

Evaluation of High-Repetition-Rate Excitation Discharge in TEA Gas Laser with Supersonic Gas Flow

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A double-pulse discharge method is used to simulate a high-repetition-rate excitation discharge in TEA gas laser with supersonic gas flow. In the gas flow with a Mach number $M = 2.0$, not only heated column but also shock wave produced by the former discharge has a key effect on stability of the subsequent discharge. A formula for estimating the maximum repetition rate of stable discharge in supersonic gas flow is proposed.

A double-pulse discharge in a supersonic gas flow is used to simulate a high-repetition-rate excitation discharge in TEA gas laser, and the influence of a shock wave and a heated column produced by the former discharge on the stability of the subsequent one are evaluated. A supersonic gas flow with a Mach number $M = 2.0$ (velocity $v = 860$ m/s) is generated using a Ludwieg tube with a two-dimensional shock-free nozzle [1]. A solid discharge electrode with spark UV pre-ionization pin is used to generate the excitation discharge. A test gas is mixture of He and Ar (He:Ar = 9:1) with a density of 0.52 kg/m³ at a discharge cavity. A breakdown voltage of the electrode is ~ 20 kV. The experimental apparatus and observation system have been described in detail elsewhere [2].

Figure 1 shows the influence of the shock wave and the heated column on the subsequent discharge. The subsequent discharges, for time interval of double-pulse discharge $t = 5\text{--}10$ μs (equivalent repetition rate of $f = 200\text{--}100$ kHz), are strong arc through the heated column existing within the discharge cavity. For $t = 17\text{--}40$ μs ($f = 60\text{--}25$ kHz), at the onset of the subsequent discharge, the heated column has already been removed from the cavity, whereas the traveling shock wave against the supersonic gas flow, SW #u, still remains within the cavity. Hence the subsequent discharges are arc in the region downstream of the SW #u. At $t = 50$ μs ($f = 20$ kHz), the subsequent discharge is glow, however, a undesirable discharge appears between the electrode and the UV pin because the SW #u reaches the downstream edge of the electrode and the heated column exists on the UV pin. Since the shock waves and heated column have already been removed from the cavity, for $t \geq 59$ μs ($f \leq 17$ kHz), glow discharge is well obtained. From the above mentioned results, we propose an equation for the estimation of the maximum repetition rate of stable excitation discharge in supersonic gas flow, f_m , as follows:

$$f_m = \frac{v_t}{CR_S(x_o - x_u)} = \frac{(M - M_S)a}{CR_S(x_o - x_u)}, \quad (1)$$

where v_t is the traveling velocity of the SW #u, CR_S is the clearing ratio for supersonic gas flow, x_o is the downstream edge of the electrode, x_u is the origin of the SW #u, M_S is the shock Mach number of the SW #u, and a is the sound speed upstream the SW #u. One should note that eq. (1) holds for $v_t > 0$, namely, $M > M_S$. According to the present results, $f_m = 17$ kHz, $v_t = 300$ m/s, $x_o = 14$ mm, $x_u = -2$ mm, and $a = 430$ m/s, CR_S is estimated to be ~ 1.1 which is almost unity because the shock wave is thin and hardly dissipates with the traveling.

[1] T. T. Son, et al., Jpn. J. Appl. Phys. **46**, 787 (2007)

[2] T. T. Son, et al., Jpn. J. Appl. Phys. **46**, 4268 (2007)

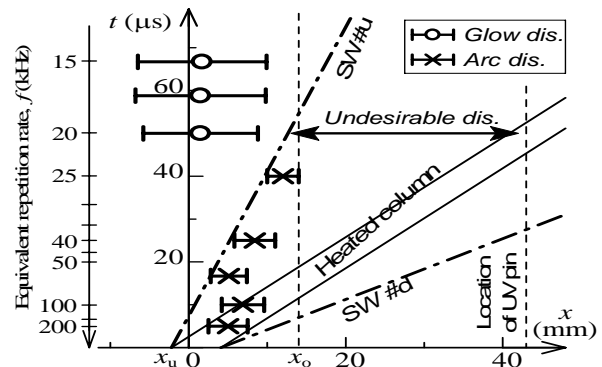


Fig. 1. Location (x) of shock waves, heated column, and subsequent discharge as a function of time interval of double-pulse

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