§12. Trapping of Pellet Cloud Radiation in Thermonuclear Plasmas

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Pellet clouds are low temperature and high density plasma structures driven by a hot thermonuclear plasma (see review ref. [1]). The experimental results show that the hydrogen pellet position in the direction across and along magnetic field becomes undistinguishable at some distance from the pellet surface resulting in "pellet disappearance" effect. The effect exists for hydrogen and is absent for impurity (in particular carbon) pellet clouds. This paper presents estimations for radiation trapping in pellet clouds.

The pellet cloud intensity distributions in the total visible range of light (400-700 nm) measured in T-10 [2] are shown in Fig. 1. Measurements have been done with exposure times of about 7 μs for hydrogen pellet clouds shown in Fig. 1a and 40 μs for carbon ones shown in Fig. 1b. It is seen from Fig. 1b that intensities of the carbon pellet cloud have a sharp maximum. The striking phenomenon is an appearance of "plateau" region of intensity in the hydrogen pellet cloud (Fig.1a). This "plateau" region has $R_{pl} \approx 3$-4 mm in the transversal and $Z_{pl} \approx 40$ mm in the longitudinal directon. It is supposed that this region is due to a transition of the radiation observed into Black-Body (BB) one for the hydrogen pellet cloud.

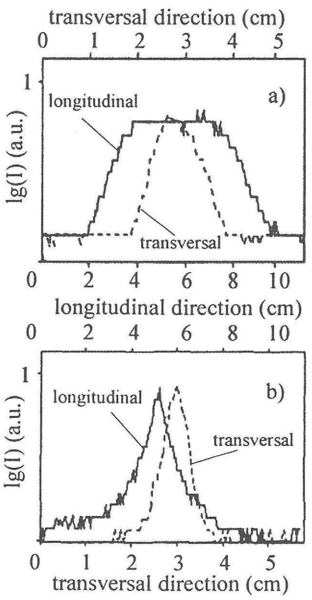

Fig. 1

A number of experimental observations (see Ref. [1]) makes possible to accept the following values of pellet cloud parameters: typical electron density is order of $10^{17}\mathrm{cm}^{-3}$; electron temperature is about of 2-3 eV. The Sakha-Boltzman equilibrium is assumed through all estimations below. The density $N_{cl}(r)$ and temperature $T_{cl}(r)$ profiles in the cloud were varied in the model with a goal to satisfy experimental data and estimation of N_{cl0} presented above: $T_{cl}(r) = T_{cl0}\,[1-\exp(-(r/L_{cl})^2)]$, $N_{cl}(r) = N_{cl0}\exp(-(r/L_{cl})^2)$, where L_{cl} is a characteristic decay length varied in simulations.

Widths of spectral lines increase with increase of optical depth of the media resulting in the BB radiation inside equivalent widths of these lines [3]. Moreover, the equivalent widths of these lines can overlap in the domain to approach a BB radiation in the total spectral range observed. The main mechanism responsible for the spectral line broadening in the cloud is the Stark effect in the electric fields of cloud plasma ions. The radiation intensity outgoing from the optically thick pellet plasma in the 400-700 nm spectral range is shown in Fig. 2. It is seen that the cloud radiation reaches that of the BB one near a specific cloud radius $r \approx 0.27$ cm that is consistent with R_{pl} evaluations from the transversal intensity profile shown in Fig. 1a.

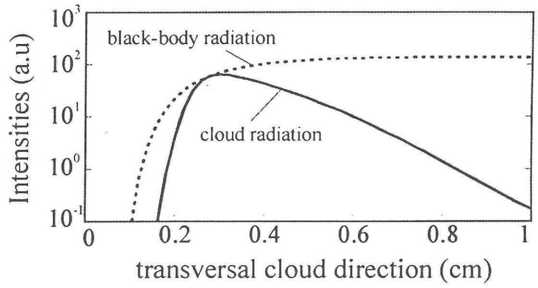

Fig. 2

The main difference between hydrogen and impurity pellet clouds is that the oscillator strengths are localized in two (or three) spectral lines for hydrogen and are distributed over the observed spectral range for impurities. This results in the quadratic Stark effect for impurities in contrast with the linear one for hydrogen as well as in different values of absorption coefficients. Such estimations show that the equivalent optical widths for the hydrogen cloud are more than one order of magnitude larger than impurity ones. Therefore, when hydrogen lines are overlapped to create black body radiation, the impurity lines are still non-overlapped. This is a possible reason for existence of the "pellet disappearance" effect for hydrogen pellets and it's absence for carbon pellets.

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References

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