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The Study of Relaxation Time in Test of 940 nm Semiconductor Laser*

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ABSTRACT

Conventional test of the peak wavelength of a laser used to be applied immediately after a device is injected current. However, the results can not be considered as an accurate description to temperature characteristic. This passage puts forward a concept of relaxation time in wavelength texts, mainly based on the experiment of 940 nm strain quantum well laser, confirming that under constant current, wavelength will get through a process of rising, and then, reach the limit. This process brings the effect on spectral characteristics of a device which cannot be ignored and the accumulated heat in relaxation time will gradually impact the emission wavelength of the laser, even crest split to form bimodal phenomenon.

Keywords: Semiconductor Laser; Test; Temperature Characteristics; Relaxation Time

1. Introduction

With the development of fiber-optical technology, the fiber pump sources manufacture has been the critical technology to improve the signal transmission efficiency. The strongest absorption peak of Yb-doped optical fiber is around 976 nm [1]. However, the absorption peak is sharp; as a result, the requirements of wavelength and bandwidth are very strict, which makes it suitable for the application of pulse signal. While the absorption peak near 940 nm has high absorption bandwidth, it will not appear concentration quenching phenomenon, which is beneficial to the application of continuous signal. As a consequence, the research of laser pump sources used by 940 nm semiconductor laser with reliable and stable high power output has a great significance.

In fact, output power of laser is constantly improving, and the problem of heating effect becomes more serious. The quantity of heat produced by a working laser makes the temperature of active layers rise sharply, which results in the wavelength red shift and the cavity surface or interior to burn down [2]. So it is an important issue to study the temperature character of the device. Nowadays, the study on testing the heat character of the device by controlling the heat or changing its current is major. But it is rare to study the effect on the device itself made by the heat which is accumulating with time and produced by the device when it works under constant current. This paper will study and analyze this effect, and makes it clear that the influence on the spectral characteristic of a device. Moreover, we put forward a concept of relaxation time that wavelength could test after it, which can estimate a device's spectral character more accurately.

2. Put Forward the Inference

In conventional test of semiconductor laser, the test is used to be applied immediately after a device is injected current. However, in practical applications, the device often works under constant current conditions, Understanding the effect on wavelength characteristics by the device's heat accumulation over time will help to accurately assess the thermal properties.

Wavelength change is due to heating of the device causing the band gap widens, thereby causing the decrease of photon energy, and the increase of wavelength. Heating of a device operates primarily from the P-cladding layer, P-cladding layer is heavily doped, the resistance rate is high, the device generates a lot of heat while continue to work. In certain process conditions, the volume resistivity will generate heat in a certain range, with certain cooling capacity of the package, we predicted that if a device work under a certain current conditions, after some time, heating degree will reach a state of equilibrium. As a response, the temperature and wavelength of the device will reach a state of dynamic equilibrium the

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same. As this process related to the change of temperature, we called it as dynamic thermal relaxation process, the corresponding time is defined as the thermal relaxation time τ_T.

In order to verify the existence of relaxation time, we carried out a set of validation experiments.

3. Experimental Verification

3.1. Chip Materials and Structural Design

An epitaxial wafer used in the test had been grown by the MOCVD system, the epitaxial structures are shown in **Figure 1**, the epitaxial layer were mainly in turn: GaAs substrate; GaAs buffer layer; $Al_{0.3}GaAs$, up and down cladding layers, 700 nm; the two $Al_{0.1}GaAs/InGaAs$ composed of strained quantum well optical waveguide layer; GaAs ohmic contact thickness 450 nm. Center wavelength is designed to 940 nm.

The electrode structures of the device are designed to ridge, the ridge width of 100 μm. The current blocking layer is grown by using PECVD systems, 200 nm of SiO_2 material are obtained, P-type electrode material is Ti and Au, N-type electrode material is AuGeNi alloy and Au, TO_3 package with seat tube, adapter copper heat sink for the heat sink, the package will be P type electrode lay a flip process, the final packaged chip cavity length is 2000 μm.

3.2. Experimental Design and Installation

Experiment is using the spectral tester to test the spectral characteristics of the instrument, first set up the device test injection current I_0 and projected peak wavelength λ_p, then began spectral measurement, the instrument will automatically λ_p' centered at 40 nm spectral range scan, the spectrum to be combined with precise measurements to complete the rotation of the grating, spectral measurements to each scanning time 25 s, 25 s intervals so experiment a peak wavelength for data recording, the device is continuously administered during the current I_0.

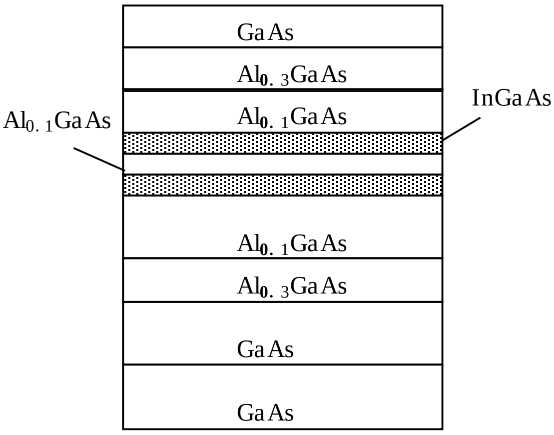

Figure 1. Epitaxial structure.

3.3. Results and Discussion

Figure 2 shows a spectrum when the injection current I_0 is 1.5A. Four curves mean four devices which fabricated by the same process and packaged. Abscissa represents for the time of duration injection current I_0, and ordinate represents the output peak wavelength of light λ_p, injection current always remains the same. The change of peak wavelength would be obtained by the curves in **Figure 2** The peak wavelength gets to an extreme value with the time increasing. This verifies the existence of the thermal relaxation time. The period, which from the beginning of the test to the peak wavelength gets a steady data, is called the test relaxation time.

The following equation which relates to peak wavelength λ_p and the relaxation time τ_T can be got.

$$\lambda_p = a/(1 + c*\exp(-b*\tau_T)) \quad (1)$$

In Equation (1), a, b and c are model parameters, and different parameters corresponding to different devices. In this paper, it based on device No.1 as an example for fitting. The fitting curve showed in **Figure 3** and gets that a = 950.7，b = 0.01114，and c = 0.009262.

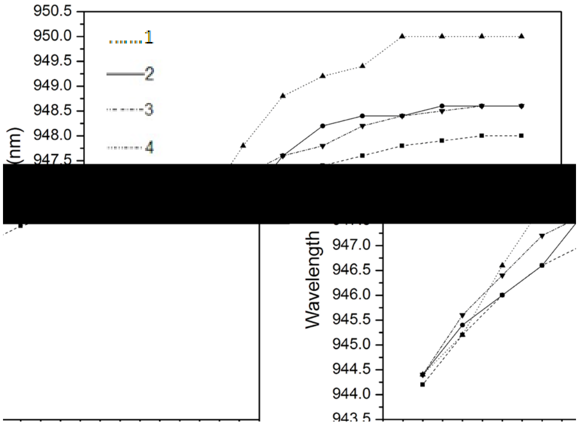
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Figure 2. I_0 = 1.5A Red shift curve of peak wavelength in relaxation time.

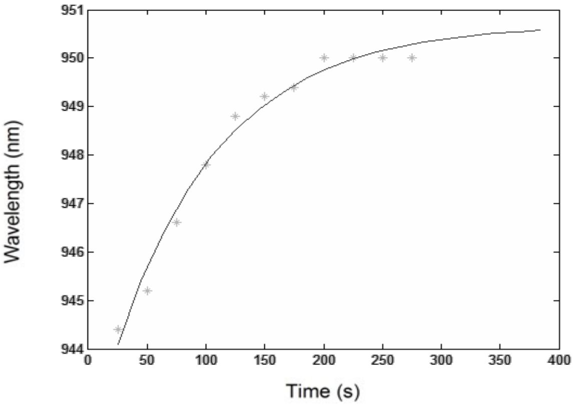

Figure 3. Simulation of peak wavelength changing in relaxation time.

4. Further Study on Relaxation Time

In order to study the variation of spectral characteristics with time in the relaxation time, we carried out the following experiments:

4.1. The Change of Peak Wavelength during Relaxation Time

One device set to continuous testing with change the injection current I0. Firstly, the injection current of 1.5A is set. Each 25 seconds record its emission peak wavelength and until the peak wavelength remains a steady value and dynamic stability condition. Then set the injection current to 1.5A and repeat the step above to measure the data. Later in the same method the peak wavelengths is measured at 2A and 3A Units

Figure 4 shows the spectrum chart when the injection current at 1A, 1.5A, 2A and 3A. After relaxation time, which keep applying test current at 1A, a limit peak wavelength of 944 nm and 2.5 nm red shift are obtained. At I_0 = 3A, red shift gets to 5 nm during the relaxation time. **Figure 3** shows when larger injection current is measured the larger limit value of red shift should be got. And increased the current value by a step 1A, the change of wavelength most gets to steady state within 300 seconds. It cannot ignore the heat accumulated with the increase of time even run at a constant current. A deviation is taken into the test results by the heat effecting and when increasing injection current the heat effect on emission wavelength of the device is also gradually increased. Predictably, when high power laser continue to run at a large current the heat produced during relaxation time will have great influence on the output wavelength. Therefore, to get a more accurate measure of the characteristics the influence of relaxation time would be considered.

4.2. Device Temperature Variation in Relaxation Time

In order to study the relationship between device temperature and peak wavelength in relaxation time, we did a test to observe temperature changes. We use a cooler to keep heat sink at room temperature 25˚C, the measured temperature with instrument is the highest temperature of the central area of the device. Inject a constant current of 3A to the device, record the temperature and the peak wavelength every 25 s. As shown in **Figure 5**, curve slowly down after, and gradually stabilized after 200 s. So, the temperature change as we predicted in the previous experiment. From the curve, in 3A constant current, we can see that the device temperature changes from 302 K to 307 K, the average rate of change over time as 0.025 K/s in the relaxation time.

Figure 6 is the relationship curve between the device temperature and the peak wavelength, the wavelength increases with increasing temperature. As shown in data distribution, data corresponding to the abscissa increasingly dense, indicating that changes of temperature the more backward the smaller it is. The rising trend has become increasingly slow curve, corresponding to the wavelength change it is getting smaller and.

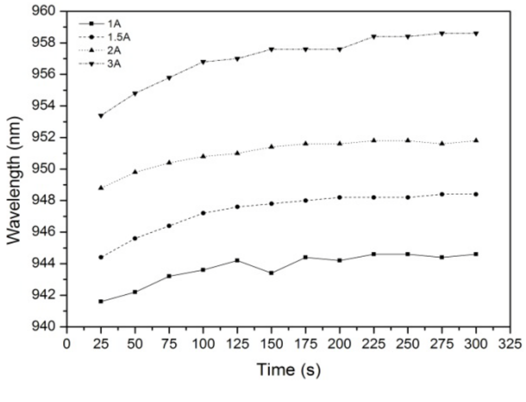

Figure 4. Redshift curve of peak wavelength in different current conditions.

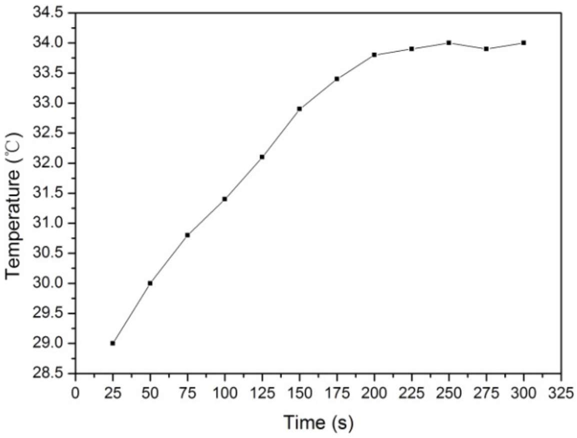

Figure 5. I_0 = 3A The temperature of device change in relaxation time.

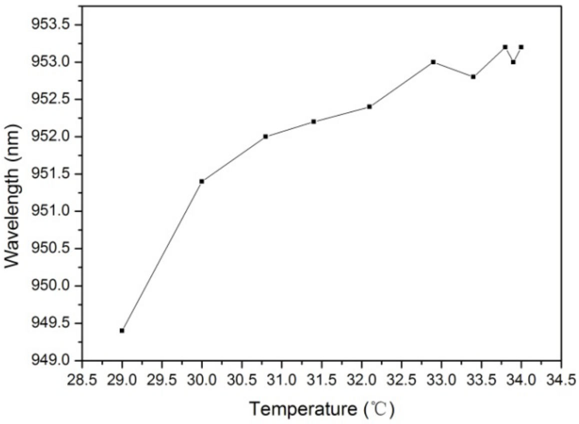

Figure 6. I_0 = 3A Device temperature and the peak wavelength of the output light of the curve.

5. Summary

Through the test of the wavelength of 940 nm strain quantum well laser under the constant current, the rise of temperature and the temperature will reach the limit. With the constant current increased, the limit value will be greater. At room temperature, under 3A continuous current condition, the peak wavelength of the laser will reach steady state after 300 s. Compared with the immediately measured data, the wavelength has increased by 4 nm and the temperature increased by 5˚C. And as the current increases, the accumulated heat in relaxation time will gradually impact the emission wavelength of the laser, even crest split to form bimodal phenomenon. Under the constant current, in order to get a well output spectral characteristics, the accumulated heat in relaxation time must be considered. Selecting suitable operating current should be based on the device performance after the relaxation time.

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