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796

SOLITON INTERACTION IN THE PRESENCE OF A WEAK CW COMPONENT

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ABSTRACT

We demonstrate both experimentally and theoretically that the presence of a weak coherent frequency-shifted cw component causes periodic variation in the soliton arrival time.

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In ultralong distance soliton transmission systems the limit to the single channel bit rate is defined by jitter in the pulse arrival time. The fundamental origin of the time jitter is the change of the soliton central frequency due to a perturbation of the soliton parameters [1]. Such perturbations can arise from spontaneous emission noise in optical amplifiers (the Gordon-Haus effect), partial overlapping of adjacent pulses ('classical' soliton-soliton interaction effect) or excitation of a weak acoustic wave. Here we consider a practically important source of perturbation - a weak cw component, and study soliton interaction in the presence of the cw wave.

The experimental configuration is shown in Fig.1. As a master source, we used a passive harmonic mode-locked fibre soliton laser which produced pulses with $\tau \sim 2$ ps FWHM. To study soliton interactions, pulses from the laser were first passed through a Michelson interferometer to convert them into pulse pairs. The pulses were amplified after the interferometer with an Er^{3+}/Yb^{3+} codoped fibre amplifier to maintain fundamental soliton propagation in the transmission fibre, which consisted of 2 km of standard telecom fibre (D=17 ps/nm·km), which makes the propagation distance of the order of 20 soliton periods with negligible low losses.

First, the laser was adjusted to mode-lock with a minimal fraction of cw component. Fig.2a shows the experimental result for soliton-soliton interaction in which we plot the pulse separation deviation from that predicted by the theory (Eq.1 in[2]) for both in-phase and opposite phase cases. For large separation i.e. where the theory gives the most reliable results, the deviation is less than 0.2τ.

However, by increasing the fraction of the cw component we observed significant changes in the soliton behaviour, with a strong dependence of the output pulse separation on the relative phase being observed for input pulse separations exceeding even 10τ. Fig.3b) and c) show the pulse separation deviations for the cw component having 10% and 20% of the average power. Corresponding optical spectra are shown in the insets.

To consider the influence of the cw component on soliton parameters, we applied perturbation theory, based on the inverse scattering transformation [1]. The results of the theoretical consideration show that a frequency-shifted cw component causes periodic perturbations (with respect to the delay between solitons) of the soliton parameters that in turn lead to a variation in soliton arrival time [3].

In conclusion, we have studied both experimentally and theoretically a practically important case of soliton interaction in the presence of a cw component. It has been shown that the existence of a frequency shifted cw wave results in a temporal shift of the soliton.

This effect may have applications in optical processing where modulation of a weak cw signal forces a large temporal modulation of the soliton position.

REFERENCES

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3. W.H.Loh, A.B.Grudinin, V.V.Afanasjev and D.N.Payne submitted to Electron.Lett.

Figure Captions

Fig.1 Experimental configuration

Fig.2 Deviation of the output pulse separation from that predicted by perturbation theory for the fraction of cw component: (a) - $<1\%$, (b) - 10 %, (c) - 20 %.

○ - interacting solitons are in-phase;

● - interacting solitons are in opposite phase.

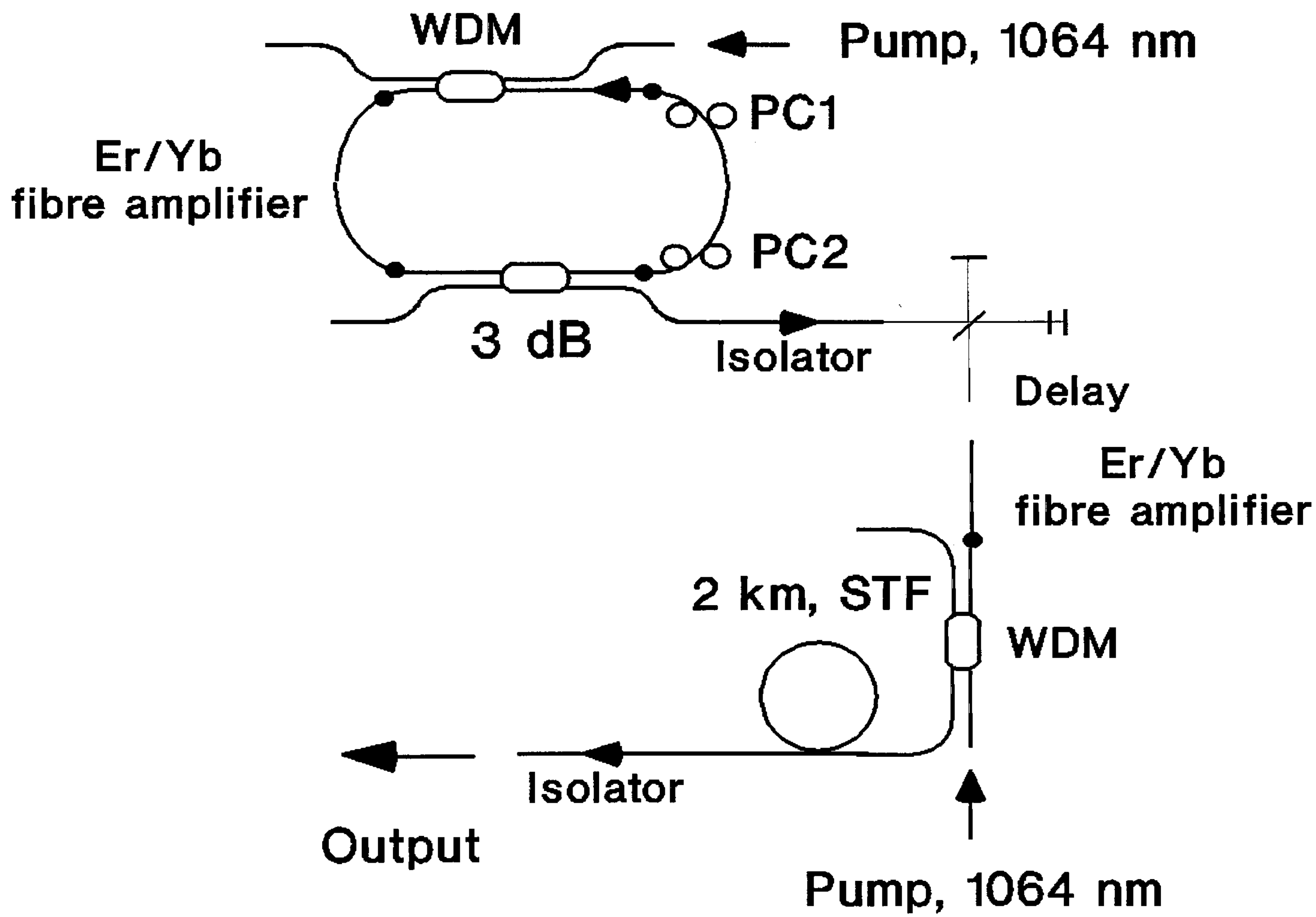

WDM
Pump, 1064 nm
PC1
Er/Yb
fibre amplifier
PC2
3 dB
Isolator
Delay
Er/Yb
fibre amplifier
2 km, STF
WDM
Isolator
Output
Pump, 1064 nm

Fig 1

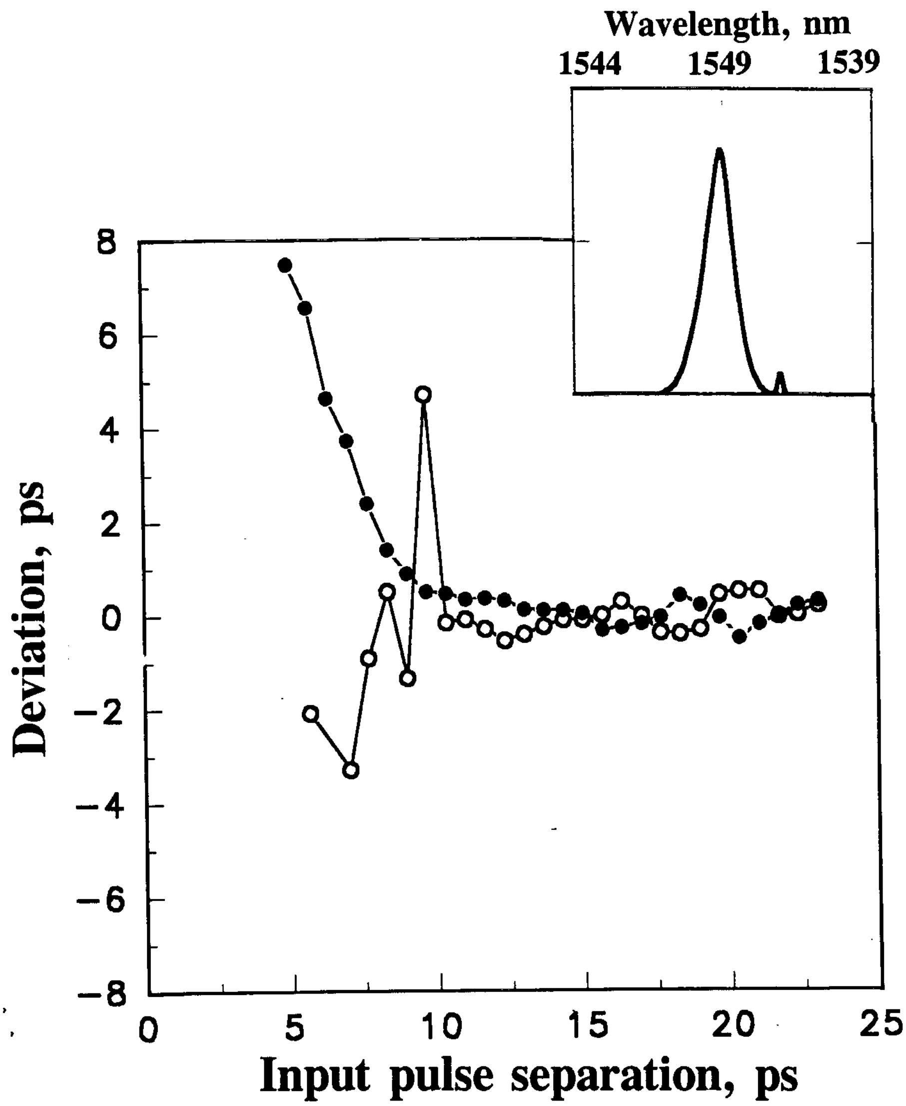
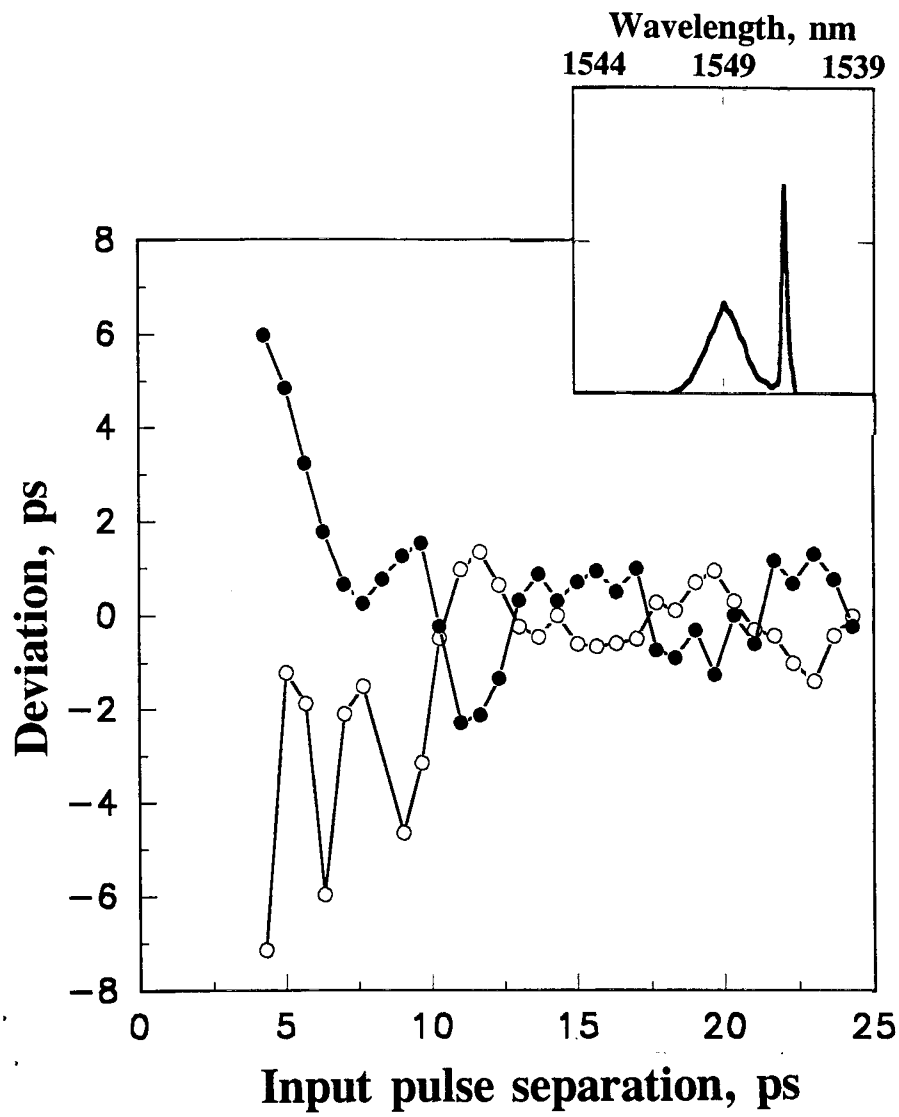

Wavelength, nm
1544
1549
1539
Deviation, ps
8
6
4
2
0
−2
−4
−6
−8
0
5
10
15
20
25
Input pulse separation, ps

Fig 2 [illegible]


Wavelength, nm
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1549
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8
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2
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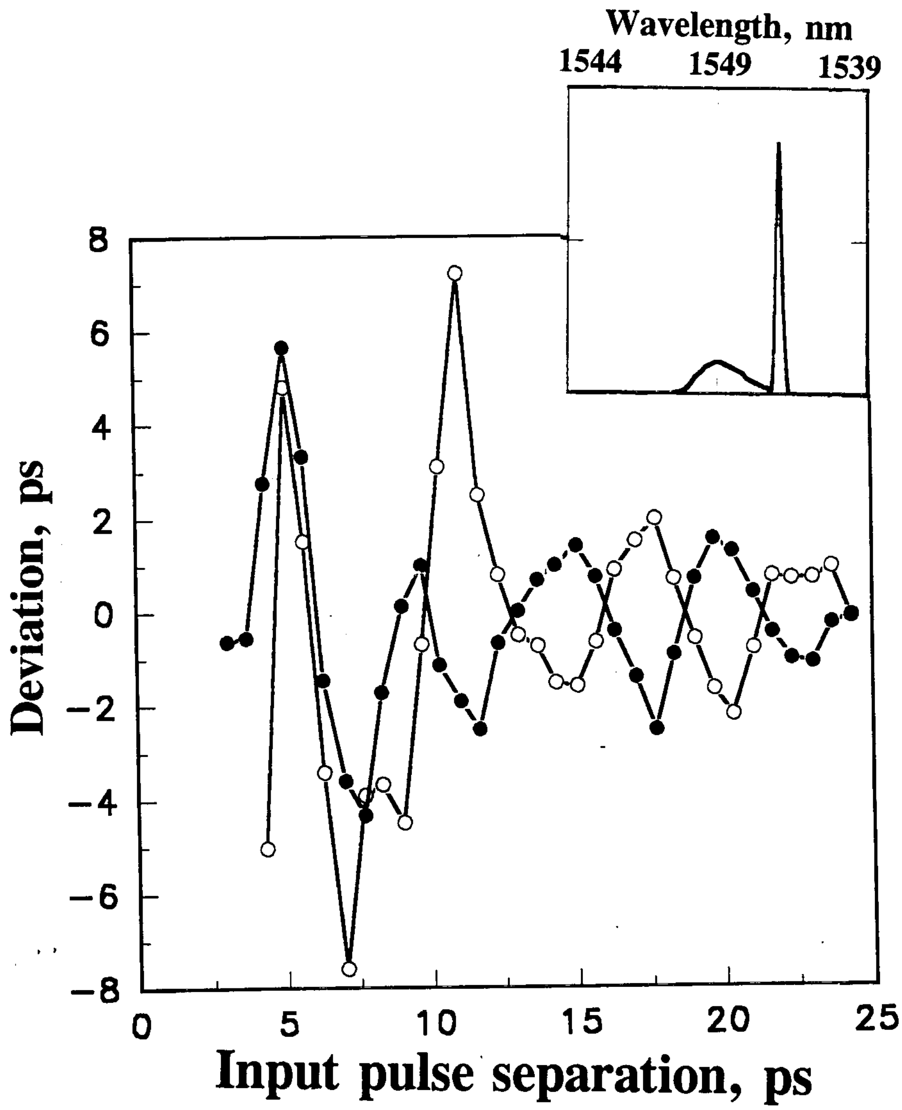
−2
−4
−6
−8
Deviation, ps
0
5
10
15
20
25
Input pulse separation, ps

Fig 2b


Wavelength, nm
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1539
8
6
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0
−2
−4
−6
−8
Deviation, ps
0
5
10
15
20
25
Input pulse separation, ps

Fig 2c