Executive Summary

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On October 26-29, 2004, the Heavy Ion Fusion (HIF) Virtual National Laboratory (VNL) hosted a workshop at Lawrence Berkeley National Laboratory (LBNL) on "Accelerator-Driven High Energy Density Physics (HEDP)." The workshop was attended by sixty five researchers, from the VNL (the HIF/HEDP groups of LBNL, Lawrence Livermore National Laboratory (LLNL), and Princeton Plasma Physics Laboratory (PPPL)) as well as LBNL's Center for Beam Physics, and LLNL's X-and V-Divisions, Sandia National Laboratory, University of Maryland, Fermilab, Argonne National Laboratory, SLAC, Mission Research Corporation, SAIC, Tech X Corp, University of Nevada, Reno, and the University of Electrocommunication,Tokyo, who, together, gave representation to accelerator-, laser-, high energy density-, and computational- physics.

The objectives of the meeting were to 1.explore options and possibilities for a staged experimental program in Warm Dense Matter (WDM)/HEDP that utilizes ion accelerator sources as they become available, from early machines that can be developed at modest cost beginning with existing equipment, to later machines that reach well into the HEDP regime. The goals included defining physics regimes and scientific objectives to be explored, requirements for targets and diagnostics, and the scientific program that can be carried out using the ion beam drivers under consideration. The objectives were also to study various accelerator approaches, including conceptual designs of three types of accelerators: pulse-power-driven single-stage diodes; pulse-power-driven multi-stage accelerators; and rf-accelerators. In addition, options for pulse compression and final focus were to be studied.

Prior to the meeting some initial parameters were specified. Target characteristics that fall within a broad range in temperature and density, were specified as goals: Temperature between 0.1and 30 eV, and density between 10^-3 to 30 g/cm^3. The temperature must be constant over a hydrodynamic expansion time, and the volume must be sufficiently large to be able to diagnose the state of the properties with minimal (<~5%) variations over the volume being diagnosed. Additionally, the energy deposition over the volume must result in similarly small (<5%) variation in the volume being diagnosed. As a specific example, a Ne+1 beam, entering a 50 micron thick Aluminum foam target (mass density rho =0.1 solid density), with ion central energy entering the foam at 19 MeV, and exiting at 4.4 MeV. The combination N_{ions}/(r_{spot}/1mm)^2 > 1.4*10^13, where N_{ions} is the number of ions in the pulse and r_{spot} is the equivialent pulse radius if the intensity were uniformly distributed over a circle of radius equal to r_{spot}. If the pulse duration is less than 1 ns, these beam parameters have been estimated to result in a 15 eV plasma, with mean ionization state of ~2.7, and mean energy density 1.3*10^11 J/m^3.

The first day of the workshop consisted primarily of talks, reporting on what had previously been learned about the possibilities for using heavy ion beams to heat matter to "Warm Dense Matter (WDM)" conditions. WDM studies would be relevant, for example, to both the interiors of planets and the early stages of capsule implosion for inertial fusion energy. Talks were presented on the WDM science to be obtained, the experiments needed to figure out the science, and the requirements needed to carry out the experiments. Talks were also given on the status of injector and drift compression/final focus.

Prior to the workshop, four working groups were established: 1. science, experiments and diagnostics; 2. rf-accelerator concepts, 3. Pulsed-power accelerator concepts, and 4. drift compression and final focus. On the first day representatives from the working groups gave summaries and status reports of previous work and gave goals for the workshop. The working groups met separately for the next two days to explore concepts and estimate parameters for different architectures. Although, the groups nominally met separately, there was a great deal of communication between groups, as some meetings were held jointly, and some members "floated" between groups. The final half-day consisted of plenary summary sessions.

Group 1 held wide-ranging discussions, including the impact of HEDP diagnostics on the final focus and chamber design (and whether to incorporate multiple chambers in the design of the accelerator); repetition rate requirements; ion stopping and equation of state tutorials; recent warm dense matter experiments in Japan using lasers, capabilities of short pulse lasers for diagnosing accelerator-driven WDM experiments, and accelerator flexibility. Discussions also occurred on the current state of uncertainty in the equation of state (see figure 1), and the implications for this uncertainty in designing WDM experiments.

Group 2 examined several options for the rf-accelerator approach including a multiple-beam 50 MHz linac that incorporated interdigital H-mode cavities with drift tubes, and 15 T superconducting solenoids for focusing. Multiple-beam options (16 beams) with different beamline geometries and single beam options with storage rings were considered.

Group 3 looked at both single gap and multiple gap architectures using pulsed power to provide the acceleration voltage. The single gap architectures would rely on existing diodes, at Sandia, NRL, or elsewhere. A unique "ionization front accelerator" using the potential of an electron beam to accelerate ions along an ionization path created by a laser (and previous experiments of this concept) were described. Multiple gap accelerators that were considered included the novel Broad Band Traveling Wave Accelerator, and a multiple beam, electrostatic-quadrupole focused, drift tube linac.

Group 4 examined the drift compression and final focus sections, including issues of switchyards, focusing, and interface. Finding a background which strips ions to the desired state while providing sufficient electrons for neutralization is a key issue for drift compression. There were discussions on various "tools" in the toolbox including neutralized drift compression, large solenoids for final focus, dipoles to stop electrons (among other purposes), solenoids to suppress instabilities, pulsed lenses to compensate tilt-induced chromatic problems, and adiabatic funnels close to the experiments.

The results of the workshop identified several workable accelerators that could meet the set of given HEDP target drive requiremnts, (although costs and critical issues such as phase space constraints and development R&D requirements and pathways were not uniformly addressed).Much more future work is required to uniformly evaluate the costs of the various approaches and development requirements, and much of that work is already in progress.