High-temperature reliable Paules Model-Locked quantum-dot lasers on GaAs

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***Abstract*—In this paper we investigate the high-temperature reliability of a Pulse Mode Locked quantum-dot laser grown on GaAs. We measured the threshold current, output power, operating conditions and wavelength stability of this laser. Test results show that this laser exhibits excellent high-temperature stability and has the potential for future commercialization.**

Keywords—Mode Locked Laser, Stress Test, Quantum-dot Laser

I. INTRODUCTION (*HEADING 1*)

The high intensity and short pulse characteristics of Colliding Pulse Mode-Locked(CPM) lasers make it a very broad application scenario in the field of optical communication and optical interconnection. High operating stability is an important requirement for the commercialization of CPM lasers. There is a desire to obtain CPM lasers with high output power, low threshold current and stable operating performance even after a long period of operation. A laser device that maintains a low threshold current and high output power will ensure a high energy efficiency ratio after a long period of operation. Stable performance means that the number of comb lines at the maximum power of 3 dB of the CPM laser frequency comb remains constant at the same injection current and reverse bias voltage, and that the wavelength of these comb lines does not drift.

II. SETUP

We set the laser at 80 degrees Celsius for a high temperature stress test, injected 150 mA of current into the laser without injecting reverse bias voltage, and allowed the laser to continuously perform laser output. We perform performance tests on this CPM laser at regular intervals to observe the change in laser performance as the stress test time increases. Starting at stress test hour 336, we performed Light current voltage characteristics(LIV) tests at 48 hour intervals to obtain the threshold current and output power of this device. We injected this laser with injection currents ranging from 0 mA to 250 mA to obtain the laser output power at different injection currents. Starting at the 400th hour of the stress test, we performed the performance of the device under different operating conditions at 200-hour intervals. The laser was fed with an injection current of 70 to 250 mA and a reverse bias voltage of 0 to 5 V. The device was tested at room temperature, higher temperature and higher temperature.

III. RESULTS AND ANALYSIS

After stress testing, we collected LIV data and compiled the threshold current and output power changes of the device as the stress time grew and gave the expected lifetime of this device. We used the spectral data of the device over a large operating range to create a heat map used to see the operating point condition and wavelength stability of the device.

A. Light Current Voltage Characteristics

The threshold current of this device kept increasing as the stress test time grew, from 69.54 mA at 336 hours to 72.39 mA at 1728 hours, a variation of only 4%. The laser output power at an injection current of 150 mA decreased from 5370 mW to 4990 mW, a seven percent reduction.

According to the fit in Fig. 1 , The mean time to failure(MTTF) [1] of this device is 20 years, which means that the device threshold current is expected to change by 100% after 20 years It is a very encouraging result and indicates that the device has an extremely long expected lifetime compared to devices in [2].

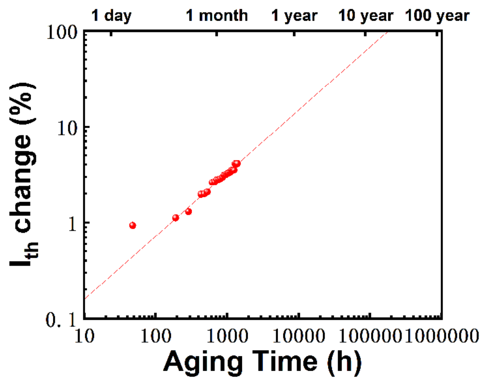

Fig. 1. Relationship and fitted straight line for threshold current variation with life test time

B. Working Performance

We use heat maps like Fig. 2 to show the performance of the CPM laser under a wide range of two-dimensional operating conditions.

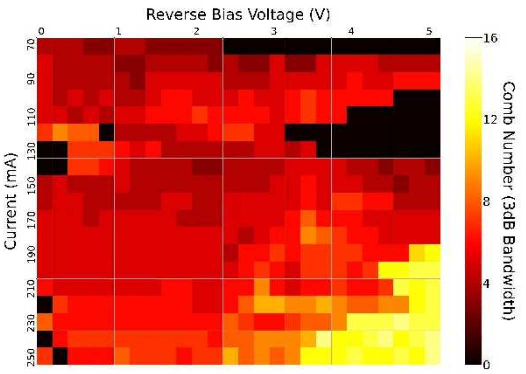

Fig. 2. Heat map obtained at 55 ℃ after 400 hours of stress testing

The horizontal coordinate of the graph is the reverse bias voltage, from 0 to 5V with 0.2V interval, and the vertical coordinate of the graph is the injected current, from 70 mA to 250 mA with 10 mA interval. Each color block of the graph represents the operating performance of the device under specific injection current and voltage conditions. The colors are used to show comb lines within 3dB optical bandwidth. The warmer the color in the heat map, the more comb lined within 3dB optical bandwidth there are. As the stress test time increases, the thermogram of this device at the same temperature remains approximately constant. As an example, in the 55 degree Celsius thermogram, the region with the highest number of roots of the number of comb lines within 3dB optical bandwidth remains in the lower right corner of the thermogram from 400 hours to 1600 hours, i.e., the region with high injection current and high reverse bias voltage.

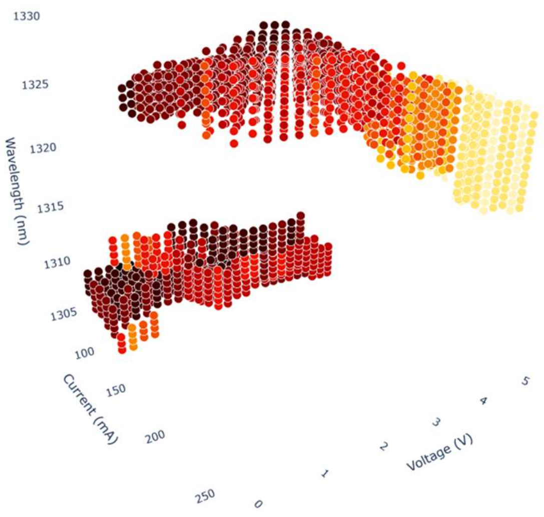

Fig. 3. 3D scatter obtained at 55 ℃ after 1600 hours of stress testing

We also plotted a 3D scatter plot to show the distribution of the location of the comb line peaks, as shown in Figure 3. The color of each point represents the number of comb lines under this working condition, and the correspondence is the same as Figure 2, so if you look at the 3D scatter plot from the positive direction of Z-axis, we will get a similar picture as Figure 2.

As can be seen in Figure 3, the position of the comb lines peaks basically remains densely distributed, with a jump of about 10 nm in the position of the peaks near the 140 mA injection current. This means that the device undergoes mode switching near the 140 mA injection current.

C. Wavelength Stability

We used another form of heat map to demonstrate wavelength stability. These heat maps represent the spectrogram information of this device after different stress test times for specific injection current and reverse bias voltage conditions. The horizontal coordinate of the graph represents the wavelength information and the vertical coordinate of the graph represents the spectrogram obtained after how long a stress test time.

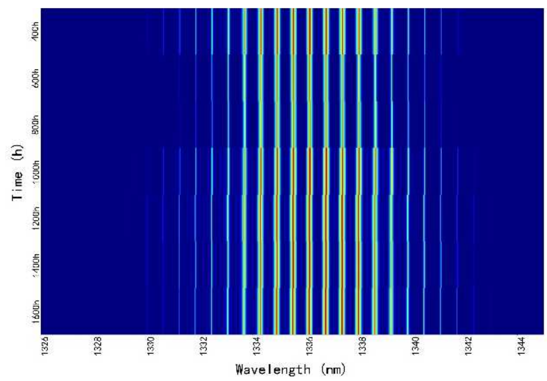

Fig. 4. Wavelength stability heat map obtained at 190 mA injection current, 0.8 V reverse bias voltage, 80 ℃

We have found some excellent working conditions. As illustrated in Fig. 4, under these operating conditions, this device maintained perfect wavelength stability under continuous stress testing for 1600 hours.

Under other operating conditions, the wavelength of the comb lines undergoes a regular drift. In each wavelength-shifted heat map, the spectra are all shifted as a whole, and the wavelength shift is a fixed amount of 25 GHz or 50 GHz.

D. Conclusion

This CPM laser has excellent high-temperature stability, having passed 1600 hours of high-temperature testing. The device's threshold current takes 20 years to double under the same pressure conditions. The operating performance of this device maintained the same excellent before and after the stress test. Such a device with excellent performance and reliability allows us to be optimistic about the application of CPM lasers in optical communications and optical interconnects.

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