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NOVEL OPTICAL METHODS FOR HIGH SPEED DIRECT MODULATION OF SEMICONDUCTOR LASERS

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Since the reliability and the optical quality of GaAs double heterostructure (DH) cw lasers have been greatly improved recently, semiconductor lasers seem to be one of the most desirable sources for opto-electronics. Among many advantages of semiconductor lasers, the ability that the output light intensity can be modulated directly at high speed is a remarkable one for the application. Although they have a modulation bandwidth of several GHz[1], practical rate of the pulse modulation is limited to a few hundred Mb/s owing to the waveform distortion caused by relaxation oscillation or intensity spiking in the output. The waveform distortion can be practically eliminated by electronic band reduction in the detection system if the modulation rate is below a certain fraction of the relaxation oscillation frequency, which lies around a few GHz. The upper limit of the modulation rate to which the electronic band reduction method is applicable has been examined theoretically and experimentally and has been found to be about 0.5 Gb/s for RZ signals and about 1 Gb/s for NRZ signals.

To attain higher rates of modulation, we have analyzed various possible schemes for improving the output waveform. This paper describes novel optical methods which have been found to be quite effective.

The relaxation oscillation can be suppressed by light injection, where a small amount of external radiation is constantly injected into resonant modes of the laser cavity, in such a manner as to reduce the initial height of the intensity spiking and to enhance the damping of the residual oscillation. In addition to the suppression, the light injection decreases the delay for the onset of lasing. Experiments were done using a pair of GaAs DH lasers and the light injection was found quite effective in reducing the waveform distortion. Detailed comparison of the observed spectra of the output from the two lasers (modulated laser and injecting laser) reveals that selective enhancement of the longitudinal modes of the modulated laser occurs at wavelengths where the wavelengths of the injected light coincide with those of the longitudinal modes of the modulated laser. Quenching of other modes is also observed. These changes associated with the light injection seem to demonstrate that the spectral gain profile of semiconductor lasers is homogeneously broadened. This method is expected to improve the degradation of spectral quality of the output such as an increase of the width of the spectral envelope[3,4] due to the intenisty oscillation. Light injection also affects amplitude modulation characteristics. A small signal analysis reveals that the height of the sharp peak in the frequency response of the modulation depth of a laser without light injection[1] is decreased by light injection, which reduces the distortion of the output and increases the effective modulation bandwidth. Similar change is brought about in the frequency spectrum of the intensity fluctuation in the output.

Another optical method consists of optical feedback, where a fraction of the output light from a laser is fed back into itself with a time delay considerably less than one period of the relaxation oscillation. The light fed back into the laser can increase the width of the initial intensity spike and can also eliminate the second spike by depleting the excess carrier density, which improves the quality of the output waveform.

Optical methods, the light injection and the optical feedback, have been shown to be very effective in reducing the waveform distortion in high speed modulation of semiconductor lasers. These methods will extend the practical rates of direct pulse modulation to the Gb/s range.

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