Chapter 48
An Efficient DFG Induced Wavelength Exchanged-OPC Using Only Two Ti:PPLN Waveguides

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Abstract Wavelength Exchanged Optical Phase Conjugation (WE-OPC) through Difference Frequency Generation (DFG) employing two identical Titanium doped Periodically Poled Lithium Niobate (Ti:PPLN) waveguides having same grating period and a single pump source is theoretically analyzed and simulated resulting in higher conversion efficiency of OPC. WE-OPC has been found very effective in mitigating nonlinearity and increasing spectral efficiency in optical transmission systems. In our proposed model with 10 channels, much higher conversion efficiencies of about 3.3 dB and 3.49 dB are obtained for higher frequency band to lower frequency band and vice versa respectively.

48.1 Introduction

For transmission of Wavelength Division Multiplexed (WDM) signals, optical phase conjugation (OPC) has been found very effective in mitigating nonlinear impairments resulting from Kerr effect [1]. In a conventional OPC, the phase conjugated idlers are generated from signal band to a different idler band and thus a large reserved frequency band is kept unused in transmission system which reduces its spectral efficiency by half. Recently WE-OPC has been reported to overcome this limitation [2]. In this scheme WDM signal is split into two frequency bands and then the Low Frequency (LF) signal band is phase conjugated to the High

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Frequency (HF) idler band and simultaneously the HF signal band is phase conjugated to the LF idler band. This process eliminates the need to keep a reserved band thereby increasing the spectral efficiency of the transmission system. In the WE-OPC schemes proposed so far, using Cascaded Second Harmonic and Difference Frequency Generation (cSHG:DFG) process, four PPLN waveguides are required for conjugated wavelength conversion [2].

In this study we achieved, for the first time, WE-OPC using two Ti:PPLN waveguides. In order to overcome the limitation of conversion efficiency, we have employed two identical Ti:PPLN waveguides for DFG process and one external pump of 767 nm is fed into the Ti:PPLN waveguide to generate the idler spectrum. The choice of DFG over cSHG:DFG for idler generation increases efficiency of OPC [3]. This reduces the complexity of practical arrangement of four Ti:PPLN waveguides. Moreover, usage of only two Ti:PPLN waveguides reduces the coupling losses associated with the waveguides.

48.2 Proposed Scheme

We propose the technique of WE-OPC using two Ti:PPLN crystals for complementary spectral inversion in WDM transmission systems through DFG. Here a Ti:PPLN ridge waveguide with single grating period is considered. The simulation parameters are taken from the PhD. dissertation by Gui [4]. In our proposed configuration we have used two Ti:PPLN ridge waveguides with identical grating period. The WDM signal band is split into two frequency bands using high/low pass filter (H/LPF). A laser diode is temperature tuned to generate the pump light of 767 nm, which is then split into two branches using 50/50 coupler. Each pump light is injected into the respective Ti:PPLN waveguide to undergo DFG with the signal in the waveguide. The HF signal (1519–1529 nm) is coupled along with one branch of 767 nm pump signal with peak power 100 mW using a WDM coupler and sent through Ti:PPLN-1 waveguide to undergo DFG. The LF signal (1543–1553 nm) is similarly coupled along with another branch of 767 nm pump signal and sent through the Ti:PPLN-2 waveguide to undergo DFG. At the output of each Ti:PPLN crystal respective idler bands are obtained which are filtered out using an optical band pass filter (BPF). The respective LF and HF bands obtained are then coupled using another WDM coupler to reconstruct the original signal band. For simulation of proposed WE-OPC in fiber optic transmission line using two Ti:PPLN waveguides we have used OptiSystem of Optiwave simulation software. In the simulated transmission system, 20×10 Gb/s NRZ WDM signal is transmitted over an 80-km long span of standard single-mode fiber (SSMF). Figure 48.1 shows the schematic of a WDM fiber optic transmission system consisting of the transmitter, span of SSMF, the dispersion compensator module, Er:Yb co-doped fiber, chirped fiber Bragg grating, circulator and the receiver.

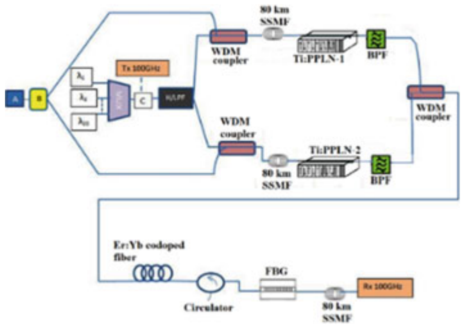

Fig. 48.1 Schematic diagram of a WDM fiber optic transmission system with the proposed Ti:PPLN waveguide. A–Laser Diode, B–50/50 coupler, C–Mach Zehnder Modulator

48.3 Result and Discussion

The power of the generated phase conjugated signal for HF band to LF band conversion and vice versa is calculated using the following equation:

$$P_i = \frac{32 d_{33}^2 P_s P_f L^2}{\varepsilon_0 c n_i n_s n_p \lambda_i^2 S_{eff}} \sin c^2\left(\frac{\Delta \mathrm{kL}}{2}\right) \tag{1}$$

where, $d_{33} = 31.5$ pm/V is the nonlinear coefficient of $LiNbO_3$, L is the interaction length, P_f is the pump power, P_s is the peak signal power, ε_0 is the permittivity in free space, c is the speed of light, n is the refractive index, λ_i is the idler wavelength, S_{eff} is the effective cross section area, Δk is the phase mismatch and the subscripts i,s,p denote idler, signal and the pump waves. Figure 48.2 shows the power spectrums of the output phase conjugated signals both for HF band and LF band input signals. The conversion efficiencies for HF band to LF band and vice versa, for an interaction length of 5 cm are obtained as 3.3 dB and 3.49 dB respectively.

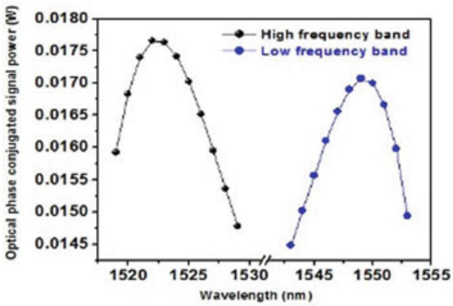

Fig. 48.2 Phase conjugated power spectrum of HF band signal and LF band signal input

48.4 Conclusion

We have successfully proposed and analyzed a design using WE-OPC which reduces the number of Ti:PPLN crystals to two by using only DFG process and thus increases the spectral efficiency of the transmission system.

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