Contribution ID: **40** Type: **not specified**

X-ray spectroscopy for Plasma Physics "Day One" experiments at FAIR

Thursday, 22 June 2017 14:45 (25 minutes)

In the framework of a project funded by the BMBF, we gather inquiries from the different parts of the APPA collaboration which have a common interest in the development of x-ray spectrometers as diagnostics in their experimental studies. It seems clear that the different applications require specific spectroscopic solutions depending on the photon energy range, the need for spectral and spatial resolution. We identify here three main topics and propose a concept of instrumentation for each of them.

The ion beam parameters are still insufficiently known, which leads to biased data interpretation. For example, the spatial energy distribution within the beam focal spot can lead to an inhomogeneous heating of the target and consequently to a variable distribution of the ion charge states in the generated plasma. The ionization characteristics can have a dramatic influence on the physical properties that are the center of interest in many experiments (e.g. stopping rates, x-ray/VUV opacities, x-ray Thomson scattering, continuum lowering). In this framework, we are designing and developing toroidal GaAs crystal-based spectrometers, such as an x-ray 1D-imager.

We also plan on developing a broadband x-ray spectrometer based on a cylindrically curved HOPG crystal (2d = 0.6708 nm) for photon energies ranging from ~ 8 to 12 keV. Using the focusing capability of such a crystal in a so-called van Hamos geometry, it is possible to increase the signal-to-noise ratio. This spectrometer is very flexible and can be used for many different purposes. On one hand, the large spectral band allows for measuring the emission from a great variety of elements (i.e. the K-shell radiation of Fe, Co, Ni, Cu, Zn or Ge, but also the L-shell lines of Ta, W, Pt, Au, Tl, Pb or Bi). On the other hand, this spectrometer is an excellent candidate for laser-driven plasma experiments, meaning that, as soon as the instrument is assembled, it will be possible to characterize it in real conditions at laser facilities such as JETi-40 in Jena or PHELIX in Darmstadt.

The modification of the energy levels of an ion under the influence of high plasma densities is known as continuum lowering. Due to their strong coupling, FAIR plasmas present a high interest in the study of the relation between equations of state and continuum lowering. Hence, we are investigating the opportunity of developing an x-ray spectrometer capable of measuring this atomic phenomenon in the framework of heavy ion plasma experiments. We have conducted the first appraisal on that project and we decided to focus on the lowering of the so-called K-edge of aluminium at 1.6 keV. A spectral bandwidth of 100-200 eV would be necessary. We foresee the use of a spherically curved mica crystal as an ideal option to perform simultaneously high spectral resolution and high reflectivity.

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Session Classification: Laser-based plasma