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CHIRPED FIBRE BRAGG GRATINGS FOR PICOSECOND PULSE TRAIN MULTIPLICATION UP TO 80 GHz

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Abstract: Pulse train multiplication based on the temporal Talbot effect in linearly-chirped fibre gratings is demonstrated. Converted optical pulse trains at 40 and 80 GHz repetition rates have been generated from a 2.5-GHz mode-locked Er-Yb:glass laser.

Introduction

Chirped fibre gratings have been demonstrated in recent years to be an effective means for pulse manipulation and dispersion compensation in high-bit-rate optical transmission systems. Another novel application, yet extremely important, where fibre gratings can be successfully exploited, is the multiplication of optical pulse trains repetition rate aimed to the development of future ultrahigh-speed optical systems. All-optical multiplication of pulse trains repetition rates has been indeed demonstrated using, e.g., soliton compression of the beat signal between two optical carriers [1], rational harmonic mode-locking [2,3] or higher-order FM mode-locking [4]. The feasibility of fibre Bragg grating technology for pulse train multiplication has been very recently demonstrated in Ref.[5], where a sampled Bragg grating in the frequency domain has been designed and fabricated to operate as a selective filter capable, by spectral mode suppression, of increasing the repetition-rate of a mode-locked pulse train. A different technique for pulse train multiplication, which uses a fibre Bragg grating as a dispersive instead of a filtering element, has been proposed in Ref.[6]. The basic physical mechanism underlying pulse train multiplication in this case is the temporal counterpart of the Talbot effect well-known in diffractive optics, by means of which temporal dispersion causes pulse broadening and pulse overlapping with an interference pattern that reproduces the initial pulse train with a multiplied repetition rate. Pulse train multiplication based on Talbot self-imaging was demonstrated earlier in Ref.[7] by using, as a dispersive medium, a long fibre dispersion line.

In this paper we demonstrate that linearly-chirped fibre Bragg gratings can be used to achieve pulse train multiplication, exploiting the temporal Talbot effect, and we report on pulse train multiplication by factors of 16 and 32 of 2.5 GHz repetition-rate picosecond pulse trains generated from a FM mode-locked Er-Yb:glass laser up to 40 and 80 GHz.

Experimental set-up and pulse-train multiplication technique

The experimental layout for pulse train multiplication includes an Er-Yb:glass laser source, FM mode-locked at 2.5 GHz, and a chirped fibre Bragg grating for pulse train multiplication, connected to a three-port optical circulator to retrieve the reflected signal. The laser source consists of a 18-cm-long, one-folded cavity with a 1-mm-thick Er-Yb:glass disk end-pumped at 980 nm, containing a high-Q $LiNbO_3$ phase modulator with a resonance frequency at 2.493 GHz and an uncoated 120 μm-thick etalon with anisotropic losses (Polarcor), which forces the polarisation state of the laser field and allows a fine tuning of the laser wavelength close to the central wavelength of the grating. Frequency mode-locking is achieved in a third-order harmonic configuration at 2.49 GHz, and Gaussian pulses of duration variable from ≅10 ps down to ≅5 ps can be generated with a time-bandwidth product of 0.63. The output laser beam is launched, by a microscope objective, into a single-mode fibre, and an average fibre-coupled optical power of ≅5 mW is available for the experiment. By means of a high-power Er-Yb fibre optical amplifier, the average power can be increased up to 1.5 W if needed. Two distinct linearly-chirped fibre grating have been designed and fabricated to achieve pulse-train multiplication factors of M=16 and M=32, with a nearly flat dispersion according to the fractional Talbot condition [6]

$$\ddot{\Theta} = 1/(2\pi M f^2) \tag{1}$$

where f is the repetition rate of the mode-locked laser and $\ddot{\Theta}$ is the grating dispersion expressed in ps^2/rad. Whenever condition (1) is satisfied, the optical field reflected from the fiber grating turns out to be an exact replica of the original pulse stream but with an increased repetition rate equal to Mf.

Fibre Bragg grating fabrication

The gratings have been written using the continuous writing technique by means of an UV beam from a frequency doubled Ar-ion laser, which is focused onto a phase mask and strobed using an acousto-optic modulator with period corresponding to the desired grating pitch. The apodization profile and chirping have been achieved by dithering and by gradually increasing the phase of the strobed beam. Furthermore, to achieve very long length gratings (≅100 cm for the M=16 multiplication and ≅50 cm for the M=32 multiplication) the fibre moves continuously

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