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Depleted optical thyristor using vertical injection method for good isolation between input and output

Woon Kyung Choi, Doo Gun Kim and Young Wan Choi
Optoelectronics and Optical Communication Laboratory, School of Electrical and Electronic Engineering, Chung-Ang University, 221 Heuksuk-Dong, Dongjak-ku, Seoul, 156-756, Korea
Phone: +82-2-820-5326, Fax: +82-2-822-5326, e-mail: ukchoi@kist.re.kr

Seok Lee, Deok Ha Woo, and Sun Ho Kim
Photonics Research Center, Korea Institute of Science and Technology, P.O. Box 131, Cheongryang, Seoul 130-650, Korea

This study demonstrates the depleted optical thyristor (DOT) using vertical injection method for good isolation between input and output. The output peak wavelength is at 1570 nm at a bias current of 1.22 I_{th}. The DOT shows excellent isolation between the input and output signal.

Recent DOT studies have focused on waveguide-type structure for laser diode operation in the long wavelength.[1,2] The first demonstration[1] of the waveguide-type DOT-LD was reported by our team. However, these WDOT-LDs have several problems such as the low confinement factor, the large sensitivity dependence on input light wavelength, and moreover, the leaking input light into the output as shown Fig. 1.

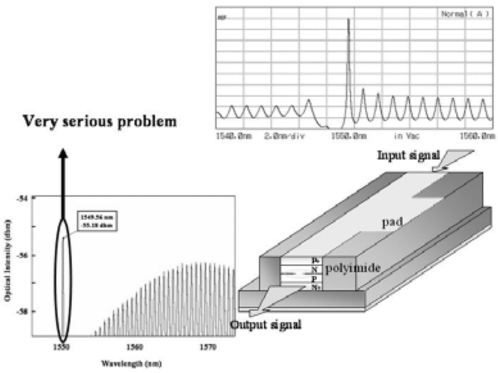

Fig. 1 Problems of the waveguide type DOT

This figure shows the spectrum of the optical output of the WDOT-LD. Optical input light is used for DFB-LD at 1550 nm. The input signal of 20 μW focuses onto the side facet of the WDOT-LD by lensed fiber. This causes a serious problem where the input signal is detected with the output signal. Most of these devices require optical filters to remove the amplified input signal and have high sensitivity for only input light with discrete wavelengths corresponding to the cavity modes. These problems can be eliminated for practical utilities by using the surface-normal light injected structure.[3] The vertical-injection depleted optical thyristor laser diode (VIDOT-LD) has potential applications in advanced optical communication systems such as optical code division multiple access (CDMA) system and optical asynchronous transfer mode (ATM) systems. In optical CDMA systems, VIDOT-LD can be used as a wavelength converter or a fast hard-limiter enhancing the peak to side-lobe ratio. Moreover, in optical ATM systems it can be used as a fundamental packet-switching device with both logical and relational functions.[4]

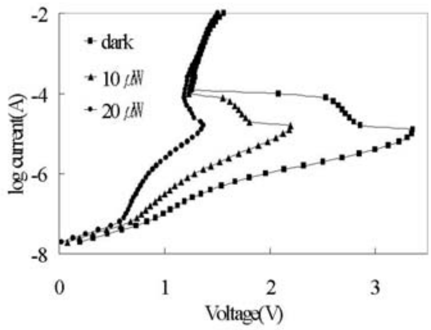

Fig. 2 Nonlinear s-shape current-voltage (I-V) characteristics of an MQW VIDOT-LD.

Fig. 2 shows the measured nonlinear s-shape current-voltage characteristics of the MQW VIDOT-LD. In the OFF-state, the device has a high-impedance up to the switching voltage of 3.36 V. It also has a low-impedance in the ON-state voltage of 1.19 V. As the input power of the injected light from a DFB laser at 1550 nm is increased up to 20 μW, the VIDOT-LD clearly shows the switching voltage decreasing from 3.36 V to 1.37 V. Having a suitable load line, it is possible to have an application of the optical switching device to get the bistability characteristics depending on the injected optical signal.

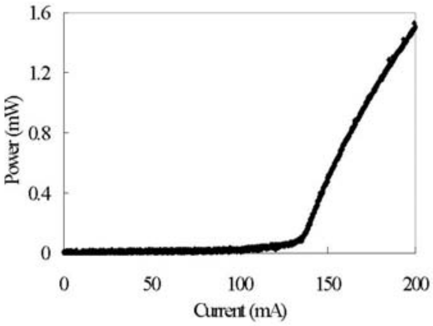

Fig. 3 Light versus current characteristic curves for the 450 μm cavity length VIDOT-LD operating at 25 ℃.

Fig. 3 shows the CW light output of an MQW VIDOT-LD at 25 ℃ for a length of 450 μm. The threshold current is 131 mA, and optical output power is 0.74 mW at a bias current of 1.22 I_{th} (at 160 mA). Although the threshold is quite large, it is important in that it is the first report of lasing characteristics in an InP-based VIDOT-LD. Modification of the device structure and fabrication taking deep etching, re-growth and high-reflection coating are expected to allow the threshold to decrease to less than 20 mA, approximately.

The spectrum of the optical output of the VIDOT-LD is shown in Fig. 4, at a bias current equal to 1.22 times the threshold and the optical input signal of 20 μW as seen in figure 1. At this point there is no longer an input signal. The DOT using the vertical-injection structure shows excellent isolation between the input and output signal. The peak wavelength of emission (λ_p) is at 1.570 μm. This result shows the typical multi-mode characteristics that are not suitable for a wavelength converter. However, a distributed feedback (DFB)[5] structure or a distributed bragg reflector (DBR)[6] structure can allow single-mode characteristics.

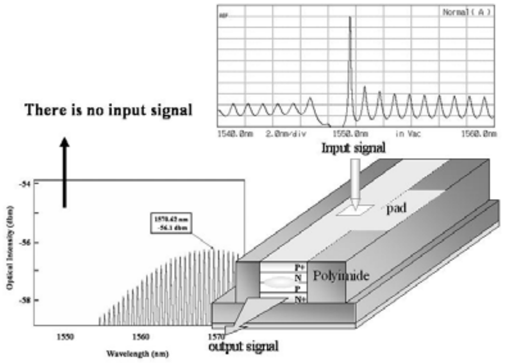

Fig. 4 Spectral output of VIDOT-LD. The peak wavelength of emission (λ_p) is at 1.570 μm

We have demonstrated VIDOT-LD with InGaAs/InGaAsP MQW structure. The PnpN optical thyristors clearly show the nonlinear s-shape I-V and lasing characteristics. This has been considered as an enhancement in switching time. The required optical switching energy is expected less than 1 nJ when the VIDOT-LD has a differential structure. It will use a novel wavelength converter without the optical filter that attached the VIDOT-LD with the DFB or DBR structure for the single mode.[7] It is believed that our results propose the potential applications of VIDOT-LD in advanced optical communication systems such as CDMA and ATM system.

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