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C+L BAND SOA MULTI-WAVELENGTH LASER WITH THE VARIATION OF OPTICAL COUPLING RATIOS

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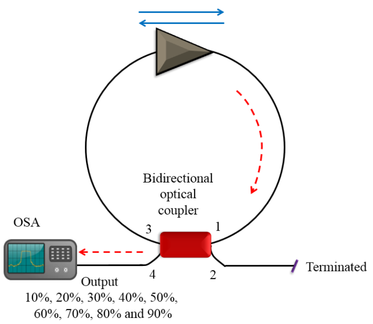
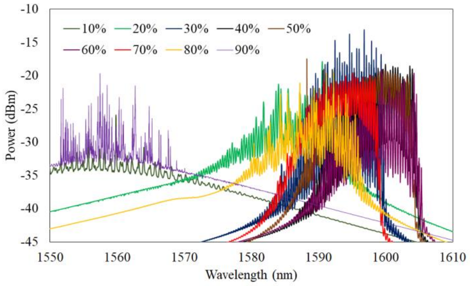
Graphical abstract





Abstract

This paper presents the characteristics of C+L band semiconductor optical amplifier based multi-wavelength laser with the variation of output optical coupling ratios. The configuration was tested with different coupling ratios from 10% to 90%. Meanwhile, the semiconductor optical amplifier injection currents varied from 110 mA to 340 mA in a step of 10 mA. The optimum coupling ratios were observed at 30%, 40%, 50% and 60% since it produces the maximum number of lasing lines, optical signal-to-noise ratio and average peak power. These coupling ratios also correspond to the minimum drive current of the semiconductor optical amplifier that initiates the first lasing lines. At 60% of the coupling ratio and injection current of 280 mA, the multi-wavelength laser has the capability to generate up to 42 dominant lasing lines with average peak power from -21 dBm to -35 dBm and an average optical signal-to-noise ratio from 9 dB to 11 dB. Furthermore, the minimum semiconductor optical amplifier current of 110 mA was required to initiate the first lasing at 60% of the coupling ratio. The semiconductor optical amplifier can effectively and practically act as a multi-wavelength source, especially in optical sensing and communication.

Keywords: C+L band, Multi-wavelength laser, Semiconductor optical amplifier, Optical coupling ratios

Abstrak

Kertas kerja ini membentangkan ciri-ciri laser berbilang jarak gelombang berasaskan kepada jalur C+L penguat optik separuh pengalir dengan perubahan keluaran nisbah gandingan optik. Konfigurasi telah diuji dengan nisbah gandingan yang berbeza dari 10% hingga 90%. Sementara itu, arus-arus suntikan penguat optik separuh pengalir diubah daripada 110 mA hingga 340 mA dalam langkah 10 mA. Nisbah gandingan optimum telah diperhatikan pada 40%, 50% dan 60% kerana ia telah menghasilkan bilangan maksimum untuk garisan pengikat, nisbah isyarat optik kepada hingar dan purata kuasa puncak. Nisbah gandingan ini juga sepadan dengan arus pemacu minimum penguat optik separuh pengalir yang memulakan garisan pengikat yang pertama. Pada 60% nisbah gandingan dan arus suntikan 280 mA, laser berbilang jarak gelombang mempunyai keupayaan untuk menjana sehingga 42 garisan pengikat dominan dengan purata kuasa puncak dari -21 dBm hingga -35 dBm dan purata nisbah isyarat optik kepada hingar dari 9 dB hingga 11 dB. Tambahan pula, arus penguat optik separuh pengalir memerlukan nilai minimum iaitu 110 mA

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untuk memulakan pengikat pertama pada 60% nisbah gandingan. Penguat optik separuh pengalir boleh bertindak secara berkesan dan praktikal sebagai sumber berbilang jarak gelombang, terutamanya dalam penderiaan optik dan komunikasi.

Kata kunci: Jalur C+L, berbilang jarak gelombang, penguat optik separuh pengalir, nisbah gandingan optik

1.0 INTRODUCTION

In recent years, the advancement of multi-wavelength laser (MWL) has been remarkable due to its various advantages, such as multi-wavelength operation, compact size, cost-effectiveness, and low insertion loss [1, 2]. One of the main contributions of MWL is its possible application in wavelength-division-multiplexed (WDM) systems [3]. With the fast development of dense wavelength-division-multiplexed (DWDM) systems in optical communication, wavelength switchable lasers have been considered an essential source in wavelength-routed WDM network systems using reconfigurable optical cross-connect to avoid channel collision [4]. The requirement for an increment in output power for multi-wavelength applications has been developed extensively. This situation encourages the implementation of many important parameters, such as the number of lasing lines, average peak power, optical signal-to-noise ratio (OSNR) and drives current that generates the first lasing line. Several investigations of different types of optical structures in the laser system have been developed to overcome the limitation of the number of lasing lines and output powers [5, 6].

Recently, linear [7] (bidirectional propagation) and ring cavity [8] (unidirectional propagation) have been studied in the long-haul optical communication system [9]. Therefore, a better solution must be undertaken to improve the number of lasing lines by optimizing the output coupling ratios. Employment of a semiconductor optical amplifier (SOA) [10] in the ring cavity configuration is one of the ways that address this issue.

The SOA based ring cavity configuration incorporating Fabry-Perot filter (FPF), bandpass filter, polarization controller (PC), isolator, SMF, coupler, and SOA has been experimentally investigated and reported [11]. The output spectra are observed from S to L band region and 10 lasing lines with fixed channel spacing of 1.6 nm are obtained. Three FBGs in the ring configuration using SOA, circulator, and coupler are reported in [12]. This work compares the output spectrum for multi-wavelength laser between SOA and erbium-doped fiber amplifier (EDFA), three lasers at 1554.4 nm, 1555.3 nm, and 1556.1 nm with peak power above -25 dBm are demonstrated. The investigation of a lasing line employing bidirectional SOA incorporated with a tapered fiber that operates in the L-band region has been reported in [13]. The result generated a triple lasing line with an output coupling ratio of 80%. However, 80% of the output coupling ratio is not the optimum value for the coupling ratio.

Meanwhile, the compact and inexpensive switchable L-band SOA based dual-wavelength fiber laser (DWFL) design is demonstrated [14]. The dual-wavelength from DWFL system can be adjusted to produce spacing output as narrow as 0.8 nm to its widest 18.7 nm spacing and the output signal has been extracted from 99:1 fused optical coupler. As reported in [15], if the value of the output coupling ratio is too large, the cavity loss is also increased. This situation becomes dominant, leading to a decrease in the output power and the performance of the fiber laser system. Meanwhile, for the lower value of the output coupling ratio, insufficient force to produce strong optical feedback is a drawback for the fiber laser system [15]. For this reason, the optimum output coupling ratio with the employment of SOA is required to produce good signal quality from the fiber laser system. Furthermore, [13-15] focussed on the fiber laser system with variations of the output coupling ratios.

A single-wavelength laser system that operates in the L band region has been the focus of an experimental study, as reported in [16]. A bidirectional SOA and single mode tapered fiber are employed in the structure. Bidirectional SOA and tapered fiber are joined together in a ring configuration. According to the results, this structure can produce only a single laser signal and uses 40% of the output coupling ratio to extract the signal. The characteristics of a multi-wavelength fiber laser based on SOA in a nonlinear optical loop mirror structure with different lengths of polarization maintaining fiber are demonstrated in [17,18]. The polarization-maintaining fiber with a length of 5 and10 meters can produce a more significant number of lasing lines up to 36 and 47 signals, respectively. This structure can also produce a wider bandwidth while operating at room temperature in the long (L) and conventional (C) bands. However, the paper in [16,17,18] focuses on the fiber laser system. Meanwhile, 50% of the output coupling ratio is not the optimum value for the coupling ratio.

This study demonstrates the characteristics of C+L band SOA based multi-wavelength laser with the variation of output optical coupling ratios. A multi-wavelength source, the SOA, is compatible with the standard silica-based optical fiber transmission in modern optical networks. The SOA is an inhomogeneous gain medium [19]; thus, the MWL does not suffer the effects of mode competition compared to MWLs employing EDFA or MWFL employing EDFA. The EDFA has the disadvantage of becoming a homogenous gain, hence susceptible to mode-competition effects. The results have shown that the proposed SOA-MWL has the capability to generate tunable multiple lasing lines with different output coupling ratios. The coupling ratios at 30%, 40%, 50%, and 60% are identified as optimum coupling since it leads to a higher number of lasing lines, OSNR, average peak power and the minimum injection current that initiates the first lasing. Furthermore, the lasing line has the ability to be tuned from C-band to L-band region when the coupling ratios are varied from 10% to 90%. Finally, various output coupling ratios and the optimum value of the output coupling ratio are important parameters to determine the characteristics of the MWL system, especially the number of lasing lines, OSNR, peak power and stability.

2.0 METHODOLOGY

Figure 1 shows the topology of the ring cavity SOA-MWL. The laser cavity consists of a bidirectional SOA with a maximum injection current of 340 mA, a bidirectional optical coupler, and an optical spectrum analyzer (OSA). The SOA acts as a gain medium and manufactures by INPHENIX, model IPSAD1503(1550 nm). The operating wavelength is 1510 nm (min) to 1570 nm (max). The saturation output power, polarization dependent gain, noise figure, gain ripple and small-signal gain at @ - 25dBm signal are 5 dBm, 1.5 dB, 9 dB, 0.5 dB and 16 dB, respectively. Meanwhile, its maximum operating bias current is 35 mA and 50 nm of 3dB optical bandwidth. The SOA can be configured to act as part of laser configuration by simply rerouting its output back onto itself, while the ring cavity MWL is obtained by simply looping the output of SOA to create a ring. It oscillates in the gain medium of the SOA until it passes the threshold power condition and begins to lase the multi-wavelength. The direction of power is denoted by red arrows, showing that the power enters the ring cavity via SOA and begins to travel to the bidirectional optical coupler. The lasing line can be extracted from the cavity using different coupling ratios of 10% to 90% at output port-4.

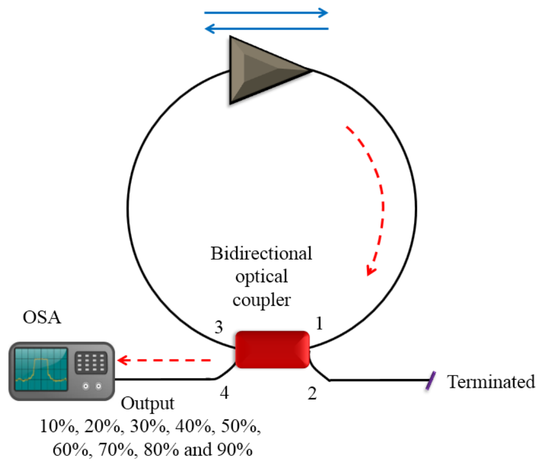


Figure 1 Experimental schematic of the ring cavity SOA - MWL with the variation of output optical coupling ratios

3.0 RESULTS AND DISCUSSION

Analysis of the SOA's current that initiates the first lasing lines against coupling ratios is shown in Figure 2. The SOA current decreases as the coupling ratio increases from 10% to 40%. The currents required to initiate the first lasing line for coupling ratios of 10%, 20%, 30%, and 40% are 280 mA, 160 mA, 130 mA, and 110 mA, respectively. For lower coupling ratios of 10%, 20%, and 30%, higher current is necessary to begin lasing as it involves higher energy in exciting electrons to the conduction band. It is also noticed that 40%, 50%, and 60% are the optimum coupling ratios with the lowest injection current of 110 mA to begin the lasing. However, SOA currents start to rise from 130 mA to 270 mA as the coupling ratio increases from 70% to 90%. In this situation, the laser configuration is experiencing cavity loss.

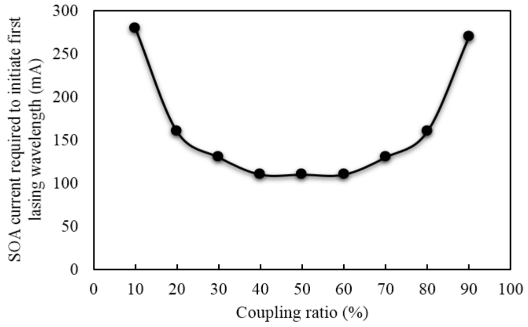


Figure 2 SOA current requires initiating the first lasing line against different coupling ratios

Figure 3 depicts OSNR dependency on the coupling ratios. It can be seen that the OSNR linearly increases from 10% to 20% coupling ratio and generates values from 7.5 dB to 8.82 dB, respectively. The OSNR remains constant at around 10 dB to 11 dB for 40% to 60% coupling ratios. Then the OSNR begins to decrease from 9.29 dB to 8.5 dB for 70% to 90%. The coupling ratios of 30%, 40%, 50% and 60% are identified as the optimum percentage for coupling ratio assisted to the maximum OSNR. The optimum signal power and number of lasing lines are achieved at this point. However, when the coupling ratios are extended to 70%, 80% and 90%, the cavity loss increases as well; thus, most of the cavity gain is invested to compensate for the light attenuation. Therefore, OSNR and lasing lines with lower energy cannot successfully compete with gain in the cavity. Consequently, OSNR degradation would significantly interrupt the entire SOA-MWL operation [20].

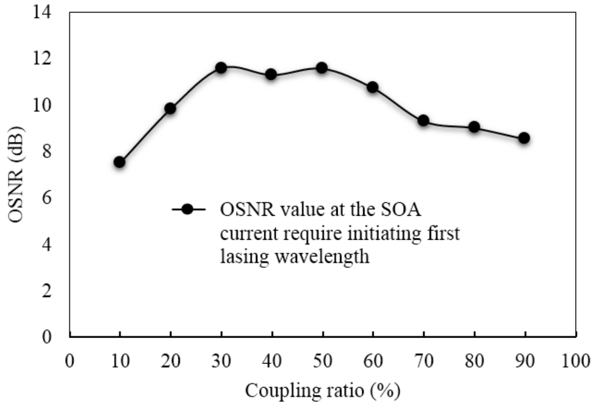


Figure 3 OSNR value at the SOA current requires initiating the first lasing line against different coupling ratios

The number of lasing lines as a function of the coupling ratios is investigated as depicted in Figure 4. In this investigation, the SOA current is fixed at 280 mA due to producing the highest number of lasing lines. It can be observed that the number of lasing increases as the coupling ratio increases from 10% to 40%. Hence 6 to 40 lasing lines are generated. However, at the coupling ratio of 50%, the number of lasing lines reduced to 38 and increased again to 42 at the coupling ratio of 60%. It can be noted that 30% to 60% is the optimum coupling ratio, although there is a slight fluctuation at 50%. The number of lasing lines decreases to 28, 26, and 23 for coupling ratios of 70%, 80%, and 90%, respectively. The lasing lines are produced due to the ring cavity configuration that allows the input signals to oscillate. Subsequently, these signals exceed the threshold power and begin forming multiple wavelengths. This is one of the reasons why the coupling ratio increases with the number of lasing lines and decreases due to the cavity loss at high coupling ratio. Similar observations are illustrated in Figures 2 and 3. The output spectrum across the C+L band captured by OSA at 280 mA and coupling ratio of 40% is shown in Figure 5. An enlarged spectrum view is shown in Figure 6, with the channel spacing [21] being constant at 0.34 nm. The multi-wavelength generation in SOA-MWL has the ability to maintain the channel spacing around 0.34 nm for 30%, 40%, 50%, 60%, 70% and 80% of the output coupling. However, channel spacing around 0.72 nm to 1.44 nm and 0.3 nm to 0.26 nm are generated from 10% and 90% of the coupling ratios, respectively, due to insufficient power and cavity loss. Consequently, a stable lasing line with constant spacing cannot be created. Nevertheless, the constant channel spacing is measured at around 0.34 nm for 30%, 40%, 50%, 60%, 70% and 80% of the output coupling, which are attributed to the inhomogeneous gain broadening of SOA [22].

It is observed that the channel spacing is 0.34 nm or equivalent to 42.35 GHz. This wide bandwidth offers high modulation level, which also depends on the speed of the signal. In addition, modulation frequencies are controlled by the SOA's bandwidth and the capability of the receiver to identify two close frequencies. Both influences eventually can limit the number of sole wavelengths, thus controls modulation range. A short laser cavity is desirable for a wider frequency modulating range, especially in the loop. The channel spacing also can be cut in half, therefore the number of channels can be doubled. This condition will ultimately create a narrow bandwidth. As a result, more users could use the available spectrum. However, wide channel spacing is required for high-speed modulation and objected to avoid overlapping that may cause significant crosstalk. Since the SOA is bidirectional, it reduces the capacity or transmission bandwidth. As a result, it can cause the signal to overlap, hence producing massive crosstalk due to frequency modulation.

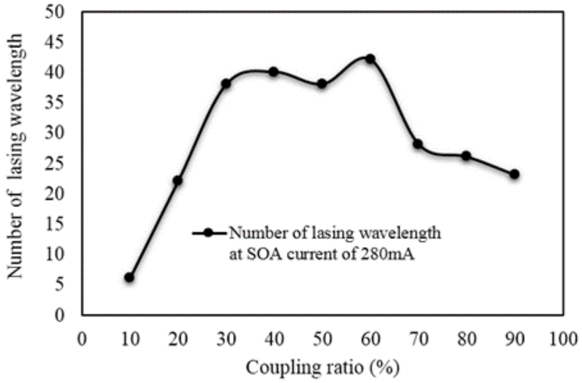


Figure 4 Number of lasing lines against different coupling ratios at 280 mA of SOA current

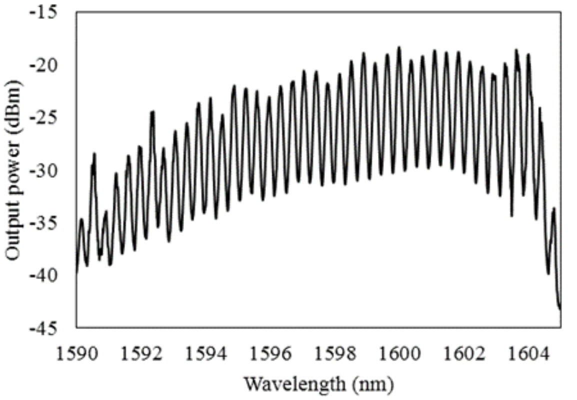


Figure 5 Output spectrum at 280mA of SOA current and 40% of the coupling ratio

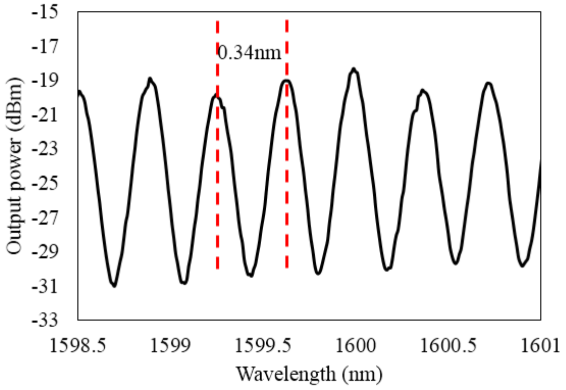


Figure 6 Enlarged view of the spectrum at 280mA of SOA current and 40% of the coupling ratio

In order to expand the investigation, the average peak power of the output lasing lines at 280 mA against different coupling ratios is plotted in Figure 7. It can be seen that the relation shows a similar trend as depicted in Figures 3 and 4. It can be observed that the average peak power increases from -29.8 dBm to -23.89 dBm for 10% to 20% of the coupling ratios. The average peak powers remain almost constant, slightly fluctuating from 30% to 50%. The average peak power decreases from -23 dBm to -24 dBm when the coupling ratios increase from 70% to 90%. Introducing more charge carriers into the gain medium, creating a population inversion, is the reason for an increment in the average peak power. The average peak powers remain almost constant for coupling ratios from 30% to 50%, which are identified as the optimum coupling ratios. However, the average peak power decreases from 70% to 90% due to cavity loss.

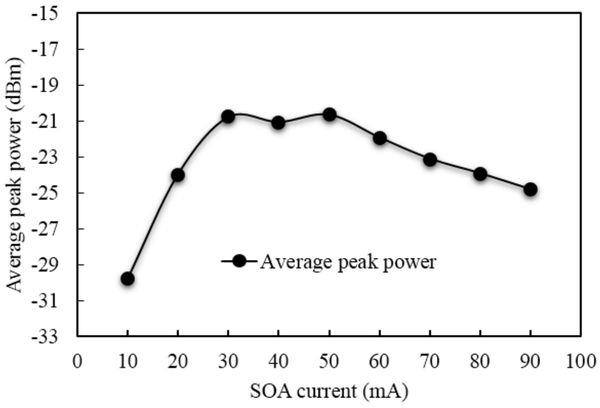


Figure 7 Average peak power of output lasing line at SOA current of 280 mA against different coupling ratio

Output power against wavelength is plotted to analyze the output spectrum at the injection current of 280 mA for different coupling ratios, as shown in Figure 8 and Figures 9(a) to 9(i). It indicates that 20% to 80% of the output power spectrum operated in the L-band region. In contrast, 10% and 90% are operated in the C-band region. The lasing lines shift towards the longer wavelength region (L-band region) due to strong optical feedback for coupling ratios of `20% to 80%. In this case, the total loss of the ring cavity SOA-MWL is too small. This situation leads to strong optical feedback in the laser cavity, thus facilitating SOA to operate at the deep saturated condition [23], [24].

This condition forces the carriers from the heavily saturated energy level to occupy less saturated levels, resulting in the oscillating spectrum shifting to the longer wavelength region [15]. In contrast, only two combs of lasing lines are observed in the C-band region for 10% and 90% due to cavity loss and insufficient power that produces strong optical feedback. The lasing center wavelength is shifted to the C-band region because of the increment of cavity loss. Thus SOA cannot be operated in a strongly saturated situation [20]. It is also noticed that the coupling ratio of 60% yields the highest number of lasing lines of 42 at SOA current of 280 mA.

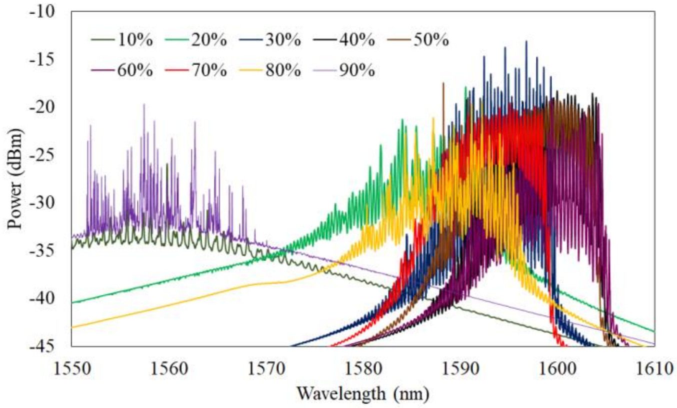
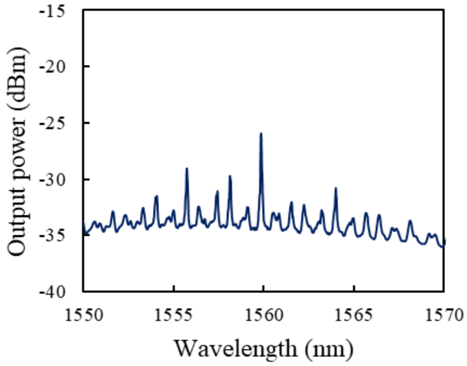


Figure 8 Output spectrum of comb lasing lines at SOA current of 280 mA for different coupling ratios

The number of lasing lines against SOA currents for different coupling ratios is shown in Figure 10. In this observation, the SOA currents are varied from 110 mA to 340 mA in a step of 10 mA. It shows a linear evolution of the number of lasing lines when the SOA current increases from 110 mA to 340 mA in all coupling ratios. This trend generates high number of lasing lines due to energy transfer and gains increment. It is detected that the laser wavelengths start to lase at different SOA currents of various coupling ratios. At 10% and 90%, the laser line starts to lase at 280 mA. Meanwhile, at 20% and 80%, the laser line starts to lase at much lesser current of 160 mA.

Moreover, the laser wavelength starts to lase at 130 mA for coupling ratios of 30% and 70%. The lowest current of 110 mA has the ability to start the lasing line at 40%, 50%, and 60%. The number of lasing lines generated increases as the current increases and begins to remain saturated with slight fluctuation. At the saturation point, it is observed that the increment in the SOA's current does not result in the generation of lasing lines. This is because the number of lasing lines is saturated, thus not capable of receiving any more gain from the SOA. Instead, the available gain is distributed to subsequent lower power lasing line [25]. The highest number of lasing lines is generated at coupling ratios of 30%, 40%, 50%, and 60%, with an average of 35 lasing lines for 260 mA to 340 mA.



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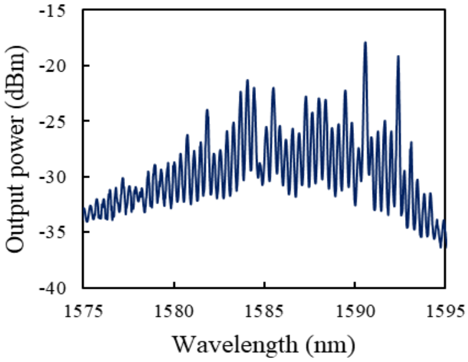

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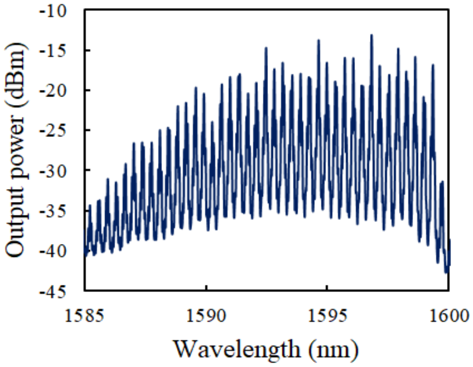

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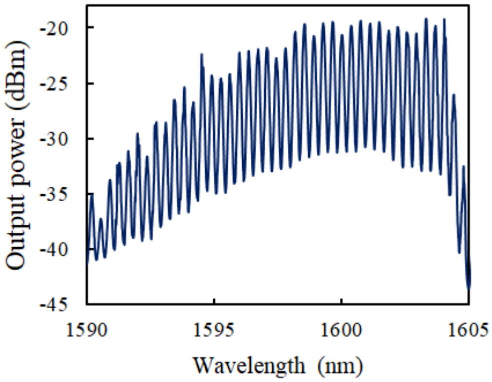

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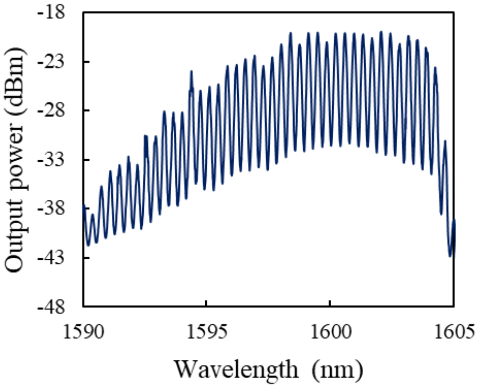

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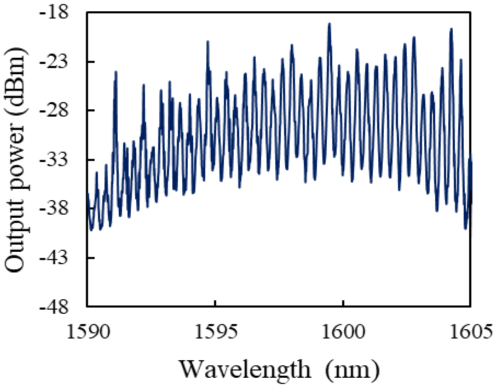
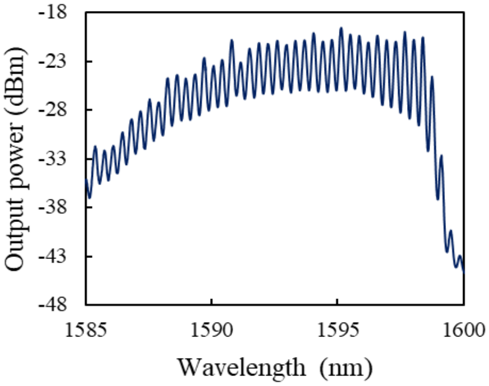
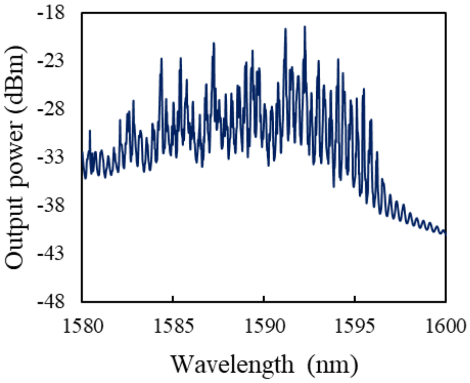


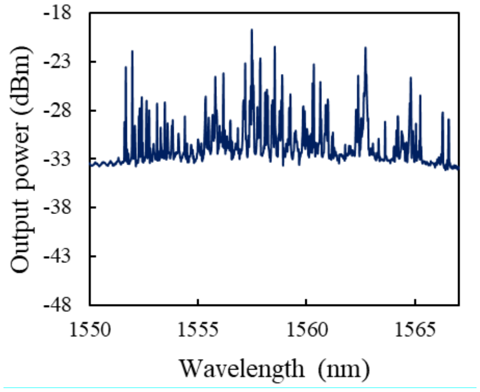
(f)



(g)



(h)



(i)

Figure 9 Output spectrum at SOA current of 280 mA for different coupling ratios. (a) 10%, (b) 20%, (c) 30%, (d) 40%, (e) 50%, (f) 60%, (g) 70%, (h) 80% and (i) 90%.

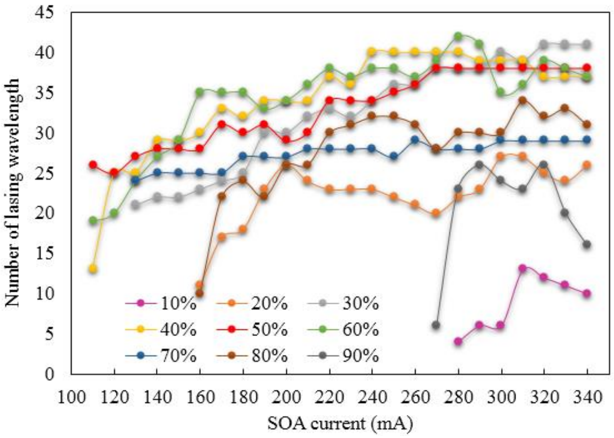


Figure 10 Number of lasing lines against SOA current from 110 mA to 340 mA and different coupling ratios

The lowest number of lasing lines is recorded at coupling ratios of 10% and 90%, with an average of 18 and 22, respectively. For the coupling ratio of 50%, the lasing starts at 110 mA with 26 lasing lines. The number of lasing lines starts to increase linearly with higher SOA current. The number of lasing lines decreases sharply after the current is fixed at 120 mA and 260 mA, generating around 25 to 36 lasing lines, respectively. However, it rises to 39 lasing lines at 270 mA and remains constant from 270 mA to 340 mA. Consequently, the number of lasing lines is decreased by the value of the coupling ratios 70%, 80%, and 90%, where the cavity gain is inadequate to compensate for the cavity loss for initiating the lasing process. Since 70%, 80%, and 90% are not an optimum output coupling ratio, the cavity loss due to the intra-cavity component is higher, which reduces the number of lasing lines.

Figure 11 illustrates the effect of injection current and coupling ratio on the average power at the peak. The average peak power rises as the SOA current increases. A similar trend is also observed in Fig. 10. The lasing saturates at 220 mA as the spectrum becomes almost flattened and there is no significant increment in the average peak power for most of the coupling ratios. The average peak power is low at a small injection current due to insufficient gain. However, when the SOA current is increased from 130 mA to 340 mA, the average peak power indicates almost a linear relation with the current. The entire lasing lines portrayed that the peak power centralized in the range of -20 to -25 dBm.

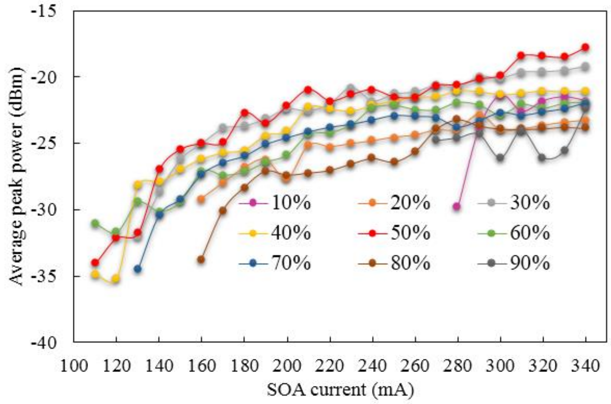


Figure 11 Average peak power against SOA current from 110 mA to 340 mA and different coupling ratios

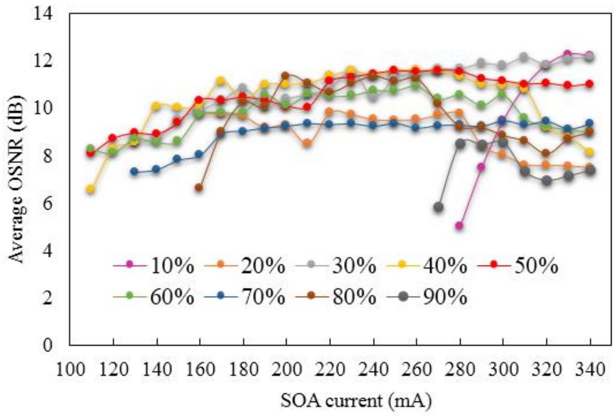


Figure 12 Average OSNR against SOA current from 110 mA to 340 mA and different coupling ratios

The average OSNR against SOA current for different coupling ratios is demonstrated in Figure 12. It can be observed that the average OSNR is linearly increased and remained almost constant for all the coupling ratios in the range of 200 mA to 260 mA. However, the OSNR decreases for the SOA's current higher than 260 mA. The decrement of average OSNR at higher current is produced by the thermalization of the optical energy leading to a high temperature which causes fluctuation in their lasing line output power and operational wavelength [26]. The strong effect of the injection current can be vividly seen in Figures 10, 11, and 12. Steady improvement of OSNR creates more wavelengths to surpass their threshold levels and begins to lase. The highest average OSNR is recorded at 30% coupling with the value of 12.15 dB at 310 mA.

Finally, the peak power stability of SOA-MWL is observed for 60 minutes. The stability test is performed at 30%, 40%, 50%, 60% and 70% of the coupling ratios. The SOA current is set at 280 mA. The selected output coupling ratios are based on the good performance from the previously presented results. Figure 13 shows the peak power signal with selected wavelength and output coupling ratios for every 10 minutes to identify any significant current laser fluctuations during the stability test [27]. Meanwhile, Figures 14(a) to 14(e) depict the multi-wavelength spectrum's peak power for 30%, 40%, 50%, 60% and 70% of the coupling ratios at 1600 nm and 1590 nm. Based on the testing results, there is a slight power fluctuation during the stability test at 40% and 50% of the coupling ratios observed between 0.45 and 0.70 dB. In addition, 30%, 60% and 70% of the coupling ratios have power fluctuation around 0.55 and 2.1 dB. The stability tests indicate that the SOA-MWL with 40% and 50% of the coupling ratios has the strongest ability to operate stably at room temperature, which can be used in the MWL applications [5]. Besides, the large power fluctuation can be caused by temperature variations and surroundings. The 1.5 dB polarization-dependent gain from the SOA can also lead to laser instability [28, 29]

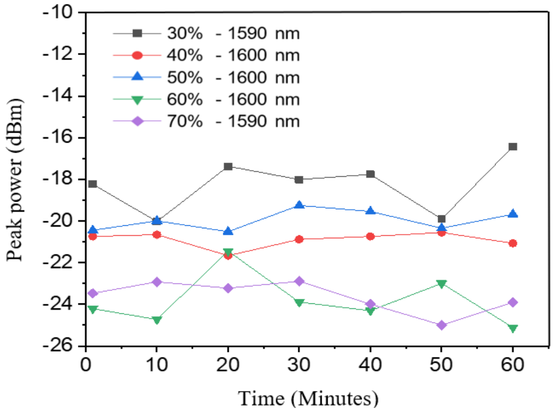
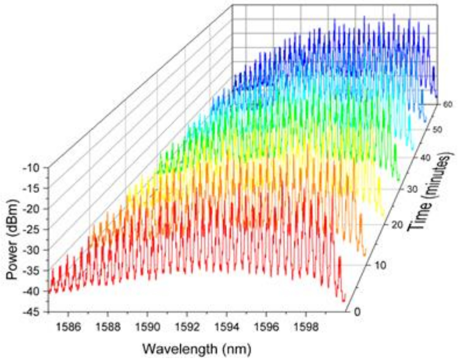
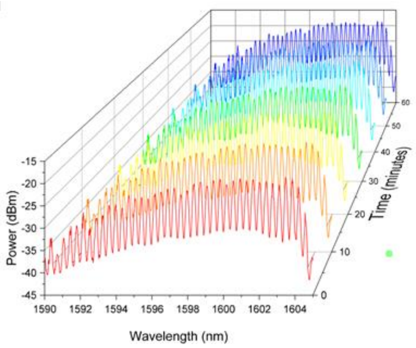


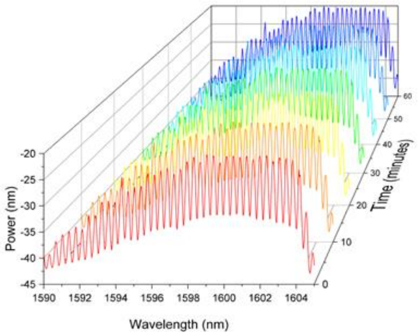
Figure 13 The peak power stability test of SOA-MWL is observed for 60 minutes at 30%, 40%, 50%, 60% and 70% of the coupling ratio



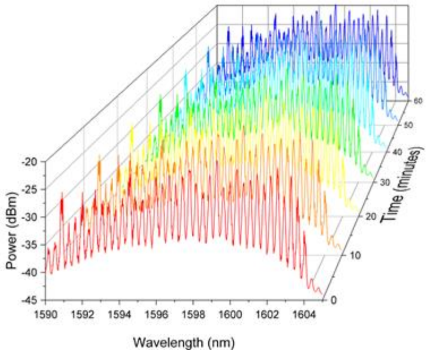
(a)



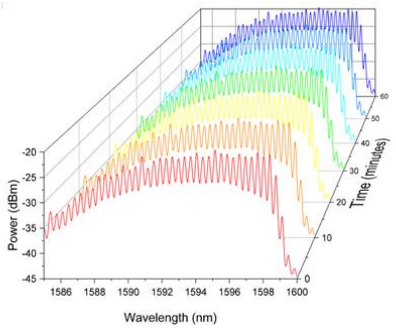
(b)



(c)



(d)



(e)

Figure 14: The SOA-MWL output spectrum at (a) 30%, (b) 40%, (c) 50%, (d) 60% and (e) 70% of the coupling ratios

Table 1 shows comparison results against different coupling ratios at 280 mA of SOA current. Based on Table 1, it can also be claimed that 30%, 40%, 50% and 60% is the optimum output coupling ratio based the higher number of lasing lines, higher average OSNR, higher average peak power and lasing lines stability. However, the cavity loss increases when the coupling ratios are extended to 70%, 80% and 90%. Thus, most of the cavity gain is invested to compensate for the light attenuation and reduce the performance of the MWL system.

Table 1 Comparison results for the number of lasing lines, average OSNR, average peak power and lasing lines stability against different coupling ratios at 280 mA of SOA current

Output coupling ratios (%)	Number of lasing lines	Average OSNR (dB)	Average peak power (dBm)	Lasing lines stability
10	6	7.50	-29.81	unstable
20	20	8.82	-23.98	unstable
30	38	11.57	-20.79	stable
40	40	11.28	-21.07	stable
50	38	11.55	-20.61	stable
60	42	10.70	-21.92	stable
70	28	9.29	-23.80	stable
80	26	9.00	-23.19	unstable
90	23	8.51	-24.61	unstable

The comparison summary from previous papers and results covering the MWL system employing SOA was tabulated in Table 2. The table describes the method, output coupling ratios, channel spacing, number of lasing lines, OSNR and operating band. From the results, the output spectrum across the C+L band is captured by OSA at coupling ratio of 40%. The lasing lines can be tuned from C-band to L-band region when the coupling ratios are varied from 10% to 90%. Meanwhile, 42 dominant lasing lines are generated from 60% of the output coupling ratio compared to the [11, 12, 13, 14, 16]. However, the paper in [17, 18] focuses on the multi-wavelength fiber laser system employing SOA, tapered fiber and PMF. A multi-wavelength fiber laser system has the capability to generate a greater number of lasing lines.

Table 2 Comparison summary from previous papers and the results

Paper	Output coupling ratio	Channel spacing (nm)	Number of lasing lines	OSNR (dB)	Band
Results	10% to 90%	0.34	42	12.15	C,L
[11]	10 %	1.6	10	-	S, C and L
[12]	10 %	-	3	30	C
[13]	80%	-	3	44	C
[14]	10%	0.8	2	42	L
[16]	40%	-	1	45	C
[17]	50%	-	47	28.86	C
[18]	50%	-	36	31.98	C

4.0 CONCLUSION

In conclusion, an analysis of the ring-cavity MWL employing the SOA and optical coupler in generating lasing lines is successfully performed. The ring cavity MWL is examined with different output coupling ratios of 10% to 90% at SOA's drive currents of 110 mA to 340 mA. It is observed that the rise of the SOA current in all coupling ratios does not result in the generation of higher peak power lasing lines but instead promotes the generation of more lasing lines at the same peak power. In this situation, the peak power lasing lines experience the saturation condition and cannot receive any more gain from the SOA. Instead, the available gain is distributed to subsequent lower power lasing lines, which results in the generation of the higher number of lasing lines rather than high peak power lasing lines. Therefore, it can be concluded that the optimum coupling ratio for the proposed ring cavity MWL is between 30% to 60%. This range produces the highest number of lasing lines, OSNR, average peak power, and the minimum SOA current required to initiate the first lasing line. There is no doubt that with further study and research, SOA based MWLs can play an essential role in improving many current applications in fiber optics as well as pave the way for developing new applications. Eventually, bringing excellent benefits to the communication system and optical sensing.

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