Title
Heavy ion fusion: Beyond ignition towards inertial fusion energy

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HIF 2002 Abstract: "Heavy Ion Fusion: beyond ignition towards Inertial Fusion Energy*"

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Demonstration of inertial fusion ignition and energy gain in the laboratory is expected with the National Ignition Facility (NIF) around 2010, which will provide the scientific basis for inertial fusion Energy (IFE). In addition, efficient and affordable drivers, mass-produced high gain targets, and long life, low activation chambers for 5 to 10 Hz pulse rates, will also have to be developed for IFE. Heavy-ion accelerators are candidate IFE drivers because (a) high energy particle accelerators of MJ-beam energy scale have exhibited intrinsic efficiencies, pulse-rates, and longevity required for IFE and (b) the clear-bore magnets used to focus heavy-ions would be much less subject to debris and radiation damage than laser final optics. Transporting and focusing higher space charge beams at lower 10-30 MeV/amu heavy ions desired for IFE is the main new challenge. The US program in heavy-ion beam science and driver development is coordinated in a three-laboratory consortium of LBNL, LLNL, and PPPL (called the HIF-VNL), with other HIF related research carried out at the University of Maryland, NRL, MIT, Mission Research Corporation, and the University of Missouri. HIF related chamber and target development is carried out as part of another OFES-sponsored virtual lab, the Virtual Laboratory for Technology (VLT), carried out by LLNL, GA, SNL, UCB, UCD and UCLA. The long-range HIF-VNL goal is to provide a comprehensive scientific knowledge base for inertial fusion energy (IFE) driven by high-brightness heavy-ion beams. Heavy-ion accelerator requirements derive from heavy-ion IFE target designs. The HIF-VNL beam science program addresses four top-level scientific issues associated with heavy-ion IFE drivers:

1. *What physics determines beam brightness in heavy-ion sources and low energy transport?*
2. *What phenomena affect the quality of space-charge-dominated beams undergoing transport and acceleration?*
3. *What role do non-linear processes and beam-plasma interactions play in chamber propagation and focusing?*
4. *How can we best apply and improve computational tools to provide the needed support (integrated modeling) for experiments, exploration of issues, and planning for the future?*

The HIF VNL is organized with four task areas that address these top scientific issues with separate experiments that concentrate on specific beam dynamics issues affecting beam brightness. Particle-in-cell simulations are in good agreement with past low current (mA level) beam experiments in transport, merging, acceleration and final focus, in which the dimensionless beam perveances (space-charge potential/ion kinetic energy) were similar to those in a driver. The program is now pursuing higher current experiments (100 mA to 1 A) in high brightness merging beamlet sources, transport at ~2 MeV, and ballistic focusing with plasma neutralization. Improved simulation capabilities enable modeling these experiments with realistic (not just idealized) beam distributions. The higher beam space-charge potentials attendant to these higher current experiments will allow us to study the effects of ionization of the residual gas by the beam, the trapping in the beam of stray electrons, and the dynamical effects on the beam of these two processes. A key strategic goal of the program is an integrated and detailed source-to-target simulation capability.

After these separate experiments are completed, the next step will be to study transverse and longitudinal emittance growth through injection, acceleration, longitudinal beam compression, and final focus in an integrated beam experiment. This integrated beam experiment will be much more challenging because prediction of the final focus spot size with integrated models depends on the accumulated beam phase space changes through each region of the system. The separate experiments in the next few years will test the key model components to be used in integrated modeling of a follow-on integrated experiment. In addition to beam experiments, HIF-VNL R&D is assessing and testing advanced accelerator technologies, including high gradient insulators, agile-waveform induction modules with solid state switching, and compact, high field superconducting quadrupoles.

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