Systematic Technology Development of the Electric Oxygen-Iodine Laser

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A systematic approach to experiments and modeling have led to improvements in the hybrid Electric Oxygen-Iodine Laser (ElectricOIL) system that significantly increased the discharge performance, supersonic cavity gain, and laser power output. The cw laser operating at 1315 nm was pumped by the production of $O_2(a^1\Delta)$ in a radio-frequency (RF) discharge in an O_2/He/NO gas mixture. A gain of 0.17% cm^{-1} and a laser power of 12.2 Watts were measured. Simulations with the BLAZE-IV model are in good agreement with laser gain data.

Oxygen-iodine lasers operate on the electronic transition of the iodine atom at 1315 nm, $I(^2P_{1/2}) \rightarrow I(^2P_{3/2})$ [denoted hereafter as I^* and I respectively]. The lasing state I^* is produced by near resonant energy transfer with the singlet oxygen metastable $O_2(a^1\Delta)$ [also denoted hereafter as $O_2(a)$]. Conventionally, a chemical two-phase process is used to produce the $O_2(a)$ at the interface of liquid basic H_2O_2 and Cl_2 gas. Several groups have investigated other continuous flowing systems and have measured $O_2(a)$ yields sufficient for gain and lasing. Carroll et al. [1] achieved a low level of gain and obtained the first lasing data in subsequent work [2]. One key difference between the traditional chemical excitation route and the electrical one is the presence of atomic oxygen levels on the same order as the $O_2(a)$ in the "active oxygen" mixture. Atomic oxygen depletes the upper laser level [3], I^*, and must be controlled. This was accomplished by the use of NO_2 titration made downstream from the discharge or by adding NO to the discharge flow or downstream of the discharge; all of these approaches resulted in the oxygen atoms being depleted to a level such that there were still enough oxygen atoms to dominate the I_2 dissociation process, but low enough such that the power loss through the I^* + O quenching channel is not prohibitively detrimental. For an excellent and comprehensive topical review of discharge production of $O_2(a)$ and ElectricOIL studies see Ionin *et al.* [4]. In the work presented herein we discuss the recent developments in our ElectricOIL technology that have produced significant increases in discharge performance, supersonic cavity gain, and laser power.

Over the past four years of systematic research and development, continual improvements in gain and lasing power have been obtained. $O_2(a^1\Delta)$ yields greater than 20% have been demonstrated along with positive gain and cw laser power in both supersonic and subsonic flow systems. *The gain has improved from the initial demonstration of 0.002% cm^{-1} to 0.17% cm^{-1}, by more than a factor of 80×, and similarly the outcoupled laser power has risen from 0.16 W to 12.2 W (with a 5 cm gain length cavity). We are obtaining ≈30% electrical energy coupling (and for the higher rf power cases more than 200 W of the power) into the desired $O_2(a)$ state*, but significant improvements in understanding the role of components of plasma generated active oxygen still need to be made in regards to laser extraction of this energy. While O atoms permit rapid dissociation of the I_2 molecule, they appear to be major problem for energy extraction (as they also act as a quencher) and alternate I_2 dissociation schemes are required at higher densities. Recent work shows that the use of an electrical iodine pre-dissociator improved the performance of the ElectricOIL system by 50%.

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