NASA Contractor Report 3175

Development of Tunable High-Pressure CO_2 Laser for Lidar Measurements of Pollutants and Wind Velocities - January 1976 to December 1977

Ali Javan

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Ali Javan
Laser Development Corporation
Lexington, Massachusetts

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Introduction

It has been known for some time that a multi-atmospheric CO_2 laser offers frequency tunability over a broad region, making this laser device an excellent candidate for a variety of applications in the 9 micron and 10 micron ranges of the electromagnetic spectrum. With the isotopic substitution of carbon and/or oxygen atoms in the CO_2 molecules, the operation of the device can be extended through the 11 micron range. In some applications, frequency tuning within thousands of MHz on either side of the peaks of each P or R branch CO_2 rotational-vibrational transition is adequate. Other important applications, however, require frequency tuning by as much as ten to twenty GHz from the peak of each line. Because of this, the useful operating pressure range of the device extends from one to two atmospheres up to eight to ten atmospheres. The operation in the higher pressure range has the added advantage of reduced frequency pulling making possible a nearly linear frequency tuning at frequencies appreciably detuned from the peak of each CO_2 line.

This report represents contractual effort to December 1977.

In a gain switched multi-atmosphere TEA laser preionized via U.V. photoionization or an energetic electron beam, it is possible to obtain pulsed operation with energy per pulse exceeding several Joules and with a pulse duration ranging from hundreds of nanoseconds up to several microseconds.

This is obtainable in a laser having tens of cm^3 plasma volume. Such a system can operate at several Hz repetition rate without a rapid gas flow; with a rapid gas flow, operation at kHz repetition rate or higher is possible.

Remote sensing of the stratosphere/troposphere from spacecraft or aircraft of trace gases with heterodyne detection requires frequency stabilities of ∿ 2 MHz for Differential Absorption Lidar (DIAL) and .2 MHz for 1m/sec Doppler Lidar wind velocity measurements. Even for direct detection in trace gas DIAL measurements frequency stabilities/bandwidths ∿ 100 MHz are desirable for optimizing long path absorption and reducing interference trace gas effects. Frequency stabilities of ∿ 100 MHz also are needed for energy conversion by molecular photo-dissociation via resonant or near-resonant infrared radiation; molecular photo-chemistry via intense vibrational heating; and laser isotope enrichment.

The multitude of this laser's applications has been a primary factor which, as we understand it, motivated NASA to undertake the support of this development project at LDC. A long term objective is, however, to use this device in global remote sensing of atmospheric trace gases and wind velocities from a space based station. As it must be expected, additional development work is needed before a fully engineered unit, with a high repetition rate and an ultimate in the frequency purity and long term stability, is at hand. Nevertheless, the frequency tunable laser developed under this contract is already a highly useful device applicable to laboratory experiments in the areas listed above - in fact, this frequency tunable laser can now be put to use to perform crucial experiments in these areas which could not be attempted previously. (The laser, used with an external frequency filter, see below, can provide a frequency spread below a hundred MHz.)

Section 1 - General Description and the Operating Principles

There are two distinct features of this device which utilize novel physical principles to achieve the specific performances. The first relates to the energy deposition and the means to produce the uniform high density plasma in the multi-atmospheric medium. The second relates to the radiative processes which are operative and prevent the laser from breaking to oscillation in a large number of modes over its broad amplification band-widths. These topics are discussed below in two separate subsections.

1(a) - Production of the High Density Plasma in the Multi-Atmospheric CO_2, N_2, He Medium

The laser device developed under this contract utilizes U.V. preionization of an organic seed gas at a low partial pressure mixed in with the high pressure CO_2, N_2, He gas mixture. The laser has been operated at pressures up to ten atmospheres.

Highly uniform laser plasma is produced with very little (less than one Joule) U.V. preionization energy. In this respect, it differs from an e-beam preionized multi-atmosphere CO_2 laser explored by the Soviet workers at the Spectroscopy Institute in Moscow and a similar laser at the Naval Research Laboratory in Washington, D.C. An e-beam preionized CO_2 laser with a volume similar to ours requires orders of magnitude higher preionizing energy. Furthermore, at elevated gas pressures, the penetration depth of the energetic electrons is sizably reduced. Because of this, the operation of an e-beam preionized device at pressures above five or six atmospheres becomes cumbersome and not very practical.

Operation of a multi-atmosphere CO_2 TEA laser with U.V. preionization has been reported previously by Alcock up to a pressure of fifteen atmospheres without the advantage of utilizing a seed gas. That system also requires orders of magnitude higher preionizing energies as compared to the LDC device constructed under this NASA contract. The need for a higher preionization energy is not by itself a drawback; it is however indicative of the difficulties which will have to be faced in order to produce the necessary preionization.

Production of a uniform high density plasma in which U.V. illumination is applied to photoionize a small partial pressure of an organic seed gas mixed in with a multi-atmosphere gaseous laser medium was first proposed and demonstrated in 1974 by Javan and Levine. The advantages of this, fully utilized in the present LDC device, are as follows:

- Without the seed gas, the sustainer electrodes must be shaped and aligned precisely, otherwise frequent arc formation occurs causing highly non-uniform distribution of the high density plasma in the multi-atmosphere medium.
- Without the seed gas, the initial electrons produced via U.V. preionization are at a low density, requiring a carefully timed application of the sustainer voltage no later than one microsecond after the U.V. illumination. With the appropriate use of the organic seed gas, it is possible to produce (for the preionization) orders of magnitude higher electron densities at much reduced level of U.V. illumination. At a high preionizing electron density, the timing of the sustainer voltage application becomes a less critical factor. In fact, a major source of instability in the operation of a gain-switched high pressure laser arises from the jitter in the timing between the application of the high current sustainer voltage and the U.V. illumination pulse (which is normally present

because of the jitter in triggering the high current electronic circuit). The use of the seed gas sizably improves the performance of the device by making it less sensitive to the jitter in the electronic timing circuit.

- The plasma distribution across the transverse electrode gap is considerably more uniform in a seeded medium.
- Because of reduced arc formation, the pulse-to-pulse reproducibility is much higher at a multi-atmosphere pressure with the organic seed gas.

There is, however, an art in utilizing the seed gas to its fullest advantage. This art is exploited to its full capabilities in the laser device developed under this contract. (See Section 2.)

1(b) - The Mode Competition Effect and the Frequency Characteristics

The laser resonator comprises a grating for frequency tuning. When used with a telescope in the resonator, the grating limits the effective regenerative amplification bandwidth to somewhat below 0.3 cm^{-1}. (The telescope in the resonator increases the spot size on the grating and thus improves the grating resolution.) Note that for a one meter resonator length, over seventy longitudinal modes lie within this 0.3 cm^{-1} regenerative amplification bandwidth--in principle a multi-mode laser oscillation can occur over all these modes.

It has been known for some time that at an elevated pressure where collision broadening results in a homogeneously broadened amplifying transition, the mode competition effect may in principle be taken to advantage to automatically reduce the number of simultaneously oscillating modes. This was initially demonstrated (at MIT) in an HF laser in which the mode competition was used to product only one oscillating mode close to the peak of the oscillating HF laser transition. It was later shown (by Javan) that a similar behavior occurs in a CO_2 laser. In that experiment, a longitudinally excited CO_2 laser at a pressure of about one hundred torr (where collision broadening dominates) was used to study this effect. It was shown that, in practice, unless care is exercised, the so-called "spatial hole burning" effect can cause mode-decoupling resulting in multi-moding.

In this NASA-sponsored LDC project, several experiments were performed to establish the nature of mode-competition in the multi-atmosphere CO_2 laser in relation to simultaneous multi-moding and the laser frequency spectrum.

A detailed Fabry-Perot analysis of the laser spectrum shows that, under the condition where the gain of the medium is sufficiently above the resonator losses, the laser frequency spectrum covers a range of about 1500 to 2000 MHz. (This result is in agreement with the observations reported by the

Soviet workers at the Spectroscopy Institute in Moscow studying the frequency spectrum of their e-beam excited multi-atmospheric laser.)

In our case, the measured laser frequency spectrum corresponded to about ten to fifteen simultaneously oscillating longitudinal modes (in the one meter resonator having 150 MHz mode-spacing). We had initially attributed this multimoding effect to the spatial-hole burning, along the lines discussed by the Soviet workers.

The spatial-hole burning effect is expected to be absent in a laser utilizing a ring resonator in which the laser oscillation is excited in a uni-directional travelling wave mode. This LDC laser developed for NASA is equipped with means to operate in a ring-resonator configuration in a uni-directional travelling wave in a clock-wise or counter clock-wise direction. (See below for discussions.) Surprisingly, it is found that the multi-mode nature of the laser spectrum is not dependent on its operation in a standing wave configuration; it occurs also in the uni-directional travelling wave mode (where the spatial hole-burning effect is absent). This important conclusion suggests that the earlier expectations relating to the mode-competition are not in detail applicable to the operation of the multi-atmospheric CO_2 gain-switched CO_2 laser under study in this program.

Detailed inspection reveals that the difference lies in the transient nature of laser oscillation build-up and decay in a gain-switched high-pressure CO_2 laser having a pulse duration of about one microsecond (or less). This is to be contrasted with operation of a CO_2 laser having a long pulse duration allowing steady-state oscillation to be reached. When e-beam or U.V. ionization provide the primary ionization (supported by a sustainer voltage) over a period exceeding the V-T decay in the CO_2 laser medium, the transient state can be extended to longer periods $\sim 10\ \mu$secs., even at higher pressure. Accordingly, in the present system, the mode competition effect must be analyzed as occurring in the transient state, as opposed to the steady-state situation.

Consider the competition effect between two modes, one lying near the peak of the grating response and the other lying on its wing. In this case, the gain-above-loss factor is considerably higher for the mode lying near the peak of the grating response as compared to the mode lying on the wing of the resonator. The competition in the build-up of oscillation in the two modes is critically dependent on their gain-above-loss factors. The mode with the higher gain-above-loss factor dominates early in the transient oscillation build-up. Accordingly, this effect inhibits build-up of energy in the mode lying on the wing of the grating response, while favoring the oscillation build-up on the mode lying near the peak.

Consider, however, the build-up of oscillation on two modes both of which lie near the peak of the grating response. In this case, the gain-above-loss factors for the two modes are nearly the same. Detailed inspection shows that in this situation oscillation build-up occurs similarly in both modes until late in the transient (and after the amplifying medium is driven to saturation), after which the mode with slightly higher gain will eventually dominate.

The laser pulse-shape and duration in the CO_2-He-N_2 gain-switched multi-atmospheric laser is dependent on the partial pressure of He. In an He-rich mixture, the laser pulse consists of a high intensity leading pulse of several hundred nanosecond duration, followed by a long tail at a considerably lower intensity lasting a duration of up to one microsecond. The laser oscillation during the leading high-intensity pulse is totally in the transient where the competition effect is far from complete for the modes lying near the peak of the grating response. In this transient gain-switched pulse, the laser energy is shared between ten to fifteen of these modes near the peak of the grating response (for which the gain-above-loss factors are nearly the same).

From the above it follows that the number of simultaneously oscillating modes should reduce on the low intensity microsecond long tail of the pulse, tending eventually to a single mode oscillation, as per expectations of the steady state situation.

1(c) - Uni-Directional Travelling Wave Ring Resonator Laser

The multi-atmospheric laser developed under this contract has the unique feature of the capability of operating either in a frequency tunable standing wave resonator configuration, or in a frequency tunable ring resonator configuration having a provision to cause the oscillation to occur in a uni-directional travelling wave. In the standing wave resonator configuration, the grating is used in Littrow. In the ring resonator, the grating is used in reflection. The uni-directional oscillation build-up in the ring configuration is obtained as follows. As the gain in the multi-atmospheric medium is switched on, the oscillation build-up initially takes place along the two counter-propagating directions around the ring. At the output mirror, the two counter-propagating waves emerge along two well resolved and distinct paths. A "suppressor" mirror is used external to the ring in the output path of one of the two counter-propagating waves. At the early build-up times, the suppressor mirror reverses the direction of the travelling wave which it intercepts and feeds it back to the other counter-propagating wave. Because of the competition effect arising from the non-linearities of the amplifying medium, the presence of the suppressor mirror inhibits a complete build-up of oscillation along the direction of the travelling wave which it intercepts, and favoring the oscillation build-up in the reverse direction. Accordingly, with the suppressor mirror carefully aligned, the oscillation occurs uni-directionally. Without the suppressor mirror, the ring resonator laser oscillates on both of the counter propagating travelling waves.

The LDC laser can reproducibly operate in a uni-directional travelling wave mode, as well as in a standing wave configuration. The capability of operating the device in a uni-directional ring configuration is a highly unique feature.

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As noted above, the LDC frequency tunable laser in its free-running mode of operation is capable of oscillating with a frequency spread of about 1500 MHz. This occurs in several modes at the peak of the grating response and is accompanied by some frequency chirping due to the index of refraction change caused by the high current pulse in the high pressure amplifying medium. Continuous frequency tuning is obtained by fine tuning of the grating. (See below for the possibility of eliminating multi-moding by injection locking.)

With a Fabry-Perot filter used at the laser output, we have sizably reduced the spectral width of the transmitted radiation (to a value of about 300 MHz). The experiments were initially performed with a low finesse filter (due to poor quality of the available mirror). With a high finesse filter, the frequency spread can be reduced below one hundred MHz when using a short time (Δt) optical switch to smoothen the frequency oscillations ($\Delta\omega$) between the modes (Note: $\Delta\omega\Delta t \geq 1$), the frequency spread can be reduced to $\lessdot$ 10 MHz.

The presence of the filter at the laser output reduces the transmitted laser power through the filter by a factor nearly equalling the ratio of the 1500 MHz oscillator frequency spread over the bandwidth of the filter. In a variety of applications, a reduction by a factor of one hundred can readily be tolerated--with a multi-atmospheric amplifier placed at the output of the filter, however, the power level can be raised to a value comparable to the laser output. In fact, with this amplifier driven to saturation, in addition to improved monochromaticity, the pulse-to-pulse amplitude jitter can be stabilized.

In some applications, multi-mode operation of the device is useful. The LDC device can be operated in a forced multi-mode fashion by means of a saturable absorber placed in the resonator. This has been tested with a novel "saturable mirror" consisting of a 1 ohm/cm P-type germanium slab with a two millimeter thickness. The germanium slab is polished on both sides. One side of it is dielectrically coated at 10.6 microns to 95% reflectivity, and the other side is antireflective coated at this wavelength. It is used as the output resonator mirror with the AR coated side facing inside of the laser resonator. With this combination mirror-saturable absorber, multi-mode operation is obtained in the form of mode-locked pulses. In this configuration, the laser is forced to oscillate on a large number of longitudinal modes equally spaced over the grating bandwidth.

Another feature of this LDC laser is that it can operate in a configuration in which a hot CO_2 absorber cell in the resonator forces the laser to oscillate at frequencies removed from the peaks of the CO_2 lines in the 10.6 micron band. This is done in a simple two mirror resonator without the use of a grating. The purpose is application to atmospheric transmission where enhanced transmission can be obtained at frequencies outside of the band width of each CO_2 absorbing line belonging to the 10.6 micron absorption band. This absorption effect can be a serious problem in particular at low altitudes, which would include vertical laser energy transmission through the atmosphere from aground base laser system. With a multi-atmosphere laser having a hot CO_2 absorber cell in its resonator, and a multi-atmosphere power amplifier, very high energy laser pulses can be obtained at frequencies removed from the regions where the CO_2 absorption occurs.

1(d) - Recommendation for Future Work

As noted, above, at a fixed position of its grating, a free-running multi-atmospheric gain-switched CO_2 laser oscillates on ten to twenty modes near the peak of the grating response. This is due to the transient nature of oscillation build-up (for a laser pulse of a duration below one microsecond) where the mode competition remains incomplete for modes having nearly the same gain-above-loss factors. This holds true as lone as instabilities leading to the laser oscillation on-set is triggered by the spontaneous emission (which produces an initial radiation field of about 10^{-11} watts per mode in the laser resonator).

If at the build-up time, a weak radiation field is injected from an external source into one of the modes, the build-up of oscillation on that mode can be speeded up compared to the adjacent modes, as long as the injected radiation is orders of magnitude higher than the spontaneous emission signal. This effect has been known as "pulse-smoothing" or "line-center" injection locking effect. A generalization of it to energy extraction at multi-frequency field is currently the subject of a separate LDC project (under sponsorhip of LASL). In that project, the laser energy from a gain-switched CO_2 laser is extracted at pre-selected multi-frequencies, each of which occurs on a single-mode near the peak of a preselected line from the 10.6 μm and 9.6 μm band. This laser has been designed for use as the master-oscillator in a hundred kilojoule oscillator-amplifier system for the laser fusion experiment.

LDC has made an extensive study of this injection locking method. As a result of this work (first discussed in an extensive proposal and experimentally demonstrated in a follow-on NASA contract) it is shown that the laser energy can be extracted at a single tunable frequency, with a frequency purity and long term stability better than ten MHz. This process is described in terms of a transient regenerative amplification effect, requiring a frequency tunable master oscillator, to provide the initial injected field. Several options are analyzed at length, one of which concerns a novel CW multi-atmospheric transverse flow tunable CO_2 laser with mini E-beam preionization in a very small electrode gap. Other options concern production of a weak frequency tunable side-band on the output of a line-tunable CO_2 laser, using the well-known electro-optical microwave modulation, and mixing of tuned CO_2/CO laser frequencies in a $CdGeAs_2$ crystal to obtain < 100 MHz (or less for isotopes) stepwise tuning over a wide infrared spectrum.

LDC studies include a complete analysis of a class of closed-cycle CO_2 laser systems operating at pressures up to several atmospheres, in which isotopic CO_2 gas is used to obtain wide frequency tuning coverage for DIAL measurements of trace gases at short and long term stability < 10 MHz. The studies are made for a space-qualified laser, consistent with the shuttle environment and the available energy. In addition, LDC has designed a unique "line-center" laser capable of offering a frequency purity and long term stability better than one hundred KHz, for Doppler Lidar wind velocity measurements.

These topics are the subject of the prev mentioned extensive LDC proposal which has b prepared for submission to NASA and a follow NASA contract.

Section 2 - Design Details of High Pressure Tunable Laser

2(a) - Mechanical

The high pressure laser chamber consists an assembly of aluminum and plexiglas plates stacked and held in precise mechanical align by a multitude of bolts passing through the The outermost plates are made of jig plate a 1.59 cm thick by 76.2 cm x 20.32 cm. This c of material is a departure from an earlier d in which thinner and softer aluminum was use sulting in a slight bowing of the container the highest operating pressure. Our current sign corrects this deficiency and insures me cal stability at pressures in excess of 10 a pheres[1].

Immediately below the top plate is a sol (except for the bolt holes) plexiglas "insul plate". Broad dimensions of the insulator p are the same as the top plate except for the tion of a 55.88 cm x 3.81 cm assymetrical pr sion which extends into the space above the feed-through to prevent arcing and/or tracki the top plate which is held at ground potent

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[1] 1 atm = 1.013 x 10^5 Pa.

Beneath the insulator plate is a .63 cm plexiglas "electrode plate". Shallow slots (5) are milled in this plate to accept the low inductance HF feed-through while still insuring the uniform transmission of pressure induced stress through to the insulator plate and ultimately to the "top plate". The HV electrode is secured to the eletrode plate via 5 bolts which pass through the plate and into the body of the electrode. A .079 cm neoprene gasket is sandwiched between the electrode and electrode plate to seal the leakage path around the electrode bolts.

The cavity plate is 3.81 cm thick plexiglas plate from which the central area has been removed to form 4 thick seamless sidewalls. Feed-throughs are provided in the walls for the spark line supply, as are means for mounting internal Brewster angle windows. O-Ring grooves are provided to make a pressure seal with the electrode plate on the top side and with the aluminum bottom plate on the underside. The bottom plate carries provision for gas inlet and venting and also supports the ground electrode which is affixed in the same manner as the HV electrode is to the HV plate. Both top and bottom plates are at electrical ground potential.

2(b) - Optical

Coarse frequency tuning is effected by adjusting the Littrow angle of a 100 lines/min diffraction grating. A micrometer screw is provided for initial wavelength selection while a PZT pusher in series with the screw allows for fine tuning over a range of approximately 2 KMC. The grating tilter is also provided with screws for angular adjustment about the horizontal axis perpendicular to the optical axis and for adjustment of groove orientation in the plane of the grating. A Galilean telescope utilizing ZnSe optics is employed intracavity to increase the grating resolution, thereby increasing the Q of the dispersive element and minimizing pulling of the laser frequency by the gain medium. The telescope is a four rod structure having a convex lens of 38.1 cm f.l. and 3.81 cm dia. rigidly mounted in one endplate and a concave lens of 8.89 cm f.l. and 1.90 cm dia. mounted in a precision slide tube affixed to the second endplate. It is desired to produce a parallel light incident on the telescope the appropriate lens spacing would be 29.21 cm. The telescope is located near the equivalent of the flat mirror (grating) of a folded confocal cavity so that the negative lens does in fact intercept a nearly plane wavefront, but not quite. The wavefront does have a slight curvature and the lens spacing is corrected empirically by small adjustments of the slider tube. Optimum lens spacing is found to be 28.57 cm. Magnification of the telescope is a factor of 4 which results in a spot size on the grating of 3.8 cm dia.; grating resolution is one part in 3.8×10^4 implying a bandwidth of .78 KMC.

All optical components are mounted on an aluminum plate 182.88 cm x 91.44 cm x 1.27 cm. The plate is braced with a network of 2.54 cm x 7.62 cm aluminum bars to prevent flexing and to clamp out discharge induced vibrations. A system of mounting blocks and clamps permit the fine adjustment of optical component placement on the table while insuring positive hold-down once positioning is determined. Sufficient mirror mounts and clamps are provided to operate the system in a travelling wave ring configuration. For this purpose the telescope is removed and the grating is used off Littrow. A flat gold coated mirror is positioned to complete a triangular cavity formed by a germanium output coupler and the off Littrow grating. The gold mirror is positioned along the direction defined by the diffracted beam of the desired wavelength from the grating. With precise alignment of all components, the system will sustain two contra-rotating travelling waves. Assymetry may be introduced into the system and consequent quanching of one travelling wave via an extra-cavity suppressor mirror. This is simply an auxiliary mirror standing just beyond the germanium output coupler and aligned to feed-back into the resonator one of the travelling wave outputs (wave A). This serves to intensify the other travelling wave (wave B) and hence rob population from wave A. This competition is sufficiently strong to completely quench wave A after an initial transient turn on time. In this way we achieve true travelling wave operations free of spatial hole burning. This in turn insures greatly reduced axial multi-moding.

2(c) - Electrical

The main discharge is driven by a two stage Marx generator. Energy storage is in arrays of 2700 pfd, 40 KV Barium Titanate capacitors tied together in parallel combination via flat aluminum plates. This arrangement allows for "fine tuning" of the capacitance of the driver by simply adding or removing individual capacitors, while insuring minimum inductance. The bank is erected by triggering a pressurized spark gap (Tachisto 501). A second pressurized (non-triggered) gap is placed between the high end of the Marx and the HV laser electrode. This gap is pressurized so that it is well overvoltaged by the erected Marx but below break-down at one half this voltage. It has been determined experimentally that a capacitance of .016 μfd per stage (corresponding to 6 capacitors per stage) charged to between 20 KV and 35KV per stage will result in uniform plasmas and strong laser oscillation between 1 atmosphere and 10 atmospheres pressure of laser gas in the plasma chamber.

H.V. for preionization is produced by two spark rods affixed to the inner "cavity plate walls" parallel to the electrodes at their mid-plane. A spark rod is essentially a string of co-axial capacitors having a common tubular di-electric and solid rod inner conductor. The individual outer "plates" are .63 cm wide and spaced by .63 cm. A copper wire soldered to each outer plate reduces the electrical separation between adjacent capacitors to about .07 cm. When a H.V. pulse is applied to the spark line, a series of high current arcs are produced along the entire length of the line. The required voltage is only that which is sufficient to break down one inter-capacitor arc. The spark lines are energized by a .02 μfd capacitor charged to 20 KV.

A self-contained oscillator produces a 15V square pulse at a rep rate of up to 1 pps for use in triggering both the spark line supply and the main discharge Marx trigger. In both cases the low voltage timing pulse is used to turn on an SCR, which discharges a capacitor into the primary of a trigger transformer. The output of the transformer is used to ionize the spark gap. It is essential to maintain a time delay between the production of U.V. by the spark lines and the application of H.V. to the laser electrodes. The delay is on the order of .1 to 1 μ sec., and is obtained by adjusting the N_2 pressure in the triggered Marx gap. If the pressure is maintained somewhat above that for self-breakdown, while the spark line gap is very close to self-breakdown, then the differential arc formation time will provide the required delay.

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16. Abstract
The paper discusses development of a tunable multi-atmospheric pulsed CO_2 laser with emphasis on new experimental features and supporting theoretical analyses important to Differential Absorption Lidar and Doppler Lidar measurement of pollutants and wind velocities. The first relates to the energy deposition and the means to produce the uniform high density plasma in the multi-atmospheric medium, through UV preionization of an organic seed gas, and detailed design features of the pulsed CO_2 laser. The second relates to the radiative processes which are operative and prevent the laser from breaking into oscillations in a large number of modes over its broad amplification bandwidth. The mode competition for the transient pulsed laser oscillation in a standing wave and traveling wave ring laser configuration is discussed and contrasted with the approach to steady state oscillations. The latter findings are important to Transient Injection Locking for production of a highly stable pulsed CO_2 laser output, treated in great detail in more recent NASA contracts.

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