Prospect of optically pumped oxygen-iodine lasers

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Abstract—In this paper two-step optical pumping process is proposed for oxygen-iodine lasers systems. Basic parameters and key implementation challenges of such system are discussed.

Keywords—oxygen-iodine laser, singlet oxygen, optical pumping

I. INTRODUCTION

Inverse population in oxygen-iodine laser is achieved via fast E-E exchange between atomic iodine and single oxygen molecules[1]:

\[ I(2P_{3/2}) + O_2(a, \Sigma) \leftrightarrow I(2P_{1/2}) + O_2(X, \Sigma) \]  

(1)

Inverse population on the \( ^2P_{1/2} \rightarrow ^2P_{3/2} \) transition of atomic iodine is reached as fraction of \( O_2(a) \) exceeds the following threshold:

\[ Y_T = 1/(2K_{eq}(T)+1) \]  

(2)

Here, \( K_{eq}=0.75\exp(401/T) \) is an equilibrium constant for reaction (1). The scheme of optically pumped oxygen-iodine laser (OPOIL) is proposed below. \( O_2-I \) flow is illuminated by light with 1315 nm wavelength to excite iodine atoms. Excited \( I^* \) atoms transfer energy to \( O_2 \) molecules, exciting them to \( O_2(a) \) state. As \( O_2(a) \) concentration increases, fraction converges to \( Y_T \). With fast temperature drop, inverse population in atomic iodine can be reached. In this paper a possible implementation of described scheme will be discussed.

II. OPTICAL PUMPING

Mixture of \( O_2: I_2: He=1:0.05:10 \) is pumped through the flow tube with transparent windows. In the first short section of tube the mixture is irradiated with light at \( \lambda_A=400+560 \) nm wavelength to partially dissociate \( I_2 \) molecules (see Fig. 1).

In the next tube section, mixture is irradiated with light from main pumping source at wavelength \( \lambda_B=1315 \) nm close to \( ^2P_{1/2} \rightarrow ^2P_{3/2} \) transition of atomic iodine. Light from main pumping source leads to atomic iodine excitation and formation of \( O_2(a) \) molecules via reaction (1). A set of reactions involving \( O_2(a) \) and \( I^* \) result in chain process of \( I_2 \) dissociation [2]. As \( I_2 \) dissociates, \( I^* \) concentration rises due to optical pumping and \( O_2(a) \) fraction converges to \( Y_T \).

Fig. 1. Two-step optical pumping system.

The nozzle array is installed in the point of tube with \( O_2(a) \) fraction virtually equal to \( Y_T \). Downstream from the nozzle array the gas flow accelerates to the supersonic velocity (Mach=3) that leads to abrupt temperature drop. Latter, in turn, lowers the threshold, that leads to formation of inverse population in atomic iodine. As the inverse population is reached, electronic excitation in iodine atoms can be extracted to the light in the laser cavity. Reactions taking place in flow tube have no side products, so mixture in the outlet can be used again after proper recovery of pressure and temperature.

III. RESULTS AND DISCUSSION

The simple model of two-step optical pumping process described above allows us to determine several basic parameters of the system in question. The estimations show that specific power of 68 W/cm² at optical efficiency up to \( \eta_A=0.6 \), as well as small signal gain up to \( g=6 \times 10^3 \) cm⁻¹ can be achieved at initial gas pressure of 85 torr and temperature of 450K.

The main challenge of the described system is efficient optical pumping of active medium due to very large effective absorption length. But it’s a common issue for the most of optically pumped gas lasers. Development of the powerful enough laser diodes with wavelength 1315 nm doesn’t seem as a great challenge. Such a wavelength lies in second telecom window, so laser diodes with close wavelength already exist. The only thing that matters is making them powerful enough.

REFERENCES
