Phase Control of Double-Pass Cascaded SHG/DFG Wavelength Conversion in Ti:(Zn:)PPLN-Channel Waveguides

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Guided wave $\chi^{(2)}$ nonlinear frequency conversion via cascaded processes such as frequency doubling and different frequency generation (cSHG/DFG) is an attractive means for wavelength conversion in high bit rate WDM-systems [1, 2]. The efficiency of corresponding devices strongly increases with the nonlinear interaction length (Fig. 1a). Therefore, longer devices are more efficient provided (quasi-) phase matching can be maintainned over the whole length. As alternative, a double-pass approach may be used to increase the interaction length. Such a configuration requires a broadband dielectric mirror on one end face of the waveguide. As it induces wavelength dependent phase-shifts of the reflected waves, the direction of energy transfer by the nonlinear interactions may be reversed in backward direction after reflection unless appropriate phase control allows readjustment.

We report wavelength conversion in the 1.55 µm telecom window by double-pass cSHG/DFG in Zn- resp. Ti-indiffused, periodically poled lithium niobate (PPLN) channel waveguides. Dispersion in LN itself is used to compensate wavelength dependent phase shifts of fundamental-, SHG (pump)-, signal-, and idler waves upon reflection. Two alternative approaches have been investigated: (1) using an unpoled section of a Zn:PPLN waveguide in front of the end face mirror to adjust the phase differences of the interacting waves by a small wavelength tuning of the fundamental wave (higher order approach); (2) tilting the domain grating of a set of Ti:PPLN waveguides and selecting the guiding channel with the right domain fraction in front of the mirror to adjust the phase differences (zero order approach).

The Zn-doped channel guides were defined by photolithographic lift-off of a 98 nm thick e-beam deposited zinc layer and subsequent indiffusion (900°C, 130 min) into a 45 mm long Z-cut $LiNbO_3$ substrate. Standard E-field poling was used to fabricate the domain grating of 17.96 µm period. A 1 cm long section of the guides adjacent to the mirror coated end face remained unpoled. The Ti:$LiNbO_3$ strip guides were photolithographically delineated in a 98 nm thick e-beam evaporated Ti layer and then indiffused (1030°C, 13 hrs) into a 32 mm long Z-cut $LiNbO_3$ substrate. A tilted (0.4°) domain grating of 16.3 µm period was again fabricated by E-field poling. On one polished end face of both samples a broadband dielectric mirror of > 98 % reflectivity at all four wavelengths was deposited. The other end face of both samples was angle polished to avoid Fabry Perot effects.

To investigate double pass cSHG/DFG wavelength conversion a tuneable external cavity laser and a DFB laser were used as fundamental- resp. signal sources. After boosting the fundamental power using an EDFA it was multiplexed with the signal wave via a 3-dB fibre coupler and launched into the PPLN-waveguide.

Single- and double-pass SHG and cSHG/DFG were investigated. By both approaches of the double-pass scheme, the frequency conversion efficiencies could be considerably improved by ~ 5 dB (SHG) and by ~ 8 dB (cSHG/DFG) using 100 mW coupled fundamental power (Fig. 1b). This improvement agrees with the theoretical prediction. However, the power levels of SH- and idler waves are significantly higher than measured (Fig.1 a). We assume that this is due to waveguide inhomogeneites (chirp) and a nonideal domain duty cycle.

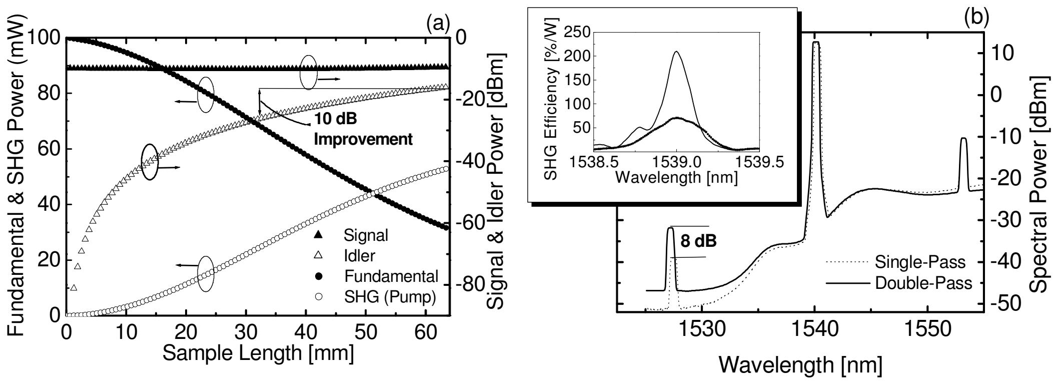

Fig. 1 (a) Calculated power evolution of the four interacting waves; (b) Wavelength conversion by single- and double-pass cSHG/DFG in a Ti:PPLN waveguide with tilted domains for phase adjustment: measured output spectra. Inset: SHG for single- and double-pass interactions.

References

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