Analysis of COIL Resonator Expanding Angle Design

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The factors of Chemical Oxygen-Iodine Laser (COIL) resonator expanding angle design are analyzed in this paper. It is shown that the primary factor is the rate of the releasing heat from the near resonant energy transfer reaction between $O_2(^1\Delta)$ and I at the resonator entrance with the laser extracting. It is a characteristic of COIL that the rate of the releasing heat with lasing is bigger than without lasing. A slightly bigger resonator expanding angle than that of constant pressure operating condition is sufficient to avoid the shock wave appearance.

It is common practice in Chemical Oxygen-Iodine Laser (COIL) devices to provide area relief (i.e., increase the flow area) to accommodate heat release, and this keeps the velocity and temperature reasonably constant. In most instances, the gain length remains constant and the sidewalls open up at some constant angle (i.e., resonator expending angle) in the flow direction. The resonator expanding angle is one of the factors impacting on the performance of a COIL. If it is smaller than needed, there would be shock waves, and the beam quality would be poorer. If it is bigger than needed, the optical extraction efficiency would be smaller which causes the overall smaller COIL chemical efficiency.

The factors of COIL resonator expanding angle design are analyzed in this paper. There are two sources of heat release in the resonator - one is the near resonant energy transfer reaction between $O_2(^1\Delta)$ and atomic iodine, the other is the quenching of I* by water vapor and residual I_2. The rate of the heat release in the resonator is described by a simplified model for predicting power extraction from COIL and a finite-rate non-equilibrium chemistry model. The COIL resonator expanding angle expression for the case of no shock waves in the resonator, which is related with the operating parameters, is deduced from the equations for quasi-one-dimensional nozzle flows cooperated with the heat release in COIL. As an example, The design of COIL resonator expanding angle is discussed using the Roto COIL data with and without lasing.

It is shown that the primary factor of COIL resonator expanding angle design is the rate of the heat release from the near resonant energy transfer reaction between $O_2(^1\Delta)$ and atomic iodine at the resonator entrance with the laser extracting. If there is no laser extracting, the primary factor is the rate of the heat release from the quenching of I* by water vapor and residual I_2. The rate of the heat release in the latter case is about 1/2.7 of which in the former case at the resonator entrance with assumptions in the paper. It is a characteristic of COIL that the rate of the heat release with lasing is bigger than without lasing, which implies that shock wave is the concomitant with laser cavity if there is shock wave during lasing, in other words, the shock wave appears where the laser cavity is. It is reckoned that a slightly bigger resonator expanding angle than that of constant pressure operating condition is sufficient to avoid the shock wave appearance.

Simple theoretical treatments can provide deep insight into resonator expanding angle design and useful understanding of COIL operation and performance. These analyses, however, do not substitute for experimental optimization and evaluation of resonator expanding angle performance totally in practice.

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