COMPUTATIONAL OPTIMIZATION OF THE GAS-JET TARGET IN THE LPP SHORT-WAVE RADIATION SOURCE

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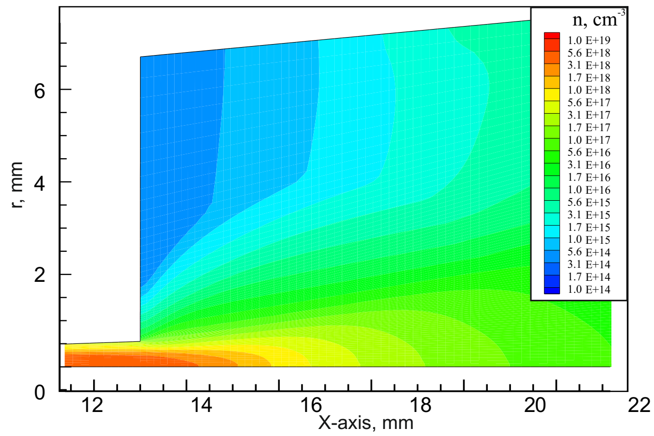
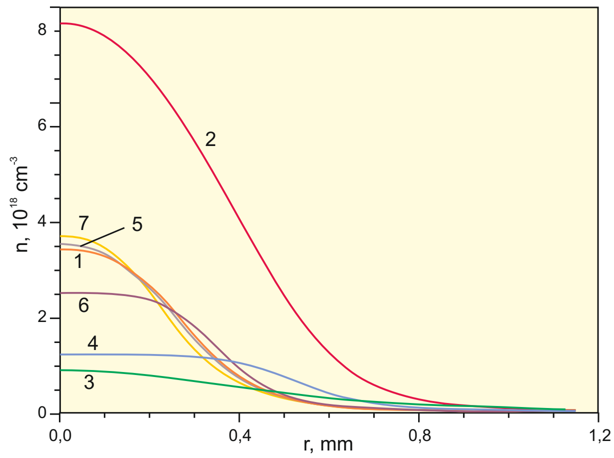
Goal of the present paper is search for optimum target jet configurations – with the highest possible core density to enhance the plasma emission and the least possible peripherical absorption.

Fluid dynamics simulation of gas outflow from a nozzle into the vacuum.



Levels of atomic concentration. Nozzle #1, P_0=5atm, Xe



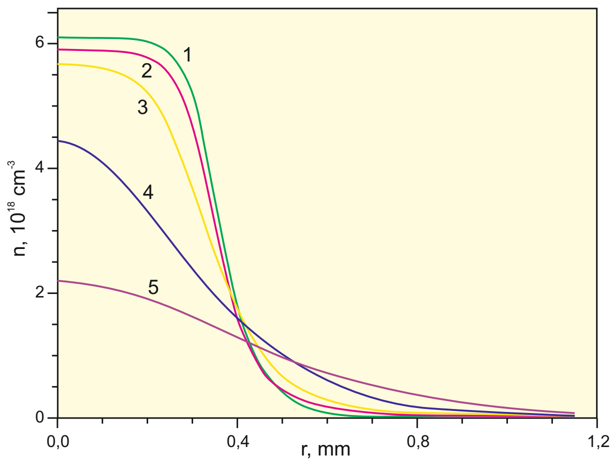
Atomic concentration radial profiles for nozzles #1 to #7. P_0=5 atm, T_0=293°K

Nozzle geometries

No.	1	2	3	4	5	6	7
r_{cr} (mm)	0.1	0.2	0.1	0.1	0.1	0.1	0.1
r_{ex} (mm)	0.55	0.55	0.1	1.1	0.55	0.55	0.55
l (mm)	13	13	13	13	17	6	25

In fact, only one conclusion can be derived directly from the simulation results: for all Laval nozzles the laser focus should be located within a distance of one exit diameter from the nozzle edge.

Huge number of profiles calculated, variability of their forms do not allow to make an unambiguous selection of the optimum.



Profile form vs. distance (in exit diameters) from the nozzle edge: 1-$\Delta x \approx 0.1d_{ex}$, 2-$\Delta x \approx 0.5d_{ex}$,3-$\Delta x \approx d_{ex}$, 4-$\Delta x \approx 2d_{ex}$, 5-$\Delta x \approx 3d_{ex}$,Nozzle #1, P_0=10 atm

Combined optimization parameter describing plasma emission as seen by an external observer

$$F = \langle n^2 l \rangle_{pl} \exp\{-\sigma_{abs} \langle nl \rangle_{peri}\}$$

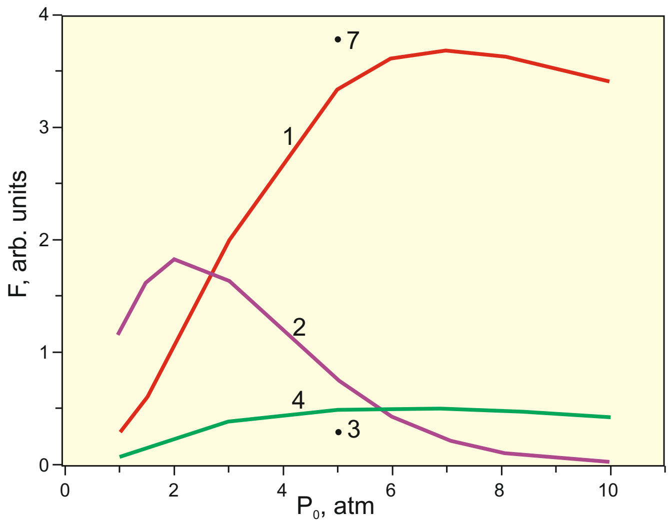
Since the local plasma emissivity is $w = (h\nu) n_e n_i \langle \sigma_{rad} V_e^{th} \rangle = (h\nu) Z n_i^2 \langle \sigma_{rad} V_e^{th} \rangle$,

the observed plasma brightness has to be proportional to $\int_{(d_{pl})} n^2 dl \equiv \langle n^2 l \rangle_{pl}$ (integration along the observation chord inside the plasma);

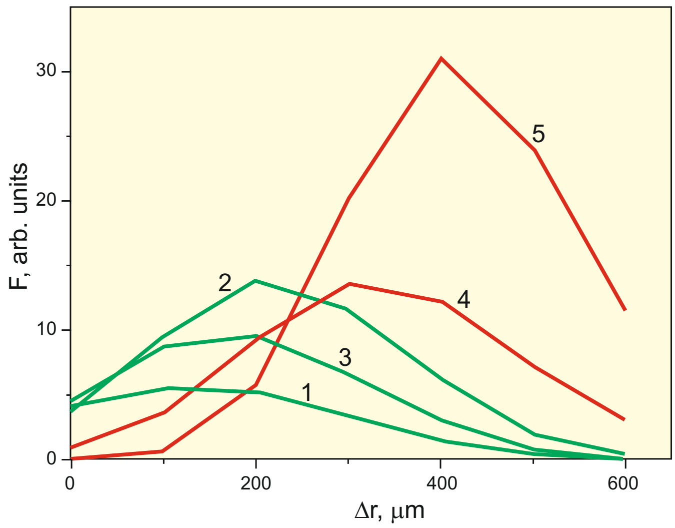
and absorption in the non-ionized surrounding gas is $I / I_0 = \exp\{-\sigma_{abs} \langle nl \rangle_{peri}\}$,

where $\langle nl \rangle_{peri} \equiv \int_{(peri)} ndl$ – integration along the line of sight from the plasma boundary up to the chamber wall, and $\sigma_{abs} = 2.365\times10^{-17}$ cm^2 is maximum absorption cross-section for Xe.

Application of the F-parameter to the liquid dynamics simulation data



F-parameter for nozzles # 1, # 2, # 3 (non-Laval, cylindrical), # 4 and # 7 when the laser beam focus is located on the jet axis – $\Delta r = 0$.



F-parameter vs. shift of the laser beam focus from the jet axis to the observer.
1 – nozzle # 1, $P_0 = 5$ atm, $T_0 = 293$ ºK;
2 – nozzle # 1, $P_0 = 10$ atm, $T_0 = 293$ ºK;
3 – nozzle # 1, $P_0 = 5$ atm, $T_0 = 200$ ºK;
4 – nozzle # 2, $P_0 = 5$ atm, $T_0 = 293$ ºK;
5 – nozzle # 2, $P_0 = 10$ atm, $T_0 = 293$ ºK.

It follows that the method described makes it possible to deduce a valid conclusion about optimum nozzle geometry, gas conditions at the nozzle entrance and location of the laser focus relative to the nozzle axis and edge.

The method has been verified

by means of comparison of data obtained in an experiment, earlier published in <V. E. Levashov et al., Kvantovaya Electronica **36** (6), 549 (2006) [Quantum Electronics **36** (6), 549 (2006)]>, with F-parameter calculated specifically for that experiment. The comparison has demonstrated good qualitative agreement.

Conclusion

Written above is proposed as a new method of computational, pre-experimental gas jet target optimization which demonstrates ways to enhance output of the short-wave plasma emission by several times. It consists of the fluid mechanics simulation of the gas jet and subsequent applying the combined optimization factor.

Publications in journals

A. V. Garbaruk et al. Technical Physics Letters, Vol. 36 (2010), No. 12, p.p. 1072-1075.
A. V. Garbaruk et al. Technical Physics, to be published in 2011.