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Applications of high resolution X-ray fluorescence spectroscopy for HIHEX-experiments at FAIR

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Intense uranium beams that will be available after commissioning of the new synchrotron SIS100 in Darmstadt can be used for volumetric heating of any type of material and the generation of extreme states of matter with Mbar pressures and some eV of temperature [1]. The investigation of their EOS is one of the main goals of the plasma physics program at FAIR. To characterize such extreme states of matter, new diagnostic methods and instruments, which are capable to operate in an environment with a high level of parasitic radiation, have to be developed.
The precise knowledge of the energy density distribution of the U-beam on the target is a very important input parameter for numerical simulations of the hydrodynamic response of the target on deposited energy. To investigate the energy density distribution, we propose to use the target and heavy ion beam X-ray fluorescence [2, 3] for imaging of the target expansion and mapping of the heavy ion beam distribution in the interaction region with a high spatial resolution of at least 100 micrometrs. First pilot experiments on measurements and characterization of the heavy ion and target fluorescence using pinholes, X-ray pin-diodes and dispersive systems have been carried out in 2016 at the UNILAC Z6 experimental area.
In experiments, the interaction of 6.5 MeV/u Au ions with a few micrometer thin Al, Cu and Ta foils has been investigated using x-ray spectroscopy. We observed intense radiation of ionized target atoms (K-shell transitions in Cu at 8-8.3 keV and L-shell transition in Ta as well as Doppler shifted Balmer transitions of Au projectiles passing through foils in the photon energy region of 10-20 keV. This radiation can be used for monochromatic (dispersive element) or polychromatic (pin-hole) X-ray mapping of the ion beam intensity distribution in the interaction region.
Using data obtained by a CdTe x-ray spectrometer and a faraday cup, we could estimate the number of Au L-alpha photons per 1 C of the Au-charge passing through Al, Cu and Ta foils, per micrometer target thickness in 4pi. This number allows us to conclude, that 10-100 fold amplification of the signal is required in order to apply this method for U-beam intensities between 1010 - 5x1011 particles/pulse. The obtained results can be scaled to high heavy ion energies available at SIS18 and SIS100 [4].
Experiments have been performed in the frame of the BMBF-Project 05P15RFFA1 in collaboration with the Plasma Physics Group of the Goethe University.
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