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Observation of induced transparency in relativistic laser-produced plasma created by two-side solid target irradiation

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Opacity is one of the most important factors in the formation of intensity and shape of x-ray line spectra of high-temperature and high-density plasmas produced by powerful laser pulses [1]. On dependence of plasma properties opacities may cause complicated non-symmetrical deformations of line contours, especially in expanding inhomogeneous plasmas. Moreover, in the presence of relative microscopic motions of plasma components, the influence of self-absorption could be reduced if, due to Doppler effect, the shift of the absorption and the emission line centers will be comparable or larger than the intrinsic width of line. In this work we present the result which demonstrates that effect of increased plasma transmission may take place if a solid target is irradiated by laser pulses from two sides.

At J-KAREN-P laser facility [3] we performed experiment on interaction of high intrinsic contrast ultra-relativistic intensity of ~ 10^{21} W/cm^2 pulses with thin (1-2 μm) 4-Chlorostyrene foils pre-heated on the rear side by specially incorporated prepulse. For the prepulse the ~ 1/100 of the main pulse power was picked up with controlled sub-nanosecond time interval prior to the main pulse and created upstream expanding preplasma with tailored density profile. The x-ray emission of highly charged Cl ions was measured by high-resolution x-ray spectrometer from rear side of target. In Figure 1 the spectra obtained without pre-heating (a) and with pre-heating (b) are shown. The spectrum (a) represents the emission of the hot front-side plasma after its self-absorption and absorption in the reminder of cold target. Spectrum (b) is also emission of front-side plasma but after passing through the preplasma with T_e of ~ few hundreds keV. In opposite to expected increase of opacity of preplasma for He-like line, the decrease of absorption was observed, in the spectrum (b) which is indicated by narrowing of He_β line and the decreasing of intensity ratio He_β /Ly_α.

One of possible explanations of observed plasma transparency is a high relative speed V_{rp} of downstream (from front) and upstream (from rear) plasma expansion. Modeling shows that at $V_{rp} > 10^8$ cm·s^{-1} the rear plasma may become optically thin for He-like lines emitted in the front-side plasma. The result is interesting. We will discuss in details experimental conditions, spectral features, method of spectral analysis and argue our conclusions.

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References

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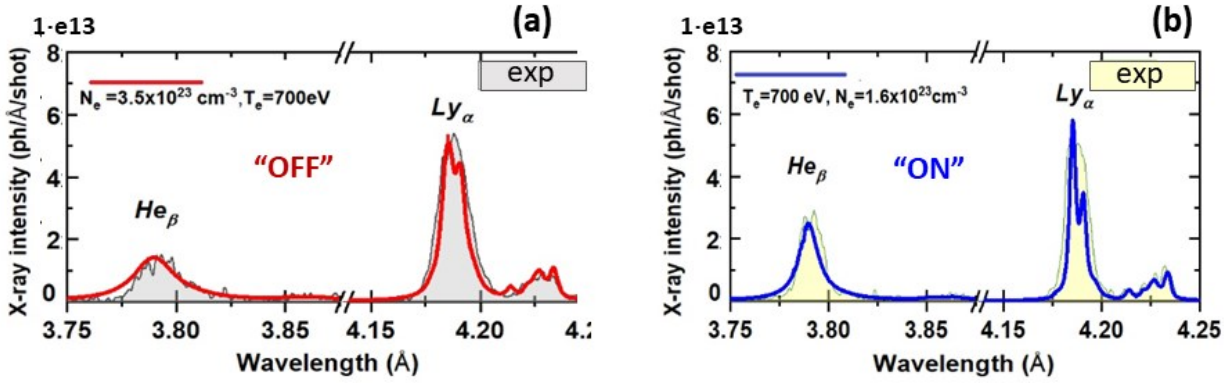

Figure 1. Experimental (shaded) and modeling (in solids) X-ray spectra of Cl observed from the rear side of 4-Chlorostyrene C_8H_7Cl foil in the spectral range of H-like 2p-1s and He-like 3p-1s transitions without pre-heating (a) and with pre-heating creating a tailored preplasma density profile on the rear side of target (b). Matching modeling performed using the collisional-radiative spectral analysis code PrismSPECT demonstrates that with pre-ionization plasma becomes optically thin.