Fast Characterization System for Multi-Channel Interference Widely Tunable Semiconductor Lasers

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***Abstract*—A fast PCB-based characterization system is developed for widely tunable lasers. Tuning-range >50 nm and wavelength-deviation <±1.5 GHz have been achieved with the characterization time reduced to two hours compared to 6 hours for conventional.**

Keywords—Tunable Lasers, multi-channel, characterization

I. Introduction

Monolithic widely tunable semiconductor lasers have wide applications in optical fiber communication systems, optical sensing and etc. [1]. The multi-channel interference (MCI) widely tunable semiconductor laser has recently demonstrated high performances according to [2]. The tuning range exceeds 50 nm, and the fiber coupled output power of all wavelengths reaches 16 dBm with the side mode suppression ratios (SMSRs) greater than 46 dB. However, different from the principle of other grating-based tunable lasers, the MCI laser is based on the constructive interference of eight arms with different arm length difference as shown in Figure 1. One of the arms is used as a reference arm, and the phase shifts of the remaining seven arms are adjusted so that they interfere to form a reflection spectrum dominated by a single reflection peak. In addition, a common phase arm is integrated at the front of the eight interference arms, which has the ability to push the longitudinal mode. Therefore, the lasing wavelength of the MCI laser can be tuned by controlling the relative position between the reflection peak and the longitudinal mode. Phase shifters are integrated below both the arm phase region (AP) and the common phase region (CP) which need to be controlled simultaneously for the characterization of the MCI laser, but it is not easy.

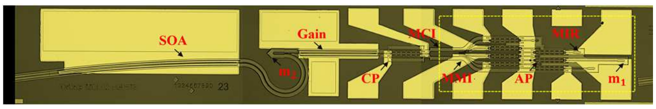

Fig. 1. Microscope image of the fabricated MCI laser.

Obviously, the control of multiple variables makes the characterization of multi-channel interference widely tunable lasers become complex and generally time-consuming, which takes over five hours using the conventional characterization system based on source meters connected to a computer through General-Purpose Interface Bus (GPIB) [3]. Moreover, it is inconceivable to characterize multiple lasers at the same time, which greatly hinders the large-scale application of the laser. In this paper, we present a fast characterization system integrated on a single PCB for the MCI laser.

II. Solution Design and Implementation

In the conventional characterization solution of multi-channel current injection wide range tuning lasers as shown in Figure 2(a), a variety of instruments such as National Instruments' (NI) extensive data acquisition and control devices, Keithley' source meters and Thorlabs' desktop temperature controllers are required, but their disadvantages are obvious, such as bulky size, complicated wiring and high cost [4]. In addition, the serial communication between instruments is extremely inefficient, which slows down the speed of laser characterization.

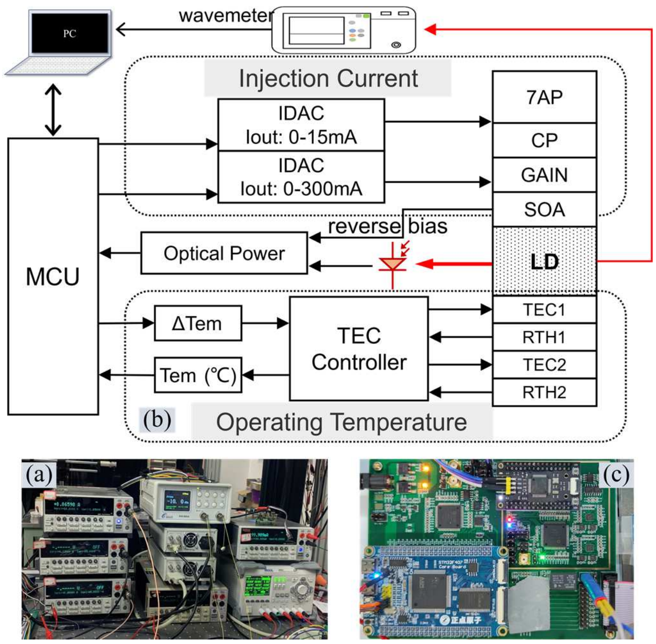

Fig. 2. (a) Conventional characterization system; (b) Structure of fast characterization system for MCI-WTL; (c) The fast characterization solution based on a single PCB.

In order to address these issues, we develop the fast characterization system, as shown in Figure 2(b). The microcontroller unit of the system adopts the microcomputer of STMicroelectronics. The 16-bit analog-to-digital converter chip of Analog Devices is used to collect the external feedback information. We choose the 16-bit current source digital-to-analog converter from Linear Technology to inject current into the laser which can provide ten high-compliance current source outputs. Finally, the entire fast characterization system on a printed circuit board (PCB) can pull off all features that

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required to characterize the MCI laser, such as precise control of dual thermoelectric coolers (TECs), multi-channel current injections into the laser, detection of optical power and calibration of wavelengths. Figure 2(c) shows that the new solution achieves the integration of many peripherals compared with the conventional solution. On the premise of satisfying all features and performance, the characterization time is saved significantly as well as the setup cost. In addition, it is possible for parallel characterization of multiple lasers using the proposed system.

III. RESULTS OF EXPERIMENTS

The MCI tunable laser moves the longitudinal mode by adjusting the current injected into the CP, and optimizes the current injected into the seven APs to adjust the reflection peak. By aligning the reflection peak with the longitudinal mode near the target wavelength, quasi-continuous tuning wavelengths can be achieved over a wide range, as shown in Figure 3(a). The core problem facing the characterization is how to achieve the phase alignment of each arm when the wavelength is calibrated. According to the theory mentioned in the [5], when the eight arms are in the same phase state, the constructive interference leads to the highest reflectivity in the laser resonator, so that the output optical power reaches the maximum value. At this time, the laser emits a single-mode beam.

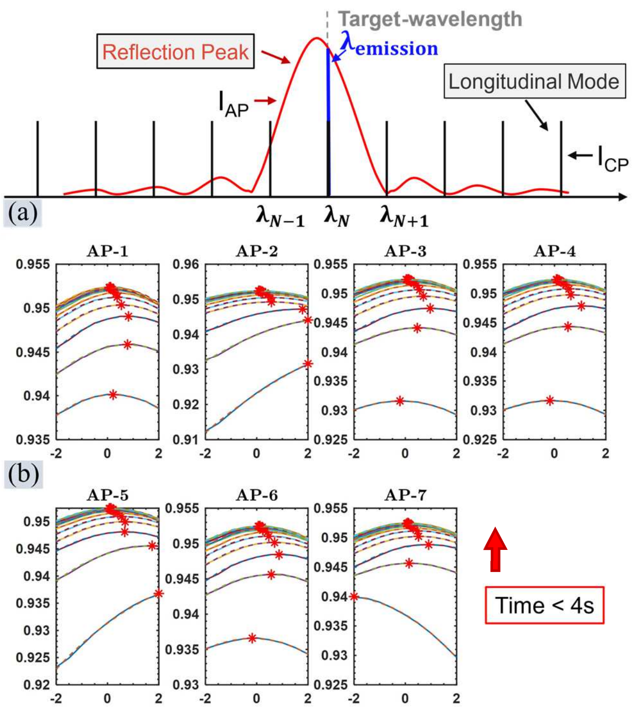

Fig. 3. (a) The tuning principle of MCI lasers; (b) The iterative process of the reflection peak fast alignment algorithm for the fast characterization system.

A. Fast alignment of the reflection peak

Taking advantage of this feature, we developed a fast alignment optimization algorithm of the reflection peak for the fast characterization system based on the idea of the hill-climbing algorithm. The iterative process of the algorithm is shown in Figure 3(b). A certain range of phase fluctuation is applied to each arm, and then the phase of each arm is updated to the position where the optical power is maximum through the method of parabolic fitting. The iterative process is repeated continuously until the phase of all arms is at the maximum optical power. At this point, it can be considered that the reflection peak has been aligned with the longitudinal mode.

In the conventional characterization system, this process requires frequent data exchange between computers and measuring instruments, which is the most time-consuming and troublesome. Therefore, the core of a fast characterization system is to entrust the reflection peak alignment algorithm to the MCU, which eliminates the communication time between instruments, thereby realizing the zero-delay optimization of reflection peak movement and power detection. This greatly improve the characterization speed for widely tunable lasers. Compared with the conventional method that takes 30 seconds to optimize a wavelength, the fast characterization system takes less than 4 seconds. Because of it, when optimizing all 120 wavelengths at once, the fast characterization system can save an hour. The results of optimizing the arm phase using the fast characterization system were checked, as shown in Figure 4. It can be seen that the reflection peak aligns neatly on the longitudinal mode, and the output optical power reaches the maximum value.

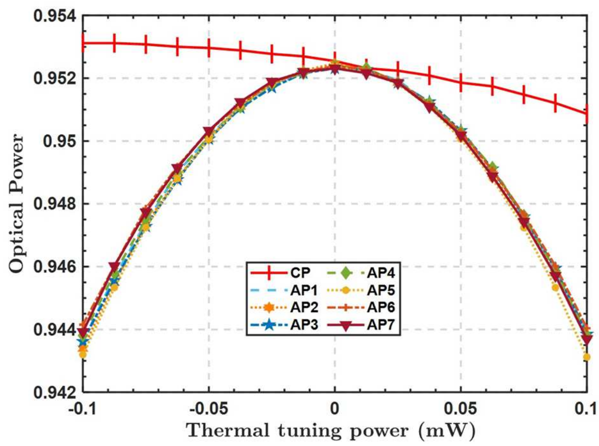

Fig. 4. The phase state of all arms optimizing by the fast characterization system.

B. Characterization results

The proposed system has been used for the characterization of the multi-channel interference (MCI) widely tunable semiconductor laser. Results are show in Figure 3. The output wavelength of the laser and the temperature inside the package under the fast characterization system are quite stable as shown in Figure 5(a) and (b). Within half an hour, the temperature variation of the laser inside the package is about ±0.01℃ and the output wavelength jitter caused by the temperature is less than ±0.5 pm. As shown in Figure 5(c)-(f), the tuning range of the MCI widely tunable laser is more than 50 nm which covers the C++ full-wave band. SMSRs are larger than 47 dB and optical powers are over 16 dBm across the whole tuning range. The frequency deviation between the output frequency and the ITU grid is less than 1.5 GHz. It is shown that these exciting performance of the MCI laser characterized using the proposed fast-characterization system agrees very well with those obtained using the conventional system mentioned in [2]. However, the time for the whole characterization of an MCI laser has been significantly saved to be less than 2 hours, which is nearly 30% of that using the conventional system.

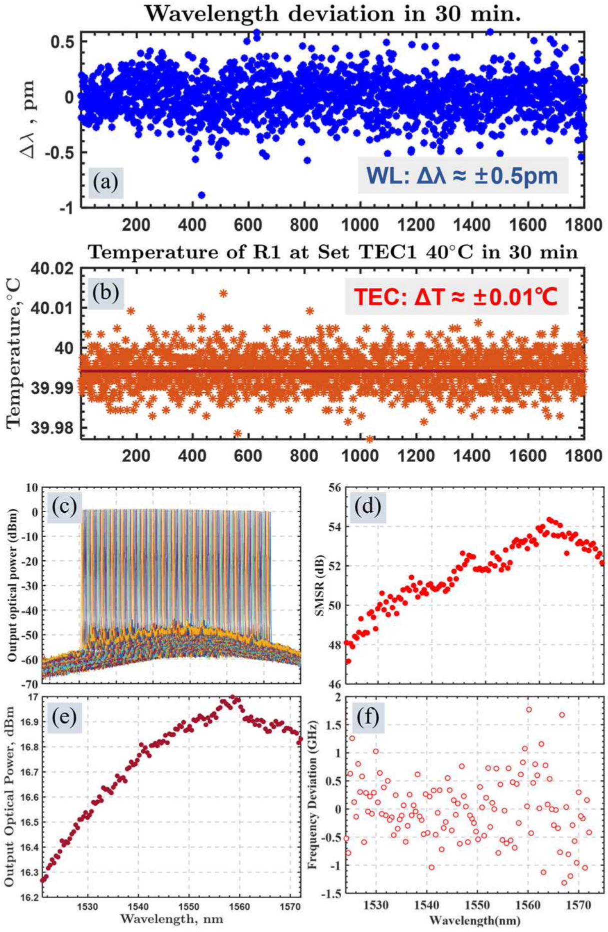

Fig. 5. Results of MCI lasers with the fast characterization system. (a) The wavelength fluctuation; (b) Temperature variation of the laser; (c) Superimposed lasing spectra; (d) SMSRs; (e) Output power; (f) Frequency deviation.

IV. Conclusion

We proposed a fast characterization system integrated on a single PCB for the MCI widely tunable lasers. All the characterization results using the proposed system are consistent with those obtained using the conventional solution. Not only that, the total time for the characterization is reduced by more than 60% and the cost is saved by 90% which is less than $200. In the future we will use etalons to find the non-hysteresis region for the wavelength setting instead of using slow wavelength meters, which will further reduce characterization time down to below 30 minutes.

Acknowledgment

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References

[1] Byrne, D. C. , Engelstaedter, J. P. , Guo, W. H. , Lu, Q. Y. , Corbett, B. , & Roycroft, B. , et al., "Discretely Tunable Semiconductor Lasers Suitable for Photonic Integration," in IEEE Journal of Selected Topics in Quantum Electronics, vol. 15, no. 3, pp. 482-487, May-june 2009, doi: 10.1109/JSTQE.2009.2016981.

[2] Quanan Chen, Chun Jiang, Kuankuan Wang, Miao Zhang, Xiang Ma, Ye Liu, Qiaoyin Lu, and Weihua Guo, "Narrow-linewidth thermally tuned multi-channel interference widely tunable semiconductor laser with thermal tuning power below 50 mW," Photon. Res. 8, 671-676 (2020)

[3] Quanan Chen, Gonghai Liu, Qiaoyin Lu, and Weihua Guo, "Optimization algorithm based characterization scheme for tunable semiconductor lasers," Opt. Express 24, 20982-20992 (2016)

[4] Quanan Chen, Kuankuan Wang, Chun Jiang, Xiang Ma, Ye Liu, Qiaoyin Lu, and Weihua Guo, "Butterfly-packaged multi-channel interference widely tunable semiconductor laser with improved performance," Opt. Express 29, 6344-6355 (2021).

[5] Kuankuan Wang, Quanan Chen, Chun Jiang, Zifeng Chen, Jiajun Lou, Mingzhi Lu, et al., "Characterization of Thermo-Optically Tuned Multi-Channel Interference Widely Tunable Semiconductor Laser for Quasi-Continuous Tuning," in Journal of Lightwave Technology, doi: 10.1109/JLT.2023.3241892.