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25,000× beam density compression may be possible on NDCX with new 8 T solenoid

The Neutralized Drift Compression Experiment (NDCX) studies simultaneous transverse and longitudinal ion bunch compression for warm dense matter applications. 2D (*r,z*) particle-in-cell design simulations use existing parameters. A 327.4 keV K^+ beam with an initial beam radius r_b = 1.43 cm, intensity I_b = 21.5 mA, ε = 0.126 mm-mrad, and pulse length of 0.7 μs is injected into the NDCX, which includes the acceleration gap, ferroelectric plasma source (FEPS), 8 T final-focus solenoid, and cathodic-arc plasma source (CAPS). Idealized, time-independent parameters are first used to model the FEPS ($n_p = 5\times10^{10}$ cm^{-3}, T_p = 3 eV) and CAPS ($n_p = 2\times10^{13}$ cm^{-3}, T_p = 3 eV) plasmas, to evaluate the compression for the case of nearly complete neutralization. Simulations predict a spot size r_b = 0.5 mm (at 1/e of maximum beam density n_b) with peak $n_b = 4\times10^{12}$ cm^{-3} at the focal plane, and the axial compression factor is 55 due to a 10% velocity tilt, for a total compression factor of 25,000.

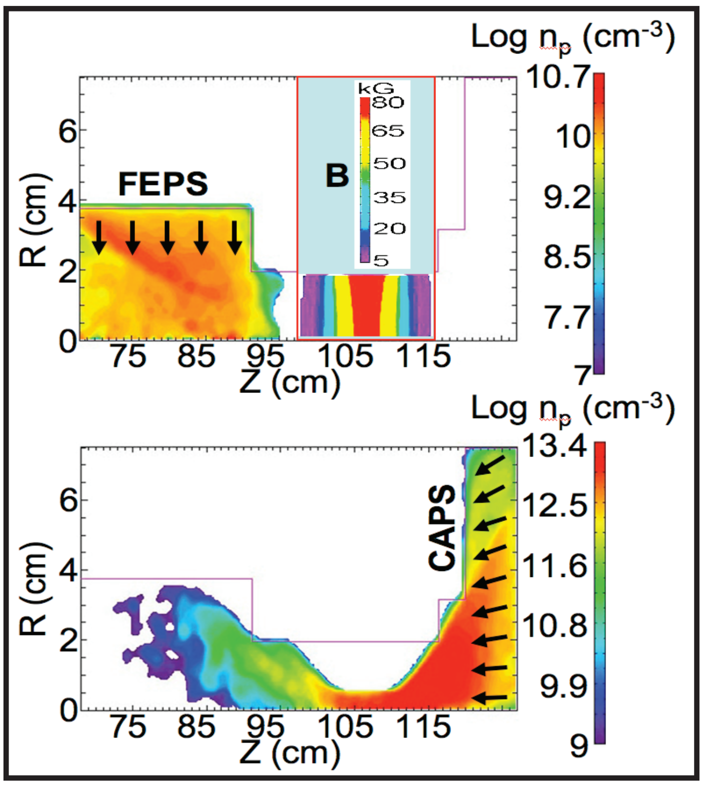

Fig. 1. Simulation set-up of plasma sources near the solenoid. (top) The FEPS plasma is injected radially upstream of the solenoid. (bottom) The CAPS plasma is injected downstream of the solenoid.

As a second step, we ran simulations in order to assess the plasma flow profiles from the sources, as depicted in Fig. 1.

The FEPS plasma ($n_p \sim 10^{10}$ cm^{-3}, T_p = 20 eV) is injected with a peak v_r^i = -0.38 cm/μs in the chamber upstream of the solenoid. The CAPS Al^+-e^- plasma ($n_p = 10^{12}$ cm^{-3}, T_p = 20 eV) is injected with supersonic ion velocity v_z^i = -3 cm/μs into the solenoid. The FEPS injection fills the drift region upstream of the solenoid, but the magnetic fringe-field keeps the highest n_p off-axis. The CAPS injection fills the solenoid up to r = 5 mm and continues to expand upstream. The plasmas from the two sources overlap so beams would not encounter plasma-free regions, except at large radii within the solenoid. Future simulations will study whether a difference in beam bunching is evident when these more realistic plasma profiles are employed, rather than the idealized profiles for which we predict 25,000× compression.

– Adam Sefkow

New consequence of relativity yields "warp-speed" computations

Relativity theory states that no matter what speed you choose for your spaceship, slow or close to light speed, the laws of physics always look the same. Yet, we have discovered that the "complexity" of some physics calculations is not the same at all speeds.

The number of computational steps required to simulate a problem grows not only with its overall size and duration, but also with the fineness of its details; it depends on the full range of scales involved, from small to large. If the laws of physics don't change with the speed, or "reference frame," of the observer, one might think that the range of scales shouldn't change either. However, one can imagine two objects that interact as they pass by one another at relativistic speeds. Each object has a certain overall length and also a certain size for its finest details. Relativity theory says that an observer in a different reference frame would see these scales altered by relativistic length contraction and time dilation. We found that the overall range of scales would change too, and potentially quite dramatically for the most high-speed interactions. Moreover, there's always an optimal frame in which the range becomes smallest. Consequently reasearchers may be able to speed up some of their calculations immensely, merely by recasting them in the best frame of reference.

For an example where a dense beam of protons passing at nearly the speed of light through a cloud of electrons, a Particle-In-Cell calculation using the HIFS-VNL code Warp required about 5000 time steps in the optimal frame, compared to more than five million in a frame fixed on the electron cloud. For other simulations involving the intense interaction of laser light with matter, as in free-electron lasers, the simulation speed may be improved by a million times or more. This work was published in the 30 March Physical Review Letters, available at ***http://link.aps.org/abstract/PRL/v98/e130405***. This note was adapted from a news story written by M. Buchanan in Physical Review Focus, published by the American Physical Society, available at **http://focus.aps.org/story/v19/st10**.

– J.-L. Vay

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