Temperature Determination of Laser Heated Plasma Targets

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Experiments for the investigation of the interaction of heavy ions with laser produced plasmas at GSI demonstrated a strong enhancement of the energy loss and charge state of the projectiles in the plasma[1–3]. The results could not be described by present theoretical models. Therefore, additional data have been measured to complete the set of known experimental parameters to support the development of suitable ion-plasma-interaction models.

Fluorine spectra in the XUV regime from 5 μm (foil) and 2 mm (plate) Teflon targets have been recorded by means of spherically bent mica crystals[4] with spatial resolution and a Flat-Field-Grating-Spectrometer with temporal resolution. These spectra have been used to calculate temperatures from line ratios and the spectral decay of the continuum. For the computation of temperatures from line ratios a Boltzmann distribution of excited states was assumed and a modified SAHA equation was utilized[5]:

$$\frac{N_{Z+1}}{N_Z} = \frac{g_{Z+1}}{g_Z} \exp\left[\xi - \frac{I_Z}{k_B T_e}\right], \quad (1)$$

$$\xi = (1.7 \times 10^{-8}) Z (k_B T_e)^{\frac{3}{2}} \left(\frac{I_Z}{k_B T_e}\right)^{\frac{5}{2}}.$$

N, I and g represent the abundance, ionization potential and the statistic weight of the ground state of the ionization state Z. In the calculations, the optically dense transitions (e.g. He_α, Ly_α) have been attenuated by an estimation matched to the measurement. The computation of the temperature was mainly due to higher transitions, that are optically thin. Figure 1 shows the corresponding example for a spatially integrated spectrum of fluorine at t=11.7 ns. The laser pulse has a FWHM of 14-15 ns. Its maximum is at $t \approx 7$ ns.

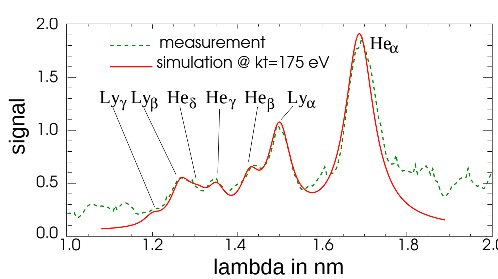

Figure 1: Comparison of a measured fluorine spectrum and a simulation for kT=175 eV at t=11.7 ns

The evaluation of the continuum was based on the exponential decay of Bremsstrahlung and recombination radiation with respect to the photon energy[6]:

$$\ln I \propto -\frac{\hbar\omega}{kT}. \quad (2)$$

An example of the temperature evaluation by the continuum is given in figure 2 at t=16.3 ns. It fits well to the value found by the evaluation of the line ratios from the same spectrum.

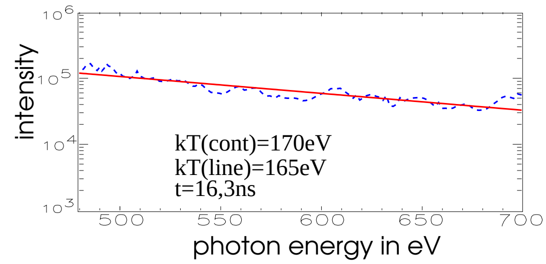

Figure 2: Measurement (dashed) and fit (solid) of the continuum emission at t=16.3 ns

Figure 3 summarizes the measured temperatures for different targets and methods. It leads to a consistant picture of temperatures between 120 and 200 eV. Values below 120 eV (later than 20 ns and farer than 1.2 mm) were not accessible with the given diagnostics.

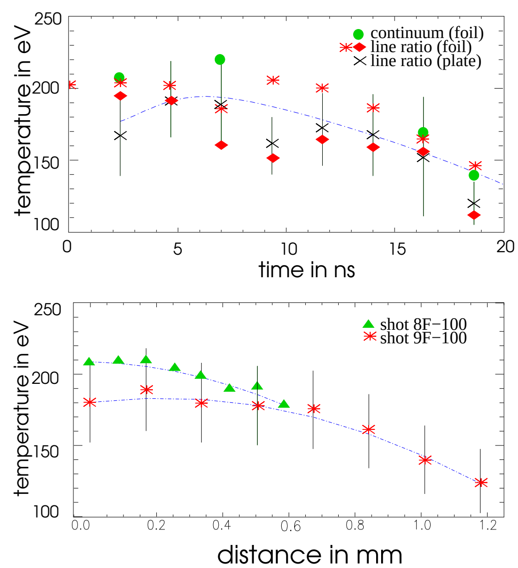

Figure 3: Temperatures for Teflon with temporal (upper) and spatial (lower) resolution.

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