Monolithic tunable lasers for low cost DWDM networks

Jian-Jun He[1,2*], Sen Zhang[1], Jianjun Meng[1], Xiaohai Xiong[1], Huabin Xing[2], Hushan Jin[2], Di Zhong[2], Jiasheng Zhao[2]

[1]State Key Laboratory of Modern Optical Instrumentation, Centre for Integrated Optoelectronics, College of Optical Science and Engineering, Zhejiang University, Hangzhou 310027, China

[2]Lightip Technologies, Co. Ltd., 11. Xi-Yuan Eighth Road, Hangzhou 310030, China

*jjhe@zju.edu.cn

Low-cost tunable lasers are key enablers for next-generation dense wavelength division multiplexing (DWDM) based access and metro networks. At present, tunable lasers are mostly deployed in long-haul optical transmission systems due to their high cost resulting from fabrication and operation complexity for structures such as sampled grating distributed Bragg reflector (SGDBR) [1,2]. For wide deployment of the WDM technology in metro, access, and data center networks, the cost reduction of tunable lasers has become a key issue. Recently, a simple and compact tunable V-cavity laser (VCL) has been proposed and demonstrated [3-4]. By using a specially designed half-wave coupler between two Fabry-Perot lasers, a widely-tunable single-mode laser with high side mode suppression ratio (SMSR) is achieved without requiring complex gratings. Discrete wavelength tuning up to 50 channels at 100 GHz spacing has been demonstrated experimentally with a simple tuning algorithm [5]. Single-electrode controlled fast wavelength tuning in the order of ~10ns has also been achieved by using a quantum well intermixed tuning section [6].

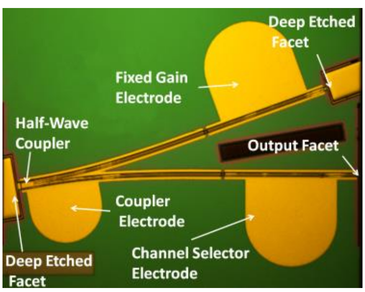

Fig. 1. Photograph of the VCL chip

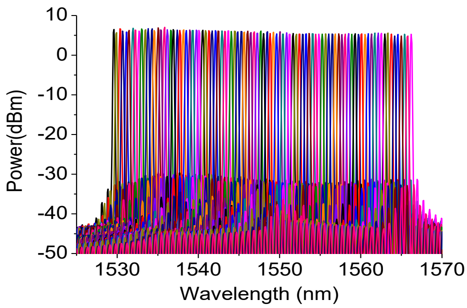

Fig.2. Measured spectra of 93 channels with 50GHz spacing.

Figure 1 shows the top-view photograph of the V-Cavity laser chip. It consists of two Fabry-Perot cavities with slightly different optical path lengths. The length of the fixed gain cavity is designed to be 450μm to match its resonant wavelengths to the ITU grid of 100 GHz spacing. The channel selector cavity is 5% longer so that the Vernier effect can be used to achieve a wide tuning range. The two cavities are coupled through a half-wave coupler which has a π-phase difference between the bar-coupling and cross-coupling coefficients to achieve high SMSR. In order to control the cavity lengths precisely, three deep etched facets are used as cavity mirrors. The output is emitted from the etched facet of the channel selector cavity. The back facets on the coupler and on the fixed gain cavity are coated with high-reflective Au film after surface passivation. Three electrodes are deposited on the top surface while a common ground electrode is deposited on the back side. The channel selector electrode on the long cavity is used for wavelength tuning through current injection and the other two electrodes provide the gain. The coupler electrode is also used for direct modulation. Standard fabrication process for ridge waveguide Fabry-Perot lasers is used with an additional step of deep etching for making the reflective mirrors. The chip size is only about 500μm × 350μm.

Figure 2 shows the measured spectra for 93-channels on the ITU grid with 50GHz spacing. A dynamic SMSR of about 37dB is achieved when the laser is directly modulated at 2.5Gbps. The static SMSRs without the modulation signal are typically 2~3dB higher. The fiber coupled power is about 6dBm. By adjusting the current of the channel selector electrode and the TEC temperature control, we can obtain 47 channels from 1529.55nm to 1566.31nm of the ITU grid in 100GHz spacing, covering the full C band. To access the 50GHz spacing grid, we change the TEC temperature by about 4-5°C to tune to 46 channels from 1529.94nm to 1565.9nm, which are shifted by 50GHz from the previous grid. By slightly adjusting the current of the coupler electrode, the output power of the channels can be balanced.

Tunable transmitter optical sub-assembly (TOSA) and SFP transceiver modules have been developed based on the V-cavity laser. For data rate at 2.5Gbps, error free transmission over 50km is achieved with excellent eye diagrams. The receiver sensitivity penalty is less than 0.5dB for 25km transmission and less than 1dB for 50km transmission. Error free transmissions are also achieved for 25km at 5Gbps and 10km at 10Gbps. Thanks to the built-in Fabry-Perot etalons in the laser, excellent wavelength stability is achieved even though no wavelength locker is used. The frequency variation over a 10-day period is about 0.5GHz under reliability test at 70°C ambient temperature. Since the VCL is much simpler and more compact compared to other widely tunable lasers, the VCL-based tunable TOSA and SFP modules have great potential for low-cost mass deployment in metro and access networks.

References

[1] B. Mason, G. A. Fish, S. P DenBaars, and L. A. Coldren, *Widely tunable sampled grating DBR laser with integrated electroabsorption modulator*, IEEE Photon. Technol. Lett. 11, 638-640, 1999

[2] L. A. Coldren, *Monolithic Tunable Diode Lasers*, IEEE J. Sel. Topics in Quantum Electron. 6, 988, 2000

[3] J.-J. He and D. Liu, *Wavelength switchable semiconductor laser using half-wave V-coupled cavities*, Opt. Express 16, 3896-3911, 2008

[4] J. Jin, L. Wang, Y. Wang, T. Yu, and J.-J. He. *Widely wavelength switchable V-coupled-cavity semiconductor laser with ~40 dB side-mode suppression ratio*, Opt. Lett. 36, pp. 4230-4232, 2011

[5] S. Zhang, J. Meng, S. Guo, L. Wang and J.-J. He, *Simple and compact V-cavity semiconductor laser with 50x100 GHz wavelength tuning*, Optics Express 21, 13564, 2013

[6] X. Zhang, J.-J. He, N. Liu, and J. J. Dubowski, *Carrier-induced fast wavelength switching in tunable V-cavity laser with quantum well intermixed tuning section*, Optics Express 23, 26336, 2015