Diagnostics of Laser Initiated Plasma Channels for Ion Beam Transport

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Laser initiated, free standing discharge channels offer many attractive advantages for the transport and focusing of intense ion beams [1, 2]. Discharge plasmas can neutralize both current and space charge of such beams, while the azimuthal magnetic field provides strong focusing all the way through the channel. Experiments at GSI have produced 50 cm long stable plasma channels with peak currents in excess of 40 kA in 2 to 20 mbar NH_3 gas fill. The discharges are initiated by a CO_2 laser pulse, fired into the chamber along the chamber axis. Absorption of the laser causes strong gas heating. Subsequent expansion and rarefaction of the gas prepare the right conditions for a stable, reproducible discharge, suitable for ion beam transport. First experiments to study the ion optical properties of such channels were already reported in [3, 4]. During the last year the channel stability was considerably improved by a new CO_2 laser with an option for wavelength tuning. The wavelength can be adjusted to the P(32) transition for peak absorption, matching the $\nu = 950\ cm^{-1}$ vibrational mode in NH_3 [5]. In this way a large fraction of the laser energy is absorbed as the beam passes through the 50 cm long gas filled chamber, down to pressures of a few mbar (figure 1).

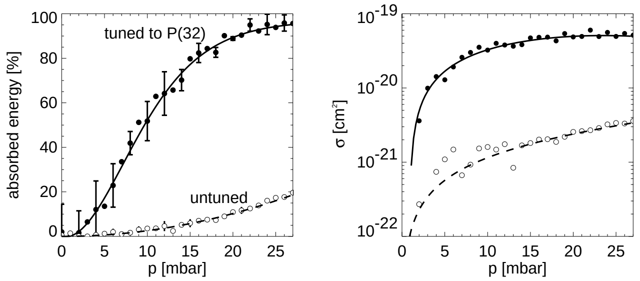

Figure 1: Improved laser gas heating due to laser wavelength tuning.

A set of plasma diagnostics was developed to gain a better understanding of the channel dynamics and the underlying physics. Schlieren measurements of neutral gas density gradients show a gas shock expanding radially with a velocity of a few $mm/\mu s$ while the discharge deposits its energy into the gas (figure 2). According to [6] this gas wall reduces the MHD instability growth rate and thus contributes to the stability of the channels. The plasma self emission was investigated by spectroscopy in the visible range. Electron densities around $10^{17} cm^{-3}$ can be estimated from Stark broadening of the observed hydrogen Balmer lines. Intensities of NII and NIII lines will be used to determine also the electron temperature. For more precise space resolved electron density measurements a Michelson imaging interferometer was set up. A pulsed Nd:YAG laser beam at 1064 and 532 nm with a diameter of several cm probes the plasma twice from a side and is then recombined with an undisturbed reference beam. The observed fringe shift (figure 2) yields the line integrated refractive index. The space resolved radial refractive index profile follows from an Abel inversion. To distinguish between contributions from the electrons and the neutral gas to the refractive index the measurements were performed at both wavelength in subsequent discharges. A maximum fringe shift around 6 was abserved at 1064 nm. A computer aided fringe counting method yields the fringeshift with a precision of around 0.2 fringes. Preliminary results are in agreement with spectroscopic density measurements.

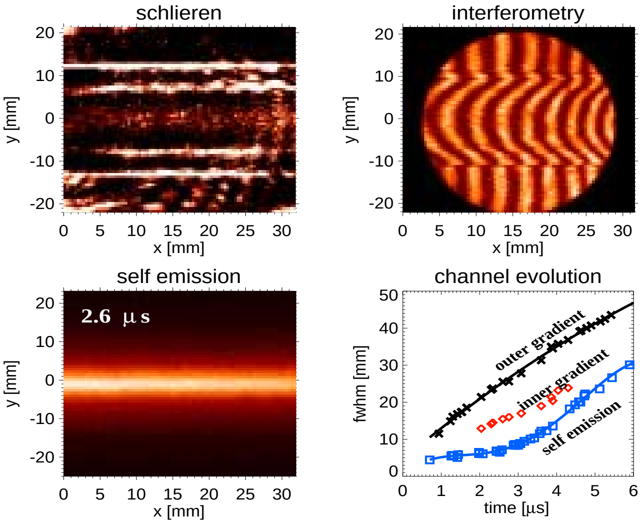

Figure 2: The channel as seen by different diagnostics.

These measurements in combindation with the ion optical investigations [7] will ultimately lead to a comprehensive understanding of the channel stability and dynamics. The results can then be used to engineer channels most suited for ion beam transport.

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