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High-Power Operation of Non-Biased Optical Bistable Devices Using Multiple Quantum Well pinip-Diodes

O.-K. Kwon, K.-S. Lee, Y.-S. Lim, E.-H. Lee, and B.-T. Ahn[1]

Basic Research Laboratory, Electronics and Telecommunications Research Institute,
P. O. Box 106, Yusong, Taejon 305-600, Korea
Phone: +82-42-860-6026, Fax: +82-42-860-6836, E-mail: okyun@utopia.etri.re.kr
[1] Department of Materials Science and Engineering, Korea Advanced Institute of Science and Technology,
Taejon 305-701, Korea

1. Introduction

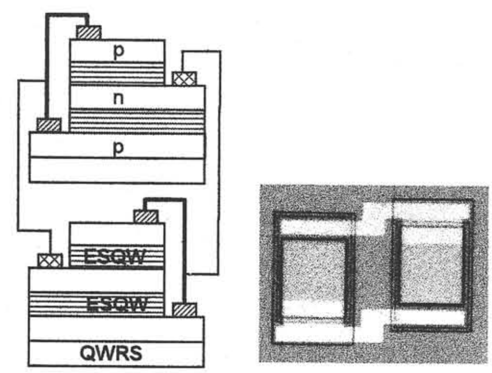
Recently, optical bistable devices (e.g., S-SEEDs) have increased interest due to future potential applications in all-optical parallel switching and processing.[1,2] Such devices based on the quantum confined Stark effect require large external reverse bias voltage in order to induce a sufficient change in electroabsorption. The high operating voltage of an external bias source with complex metal wiring and pads causes an increase in both switching energy and heat dissipation.[3] On the other hand, non-biased optical bistable (NOB) devices without external biases have shown a number of advantages, such as low switching energy, low heat power dissipation, and simple layout.[4-6] For fast switching operation, however, those *pin*-diode devices showing a capacitor-like behavior needed a high optical power for the generation of large photocurrent, resulting in the degradation of device performance.

In this report, we demonstrate the high-power performance of a NOB device fabricated with non-resonant *pinip*-diodes which have a large number of quantum wells for better light absorption. Multiple quantum wells were equally divided into two intrinsic regions in order to maintain high field swing (ΔF_s) and to improve the NOB performance in both ΔR the ON/OFF signal difference and the contrast ratio (*CR*) of NOB device.

2. Result and Discussion

The schematic cross-sectional diagram of a NOB device with a serial connection of two *pinip*-diodes and its photograph are shown in Fig. 1 (a) and (b), respectively. In each *pin* structure, 20 pairs of 10/5 nm-wide GaAs/ $Al_{0.05}Ga_{0.95}As$ extremely shallow quantum wells (ESQWs) and 20 nm-wide $Al_{0.1}Ga_{0.9}As$ spacers are sandwiched between p- and n-doped $Al_{0.1}Ga_{0.9}As$. Quarter-wavelength reflector stacks (QWRS) consist of 14 pairs of 72.5/61.6 nm-wide $AlAs/Al_{0.1}Ga_{0.9}As$. Anti-reflection coating was made on the top of the device. Contrary to conventional externally biased devices, this non-biased device is electrically independent of external electrical source.

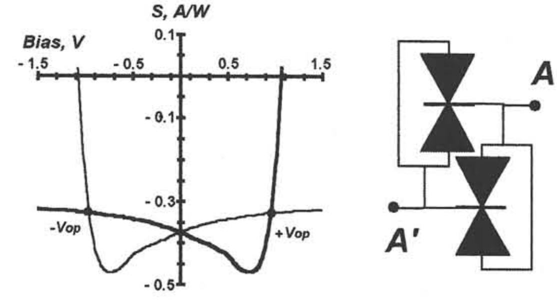
Figure 2 plots (a) the load-line curve obtained from the measured responsivity, S, defined by the ratio of the photocurrent to the input laser power with no external bias voltage and (b) the equivalent circuit of the NOB device. A-A' represents the measured points of the *pinip*-structure made of two *pin*-diodes connected in parallel. The device shows the negative differential resistance (*NDR*) feature of the *pin* diode as well as the maximum photocurrent ($I_{ph,max}$) at forward bias, satisfying NOB operation conditions.[4,5]



(a) (b)

Fig. 1 (a) The schematic diagram of a NOB device using a serial connection of two *pinip* diodes and (b) the photograph of a fabricated device.

The *pinip*-diode made of ESQWs which have low-field exciton ionization characteristics[7,8] is very suitable for the NOB operation



(a) (b)

Fig. 2 (a) *I-S* load-line curve of a *pinip* diode under the illumination of 1 mW laser at the exciton wavelength with no external bias voltage. (b) The equivalent circuit of the NOB device. V_{op} denotes the bistable operation voltage.

Figure 3 plots V_{max} the measured voltage at peak S position (S_{max}) and R_o the ratio of S_{max} (at V_{max}) to S_{min} (at

V_{op}). V_{max} at the forward bias means a stable NOB operation. The condition for *NDR* is that $S_{max}/S_{min} > 1$. However, the high laser power causes problems such as photocurrent saturation and I-V ohmic heating, resulting in the degradation of ΔR and *CR*. If the input power exceeds about 5 mW, R_o approaches to 1, and V_{max} can be negative due to absorption saturation at the forward bias and the thermal heating at the reverse bias.

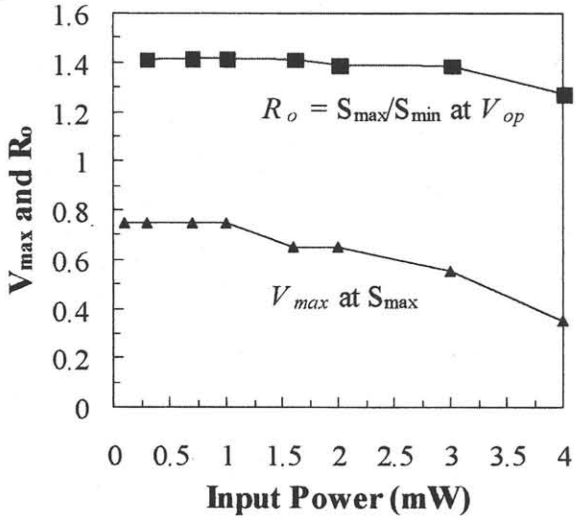


Fig. 3 Measured V_{max} and R_o versus the incident laser power.

Figure 4 shows the measured ΔR of a NOB device made of *pinip*-diodes as a function of the bias voltage for various input laser powers. As the input power increases for the NOB operation, the degradation of R_{on} (V_{op}) and R_{off} ($-V_{op}$) are resulted because of thermal heating and exciton saturation, respectively. The high-power performances of the present device is improved in comparison to other applied-bias structures[3,4]. Without an external bias, heat dissipation power is greatly reduced, while maintaining a strong absorption and a large electric-field induced by the *pinip* structure.

3. Conclusions

We demonstrated that the high-power performance of the NOB device was considerably enhanced by using ESQWs in the intrinsic regions of a non-resonant *pinip*-structure, which showed the large low-field electro-absorption and exciton ionization, large ΔF_s, and strong light absorption without external bias voltage. Contrary to the conventional devices, the proposed NOB devices are electrically independent from each other, and a more densely packed and fault-tolerant optical bistable array can be realized in a simple layout.

Acknowledgment

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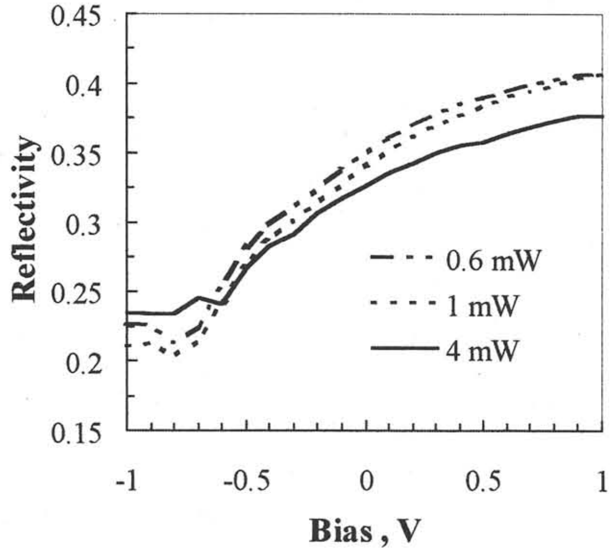

Fig. 4 The reflectivity of *pinip*-diode versus the bias voltage for various incident laser powers on a spot with the diameter of 5 μm. The reflectivity of the NOB device is determined at V_{op}'s in Fig. 2 (a).

References

1) H. M. Gibbs, Optical Bistability : *Controlling Light with Light* (Academic, New York, 1985)
2) D. A. B. Miller, D. S. Chemla, T. C. Damen, T. H. Wood, C. A. Burrus, A. C. Gossard, and W. Wiegmann: IEEE J. Quantum Electron. **21** (1985) 1462.
3) O. K. Kwon, Y. W. Choi, K. Kim, and E. H. Lee: IEEE Photon. Technol. Lett. **7** (1995) 50.
4) Y. W. Choi, O. K. Kwon, J. H. Baek, B. Lee, and E. H. Lee: Electron. Lett. **30** (1994) 1978.
5) O. K. Kwon, K. Kim, K. S. Hyun, Y. W. Choi, E. H. Lee, X. B. Mei, and C. W. Tu: IEEE Photon. Technol. Lett. **8** (1996) 224.
6) O. K. Kwon, K. Kim, K. S. Hyun, J. H. Baek, B. Lee, and E. H. Lee: Appl. Phys. Lett. **68** (1996) 3216.
7) R. A. Morgan, M. T. Asom, L. M. F. Chirovsky, M. W. Focht, K. G. Glogovsky, G. D. Guth, G. J. Przybylek, L. E. Smith, and K. W. Goossen: Appl. Phys. Lett. **59** (1991) 1049.
8) J. Feldmann, K. W. Goossen, D. A. B. Miller, A. M. Fox, J. E. Cunningham, and W. Y. Jan: Appl. Phys. Lett. **59** (1991) 66.