Experimental reduction of WDM signal crosstalk in fiber optical parametric amplifiers by using orthogonal pumps
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Abstract We show that the signal quality degradation of WDM channels in a two-pump optical parametric amplifier (OPA) is dominated by the cross-gain modulation (XGM) and we demonstrated experimentally that it can be improved significantly by a two-orthogonal-pump OPA (2OP-OPA).

Introduction
Fiber optical parametric amplifiers (OPAs) have recently been demonstrated to be practical amplifiers with high gain [1], large bandwidth [2] and polarization-independence [3]. The quality of signals emerging from OPAs used as signal processors has been investigated by several groups recently, especially with regards to the pump-to-signal RIN transfer [4], cross-phase modulation (XPM) amongst WDM channels [5], etc. However, four-wave mixing (FWM) and cross-gain modulation (XGM) seem to be the fundamental limits for using OPA as WDM amplifier. Previous work has shown that this kind of degradation is already severe with three WDM channels in one-pump OPA (1P-OPA) system [6]. It was also shown that unequal channel spacing slightly improves the degradation. However, the XGM effect still provides a basic detrimental effect when using OPA in WDM systems, mediated through the depletion of the pump(s). Comparing with 1P-OPA, two-pump OPA (2P-OPA) provides an extra degree of freedom, such that a flattened gain spectrum can be achieved by trading with the gain bandwidth [7]. Besides, with complementary phase-dithering, one can obtain a narrow-linewidth idler spectrum, as well as effective suppression of stimulated Brillouin scattering (SBS) [8]. Mid-span spectral inversion (MSSI) using 2OP-OPA in a 320-km transmission link has already been demonstrated [9]. However, there has not yet been any quantitative study about the signal degradation of the WDM channels for such systems. In this paper, we will investigate experimentally how the 2OP-OPA improves performance in terms of XGM and FWM, compared to 2-parallel-pump OPA (2PP-OPA).

Experiment

Fig. 1 2P-OPA configuration. Refer to the text for detail.
Results and Discussion

The results for the polarization sensitivity of the 2P-OPA are shown in Fig. 2. We varied PC6 and observed the gain variation with respect to the signal SOP. The nominal 13 dB signal gain varies by +/- 1.2 dB. Comparing with the conventional 2PP-OPA with the same nominal gain, the latter varies by as much as 11 dB when the signal SOP changes by 90°. The residual polarization sensitivity of the 2OP-OPA may due to the polarization-dependent crosstalk FWM waves, causing asymmetrical depletion of the two pumps and of the input signal [10]. The signal wavelength, \( \lambda_s \), is 1551.1 nm in Fig. 2; similar behavior was obtained for different WDM channels.

The crosstalk levels for 2OP-OPA and 2PP-OPA are –19.45dB and –19.35dB, respectively; both of them are measured with respect to the channel #1 (1551.1nm) as shown in Fig. 3. Therefore, the improvement of the FWM crosstalk level in 2OP-OPA compared to that in 2PP-OPA is insignificant, even though the spurious FWM terms of the latter are severe. The situation is even more severe with all four WDM channels are ON. However, the eye diagrams for 2OP-OPA are much better than 2PP-OPA as shown in Fig. 5. Therefore, it implies that the signal degradation is mainly due to XGM but not FWM. If it was due to FWM, there should be much improvement in terms of the FWM crosstalk when we switch from 2PP-OPA to 2OP-OPA, provided that gain is the same. Similar behavior has been observed for the 1P-OPA that even with uneven channel spacing, the signal quality is still severely degraded [6].

Conclusions

We show that the signal quality degradation of WDM channels in a 2P-OPA is dominated by XGM and we demonstrated experimentally that it can be improved significantly by a 2OP-OPA. Since this OPA is also polarization-independent, polarization interleaving of WDM signals can also be used, leading to an additional improvement in signal quality. These results should help design high-performance OPAs for use in WDM communication systems.

References

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