NASA TECH BRIEF
Langley Research Center

Wavelength-Selective, Sequential Q-Switching Laser Cavity

A new device converts the single-frequency continuous output of a laser into a series of high-power laser pulses at high repetition rates, with each succeeding pulse in the series corresponding to a different emission wavelength of the particular laser. The process is known as line-selective, sequential Q-switching, and it has a variety of applications, including pollutant detection by absorption, laser gain measurements at discrete wavelengths, laser propagation measurements, and laser plasma diagnostics.

In the sequential Q-switching technique, an oscillating mirror is used as an optical folding element in a cavity consisting of a partially reflecting mirror and a stationary diffraction grating. The oscillating mirror sequentially aligns the various CO_2 laser wavelengths in first-order Littrow reflection, converting the continuous wave (CW) output of the laser into a series of high-power pulses with multiwavelength spectral output. This technique has been used with a conventional CO_2 laser to Q-switch at least 62 rotational transitions between 9.2 and 10.8 μm. The technique should be applicable to Q-switching other molecular lasers (e.g., CO, HF) by using appropriate diffraction gratings.

Figure 1 shows the apparatus used to Q-switch sequentially a high-flow CO_2 laser. The inverted medium, a mixture of CO_2, N_2, and He, is excited by an electrical discharge and made to flow at high velocities in a tube 2.5 cm (1 in.) in diameter and 0.5 m (20 in.) long. Brewster angle windows of KCl are used. The laser beam is coupled out with a 90-percent-reflecting germanium mirror having a 10-m radius of curvature. A standard Bausch and Lomb grating, or equivalent, with 150 grooves per millimeter is used. The scanning mirror is a Bulova model NAS-L44 scanner, or equivalent, sinusoidally driven at a frequency of 200 Hz (for high-repetition rates, scanning frequencies of 1000 Hz are available). The mirror on the scanner is optically flat to one-twentieth of a wavelength at the sodium D line.

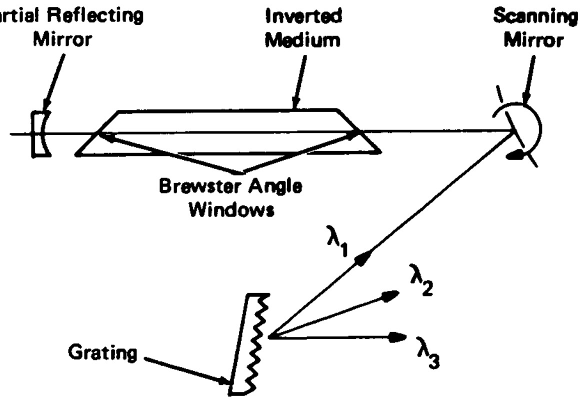

Figure 1. Sequential Q-Switching Apparatus

To understand the device, consider a laser with three possible transitions and with the folding mirror to be stationary at an angular position where only one wavelength incident on the grating is reflected back through the optical cavity (λ_1). The other wavelengths are reflected out of the optical cavity by the grating (λ_2, λ_3). Thus, the laser output is single frequency and continuous. Then consider that the scanner rotates clockwise so that λ_1 is no longer reflected back through the cavity. Lasing stops until the angular orientation of the grating is such as to reflect wavelength λ_2 back into the optical cavity. The process continues so that each of the three wavelengths is Q-switched.

Using the optical scanner, the continuous output is converted into three pulses, each pulse corresponding to a different possible lasing transition. For the CO_2 laser, more than 62 transitions (wavelengths) have been obtained with the scanner. Using a scanning element with a 200-Hz vibrational frequency, the individual pulses are separated by approximately 25 μs with output peak power in excess of 0.5 kW.

Figure 2 shows the results of an experiment performed to demonstrate the capability of this technique

(continued overleaf)

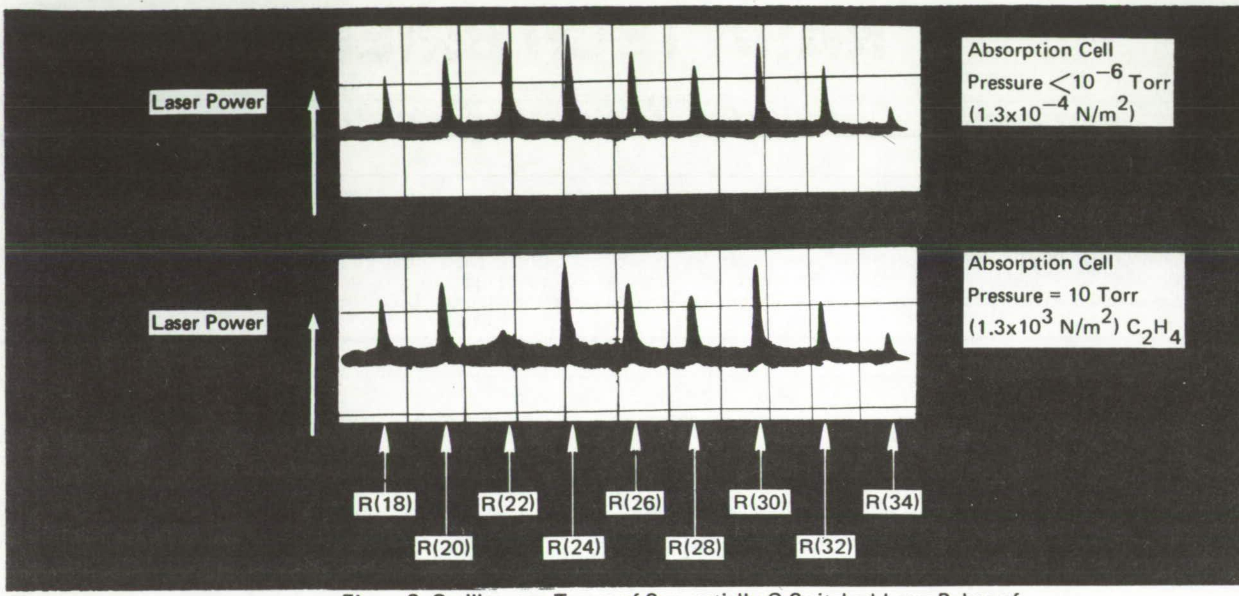

Figure 2. Oscilloscope Traces of Sequentially Q-Switched Laser Pulses of 10.4-μm Band of CO_2 (50-μs/cm Sweep Rate) Showing Absorption by C_2H_4 of R(22) Transition

to measure small concentrations of atmospheric pollutants over long path lengths. The top oscilloscope trace shows the results of transmitting a sequentially Q-switched laser beam through a 20-cm-long cell containing no gas. A series of sequentially Q-switched laser pulses are displayed. The bottom trace shows the results of transmitting the beam through the same cell containing 10 torr (1.3×10^3 N/m^2) of C_2H_4 (ethylene). Ethylene selectively absorbs the R(22) wavelength and none of the adjacent transitions. These results indicate that, assuming a capability of detecting a 5-percent signal change over a 1-kW path length, a concentration smaller than 20 ppm of C_2H_4 can be detected with a sequentially Q-switched laser.

An important feature of this technique is the ability to select a limited number of wavelengths in either the P or R branch of the spectral lines in one sweep of the oscillating mirror. With a given grating, this can be accomplished by limiting the sweep of the laser beam across the grating with field stops or by limiting the scan angle of the oscillating mirror. By varying the scan angle of the oscillating mirror, the number of pulses for the configuration shown in Figure 1 was varied from a minimum of 3 to a maximum of 22 pulses. Another interesting feature of this technique is the ability to vary the Q-switching time of the cavity either by changing the scan frequency of the oscillating mirror or by varying the dispersion of the grating. A grating with reduced dispersion will shorten the Q-switching time of the individual pulses and decrease the time interval between successive pulses.

Because of its unique characteristics of high power and rapid switching of laser wavelengths, the sequentially Q-switched laser represents an ideal radiation source for long-path absorption spectroscopy, since it provides the ability to discriminate rapidly between absorption by selectively absorbing molecules and absorption by the atmosphere. The use of CO_2 lasers in long-path absorption spectroscopy for the sensitive detection of NH_3, C_2H_4, and O_3 has previously been suggested.

Note:

Requests for further information may be directed to:

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Patent status:

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