Gain Clamping in a Fiber Optical Parametric Amplifier

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Abstract: We have experimentally shown that gain clamping is required in fiber optical parametric amplifiers. By using optical gain clamping (OGC), we have reduced gain variation to 1 dB, for signal input variation of 12 dB.

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1. Introduction.

Fiber optical parametric amplifiers (OPAs) can provide high gain with very large bandwidths [1]. Their application in WDM optical communication networks requires gain control under different input conditions, as channels are dynamically reconfigured.

Different gain clamping techniques have been used to control the gain of other type of amplifiers. The most common technique, however, is optical gain clamping (OGC), which has been used to control the gain of erbium-doped fiber amplifiers (EDFAs), thulium-doped fiber amplifiers (TDFAs), and Raman amplifiers [2-4].

A theoretical investigation of performance of fiber OPAs within the context of agile multi-wavelength systems has been performed, and it has been shown that gain clamping may be required to reduce gain variations associated with changes in signal levels [5]. But to our knowledge no experimental work has been performed to date.

In this paper we confirm from experimental data that gain clamping is required in fiber OPAs for their application in photonics networks. We also report, for the first time to our knowledge, a gain-clamped CW fiber OPA with a 1 dB of variation in gain, for signal input variation of 12 dB.

2. Experimental Setup

The approach that we chose for implementing optical gain clamping is that of controllable lasing in the bandwidth of the amplifying medium. The basic principle is to establish by means of fiber couplers a feedback path containing a tunable narrowband filter and a variable optical attenuator. By controlling these components, it is possible to obtain laser oscillation at an arbitrary wavelength, with an adjustable intensity. For high lasing levels, the pump power is depleted, and the gain for the other signal wavelengths is reduced. Under these conditions, the gain variations caused by changes in signal input power are greatly reduced, compared to what happens under open-loop conditions.

The experimental setup for our gain clamping experiment is shown in Fig. 1. Tunable laser (TL1), with a wavelength of 1561.5 nm, was used as the OPA pump source. It passed through a phase modulator (PM) for the suppression of stimulated Brillouin scattering (SBS). The PM was driven by a 10 Gb/s pseudo-random bit sequence (PRBS). The pump was then amplified by high-output- power amplifiers (EDFA), to a level of up to 3 W. The amplified spontaneous emission (ASE) from the EDFA was filtered out by a band-pass filter centered at the pump wavelength. The signal was taken from another tunable laser (TL2), which passed through a polarization controller to maximize the OPA gain, and then through a variable optical attenuator (VOA1), to vary the signal input power. The pump and the signal were then combined by a broadband wavelength division multiplexer (WDM 1480/1550 nm), and injected into a 340-m long highly-nonlinear fiber (HNLF) through a 20-dB coupler. One power meter was placed after the coupler to monitor the power injected into the fiber, and another one measured the pump power reflected by SBS. The output from the HNLF then passed through a 3-dB coupler, which coupled half of the power into the feedback loop; the other attenuated half went to the optical spectrum analyzer (OSA), which was controlled by a computer through a general purpose interface bus (GPIB). In the loop we had a tunable band-pass filter (TBPF), which determined the lasing wavelength (1535 nm), which was different from the signal wavelength (1520 nm). After TBPF, VOA2 was used to set different levels of gain-clamping. Then we used a polarization controller (PC), to maximize the lasing signal power. A second WDM coupler was used to launch the signal into the HNLF. Another power meter was used to keep track of the signal input power to the HNLF; it was controlled by the same computer as the OSA.

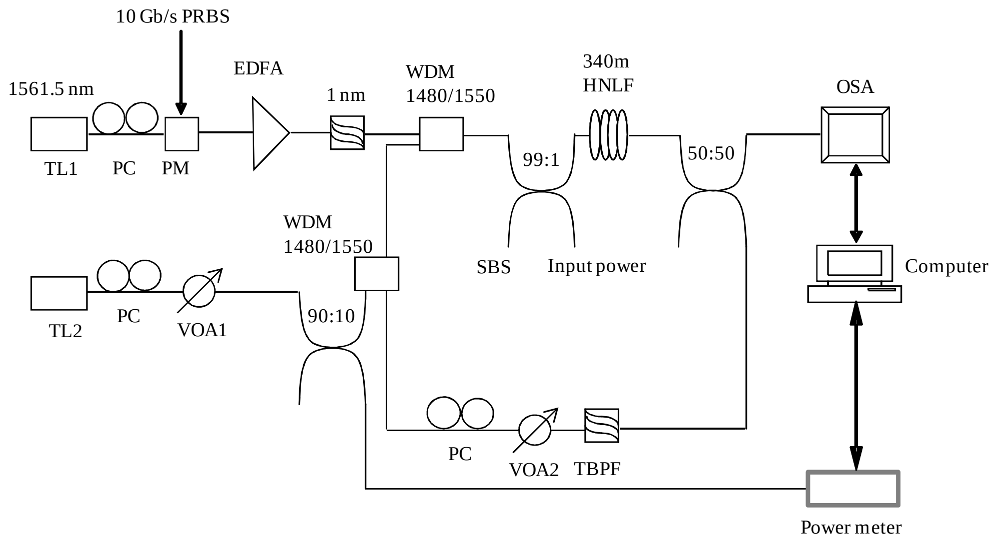

Figure 1 Experimental setup of the gain-clamped OPA

3. Results

In Fig. 2 (a), the open loop signal gain variation for different wavelengths with varying signal input power is shown. Our experimental results match qualitatively with the theoretical simulations presented in Ref [5]. For signal wavelength of 1520 nm, and a pump power of about 30 dBm to the HNLF, there was a signal gain variation of about 4 dB, for a signal input power variation of 12 dB.

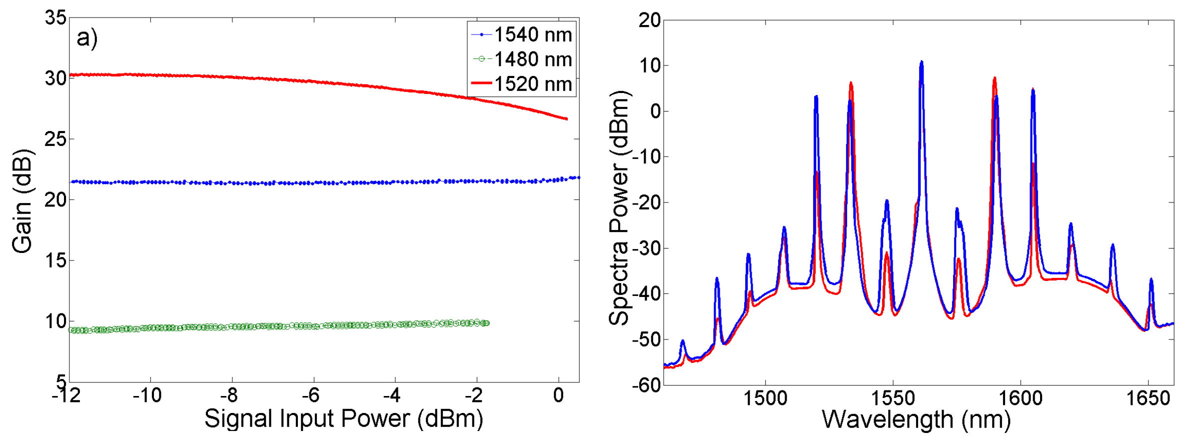

Figure 2 (a) Open loop signal gain variation of different sections of gain profile of fiber OPA. Mid-band region (1520 nm)(solid, red), shorter wavelength region (1480 nm)(green line with circles), and longer wavelength region (1540 nm)(blue line with stars). (b)Gain profile of the OPA with high signal input power (blue line), and low input signal power (red line).Signal wavelength is at 1520 nm, and lasing wavelength is 1535 nm.

For high signal input powers, the gain was reduced, while for low signal input power the gain increased slightly. From these results it can be concluded that gain clamping is required in fiber OPAs.

Fig. 2 (b) shows the working principle of gain-clamping in fiber OPAs. At low signal input power (red line), the lasing wavelength amplitude increases, and it depletes the pump. So, the OPA gain is clamped through the lasing signal amplitude.

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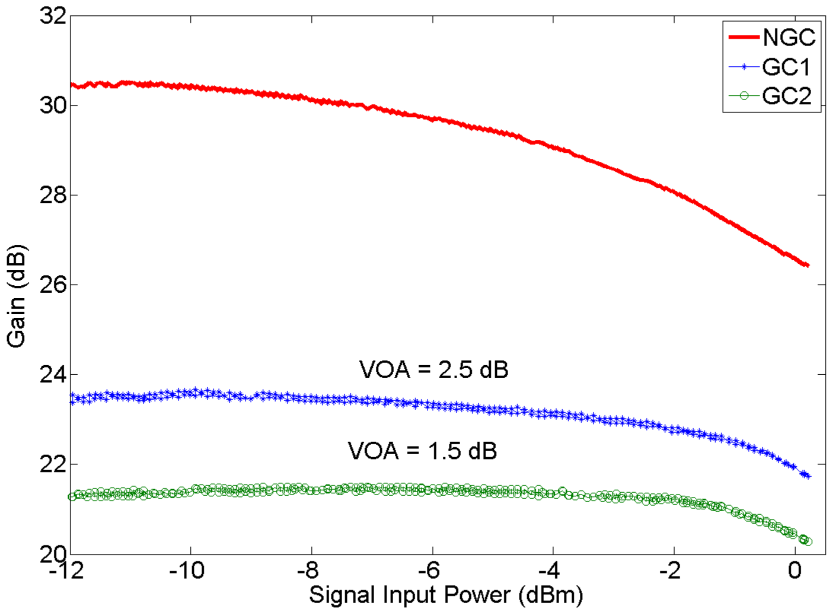

Figure 3. Fiber OPA signal gain variation with signal input power, open loop (red solid line), and with different levels of gain clamping set by VOA (blue line with stars and green line with circles).

Fig. 3 shows the results of gain clamping. With no gain clamping (NGC), we had a variation of about 4 dB in signal gain, with signal input power variation of 12 dB. By contrast, for gain clamping 1 (GC1), the VOA attenuation was set at 2.5 dB, and the signal gain variation with input power was reduced to 1.8 dB; for gain clamping 2 (GC2), the VOA attenuation was set at 1.5 dB, and the gain variation was further reduced to about 1 dB.

4. Conclusion.

We have experimentally verified that gain clamping is needed in fiber OPAs for application in photonic networks. Furthermore, by using optical gain clamping we have reduced the signal gain variation to about 1 dB, for signal input variation of 12 dB. To our knowledge this is the first report of optical gain clamping in fiber OPAs, which shows that OGC should be usable to increase the usefulness of fiber OPAs in WDM optical communication systems.

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5. References

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