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HOLEY FIBER BASED TUNEABLE WDM WAVELENGTH CONVERTER USING CROSS-PHASE MODULATION AND FILTERING

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Abstract: *We demonstrate a tuneable WDM wavelength converter based on XPM and filtering in just 6m highly nonlinear holey fiber. Broadband 10Gbit/s wavelength conversion (~20nm) with a constant pulsewidth was achieved due to the reduced walk-off.*

Introduction

Holey fiber (HF) technology has progressed rapidly in recent years and is of great interest for various fiber device applications due to the broader range of optical properties that are possible in these fibers relative to conventional fibers /1,2/. One of the most promising applications of HFs is in the development of nonlinear optical devices for fiber-optic communication systems. HFs can have much higher nonlinearity per unit length than conventional fibers, and devices based on such fibers can thus be much shorter in length, and/or operate at lower power levels. For example, we have demonstrated a regenerative all-optical switch based on SPM and spectral filtering in just 3.3 m of HF /1/. We also showed that it was possible to obtain ~ 42 dB signal gain in an L^+-band Raman amplifier based on just 75 m length of HF /2/. Recently results on the operation of a nonlinear optical loop mirror switch based on cross-phase modulation (XPM) in a 5.8m HF have been reported /3/.

In this paper, we show that HF technology can be applied to provide another important nonlinear function required within wavelength division multiplexing (WDM) systems – namely tuneable WDM wavelength conversion. We demonstrate broadband wavelength conversion over ~20nm bandwidth at a data rate of 10 Gbit/s using a combination of XPM in a short length of HF followed by narrowband filtering.

Experimental results

Our experimental set up is shown in Fig. 1. 2.5ps pulses at a repetition rate of 10GHz are first generated using a regeneratively mode locked erbium fiber ring laser (EFRL) operating at 1551nm. These pulses are then modulated to obtain a 10 Gbit/s, 2^{15}-pseudorandom control pulse stream. We combined the control pulses and three probe beams together using a combination of 50/50 couplers prior to launching the light into the HF. The probe beams were generated from continuous wave (CW) external cavity lasers tuneable in the range of 1530~1580nm. Polarisation controllers were included on both the control and probe launching paths into the HF so that all of the beams could be launched onto a single polarisation axis of the polarisation maintaining HF. Both the control and probe signals were amplified using an Er/Yb amplifier with a maximum saturated output power of ~800mW, and were then lens coupled into a 6m length of HF with a coupling efficiency of 40%.

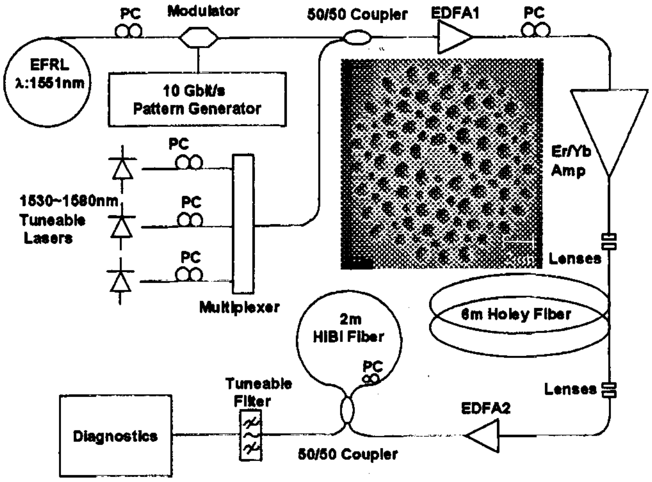

Fig.1 Experimental setup. Inset; cross-sectional SEM image of the holey fiber used.

A cross-sectional SEM profile of the highly nonlinear HF used in this experiment is shown in the inset of Fig. 1. The core diameter is ~2.0μm and the outer diameter is 125μm. The measured dispersion at the wavelength of 1550nm was +100 ps/nm-km and the measured fiber loss was 50dB/km. From a measurement of the SPM induced nonlinear phase shift versus launched optical power, we obtained an estimated value of $\gamma=31W^{-1}\cdot km^{-1}$ for the nonlinearity coefficient and an estimated effective area of $A_{eff}=2.93(+/-0.3)\mu m^2$. This nonlinearity is ~20 times higher than that of a conventional dispersion shifted fiber.

XPM between the control signal and the CW beam results in chirping of the CW laser beam where these beams overlap temporally within the fiber. This frequency chirping can then be converted to a frequency converted signal by passing this chirped signal through a narrowband filter with which to eliminate the residual unchirped CW signal. In our initial experiments we used a loop mirror based on 2m of HiBi fiber to obtain a notch filter (~25dB extinction ratio) to eliminate the CW wave. The filter also has a periodic response in the wavelength domain making it suitable for multi-wavelength operation. The notch filter was followed by a 1-nm bandwidth tuneable filter to allow us to select one of the two XPM- induced side bands /4/.

At first, we performed a tuneable single wavelength conversion experiment to characterise our HF based device. Fig.2 shows the measured optical spectra using a 1542nm probe beam after the HF only and after both the HF and the 1nm filter.

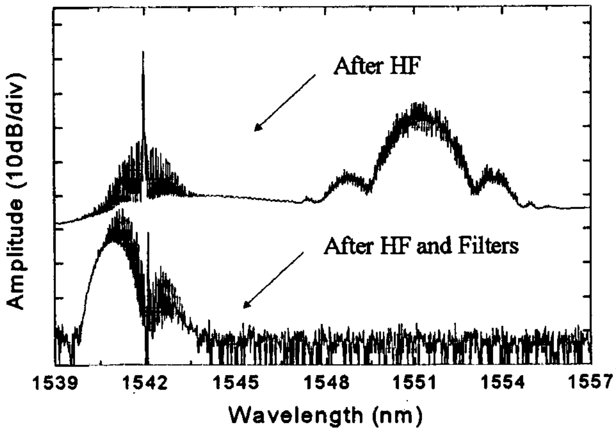

Fig.2 Measured optical spectra of control and probe signals after the HF.

Fig. 2 clearly shows that the 1542nm probe is spectrally broadened due to XPM with the control signal, whilst the control signal itself also shows a small amount of spectral broadening caused by self-phase modulation.

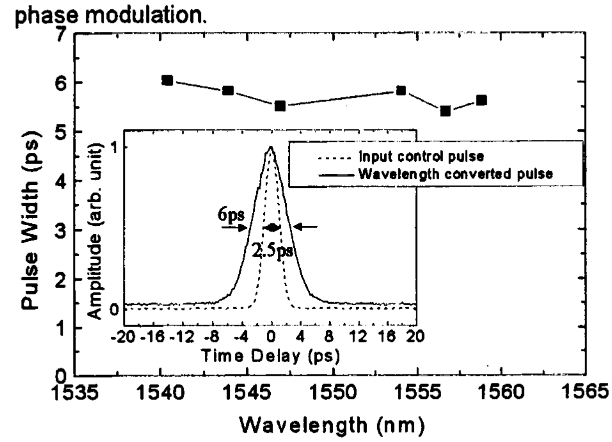

Fig.3 Measured FWHM of wavelength converted pulses as a function of probe beam wavelength. Inset: SHG autocorrelation traces of wavelength converted pulses at 1540nm.

In Fig.3, we plot the measured temporal width of the wavelength-converted pulses as a function of probe beam wavelength. The pulsewidths of the converted pulses were observed to be almost constant at ~5.8ps over a wavelength range of ~20nm. This operation range was limited solely by the tuning range of the tuneable filter since the walk-off effect between control and probe light was essentially negligible due to the short length of HF used. The time-bandwidth product of the converted pulses was ~0.46 which is although somewhat larger than that of the original control soliton pulses (0.35, transform-limited) still indicates high quality pulses. A degree of amplitude noise was observed on the converted channels and which can be attributed to coherence degradation due to the anomalous dispersion of this particular fiber /5/. Normal dispersion within such fibers can however, readily be obtained by slight modification of the fiber structure.

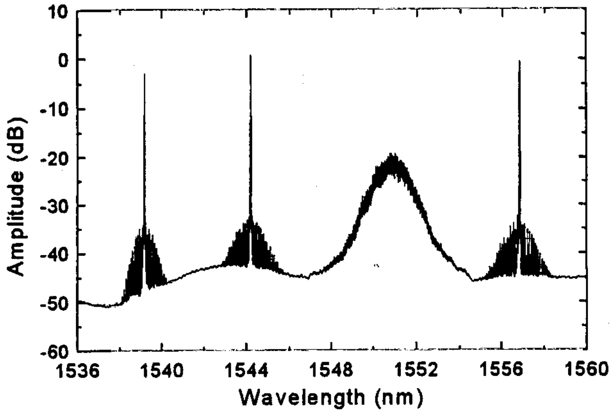

Fig.4 Measured optical spectrum of three probe signals with control pulses after the HF.

Finally, in order to confirm the possibility of simultaneous wavelength conversion to multiple wavelengths, we launched three probe beams with the control pulses into the HF. Each probe beam was observed to broaden spectrally (as shown in Fig.4), and by tuning our filter we were able to generate pulse streams at each of the three wavelengths.

Conclusions

We have experimentally demonstrated a tuneable WDM wavelength converter using XPM and spectral filtering employing just 6m of HF. Wavelength conversion over a ~20nm tuning range was achieved with negligible pulse width variation due to pulse walk-off. Simultaneous conversion of multiple wavelengths using the same configuration was also demonstrated. The use of a HF with normal dispersion to reduce coherence degradation, and fiber grating technology to provide improved spectral selection of the wavelength converted signal should allow for the development of practical, all-fiber, high performance WDM wavelength converters.

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References

1 P. Petropoulos et al. Optics Lett., 26(2001) p.1233.
2 Z. Yusoff et al. Optics Lett., 27(2002), p.424.
3 J. E. Sharping et al. IEEE Photon. Technol. Lett., 14(2002), p.77.
4 P. Ohlen et al. IEEE Photon. Technol. Lett., 12(2000), p.522.
5 N. Nakazawa et al. Optics Lett., 24(1999), p.318.