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All-optical 'AND' gate using gap soliton formation in a fibre Bragg grating

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Abstract: We experimentally demonstrate an all-optical 'AND' Gate based on coupled gap soliton formation in an unchirped fibre Bragg grating. A switching contrast of better than 17dB was otained with an incident pulse peak power of 2.5kW.

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The potential applications of gap solitons formed due to the interplay of nonlinear refractive index changes and dispersion in nonlinear Bragg gratings have been well documented on a theoretical basis [1, and references therein] and recently we have demonstrated their generation in photorefractive fibre Bragg gratings (FBGs) [2]. We present, for the first time to our knowledge, an all-optical 'AND' gate based on a configuration proposed by S. Lee and S.T. Ho [3]. The operation of the gate relies on the formation and propagation of coupled gap solitons by two orthogonally polarised high intensity input beams incident within the bandgap of a FBG. Individually, each input operated below the threshold for gap soliton formation and was strongly reflected by the FBG.

The experimental set-up is shown in Figure 1 and apart from the beam splitting optics was identical to that used in reference [5]. The grating, written into a germanosilicate fibre with a mode-area of 30μm^2 (N.A.=0.25, λ_C=1250nm) with a technique similar to that reported in [4], was 8cm long, apodised and unchirped, with 98% peak reflectivity at 1536nm and a 3dB bandwidth of 4.1GHz. The pulses were obtained from a large mode area, erbium doped fibre amplifier chain seeded by a directly-modulated, semiconductor DFB laser [5] giving 25μJ pulses with ≈2ns duration (inset Figure 1).

With the incident signal wavelength tuned into the short wavelength side of the FBG bandgap, good switching was observed with lauched peak powers over 2kW in each beam. Figure 3 demonstrates the case for 2.5kW launched peak power, with traces A and B showing the transmitted pulse intensity profiles for '0+1' and '1+0' inputs to the 'AND' gate. The first two peaks were artifacts of the sharp leading edge spike of the incident pulse and could be systematically removed, leaving only a low level signal accounting for a few percent of the input pulse energy. Figure 3C shows the corresponding '1+1' gate input giving an switching contrast of ≈10dB for the 'AND' gate (excluding leading spikes). The performance was further improved by adding a polariser at the output of the FBG allowing preferential selection of the switched pulse and producing a switching contrast of approximately 60 (excluding the spikes).

The switching behaviour was further studied by varying the power incident in beam A whilst keeping that in beam B constant, the transmitted power is presented in figure 4. Between 2.4kW and 2.6kW incident peak power a distinct jump in the transmission was observed, associated with gap soliton formation within the bandgap of the FBG.

In conclusion, we have demonstrated, for the first time to our knowledge, an all-optical 'AND' gate based on the transmission of gap solitons through a FBG. Switching contrasts of better than 17dB between '0+1'/'1+0' and '1+1' input states were observed at input pulse peak powers above 2kW. The transmitted 500ps switched pulse and the accompanying sharp jump in transmitted energy confirmed the formation of gap solitons within the bandgap of the FBG.

References

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Captions

Figure 1: Experimental setup. LA-EDFA: Large mode-area erbium-doped fibre amplifier. WP1, WP2, WP3: Waveplates. FBG: Fibre Bragg grating. PBS: Polarisation beam-splitter. POL: Optional polarizer. The directly detected (≈50ps resolution) input pulse temporal profile is shown inset.

Figure 2: Directly detected (≈50ps resolution) transmitted pulse intensity profiles for each individual input beam (A, B) and both beams simultaneously (C).

Figure 3: Transmitted pulse energy varying with launched peak power in beam A. The peak power in beam B was held constant at 2.8kW.

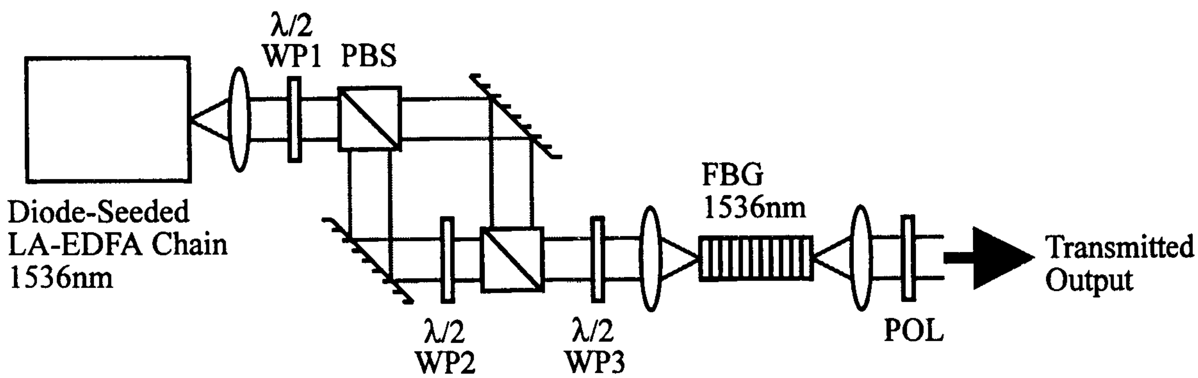
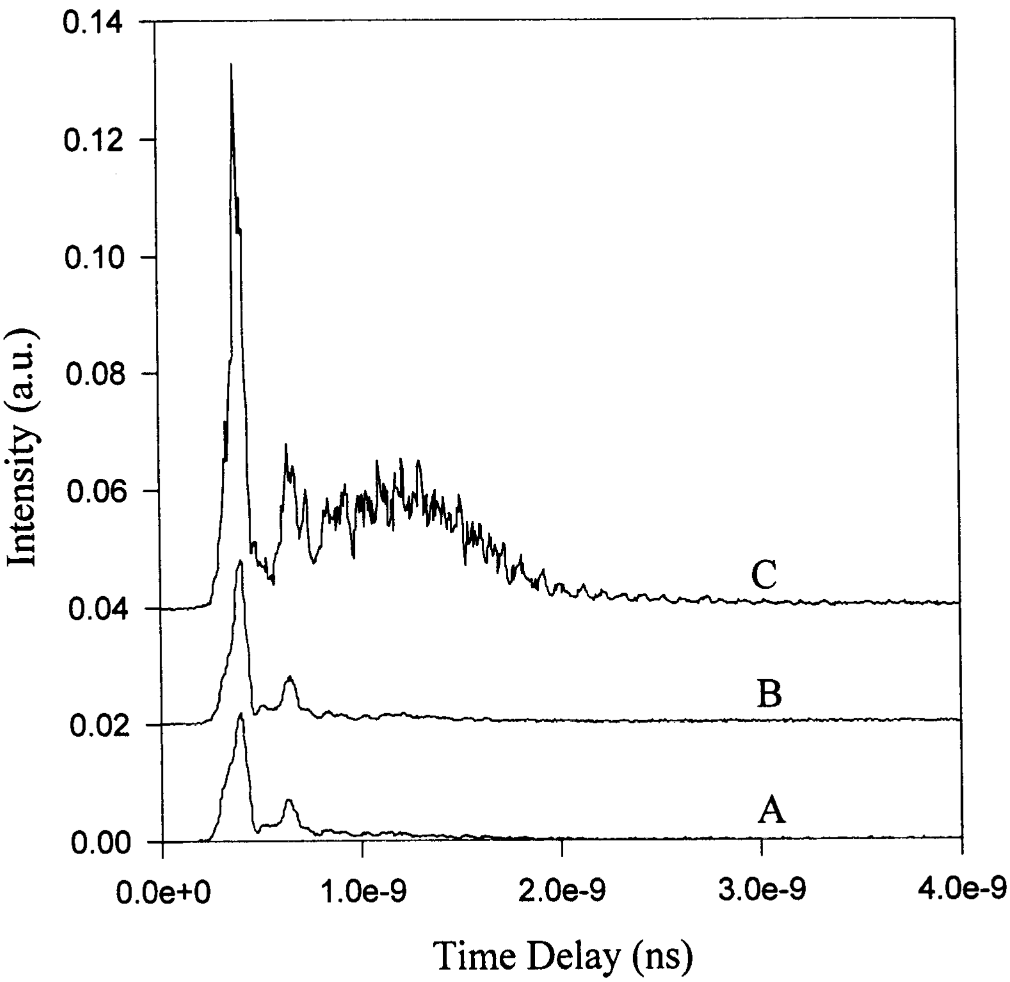

λ/2
WP1
PBS
Diode-Seeded
LA-EDFA Chain
1536nm
FBG
1536nm
Transmitted
Output
λ/2
WP2
λ/2
WP3
POL

figure 1



0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
Intensity (a.u.)
C
B
A
0.0e+0
1.0e-9
2.0e-9
3.0e-9
4.0e-9
Time Delay (ns)

figure 2

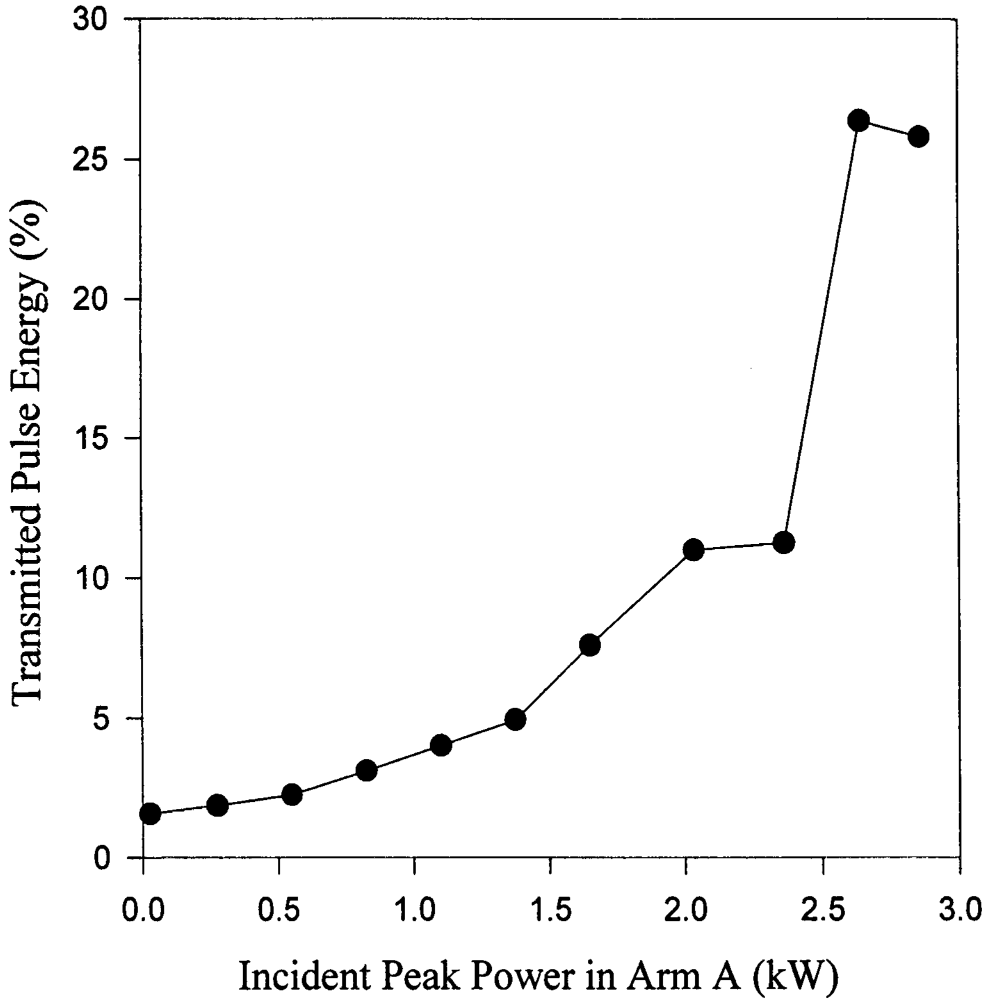

30
25
20
15
10
5
0
Transmitted Pulse Energy (%)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Incident Peak Power in Arm A (kW)

figure 3