A HIGH POWER CHEMICAL OXYGEN IODINE LASER

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Abstract - Optimization tests are being conducted on a high power chemical oxygen iodine laser. Optical diagnostics were developed to monitor variations in laser medium species. Presently 570 watt laser output was obtained and a laser power of at least one kilowatt is expected.

1 - Introduction

The chemical oxygen iodine laser (COIL) has a cw high power capability^(1,2). It emits at 1.315 μm on an atomic iodine electronic transition. The upper level of laser transition $\text{I}^*(^2\text{P}_{1/2})$ is excited by collisional energy transfer from the oxygen metastable state $\text{O}_2(^1\Delta)$ which is chemically generated. The 1.315 μm wavelength has excellent atmospheric and optical fiber transmission properties⁽³⁾. The COIL systems are interesting for many industrial, military and aerospace applications.

2 - Description of the experimental set-up

The COIL system (figure 1) consists of a bubble column singlet oxygen generator, a water vapor cold trap, a rectangular duct laser cavity, an iodine heater and injector system, a liquid nitrogen trap and a group of Roots pumps. The bubble column, 600 mm in diameter, contains an aqueous solution of H_2O_2 (85%, 20 dm^3) and NaOH (6 N, 15 dm^3). Chlorine gas is introduced into a drilled plate (at a maximum flow rate of 0.3 mole/s) and then bubbled through the reactive solution. The bubbler plate, 500 mm in diameter, has 1000 holes each 2 mm in diameter. The water vapor trap is composed of two spiral tube heat exchangers, each 300 mm in diameter, with a total exchanger surface of 5 m^2 and a typical operating temperature of -40°C. The laser cavity has a rectangular flow channel of 150 $\times$ 6 cm^2 . The typical flow velocity is 50 m/s. The optical cavity can be used in singular or multipass arrangement to provide gain lengths of 1.5 or 4.5 m. To obtain the nominal pressure of 1 Torr in the laser cavity, a nitrogen buffer gas is often used. The iodine vapor is injected at a distance of 14 cm in front of the optical axis. In order to obtain a reliable iodine flow rate with good O_2 - I_2 mixing, a new iodine system has

been developed⁽⁴⁾. Iodine vapor is produced by sublimation of several thin iodine plates in vitreous phase. The iodine plates provide a total sublimation surface of 2500 cm². Fifteen iodine plates are distributed between five iodine heaters. The iodine heaters, of the double boiler type, are water heated to a temperature between 45°C and 70°C (see figure 2). The iodine flow rate depends on the water temperature (which remains constant during testing) and an adjustable gas flow which is introduced into the heater. The iodine injector system inside the laser cavity consists of 75 nickel tubes positioned 19 mm apart. Each tube, 6 mm in diameter, is drilled with two rows of eleven 0.3 mm holes. The direction of the iodine injection is positioned at a 45° angle in the direction of the oxygen flow (figure 3). The liquid nitrogen trap, with seven cold fingers, has a diameter of 1.2 m and a total exchanger area of 7 m². The vacuum pump system consists of a series of adjustable-speed Roots pumps, with a maximum pumping speed of 18000 m³/h for pressures varying from 1 to 10 Torr. A numerical model and optical diagnostics have been developed to monitor variations in laser medium species^(5,6).

3 - Optical diagnostics

Several optical diagnostics are used to measure the iodine vapor, singlet oxygen residual chlorine and water vapor concentrations.

The iodine vapor concentrations are monitored in the laser cavity by absorption at 520 nm (filtered white light) with an absorption length of 3 m (figure 1, position C). Absorption percentage rates were measured at several heater temperatures as a function of the iodine heater nitrogen flow rate (figure 4). Absolute values of iodine flow rates can be deduced from the iodine absorption rate⁽⁷⁾. This result has been verified by iodine weight loss at a water heater temperature of 55°C. Both measurements gave iodine flow rate of 0.19 g/s ($\pm 10\%$). The quality of O₂-I₂ mixing has been checked by Laser Induced Fluorescence (LIF). The absolute singlet delta oxygen concentration (figure 1, position A) is measured from the emission intensity at 1.27 μ m with calibrated Ge detectors. The sensitivity of the detectors was measured using a blackbody reference emission 1.27 μ m. By absorption at 325 nm and using an absorption length of 1.5 m, the residual chlorine concentration can be detected after the laser cavity (figure 1, position D). The water vapor concentration is deduced and calculated using a ratio between the emission intensities of 760 nm from O₂(¹ Σ) and 635 nm from the 2 $\times$ O₂(¹ Δ) collision complex^(4,8). Emissions at 760 and 635 nm are detected with two photomultipliers (PM) preceded by two filters (figure 1, position B).

By absorption at 325 nm and using an absorption length of 1.5 m, the residual chlorine concentration can be detected after of the laser cavity (Fig. 1, position D).

4 - Tests

Several parameters are adjustable during a test, specifically: the oxygen flow rate, iodine flow rate, vacuum pumping speed, and the buffer nitrogen gas flow rate. For each test, the water iodine heater temperature can be changed and the optical cavity characteristics can also be modified. At present, a total of twenty tests have been performed with the completed installation⁽⁴⁾. For the time being,

typical oxygen flow rates are 0.1 mol/s with an iodine flow rate between 0.7% and 1.4% of the oxygen flow rate. A laser cavity pressure of 1 Torr has been obtained at the maximum pumping speed, by adding a large amount of buffer nitrogen gas. For the moment, excessive levels of water vapor concentrations have been noticed resulting in a low laser gain which has required the use of an output mirror with a 99% reflectivity coefficient. Typical results from 500 watt testing expressed as a function of time are represented in figures 5a and 5b. A maximum output of 570 watt was obtained using a chlorine flow rate above 0.1 mol/s.

5 - Conclusion

Optimization tests are being conducted on a high power COIL system at ONERA. A new iodine heater and injector system has been developed and successfully tested. Optical diagnostics have also been developed to measure all laser medium species. Experiments are in progress and an output power of at least one kilowatt is expected.

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Fig. 1 - Schematic view of the experiment with positions of optical diagnostics.

1) Chemical generator	4) Liquid nitrogen trap
2) Water vapor cold trap	5) Vacuum pump system
3) Laser cavity and iodine injection.	

Fig. 2 - Schematic cut-away view of an iodine heater.

Fig. 3 - Schematic view of an iodine injector.

Fig. 4 - Variation of iodine absorption

Fig. 5a and b - Variations in laser medium species as a function of time:

Test conditions: 120 l/mn chlorine flow rate (0.084 mol/s),
18000 m³/h vacuum pumping speed, 55°C iodine heater temperature.