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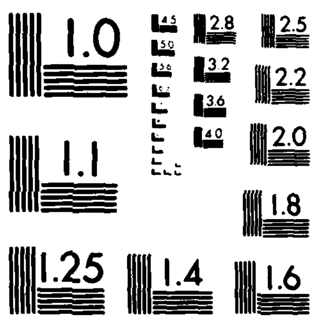

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PARAMETRIC CHARACTERISTICS OF AN ELECTRICALLY INITIATED HF LASER

by

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Parametric Characteristics of an Electrically Initiated HF Laser /286

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Abstract: An electrically initiated 1 joule output HF laser was reported in this paper. The dependence of its output characteristics on the operating parameters was studied experimentally.

I. Introduction

Some laser applications require a high coincidence frequency or a high peak output power. An electrically initiated pulsed HF laser using a mixture of H_2 and SF_6 is simple and effective in studying the basic parametric characteristics of an HF laser to improve the device because the operating system is simple, the corrosiveness of the H_2 and SF_6 is insignificant, the chemical reaction before initiation is stable, and short pulse, high coincidence frequency operation is easy to materialize.

This paper reports an electrically initiated pre-ionized ultraviolet HF laser developed by us. The output energy was 1 joule and the pulse width was 100 nanoseconds. The device could work stably using the optimal electrical discharge parameters. The reproducibility was good.

II. Experimental Apparatus

Figure 1 is a schematic diagram of the electrically initiated HF laser device.

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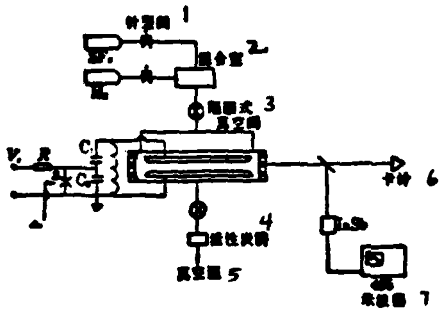

Figure 1. An Electrically Induced HF Laser
S-triggering spark gap; R-current stabilizing resistor;
C_1= 39 nanofared; C_2 = 19 nanofared;
1-needle valve; 2-mixing chamber; 3-vacuum diaphragm valve;
4-activated carbon trap; 5-vacuum pump; 6-calorimeter;
7-oscilloscope

The laser discharge cavity is a transparent organic glass cylinder. Both ends were sealed with flanges. The electrodes were made of tempered aluminum, 76 cm long. A constructive method was used to make several curvatures. After smoothing, polishing, and sand blasting treatments, they were secured on the top and bottom of the discharge cavity with a spacing of 2 cm. In order to overcome the filament discharge caused by the electronegativity of SF_6 gas, auxiliary stainless steel /287 electrodes on both sides were used to generate a series of sparks to produce ultraviolet radiation to pre-ionize the discharging material. The laser cavity was formed by a gold plated totally reflective concave mirror with a radius of curvature of 5m and an infrared quartz plate.

The main discharge circuit was a transversely initiated Blumlein discharge circuit. C_1 and C_2 were the pulse generating capacitors. $C_2 < C_1$ because of consideration to shorten the rise time of initiation to the extent possible.

A total metal gas handling system was used. Vacuum diaphragm valves and needle valves were used to control the partial pressures in the gas mixture. Because HF is toxic, the effluent was filtered by activated carbon.

The energy output of the laser was measured by a calibrated calorimeter. The waveform of the laser pulse was displayed on a Tektronix 485 oscilloscope which was calibrated by an ambient temperature InSb detector. The spectral output was measured by a W44 monochronometer which was connected to a calorimeter.

III. Output Characteristics

HF laser oscillation was obtained in a higher pressure range from 30-180 torr by using the apparatus described above. Experimental results showed that the laser energy output was closely related to the total pressure and partial pressure ratio of SF_6 and H_2. Figure 2 is the curve showing the dependence of the total energy output on total pressure. At a high operating pressure of 120 torr, the highest output was obtained.

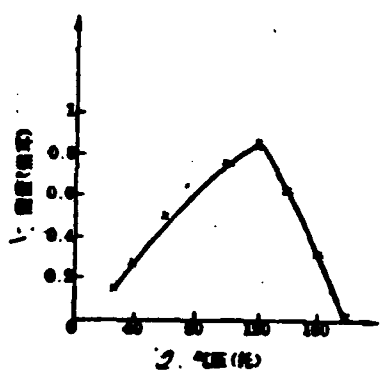

Figure 2. Relation Between Laser Output and Total Pressure
$r = P_S/P_H = 5$; primary discharge 32.5kV; pre-ionization 23kV
1 - energy (joule) 2 - pressure (torr)

As the partial pressure ratio of SF_6 to H_2, $r = P_S/P_H$, was adjusted from 1 to 30, the laser output varied as shown in Figure 3. The optimum ratio is r = 5. An analysis of the above experimental results show that the laser output is closely related to the amount of F atoms and the number of excited HF molecules generated.

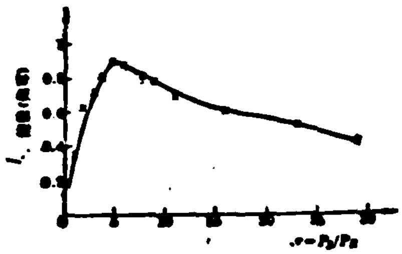

Figure 3. Relation Between Output and Gas Partial Pressure

P_{total}=120 torr; primary discharge 32.5kV; pre-ionization 23kV;

1 - energy (joule)

Under our experimental conditions, the laser energy output increased with increasing charging voltage, as shown in Figure 4. At 34kV, the laser energy output was 1 joule. The light spot was 2cm long and 8mm wide. The total electrical efficiency was 3%. The orientation was measured by a long focal length quartz lens to be approximately 10 milliradian.

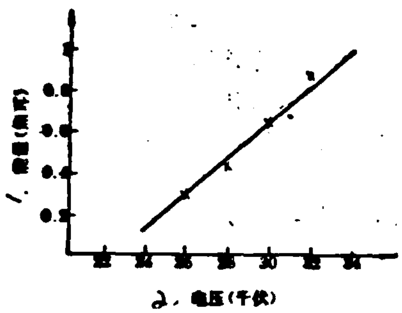

Figure 4. Relation Between Laser Output and Primary Discharge Voltage

P_{total}=120 torr; r = P_S/P_H= 5; pre-ionization voltage 23kV; 1 - energy (joule); 2 - voltage (kV)

An ambient temperature InSb detector was used to receive the laser pulse. Its response time was 10^{-8} sec. It was displayed on a Tektronix 485 oscilloscope. In order to prevent the electrical interference from high voltage pulsed discharge the entire detection system was placed in a shielded room. A low-pass filter was also used for the ac power source. Figure 5(a) is the waveform of the HF laser pulse at a total pressure of 120 torr. The full width at half maximum height (FWHM) was approximately 100 nanoseconds. When the operating pressure dropped, the pulse width varied significantly. At a total pressure of 40 torr, the width was increased to 200 nanoseconds [Figure 5(b)]. The pulse width became shorter at higher pressures because the number of excited HF molecules was increased due to vibrational excitation from F atoms and other HF molecules. The unsmooth waveform of the laser was due to a cascade /288 effect of the vibrational energy levels, creating various resonance peaks.

(a) P_{total} = 120 torr (b) P_{total} = 40 torr

Figure 5. Laser Pulse Waveforms

$r = P_S/P_H = 5$; primary discharge 32.5kV; pre-ionization 23jV;

time scale: *100 nanoseconds/division*

A W44 grating monochrometer (300 lines/mm) was used to measure the relative energy distribution of the spectrum. At an operating pressure of 120 torr, 19 spectral lines were detected. The strongest line was the $P_1(10)$ branch (wavelength 2.86 micron). The $\nu=1\rightarrow 0$ transition line was the strongest and the $\nu=3\rightarrow 2$ spectral line was weaker because the $\nu=1\rightarrow 0$ transition was enhanced and $\nu=3\rightarrow 2$ lagged behind due to a cascade effect when HF molecules were excited. The study of time resolution spectrum was not performed.

In our experimental work, when operating the same gas for over 100 times, the laser output energy was decreased by 20%. Because of the irreversibility of the reaction, new gas must be filled after a number of operations.

IV. Discussion

Two primary factors are affecting the optimization of excitation parameters. One is the optimization of gas operating parameters as studied above. It determines the rate of production of F atoms and the number of vibrationally excited HF molecules. The strongest laser irradiation can be obtained at a given electrical discharge condition. The other factor is to optimize the electrical discharge parameters. Because the vibrational relaxation of HF molecules is very fast, rapid excitation is required. For comparison, we used C804 inductionless capacitors instead of parallel plate capacitors, which were symmetrically connected to the device with copper foil. Under the same energy storage condition, the output of HF laser was only 40 millijoule. The efficiency was approximately 0.1%. The reason was that the electrical induction of the capacitors would slow down the rising rate of excitation current. In addition, the characteristic impedance of the line must be matched with that of the laser plasma. This study should primarily be focused on the selection of primary discharge elements and their rational arrangement.

References

[1] T.V. Jacobson et al; IEEE J. Quant. Electr. 1973, QE 9, 496.