

## **Simulating Intense Beam Propagation in Ten-Kilometer-Long Accelerators in a Table-Top Experiment**

Studying a trapped, one component plasma in a simple compact experiment gives insight into the behavior of kilometer-long charged-particle beam transport systems.

The Paul Trap Simulator Experiment (PTSX) at the DOE Princeton Plasma Physics Laboratory (PPPL) has begun studying intense charged particle beams that travel over equivalent distances of about ten kilometers. An actual ten-kilometer-long transport system would be expensive and difficult to build, operate, and maintain. Such a system would use thousands of magnets to transport the particle beam, and making daily changes to those magnets in order to see what effects the changes would have would be time-consuming and expensive.

PTSX is doing experiments just like that in a device only three meters long and without the difficulty of thousands of magnets by considering the dynamics of the charged particle bunch in the beam frame. In the beam frame, by definition, the charge bunch is at rest, and the alternating-gradient magnetic fields of the long transport system can be modelled by applying oscillatory transverse electric fields. Moreover, the configuration of these electric fields is that of the well-known cylindrical Paul trap used for trapping charged particles in the laboratory. These oscillating electric fields alternately squeeze and stretch the bunch with the net result being an overall squeezing so that the particles are confined in the trap. The remarkable fact is that the equations that describe the transverse dynamics and collective processes of the charge bunches in the two systems are the same.

The novel features of PTSX are its large equivalent propagation distance, its intense “beam”, and its tremendous flexibility in simulating various transport system magnet configurations. The equivalent propagation distance is so long because the lifetime of the charge bunch in PTSX is a few hundred milliseconds while the frequency of the oscillating electric field is 75 kHz. Compared to the confining fields of the system, the intensity of the charge bunch in PTSX is greater than that at many accelerator facilities around the world (such as SLAC, Fermilab, and CERN) because PTSX can adjust both the amount of charged particles injected and the strength of the confining electric fields. Because the electric field is generated by voltage waveforms from a PC-controlled arbitrary function generator, the number of transport system magnetic field configurations that can be studied on PTSX is almost limitless.

Having previously demonstrated the principles of the PTSX concept, initial results are presented at this conference on the effects of waveform changes on the propagation of moderately intense beams. Our success in measuring the influences of these changes on the system give us confidence that PTSX will soon be able to shed light on important beam physics issues – issues such as the conditions for quiescent beam propagation over large equivalent distances, and the generation and dynamics of “halo” particles that escape from the beam and strike the walls, degrading the overall beam quality. These are key issues to understand as scientists plan and design the charged-particle transport systems and accelerators of tomorrow.

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**Further Information:** "Paul Trap Simulator Experiment to Model Intense-Beam Propagation in Alternating-Gradient Transport Systems", E. P. Gilson, R. C. Davidson, P. C. Efthimion, and R. Majeski, Physical Review Letters **92**, 155002 (2004).

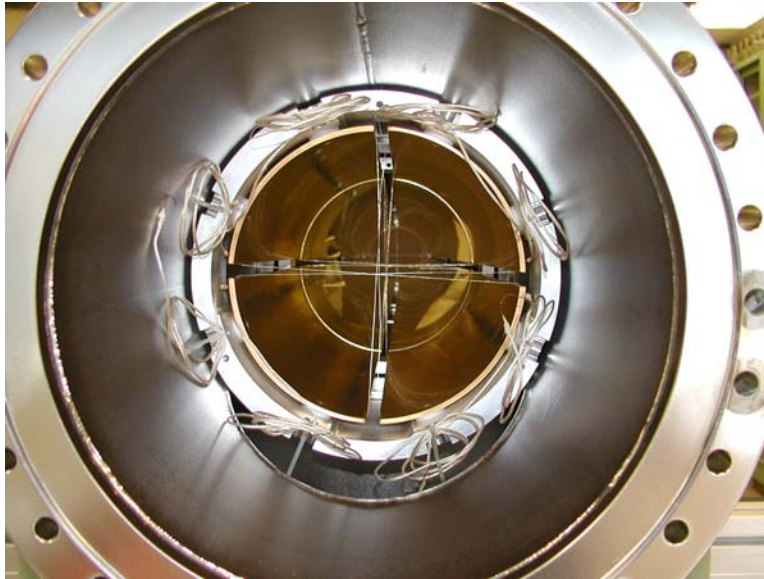


Figure 1: The view down the axis of PTSX shows the gold-plated, three-meter-long electrodes and the temporary alignment wires inside of the opened vacuum vessel. The strength of PTSX is in its simplicity of design and its flexibility to study a wide variety of beam physics topics.

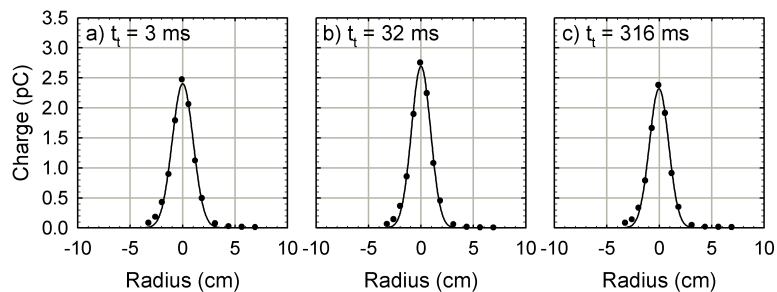


Figure 2: The profile of this moderately intense plasma does not change much over 316 ms. This corresponds to equivalent propagation distances of more than 20 km in an actual accelerator. Measurements like this lay the foundation for experiments that will explore the behavior of long charged-particle beam transport systems.