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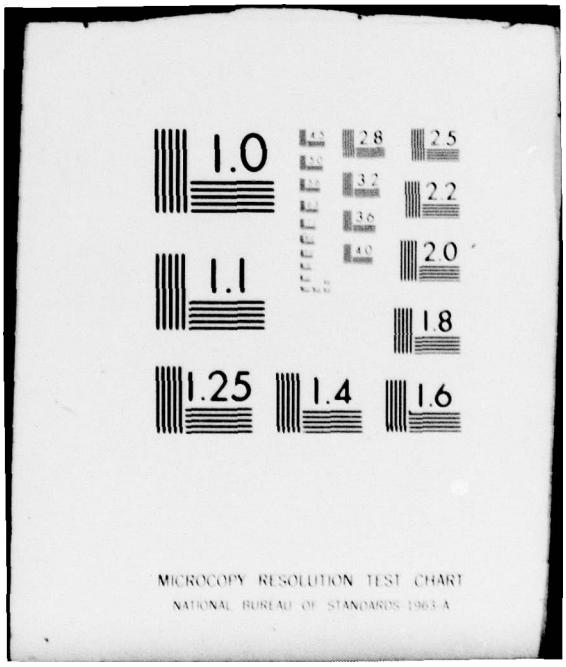
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PERFORMANCE AND DIAGNOSTICS OF LASERS INITIATED BY THE REACTION OF NO WITH ClO_2

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(6) PERFORMANCE AND DIAGNOSTICS OF LASERS INITIATED BY THE REACTION OF NO WITH ClO_2

by

(10) S.J. Arnold, K.D. Foster and D.R. Snelling

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RESUME

Nous avons fait fonctionner en écoulement transversal un laser chimique pur au HCl avec une puissance maximale de sortie multiligne de 13 W. Si l'on se base sur l'exothermicité de la réaction de pompage, l'efficacité chimique est de 8.6%. La concentration en non-équilibre requise d'atomes de Cl est produite par une réaction en chaîne ramifiée du NO avec du ClO_2. Les mesures d'absorption spectroscopique et une analyse par spectromètre de masse ont montré que l'efficacité de la réaction ramifiée diminue lorsque l'on augmente la pression totale. (NC)

ABSTRACT

A purely chemical HCl laser employing transverse flow was operated with a maximum multiline output power of 13 W, which represents a chemical efficiency of 8.6% based on the total exothermicity of the pumping reaction. The required nonequilibrium concentration of Cl atoms was generated by the branched-chain reaction of NO with ClO_2. Mass spectrometric and absorption spectroscopic measurements of species concentrations in the NO/ClO_2 reaction system showed that the effectiveness of production of the branched chain decreased with increasing total pressure. (U)

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1.0 INTRODUCTION

Interest in radar-related applications of eye-safe lasers has focused on the 3-5 μm and 8-13 μm regions. Specifically, either DF or HCl chemical lasers operate in the 3-5 μm region and CO_2 lasers in the 10 μm region. Because vibrationally excited HCl transfers its energy efficiently to CO_2, HCl laser devices operating at 3.8 μm may easily be converted to CO_2 lasers operating at 10.6 μm. The performance characteristics of a subsonic purely chemical HCl laser and of a HCl/CO_2 transfer laser are described herein.

Recently, DREV reported the development of a purely chemical HCl laser which used the reaction of NO with ClO_2 as a chlorine atom source (Refs. 1, 2). A three-step branched-chain mechanism, hereafter referred to as the prepumping chemistry, is involved:

$$NO + ClO_2 \rightarrow NO_2 + ClO \quad k_1 = 3.4\times10^{-13}\,cm^3s^{-1} \quad \text{(Ref. 3)} \quad [1]$$

$$NO + ClO \rightarrow Cl + NO_2 \quad k_2 = 1.7\times10^{-11}\,cm^3s^{-1} \quad \text{(Ref. 3)} \quad [2]$$

$$Cl + ClO_2 \rightarrow 2\,ClO \quad k_3 = 5.9\times10^{-11}\,cm^3s^{-1} \quad \text{(Ref. 4)} \quad [3]$$

The net effect of this branched-chain mechanism is to produce Cl atoms in preparation for the laser pumping step in which vibrationally excited hydrogen chloride, HCl, is formed:

$$Cl + HI \rightarrow HCl + I \quad k_4 = 1.6\times10^{-10}\,cm^3s^{-1} \quad \text{(Ref. 5)} \quad [4]$$

$$Cl + HBr \rightarrow HCl + Br \quad k_5 = 7.4\times10^{-12}\,cm^3s^{-1} \quad \text{(Ref. 5)} \quad [5]$$

$$Cl + H_2S \rightarrow HCl + HS \quad k_6 = 6.0\times10^{-11}\,cm^3s^{-1} \quad \text{(Ref. 6)} \quad [6]$$

It was demonstrated (Ref. 2) in an actual flow device that the prepumping and pumping chemistry could be carried out in 3 distinct ways. The first way (referred to as Chemical Mode I (Ref. 2)) involved the addition of the prepumping reagents in the ratio of NO:ClO_2 of 2:1 to form Cl atoms followed by the addition of the fuel to produce vibrationally excited HCl. In the second method (Chemical Mode II (Ref. 2)),

the NO and ClO_2 were mixed in the ratio of 1:1 to yield ClO radicals. A subsequent addition of NO/fuel then converted the ClO radicals to Cl atoms, which in turn reacted with the fuel to form HCl. In the third method (Chemical Mode III (Ref. 2)), both the prepumping and laser pumping chemistries were initiated together by the addition of 2 parts of NO to a stream containing 1 part each of ClO_2 and fuel.

If the scaling of purely chemical lasers based on the NO/ClO_2 reaction is contemplated, operation at supersonic velocities may be necessary. Because supersonic lasers require the expansion of gases from a high-pressure plenum to a low-pressure region, a knowledge of the NO/ClO_2 chemistry at high pressures would be desirable. The unwanted loss of the chain carriers, Cl and ClO, is believed to be more significant at higher pressures.

Previous calculations (Ref. 2) have shown that ClO radicals should survive longer than Cl atoms in the presence of NO_2 in a high-pressure environment. The NO_2 catalytically recombines Cl atoms via the reaction

$$Cl + NO_2 + M \rightarrow NO_2Cl + M \quad k_7 = 7.2\times10^{-31} cm^6 s^{-1} \quad \text{(Ref. 7)} \quad [7]$$

followed by the reaction

$$Cl + NO_2Cl \rightarrow Cl_2 + NO_2 \quad [8]$$

which is believed to be fast. Thus, the Cl atoms disappear with an effective termolecular rate coefficient of $1.4\times10^{-30} cm^6 s^{-1}$. ClO recombines with NO_2 by the slower three-body process

$$ClO + NO_2 + M \rightarrow ClNO_3 + M \quad k_9 = 1.2\times10^{-31} cm^6 s^{-1} \quad \text{(Ref. 8)} \quad [9]$$

which is $\sim$ 12 times slower than the analogous loss process for Cl atoms.

This work was performed at DREV between November 1976 and January 1978 under PCN 33H07, Research on Chemically Excited Lasers.

2.0 EXPERIMENTAL

2.1 Chlorine dioxide generator

Chlorine dioxide was prepared on demand by passing molecular chlorine and diluent helium through a column containing $NaClO_2$ flakes. The chlorine was quantitatively converted to ClO_2. The procedures for generating and measuring ClO_2 are described in detail in Ref. 2.

2.2 Laser assembly

The transverse-flow laser is shown schematically in Fig. 1. The laser body was constructed of stainless steel with the interior metal surfaces covered with Teflon. The flow channel was rectangular with a cross section 1 x 40 cm. A choke screen, consisting of a Teflon gasket through which 243 uniformly spaced holes were drilled, was placed at the upstream end of the flow channel in order to make the flow of ClO_2/He uniform across the full channel width. Secondary gas injection was provided by 3 rows of tubular injectors. The first row was located 6.4 cm downstream of the choke screen. The second and third rows were located 11.1 and 11.4 cm downstream of the first, with the third row in line with the edge of the window section. Each row consisted of 60 tubular injectors, 0.85 mm in internal diameter, containing 11 holes of 0.3-mm diameter. These were disposed so that the gas passing through them entered near the center plane of and perpendicular to the mainstream flow.

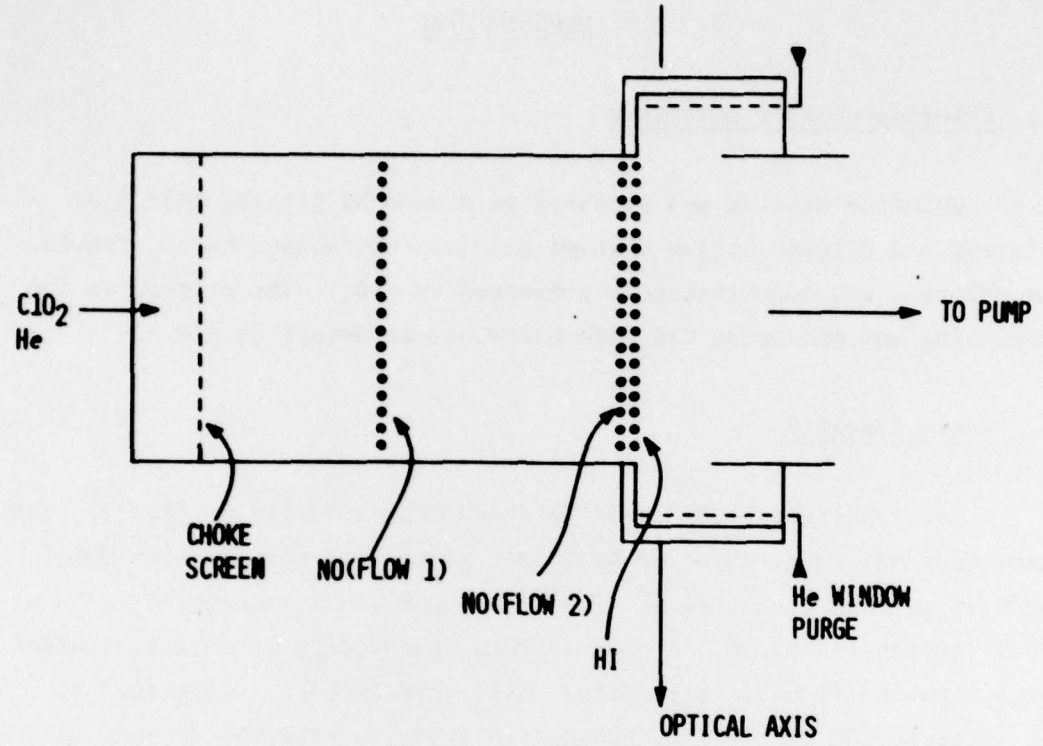

FIGURE 1 - Schematic diagram of a transverse-flow HCl laser employing the $NO/ClO_2/HI$ reaction sequence

Nitric oxide could be added through the first (hereafter referred to as NO (flow 1)) and/or second (hereafter referred to as NO (flow 2)) injector rows. Hydrogen iodide was added through the third injector row. It was noted previously (Ref. 2), that a single downstream injector row for NO (flow 2) and HI could not be used because when NO and HI were mixed at relatively high pressures, molecular iodine formed which choked the injector holes. The apparatus could be used for operation in Chemical Modes I, II or III or as a HCl/CO_2 transfer laser.

For the experiments in which the device was used as an HCl laser at 3.6 - 4.0 μm, the mirrors were externally mounted. The windows were CaF_2 flats mounted at the Brewster angle. A flow of helium near the window kept the surface clean and the optical path free of deactivated HCl.

For experiments in which the device was used as a HCl/CO_2 transfer laser at 10.6 μm, the windows were eliminated and the mirrors internally mounted on bellows supports.

Measurements of the total output power were made with a Coherent Laboratories power meter.

Mass spectrometric measurements of the reaction products were performed on a Consolidated Electrodynamics Model CE-104 mass spectrometer.

Absorption spectroscopy was used to measure the concentrations of ClO and ClO_2. Ultraviolet radiation from a stabilized deuterium lamp passed through a quartz collimating lens and an adjustable aperture, whereupon it was chopped at 670 Hz before traversing the flow channel. A second quartz lens focused the radiation onto the entrance slit of a 0.3-m MacPherson monochromator. The monochromator entrance and exit slits were set at 50 microns. An EMI 9718 photomultiplier, a Hewlett-Packard HR-8 locking amplifier and a chart recorder completed the detection system.

To determine the concentration of ClO, measurements were made on the band head at 277.2 nm whereas for ClO_2 they were made on the band head at 351.5 nm. The concentrations of ClO and ClO_2 are related to the corresponding intensities of absorption by the expression

$$c = \left(\frac{-1}{\varepsilon L}\right) \log_{10}\left(\frac{I}{I_o}\right) \qquad [10]$$

where c = concentration, L = path length (width of laser cavity), I_o = light intensity and ε = extinction coefficient. Clyne and Coxon (Ref. 9) have determined the values of ε for ClO and ClO_2 to be 1900 M^{-1} cm^{-1} (294 K) and 3000 M^{-1} cm^{-1} (294 K) respectively.

3.0 LASER OUTPUT POWER MEASUREMENTS

3.1 HCl laser based on the reaction of Cl with HI

The maximum total HCl multiline output power achieved in the present device was 13 W. The experimental conditions were as follows: flow rates in mol/s; He 7.16×10^{-2}, ClO_2 1.04×10^{-3}, NO (flow 1) 3.11×10^{-3}, and HI 1.35×10^{-3}; total pressure 0.32 kPa; flow velocity 2.2×10^{4} cm/s; output coupling 10%. The laser was operated under Chemical Mode I conditions: all the NO was added at the upstream injector location so that the ClO_2 was first converted to Cl atoms before the HI was injected. For Chemical Mode II operation, the laser power is $\sim$ 70% of that obtained for Chemical Mode I operation whereas for Chemical Mode III operation, it is $\sim$ 12%. These lower powers for Chemical Modes II and III operations are consistent with previous observations (Ref. 2).

The maximum observed power of 13 W represents a chemical efficiency of 8.6% based on the exothermicity of the Cl + HI pumping reaction and the limiting flow rate of ClO_2. This efficiency is higher than the 6.6% efficiency previously observed (Ref. 2), and is attributed to improved mixing of the reagents. This was accomplished by employing proportionally more injector holes and by preferentially locating these holes near the center of the injector to take into account the assumed parabolic velocity distribution of the main flow stream.

The HCl multiline laser power under Chemical Mode I operating conditions was measured for several different decoupling fractions. Figure 2 shows a plot of laser power as a function of minimal mirror transmission. The laser power is quite insensitive to the decoupling fraction used for nominal transmissions between 5 and 15 percent. This observation suggests that, for lines of equal output intensity, the intercavity power is approximately 3 times higher for 5% transmission than for 15% transmission.

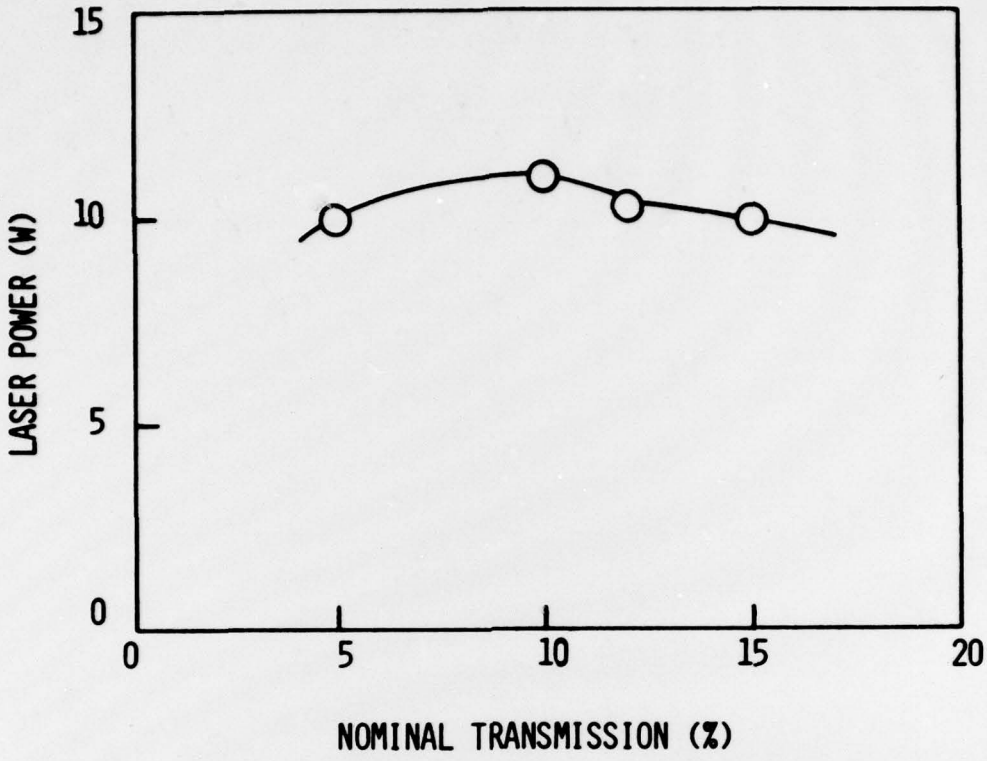

FIGURE 2 - Total HCl multiline laser output as a function of nominal transmission

Similar experiments with a supersonic HCl laser (Ref. 9) showed that the spectral composition of the laser output power may vary markedly with the decoupling fraction even if the total multiline power does not. Stimulated emission from transitions in the $v=3\rightarrow2$ band becomes relatively more important as the overall medium saturation increases.

Stimulated emission was obtained from 12 P branch lines of the $H^{35}Cl$ isotopic species and 2 P branch lines of the $H^{37}Cl$ isotopic species. Laser power originated from the $v=3\rightarrow2$, $v=2\rightarrow1$ and the $v=1\rightarrow0$ vibrational bands. The observed lines together with their relative contributions to the total power are given in Table I. Nominal mirror transmission was 10%. The laser axis was located 0.5 cm from the HI injector.

TABLE 1

LASER OUTPUT SPECTRA

Line	Approx. % total power	
	$H^{35}Cl$	$H^{37}Cl$
$P_{3-2}(8)$	1.1	
(7)	6.7	
(6)	7.8	
$P_{2-1}(8)$	7.5	
(7)	15.5	
(6)	17.4	3.2
(5)	1.3	
$P_{1-0}(9)$	0.9	
(8)	3.8	
(7)	14.8	
(6)	15.1	
(5)	2.6	2.3
% V = 3→2	15.7	
V = 2→1	44.9	
V = 1→0	39.4	

3.2 HCl laser based on the reaction of Cl with H_2S

Since Coombe et al (Ref. 11) had shown that HCl laser action could be achieved from the photolysis of Cl_2/H_2S mixtures, a few experiments have been conducted under Chemical Mode I operation in which H_2S replaced HI as the fuel. The laser pumping reaction is 6 which has an exothermicity of 11.5 kcal/mole compared with 32 kcal/mole for the corresponding reaction with HI (reaction 4).

A maximum HCl multiline output power of 0.15 W was obtained for the following conditions: flow rates in mol/s; He 7.81×10^{-2}, ClO_2 1.18×10^{-3}, NO 3.11×10^{-3} and H_2S 6.26×10^{-4}; total pressure 3.47 kPa; output coupling 2%. Lasing was observed on v = 1→0 transitions with the P_{1-0} (Ref. 7) line being the most intense, ∿72% and the P_{1-0} (Ref. 8), ∿28%. The laser output power was observed to be very sensitive to the H_2S flow.

At the termination of this experiment, H_2S was replaced by HI and a maximum multiline laser output power of 3 W was obtained. The lower laser output power experienced when H_2S was used as a fuel probably reflected the lower pumping reaction exothermicity and the rapid HCl relaxation by H_2S via

$$H_2S + HCl(v=1) \rightarrow H_2S + HCl(v=0) \quad k_{10} \approx 2.3 \times 10^{-12} cm^3 s^{-1} \text{ (Ref. 12)[11]}$$

3.3 HCl/CO_2 transfer laser

If CO_2 was added to the gas stream before the point of addition of HI, the device operated as a HCl/CO_2 transfer laser at 10.6 μm. Internal mirrors were installed forming a cavity that consisted of a total reflector and a 90% reflector at 10.6 μm. Laser output power of 5 W was obtained at 10.6 μm for the following experimental conditions: flow rates in mol/s; He 8.16×10^{-2}, ClO_2 9.96×10^{-4}, NO 1.29×10^{-2}, HI 1.05×10^{-3} and CO_2 1.44×10^{-2}; total pressure 0.60 kPa. This power represents a chemical efficiency of ∿4.4%. Since the laser burn pattern at 10.6 μm was aperture limited, the efficiency might be improved by using a cavity that was capable of extracting power over a greater flow distance. A laser output power of 10 W was obtained when the flow rate of all gases was approximately tripled.

This single-path efficiency of ∿4.4% at 10.6 μm obtained for the present HCl/CO_2 transfer laser compares favorably with the corresponding efficiency of 4.6% obtained from a DF/CO_2 transfer laser by Cool et al (Ref. 13).

4.0 THE NO/ClO_2 PREPUMPING CHEMISTRY: DIAGNOSTIC MEASUREMENTS

A number of experiments were performed to determine the behavior of the prepumping chemistry (reactions 1-3) as a function of pressure. As noted in the introduction, the ClO radical is produced by the prepumping chemistry for Chemical Mode II operation. Since the NO_2 catalyzed three-body destruction of ClO radicals is slower than the corresponding process for Cl atoms, one possible design of a supersonic laser envisions the production of ClO radicals in the high-pressure region with Cl atoms being formed after expansion, when additional NO and fuel are added. Diagnostic experiments for Chemical Mode II operation were carried out to determine if ClO radical production could be efficiently carried out at high pressures.

4.1 Mass Spectrometric measurements

In these experiments, mass spectra were taken of the stable products of the NO/ClO_2 prepumping chemistry. Gas samples were extracted from the exhaust section, well downstream of the point of initiation of the prepumping chemistry, by drawing a small portion of the product gas stream through a pyrex trap, at liquid-nitrogen temperatures, using a small laboratory pump. The trap was sealed and removed for analysis by mass spectrometry. It was held at liquid-nitrogen temperature until just before the mass spectra were taken.

To minimize uncertainties in the sampling procedure and in the reproducibility of the mass spectrometer sensitivity, a flow of condensible gas, CO_2 was added to the mainstream to act as an internal standard.

Mass spectrometric measurements were made for the following conditions: flow rates in mol/s; He 6.68×10^{-2}, ClO_2 1.29×10^{-3}, NO 1.30×10^{-3}, and CO_2 9.01×10^{-5}. The pressure was varied from 0.27 to 2.13 kPa. An initial experiment was performed at a total operating pressure of 0.31 kPa which approximates the typical operating pressure of the HCl laser. A sample was drawn through a liquid-nitrogen trap for a specified time and then isolated. The condensed gases formed a whitish deposit in the trap. The total pressure in the flow channel was then increased to 2.11 kPa by throttling the main pump. The sampling procedure was then repeated for a shorter sampling time. At this high pressure, a bright yellow deposit formed immediately in the liquid-nitrogen trap.

The mass spectra were characterized by peaks associated with Cl_2 at m/e = 70, 72 and 74 (for isotopic combinations of Cl^{35} and Cl^{37}) and with NO_2 at m/e = 30 and 46. For the sample taken at 2.11 kPa, additional peaks appeared at m/e = 51, 53, 67 and 69 indicating the presence of unreacted ClO_2. A study of the product spectra as a function of total pressure showed a systematic increase in the amount of unreacted ClO_2 with increasing pressure.

The peak heights for m/e = 46 and 51 were in excess of the heights expected for normal 70 eV spectra of NO_2 and ClO_2. This excess in peak height increased with increasing pressure. The peak heights also varied in an erratic manner. These observations may indicate the presence of NO_3Cl in the sample although no parent peak was observed at m/e = 97.

The sensitivity of the mass spectrometer to the m/e = 70 peak of Cl_2 and the m/e = 67 peak of ClO_2 was measured in order to convert mass spectral data for Cl_2 and ClO_2 into absolute flow rates. Figure 3 shows the variation in the amount of Cl_2 and unreacted ClO_2 in the stable products as a function of total pressure. The dotted line is the sum of the ClO_2 flow plus twice the Cl_2 flow or, the apparent total chlorine content. The measured amount of Cl_2 formed decreases as

the pressure increases. The decrease in the amount of Cl_2 formed is only partially accounted for by the unreacted ClO_2 because the apparent total chlorine also decreases as the pressure increases. The apparent shortfall in the chlorine mass balance increases with increasing pressure and may be due to the presence of NO_3Cl.

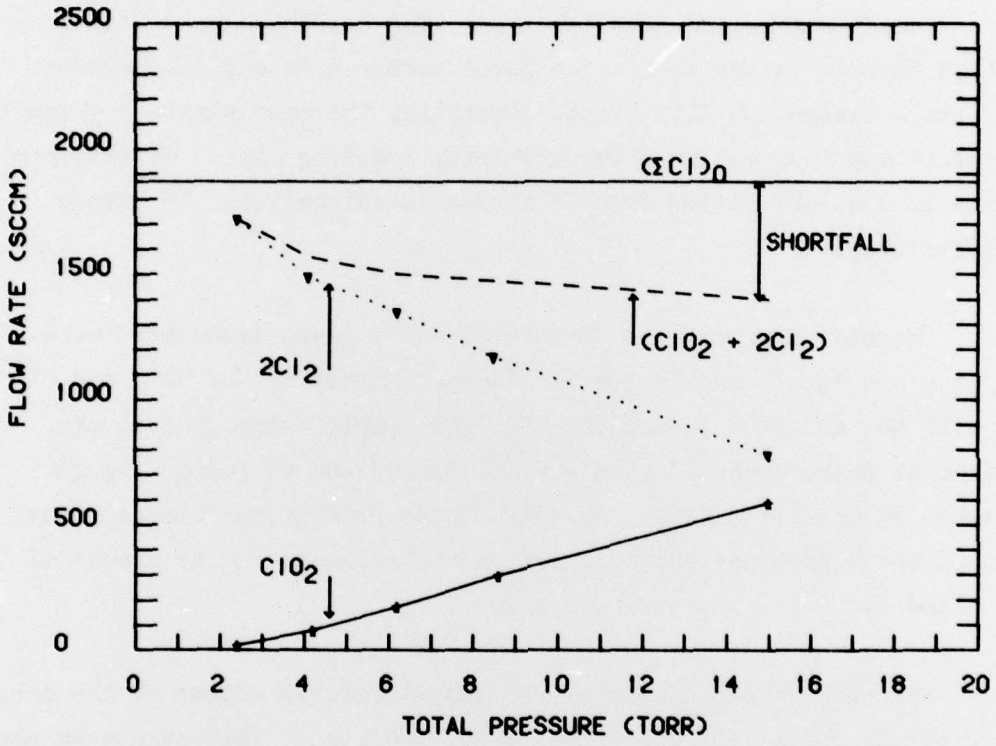

FIGURE 3 - Flow rates of ClO_2 and ClO as a function of total pressure

Mass spectra of the stable products of Chemical Mode II pre-pumping chemistry indicate that the ClO_2 is not completely reacted at higher pressures. In the fully developed chain, the ClO_2 is consumed rapidly by atomic chlorine in the chain branching step (reaction 3). The effectiveness of this step then, in the overall chain sequence, apparently decreases with increasing total pressure in the present apparatus.

The fate of the ClO radicals that are formed is likely to be eventual three-body combination with NO_2 to form NO_3Cl. Although NO_3Cl was not directly detected in these experiments, its presence was suggested indirectly by the excess ion currents for the m/e = 46 and 51 peaks.

4.2 Absorption spectroscopic measurements

Several experiments were conducted to determine the extent of conversion of ClO_2 into ClO under Chemical Mode II operating conditions. In the first set of experiments, (case 1), NO diluted in helium was injected through the final row of tubular injectors into a ClO_2/He stream. The ClO and ClO_2 concentrations were measured as a function of distance from the injector row. The reaction was considered to be complete when the ClO_2 consumption reached a maximum corresponding to a reaction time t_r. The maximum loss of ClO radicals by three-body combination with NO_2, which could occur within the time t_r, was estimated to be less than 10% of the maximum value. This loss was estimated from measured ClO decay curves at a total pressure of 20 torr, assuming a pseudo first-order rate coefficient. Measurements of ClO_2 and ClO concentrations were then made at different pressures but with the same initial molar flow rates and for the same reaction time. The set of measurements was then repeated but with the order of injection of reagents reversed, (case 2); the ClO_2 diluted in helium was injected into a NO/He stream. The flows (in mol/s) were as follows: He(mainstream) 6.33×10^{-2}, He(secondary gas flow) 9.89×10^{-2}, NO 4.43×10^{-4} and ClO_2 4.15×10^{-4}. The results of these experiments are summarized in Table II where $D = ([ClO_2]_{destroyed}/[ClO_2]_{initial}) \times 100\%$ and $R = ([ClO]/[ClO_2]_{initial}) \times 100\%$.

TABLE II

THE PARAMETERS D AND R AS A FUNCTION OF PRESSURE

	Case 1 NO through tubular injectors		Case 2 ClO_2 through tubular injectors	
Pressure (kPa)	D	R	D	R
0.67	77	53	85	62
1.33	73	42	85	49
2.67	65	28	80	30

The data from the absorption studies (case 1) and from the mass spectrometric experiments may be compared, since in both cases NO was added through the tubular injectors. As indicated in Table II, the fraction of initial ClO_2 destroyed, D, decreases with increasing pressure confirming a trend noted in the mass spectrometric studies. The absorption studies indicate that the fraction of initial ClO_2 converted to ClO, R, also decreases as the pressure increases.

Table II shows that for case 2, in which ClO_2 is added through the tubular injectors, marginally higher extents of ClO_2 destruction and ClO formation occur. The trend of decreases in both D and R with total pressure persists.

An attempt was made to vary the extent of secondary gas penetration into the mainstream by varying the percentage of total helium flow added with NO in the secondary flow stream.

The value of R to within ±10% was found independent of the percentage of total helium added through the secondary injectors, $2\% \leq \%\ He \leq 20\%$.

Computer simulations of the NO/ClO_2 reaction system, assuming instantaneous mixing (Ref. 2), showed that for Chemical Mode II conditions three-body recombination of ClO radicals should not be significant at pressures $\sim$ 6.67 kPa. Three-body loss of the Cl atom chain carriers is also insignificant at these pressures because Cl atoms would be preferentially consumed by ClO_2 in the fast chain-branching step, reaction 3. The value of R, an indicator of the effectiveness of the prepumping NO/ClO_2 chemistry in producing ClO radicals, is predicted by the simple model to be fairly close to unity for the range of pressures studied. A tentative explanation of the observed decrease in R with pressures follows; before mixing is complete, significant gradients will occur in the spatial distribution of species. These gradients could manifest themselves in such a way that Cl atoms formed in a region of low local ClO_2 could cease to be chain carriers by being consumed in a three-body combination with NO_2. The concentrations of Cl and NO_2 would tend to be locally high at the same location because they are formed together in reaction 2. As the total pressure increases then, two effects occur which tend to reinforce one another: the rates of diffusion of various species decrease and the NO_2 catalyzed three-body recombination of Cl atoms increases. Studies in which argon replaced helium as a buffer gas tend to support this explanation. In this case, the decrease in R with increasing pressure is even more pronounced. At a given pressure, the rate of diffusion in argon is less than in helium. Moreover, argon is believed to be a more efficient third body for reaction 7 than is helium.

These experiments show that in a real system, the operation of Chemical Mode II (ClO producing mode) is limited by Cl atom loss rather than by ClO radical loss. This appears to be a direct result of the increasingly important limitation of imperfect mixing as the total pressure increases.

5.0 IMPLICATIONS FOR EFFICIENT SCALING OF THE HCl LASER

Mass spectrometric analysis of the stable products for Chemical Mode II prepumping chemistry and absorption spectroscopic measurements of ClO and ClO_2 show that reaction is incomplete at high pressure (>1.33 kPa). Moreover what reaction that has taken place does not lead to quantitative conversion of ClO_2 into ClO. Apparently, in a real system having a finite mixing time, the NO/ClO_2 prepumping chemistry is adversely affected at high pressures.

The consequences of these observations for the design of a supersonic laser based on the NO/ClO_2 prepumping chemistry are two-fold:

a) the characteristic diffusion distances should be kept to a minimum by employing many small-diameter secondary-injection orifices,

b) if possible, the prepumping chemistry should transpire at a pressure where the rate of NO_2 catalyzed three-body recombination of Cl atoms is slow.

6.0 CONCLUSIONS

A purely chemical HCl laser employing transverse flow was operated with a maximum multiline output power of 13 W. This power represents a chemical efficiency of 8.6% based on the exothermicity of the Cl + HI pumping reaction and the limiting flow rate of ClO_2. The total multiline power was relatively insensitive to output mirror transmission from T = 5% to T = 15%. The spectral output consisted of P branch lines from the v = 3→2, v = 2→1 and v = 1→0 transitions of $H^{35}Cl$ and v = 2→1 and v = 1→0 transitions of $H^{37}Cl$.

When the same laser was operated as a HCl/CO_2 transfer laser at 10.6 μm, the chemical efficiency was ∿ 4.4% in a single-pass optical configuration. This efficiency compares favorably with that obtained from DF/CO_2 transfer lasers.

Diagnostic experiments which permitted monitoring of ClO and ClO_2 showed marked quenching of the NO/ClO_2 branched chain prepumping chemistry at elevated pressures. Reduced diffusion rates at high pressures lead to Cl atom recombination being significant at lower pressures than would be expected on the basis of simulations employing the assumption of instanteous mixing. These observations suggest that the scaling of the HCl laser to supersonic velocities can best be accomplished if the prepumping and pumping chemistry are carried out in the expanded region.

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DREV R-4144/79 (UNCLASSIFIED)

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A purely chemical HCl laser employing transverse flow was operated with a maximum multiline output power of 13 W, which represents a chemical efficiency of 8.6% based on the total exothermicity of the pumping reaction. The required nonequilibrium concentration of Cl atoms was generated by the branched-chain reaction of NO with ClO_2. Mass spectrometric and absorption spectroscopic measurements of species concentrations in the NO/ClO_2 reaction system showed that the effectiveness of production of the branched chain decreased with increasing total pressure. (U)

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