 ps pulses, corresponding to a mark-space ratio of 7.3:1. A $sech^2$ fit to the relative peak heights in the spectrum is shown plotted on a log scale in Fig.3 - the fit is seen to be excellent. The best fit spectral halfwidth comes out as 0.75 nm yielding a best fit time - bandwidth product of 0.32 in excellent agreement with that expected for soliton pulses. The average output power of 37 mW yields an estimated pulse energy of 0.9 pJ in excellent agreement with the value 0.8 pJ calculated for a fundamental order soliton calculated taking D = 0.8 ps/nm/km and assuming a mode area of 100 $(\mu m)^2$. In order to check the stability of the train the pulses were propagated over 7.5 km span of DSF (D = 0.5 ps/nm/km), corresponding to approximately one soliton period for 3.4 ps pulses. Once the launched pump power into the DSF was adjusted to match the discrete dispersion change from DDF to DSF the pulses were found to propagate stably with little change in pulse parameters confirming the high quality of the train.

In conclusion, we have demonstrated for the first time a new technique for beat-signal to soliton train conversion based on multisoliton compression effects. This technique permits the use of considerably shorter fiber length than all previous DDF based conversion schemes and permits the generation of soliton trains with repetition rates in the range 30 - 40 GHz - a repetition rate of interest for future telecommunication applications. The method is also considerably simpler and less environmentally sensitive than other interferometric, NOLM based conversion schemes that can also operate in this repetition rate regime. The high quality of the solitons so generated is demonstrated by measurements of individual pulse parameter and by propagation of the pulses in an additional fiber span.

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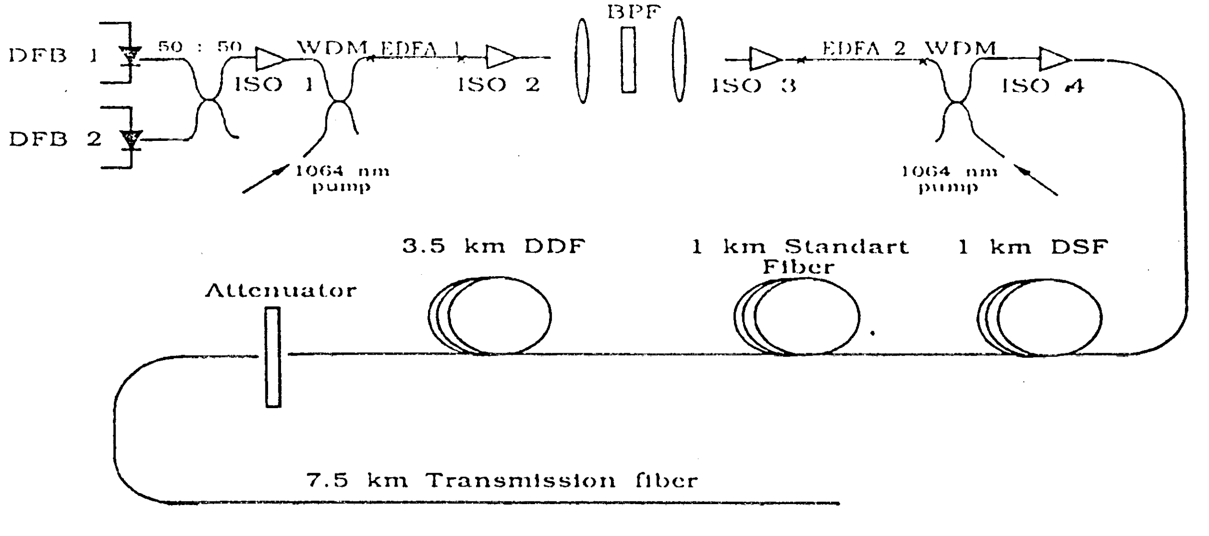

Fig.1. Experimental set up

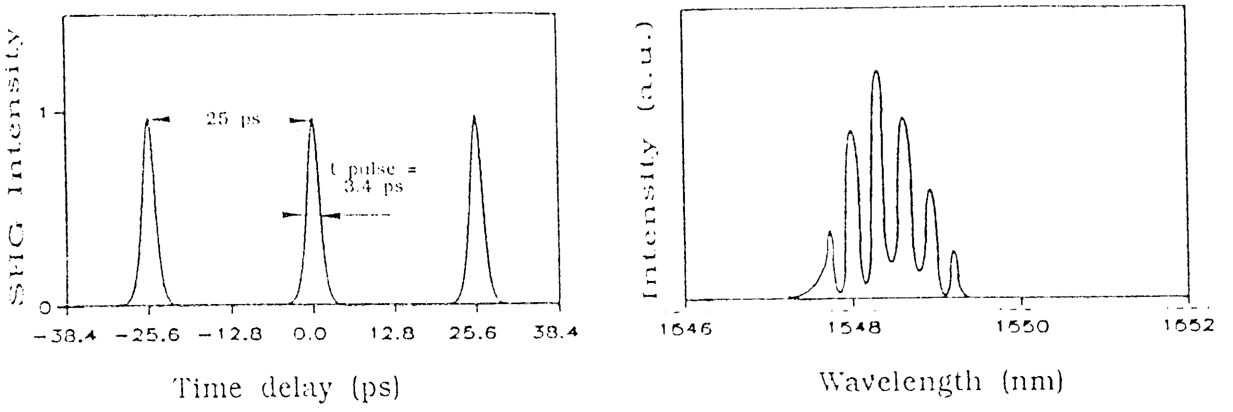

Fig.2. Experimental spectrum and autocorrelation trace of 40 GHz 3.4 ps soliton train obtained at the end of the DDF fibre

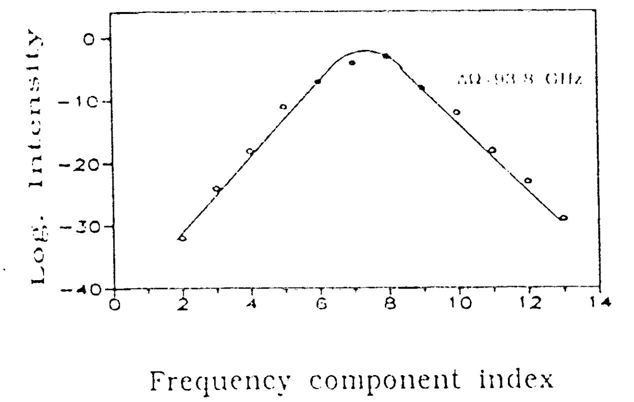

Fig.3. Sech^2 fit (solid line) to spectral peak amplitude on logarithmic scale for 40 GHz pulse train shown in Fig.2. Best fit spectral halfwidth value of 93.8 GHz leads to an estimated time-bandwidth product of 0.32.