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STUDY OF PHASE SENSITIVE AMPLIFIER (PSA) CHARACTERISTIC FOR 80 GBIT/S DPSK DATA INPUT SIGNAL

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ABSTRACT

Simulation of phase sensitive amplifier (PSA) of differential phase shift keying (DPSK) data signal in dual pump is presented. The PSA is designed and simulated using OptiSystem software. A dual pump PSA based on cascaded fiber optic parametric amplifier (FOPA) of 80Gbit/s DPSK data signal is investigated in detail on its gain and noise figure. Results show that PSA has higher gain and lower noise than Phase Insensitive Amplifier (PIA).

Keywords: phase sensitive amplifier (PSA), dual pump, gain, noise figure.

INTRODUCTION

Optical amplifier can be divided into two types, which are Phase Insensitive Amplifier (PIA) and Phase Sensitive Amplifier (PSA). These types of optical amplifiers have their own characteristics. PIA already known has a quantum limited noise Figure-3 dB but the presence of PSA had been break the PIA quantum limited noise figure.

In the last decade, rapid design development of PSA has been witnessed. PSA can be an interesting remarkably powerful tool if carry out with a correct design because it allows amplification with a noise figure lower than quantum mechanics normally determine, and also allows the development of systems that clearly process the phase of their optical inputs (Francesco Da Ros *et al.* 2014). It is recently used to amplify signals in a certain phase and can also remove accumulated phase jitter, which is a critical function for an all-optical phase shift keyed network, and suppress the noise induced phase jitter.

Degenerate PSA (A. Bogris et al. 2010)(T. Umeki, *et al* 2011) and non-degenerate PSA (Z. Tang *et al,* 2010) (P.L Voss *et al*. 2006) are two manner methods of PSA. But these two methods have their own issues that make the PSA held back their progress. However, J. Kakande and R. Tang came out with the idea to overcome this issue by using nondegenerate PSA based on cascaded FOPA. (Joseph Kakande *et al*. 2010) (R. Tang *et al.* 2005).

PSA can be built using nonlinear media, such as highly nonlinear fiber (HNLF) (R. Malik *et al.* 2014), (André A. *et al.* 2015), silicon waveguides (Albuquerque *et al*. 2015), semiconductor optical amplifier and periodically poled lithium niobate (PPLN) (Albuquerque *et al.* 2015). Nonetheless, most researchers tend to use HNLF as the nonlinear media in PSA (Marhic *et al*. 2015).

This paper shows simulation work in OptiSystem software that used dual pump insteed of the single pump. Dual pump can avoid idler spectral broadening due to pump modulation if the pumps are counter phase modulated, as well as requiring lower peak pump powers thus reducing susceptibility to stimulated Brillouin scattering (SBS). In this simulation, we investigate the gain and the noise figure for dual pump PSA based on cascaded FOPA when 80Gbit/s DPSK data signal was injected.

NON-DEGENERATE DUAL PUMP

Non-degenerate dual pump scheme has the potential for WDM regeneration but requires three waves phase-locked with the signal. The PSA scheme considered in this work is based on the dual-pump degenerate FWM in fibers where the two pumps and the signal have the same polarization state. The conceptual scheme of this amplifier is shown in Figure-1. In the same figure, the pump amplitude and phase noise effect on parametric gain are highlighted as well (Bogris *et al*. 2010). Under this condition, the idler coincides with the signal, and their interaction becomes dependent on the input signal phase (McKinstrie and Radic, 2004).

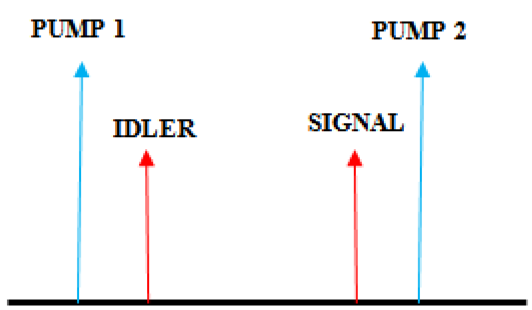

Figure-1. Non-Interferometric fiber based PSA (Non-degenerate dual pump).

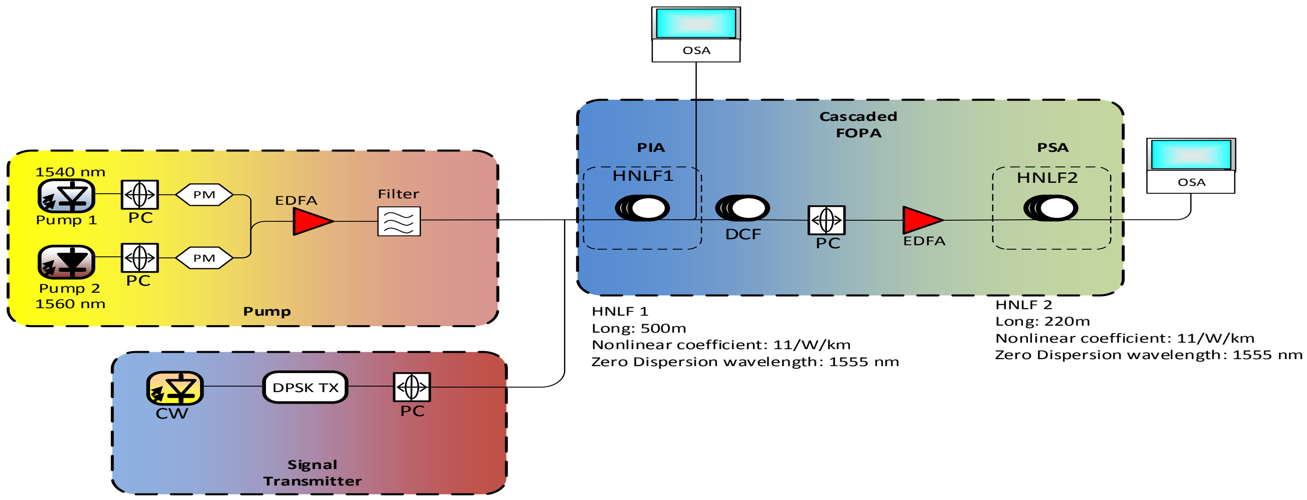

Figure-2. Phase sensitive amplifier simulation setup. CW – tuneable laser source, PC – polarisation controller, PM – phase modulator, EDFA – erbium doped fiber amplifier, HNLF – highly nonlinear fiber.

NOISE FIGURE

Noise figure (NF) of PSA is

$$NF = \frac{1}{G} + \frac{P_{in}\,(S_{out} - S_{in})}{2h\nu I_{out}^{2}} \qquad (1)$$

where P_{in} is the input signal power, S_{out} and S_{in} are the noise power spectral density measured at the input and output of the amplifier, respectively, and I_{out} is the detected output signal photocurrent (Tong et al. 2010).

SIMULATION SETUP

The simulation setup by using OptiSystem software is shown in Figure-2. The setup is divided into three sections, which is pump, signal transmitter and cascaded FOPA. The pump section consists of two tuneable lasers. These two lasers were phase modulated with four RF tones at approximately 100 MHz, 300 MHz, 900 MHz and 2700 MHz to suppress stimulated brillouin scattering (SBS) that caused by the presence of the optical signal itself. The pump then amplified by an erbium doped fiber amplifier (EDFA) and filtered by a 2 nm bandwidth optical bandpass filter (OBPF) to suppress generated amplifier spontaneous emission (ASE). A third tuneable laser was used as a signal source. The signal is external modulated to provide a 80 Gbits/s DPSK signal. Then both pump and signal section were launched at Highly Nonlinear Fiber 1 (HNLF 1). The HNLF 1 act as the PIA, where a conjugated idler is generated by four wave mixing process (FWM). This fiber using a 500 m long with a nonlinearity coefficient of 11/W/km and zero dispersion wavelength (ZWD) 1555 nm. Followed by a dispersion compersating fiber (DCF) to compensate for the dispersion between HNLF 1 and HNLF 2. Subsequently, the pumps, signal and idler waves were boost by using EDFA and input to the second HNLF to realize PSA.

RESULTS AND ANALYSIS

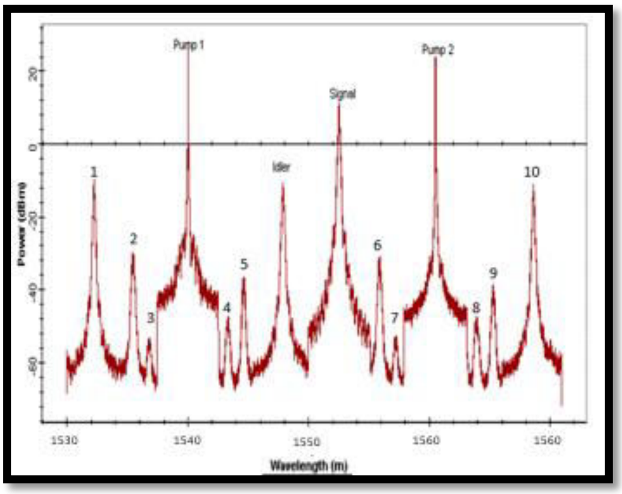

Figure-3. Output spectral for dual pump PSA.

Figure-3 shows the output spectral of this simulation. It shows that the combination between signal and two pump after passing through HNLF 1. The degraded data signals are applied as the pump in the FWM processes. The input signal is parametrically amplified by the strong pump and a phase conjugate new idler field is generated in the process. The pumps are combined with the signal and delivered to a length of highly nonlinear fiber (HNLF) and idler is typically generated at frequency. All idlers act as wavelength shifted replica of the signal and exhibit much less noise compared with the signal. It also shows sidebands labelled 1-10 that produce or generated at HNLF 2. These sidebands can become larger then the signal and it can affect the amount of signal attenuation achievable by adding noise to the signal. The sidebands can be removed by using low gain operation (J. Kakande *et al.* 2010).

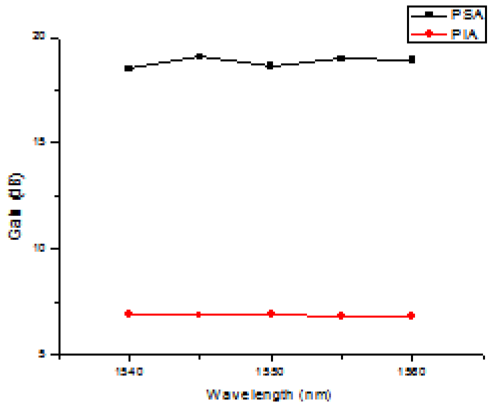

Figure-4. PIA and PSA gain for dual pump at 1540 nm and 1560 nm using 2 W power pump.

Figure-4 shows the gain achieved for dual pump PIA and PSA based on cascaded FOPA. These gain reading had been taken between the two pumps, 1540 and 1560 nm. We can see the average PSA gain achieved is 19 dB for the pump power of approximately 2 W. The PSA gain is about 12 dB higher than PIA gain.

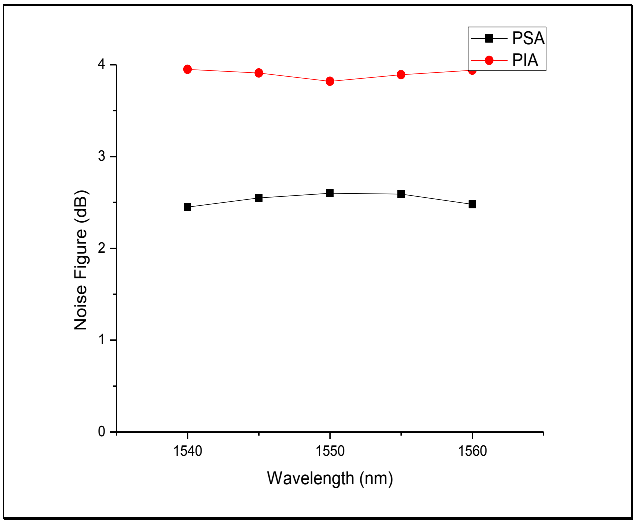

Figure-5. PIA and PSA noise figure for dual pump at 1540 nm and 1560 nm using 2 W power pump.

Figure-5 shows the noise figure for PIA and PSA. It shows that the noise figure for PSA still below than 3 dB. This proved that PSA noise figure lower than the quantum limit of PIA. NF of PIA shown is above 3dB.

CONCLUSIONS

In conclusion, this simulation has proposed the PSA dual pump design. By using 80 Gbits/s Differential Phase Shift Keying (DPSK) data signal, its achieved the high gain for this simulation is 19 dB. For NF reading shows that the PSA NF is lower that PIA NF. These results are in accordance with theory, which is NF for PSA can break the 3 dB quantum limited NF for PIA.

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