Ti-wire isochorically heated by intense short pulse laser*

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For the characterization and the investigation of the behavior of warm dense matter, that will be generated at FAIR, it is necessary, to find diagnostics suitable for these tasks and able to operate under extreme conditions. Already, small samples of WDM, with dimension of a few micrometer, can be generated by using intense short pulse lasers like the PHELIX-facility at GSI.

To generate WDM, high energy densities respectively high pressures ($>1\,Mbar$) are required. During the interaction between an intense short pulse laser and matter, a part of the energy is transferred to electrons. These electrons are accelerated to energies above a few MeV by the ponderomotiv force of the laser field [1, 2].

The experiment was carried out in the laserbay of the PHELIX-laser facility. The experimental setup consisted of Ti-wires with a diameter of $50\,\mu m$ and a length of 2-3 mm. The PHELIX-laser (E_L=120 J, t_p=500 fs, λ=1064 nm) was focused to the tip of the wires with a focal spot size down to $6\,\mu m$, leading to intensities of I_L=$10^{21}\,W/cm^2$ with a ns-contrast up to 10^{-10}. The electrons, accelerated during interaction between laser and wire, penetrate the wire and deposit energy therein, heating the wire up to the plasma state by collisions. Because of their high kinetic energies, the electrones are propagating into the matter with nearly the speed of light. This leads to a heating process that is faster then the expansion of the wire, resulting in an isochoric heating [3].

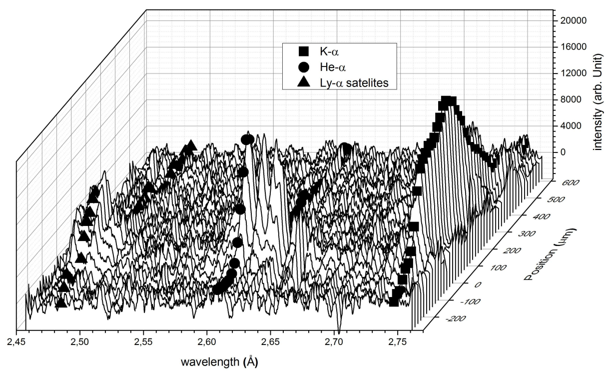

Figure 1: characteristic x-ray spectra along wire axis

While penetrating the wire, the hot electron component ionize the Ti atoms through K-shell ionisation. As a result, characteristic x-rays are emitted. Outer shell electrons are ionised with high efficiency by electrons with bulk temperatures at tens of eV. The energy of inner shell transitions depends on the effective nuclear charge and thus on the charge state of the ions. This leads to a superposition of Kα transitions from Ti^{+1} up to Ti^{+11}. The characteristic x-rays were measured spatially resolved along the wire axis (fig. 1) with a focusing spectrometer with spatial resolution (FSSR), that consists of a spherical bend crystal as dispersive element and x-ray film as detector. With the FSSR spectrometer high spectral ($\lambda/\Delta\lambda$=$3\cdot10^3$) and spatial resolution ($50\,\mu m$) can be achieved.

The laser can only penetrate the underdense region of the target. It is mostly absorbed at the critical density of the expanding plasma. At this point, the target is heated to temperatures of a keV, resulting in emission of He-α and Ly-α. The overdense region can only be penetrated by the accelerated particles and is heated to moderate temperatures where a broadened Kα-line is observed (fig.1). The Kα broadening can be calculated by a superposition of emission lines of ionised Ti bulk atoms, weighted by the charge state distribution related to a specific bulk temperature (fig. 2).

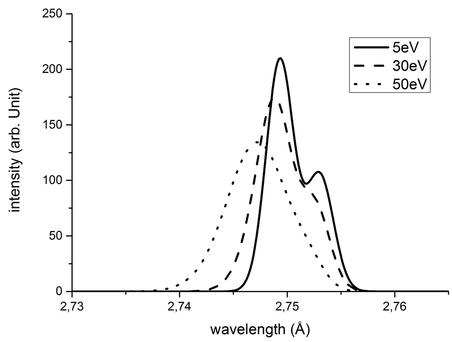

Figure 2: broadening of the Kα-line for different bulk temperatures

It is shown, that WDM can be generated by isochoric heating with hot electrons. Analysis of characteristic x-rays with FSSR provides possibility to distinguish between direct and particle heated areas and allows a spatial resolved temperature diagnostic which helps to investigate the collisional heating process.

References

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