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Parameter Extraction by Microwave Characteristics of two-section Distributed feedback lasers

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Abstract
We extracted the parameters of two-section distributed feedback lasers which had 6.5 pairs' distributed Bragg reflector by the regeneratively amplified field, the four-wave-mixing fields and the microwave signals which measured by electrical spectrum analyzer (ESA).

1. Introduction

The way to communicate with other people has become more and more important these days. Wireless and optical communications are among the predominant methods that are widely available today. The microwave photonics (MWP), which combines the advantages of these two fields, has attracted many attentions across different academic disciplines. Previously, we proposed a two-section distributed feedback laser with distributed Bragg reflector (DBR) section to realize a compact microwave generator [1] [2]. In this paper, a parameter extraction algorithm based on four-wave mixing (FWM) is built and the internal laser parameters can be extracted from the optical and microwave measurements. Some of the parameters such as linewidth enhancement factor are difficult to acquire under individual laser condition, and this dual-wavelength laser can play a very valuable role for laser characterization.

2. Structure Design and Measurement system

In this experiment, DFB lasers emitting photons around 1550nm are selected and the gain medium is the InGaAsP multiple-quantum-well double heterostructure. Two DFB lasers are lined up with a DBR section in between them. The focus-ion-beam (FIB) was used ti etch the semiconductor away to form this DBR section. Each pair of mirrors contains a 5/4 λ InP and a 3/4 λ air gap, and the designed wavelength (λ) is 1550 nm. The etch depth was chosen to be 5 μm, due to electrical isolation concerns. The details of the processes can be seen in previous reports [1] [2]. The schematic diagram is shown in Fig. 1 (a). In the integrated chip, we denote the front laser as the slvae laser and the backside laser as the master laser.

The measurement system, as shown Fig. 1 (b), is composed of two current drivers for DFB lasers, a fiber-alignment stage and the erbium-doped amplifier (EDFA) to enhance the input photons. The output after EDFA is then fed into an optical splitter, one branch goes into optical spectrum analyzer (OSA), and the other goes into a high-speed Photodetector and eventually the microwave signal analyzer (PXA) to show the RF spectrum.

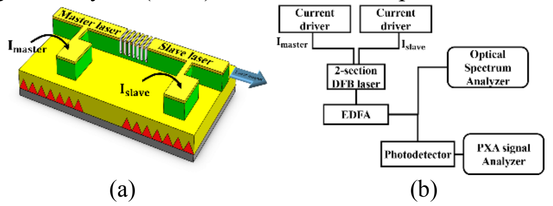


Fig. 1. (a) The schematic diagram of a monolithic two-section DFB laser with 6.5 pairs bragg grating. (b) The measurement system.

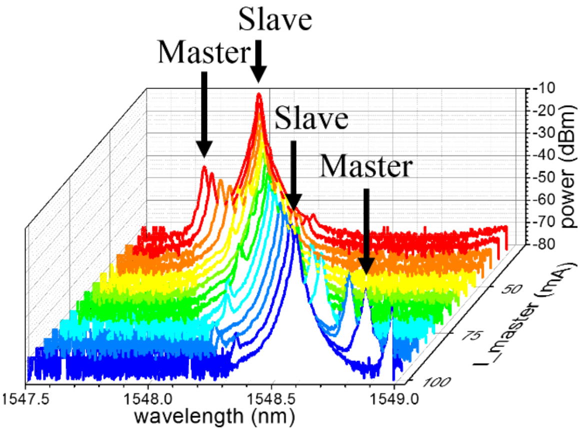


Fig. 2. The optical spectrum under the slave's current is 30 mA and the master's current is 40-100 mA.

3. Parameter extraction via Four-wave-Mixing

When both lasers are driven, two major emission peaks can be observed in the optical spectrum as shown in Fig. 2. We fixed the current of the slave laser (I_{slave}) while tuning the driving current of the master laser (I_{master}) up from 40 mA to 100 mA. As a result, the wavelength of the slave moved slightly due to the rising temperature of the chip, meanwhile, the master laser's emission peaks red-shift much faster and eventually pass the slave laser's. When the emission wavelength of the two lasers are close, extra peak in the optical spectrum can be seen in Fig. 2. This extra peak, originated from the four-wave-mixing effect [3], locates at the same distance from the slave laser as the master laser's peak does, but it is on the other side of the optical spectrum. When this FWM effect happens, a good radio frequency signal can be detected on the electrical spectrum domain. The resultant frequency of this RF signal is the differential frequency between the slave's and master's emission peak, and this frequency can be tuned by different I_{master} as show in Fig. 3.

In the past, the completed results of FWM effect on both optical and RF signal have been deducted as [3]:

$$\left|\frac{A_f}{A_r}\right|^2 = \frac{(\Omega_r^4+\Omega^2\gamma_p^2)(1+b^2)/4}{(\Omega^2-\Omega_r^2/2-b\Omega\gamma_p/2)^2+(\Omega\gamma_r-\Omega\gamma_p/2-b\Omega_r^2/2)^2} \quad (1)$$

$$\sigma^2 = \left|\frac{\eta * A_i}{A_0}\right|^2 \frac{\Omega^2+(\gamma_r-\gamma_p)^2}{(\Omega^2-\Omega_r^2)^2+\Omega^2\gamma_r^2} \quad (2)$$

where A_r is the regeneratively amplified field, A_f is the four-wave-mixing fields, η is the coupling rate, Ω is the frequency, Ω_r is the relaxation resonant frequency, γ_r is the relaxation rate, γ_p is the relaxation rate of photon density, b is the linewidth enhance factor. In the above, A_r and A_f was known by measurement, however A_i and η are unknown in our integrated chip. So instead of the original A_f /A_i and A_f /A_i ratio, we divide one by the other to eliminate A_i term in our formula. The combined experimental data is fitted with Eq. (1) and plotted in Fig. 4 (a).

As for the measured RF power, we can apply another equation involved in the same set of laser parameters as in Eq. (2) [3]. The unknown quantity of A_i is now treated as a fitting parameter and the fitted result can be seen in Fig. 4 (b). From the fitted data, the A_i evolved just like a regular roll-over L-I characteristics which is expected for the master laser output. The final set of extracted parameters are listed in Table 1. The γ_r, γ_p, Ω_r are the shared number between the optical and RF data.

Table I

Symbol	Value	Parameter
γ_r	12.742	Relaxation rate
γ_p	0	Relaxation rate of photon density
Ω_r	48.4548 GHz	Relaxation resonant frequency
b	2.0659	Linewidth enhance factor
η	232.4306	Coupling rate

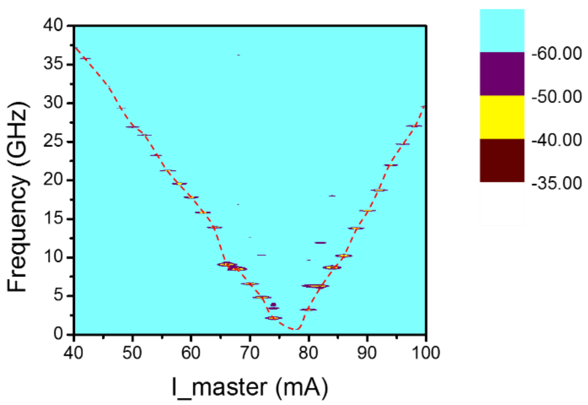
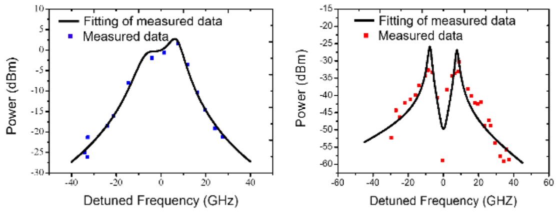


Fig. 3. The electrical spectrum under the slave's current is 30 mA and the master's current is 40-100 mA.



(a) (b)

Fig. 5. (a) The blue dot is measured data and the black line is the fitting result. (b) The red dots is measured data and the black line is the fitting resul.

4. Conclusion

In summary, we use the two-section DFB laser to extract the important laser parameters such as linewidth enhancement factor and the relaxation resonant frequency. The effect of four-wave-mixing is utilized during our modeling to set up the basic equation for fitting. The fitted optical amplitude and RF signal power show great agreement between data and calculation. This non-destructive method should be useful for further investigation of laser internal dynamic mechanisms.

5. Acknowledgement

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6. References

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