GENERATION OF ULTRA-SHORT PULSES FROM HIGH-GAIN NARROW-LINEWIDTH
GASEOUS LASERS

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ABSTRACT

Ultra-short light pulse generators are important as the light source of a laser radar system. Ordinarily the technique of mode-locking[1] is used to obtain ultra-short pulses. For this technique, however, the pulse width is limited by the finite linewidth of the laser medium. Since most gaseous lasers, especially those of infrared region, have narrow linewidth, it has been considered difficult to obtain ultra-short pulses from gaseous lasers by the technique of mode-locking. This fact limits the applicable wavelength region of a laser radar. In order to avoid the difficulty described above, we have proposed [2] the method which does not use a mode-locking technique. Since a Fabry-Perot electro-optic modulator (FP modulator) is used as an output coupler of a laser resonator, the linewidth does not limit the width of the light pulses. In fact, we have succesfully obtained picosecond light pulses using a He-Ne 6328Å laser[2]. In this method, the power efficiency (defined by the ratio of the output peak power to the optimum output power in CW operation) is high for low-gain laser such as a He-Ne 6328Å laser. For high-gain lasers, however, the power efficiency is not high and it is desirable to develop another method for lasers such as a He-Ne 3.39μ laser.

In this paper, we propose a method suitable for high-gain lasers which could be regarded as a modified mode-locking technique.

If the short pulse should be obtained from the narrow-linewidth laser by the mode-locking, the passive modes which lie beyond over the linewidth should be utilized. In a high-gain laser, a large number of passive modes can be maintained without stopping the laser oscillation although the large locking signal is required. Therefore, the mode-locking is still the effective method for obtaining short pulse for a high-gain laser. To avoid the undesirable effect due to the dispersion of the laser medium[3], single-active-mode operation is used in contrast to the conventional mode-locking technique.

Several authors have reported[4]-[6] the analyses for the mode-locking under the single-active-mode condition (MLSAM). They assumed small locking signal and

neglected the variation of the saturation gain along the laser beam[7]. A rigorous analysis taking account of the effect of large locking signal and the variation of saturation gain which is significant in a high-gain laser was developed. It is concluded from the analysis that pulse shape in MLSAM is analogous to that of the output from the FP modulator and also the high power-efficiency is obtained for high-gain homogeneously broadened laser. Fortunately, most of infrared gaseous lasers behave like homogeneous lasers under the suitable conditions, e. g. high-saturated condition or high gas pressure. In Fig.1 the calculated peak power and width of output pulses are plotted as functions of the index of phase modulation (FM locking case) for a homogeneous laser.

An experiment was done by using the typical high-gain laser, He-Ne 3.39μ laser. Figure 2 shows the observed spectrum of the pulses. It is seen from the figure that several passive modes are excited however it is not clear how many numbers of the active modes exist. The estimated pulse-width is about 0.8nsec. and the power efficiency is about 2. This result confirms that ultra-short pulse can be obtained from the narrow-linewidth laser if the gain of the laser medium is considerably high.

In conclusion, the ultra-short pulse can be obtained with high power-efficiency from the narrow-linewidth laser, by using a MLSAM for a high-gain laser or using a FP modulator for a low-gain laser.
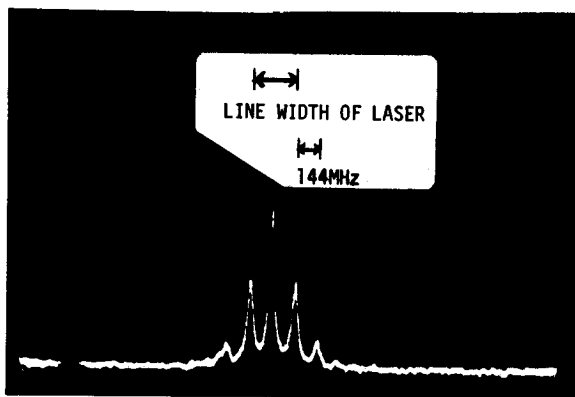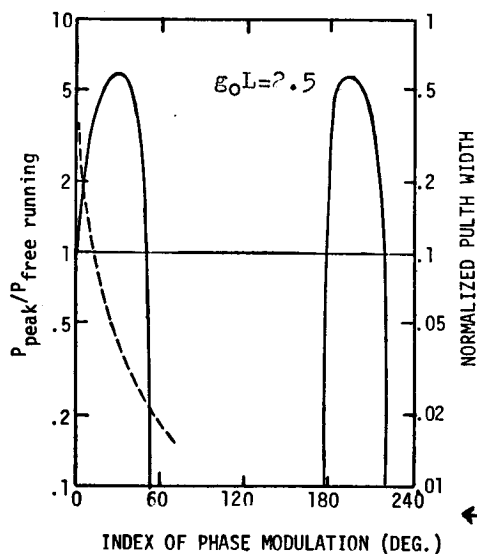

Fig.2 Spectrum of the obtained pulse from a He-Ne 3.39μ laser (linewidth ~300MHz). 144MHz phase modulation (index ~0.3) is used for a locking signal.

Fig.1 The calculated peak power (solid line) and width (broken line) of output pulses as functions of the index of phase modulation (FM locking) for a homogeneous laser. It is assumed that the mirror transmittance and the internal loss are both 10%. The pulse width is normalized by the period of the locking signal.

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