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X-ray spectra features of ultra-relativistic laser plasma with above critical density generated in cryogenic cluster targets by a PW laser pulse

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Recently it was shown that injection of gas preliminary cooled down to cryogenic temperatures is a promising way to produce micron-scale clusters. For example, in [1,2] hydrogen clusters with the size up to ≈2 μm were produced via a conical nozzle at 25 K, 6 MPa. Micron scale clusters can be also created with another pre-cooled gases, for example Ar or Kr, but for other temperature values.

So large clusters diameter value becomes comparable with the waist width and Rayleigh length of the Gaussian beam produced by the J-KAREN-P laser facility [3,4].As a result, an experimental case can occur, when most of the laser energy is absorbed by a single cluster. Such situation can be considered as an interaction of a laser pulse with matter at the state close to the solid-state.

In the presentation, the features of plasma X-ray spectra indicating the observation of the described above case of a high-intensity laser pulse interaction with a large-scale cluster are discussed. The spectra were measured during irradiation of cryogenic (T = 140 K – 220 K) Ar flows by ultra-intensive (I = 10^{22} W/cm^2) femtosecond laser pulses generated by the J-KAREN-P laser. Registered X-ray spectra of produced plasma contains Ar XVIII Ly-α and Ar XVII He-α of comparable intensities. It should be noted that concentration of Ar H-like ions high enough to produce so intensive Ly-alpha line has not been achieved before in laser-cluster interaction experiments. That indicates that the density of irradiated matter is high enough to provide a rate of impact ionization process, which is sufficient to create a significant amount of H-like Ar ions. It is a challenge to reach such condition for a pure gas or small clusters. Thus, the observed spectra are considered as an evidence of a large micron cluster existing in the beam waist region.

References

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