An amplification of 1550 nm distributed feedback (DFB) laser using 980 nm optical injection

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Distributed feedback (DFB) lasers currently offer steady single mode emission for a wide wavelength range of applications. 980 nm was used as pump source into a commercially available distributed feedback DFB operating in the 1550 nm wavelength range. The device were characterized experimentally through light output-current-voltage I-V-L measurements and emission spectra at fixed and at various threshold currents and temperatures. In addition, amplification of the device was detected using pump laser at threshold current of I_{th}=22 mA and room temperature of T=25 °C.

1. Introduction

Distributed feedback (DFB) laser devices are commonly used in network and optical communication system. In general, the grating of the DFB laser is formed in the vicinity of the active region to be used in such an applications [1-3], and the sample grating is the best way for tailoring the optical characterization of grating structure [4]. The semiconductor lasers of DFB under test of optical injection had been reported previously [5,6], which have an enormous applications [7,8]. Modern communication systems needs highly stable devices, arrow linewidth and high output power light. However, most of the studies were performed at very weak, moderate and high injection ratio [9,10]. In fact, the conventional DFB lasers suffer from low single-longitudinal-mode yield, poor operating wavelength accuracy and high cost of manufacturing process [11]. The oscillation wavelength of DFB laser is determined mainly by the equivalent refractive index of the grating region and the grating pitch [12]. All the wavelength-conversion from 1310 to 1550 nm is based on optical pumping of a DFB laser operating below threshold [13].

In this contribution, the effect of 980 nm driven optical injection of laser on commercial 1550 nm DFB laser was studied at different temperatures. In addition, an amplification of DFB laser is demonstrated using 980 nm pump laser. Keating et al. [14] investigated the temperature dependence of optical modulation of a 1550 nm DFB pumped with a 1300 nm laser, that probably not build significant variants in the threshold and the wavelength due to their limited primary laser power. Distributed feedback (DFB) semiconductor laser was also studied under strong optical injection and it was compared with the weak injection regime [15]. Further study on the DFB laser behaviour was carried out using excitation wavelengths of 1426, 1460 and 1490 nm emitting semiconductor laser at different operating currents and temperatures [16].

2. Experimental details

The experimental setup is shown in Fig. 1. The system involves a 980 nm pump laser source to inject into the DBF laser of 1550 nm wavelength operation. In this work, the commercial laser DFB (Lasertron QLM5S790) is denoted as a slave laser, operating at various threshold currents and temperatures. A 980 nm fibre pigtailed single mode diode laser (1999 PLM 980 nm pump module) is used as an excitation laser and connected to an isolator to prevent the light to be returned back. The output power from the laser is about 810 mW and is reduced to <250 mW at the sample due to the losses through fibres. The output beam of 980 nm pump laser, with fixed temperature of 15 °C, was directed into an optical circulator and the light was then split through a fiber optic 10:90 coupler. The circulator is used as a special fibre optic component to separate the amplified signal from the input signal and the pump light. The 90% output signal was directed into the 1550 nm DFB laser (SL) through the isolator, while the remaining 10% was used to monitor the input power (P_{in}) with a lightwave multimeter (Agilent 8163A). The reverting power from the 1550 nm DFB laser (SL) by the 10:90 coupler was sent via the circulator into an optical spectrum analyser (OSA) to observe the optical signals.
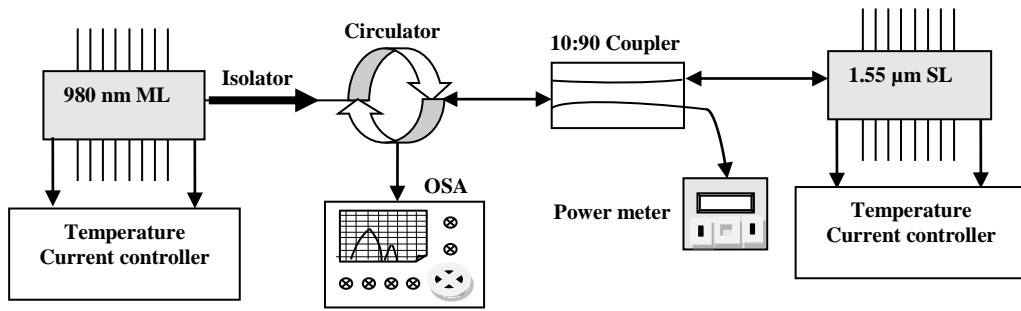
Fig. 1. Experimental setup of the 1550 nm DFB laser under using 980 nm pump laser

3. Results and discussions

The DFB laser was tested on temperature-controlled test bench under continues wave (CW) excitation, and the emission spectra is detected on an OSA. Fig. 2 shows the applied voltage and light output against drive current (V-L-I) characteristics of the DFB laser at different stage temperatures. The device that operating between T=10 to 20 ºC has a threshold current between 17 to 22 mA. When the temperature of the DFB laser increases, the threshold current is also increase and their output power is decrease. Conventional DFB laser is usually producing output powers up to 100 mW [17].

Peak amplification of DFB laser as a function of driven current and wavelength were measured at various temperatures. Fig. 3 shows the amplitude of SL over injection current characteristic at various temperatures, in which their peak amplitude shifts to the longer wavelengths by increasing the temperature from 15 to 35 ºC. Peak amplitudes of the device was around -15 dBm. The figure shows that the device has been realized at threshold currents and at temperatures of I_{th}=18, 22 and 27

mA and T=15, 25 and 35 ºC, respectively, and then gets saturated might be due to heating issue with the chip.
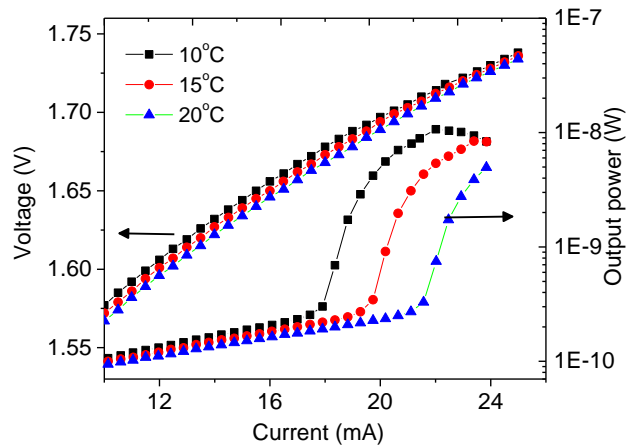

Fig. 2. V-L-I characterisations for the DFB laser investigated in CW operation at various temperatures
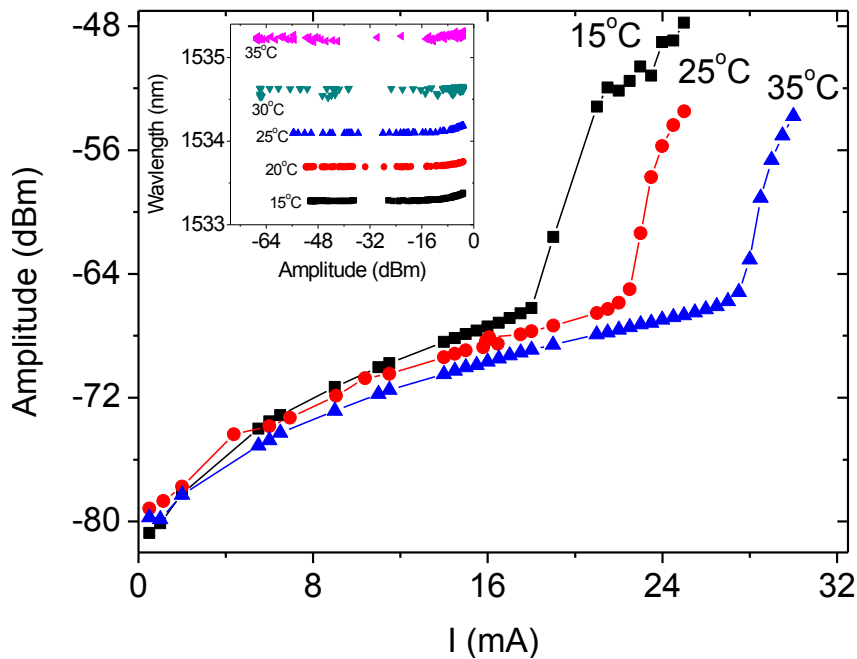

Fig. 3. Amplitude of DFB laser as a function of driven currents at T=15, 25 and 35 ºC. The inset shows amplitude versus wavelengths at various temperatures

Wavelength versus injection current at different temperatures under 980 nm pump laser is depicted in Fig. 4. It shows the changes in wavelength of the laser with current at room temperature, in which the emission peaks at an injection current of I_{th}=30 mA is around $\lambda \sim$ 1533, 1534 and 1535 nm at temperature T=15, 25 and 35 ℃, respectively. The current-tuning rate of the DFB mode is around 0.01 nm/mA at T=25 ℃, where the ratio of changes in wavelength over injected current in most of 1300 and 1500 nm conventional lasers is corresponding to 0.015 nm/mA [18].
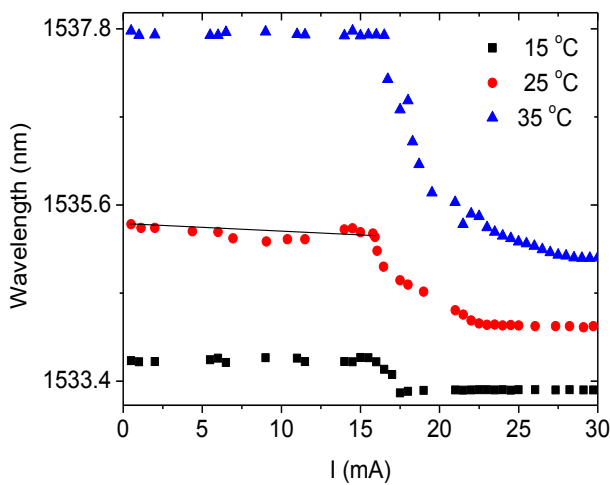

Fig. 4. Wavelength variation with the change in an injected current at temperatures of T=15, 25, and 35 ℃

The DFB laser spectra can be seen in Fig. 5, which is corresponded to peak amplitudes when 980 nm pump laser is off and on. The emission wavelength of DFB laser is around 1533.4 nm at temperature of T=15 ℃. At drive threshold current of I_{th}=17, 18 and 19 mA, and when the operating pump laser is off, the single mode intensity amplitude are about 11, 15, 31 dBm, respectively. The full width at half maximum (FWHM) for such spectra is around 0.65 nm, 0.78 nm, and 0.75 nm. However, when the pump laser is on under using the same threshold currents, the amplitude intensity are around 13, 22 and 35 dBm and their bandwidths are about 0.72 nm, 0.66 and 0.73, respectively.
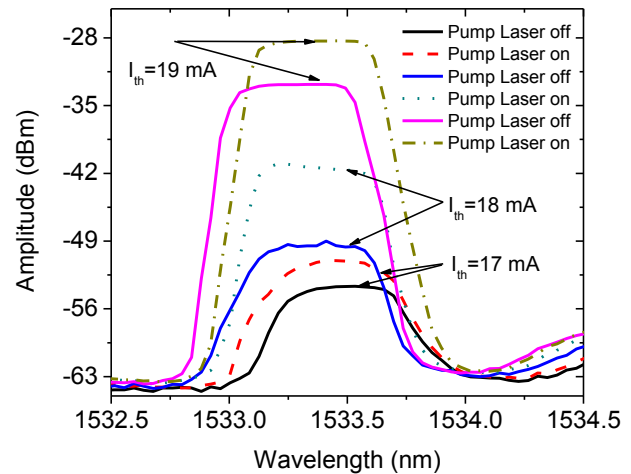

Fig. 5. Measured spectra from the DFB laser at various threshold currents of I_{th}=17, 18 and 19 mA under pump laser off and on at temperature of T=15 ℃

In Fig. 6, we show the emission spectra for the DFB laser when the Master laser ML (980 nm pump laser) is off and on at operating temperature of T=25 ℃ and at threshold current I_{th}=22 mA. The single mode emission wavelength is around 1534 nm when the 980 nm pump laser is off. Additionally, when the laser is on and at pump current of I_P=200 mA, an amplified signal intensity is measured on a log scale and has a maximum peak of -45 dBm, and an amplification at around 6 dBm is demonstrated. It also shows that the emission wavelengths is slightly shift to the longer wavelengths when the 980 nm pump laser on. Therefore, when the pump current is switched on, the carrier in the cavity changes rapidly. This causes a change in the refractive index and in the resonant wavelength of the grating and then the emitted laser wavelength [19]. The inset of figure shows the plot of temperature versus wavelength for the SL driven with using 980 nm pump laser at I_P=200 mA and also without using pump laser. It clear from the figure that the peak intensity of the device shifts toward longer wavelength, where the performance of DFB laser deteriorates rapidly as temperature increases. Thus, the shift wavelength of DFB laser follows only the temperature dependence of the material refractive index [20]. In this investigation, the emission spectra of the device are yielding a temperature dependency of emission wavelength of 0.011 nm/K, which shows relatively linear relation between wavelength and temperature.
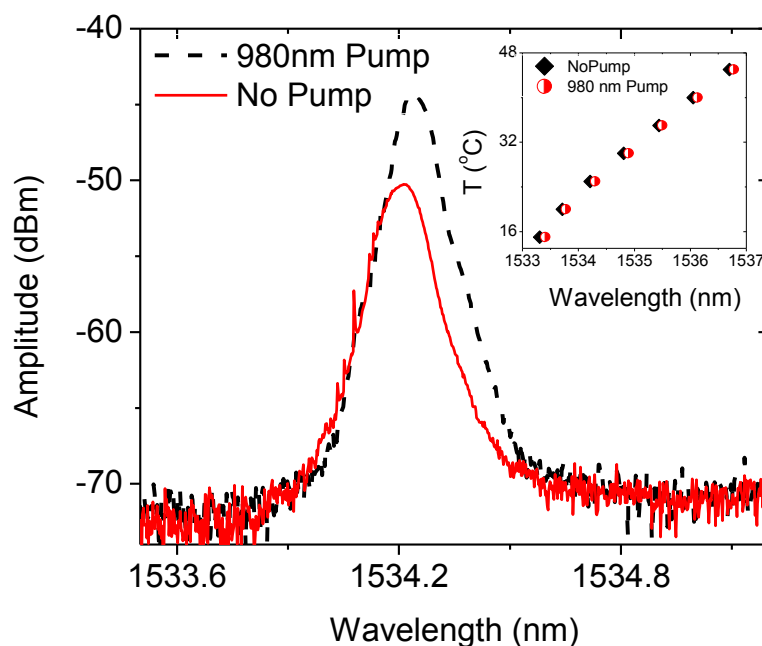
Fig. 6. Emission spectra of DFB versus wavelength at T=25 °C and I_{th}=22 mA using 980 nm pump laser at pump current of I_P=200 mA and without pump laser at T=25 °C. The inset shows temperature against wavelength with pump and without pump lasers

4. Conclusion

In conclusion, we have measured the effect of an optical injection of 980 nm beam into 1550 nm commercial DFB laser. When the pump laser switched on, an optical amplification at around 6 dB is demonstrated at peak emission wavelength of about 1534 nm. Although the lack of information on the DFB layers structure and their compositions, it is clear that different behaviours occur depending upon the injection current and operating temperatures. The emission spectra of the device were also measured at various threshold current and temperatures when the pump laser is off or on. Such measurements could lead to the design of devices as in amplifiers, according to the injected signal.

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