Measurement of edge plasma parameters at KSTAR using a combination of Lithium and Deuterium Beam Emission Spectroscopy

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A 60 keV neutral Lithium beam system was designed and built up for beam emission spectroscopy measurement of edge plasma on KSTAR. The measurement will be the complementary of the heating beam based emission spectroscopy system which was built up in 2012, using the same observation system with different interference filters.
The electron density and its fluctuation, thus the density distribution, the transport and different turbulent modes can be measured using the accelerated Lithium beam based emission spectroscopy system [1,2]. A new thermionic ion source is developed with SiC heater to emit around 4mA ion current. The ion optic is following the original 2 steps design with small modifications to reach about 2 cm beam diameter in the plasma. The newly developed ion gun system is built up first in the Wigner RMI for detailed testing of every beam parameter. The maximum 60 keV beam energy with 4 mA ion current were successfully reached at KSTAR which is sufficient for beam emission spectroscopy measurements. A newly developed Sodium vapour neutralizer neutralizes the accelerated ion beam at around 260-280 C degrees even at long (<20s) discharges. The base of the newly developed Li-BES system and the first results are discussed in this paper.

Integration on KSTAR

The Lithium beam – installed in 2013 June – works as a parasite of the NBI BES [3]. It uses the same observation and optical system (i.e. both systems cannot measure in the same time), the geometry is shown in Figure 1. The vacuum window is located approximately along field lines crossing the NBI beam-line causing also a sufficient Doppler shift. The Lithium beam system is located at port K around 5 m from the plasma (because of place limitations) and shoots into the same observation area. Effect of the heating beam on the Lithium beam is negligible [3]. The wavelengths of the resonant Lithium and the resonant Deuterium line are differing by about 14 nm. As the maximum Doppler shift (given by the geometry) is less than 3 nm filtering the observation lines cannot interfere. The arrangement of the Lithium beam system can be seen on Figure 1.b.

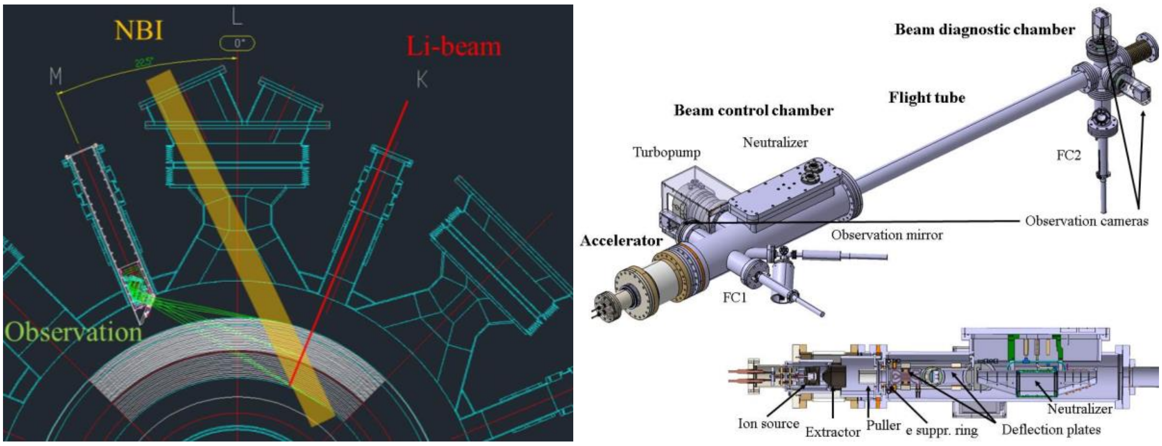

Figure 1: a, Observation geometry. b, Hardware elements of the Li-BES system.

The observation system consists of two detector lines: an APD based camera which has to image the plasma with 2MHz on a 4 by 8 channel array with 1cm spatial resolution and a a CMOS camera has to view the whole object space and the absolute spatial calibration should be performed with it.

Li-beam hardware developments

Two major developments were make for the Li-beam system. A new ion source is developed with higher ion emission capacity (j > 2.5mA/cm^2) and a novel neutralizer is improved with the possibility of longer pulse operation. The new ion source can be seen in the Pierce electrode on Figure 2. a. The base of the emitter is a Molybdenum housing. A 14 mm diameter porous – also Molybdenum – plug is situated on the top of it. This is the holder of the ion emission material (B-eucrytite). The heating system consists of a SiC discs, a graphite (CFC) current conductor and a Tungsten current lead. The heating power is generated in the SiC discs by applying about 70 Amps/4V AC. At this current value the surface of the plug – filled up with B-eucrytite – reaches about 1350 C degree temperature. At this temperature the extracted ion current does not saturate at 2 mA but at around 4 mA at 7keV extraction voltage in this electrode arrangement.

The improved neutralizer has a central cell – called oven – whose top and bottom part can be heated separately. During operation the oven is at 250-280 C temperature (depends on the beam energy). Liquid Sodium is present at the bottom of the oven. The central cell can also be cooled by a compressed air flow: the pipes are located at the middle of the cell. Cooling serves for reducing the temperature of the oven quickly after measurement, so as Sodium loss is minimised between plasma discharges. The reflow cells with the diaphragms on both ends

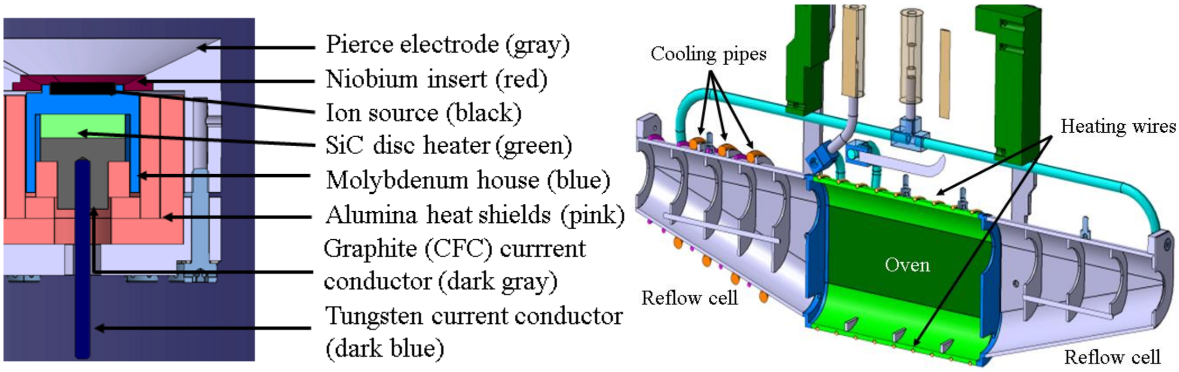

Figure 2: a, Cross section of the new ion source in the Pierce electrode. b, Cross-section of the recirculating neutralizer.

have a lower temperature where Sodium condenses but still in liquid state, at around 130 C degrees. The cross section of the neutralizer can be seen on Figure 2. b.

First results

Radial light profile measurement with Lithium beam can reveal the plasma edge density profile. The measured light profile has to show both the increasing and decaying part of the profile. The background light can be separated from the Lithium beam radiation by chopping the beam using a fast high voltage switch [2]. An example camera image of the Li-beam emission with background correction can be seen on Fig. 3.a. Beam parameters are 50keV beam energy, about 0.5 mA neutral current and about 2cm beam diameter. The exposure time of the CMOS camera was synchronized to the beam chopper and the chopping frequency was 20Hz. The relative error of the light profile depends on the background to Li2p-2s signal ratio. In the present case this ratio is 1:1 while the signal to noise ratio is about 20-15:1. The reason of this limited signal to background ratio is that the final filter was not yet available during these measurement.

Estimation of the electron density profile from the measured data is done with the help of Bayesian Probability Theory. The reconstruction method applied in our work is based on the probabilistic approach [4]. It is based on the forward model of the Li-beam diagnostics and statistical description of the measurement data. The advantage of this method is that the noisy and incomplete data can not cause trouble during the inversion instead determines the reliability of the reconstructed density profile. Additionally, the problem determining the electron density from the measured data is ’ill-posed’, that is the solution is not unambiguous and sensitive to the noise. The Bayesian Probability Theory allows us to reduce the space of possible solution to a physically meaningful one. The calculated electron density can be seen on Figure 3. c.

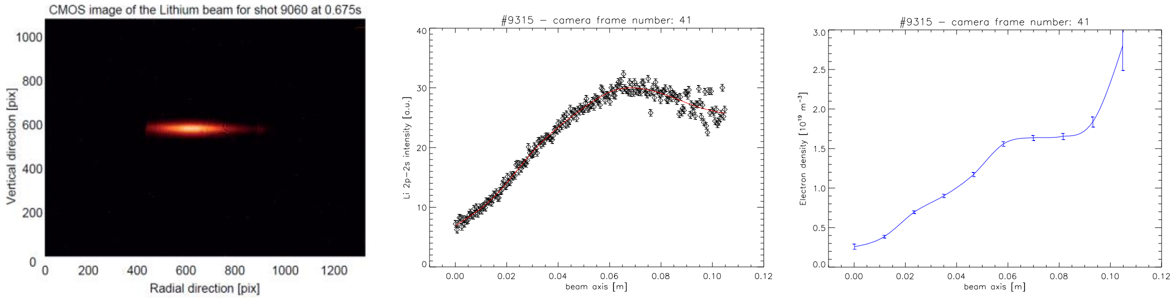

Figure 3: a, Background subtracted CMOS image of the Lithium beam for shot 9060 at 0.675s (The beam goes from left to right.) b, The measured data with error bars (black diamonds) and the back-calculated Li-2p occupation densities (multiplied with the absolute calibration factor) as a function of the beam axis (red) c, Density profile and 68% confidence interval of the reconstructed density profile at some point as a function of the beam axis.

APD camera signals for discharge 9060 20 Hz frequency can be seen on Fig 4. Signal to background ratio is approximately 1:1 while signal to noise is around 10:1 on the 500 kHz bandwidth. The SNR can still be enhanced with modified filter and better beam focusing but the flux is already enough to reveal some information about turbulence structures in the SOL region.

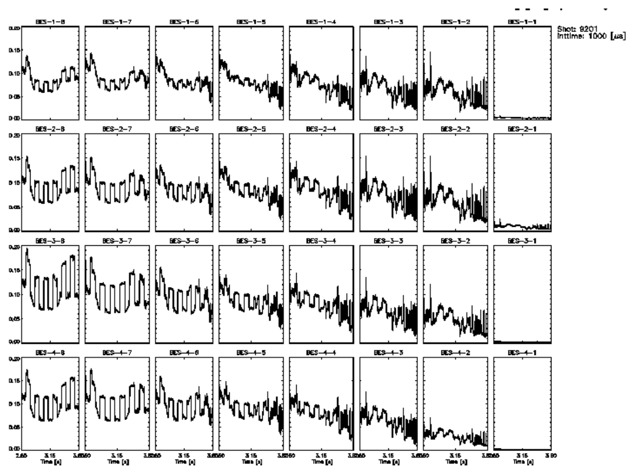

Figure 4: 20Hz chopped Lithium beam emission measurement with the APDCAM (BES-*-1 features no signal due to vignetting of the smaller filter)

References

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