Interaction of Ca^{10+} ion beam with a hydrogen theta-pinch plasma*

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Introduction

The interaction of heavy ions with plasma is important for research in a field like warm dense matter (WDM), laboratory astrophysics and inertial confinement fusion (ICF), where the high repetition rate of ion-beam pulses are of an advantage as a driver. Also applications like using the plasma as an efficient beam-stripper are of importance with respect for the future Facility for Antiproton and Ion Research (FAIR).

Experiment

The Plasma Physics Group of the Goethe University in Frankfurt has developed and built a spherical Theta-pinch device [1, 2]. Different than in a Z-pinch, there is no need for electrodes in direct contact with the plasma.

Fig. 1 shows the set-up of the Theta pinch device. A spherical glass vessel is encircled by 7 segments of a copper coil. The coils together with a capacitor bank (37.5 μF) and a thyristor-stack [3] is part of a LRC electric circuit. At an operation voltage of 14 kV the stored energy in the capacitors is 3.7 kJ. Once triggered by the thyristor-stack, the energy will be released in the discharge in several milliseconds. The peak current in the circuit reaches up to 50 kA. Hydrogen is chosen as target gas in the vessel because hydrogen is easily fully ionized which is an advantage for obtaining a high charge state of the beam ions. The plasma is created by discharging the energy of the capacitor bank into the gas volume, which leads to an alternating strong current in the coil ionizing the gas and resulting also in a strong magnetic field compressing the plasma (pinch-effect). The Theta-pinch is differentially pumped over a two-stage aperture-system on both sides of the glass vessel, reducing the initial gas pressure of up to 1 mbar to the vacuum of 10^{-5} mbar of accelerator beam line the device is integrated in for measurements.

The interaction experiments were carried out at the Z6 experimental area of GSI. The Theta-pinch was integrated in the accelerator beam line, where a 3.6 MeV/u $Calcium^{10+}$ pulsed ion beam with a 108 MHz frequency is provided, resulting in a time-structure with 9 ns distance between the micro beam-pulses, while the maximum duration of the macro-pulse is 5 ms. The ion-beam-pulse, triggering of the discharge and timing of diagnostic tools were synchronized by a high precision trigger system.

Results

Figure 2 shows the Ca-beam signal obtained by a stop detector, black curve. The blue curve is the light emission from the plasma which is detected by a photo diode. Here the beam micro pulse was 4 ms. During the first 100 μs, until the discharge is triggered, the beam is interacting

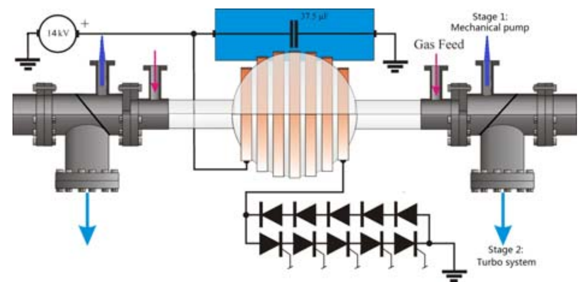

Figure 1: Schema of the set-up of the Theta-pinch device

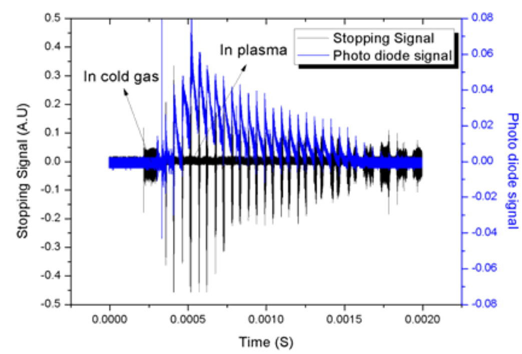

Figure 2: Beam transmission and plasma light emission

with cold gas. Later when the hydrogen is ionized, visible in figure 2 by the start of the signal from the light emission (blue curve) the target is in the plasma state. The light emission is not constant but oscillating, following the oscillations in the discharge current. Fig. 2 also shows the transmission of the ion beam during the whole time of the plasma duration. The ion-beam signals show the same oscillating behaviour like the light emission, the pulse intensity increases even over the transmitted pulse intensity in cold gas and disappears at other times, this result depends probably from the time dependent magnetic field imaging the beam ions like a solenoid.

References

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