CHEMICAL OXYGEN-IODINE LASER BASED ON HIGH PRESSURE SINGLET GENERATOR

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Abstract. - The singlet oxygen generator based on the injection of jets of the base hydrogen peroxide solution into chlorine flow has been developed. The optimal parameters of the jet generator were found to achieve efficient chlorine utilization and high $O_2(^1\Delta)$ yield up to the pressures of 30 torr. The chemical oxygen-iodine laser performance without water vapor trap up to 30 torr of the generator pressure has been attained.

1.- Introduction.

The chemical oxygen-iodine laser (COIL) is based on the resonant energy transfer between $O_2(^1\Delta)$ and iodine atoms [1]. It usually uses the singlet oxygen generators (SOG) that create high $O_2(^1\Delta)$ yield with high chlorine utilization at the low exiting pressures (several torrs) only. One has to place the water vapor trap between the SOG and the resonator body of the COIL. Increasing the overall oxygen pressure up to 30 torr and providing the solution temperature is -10°C allows to achieve desirable water vapor contents at the SOG outlet. Moreover, some efficient schemes are possible for gas exhaustion at supersonic COIL operation. In this work the SOG based on continuous injection of jets of the hydrogen peroxide solution into chlorine flow has been developed. This type SOG operates up to 30 torr of the initial chlorine pressures with high $O_2(^1\Delta)$ yield and efficient chlorine utilization. The subsonic COIL operation has been achieved up to 30 torr of SOG pressures.

2. -Experimental set-up.

The design of the continuous jet SOG is very similar to the pulsed one described earlier [2]. In the jet SOG solution jets move in the direction opposite to that of the chlorine flow. The design of the jet SOG permits to change the number of jets, gas and jets velocities, gas-liquid interaction length. The upper and lower tank for the solution and the jet SOG body are supported at -10°C . The partial pressures of $\text{O}_2(^1\Delta)$, Cl_2 and H_2O are measured at the exit of the jet SOG. After the jet SOG outlet the oxygen pressure is released 15 times by means of gas constrictors and then the oxygen is introduced into the resonator body. The active length of the laser duct is 25 cm, the height is 7 mm. The iodine vapor is carried out from the radiatively heated iodine cell by the argon flow and transversely injected into the oxygen flow.

3. -Jet SOG modelling.

The jet SOG modelling is based on the surface reaction approximation [3]. In this model the kinetics of chlorine absorption by solution is described by the gas-liquid mass transfer coefficient β (cm/s) depended on the HO_2^- ions concentration on the solution surface. The HO_2^- concentration depletion on the jet surface is described by the diffusion equation with the boundary condition on the jet surface. Joint solution of the equations for $\text{O}_2(^1\Delta)$, Cl_2 in a gas phase and for the HO_2^- along the jet SOG axis allows to calculate the Cl_2 utilization, the $\text{O}_2(^1\Delta)$ yield at the exit of jet SOG vs its initial parameters.

4. -Jet SOG testing

a) Measurements of the chlorine absorption rate.

The jets in the SOG body for this measurements were produced by the injector with 45 holes of 0,3 mm in diameter. The velocity of the $\text{KOH-H}_2\text{O}_2\text{-H}_2\text{O}$ solution jets equaled to 7 m/s. The $\text{Ar-Cl}_2=9:1$ mixture at a low pressure was flowing through the SOG. The efficiency of chlorine absorption vs the gas-liquid contact time and the KOH concentration was measured. Assuming that the contact surface was equal to the surface of 45 smooth jets of 0,3 mm in diameter we deduced the mass-transfer rate $\beta=\beta_0[\text{KOH}]^{0,5}$, where $\beta_0=(146\pm60)$ cm/s $\text{M}^{0,5}$. Taking into account the theoretical formular for β [3] we estimate the rate constant for the reaction

$k \approx 4 \cdot 10^8 \text{ M}^{-1} \text{ s}^{-1}$ in agreement with [4].

b) Performance of the jet SOG at high chlorine pressures.

The $O_2(^1\Delta)$ yield and the residual Cl_2 traces at the high initial chlorine pressures are represented in Fig 1. In this case the gas velocity was 10 m/s, the jets velocity 7 m/s, the length of gas-liquid contact 10 cm. The measurements showed that increasing of the gas flow velocity and decreasing of the KOH concentration result in increasing of Cl_2 traces. The computer analysis of this and other results allowed us to reach the conclusion that the renovation of the jets surface by HO_2^- ions is supported mainly by the molecular diffusion mechanism and the role of hydrodynamic processes are negligible. Decreasing of the jets velocity results in increasing of Cl_2 traces. At higher initial Cl_2 pressures this effect is stronger. Injection of mixture $Cl_2:Ar = 1:1$ into jet SOG allowed to increase the overall exiting pressure up to 60 torr without significant decrease of $O_2(^1\Delta)$ yield and increase of chlorine traces at the exit of the SOG.

Fig.1 $O_2(^1\Delta)$, Cl_2 yield vs initial Cl_2 pressure.

circle-injector 140 holes of 0,3 mm i.d.

square-injector 280 holes of 0,3 mm i.d.

dark- Cl_2 , light- $O_2(^1\Delta)$

c) Water vapor pressure

The tests of the jet SOG showed that water vapor pressure at the exit was near its saturated value at $-10^\circ C$. Thus the heat effect of the chlorination reaction is effectively compensated by the solution mass flow rate.

5. - COIL performance with jet SOG

The main goal of the COIL test with the jet SOG was to demonstrate the possibility of its operation at high oxygen

pressures at the exit of the jet SOG. For this test pure chlorine was introduced into the jet SOG body. Then the gas mixture from the jet SOG was injected into resonator body through measuring cavity. The system of the gas constrictors provided the gas pressure relation 15 : 3 : 1 at the exits of the SOG, the measuring cavity and the resonator cavity accordingly. The resonator cavity 80 cm in length consists of two spherical mirrors ($r = 5$ m), $R_1 = 100\%$, $R_2 = 99\%$. The molar flow rate of I_2 was 30 $\mu\text{mol/s}$ for any oxygen pressure. The output COIL power vs exiting SOG pressure is represented in Fig.2.

Fig.2. The output power vs exiting jet SOG pressure

O-jet injector 140 holes of 0,3 mm i.d

□ jet injector 280 holes of 0,3 mm i.d

The overall COIL efficiency is less than 5% in the best case. Nevertheless we believe that future improvement of the iodine mixing, the optimization of iodine injector -optical axis distance and resonator coupling will allow us to increase the overall efficiency.

6.-Conclusions.

The jet SOG is a very effective source of $O_2(^1\Delta)$ with high energy density. The possibility of the COIL operation up to 30 torr of the exiting SOG pressures has been demonstrated. A maximum power 7 wt at 20 torr of exiting SOG pressure has been attained.

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