# 28PD8 WAVELENGTH-AGILE AND SINGLE-LONGITUDINAL-MODE $CO_2$ LASERS FOR THE RETROREFLECTOR IN SPACE (RIS) EXPERIMENT

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**ABSTRACT**

Single-longitudinal-mode output from a pulsed TEA carbon dioxide laser has been achieved using a time-gated gain cell. The gain cell is operated as an oscillator for the time periods between laser pulses. During this time, dither stabilization is applied. Before the TEA laser is triggered, the gain cell is rapidly switched below threshold to avoid saturation of the gain-switched spike in the TEA laser pulse. Wavelength-agility is also incorporated in the laser design to select different output wavelengths from the laser rapidly. Different emission lines can be accessed at a rate of one per second, and the pulse repetition rate of the laser is 50 Hz. Two such lasers are required for the Retroreflector in Space (RIS) experiment. The lasers will be installed in the Communications Research Laboratory in Tokyo in early 1995.

## LASER DESIGN REQUIREMENTS

The single-longitudinal-mode (SLM) laser design discussed here was motivated by the laser requirements of the Retroreflector in Space (RIS) experiment. This experiment has been described extensively in the literature [1-3]. It is being conducted by the National Institute for Environmental Studies in Japan. In this experiment, two ground-based SLM carbon-dioxide lasers will be used to monitor the concentrations of various gases in the upper atmosphere by reflecting the laser pulses from a retroreflector located on the ADEOS (Advanced Earth Observing Satellite). One laser will operate at a fixed output wavelength for the experiment. This will serve as the reference wavelength in the differential absorption measurement. The second laser will be wavelength-agile, shifting its output wavelength among several preselected emission lines of carbon dioxide during the experiment.

Spectral signatures of atmospheric absorption lines will be produced by recording the return signals as a function of the satellite position. Because the Doppler shift imparted to the return laser pulses will change as the location of the satellite relative to the ground station changes, narrow spectral regions on the short wavelength side of each transmitted laser wavelength will be obtained during an encounter with the satellite. The pulse repetition rate for each laser will be 50

Hz, and the output wavelength from one of the lasers will be changed once every second during the experiment. Frequency doubling and tripling of the outgoing pulses using $AgGaSe_2$ crystals will add versatility to the facility.

Single-longitudinaal-mode operation is important for the creation of the spectral signatures. Multi-frequency output from the lasers would produce ambiguous results in the Doppler shifted returns. The task of incorporating both SLM operation and wavelength-agility into a single laser design was a technical challenge. The time-gated gain cell is our solution to this challenge.

**LASER DESIGN**

Details of the laser design have been published elsewhere [4,5], and is somewhat similar to other designs[5,6]. The time-gated gain cell laser is shown in Figure 1. The gain cell is a water-cooled glass laser tube approximately 70 cm in length, fabricated with ZnSe Brewster windows. It is mounted in the cavity of the pulsed TEA laser. The resonator consists of an 80% reflector output coupler, 10 m radius if curvature, and a gold-coated, 135 lines-per-millimeter diffraction grating operating in Littrow.

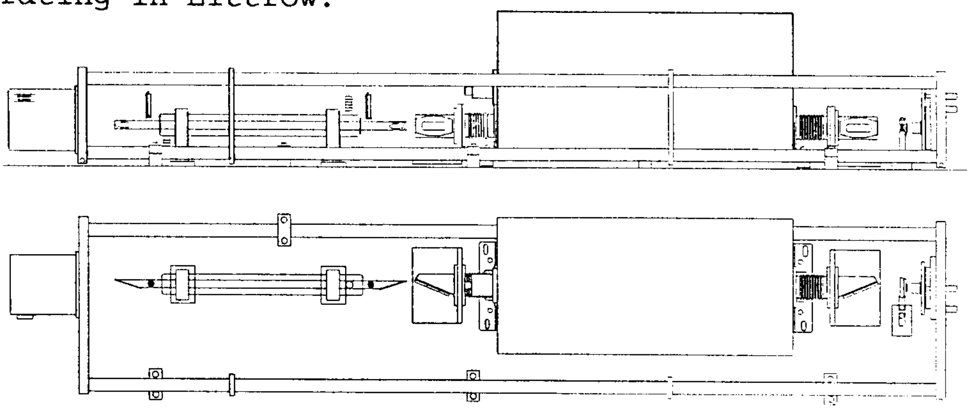

*Figure 1: Laser design*

The pulsed TEA chamber is a modification of the Laser Science, Inc. PRF-150 model fitted with ZnSe Brewster windows. It contains the 40 cm long electrodes, uv preionizers, circulating faans, and heat exchanger. For these experiments, the gas mixture was 11% $CO_2$, 22% $N_2$, and 67% He. The gas was slowly flowed through the chamber to reduce build-up of CO and $O_2$ in the discharge.

With this configuration, the total cavity length is 1.7 m, and the pulses are over 100 mJ on the high-gain lines. An aperture in the cavity is used to create $TEM_{00}$ output. With this geometry for the laser, the cavity mode spacing is approximately 88 MHz, which is greater than the 50 MHz Doppler width of the low-pressure gain profile from the gain cell. This prevents the possibility of two laser modes being present in the Doppler bandwidth.

The gas pressure in the gain cell is below 20 Torr and the tube is sealed during the measurement period. A valve on the gain cell permits the tube to be pumped and filled with isotopic carbon dioxide for experiments requiring wavelengths of $^{13}CO_2$. The gas pressure in the TEA chamber is approximately 930 Torr, creating a gain profile of 4 GHz.

Wavelength agility is achieved through the use of a non-resonant galvanometer. The galvanometer positions a small intercavity mirror through computer control to direct the laser beam onto different locations of a fixed diffraction grating as shown in Figure 2. The angular positioning of the beam on the grating adjusts the output wavelength. The speed of the galvanometer is sufficient to operate the laser at 150 Hz, so the 50 Hz operation is well within the operation limits of the wavelength-agile unit.

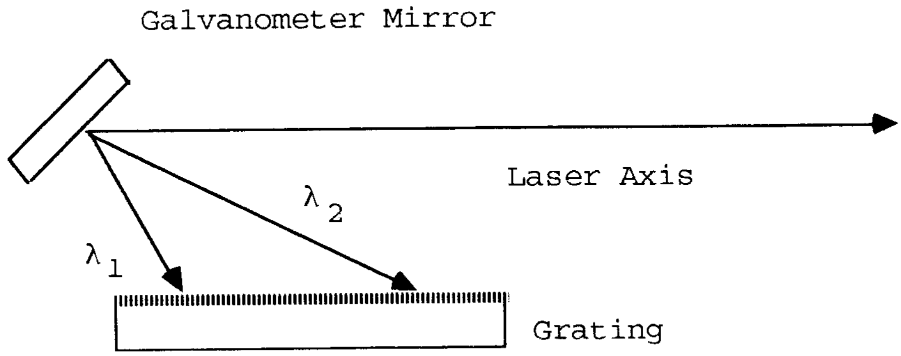


*Figure 2: Wavelength agility concept*

**RESULTS AND DISCUSSION**

Figure 3 shows various output pulses from the laser. Pulse c) was obtained without the use of the gain cell. It shows mode beating between adjacent $TEM_{00}$ modes in the output. Pulse a) was obtained by turning on the gain cell and leaving it on during the TEA laser pulse. Although a clean, SLM pulse is created, the gain-switched spike is saturated. This condition is not optimum for the RIS experiment. Pulse b) was obtained by switching off the gain cell just prior to triggering the TEA laser. Sufficient radiation from the gain cell exists to seed the cavity, and the gain-switched spike is strong.

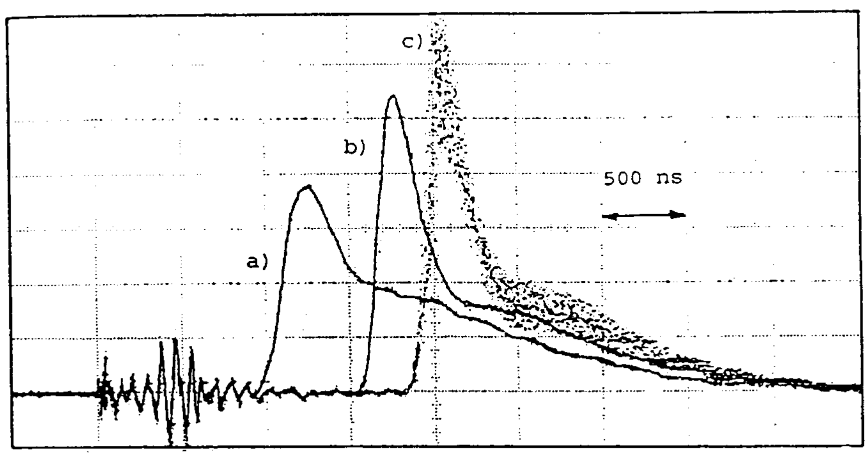


*Figure 3: Laser pulse traces*

During the time between the TEA laser pulses, standaard dither-stabilization techniques are used to position the output coupler for SLM output. These techniques are well understood. The challenge in this design, however, was to create the SLM condition in a timeframe of only 20 ms (reciprocal of the pulse repetition rate). This requires a high-speed PZT to create the dither. The frequency-stabilization requirement for the lasers in this experiment is 10 MHz. Studies indicate that this method of frequency stabilization and SLM output will provide much better frequency stability than the specification.

**CONCLUSIONS**

A simple method for obtaining repeatable SLM operation from a pulsed TEA carbon dioxide laser has been discussed and demonstrated. The technique is fast and applicable to any emission line in the $CO_2$ emission manifold. The resulting laser pulses show unsaturated gain-switched spikes which can contain as much as 50% of the pulse energy.

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