

# Initial Development of Hybrid Plasma Jet Generator of $O_2(^1\Delta)$ for DOIL

**Josef Schmiedberger**<sup>a1</sup>, Karel Rohlena<sup>a</sup>, Petr Filip<sup>b</sup>, Jan Gregor<sup>b</sup>, Milan Hrabovský<sup>b</sup>,  
Petr Křenek<sup>b</sup>, Vít Jirásek<sup>a</sup> and Jarmila Kodymová<sup>a</sup>

<sup>a</sup> Institute of Physics, Academy of Sciences CR, Na Slovance 2, 182 21 Prague 8, Czech Republic

<sup>b</sup> Institute of Plasma Physics, Academy of Sciences CR, Za Slovankou 3, 182 00 Prague 8, Czech Republic

The initial stage in development of hybrid plasma jet generator of singlet oxygen for DOIL is presented. This novel type of generator is based on a fast mixing of hybrid argon plasma jet of DC electric arc and radio-frequency discharge with a neutral molecular oxygen stream. Key features of physical and technical design are included in this paper.

Results of the initial stage in development of hybrid plasma jet generator of singlet oxygen (SO) for DOIL are presented. This novel apparatus [1] is based on a fast mixing of hybrid argon plasma jet of DC electric arc and radio-frequency (RF) discharge with a neutral molecular oxygen stream. It is our latest Discharge Singlet Oxygen Generator (DSOG), denoted as DSOG-6, which is an alternative to the chemical generation of SO for a COIL and also to the classic high-frequency discharge methods used since the first successful experimental demonstration of DOIL in 2004.

The main world effort is now concentrated on searching for a more efficient DSOG with a higher SO yield attainable at higher pressures. The goal of our own effort is the achievement of DOIL oscillations using DSOG-6, which should provide the SO yields exceeding 30% at the total pressures higher than 10 Torr. Employing this method the DOIL could be scaled up at a reasonable price.

The arc plasma jets have a much higher density of electrons (by several orders of magnitude) than the RF plasma jets and they can be easily operated at a higher pressure, which is desirable for an efficient supersonic expansion cooling in DOIL. The arc plasma jet mixing with the neutral oxygen stream can achieve considerably higher power densities in much smaller plasma volumes than in the case of conventional non-self sustained discharges.

An electrode coupled RF discharge is applied to the DC arc plasma jet at the hollow anode of the plasmatron. There are two expected consequences: (1) an enhanced non-equilibrium in the plasma jet and (2) a switch from a hot-spot mode at the hollow arc anode to a diffusive mode. The enhanced non-equilibrium is desirable for an efficient SO generation. The diffusive mode is of advantage with the use of aluminum anode, which has a low melting point. The aluminum anode replaces a standard copper anode, because the copper vapors would strongly quench SO.

The RF discharge gives some additional energy preferentially to electrons in order to keep them detached (oxygen is an electronegative gas forming negative ions) at a low reduced electric field  $E/N \sim 10^{-16} \text{ V}\cdot\text{cm}^2$  (the limit of non-self sustained discharge existence region in oxygen mixtures), while ions and neutrals are cooled down by the injected neutral cold oxygen stream and a non-equilibrium scenario is thus created. The temperature of the arc plasma jet electrons can be controlled in the range 5000-50000 K (0.43-4.3 eV), which coincides well with the energy of SO  $\sim 0.98 \text{ eV}$ . Preliminary calculations on the equilibrium composition of  $O_2$ -Ar mixture suggest that the arc temperature should be kept well down to prevent an excessive dissociation of the molecular oxygen. The arc plasma jet technology is a much cheaper source of the plasma with a high electron density than the electron beams or the electron avalanches, especially at scaling up to a high power.

Numerical simulations of the reactive flow inside the suggested DOIL device [1] were performed. A discharge generation of atomic iodine was considered. According to the modeling results, the output power of  $\sim 100 \text{ W}$  at 10 mmol/s of  $O_2$  with 30% yield and a partial pressure of 2 Torr were estimated.

[1] Schmiedberger J., Jirásek V., Kodymová J., Rohlena K., "Advanced Concept of Discharge Oxygen-Iodine Laser", 38th AIAA Plasmadynamics and Lasers Conference, CD Proceedings 2007, paper AIAA 2007-4239, 1-13.

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<sup>1</sup> E-mail: schmiedb@fzu.cz