10.00 CTuD6

All-Semiconductor Miniature Nonlinear Optical Loop Mirrors for GHz All-Optical Switching Operation

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Conventionally, a nonlinear Sagnac interferometer consists of an optical fiber loop, connected with a fiber coupler. In this paper, we report our experimental results of a monolithic all-semiconductor-optical-amplifier nonlinear optical loop device with psec signals. The device includes a circular loop, a multi-mode interference waveguide amplifier (MMIWA, acting as a nonlinear coupler), and input/output ports [1]. All parts of the device are made of GaAs/AlGaAs ridge waveguide semiconductor optical amplifiers. The electro-pad is divided into four disconnected regions to provide gain separately. Particularly, the loop is divided into two different injection areas to make the loop asymmetric. In our experiments, we used the pulsed signals with a pulse width of 1.4 psec.

Figure 1 shows a self-switching result. The horizontal axis shows the input power before entering the input waveguide. TE polarized psec signals at 834 nm (gain peak) were used. We can see the oscillatory behaviors of average output power as the average input power increases. It is a typical input power dependent phenomenon observed in a nonlinear optical loop mirror [2]. Figure 2 shows a result of the pump-probe experiment. Here, the pump was TM-polarized at 834 nm with the input power at 0.75 mW and the probe was TE-polarized at 834 nm with the input power at 0.25 mW. The injection current values were the same as those in Fig. 1. One can see the narrow two-hump feature of about 5 psec in width around the zero time delay. After that, a long tail in an oscillatory manner can be observed. This long tail is supposed to come from the period of gain recovering from saturation in the MMIWA and loop. This time scale is in the range of a few hundreds psec, implying that several GHz operation of the device is feasible.

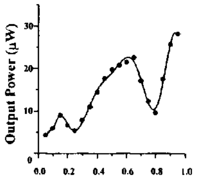

Fig. 1 Output power as a function of average input power.

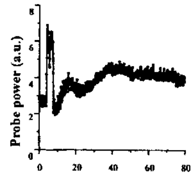

Fig. 2 probe power as a function of delay between the pump and probe.

References:
[1] J. H. Lee et al., J. Quantum Electron., vol. 35, 1469-1477, 1999.
[2] N. J. Doran et al., Opt. Lett., vol. 13, 56-58, 1988.

10.15 CTuD7

Picosecond all-optical switching using 1.55 μm intersubband transition in an InGaAs/AlAs/AlAsSb coupled double quantum well (C-DQW) structure

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The intersubband transition (ISB-T) in quantum wells is attractive for the application to all-optical modulators and switches due to its ultrafast relaxation, large transition dipole moment, and widely tunable transition wavelength [1]. Also, we have proposed the use of ISB-T in coupled double quantum well (C-DQW) structures to enable ultrafast all-optical switches operating at the communication wavelengths by utilizing enhanced electron-LO-phonon scattering in C-DQW [2]. We show in this paper the first observation of picosecond all-optical switching based on the ISB-T at near-infrared wavelengths down to 1.55 μm in an InGaAs/AlAs/AlAsSb C-DQW structure.

We prepared a n-type multiple C-DQW structure with 80 periods C-DQW, which consisted of 2.7 nm thick $In_{0.53}Ga_{0.47}As$ quantum wells coupled by a 0.9 nm thick AlAs barrier and separated by a 10 nm thick AlAsSb barrier, were grown on an InP substrate by MBE. The well layers were doped with Si by $1\times10^{19}cm^{-3}$. The facets of the sample were polished at 45 degree to enhance the absorption by multiple internal reflection.

The polarization angle dependence of transmission spectra measured for the sample by using FTIR is shown in Fig. 1. Three dips in transmission originated from the ISB absorption due to the 1-4 and 2-3 transitions were observed at 1.6 μm and 2.7 μm for the p-polarized incident light from a halogen-lamp. The absorption due to the forbidden 1-3 transition in this symmetric structure was also observed at 2.2 μm, which might be resulted from a slight asymmetry caused by interface roughness and interdiffusion.

The ISB-IB pump-probe measurements were performed by using the 150 fs near infrared pump pulse from optical parametric amplifier (OPA). The white-light probe pulse, which was generated from a sapphire plate and transmitted through a long-pass filter and the sample, was monochromated by a grating and detected by an InGaAs array detector. The transient responses of 1.2 μm IB absorption (probe signal) induced by 1.55 μm ISB excitation pulse is plotted in Fig. 2. The recovery time of the IB absorption change was about 1.7 ps. For the probe wavelength of 1.3 μm, ultrafast recovery within 1.3 ps was observed. For the probe wavelength of 1.15 μm, the decay time was about 2.2 ps. This result can be explained by considering the subband filling process involving both the inter- and intra-subband relaxation.

We have achieved near-infrared ISB absorption down to the communication wavelength by introducing an InGaAs/AlAs/AlAsSb C-DQW structure. Ultrafast recovery of the IB absorption within 1-2 ps induced by 1.55 μm ISB excitation has been demonstrated by pump-probe measurements by using a femtosecond OPA and white-light generation. This indicates promising feature of the present structure for ultrafast all-optical modulators and switches.

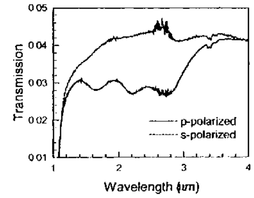

Fig. 1 Polarization dependence of the ISB absorption spectra measured by FTIR

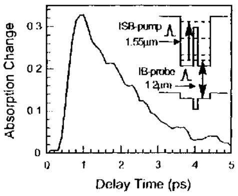

Fig. 2 Transient response of IB absorption change at 1.2 μm due to ISB excitation by 1.55 μm pump pulse

[1] S. Noda, T. Uemura, T. Yamashita, and A. Sasaki, IEEE J. Quantum Electron., 28, 493 (1992)
[2] H. Yoshida, T. Mozume, A. Neogi, and O. Wada, Electron. Lett., 35, 1103 (1999)