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New SOA Based ASE Source Module With High Power, Flat Output spectrum and Low PDL

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Abstract: We propose a new ASE source module configuration based on two SOA for future WDM systems. With carefully selected SOA chips, 1-dB flat output spectrum and low PDL (0.2 dB) are achieved and up to 145mW output power is reported over the L-band at 30°C.

Introduction

To optimize cost and power consumption of modern WDM systems, reducing operational margins is key [1]. However, this would be possible only if the system is continuously operating at the fully filled line systems. Since transmission systems are optimised for a given number of channels and spectral band, a partial usage of the bandwidth would lead to performance variability due to the partial loading of the amplifiers. Indeed, optical amplifiers performance is sensitive to input power which is proportional to the bandwidth usage. The variability of the latter would lead to gain variation and transient effects which would translate into performance penalty. In addition, operating continuously fully loaded systems would ensue simpler optical spectrum management algorithms and simultaneously the continuous monitoring of the hardware operation. Therefore, the loading of the unoccupied portion of the spectrum with amplified spontaneous emission (ASE) has been suggested and used in WDM systems [1].

Besides Erbium doped fibre, Semiconductor Optical amplifier (SOA or Super-luminescent light emitting diodes (SLED)) technology is a very attractive solution for ASE sources due to their small footprint and low power consumption. Therefore many research groups/companies have investigated this technology. It was reported up to 50 mW [2] and 30 mW [3] output power over 50 and 100nm bandwidth respectively. However, performance doesn't meet either the power level or the spectral band of interest of modern and future telecom systems operating in C and C+L band. In addition, a flat output power across the spectral band is highly desirable in order to simplify the system management.

In this paper, we present a new flat ASE source design based on SOA. We report up to 145 mW output power and 1-dB flat output spectrum in L-band with less than 0.2dB polarisation dependence loss (PDL) at 30°C operating temperature. Last, we will compare the output power measurement with the reported state-of-the-art.

ASE source design

The new ASE source design is based on two identical SOA in a loop configuration (Fig. 1) in order to achieve high output power. Indeed, in this configuration, the ASE from the first SOA (e.g. SOA 1) is amplified by the second SOA (e.g. SOA 2), and vice versa. Hence, the total output power can be expressed as the following:

$$\mathrm{P_{out}} = 2\mathrm{P_{ASE}} \times (G + 1) \qquad (1)$$

Where $\mathrm{P_{out}}$ is the source output power, $\mathrm{P_{ASE}}$ and G are the ASE power and gain of an SOA.

A carefully designed gain flattening filter (GFF) based on SOA parameters such as ASE and Gain spectral profiles, is inserted within the loop to produce flat output power across the L-band and to suppress the out-of-band power. The filter profile would hence enable a more efficient amplification of the spectral band of interest.

Since the SOA output light is polarised (TE), the polarisation diversity is achieved by rotating one SOA output to the opposite polarisation (TM) using a half-wavelength (λ/2) plate before combining both beams through a polarisation beam combiner (PBC). This scheme results a low polarisation output light.

Last but not least, isolators are placed after each SOA output in order to suppress optical feedback.

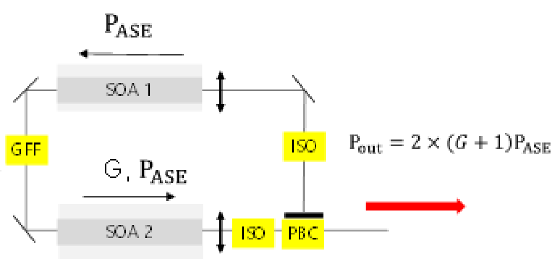

Fig.1: ASE Source design

Selected SOA chips characteristics

The selected SOA chips that were used to

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produce the ASE source module are 3mm long and are based on InGaAsP multi-quantum wells. They include in particular a thick under-cladding layer to attract the mode in the low loss n-doped region. The waveguide is tilted by 7° with respect to the cristallographic direction to reduce optical feedback. Anti-reflection coating was also applied to the optical facet in order to achieve less than 10^{-6} effective facet reflectivity.

The chips were mounted separately on a dedicated carrier with a thermistance (NTC) before characterisation. The carrier thermistance was used to control the operating temperature.

The measured ASE spectrum and gain over the L-band at 1A and 30°C operating temperature are shown in Fig. 2 (a) and (b) respectively. The measured ASE profile is centered at 1600 nm and has a 62 nm 3-dB bandwidth (BW). The measured fiber-to-fiber gain varies between 23 and 25 dB over the L-band. Based on these measurements, we designed a GFF with a parabolic profile, with 4dB loss in the center (Fig. 2(c)). The GFF measured profile was compared with the design. An extra 0.2-dB ripple from the original profile was noted.

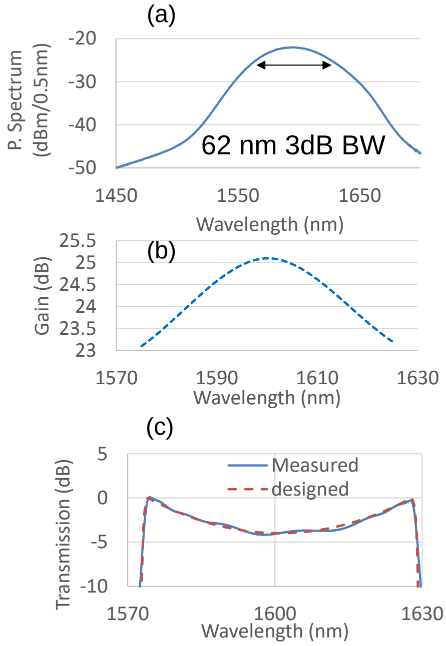

Fig. 2: (a) SOA ASE profile and (b) SOA Gain measured at 1A and at 30°C, (c) Designed and Measured GFF profile

ASE source module description

The ASE source module was assembled in a Kovar housing with free-space optics as per Fig 1. The SOA output beam was collimated with lenses. After the PBS, the combined beams were coupled to an output fibre.

The chips mounted on a carrier were placed on a CuW platform. A Thermo-electric cooler (TEC) was placed between the platform and the housing base to enable the control of the operating temperature with a TEC controller. The module was mounted on a heatsink and was actively cooled.

Module Performance

The module operating temperature was set at 30°C. The SOAs were biased at the same current. The output fibre of the module was connected to an optical spectrum analyser (OSA) for spectrum and power measurements. The results are shown in Fig. 3 and 4, for a bias current on each SOA ranging from 1 to 1.9A.

As the bias current increases, the total output power in L-band linearly increases from 30 to 145mW (Fig. 3). The corresponding optical spectra recorded on the OSA display flat output power across the L-band and over the bias current range (Fig. 4). Indeed, less than 1-dB power variation is measured across the L-band. This is partially due to the GFF ripple, and hence can be decreased to less than 0.5 dB with a GFF with lower ripple. The ripple due to residual feedback is around 0.1 dB.

In Fig. 5, we show the output spectrum of a module with and without GFF in the loop. The introduction of the latter increases the 1-dB bandwidth from 24 nm to 52 nm resulting in a flat spectrum over the L-band.

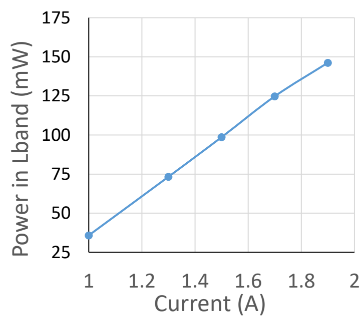

Fig.3: Module output power at 30°C vs SOA bias current

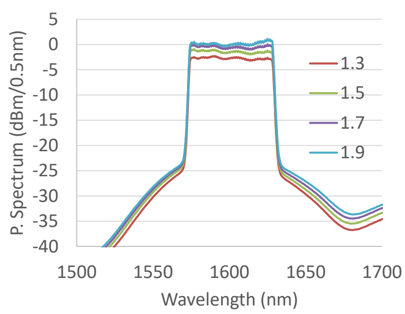

Fig.4: Module optical spectra at 30°C and different SOA currents ranging from 1.3 to 1.9A.

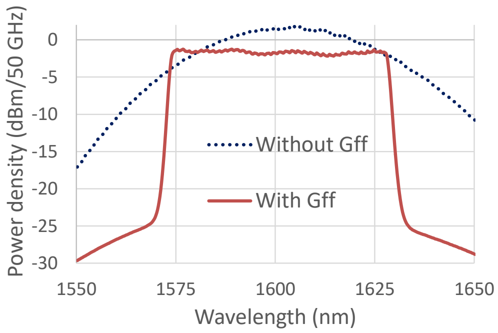

Fig.5: impact of GFF on output spectrum

In Fig. 6, the max output power reported in this paper (referred as “This work” in the legend) is compared with reports in the state-of-the-art and is plotted against the bandwidth range defined at 3-dB. The state-of-the art is a collection of data extracted from scientific publications [2-6] - referred to “Papers” in the legend- and available products to our knowledge – referred to “Products” in the legend. Here fore, the presented module for ASE source is in a leading position in term of output optical power and by almost a factor of 3.

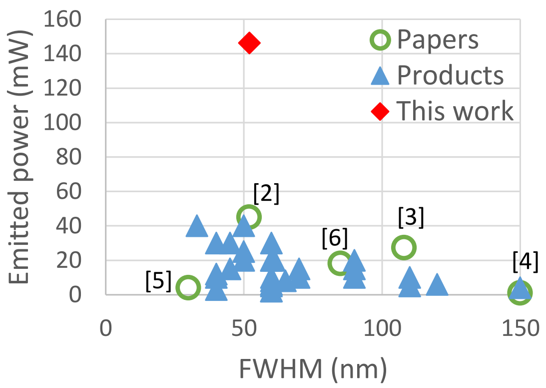

Fig.6: Comparison of the module output power (”This work”) with the state-of-the-art (“Papers” and “Products”)

Although the SOA emits and amplifies only the light polarised in TE, the polarisation diversity of the output is achieved by converting in TM the light travelling in the clockwise direction i.e. the sum of the SOA1 ASE with SOA2 ASE amplified by SOA 1, with the λ/2 waveplate before combining it with the counterclockwise travelling light. As the SOAs are identical and both waves have travelled through almost the same optical elements, the polarization dependence loss (PDL) is expected to be low. This was confirmed by measurement using the set-up in Fig. 7. In this instance, the module output fibre was connected to a polarization controller (PC) followed by a polarization beam splitter (PBS) with one output connected to the OSA and the other output connected to the power meter (PM).

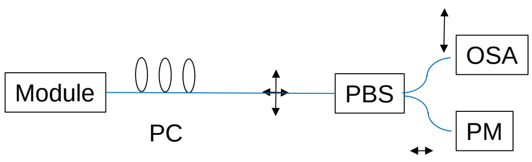

Fig.7: Polarization Dependent loss (PDL) module measurement setup

With the PC, all the polarisation states were swept while monitoring the output power variation on the PM and recording the min and max traces through the function max hold/min hold available on the OSA.

Over polarisation states, the total output power measured on the PM varies only by 0.1dB.

On the OSA, the recording was performed after each polarisation state. After measurement of different polarization states, the min value was substracted to the max value (fig 8). The measurmeent was repeated for different SOA bias currents. As expected, the measured PDL is small and less than 0.2dB. However, a small PDL modulation across wavelength is noted. This may be due to a difference in residual feedback between the two loop propagation directions.

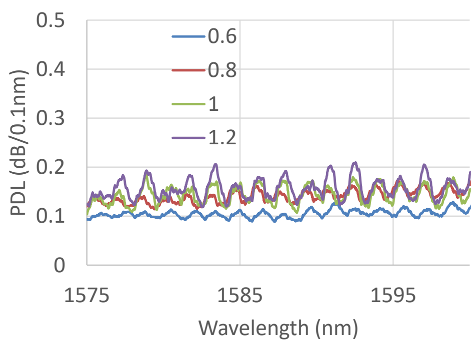

Fig. 8: Polarization Dependent loss (PDL) module measurement results for different SOA bias current

Conclusions

We presented a new ASE source design based on SOA and reported a high power (>145mW) module with flat output power (<1dB variation) and low PDL (>0.2dB) over the L-band and 30°C operating temperature. In future work, we will focus on the chip design enabling operation at higher temperatures with lower bias current.

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