Dusty Structures Influence on Excited Atoms Densities in Plasma

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Plasma with levitated macroparticles is called dusty or complex plasma. Ordered dusty structures influence plasma conditions. In a glow discharge the dusty particles have negative charge because electrons have much more temperature and much less mass than ions. Hence, electron density become less than ion density. Electrons and ions recombine on particle surfaces, and electron temperature increases to compensate these losses. Metastable atoms also die on the surfaces.

In papers [1–3] the influence of dusty particles on excited atoms density has been investigated in Ne and Ar rf discharge. The effect value and even its sign depends on gas, particle size and discharge conditions.

In [4] the influence of the structures on Ne levels population was investigated with laser-induced fluorescence in a glow discharge. Dusty particles increase the population, but only in one condition set the increasing was statistically significant.

In this report we present continuation of the work [4].

We use laser-induced fluorescence method [5]. The plasma is irradiated with a dye laser turned in resonance with absorption line of an excited atom. The atom transits to more excited state and can relax in several spectral lines. Hence, laser shot leads to fluorescence impulse, and the higher the atom density in the initial excited state, the stronger fluorescence pulse is registered. Our dye laser produces the pulses with time-length about 10 ns and frequency of 6 Hz. The laser line width is of the order of 0.01 nm which is much wider than a spectral line profile in the discharge.

A principle experimental setup scheme is presented in fig. 1. The discharge tube (Ø 30 mm) has plane windows that do not distort the laser beam. Also, the tube contains a narrowing that stabilizes the plasma stratification and creates a perturbation for the dusty structures (see fig. 3C).

We have studied glow discharges in neon and argon with Al_2O_3 polydisperse particles and melamine-formaldehyde monodisperse particles with the diameter of 4.83 μm. In neon we investigated levels $2s^2 2p^5(^2P^o_{1/2})3s\ \ ^2[1/2]^o\ \ J=1$ (pumping — 692.9 nm, fluorescence — 614.3 nm) and $2s^2 2p^5(^2P^o_{3/2})3s\ \ ^2[3/2]^o\ \ J=2$ (pumping — 703.2 nm, fluorescence — 724.5 nm). In argon we dealt with $3s^2 3p^5(^2P^o_{3/2})4s\ \ ^2[3/2]^o\ \ J=2$ level (pumping — 696.5 nm, fluorescence — 727.3 nm).

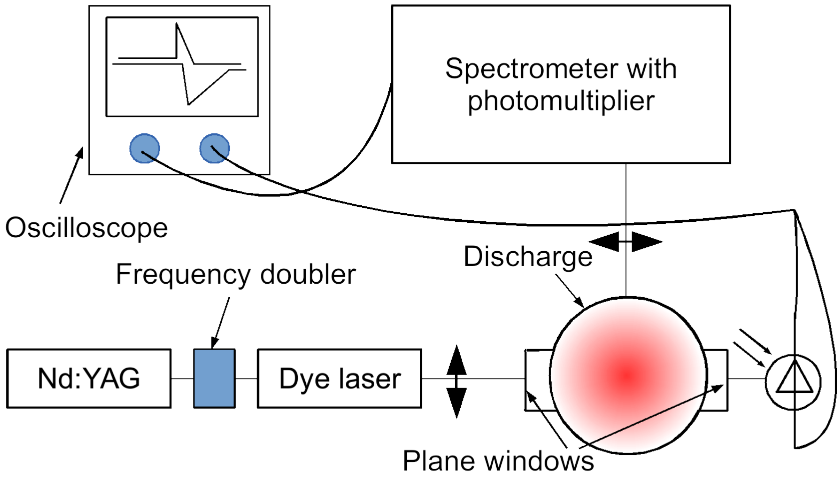

Figure 1: *Experimental setup*

For each of the investigated condition, we conducted 3–10 series of experiments. In every series we interlaced 5–15 measures with and without dusty particles. Every measured value was averaged of 800 fluorescence pulses.

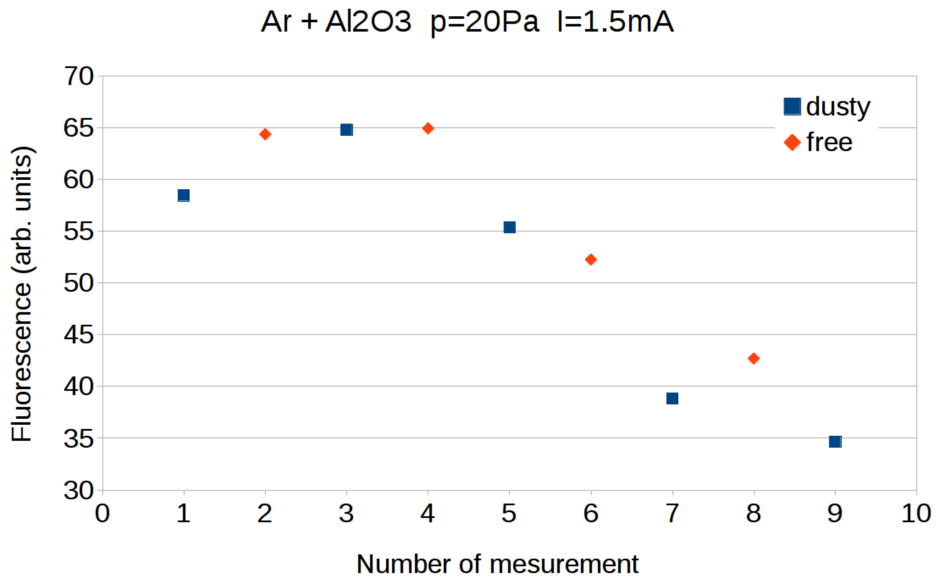

Figure 2: *One series of measurements*

Our laser was not perfectly stable. To reduce laser instability we calculated the difference between the fluorescence pulse heights with and without particles for every measurement and its neighbors. This means that for measurement with dust we calculated

$$difference = dusty - (free_{before} + free_{after})/2$$

where $dusty$ — the fluorescence value with particles, $free_{before}$ — the value without particles

Table 1: Relative difference between fluorescence with and without particles

Gas and particles	Wave length of pumping and fluorescense, ns	Pressure, Pa	Current, mA	Difference, %
Ne + Al_2O_3	693; 614	100	1.5	0.1 ± 0.6
			2.0	-0.3 ± 0.5
		150	1.5	-1.0 ± 2.9
	703; 724	100	1.5	0.2 ± 1.0
Ar + Al_2O_3	696; 727	30	1.5	-9.1 ± 3.2
Ar + MF	696; 727	15	3.0	1.9 ± 5.5
		20	3.0	3.7 ± 3.4

that was registered just before and $free_{after}$ — the value without particles that was registered just after the dusty measurement. Similarly, for measurements without particles we calculated

$$difference = (dusty_{before} + dusty_{after})/2 - free$$

An example of one series is presented in fig. 2.

The results of the experiments are presented in table 1. In most cases the population change was negligible in comparison with inaccuracy. Al_2O_3 particles cause decrease of the fluorescence. In contrast, melamine-formaldehyde particles increase the population at least with pressure of 20 Pa and current of 3.0 mA.

The results are in agreement with the difference of plasma radiation with and without particles that can be seen in photos (fig. 3). Al_2O_3 dusty structures dramatically change Ar plasma luminosity. The effect is not eye-visible in Ne or Ar with melamine-formaldehyde particles.

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References

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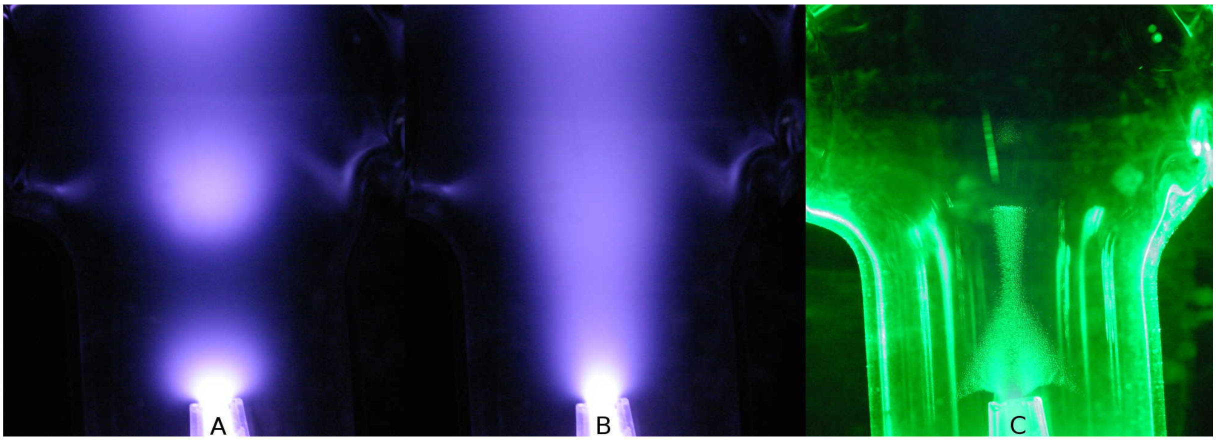

Figure 3: *Photographs of the discharge. Ar P = 30 Pa, I = 2 mA. A — plasma without particles; B — plasma with Al_2O_3 polydisperse particles; C — the dusty structure illuminated with a laser knife. The plane windows are visible at the top and the narrowing is at the bottom.*