Density measurements of a gas rarefaction channel

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The transport of heavy ion beams inside large chambers with considerable amounts of rest gas has been studied as part of the ARIES program. Three different approaches to the transport of the heavy ion beam inside the chamber are probed: ballistic transport, self-pinched transport and channel transport.

While ballistic transport is the mainline approach, channel transport is a promising alternative since it reduces the requirements for the final quadrupol magnets outside the chamber. Another advantage is that only two ion beams are required, in contrast to over 50 beams for ballistic transport, which are necessary to reduce space charge and return current effects. In a collaboration of GSI and Berkeley Labs the dynamics of the channel as well as its transport properties for ion beams are studied. Measurements are carried out with a discharge chamber, which is made of stainless steel, has a length of 50 cm, and is filled with gas at a low pressure.

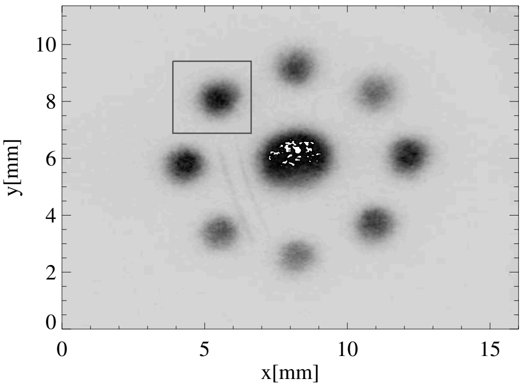

Figure 1: Scintilliator image with selected beamlet

The channel creation takes place in three steps[2]. Firstly the gas is heated on the axis by a CO_2 laser. The pulse has a duration of 1 μs and an energy of about 1 J. It leads to an expansion and thereby rarefaction of the gas on axis. In addition it gets slightly ionized. Secondly a small discharge with an energy of 40 J is triggered. This prepulse also heats and ionizes the gas on axis. Finally the main discharge (3.1 kJ) is triggered and thereby a plasma channel is created.

The laser heating in the first phase creates a wall of increased gas density surrounding the axis. Thereby the channel is stabilized against kink instabilities[3], which would otherwise deteriorate the transport properties of the channel. Because of that it is important to measure the development of the gas density. An interferometer working at two wavelengths can measure neutral gas densities in principle, but it is only sensitive to large density gradients. Therefore a new measurement technique was developed.

It is based on the scattering of an ion beam passing the chamber. The width of the beam is only influenced by small angle scattering with the gas particles and depends on the gas density. A pepperpot mask is mounted at the

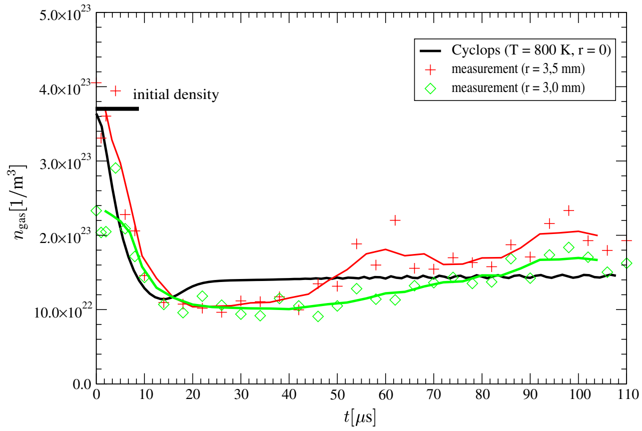

Figure 2: Measurements and simulation of density development (r is the distance from the axis)

entrance of the chamber; thereby only small beamlets can enter the chamber. At the end of the chamber they hit a scintillator, which is photographed with a high-speed digital camera. The used plastic scintillator (BC 700) has an afterglow duration of only 7 ns; therefore it allows a high time resolution. The intensity of the beam varies on a longer timescale, so the measurement of the beam width is not affected.

A pointlike ion beam results in a gaussian intensity distribution at the end of the chamber. Since the real beamlets have a finite extension, the intensity profile at the end of the chamber is given by the convolution of the initial intensity with the gaussian profile.

The widths of the intensity profiles of the beamlets are measured with a computer program. Therefore the area of a beamlet is selected (see fig. 1) and fitted with a 2d gaussian curve. The correlation between beam width and gas density is obtained by taking a calibration curve. Therefore the gas pressure is varied and the laser is turned off. During the experiment snapshots are made at different points in time, so that the devolpment of the density can be tracked. The different beamlets also allow a limited spatial resolution.

For comparison the channel devolopment is also simulated with an 1D MHD code (Cyclops), which calculates the hydrodynamic expansion starting from an initial gaussian temperature profile. The results are in good agreement with the measurements (see fig. (2)). Both show a sharp decline in on-axis gas density during the first 15-20 μs and a slow increase afterwards, proving the efficiency of the laser for density reduction.

References

[1] http://aries.uscd.edu/ARIES

[2] C. Niemann et al., JAP, **91**, 617–623 (2002)

[3] W. M. Mannheimer et al., Physics of Fluids, **16**, 1126-1134 (1973)