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Isotopic HCl Transfer Laser

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15 December 1977

Prepared for VICE PRESIDENT AND GENERAL MANAGER
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ISOTOPIC HCl TRANSFER LASER

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ABSTRACT

An HCl laser which uses isotopic V-V energy transfer collisions as a pumping mechanism has been demonstrated. This multiline laser, which utilized an intracavity cold gas isotope filter, increased the energy from the P_1 lines of $H^{37}Cl$ while decreasing the energies of the P_1 and P_2 lines of $H^{35}Cl$. Previously unreported lines, including emission from R branch transitions, have also been observed from single-line HCl and HBr lasers.

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ISOTOPIC HCl TRANSFER LASER

An HCl laser which uses isotopic V-V energy transfer collisions as a pumping mechanism has been demonstrated. This laser was developed several years ago as a possible alternative to the use of extracavity isotope filters in laser chemistry studies [Ref. 1]. A number of previously unreported lines from single-line HCl and HBr lasers have also been observed.

The multiline isotopic V-V transfer laser contains an intracavity isotope filter which lowers the gain for several lines of one isotope and increases the energy of lines of the other isotope via the V-V energy transfer collisions,

The filter increases the density of $\text{H}^{35}\text{Cl}(v = 1)$ and decreases the density of $\text{H}^{35}\text{Cl}(v = 0)$. Thus, the total rate of the forward reactions is increased while the total backward rate is decreased. This mechanism involves isotopic energy transfer between levels of the laser transitions rather than the V-V transfer mechanism of usual transfer lasers, which do not directly couple with the terminating laser level [Ref. 2]. This method of producing isotopic radiation should be more efficient than the use of either an intracavity dispersive element which can produce only one isotopic line or an extracavity filter which cannot increase the energy of the lines of the other isotope. This type of laser is especially useful for producing or enhancing energy from lines of minor isotopes, which are exactly the ones needed for most isotope enrichment schemes. It is also much more economical than the use of isotopic lasing material.

The laser was a transverse excitation pin discharge type [Ref. 3] operating at 12-16kV with mixtures of He, H_2 , and Cl_2 (or Br_2) flowing through a 1.9m long tube. The 2.4m resonator was formed by a 10m radius, partially transmitting ZnSe reflector and either a plane reflector for multiline operation or a 240 grooves/mm grating blazed at $3.75\mu\text{m}$ for single-line operation. The intracavity filter cell was 7.6cm long with Brewster angle windows. A cold finger was used to cryogenically

remove the filter gas, one torr of 97 percent H^{35}Cl with three percent H^{37}Cl , from the resonator. The laser radiation passed through a 1/4m grating monochromator and was detected by either a 77°K PV InSb or a room temperature PbSe detector.

The output of the P_1 lines from the HCl transfer laser are shown in Table 1. Pulse durations were measured between the ten percent intensity points and the delays are relative to the electrical discharge. The isotope filter initiated P_1 lasing with H^{37}Cl lines, increased the H^{37}Cl P_1 energies by 42 percent, and decreased the P_1 energies of H^{35}Cl (the major isotope) by 65 percent. The total energy of P_1 lines from both isotopes decreased by 53 percent. Higher pressures in the filter cell decreased H^{37}Cl energies due to absorption by H^{37}Cl . A more effective transfer laser would be expected with higher pressures of greater purity H^{35}Cl in the cell.

The $\text{H}^{37}\text{Cl} : \text{H}^{35}\text{Cl}$ energy ratio also increased for the P_2 lines, which were not directly affected by the cold gas isotope filter. Since the lasing duration of the P_1 and P_2 lines overlapped, changes in the P_1 emission rate altered the inversion of levels associated with the P_2 lines. The total H^{37}Cl P_2 energy did not increase and no trends were established for the P_3 lines.

A more dramatic demonstration of the transfer laser is shown by the oscilloscope traces in Figure 1. The laser was operated under unoptimized conditions so that only the H^{35}Cl and not the H^{37}Cl $P_1(6)$ line was present with no filter gas in the cavity. When the filter gas was placed in the cavity, the H^{35}Cl $P_1(6)$ line was completely suppressed and lasing of the H^{37}Cl $P_1(6)$ line was induced.

A number of HCl and HBr laser lines which, to our knowledge, have not been reported previously are given in Table 2. The lines were observed using an intracavity grating without filter. The intensities of the HBr lines are relative to the $P_1(6)$ line. Isotopic lines were observed for HCl $P_1(3)$ and $P_1(4)$. The other HCl lines were most probably from H^{35}Cl . Isotopic lines of HBr were not resolved. The detection of the R

Table 1. Output of P_1 Lines

Laser Line	Relative Energy		Pulse Duration (10% Points) in μsec		Delay (Relative to Discharge) in μsec	
	No Filter	Filter	No Filter	Filter	No Filter	Filter
$\text{H}^{35}\text{Cl } P_1(4)$	0.25	0.01	1.3	2.0	2.0	3.7
$\text{H}^{37}\text{Cl } P_1(4)$	0.08	0.09	1.6	1.6	3.1	3.1
$\text{H}^{35}\text{Cl } P_1(5)$	0.47	0.24	2.0	2.9	2.0	3.8
$\text{H}^{37}\text{Cl } P_1(5)$	0.21	0.35	4.4	3.6	3.1	3.3
$\text{H}^{35}\text{Cl } P_1(6)$	0.96	0.62	2.6	0.8	2.2	3.6
$\text{H}^{37}\text{Cl } P_1(6)$	0.10	0.11	6.2	5.8	6.2	7.1
$\text{H}^{35}\text{Cl } P_1(7)$	1.00	0.10	4.9	1.9	1.9	7.3
$\text{H}^{37}\text{Cl } P_1(7)$	<0.01	0.01	1.3	1.3	13.8	16.0

Figure 1. Oscilloscope traces of $\text{HCl } P_1(6)$ lines: (A) H^{37}Cl with isotope filter in place; (B) H^{35}Cl with isotope filter in place; (C) H^{37}Cl without filter; (D) H^{35}Cl without filter. Time response was limited by slow PbSe detector.

Table 2. New HCl and HBr Laser Lines

Line	Relative Intensity
HCl * P ₁ (2)-P ₁ (3)	-
HCl P ₁ (1)	-
HCl R ₂ (3)-R ₂ (5)	-
HBr P ₁ (3)	0.3
HBr P ₁ (2)	0.3
HBr R ₁ (1)	0.03
HBr R ₁ (2)	0.01 ₅
HBr R ₁ (3)	0.01 ₅

* Both H³⁵Cl and H³⁷Cl

branch transitions imply that a complete rather than a partial inversion existed between the $v = 0$ and $v = 1$ levels of HBr and the $v = 1$ and $v = 2$ levels of HCl. These results are in agreement with the product vibrational energy distributions for the $H + Cl_2$ and $H + Br_2$ reactions [Ref. 4]. The absence of HCl R_1 lines may be due to the decreased efficiency of the laser grating for those wavelengths.

This isotopic energy transfer laser technique is not restricted to the HCl system or to vibrational transitions but is applicable to electronic [Ref. 5] and rotational transitions as well. It is efficient and inexpensive and can also be a tool for studies of the detailed behavior of lasers. The successful use in the HCl system indicates that the isotopic V-V transfer rate for HCl, which is about one-tenth of gas kinetic [Ref. 6], can compete with the rates of emission and vibrational deactivation. The effects of the cold gas filter on the P_2 and P_3 lines could also be useful in a detailed analysis of the laser cascading processes.

REFERENCES

1. C. C. Badcock, W. C. Hwang, and J. F. Kalsch, Chem. Phys. Lett. 50, 381 (1977).
2. T. A. Cool, Handbook of Chemical Lasers, Chapter 7, edited by R. W. F. Gross and J. F. Bott, John Wiley and Sons, New York, 1976.
3. O. R. Wood and T. Y. Chang, Appl. Phys. Lett. 20, 77 (1972).
4. K. G. Anlauf, D. S. Horne, R. G. Macdonald, J. C. Polanyi, and K. B. Woodall, J. Chem. Phys. 57, 1561 (1972).
5. S. Datta, R. W. Anderson, and R. N. Zare, J. Chem. Phys. 63, 5503 (1975).
6. S. R. Leone and C. B. Moore, Chem. Phys. Lett. 19, 340 (1973).

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