Abstract

Efficient ultra-fast integrated all-optical wavelength converters and parametric amplifiers transparent to the polarization, phase, and modulation-level and -format are investigated. The devices take advantage of the optical nonlinearity of Ti:PPLN waveguides exploiting difference frequency generation (DFG). In a DFG, the signal (λ_s) is mixed with a pump (λ_p) to generate a wavelength shifted idler ($1/\lambda_i = 1/\lambda_p - 1/\lambda_s$). The mode-selective excitation of the pump (shorter wavelength) is difficult in a directly pumped DFG. However, by internal generation of the pump via cascaded second harmonic generation and DFG (cSHG/DFG) or sum frequency generation and DFG (cSFG/DFG), the phasematched pump (SH or SF) mode can be excited selectively. Therefore, efficient generation of the pump in Ti:PPLN channel guides is investigated using different approaches.

In the waveguide resonators, first a resonance of the fundamental wave alone is considered. It is shown that the maximum power enhancement of the fundamental wave, and therefore the maximum SHG efficiency, can be achieved with low loss matched resonators. By this way, SHG efficiency of ~ 10300%/W (10.3 %/mW) has been achieved in a 65 mm long waveguide resonator. Its operation for cSHG/DFG requires narrowband reflector for fundamental wave only. Thus, the SH (pump) wave resonator is investigated. The SH-wave resonator enhances the intracavity SH power only. Based on this scheme, an improvement of ~ 10 dB for cSHG/DFG-based wavelength conversion efficiency has been achieved with 50 mW of coupled fundamental power in a 30 mm long Ti:PPLN. However, operation was limited to relatively small fundamental power levels (< 50 mW) due to the onset of photo-refractive instabilities destroying the cavity stabilization.

The cSHG/DFG efficiency can be considerably improved by using a double-pass configuration in which all the interacting waves were reflected by a broadband dielectric mirror deposited on the one endface of the waveguide. However, due to the wavelength dependent phase change by the dielectric folding mirror phase compensation is required to maintain an optimum power transfer. Three different approaches are investigated and up to 9 dB improvement of the wavelength conversion efficiency in comparison with the single-pass configuration is achieved.

Polarization-insensitive wavelength conversion is based on a polarization maintaining fiber loop configuration. Since both polarization components can be converted in a contra-directional single-pass waveguide, differential group delay (DGD) equalization between them is automatically provided. With such polarization diversity scheme an error-free polarization insensitive conversion of 320 Gb/s differential quaternary phase shift keying (DQPSK) data with signal pulses of 1.4 ps width has been achieved using the packaged and pigtailed cSHG/DFG-based

wavelength converter. No significant broadening or distortion of the converted data pulses was observed. This indicates an almost unlimited bandwidth for cSHG/DFG.

Using a ring type diversity scheme, a tuneable polarization insensitive cSFG/DFG is investigated. This approach results in a tuneable output wavelength of the idler whereas the input signal wavelength can be kept fixed. In a 70 mm long Ti:PPLN channel guide a conversion efficiency of ~ -7.5 dB has been achieved by 80 mW (20 mW) of coupled pump (control) power level with less than ± 0.5 dB of residual polarization dependence. The tuning range of the idler covers the whole C-band. However, in contrast to cSHG/DFG, pulse broadening of the converted signal will limit the data rate for cSFG/DFG.

For sufficiently high pump power levels wavelength conversion by DFG is accompanied by significant optical parametric amplification (OPA) of the input signal. To increase the fundamental power handling flexibility and to avoid photo-refractive effect, a low duty cycle Q-switched diode-pumped-solid-state (DPSS) laser has been used as the fundamental source. With 2.5 W of fundamental peak power ~ 22 dB of signal gain has been measured.