A Compact 4-Channel Multi-Wavelength Ringlaser

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A ringlaser was realised by monolithic integration of a 4×4 phased array (de)multiplexer with four amplifiers in InP. The phased array was fabricated using a double-etch technique, enabling a total size of the ringlaser of only 1×1.5 mm^2. Light was coupled out by putting outcoupling guides at the outer phased array-arms. Reflections are minimized by using modefilters and angled facets. Threshold-currents of 70 mA and a side mode suppression ratio of 40 dB were measured.

Introduction

Key components in a WDM-network are multi-wavelength lasers (MWLs). Two strategies for the realization of MWLs have been reported in literature. One way is combining the signals of an array of integrated distributed feed-back lasers or distributed Bragg reflector lasers into a single output waveguide using a power combiner [1] or a star coupler [2, 3]. Another way is using an array of Semiconductor Optical Amplifiers (SOAs) in combination with a phased array that acts as an intracavity-filter [4, 5]. Integrated MW-lasers reported so far work as Fabry-Perot lasers. Integrated ringlasers have been reported for single channel operation [6, 7]. MW ringlasers reported are assembled from discrete components connected with fibres [8, 9]. In this paper, we present the first integrated multi-wavelength ringlaser.

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 four 500 μm long, 2 μm wide, integrated SOAs integrated with a wavelength filter (the phased array). The SOAs act as a gain medium. If the gain of one of the SOAs is sufficient to overcome the total loss of the ring (waveguides and phased array), the device will start lasing at the wavelength determined by the passband of the phased array for that particular channel.

The output is tapped from the outer phased array arms since none of the four amplifier waveguides contains all frequencies. The number of arms in the phased array was limited in order to couple some light to the outcoupling guides.

The (de)multiplexer has a channel spacing $\Delta\lambda$ of 1.6 nm (200 GHz) and a Free Spectral Range (FSR) of 15 nm. However, the MWL-channels are spaced by 3.2 nm because neighbouring laser channels step two channel spacings $\Delta\lambda$: one at the input side and one

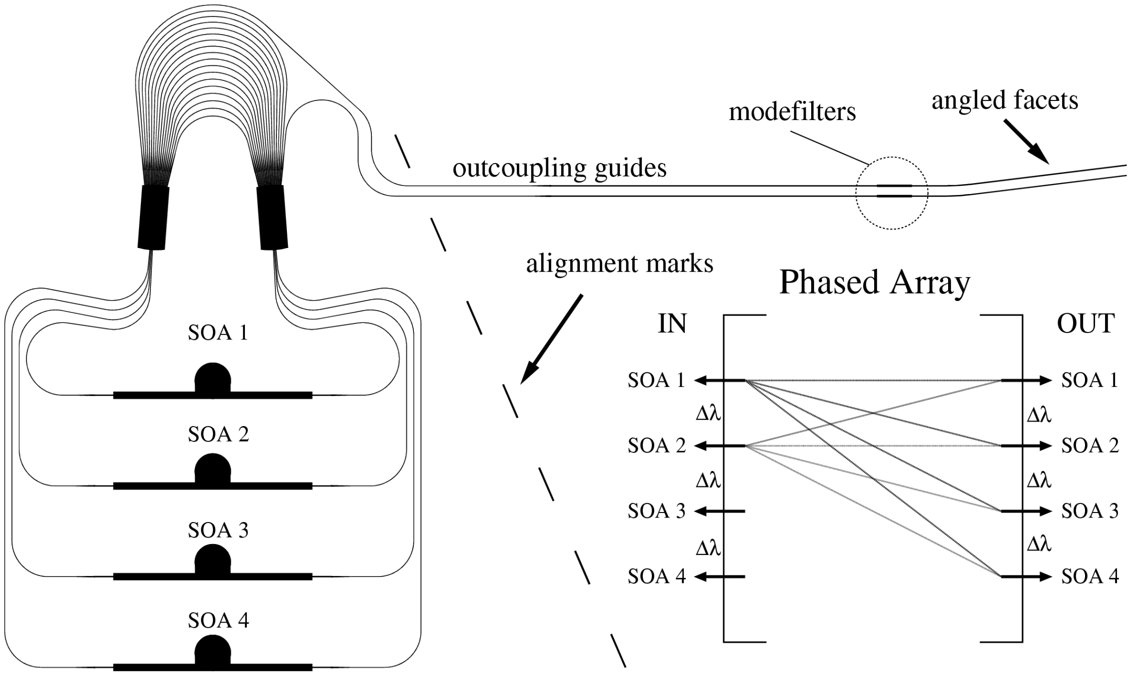

Figure 1: *Mask layout of the MW ringlaser. The outcoupling guides are placed at the outer phased array-arms. Angled facets and modefilters are used to reduce reflections from the facets. The total size of the ringlaser is 1×1.5 mm^2.*

at the output side of the array. This is understood from the inset in figure 1. The waveguide structure of the phased array was realised with the double-etch technique described in [10]. All waveguide bends in the device are deeply etched, which enables the very small size of the total ringlaser of only 1×1.5 mm^2, while the amplifiers are shallowly etched, to minimize propagation loss and to ensure a monomode waveguide.
To reduce facet reflectivity , the output waveguides are angled by 7° with respect to the facets normal [11]. 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.

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 λ = 1550 nm InGaAsP layer embedded between two λ = 1250 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 λ = 1250 nm InGaAsP layer for the passive sections by the procedure described in [12]. 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_x-layer by CHF_3 reactive ion etching. The ridge waveguides were etched employing an optimized CH_4/H_2 etching and O_2 descumming process [13], both for the deeply and shallowly etched waveguides. The amplifiers were passivated with a 380 μm thick SiN_x-

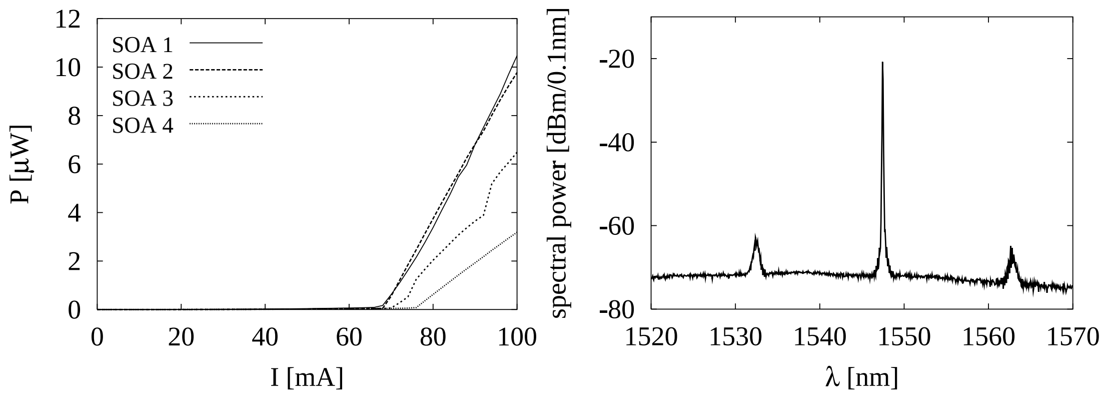

Figure 2: *LI-curve for all four operating wavelengths (left) and output spectrum when SOA 1 is driven at 100 mA (right).*

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

Experimental results

CW-measured LI-curves of all 4 channels of the ringlaser are shown in figure 2. Threshold currents are around 70 mA. 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. The LI-curves show no kinks, except for channel 3, for reasons not yet understood. Also shown in figure 2 is the output spectrum if only one amplifier is pumped. The Side Mode Supression Ratio (SMSR) is 40 dB when the laser is operated at 100 mA. The side modes lie 15 nm left and right of the main peak, exactly one FSR of the phased array.
Figure 3 shows the uncalibrated spectra of all four lasers, biased one after another. The four wavelengths lie 3.2 nm apart, as expected. Except for channel 4, all lasers have a SMSR of 40 dB at 100 mA. The output power is only -20 dBm which is due to the high intracavity loss in combination with the low output coupling efficiency. The main reason for the latter is that the outcoupling guides are connected to the outer phased array arms, while most of the power is guided by the central arms. Furthermore, because 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.

Conclusions

A very compact integrated multi-wavelength ringlaser has been realised for the first time. It operates CW at four adjacent wavelengths with threshold currents of 70 mA and a SMSR of 40 dB when pumped at 100 mA.

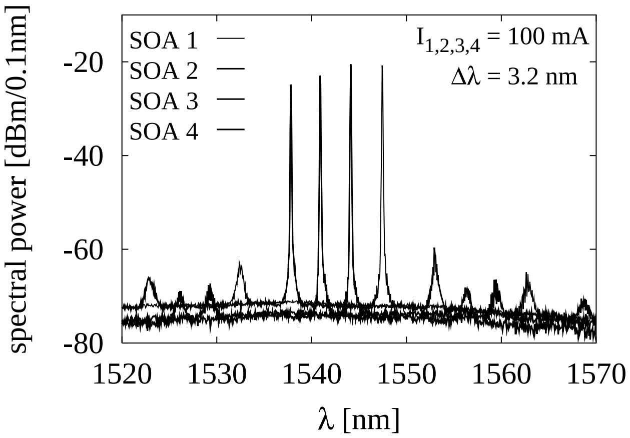

Figure 3: *Combined spectra for all four wavelengths (operating one at a time).*

Acknowledgements

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