CONTINUOUS OPTICAL DISCHARGES SUSTAINED BY NEAR-IR LASER RADIATION

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This work represents studies of several new effects specific for continuous optical discharges (COD) sustained by focused radiation of near-IR band lasers in high pressure rare gases. The experiments have being carried out in IPMech RAS during last several years.

Threshold laser power to sustain COD may be estimated through laser radiation absorption coefficient calculated by Kramers-Unzoeld formula [1]. At the same time values of near-IR radiation absorption coefficient for COD plasma was measured to be an order of magnitude higher than calculated. The difference is explained by a major contribution of groups of widely broadened absorption spectral lines of highly excited Ar and Xe atoms in high-temperature high-pressure plasma, even when laser radiation band is 10 or more nanometers apart from strong atomic absorption lines. Due to that in wide laser wavelength range 0.96-1.09 um COD threshold laser power appeared to be as low as several tens Watts in Xe and several hundreds Watts in Ar (pressure range 10-25 bar).

Spatial structure and other COD plasma characteristics demonstrate strong dependence on the laser beam refraction on the density gradients of electronic and neutral plasma components. Characteristic feature of 1 um laser wavelength band is that both electronic and neutral components of COD plasma make contributions of the same order of magnitude to the overall refraction and neutral component contribution usually prevails, whereas at 10 um mid-IR laser band refraction on free electron density gradients dominates. Due to those features new phenomena are displayed: formation of plasma spatial structures with two or three temperature maxima, COD bistability, when two locally stable plasma states different in their dimensions, structures and percent of laser power absorbed may exist under the same conditions [2].

Due to high plasma temperature and localization near the waist of the focused laser beam COD has prime advantages as a high brightness radiation source [3]. In general, growing radiation power of supported laser leads to the increase of laser power absorption and spectral brightness of COD plasma. Elevated gas pressure is also followed by the increase of laser radiation absorption coefficient, dissipated power density and plasma brightness. Meanwhile laser beam refraction effects are also growing with laser power and gas pressure. If the growing influence of the refraction is not compensated, it may disturb stability and decrease plasma brightness. Main refraction compensating agents are laser beam focusing, plasma control by coaxial gas flow (including natural convection), and adjusting supporting laser wavelength detuned to strongly absorbing spectral lines.

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References

1. Zel’dovich Ya.B., Raizer Yu.P. Physics of shock waves and high-temperature hydrodynamic phenomena / Dover Publications, NY, 2002. Pp. 270-277.
2. Zimakov V.P., Kuznetsov V.A., Shemyakin A.N., Solov'yov N.G., Shilov A.O., Yakimov M.Yu. Bistable behavior of a continuous optical discharge as a laser beam propagation effect // Proc. SPIE 8600-02-01-12, 2013.
3. Smith D.K. et al. Laser driven light source // US patent # 7,435,982, 2008.