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ELEC 413 Final Project 2

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Abstract This study shows a design of external cavity laser using the SAF1126C RSOA and a Bragg grating. The target parameters are to achieve high output power and wall-plug efficiency with an output wavelength of 1550±1nm. Using simulations on Lumerical INTERCONNECT software, the performance of the design is analyzed. The results show that while the design could satisfy the requirements, it could be refined to give better results.

1 Introduction

The objective of the study is to design and simulate a external cavity laser(ECL)using a given reflective semiconductor optical amplifier(RSOA) with silicon photonic reflectors, and adjust to meet the technical requirements. In this paper, we show a design of a ECL using the SAF1126C RSOA with a Bragg grating as reflector, with the goal of achieving an output wavelength of 1550 ± 1nm , good wall-plug efficiency, efficient optical output power and be able to operate at 2.5Gb/s.

2 Design Methodology

The design follows the given guidelines of using the SAF1126C InP RSOA and Bragg grating on silicon photonic(SiP) chip to create a ECL using optical coupling via photonic wirebond(PWB). The design forms a Fabry Perot laser where the RSOA provides the gain region and one of the reflective mirrors, and the Bragg grating as the second mirror, as shown in Fig. 1. The photonic wirebond is chosen as the connector to minimize loss, as there is less than 1.5dB loss per facet compared to 7dB in butt coupling and 3dB in fibre packaging [1]. The layout of the SiP chip is shown in Fig. 2., and consists of a edge coupler and Bragg grating.

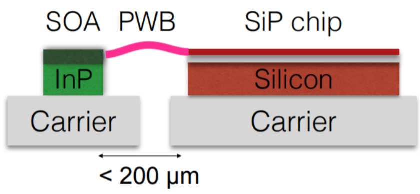

Fig. 1 Structure of ECL laser design [2]

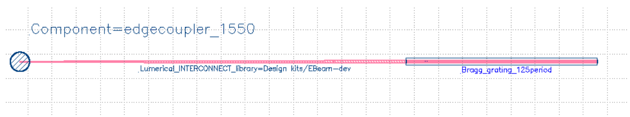

Fig. 2 SiP layout with edge coupler and Bragg grating

The design objective of this laser is to make a single-mode laser with target wavelength of 1550nm, with good wall-plug efficiency. To ensure these requirements are met, we designed a Bragg grating with high reflectivity , and simulated a circuit of the laser with SOA on Lumerical INTERCONNECT. Then “Cold Cavity” simulations were done by replacing the RSOA with a waveguide and mirror were done to confirm the Bragg grating parameters, as shown in Fig. 3. The length of the waveguide is 38μm to ensure several modes can be observed for analysis. Final simulations of the complete

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laser design is done once the parameters were chosen for best expected performance. The SiP design was also made in klayout to check for fabrication issues.

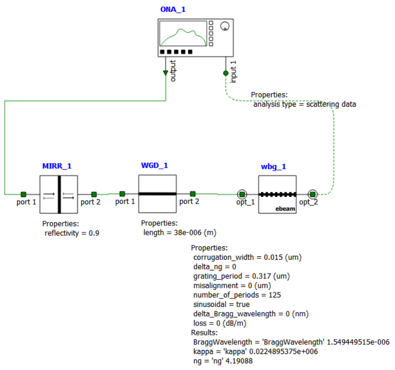

Fig. 3 Circuit for "cold cavity" simulations

3 Performance parameters

The main performance goals of this ECL design is to have an output wavelength of 1550 ± 1nm , a good wall-plug efficiency, efficient optical output power, and be capable of operation at 2.5Gb/s. Based on the simulations of the design, we obtain Table 1. These parameters are found by simulation and calculations shown in the sections 4 and 5.

4 Simulation Results

To simulate the performance of the laser, the circuit in Fig. 4. was made in INTERCONNECT. Various analyzers are connected to the outputs of the laser to obtain the graphs in 4.2 to 4.4.

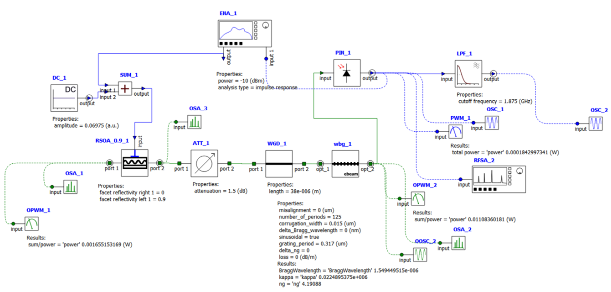

Fig. 4 Simulation circuit for 4.2 to 4.4

Threshold Current (I_{th})	15.5mA
Lasing Wavelength	1550.8nm
Maximum optical power at 300mA ($P_{out,max}$)	44mW
Wall-plug-efficiency at 100mA (WPE)	0.93
Digital modulation bias (I_{bias})	1mA
Digital modulation current ($I_{modulation}$)	23.25mA
Side-mode suppression ratio (SMSR)	21dBm
Relaxation Oscillation Frequency (ω_R)	0.88Ghz
Laser Linewidth	N/A
relative intensity noise (RIN) at 1GHz	-150.8dB/Hz

Table 1 Performance parameters obtained from simulations

4.1 Optical Spectra

Optical spectrum was obtained using a optical network analyzer(ONA) as shown in Fig. 5. The graphs below show peaks at 1550nm, ensuring that the laser meets the given requirement of an output wavelength at 1550± 1nm.

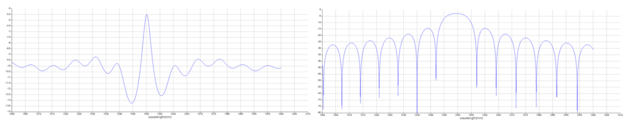

Fig. 5 Transmission spectrum of Bragg grating(left) and cold cavity(right)

4.2 Light Output Versus Current and I_{th}

The light output is measured using a script in INTERCONNECT that increases the amplitude of the DC source, or the input current of the laser. The script then generates a graph for current against light output measured by the optical power meter(OPWM_2). The graph on the left in Fig. 6. shows this overall light output versus current graph up to 300mA, while the right shows a enlarged scale to find the point where the slope of the curve changes. By exporting the data and measuring slopes on Matlab, it was found that the point at which the slope changes is at 15.5mA, as seen by the red line . Hence the threshold current of this ECL is 15.5mA.

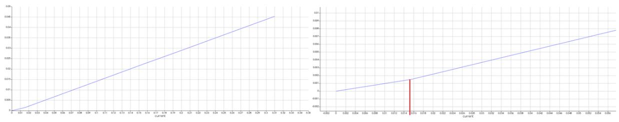

Fig. 6 Light output versus current graph(left) , enlarged scale(right)

4.3 Turn On Response and SMSR

To obtain the turn on response, an optical oscilloscope(OOSC_2) is used to graph the power against time, as shown in Fig. 7. It can be seen that initially the output is unstable but after time, at around 4.2ns, the output power reaches steady state. Furthermore, the side-mode suppression ratio can be measured from Fig. 7. By measuring the difference between the peaks of the first two mode peak, we find that the SMSR is 21dBm.

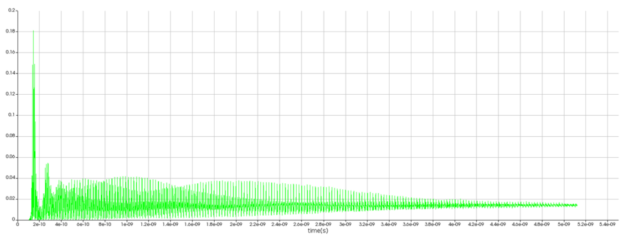

Fig. 7 Turn On response of ECL

4.4 Lasing Spectrum

The lasing spectrum can be observed by using a optical spectrum analyzer (OSA_2) at the output of the laser. We export the simulation results to Matlab and compilie the data into one graph shown in Fig. 8., it can be seen that at 5 times the threshold current($5*I_{th}$), the power is significantly higher than the others. This can be further confirmed in the enlarged graphs in Fig 9. and Fig. 10.

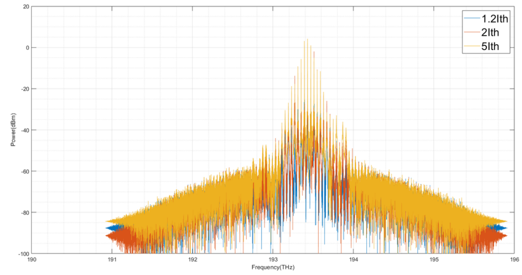

Fig. 8 Lasing Spectrum for $1.2*I_{th}$, $2*I_{th}$, and $5*I_{th}$

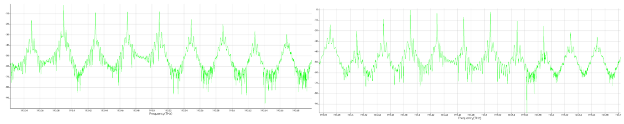

Fig. 9 Enlarged graph of lasing spectrum peaks for $1.2*I_{th}$ (left) and $2*I_{th}$ (right)

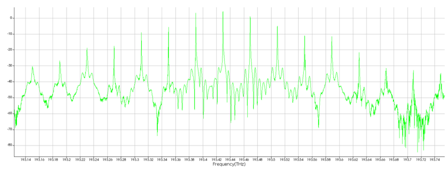

Fig. 10 Enlarged graph of lasing peaks for $5*I_{th}$

4.5 Small-Signal Modulation Frequency Response

The small-signal modulation frequency response were found using a electrical network analyzer (ENA_1 on Fig. 4.) at -10dBm power. The data is exported and compiled to one graph on Matlab. By changing the operating current to $1.2*I_{th}$, $2*I_{th}$, and $5*I_{th}$, we find that as the operating current increases, so does the magnitude of the response. This is clearly seen in Fig. 11. , where the blue curve representing 5 $*I_{th}$ has higher magnitude than at lower current. A separate graph in Fig. 12. shows the response at chosen modulation high and low currents($1.5*I_{th}$ and $4.5*I_{th}$), which has the same trend.

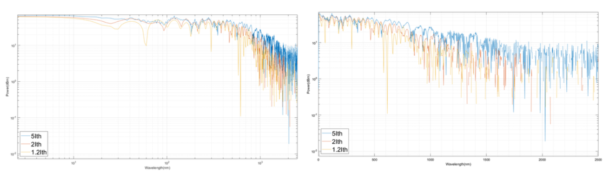

Fig. 11 Small-signal modulation frequency response in loglog(left) and semilogy(right)

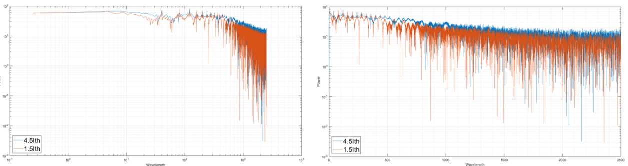

Fig. 12 Small-signal modulation frequency response in loglog(left) and semilogy(right

4.6 Eye Diagrams at 2.5Gb/s

To obtain the Eye diagram, the circuit in Fig. 4. was changed to the one shown in Fig. 13. , where a butterworth filter(LPF_1) is added after the PIN photodetector (PIN_1) to filter out unwanted frequencies. Note that the filter has a matched bandwidth of 0.75* bitrate, which gives a much cleaner graph as the filter ensures the signal to noise ratio is maximized so sensitivity to noise is reduced. Moreover, the DC source is replaced by a Pseudo-random bitstream(PRBS_1) and Non-return to zero modulation format(NRZ_1) to simulate the transfer of data by modulating the power input of the RSOA. The resulting eye diagram in Fig 14. shows a clear graph, with eye vertical opening at 0.009161 dBm, and horizontal opening at 398.8ns. An optical fibre of 1km was added after the Bragg grating(Wbg_1). The resulting eye diagram is shown in the right of Fig. 14. From the graph, the eye diagram is distorted as the signal-to-noise ratio increases. Since the mask is heavily distorted, it is not possible to define an exact vertical and horizontal opening.

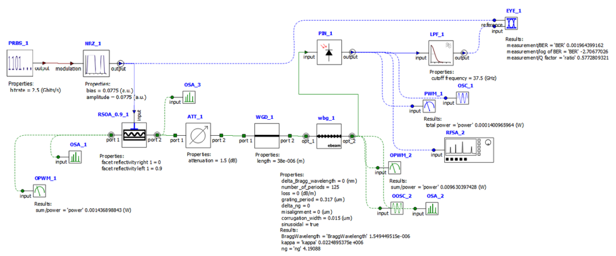

Fig. 13 INTERCONNECT circuit for finding eye diagram in 4.5

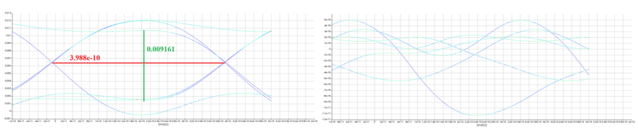

Fig. 14 Eye diagram, back-to-back directly out of laser(left), after transmission (right)

4.7 Ρελατιε Ιντενσιτψ Νοισε Σπεςτρυμ ανδ ω_P

To find the RIN, we use the data obtained from the spectral analyzer(RFSA_2) and the power meter(PWM_1) using a script to calculate RIN and create a plot of RIN against the frequencies. Fig. 15. shows this graph, and shows the trend that as the input current is increased, the lower the noise. This is further demonstrated on the right of Fig .15. , which shows the relation of the modulation currents. The relaxation oscillation frequency, ω_R is the peak of the RIN spectrum graph, which is found graphically to be 0.88GHz. Furthermore, we find that the RIN at 1GHz is averaged at -150.8dB/Hz.

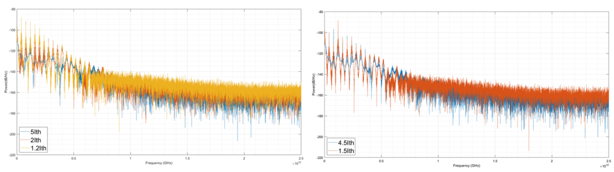

Fig. 15 RIN spectrum for 1.2*I_{th} , 2*I_{th} , and 5*I_{th} (left) and for modulation currents (right)

4.8 Linewidth

In order to find the linewidth of the laser, the circuit in Fig. 16. was made in INTERCONNECT. Another laser(CWL_1) was added and mixed with the designed ECL, and a RFSA connected to PIN photodetector to record the results. This gives the power to frequency graph shown in Fig. 17. From the graph it can be seen that the spectrum spans across a much larger frequency than expected. This is due to the inability to match the output frequency of the ECL as it varies significantly, so the resulting graph from RFSA would have to span that difference in frequency, one that cannot be fitted to find the linewidth.

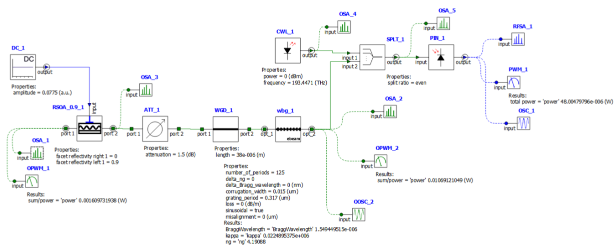

Fig. 16 Circuit used for finding linewidth

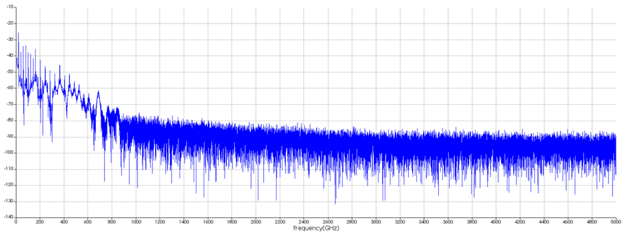

Fig. 17 Result from RFSA

5 Analysis and Calculations

5.1 Output Wavelength

Based on Fig 9 and 10, the highest peak of the lasing spectrum, it is found at around 193.44THz, the laser has highest power output. This gives the lasing wavelength of the ECL design:

$\lambda = \frac{c}{f} = \frac{(3 \cdot 10^8 ms^{-1})}{(193.44THz)} = 1550.8nm$

This confirms that the design will meet the requirement of an output wavelength of 1550 ± 1nm.

5.2 Wall-Plug Efficiency (WPE)

To calculate the wall-plug efficiency, an assumption that the device will run on 1.5V D.C. is made. From Fig. 6., we find that at 100mA, the power output is 14mW. Hence we can calculate WPE:

$WPE = \frac{(P_{out})}{(I \cdot V)} = \frac{0.014}{1.5 \cdot 0.01} \cdot 100\% = 93.3\%$

6 Conclusion

Based on the simulations and calculations, the designed ECL meets the requirements. The resulting output wavelength is at 1550.8nm, which is within the given parameter of 1550±1nm, and the power efficiencies were within 90%. The design had flaws in that the output noise could affect its performance greatly. It is suggested that a high bias current be used for this design if possible to lessen this issue.

Still, the design can be better refined. It is suggested that future iterations be made with a RSOA with 99% reflectivity on one side to reduce absorption losses. Another possible solution would be to have a 99% reflective Bragg grating and have the laser output from the low reflectivity side of the RSOA.

7 Acknowledgements

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8 References

[1] Lukas Chrostowski, Slide 9 inËLEC413-2020-04-07-Bragg-SOA_LaserProject ", [Powerpoint Presentation], 2020.[Accessed online: April 17,2020].

[2] Lukas Chrostowski, Slide 33 inËLEC413-2020-04-07-Bragg-SOA_LaserProject ", [Powerpoint Presentation], 2020.[Accessed online: April 17,2020].