Experimental Study of Crosstalk in Pump-Modulated Parametric Multicasting Device

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Abstract

We present an experimental study of crosstalk in a 1:40 multicasting architecture based on a one-pump modulated parametric amplifier. The optimal operating region is determined by an extensive sweep of pump and signal powers.

Introduction

Fiber parametric amplifiers (FOPAs), in addition to high gains and wide bandwidth are used in signal processing in optical communication systems [1],[2]. Recently, 1-to-40 multicasting in a one-pump parametric amplifier with a minimum of 12.5dB conversion efficiency and less than 0.5dB of power penalty was demonstrated [3].

The unique combination of wideband multicasting and inherent gain allows the pump data pattern to be efficiently transferred to scalable number of signal copies. However, the presence of more than one channel in a parametric amplifier also leads to signal-signal (idler-idler) crosstalk. Worse, propagation near the zero dispersion wavelength allows for near phase-matched growth in parasitic four wave mixing (FWM) between newly generated copies. Consequently, for equidistantly spaced channels this parasitic FWM represents a dominant source of impairments. In addition to first-order (signal-signal) interaction, the crosstalk due to cascaded FWM that originates from signal-idler and signal-pump interaction is identified as limiting impairment. Furthermore, the interaction complexity describing the total multicasting impairment increases with the number of channels.

In this paper we present an experimental study of FWM-induced crosstalk in a wideband parametric amplifier achieving 1-to-40 multicasting.

Experimental setup

The one-pump parametric amplifier (OPA) experimental setup is shown in Figure 1. A tunable pump source was phase modulated by two harmonics for stimulated Brillouin scattering (SBS) suppression, and amplitude modulated with 10Gb/s NRZ OOK data. The pump was then amplified (EDFA1 and EDFA2) and the excess amplified spontaneous emission (ASE) was rejected by band pass filters (BPF1 and BPF2). The pump was coupled into a 100m long segment of highly non linear fiber (HNLF) with a zero dispersion wavelength at 1559.6nm. 20 continuous wave (CW) DFB lasers were coupled into the HNLF along the pump. The seeds were aligned on standard 100 GHz grid and their center wavelengths ranged from 1578.2nm and 1594.4nm. The parametric process within the HNLF generated 20 idlers positioned between 1528nm and 1542.3nm. The pump-carried data was transferred to the complement of 20 signals and 20 idlers. The parametric process was monitored on a spectrum analyzer (OSA). At the output of the HNLF, the pump was stripped by a WDM coupler, while the amplified signals and the idlers were directed to a band pass filter (BPF3). This filter was tuned to select one of the generated data copies, which was then sent to an OSA and a sampling scope for performance assessment.

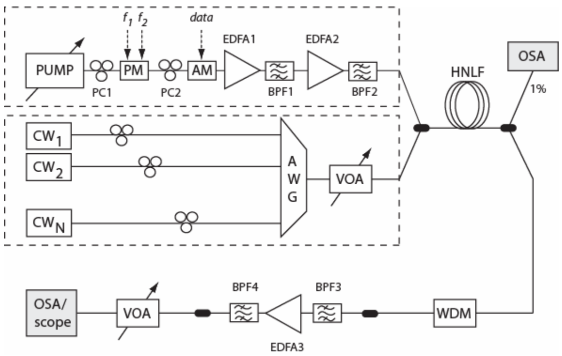

Figure 1: Experimental setup; PC: polarization controller; PM: phase modulator; AM: amplitude modulator; AWG array waveguide multiplexer.

The pump was positioned at 1560.5nm and its average power coupled into the HNLF was swept from 0.5W to 1.5W. The signal input power was controlled by a variable optical attenuator (VOA) positioned before the HNLF. The signals power was also swept from -27dBm to -1dBm per wavelength. The Q factors were measured at the output of the multicast block for different pump and signal powers on 3 idlers: idler 1 at 1542.72nm, Idler 10 at 1534.8nm and Idler 20 at 1528nm.

Experimental results

The spectra at the output of the HNLF for a 1W pump and 3 signal powers are shown in figure 2. In the presence of the pump, the signals are amplified,

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and idlers are generated. At low signal power (-21dBm, Fig. 2(a)), negligible FWM cross-talk generation was observed. As the signal power is increased, the onset of cascaded FWM is observed in vicinity of the pump (fig. 2(b) for -11dBm signal) and signal and idler bands (fig 2(c) and (d)).

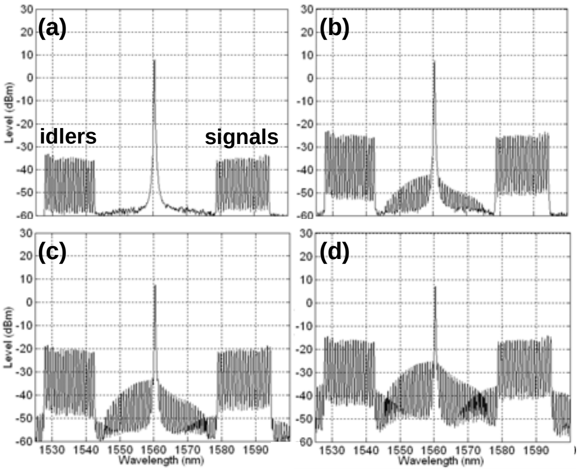

Figure 2: Optical spectra at output of HNLF for 1W pump power and for signal input powers of: (a) -21dBm; (b) -11dBm, (c) -6dBm (d) -1dBm

Experimentally measured Q-factor contour plots for the 2 edge idlers (1528nm and 1542.72nm) and the middle idler (1534.8nm) are shown in Fig. 3 (a), (c) and (b), respectively. An optimal operating region where all idlers have comparable (Q>20dB) performance can be found in between the OSNR-limited region (bottom left corner) and the FWM-limited region (top right corner). It can be observed that the performance evolution of the idler depends on its position; the optimal operating region is dictated by the middle idler which experiences the highest level of cross-talk impairment. It was also observed that the optimum input signal power shifts towards lower values as the pump power increases (i.e. as the gain increases). A linear response with a slope of -1 was measured between the optimum signal input power and accumulated gain. We note that pump power increase beyond 1.3W leads to the Q-factor decrease. This behaviour was attributed to combined increase of in-band cross-talk and uncontrolled pump depletion. Finally, a wide dynamic range operating region was found for pump powers between 0.5W and 1.3W, enabling a 45% input signal power variation around the optimum input power while guarantying a minimum of Q=20dB for all generated copies.

Conclusions

We measured the performance of one-pump multicasting process limited by signal-signal (idler-idler) and signal-pump FWM crosstalk. The power of crosstalk scales with the input signal power and inter-HNLF power evolution and critically depends on the pump power and precise phase matching conditions. This dependence is complex as it involves first-order (linear) and higher-order parametric exchange whose complexity rapidly increases with number of scaled copies. However, we have experimentally shown that a wide operation regime can be constructed, providing nearly impairment-free multicasting of densely positioned channel grid.

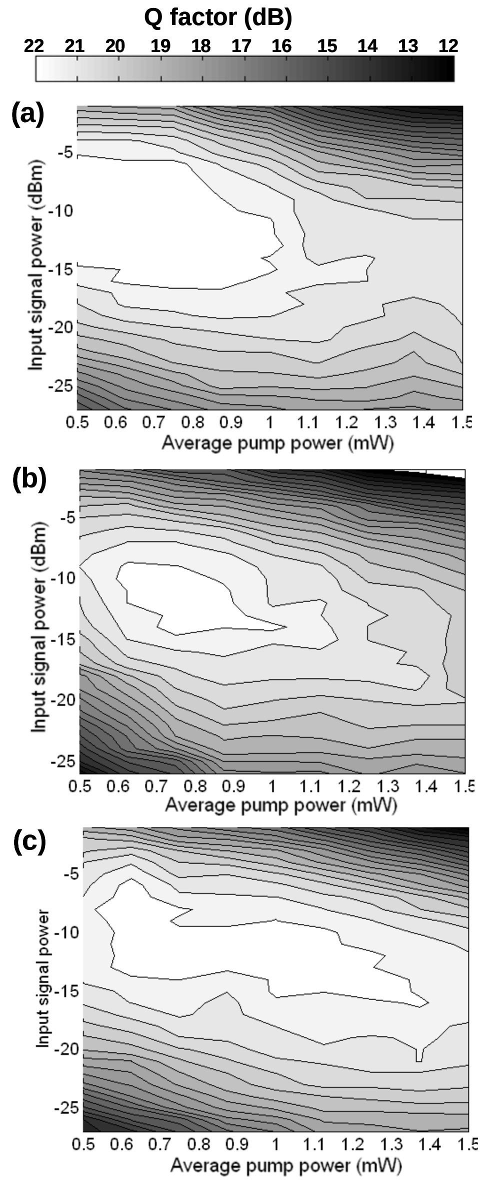

Figure 3: Contour plots of Q factors (dB) as a function of average pump power and input signal power for: (a) Idler 20, (b) Idler 10, and (c) Idler 1

References

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