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SYNCHROTRON RADIATION OF A STOCHASTICALLY HEATED CLUSTER MEDIUM IRRADIATEW BY AN INTENSE ULTRA-SHORT LASER PULSE *)

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Cluster and dust plasma, being a unique medium due to volumetric stochastic heating, are a promising source of laser-heated electrons and short-duration soft X-ray bursts [1-2]. The use of a cluster plasma, in principle, does not require an additional converter - radiation can be generated directly in it by bremsstrahlung and synchrotron processes.

The goal of the study was to evaluate the yield of synchrotron incoherent radiation from such a medium, characterized by a random distribution of large, submicron-sized clusters of heavy atoms. Such a target was irradiated with a compressed laser pulse (15 fs) with an energy of ~1 J. 3D simulation of the interaction of an ultrashort laser pulse with a microcluster medium was performed using the PIC code VSIM for the laser intensity range $I_L \approx 2 \times 10^{18}$ - $5 \times 10^{19}\ \mathrm{W/cm^2}$. An original numerical modeling method was used, based on dividing the region of laser-plasma interaction into cells, and applicable to large volumes of a cluster medium. For optimal parameters of a microcluster plasma, the electron spectra are characterized by the formation of a wide plateau-like region of the energy distribution, the width of which increases in proportion to the intensity [2]. The presence of this region is associated with the identified group of particles performing complex stochastic motion in a combined laser and Coulomb field. Calculated synchrotron emission spectra for selected particles from the plateau indicate that the characteristic emission frequency lies in the range of 50-500 eV, which falls within the water transparency window.

Estimate of the conversion coefficient of laser pulse energy into secondary radiation energy when the laser intensity changes from $I_L \approx 2 \times 10^{18}$ - $5 \times 10^{19}\ \mathrm{W/cm^2}$ gives a value varying from 10^{-6} to 10^{-5}, while the number of photons with a characteristic energy of 200 eV is estimated at 10^{12} for $I_L \approx 4 \times 10^{19}\ \mathrm{W/cm^2}$ at a laser pulse energy of approximately 1 J. The characteristic duration of the expected burst of radiation is approximately 0.5 ps. Obtaining short pulses with a duration (shorter than 1 ps) of soft X-ray radiation (including in the field) with a tunable spectrum is of interest for the diagnosis of complex systems and dense heated matter, including for materials science, biology and medicine.

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References

[1]. Faenov A. Y. et al. Generation of Quantum Beams in Large Clusters Irradiated by Super-Intense, High–Contrast Femtosecond Laser Pulses //Contributions to Plasma Physics. – 2013. – Т. 53. – №. 2. – С. 148-160.

[2]. Gozhev D. A., Bochkarev S. G., Bychenkov V. Y. Electron heating of the cluster plasma by an ultrashort laser pulse //JETP Letters. – 2021. – Т. 114. – С. 200-207.

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