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# TIME-DOMAIN SENSITIVITY ENHANCEMENT IN PULSED Pb-TDL GAS MONITORS

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## INTRODUCTION

A Pb-salt tunable diode laser (TDL) has found many applications in the field of atmospheric gas analysis. Its continuous tunability and fine spectral purity in the mid infrared region are outstanding from other lasers. The only shortcoming is that it requires cryogenic operating temperature, though it is improved year by year towards the room-temperature operation. Nevertheless, a repeated pulse operation of Pb salt diode lasers is possible with a thermoelectric cooling device, which allows an instrument a portable geometry disusing a heavy, bulky and power-consuming mechanical refrigerator.

A derivative spectrometry system has been exploiting the quick tunability of Pb-salt diode lasers, though they are cw operated with refrigerator or liquid nitrogen so far. A new system for derivative spectrometry with a pulsed diode laser will extend its field of applications because of reduced weights and size of measuring instruments.

Taylor and Thomas demonstrated the $H_2O$ line profile measurement[1)]. The authors showed a preliminary result that demonstrates the feasibility of an attempt to implement the derivative spectrometry with repeatedly pulse-driven diode lasers : atmospheric methane was measured with 8ppm·m sensitivity[2)]. This paper gives further results of the parametric optimization for the best SNR under any given device characteristics as well as for available real devices. A guiding principle has been obtained for selecting a HgCdTe infrared detector.

## PRINCIPLES

Principle of the derivative spectrometry with a pulsed diode laser is explained by Fig.1. A rectangular pulse of width $T_w$ and height $i_p$ is imposed on a heat-up current $i_h$ to control the laser frequency (a). The laser pulse is emitted only during this period with decreasing power due to the rising junction temperature $\theta_J$, and the lasing frequency slightly chirps upwards (b). The driving pulse is again applied after the junction has been cooled down.

The pre-amplifier output responds to the ir-power transmitted through the specimen gas, which is a composite of signal $x(t)$ and white noise $n(t)$. The SNR of the lock-in amplifier output is poor if the crude signal $x(t) + n(t)$, (c), is fed. As shown in Fig. 2, a temporal gate which opens when the signal $x(t)$ arrives and closes when it disappears between the pulsed laser-emissions suppresses the noise on the lock-in amplifier output.

The driving pulse is applied repeatedly with period $T$, while the heat-up current $i_h$ is controlled so as that laser frequency should change according to the sequence, ---, $\nu_0$ , $\nu^+$ , $\nu_0$ , $\nu^-$ , $\nu_0$ , $\nu^+$ ,---, which implements the second-derivative spectrometry.

## PARAMETER OPTIMIZATION

The optimal value of the gating width $T_g$ was calculated for $T_w$ , laser pulse width, as well as $T_p$ and $T_i$, time constants of the pre-amplifier and the IRD, respectively.

A result of calculated SNR-enhancement performance is shown in Fig.3. The optimal gating width $T_g$ is equivalent to a larger value of $T_i$ and $T_w$ , in either the case $T_w << T_i$ or $T_w >> T_i$. This result is acceptable considering that the optimal gate-width should be equal to the signal width of the pre-amplifier output. Experimental results are given in Fig. 4 for three gating widths, where $T_g$=2μs had been calculated to be the optimal. The laser pulse-width is specific to a laser element and is fixed at $T_w$=300 ns. The preamplifier bandwidth is not critical if it is wide enough to track the IRD output, being taken as $T_p$=50ns.

The achievable smallest error in the absolute absorption obtained with a measurement apparatus reported earlier[2)] was calculated for various $R_e$ , responsivity, and $T_i$ of IRD and is shown in Fig.5. An assumption is made that the pre-amplifier noise is dominant over the IRD noise. The marks * denote possible combinations anticipated from a theoretical consideration made by Hamashima and Itoh[3)] . Detectors represented by marks Δ and ° were actually tested by the authors. It is concluded that a sensitive IRD, though it does slowly respond, is desirable for a better system sensitivity.

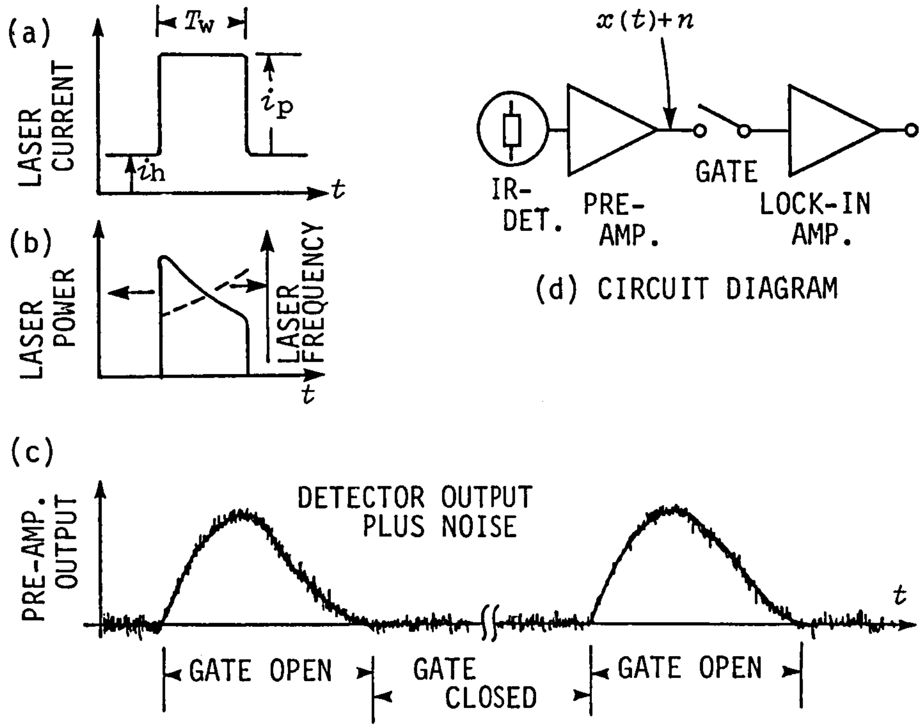


Fig.1 Principle of noise-suppression in pulsed TDL spectrometry.

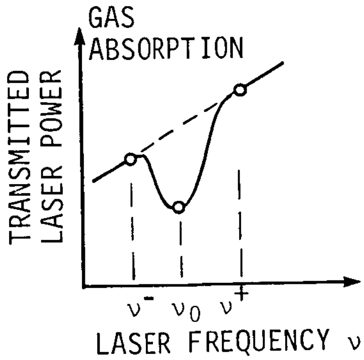


Fig.2 Implementation of the derivative spectrometry with successive laser pulses.

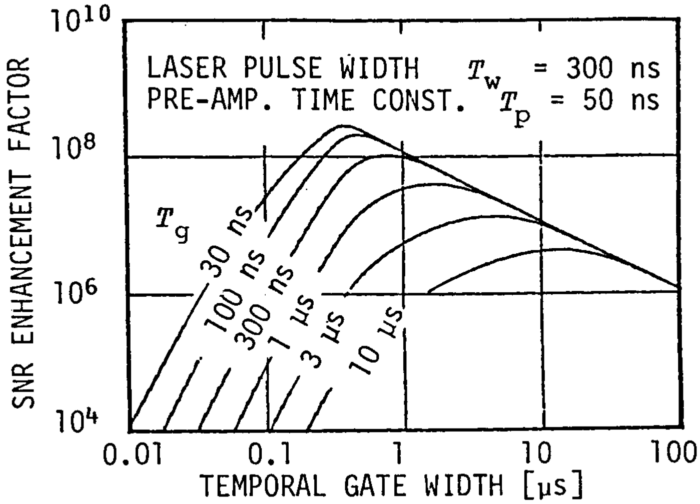


Fig.3 Effect of temporal gate width on the SNR enhancement in the 2nd derivative spectrometry.

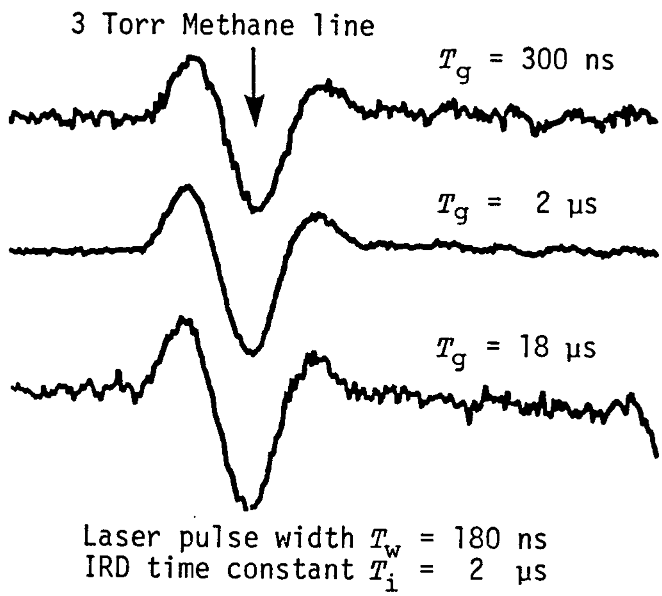


Fig.4 Spectra of methane lines with different temporal gate width. Magnitudes are normalized so that methane lines have the same strength.

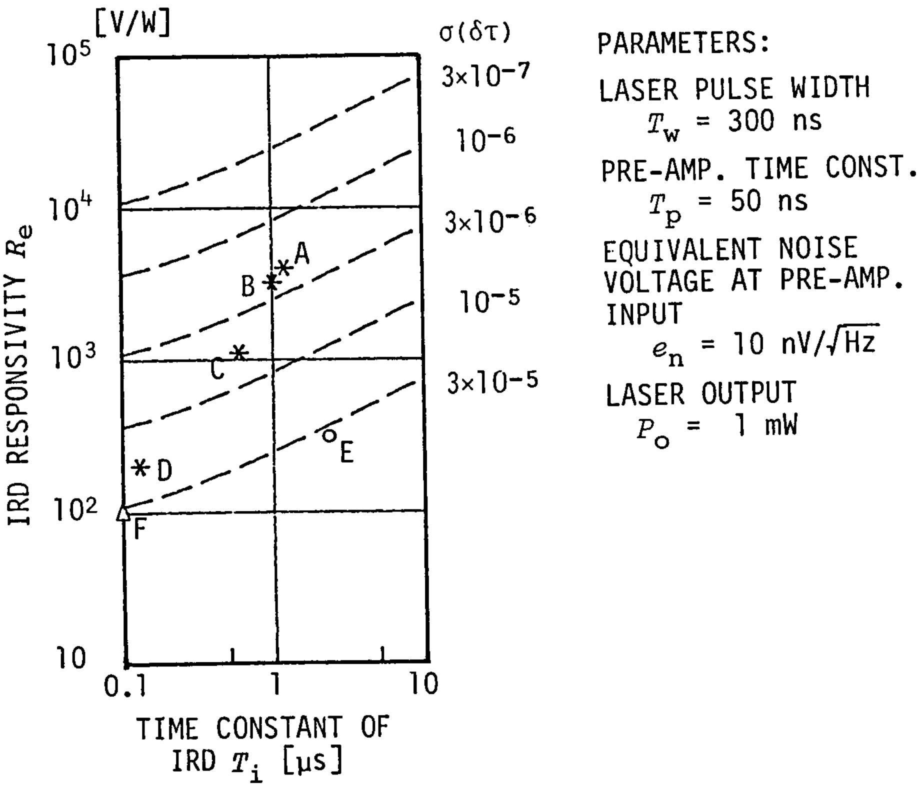


Fig. 5 Attainable maximum sensitivity of the TDL absorption spectrometry system for various response time-constants and responsivities of infrared detectors.

## CONCLUDING REMARKS

Random noise of a pulsed mode TDL absorption spectrometry can be suppressed down enough to $10^{-6}$ level in terms of absolute absorption, which is already dominated by the etalon fringe noise. This conclusion certifies a feasibility of a handheld TDL equipment for atmospheric surveillance.

## REFERENCES


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3) S.Hamashima and M.Itoh, "Characteristics of HgCdTe Photoconductive Detectors" IECE Japan. Tech. Rep. ED 84-159(1984).