

A Dual-Phasar Multi-Wavelength Ringlaser

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We present an integrated multi-wavelength ringlaser. The ringlaser contains two identical 4-channel phased-array (de)multiplexers with 4 integrated SOAs in 4 waveguides connecting them, 1 for each wavelength channel (400 GHz spacing). Another SOA is placed in the multiplexed part of the ring. Light is coupled out by waveguides that are positioned in the second order of the multiplexers. The phased arrays were fabricated using a double-etch technique, enabling a total size of only $1.5 \times 3 \text{ mm}^2$. Facet reflections are minimized by using modefilters and angled facets. Threshold-currents of 70 mA and a side mode suppression ratio of 30 dB were measured.

Introduction

In a WDM-network multi-wavelength lasers (MWLs) are important components. The most commonly used sources are arrays of distributed feed-back lasers or distributed Bragg reflector lasers. Multiwavelength Fabry-Perot lasers consisting of a PHASAR integrated with an array of SOA's have been proposed as a compact alternative [1][1, 2]. A MW-ring laser consisting of a PHASAR integrated with an array of SOA's has been reported by us [3]. This device consisted of four SOAs connected to the output ports of a 4×4 phased array (de)multiplexer. While the Side Mode Suppression Ratio was good (40 dB), it had a very low output power, because the power was tapped from the edge of the phasar. In this paper we report a MW-ringlaser which was realized using the integration of five SOAs and two phased arrays, which can produce much higher output power.

Operation and design

The operating principle of the phased array multi-wavelength ringlaser is understood from figure 1, which shows the actual mask layout of the ringlaser we fabricated. The device consists of 500 μm long, 2 μm wide SOAs integrated with two wavelength filters (the phased arrays). Four of the SOAs are placed in separate wavelength channels in between the two phased arrays. The other SOA is placed in the common part of the ring. This SOA amplifies all signals and needs to be biased at all times. If the gain of one of the other SOAs is sufficiently high to overcome the total loss of the ring (waveguides and phased arrays), the device will start lasing at the wavelength determined by the passband of the phased arrays for that particular channel. The output is coupled out of the ring via the second order of the phased-arrays. This yield rather low output power. Higher output power can be obtained by placing a 3-dB coupler before or after the common SOA. This

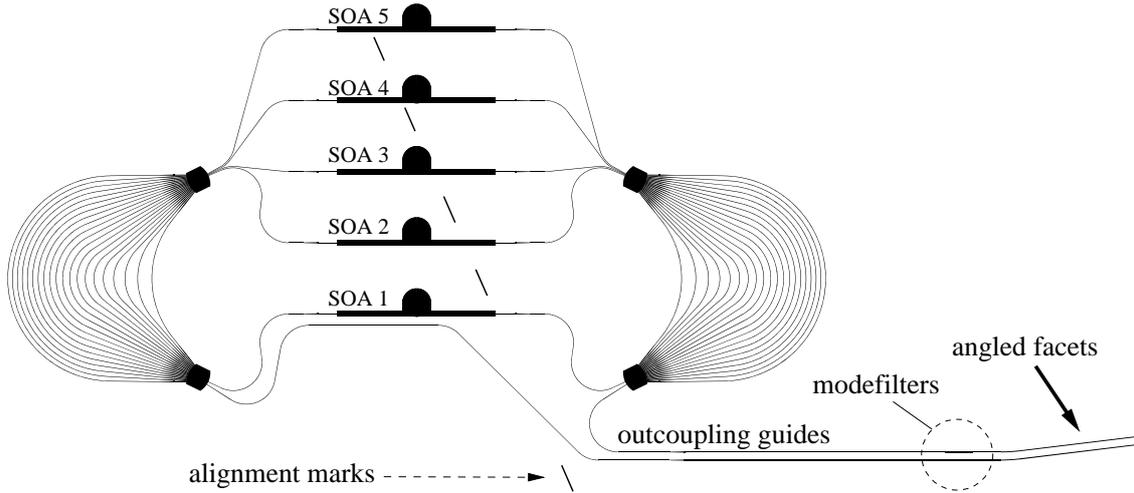


Figure 1: Mask layout of the dual-phasar MWL ringlaser. The outcoupling guides are placed in the next order of the phased array. The total size of the ringlaser is $1.5 \times 3 \text{ mm}^2$. Angled facets and modefilters minimize the reflections from the facets.

feature is not available with the single PHASAR ring laser [3], because in that laser there is no waveguide containing all multiplexed wavelengths.

The (de)multiplexers are identical, they have a channel spacing $\Delta\lambda$ of 3.2 nm (400 GHz) and a Free Spectral Range (FSR) of 12.8 nm. The waveguide structure of the phased array was realised with the double-etch technique described in [4]. All waveguide bends in the device are deeply etched, which enables the small size of the total ringlaser ($1.5 \times 3 \text{ mm}^2$), while the amplifiers are shallowly etched, to minimize propagation loss and to ensure a monomode waveguide. The outcoupling guides are also shallowly etched, to minimize propagation loss.

To reduce facet reflectivity, the output waveguides are angled by 7° with respect to the facets normal [5]. Since at this angle only the reflection from zero-order to zero-order mode is reduced, a modefilter is inserted to suppress the first-order mode, which can be guided by the SOA [6].

Device Fabrication

All epitaxial layers for the MWL were grown by Low-Pressure Metalorganic Vapour Phase Epitaxy (LP-MOVPE) at 625°C . The SOA active layer consists of a 120 nm thick $\lambda = 1550 \text{ nm}$ InGaAsP layer embedded between two $\lambda = 1250 \text{ nm}$ InGaAsP layers. The structure was clad by a 200 nm thick p-InP layer. Next, the active layer stack was butt-joint to a $\lambda = 1250 \text{ nm}$ InGaAsP layer for the passive sections by the procedure described in [7]. In the third epitaxy step a 1300 nm thick p-InP cladding layer and the p-InGaAs contacting layer were grown.

A 100-nm PECVD-SiN_x layer served as an etching mask for the waveguides. The pattern was defined using contact illumination with positive photoresist and transferred in the SiN-layer by CHF₃ reactive ion etching. The ridge waveguides were etched employing an optimized CH₄/H₂ etching and O₂ descumming process [8], both for the deeply and shallowly etched waveguides. The amplifiers were passivated with a 380- μm -thick SiN_x-

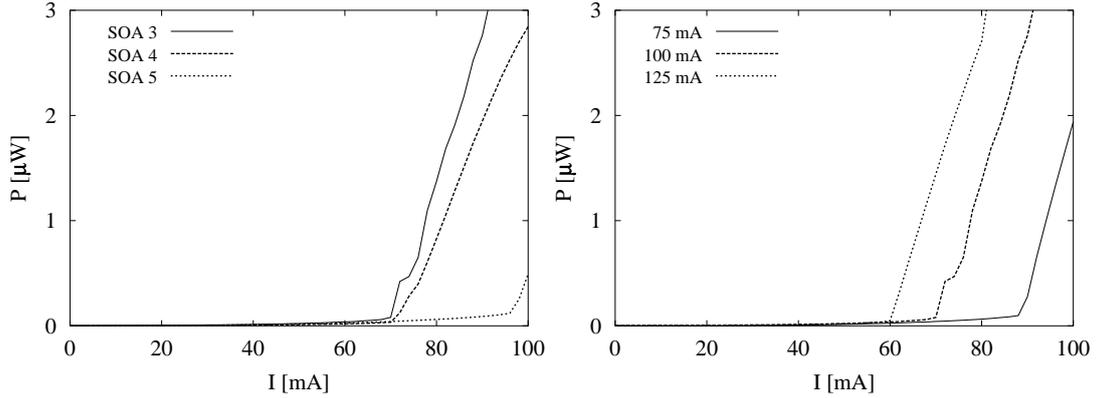


Figure 2: *LI-curves of the three lasing channels (left) and LI-curves of SOA 3 at different driving currents of SOA 1 (right). SOA 2 did not function properly.*

layer before the metalization pattern was defined by lift-off.

Experimental results

To measure the LI-curves of the four amplifiers in the separate channels of the demultiplexed waveguides, SOA 1 was driven at 100 mA. Figure 2 shows the LI-curves of three of the channels. The lowest threshold currents are 70 mA. SOA 2 did not work for unknown reasons. Extended cavity lasers on the same chip with amplifiers and cavities of the same length showed threshold currents of 62 mA. Since the ringlaser does not use cleaved facets but has a lower fractional output coupling from the ring cavity, one might expect lower threshold currents for the ringlaser than for the extended cavity lasers. However, the double-etched phased array introduces a significant extra loss that appears to be similar to the losses of two cleaved facets.

Also shown in figure 2 are the LI-curves of SOA 3 when SOA 1 is driven at three different currents. If SOA 1 is biased at a higher current, it produces more gain in the common part of the ring. Therefore, the total cavity losses to overcome by the SOAs in the demultiplexed part of the ring decrease, and, as a consequence, their threshold currents also decrease. It is unknown why the LI-curve at 100 mA show a kink and the LI-curves at 75 and 125 mA are smooth.

Figure 3 shows the uncalibrated spectra of all three working lasers, biased one after another. The wavelengths lie 3.2 nm apart, as expected. Because of a higher threshold current, the peak of SOA 5 was shifted somewhat due to heating. The SMSR for the three channels is 30 dB when driven at 100 mA. The output power is rather low with a value of -30 dBm. The main reason for this is that the outcoupling guides are connected to the second order of the phased array, while most of the power is focused onto the first order. Furthermore, since the device is lasing both clockwise and counter clockwise, only half of the power is coupled out by each of the outcoupling guides. In addition, the fiber-chip coupling caused 4 dB loss. In future designs the output power can be boosted by integrating an extra SOA in the outcoupling guides. As mentioned before a higher output power is possible by placing a multimode interference coupler (MMI) in the common arm.

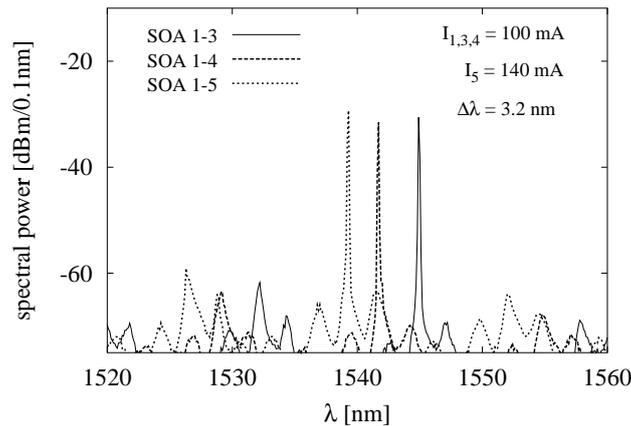


Figure 3: Combined spectra of the ringlaser. SOA 1 needs to be biased at all times. All other amplifiers are biased one at a time.

Conclusions

We presented the first integrated WDM ringlasers (see also [3]). It operates CW at three adjacent wavelengths spaced by 3.2 nm. Lowest threshold currents are 70 mA and the SMSR is 30 dB when both the common and the selected SOA are operated at 100 mA. The output-power can be increased by inserting an MMI in the common arm of the ring laser. The small size of the device ($1.5 \times 3 \text{ mm}^2$) demonstrates the potential of compact technology.

Acknowledgements

A. Suurling-van Langen is acknowledged for EBPG mask fabrication. This work was supported by the IST-project OBANET and the Dutch NRC-Photonics programme.

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