Achievement of Positive Gain in the Amine-Based All Gas-Phase Iodine Laser System

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Numerical simulation and flow-tube experiments are conducted to understand the chemistry of the amine based all gas-phase iodine laser (AGIL). We find that the key reactions to achieve positive gain are the deactivation reaction of excited I by Cl and the self annihilation reactions of $NCl(^1\Delta)$. The order of the injection nozzles is crucial to suppress these reactions. A small signal gain of 0.01 %/cm is achieved by the new nozzle arrangement. To our knowledge, this is the first time achievement of positive gain of the amine-based AGIL system.

Chemical Oxygen-Iodine Laser (COIL) is expected for various applications because it has many attractive characteristics. However, the requirements of liquid fuel place some limits on the COIL device because it is heavy and unsuitable to long preservation. Consequently, there has been considerable interest in developing alternate system that uses different energy transfer partners that is produced by all gas phase chemical reaction, namely, all gas-phase iodine laser (AGIL). Although successful lasing has been reported for $F+Cl+HN_3$ (azide-based) reaction system, we paid great attention to $H+NCl_3$ (amine-based) reaction system because NCl_3 is comparatively suitable for long preservation. However, the achievement of laser oscillation by this system has stayed in a fundamental possibility.

We developed a numerical simulation code for amine-based AGIL system for revealing the conditions that the laser oscillation can be achieved. To confirm validity of the code, the calculated results were compared with experimental results obtained in other laboratories. The excellent agreement of calculations with those experimental results encouraged us to develop our own apparatus. We found that the key reactions to achieve positive gain were the deactivation reaction of excited iodine atoms by chlorine atoms and the self annihilation reactions of $NCl(^1\Delta)$. The order of the injection nozzles was crucial to suppress these reactions. In the new mixing nozzle configuration, NCl_3 injection nozzle was located at uppermost position and HI and H_2/H injection nozzles were located at the same point downstream. This new arrangement was investigated and implemented to experimentally optimize flow condition. Fig.1 shows the results of small signal gain measurement at 0.003 mmol/s of HI molar flow rate and 0.62 mmol/s of H_2 molar flow rate. As the microwave source worked only half cycle of the alternate current, we had two distinctly different traces. When the microwave was off, we observed absorption (dip) at the iodine transition. When microwave was on, we observed a hump at the same position, a small signal gain of 0.01 %/cm. To our knowledge, this is the first time achievement of positive small signal gain of the amine-based AGIL system.

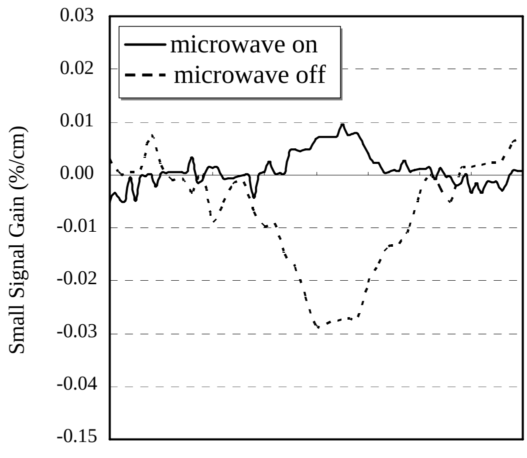

Fig. 1: Results of small signal gain measurement.

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