High-Power 840-nm ASE Source Using an SLED-SOA MOPA Architecture

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Abstract **– We are demonstrating a high-power, broadband 840-nm light source, where amplified spontaneous emission (ASE) from a superluminescent light emitting diode (SLED) is amplified by a semiconductor optical amplifier (SOA) in order to generate power levels of 100-300 mW in free-space. The optical architecture of this light source resembles a master oscillator power amplifier (MOPA) configuration.**

I. INTRODUCTION

There are various applications that require high-power and broadband light sources in the visible or near-infrared wavelength range, for example certain RGB projection systems, machine vision systems or optical coherence tomography (OCT) systems, where semiconductor-based SLED sources are preferred light sources due to their high spatial coherence, which allows for efficient coupling to single-mode waveguides and fibers, and due to their broad emission spectrum, which eliminates coherent speckle noise or which allows for high imaging resolutions. Some of those systems need to illuminate larger areas such that higher power levels of a few 100 mW are required, while maintaining lateral single-mode.

SLEDs generate broadband light based on amplified spontaneous emission (ASE) that is generated and traveling along a single-mode ridge waveguide towards an emitting output facet [1]. Typically, a high optical confinement in the epitaxial design is used in order to achieve a large modal gain and thus a good electro-optical efficiency and broad optical bandwidth for the ASE light output. Consequently, SLED devices exhibit rather broad vertical far-field (VFF) distributions compared to laser diodes (LDs) with typical full-width at half maximum (FWHM) angles of 35°-45°, which might be problematic for beam collimation. Furthermore, the high optical confinement goes along with small vertical mode sizes in the waveguide and, therefore, high optical intensities at the output facet, which can result in reduced long-term reliability or in severe catastrophic optical damage (COD) of the output facet when high output power levels of 100 mW or more are generated.

Master oscillator power amplifier (MOPA) architectures are known configurations for free-space space communication where the output of a narrowband semiconductor laser source is amplified by a high-power SOA [2]. In this paper, we present, to our knowledge for the first time, a MOPA configuration using a high-confinement SLED as an optical seed followed by a low-confinement SOA for generating broadband light with high output power levels of several 100 mW. Due to the lower optical confinement, the vertical waveguide mode size in the SOA is larger, which results in lower VFF angles of 20°-25° (FWHM) and thus more efficient beam collimation with good beam profiles. Furthermore, the COD threshold is significantly enhanced.

II. SLED-SOA MOPA ARCHITECTURE

The optical set-up for realizing an SLED-SOA MOPA is shown in Fig. 1. Here, a broadband 840-nm SLED with an ex-fiber output power of up to 12 mW and a 3-dB ASE spectral bandwidth of almost 50 nm is used as an optical seed source. The light is injected into a broadband 840-nm booster SOA of low optical confinement using a single-mode fiber link. The polarization of the input light to the SOA is controlled using polarization paddles and is adjusted for maximum output power after the SOA, which occurs when the polarization is linear and in horizontal (TE) orientation. The optical output after the SOA is characterized using a free-space optical power meter (OPM) or an optical spectrum analyzer (OSA) that is connected through another single-mode fiber link.

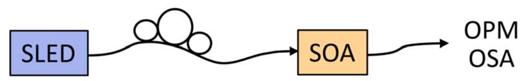

Fig. 1. Realized MOPA architecture using a broadband, fiber-coupled 840-nm SLED that is connected to a broadband booster SOA. The input polarization to the SOA is controlled through polarization paddles.

III. ELECTRO-OPTICAL PERFORMANCE

The SLED-SOA MOPA configuration has been investigated in detail by comparison of the measured with simulated electro-optical performance. The simulation results are based on a full 3D simulation software tool, which has been calibrated using the measured intrinsic electro-optical properties of the SLED seed chip and the booster SOA chip. All measurements and simulations have been performed at a heat-sink temperature of 25°C.

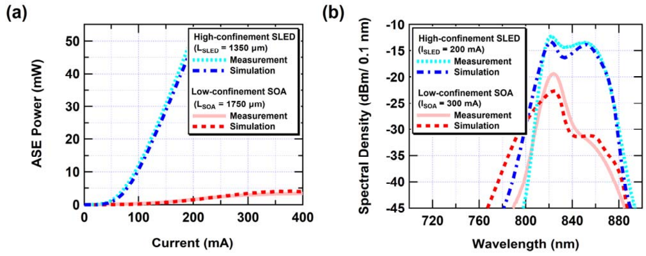

Fig. 2. (a) Ex-facet output power and (b) ASE spectra of the SLED seed chip (blue lines) and the booster SOA chip (red lines), as described in the text. The solid and dotted lines represent measurement results, whereas the dashed and dashed-dotted lines are obtained from simulations.

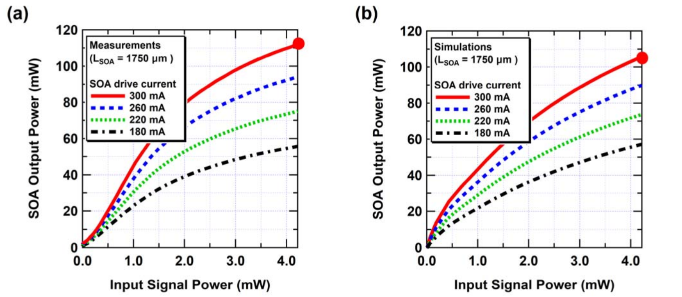

Fig. 3. (a) Measured and (b) simulated free-space output power of the SLED-SOA MOPA configuration as function of the signal input power into the SOA. The different curves are obtained for various drive currents of the SOA gain chip. The filled circles correspond to the operating point for which the SOA's input and output ASE spectra are plotted in Fig. 4.

Figure 2 shows the ex-facet output power and ASE spectra of both the high-confinement SLED chip and the low-confinement SOA chip, as measured and simulated for a fixed drive current. The corresponding VFF distributions show values of about 37° and 22° FWHM, respectively. As shown, the agreement between simulated and measured curves is excellent with only slight deviations in the ASE spectra.

Figure 3 shows the free-space output power of the MOPA configuration as a function of the signal input power (ASE light from the SLED) that is coupled into the SOA. The booster SOA has a length of 1750 µm and is operated at various drive currents. As can be seen, the experimental curves are also quite well reproduced by simulations. Probably, the small discrepancies are caused by not knowing the exact value of the coupling efficiency for the input light entering the SOA waveguide from the single-mode fiber.

In Fig. 4, we compare the ASE spectrum at the input of the SOA with the amplified output spectrum from the MOPA configuration for a fixed signal input power of 4.2 mW and a fixed SOA drive current of 300 mA. This corresponds to an electrical linear current density (drive current per chip length) of around 170 mA/mm. The measured ASE input spectrum was also used as a seed signal for the SOA simulation. The spectral shape of the measured output spectrum resembles the shape of the input spectrum with somewhat reduced bandwidth. The reduction of the 3-dB bandwidth from 46 nm to 36 nm is relatively small taking into account that the signal input power has been amplified by a factor of about 26 or 14 dB. Obviously, the simulated spectral shape is somewhat broader and does not show the double-humped behavior. This can be explained by the mismatch between the experimental and the theoretical spectral gain characteristics of the low-confinement SOA, which manifests itself also in the different ASE spectra shown in Fig. 2 (b).

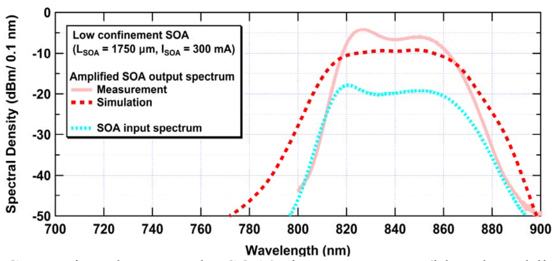

Fig. 4. Comparison between the SOA's input spectrum (blue dotted line) from the seed SLED and the amplified MOPA output spectrum (red lines). The operating point corresponds to the filled circles shown in Fig. 3. The measured output spectrum is somewhat narrower and double-humped compared to the simulated flat-top spectrum.

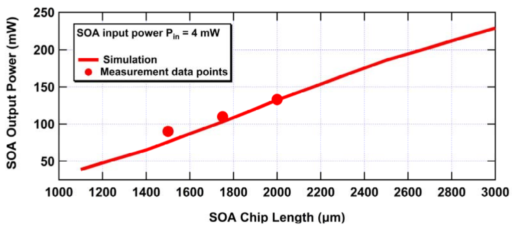

Fig. 5. Free-space output power of the MOPA system as function of the SOA chip length. The solid line follows from simulations and the dots are experimental data points. The drive current has been adjusted for different chip lengths in order to keep the linear current density constant at around 170 mA/mm.

The most obvious way to increase the amplified output power of the MOPA system is to increase the gain amplification section by using longer SOA chips and/or increase their drive current. Fig. 5 shows that output powers of more than 200 mW can be achieved with our current MOPA architecture by using SOA gain chips with a length of 2.5-3.0 mm. It is interesting to note that for our low-confinement SOA chip the output power increases almost linearly with chip length without showing any saturation if the current density is kept constant, as described in the legend of Fig. 5.

IV. Summary

We have presented a high-power, broadband 840-nm light source, which is based on an SLED-SOA MOPA architecture. Our current set-up using low-confinement SOA chips with a length of 1.5-2.0 mm delivers output powers of 100-150 mW in combination with much narrower VFF distribution compared to standard SLEDs. The lower optical power density at the output facet leads to a strongly improved long-term reliability and a significantly enhanced COD threshold.

Our simulations show that output powers of 200-250 mW can be achieved by using longer SOA chips. Using higher drive currents or larger optical input signals can generate ASE output power levels of 300 mW. Simulations predict that even higher power levels could be achieved but would require some modifications of the SOA's epitaxial design, for example using a somewhat higher optical confinement and thus a higher modal gain by allowing the vertical near-field and far-field behavior to degrade slightly. That may increase the VFF angles to a range of 25-30°, which would be still significantly lower than typical VFF angles of SLED chips.

References

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[2] S. Spiessberger *et al.*, "1 W narrow linewidth semiconductor based laser module emitting near 1064 nm for the use in coherent optical communication in space," *International Conference on Space Optical Systems and Applications* (ICSOS), DOI: 10.1109/ICSOS.2011.5783691, Santa Monica, CA, USA, May 11-13, 2011.