Compression of picosecond pulses using photonic crystals

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We demonstrate picosecond pulse compression of up to 40% by transmission through a 6μm long planar photonic crystal waveguide. The corresponding dispersion value is $>10^6$ larger than that of standard single mode fibre.

Keywords: guided-wave optics, photonic crystals, periodic structures, pulse compression

Introduction

The recent development of integrated photonic crystals placed within planar waveguides offers the potential of high density integrated optics with significant functionality [1]. Here the high refractive index contrast structure achieved within the photonic crystals leads to strong spatial and temporal effects, which in turn enable ultracompact components to be formed. Of particular interest to optical communications are devices that are designed to operate in the 1.3μm and 1.55μm wavelength regimes, where photonic crystal based wavelength filters and dispersion compensators could have impact in future high speed systems. However although wavelength filtering has been readily observed in photonic crystals [1], to date pulse compression has not been achieved to the authors knowledge. In this work therefore we report preliminary studies of photonic crystal transmission guides which show significant pulse compression.

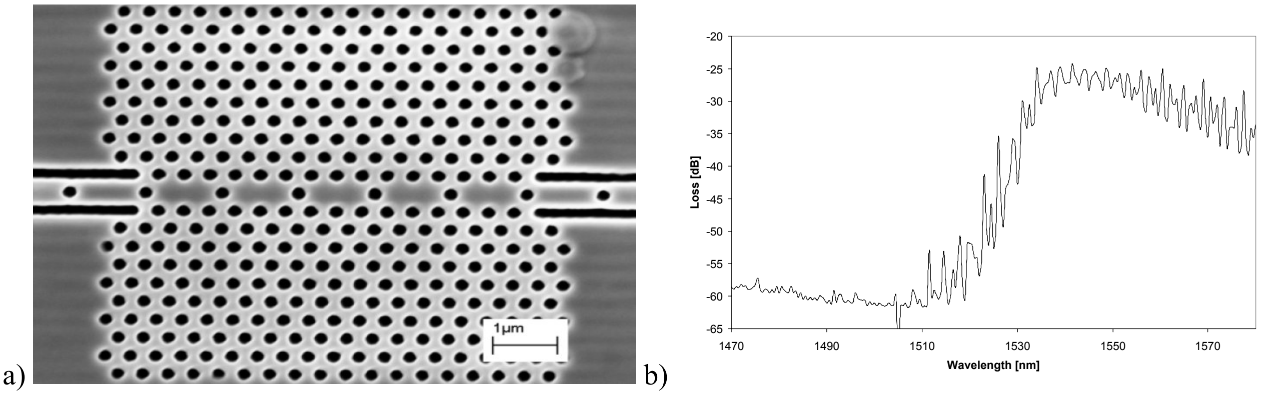

Figure 1 : a) SEM image of photonic crystal in deep etched waveguide, b) Transmission passband characteristic of lattice constant a=460nm.

The photonic crystal structures employed in this paper are L2in1 coupled cavity waveguides [1,2], as shown in figure 1a). The photonic crystal and waveguide are fabricated in a GaAs heterostructure slab waveguide by a two step reactive ion etch process. The etch depth is typically 1μm for the 200-300nm diameter holes in the photonic crystal. By changing the lattice constant, the effect of the photonic crystal can be tuned over a wide spectral range. Figure 1b) shows the measured transmission characteristic for a lattice constant of 460nm, where a strong rising edge for the passband can be observed between 1520nm and 1540nm. The authors have reported initial investigations of the transmission of picosecond pulses through these structures [3], where for the first time the effect of the photonic crystal on high repetition rate pulses in the C-band EDFA region (1535-1560nm) was observed. This paper demonstrates the ability of the photonic crystal to compress sub-picosecond pulses by factors of up to 40%.

Experimental arrangement

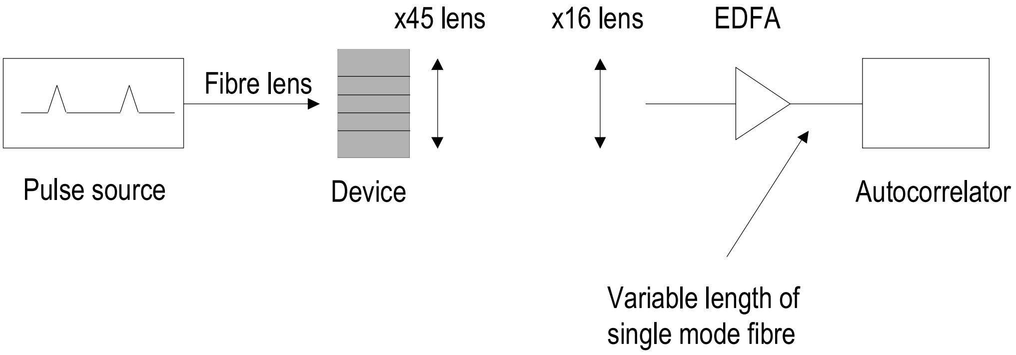

Figure 2 : Experimental setup for pulse compression measurements.

Figure 2 shows the experimental arrangement. The pulse source uses a gain switched DFB laser operating at 1536.1nm with a repetition rate of 1GHz. The pulses are then passed, in turn, through a length of dispersion compensated fibre (DCF) to provide linear pulse compression of the chirped pulse, a length of dispersion shifted fibre (DSF) followed by standard single mode fibre (SMF) to provide nonlinear compression and finally a dispersion-imbalanced loop mirror which acts to suppress the pulse pedestal and broaden the pulse spectrum [4]. After compression, the pulse is transform limited to a minimum width of 500fs, and has a spectral width of 7nm. Due to this short minimum duration, the pulse can be reliably broadened by increasing or decreasing the overall length of standard single mode fibre (SMF) in the system after the DILM. This technique is used to allow pulse compression measurements to be carried out at a range of different input pulse widths. In order to assess the absolute pulse compression performance of the dispersive photonic crystal, measurements of the pulse transmission through the photonic crystal are carried out and compared with transmission measurements through an identical waveguide without a photonic crystal.

Results

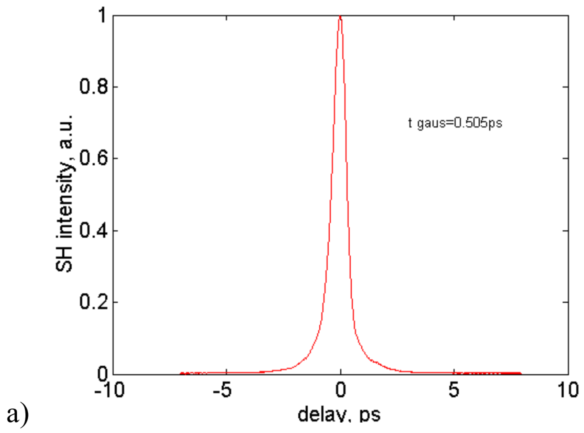

Figure 3: Observed autocorrelation trace of transform limited 500fs width pulse.

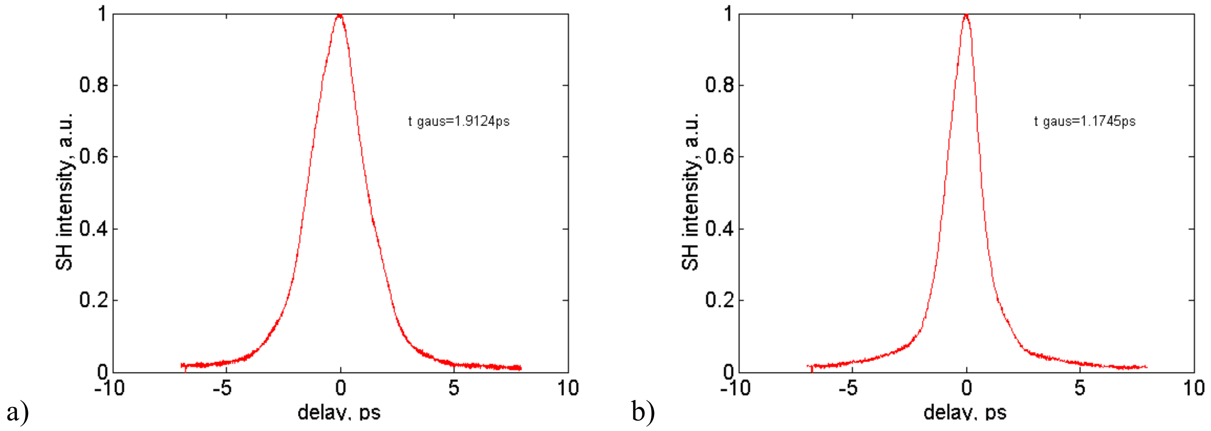

Figure 4: Observed autocorrelation traces of pulse for same fibre length after transmission a) through blank waveguide, b) through waveguide with L2in1 photonic crystal.

Experiments have been carried out to determine the dispersive properties of the photonic crystal by examining the autocorrelation traces of the transmitted pulses. Examples of these are shown in figures 3 and 4. Figure 3 shows the autocorrelation trace of the transform limited input pulse with a duration of 500fs; adding extra fibre to the system increases the pulse width and figure 4 shows the resulting pulses transmitted (a) through the control waveguide without the photonic crystal and (b) that with the photonic crystal. It is clearly observed that the pulse transmitted through the photonic crystal is output with a significantly shorter pulse width (1.17ps) compared with that from the conventional waveguide with a pulse width of 1.91ps. The photonic crystal has therefore caused a pulse compression of 40% in this case.

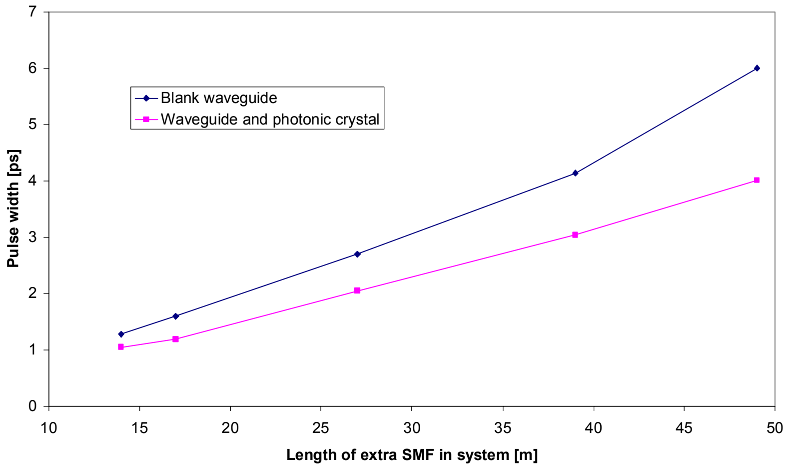

Figure 5: Variation of pulse width with increase of length of SMF in system.

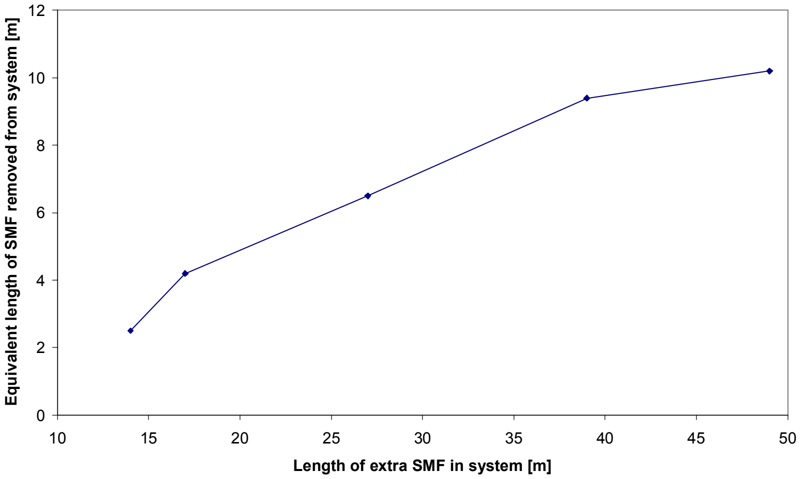

Figure 6: Equivalent length of SMF required to produce compression observed due to photonic crystal.

Furthermore, a series of measurements have been carried out to investigate the compression effect of the photonic crystal as the length of SMF within the system is greatly increased. Figure 5 shows the measured pulse widths for both the blank waveguide and the photonic crystal waveguide, indicating pulse width reductions of up to 2ps across the range of SMF lengths measured.

Comparisons of the length of fibre in the system required to produce a given pulse width through the blank waveguide with the pulse widths observed for the photonic crystal waveguide can be made. These values demonstrate the length of fibre that needs to be removed to produce a compression equivalent to that achieved by the photonic crystal. Figure 6 illustrates these values, showing that the 6µm long photonic crystal can achieve compressions equivalent to SMF lengths of up to 10m. Thus the dispersion induced by the photonic crystal is $>10^6$ larger than that of standard single mode fibre at these wavelengths.

Conclusions

We have shown picosecond pulse compression using an integrated photonic crystal. Compression values of up to 40% were achieved, with the dispersion value being $>10^6$ larger than standard SMF. We believe that this is the first demonstration of pulse compression observed in a planar photonic crystal waveguide using the dispersive properties of the photonic crystal. Such high dispersion is very attractive as it will allow photonic crystals to be used in applications such dispersion compensation and integrated nonlinear components where dispersion is used as part of the switching mechanism. It is believed that higher compression ratios can be achieved by careful design of the photonic crystal dispersion characteristics and the use of a shorter pulse with a broader spectrum.

References

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