Title

Commissioning Results of the Upgraded Neutralized Drift Compression Experiment

Author

Lidia, S.M.

Publication Date

2009-06-17

COMMISSIONING RESULTS OF THE UPGRADED NEUTRALIZED DRIFT COMPRESSION EXPERIMENT*

S.M. Lidia[1], P.K. Roy, P.A. Seidl, W.L. Waldron, Lawrence Berkeley National Laboratory

E.P. Gilson, Princeton Plasma Physics Laboratory

Abstract

Recent changes to the NDCX beamline offer the promise of higher charge compressed bunches (>15nC), with correspondingly large intensities (>500kW/cm^2), delivered to the target plane for ion-beam driven warm dense matter experiments. We report on commissioning results of the upgraded NDCX beamline that includes a new induction bunching module with approximately twice the volt-seconds and greater tuning flexibility, combined with a longer neutralized drift compression channel.

INTRODUCTION

The US heavy ion fusion science program is developing techniques for heating ion-beam-driven warm dense matter (WDM) targets. WDM conditions (T~1eV, P<1Mbar) in beam targets are achieved by combined longitudinal and transverse space-charge neutralized drift compression of the ion beam to provide a hot spot on the target with a beam spot size of about 1 mm, and compressed pulse length about 2 ns. Current experiments use a 0.3 MeV, 30-mA K^+ beam (below the Bragg peak) from the NDCX accelerator to heat 100-nm thick foil targets such as Au, Al, Si, and C.

The NDCX beam contains an uncompressed pulse length up to 20 µs with a peak energy flux ≈600 kW/cm^2, and a compressed pulse of fluence ~10 mJ/cm^2. The NDCX beamline is shown in Figure 1. A transport and matching beamline composed of 4 pulsed solenoids and 3 x-y magnetic dipole pairs carries the beam pulse from the source to the bunching module (IBM) and downstream neutralized transport channels (FEPS). A pulsed, 8-Tesla final focus solenoid (FFS) concentrates the beam onto the target plane, while a final filtered cathodic arc plasma source (FCAPS) maintains charge neutralization during the final drift.

Induction Bunching Module (IBM)

A new induction bunching module (IBM) has been installed on the NDCX beamline (Figure 1). This module holds 20 independently-driven 50%-Ni, 50%-Fe Astron cores that supply voltage to a 3cm long acceleration gap approximately 283 cm downstream from the ion source.

The IBM cores are driven by dedicated pulsed power circuits. An 18-kV, 27-nF charging circuit produces a 16-kV peak gap potential over a ~600-ns (full width) pulse in the IBM gap. A capacitive voltage monitor in the gap region delivers a monitor signal with a calibration of 12 kV/V. The useful integrated volt-

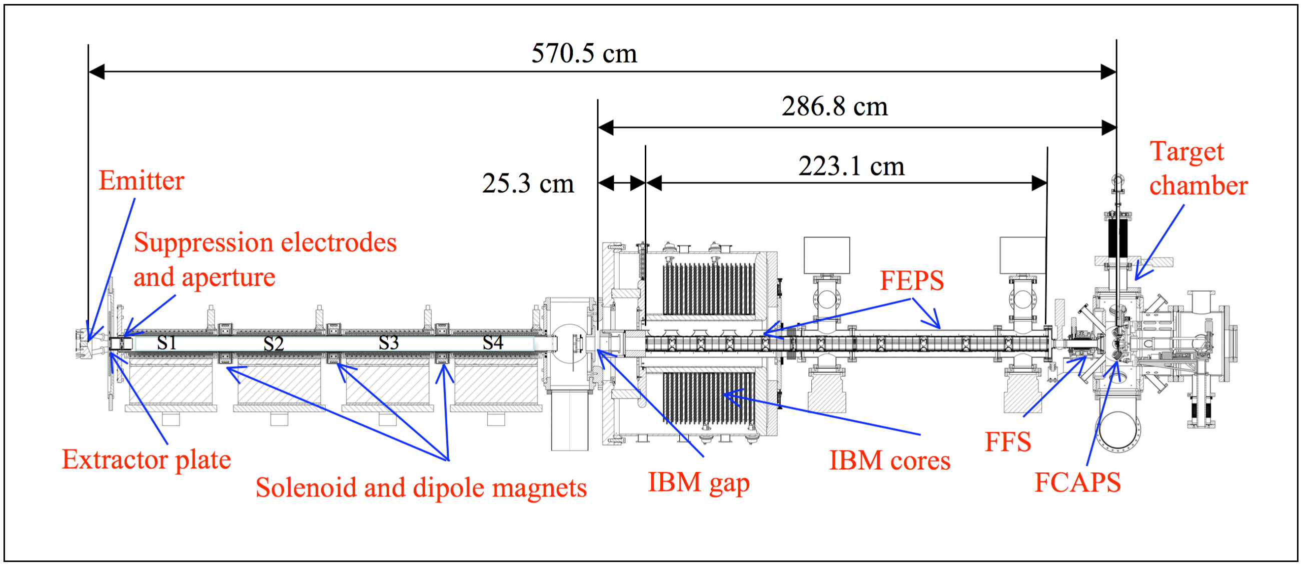

Figure 1. NDCX beamline.

---

*This work was supported by the Director, Office of Science, Office of Fusion Energy Sciences, of the U.S. Department of Energy under Contract No. DE-AC02-05CH11231.

[1] SMLidia@lbl.gov

seconds in the main region of the waveform is 4.9 kV-µs, or 98 kV-µs for the entire module. Because the core losses are not sufficient to critically damp the circuit, there is some voltage reversal delivered to the gap following the main pulse. This ~0.6-kV-µs pulse represents approximately 12% of the main pulse volt-seconds and contributes to the final tuned waveform.

The voltage waveform generated in the IBM produces the velocity chirp necessary to longitudinally compress the ion beam [1]. The ideal waveform is an optimization for utilizing the increased number of IBM volt-seconds while maintaining the same absolute voltage swing. Increasing the chirp time increases the total amount of beam charge that will evolve dynamically into a longitudinal current peak. Holding the voltage swing amplitude constant maintains a limited degree of chromatic defocusing in the compressed pulse, which can limit the compressed pulse intensity on target. The tuned waveform is presented in Figure 2 with the ideal waveform superposed. The voltage difference is also shown and is limited to a 6-kV range over the 600ns useful working section of the waveform. The previous IBM and tune also displayed a 6-kV difference range from the ideal, but over a much shorter duration (~220-ns) pulse. The larger number of independently-tunable induction cores (20) in the present IBM compared to the previous IBM (12 were used) allows for greater accuracy and finesse in fine tuning details.

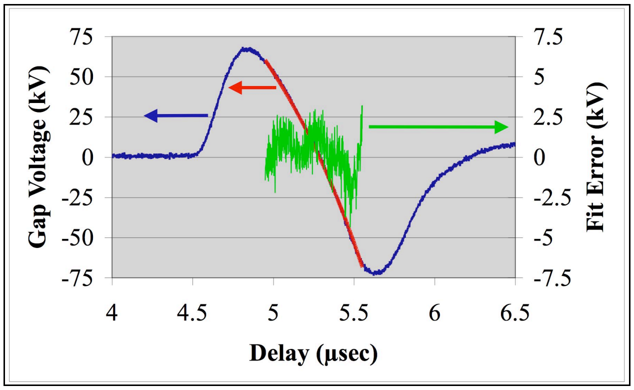

Figure 2. Tuned IBM waveform (blue), Ideal waveform (red), and the difference (green).

Extended Ferro-Electric Plasma Source

The newly installed sections of the Ferro-Electric Plasma Source (FEPS) [2] have been integrated with the previously installed sections, extending the overall neutralized drift length from 1.44m to 2.88m. A picture of the new FEPS module before installation is shown in Figure 3.

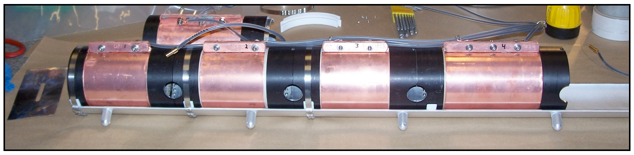

Figure 3. New FEPS module prior to installation.

BEAM INTENSITY RESULTS

An initial round of tuning the matching solenoids upstream from the IBM has been performed. Figure 4 shows the variation of the beam spot size (50% intensity radius) at the target plane as the peak field in the final solenoid (S4) is varied. For this beam energy (284 kV), a minimum spot size is seen for ≈1.7-T S4 peak field. For peak fields greater than 1.8-T the beam distribution is hollow, and the spot size is several times larger.

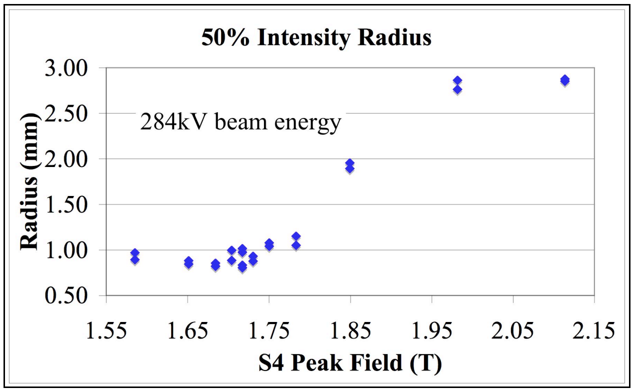

Figure 4. Parametric scan of beam spot radius with final matching solenoid field.

The peak intensity has been measured at the target plane, and an initial parametric scan has been performed by varying first the peak solenoid field in S4 and then the beam energy itself (with energy dependent solenoid field scaling). The variation of peak intensity with solenoid field is shown in Figure 5. The peak intensity is seen to correspond to the solenoid tune that produces the smallest beam spot size. The variation in peak and 50% beam intensity with beam energy is shown in Figure 6. We see that at the lower energy range, the peak beam intensity can surpass 600 kW/cm^2.

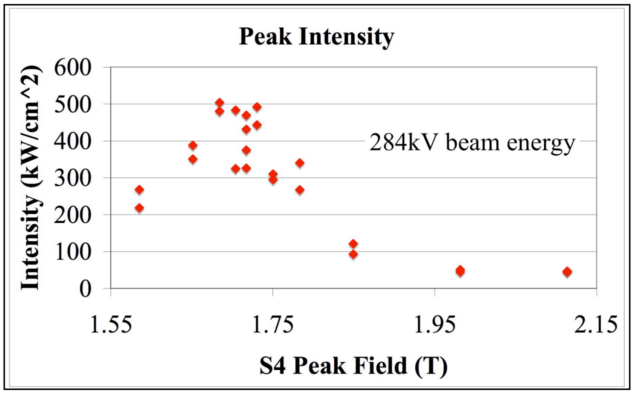

Figure 5. Parametric scan of beam intensity with final matching solenoid field.

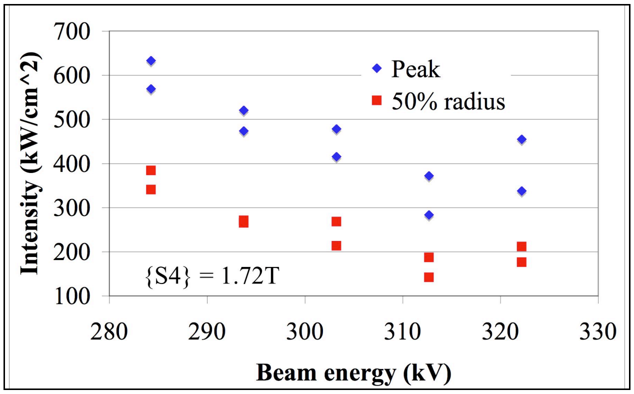

Figure 6. Parametric scan of beam intensity with beam energy.

Studies of pulse to pulse variations in the beam intensity distribution and centroid position were performed. Consecutive shots display very little variation in the intensity distribution. The jitter in the centroid position is ~100µm. Figure 7 shows the intensity map of one shot. The full width half maximum for the distribution is ~1mm, with ~100s µm wide peak intensity spot, which is the limit of the CCD camera resolution.

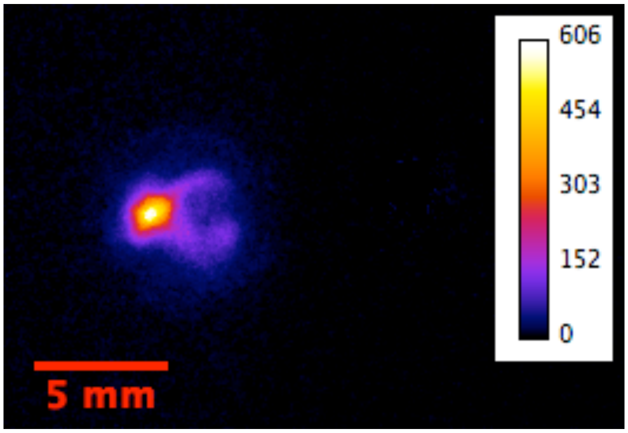

Figure 7. Intensity map of the beam distribution at the target plane. Units are kW/cm^2.

BEAM COMPRESSION RESULTS

The new IBM has been utilized to create compressed beam pulses, which are then transported to the target chamber. The Fast Faraday Cup [3] in the target chamber is used to measure the temporal profile of the ion beam after longitudinal compression, and in the presence of a high density ~10^{13} cm^{-3} background plasma. Initial beam measurements employing an optimized IBM tune readily yielded compressed pulses carrying 2.7A peak current with pulse durations ~3.2ns (FWHM). An example is shown in Figure 8. The upgraded IBM and longer FEPS channel can now deliver ~2-3 times more ion beam charge in a compressed pulse than the previous implementation. Improved tuning will increase the captured and compressed ion beam charge, and the fluence of compressed beams on to the target plane.

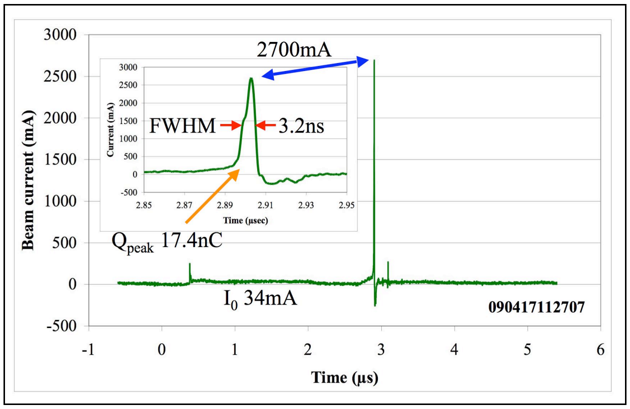

Figure 8. Compressed pulse waveform measured in the target chamber.

CONCLUSIONS

Recent improvements to the NDCX beamline have been discussed. The upgraded IBM has resulted in higher compressed pulse charges pulses delivered to the target for warm dense matter experiments.

ACKOWLEDGMENTS

The authors would like to acknowledge the assistance of Wayne Greenway, Tak Katayanagi, Cory Lee, Matthaeus Leitner, Ahmet Pekedis, and Craig Rogers.

REFERENCES

[1] P.A. Seidl, *et. al*., Proceedings of the XXIV Linear Accelerator Conference (2008).
[2] P. Efthimion *et. al.,* Proceedings of the 16th Heavy Ion Fusion Symposium (2006).
[3] A.B. Sefkow, *et. al*., Phys. Rev. ST - Accel. Beams 9, 052801 (2006).