HEDLP Status

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Presented to FESAC

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Key Points

- Public release of the interagency Task Force Report is imminent
- NAS report Plasma Science 2010 describes HEDLP, in particular IFE science, as a compelling subfield of plasma science for the DOE Office of Science
- Two Workshops have been held since the last FESAC
  - An IFE Strategic Planning Workshop was hosted by LLNL at San Ramon, CA
  - A HEDLP Workshop was held at ANL in May, chartered by the Under Secretary for Science
- Future meetings and plans

The IFE Workshop in April was organized by the community, driven by a sense of urgency …

- About 115 registrants
- 3.5 days. Talks with lots of discussion time; breakout sessions. Mostly U.S., with strong talks from Japan and the U.K.
- 1 day specifically on HEDLP opportunities & issues, w/ breakouts. Other days also had some HEDLP-related talks and discussion
- Proceedings will be published in the Journal of Fusion Energy

All the program elements for an IFE R&D program were discussed. HEDLP will have a large impact on the optimal vision

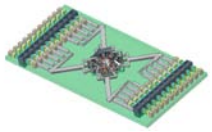
The IFE R&D program rolls back from this

World IFE Program ~2007-2020

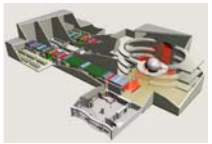
HEDLP

- Target optimization
  NIF, Omega, LMJ, Z…
- Rep-ratable drivers ("beamlets")
- Chambers (liquid,solid) and nuclear technology
- Support technology (target fab, injection, optics…)

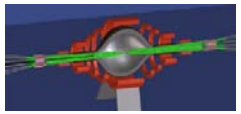
High Average Fusion Power Facility ~2015-2025



NRL's FTF



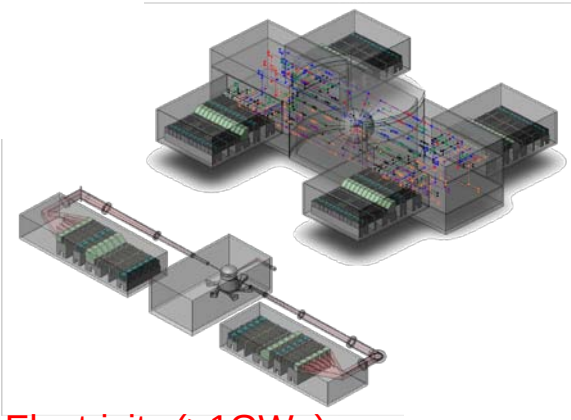
HiPER



HI-FTF, etc…

- High av. power 10's-100's MW
- Demonstrates sustainable fusion energy in steady-state
- Not req'd to demonstrate commercial viability

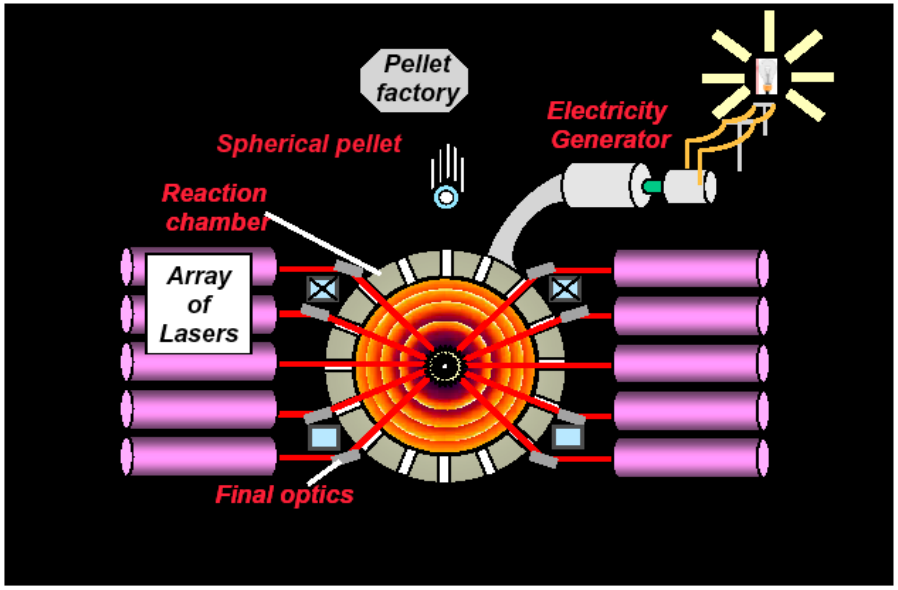
Attractive Commercial Plant Competitive with Advanced (Breeder) Fission



- Electricity (>1GWe)
- Hydrogen production
- Desalinated water
- Fission hybrid (breed/transmute)
- Etc, ….

Courtesy of E. Synakowski

The Workshop heard from the HAPL program, where much laser IFE research is performed

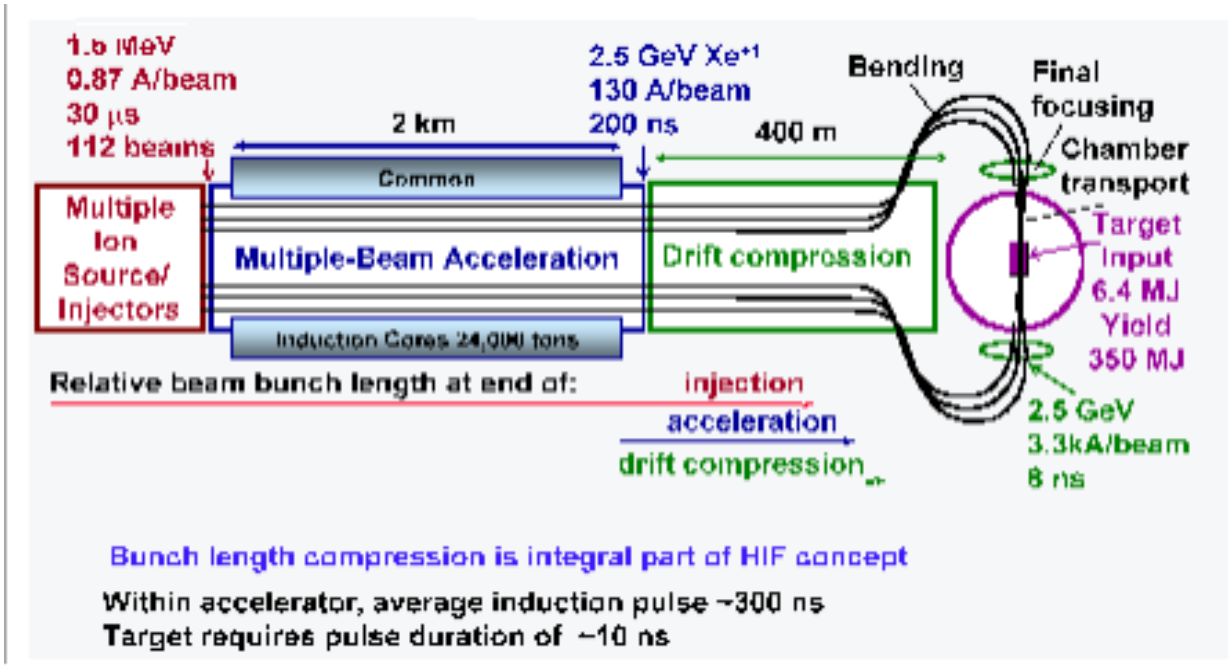


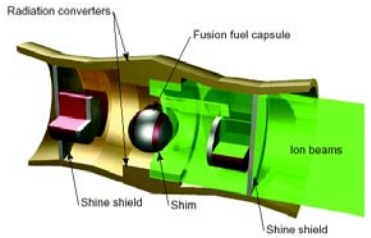
- HAPL: High Average Power Laser (HAPL) program. Laser-driven IFE R&D.
- HAPL includes both **KrF** & **Diode Pumped Solid State Laser (DPSSL)** options
  - KrF progress was described (5 Hz, 10,000 shots)
  - DPSSL
    - cost scaling and efficiency issues discussed
  - HAPL focus: *the integrated problem*. Particular attention to a particular vision for an FTF (NRL (direct drive, dry wall, 5 Hz, ~ 150 MW, research tool)

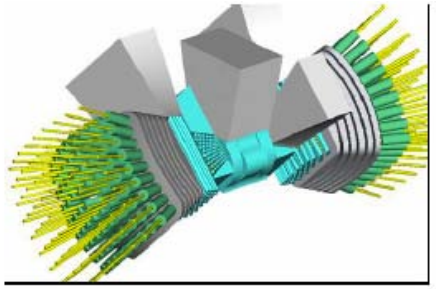
Courtesy of E. Synakowski

Another mainline approach discussed was heavy ion fusion

- Funded by OFES. It's research was directed towards HEDLP in 2004. HIFS-VNL (LBL, LLNL, PPPL)
- An emphasis in HIF research has been the possibility of using thick liquid wall chambers. Such chambers may also support other IFE approaches.





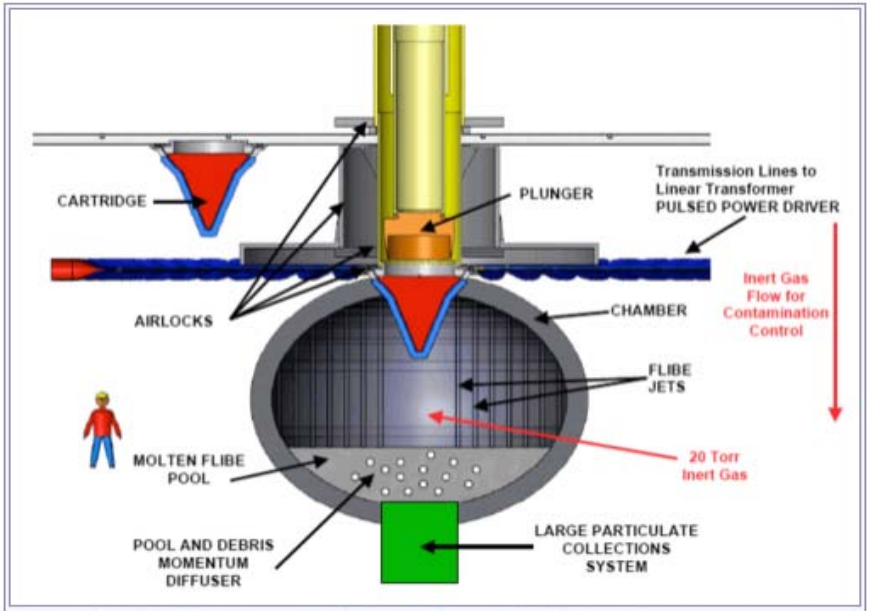


Long lasting, low activation chambers that can withstand 300 MJ fusion pulses @ 5 Hz

Courtesy of E. Synakowski

The Workshop heard updates for Z-IFE

- NNSA funding in FY04-05 and internal funding in FY06 allowed Sandia NL to engage the broader IFE community to advance the concept in an integrated way.



Cutaway of a planned Z-IFE reactor, with a human being (on the left) for scale.

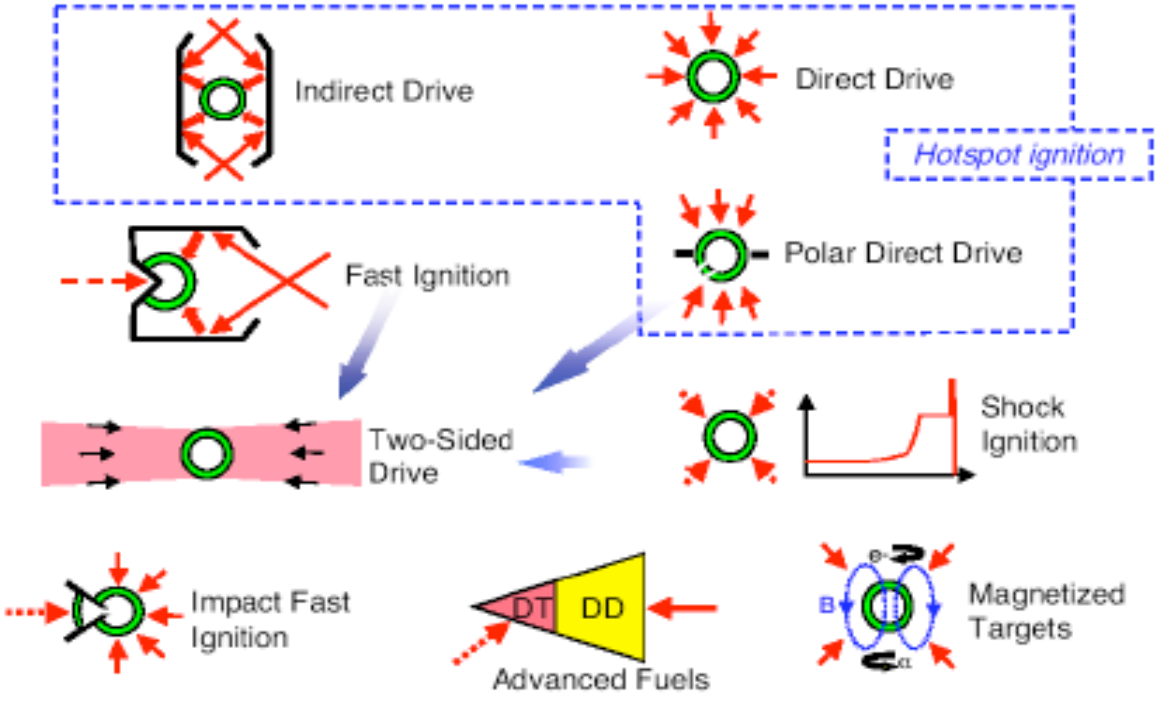
- Chamber is based on thick-liquid wall concept and the R&D is synergistic with the HIF approach.

Courtesy of E. Synakowski

NIF ignition will serve as a linchpin in developing energy-related HEDLP, especially when supported by research on a range of facilities

- The reach of HEDLP target physics is broad: NIF will obtain first-of-a-kind required data on basic questions about HEDLP relevant to all approaches.

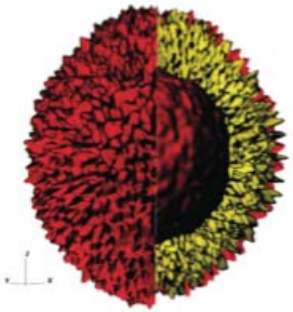
- Post-ignition: Optimizing the target physics through HEDLP will sharpen our vision for what an IFE plant can ultimately be.
- Approach: *benchmark the science in a range of conditions* on facilities to maximize the output of the science extracted from NIF and in extrapolating beyond NIF's results

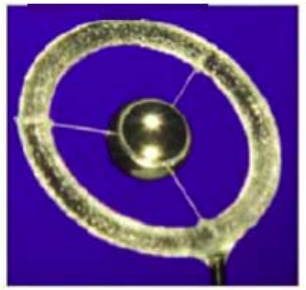


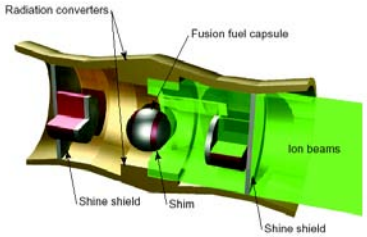
Courtesy of E. Synakowski

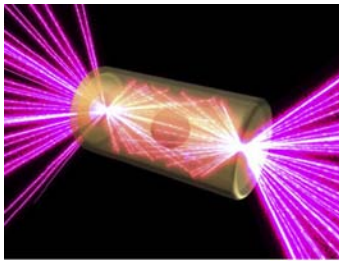
HEDLP physics will be a major factor in making choices between these visions and in optimizing them. A sampling of issues…

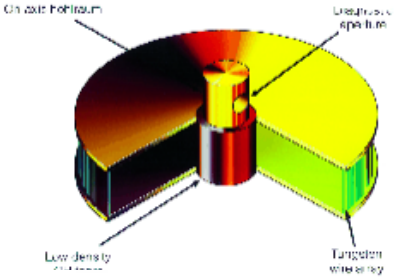
- **Direct drive vs indirect laser drive**: Rayleigh-Taylor instability OK in both? Polar direct drive reduce symmetry requirements? One have favorable LPI compared to another?
- **Heavy ions**: can they be focused sufficiently to heat a target to fusion conditions? Beam ion/fuel interactions make direct drive attractive? Can beam “wobbling” stablize the R-T instability?
- **Laser plasma interactions**: What wavelength will we need to make LPI acceptable for IFE? Should we consider a Z pinch, which has no LPI issues? Or heavy ions?
- **Fast ignition, shock ignition, and advanced targets**: Will HEDLP physics provide basis for these tools & enable increased gain and simpler power plant architecture?

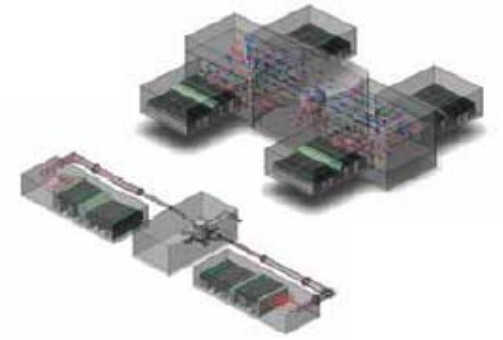








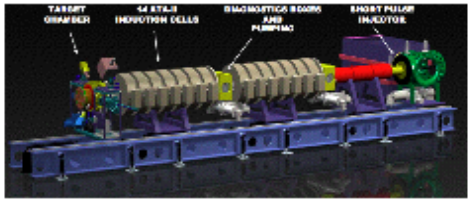




Courtesy of E. Synakowski

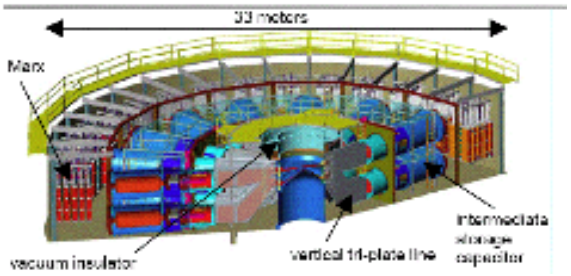
The experimental tools span a broad basis for developing HEDLP science

Courtesy of E. Synakowski

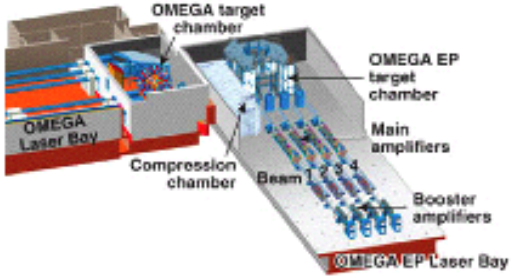


NDCX/NDCX-II

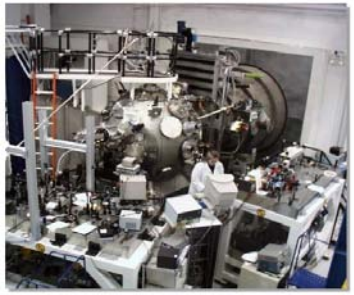
ZR



Omega-EP

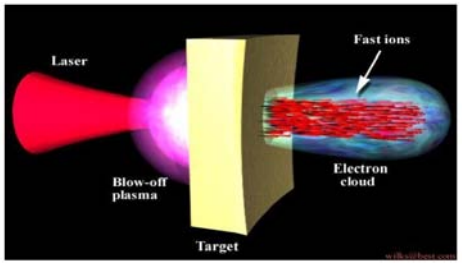


NIF

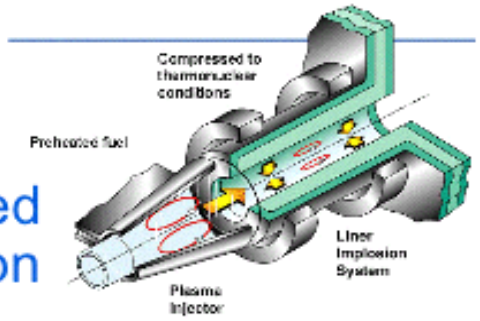


Nike; Electra

University/nat'l lab petawatts



Magnetized inertial fusion



The General Concludions from the IFE Workshop

- With the imminence of ignition in NIF, DOE should plan for a transition from a laboratory ignition feasibility experiment to a program that addresses the science required for the energy application of inertial fusion
  - Explore attractive ignition schemes and/or target physics for power applications
  - Address the feasibility of the rep-ratable technologies that underpin the scientific feasibility of inertial fusion for power application.
- New experiments and computational capability are ushering in a new age of exploration of HED laboratory plasmas, and the science at the heart of HEDLP is rich
  - The Workshop participants eagerly embrace the opportunity to advance IFE science through HEDLP research

The HEDLP Workshop in May at ANL was chartered by the Under Secretary of Science

- Charter: Assess frontier experiments on major HED science facilities, with a particular focus on NIF and the opportunities there to perform experiments related to the science of high energy density plasmas.
- Chairs: Bob Rosner, the Director of ANL, and John Browne, former Director of LANL. Workshop Report in final stages of preparation.
- Three principal scientific themes emerge from the Workshop:
  - Enable fusion energy by high energy density laboratory plasmas
  - Create, probe and control new states of matter in HEDLP
  - Ultrafast dynamics: catching reactions in the act

Workshop Product Theme #1: Enable fusion energy by high energy density laboratory plasmas

- Ignition at NIF will focus world attention on the potential of IFE
  - The science of HEDLP will create the basis for interpreting these ignition results, and for developing laboratory scenarios that extend fusion promise beyond ignition and toward fusion power
  - This science needs to be grounded in improved knowledge of the EOS in warm and hot dense matter
- Ion beams, two-stage ignition, and HEDLP systems with embedded magnetic fields have the potential of simplifying fusion power plant system architecture, and may lead to improved inertial fusion energy systems
- The grand challenge of inertial fusion energy represents the best of all attributes of scientific research, combining aspirations of the highest and best impact to civilization with multi-scale scientific questions of the richest subtlety and complexity.

Workshop Product Theme #2: Create, probe, and control new states of matter in HEDLP

- The next generation of experiments puts us at the frontier of a new regime in physics
  - Qualitatively new phenomena emerge when energy density exceeds a certain threshold
  - How do radiation-dominated plasmas behave?
  - What happens in high-pressure quantum matter?
  - What happens in strong-shock-dominated HED plasmas, involving high Mach-number shock waves, plasma jets, turbulence, etc?
  - What happens when plasmas go relativistic?
  - How are elements made in dense plasmas?
  - How can one use coherent, nonlinear, collective processes to control HEDLP?
  - What novel magnetic regimes can be created?

Workshop Product Theme #3: Ultrafast dynamics – catching reactions in the act

- HEDLP experiments can now produce x-ray pulses with durations short enough (femto-seconds) to freeze frame atomic motion, with the wavelengths short enough to probe atomic spatial scales (angstroms)
- Intense lasers coupled with large accelerator-based light sources will enable unprecedented probing of chemical reactions or rearrangement of atoms
- Intense lasers can place several photons per cell in a solid or large molecule
  - Modify matter
  - Concentration of energy on fast time scales may lead to new phase changes or novel molecular configurations
- HED plasmas can be used to generate very intense pulses such as magnetic fields, x-rays, electrons, ions or even neutron bursts

General Conclusions from the HEDLP Workshop

- Compelling scientific opportunities of high intellectual value exist across the field of HEDLP
- An well-organized and appropriately funded DOE program would produce significant and exciting advances of this emerging field of science

Future Meetings and Plans

- We will be holding the First International Conference on HEDP as part of the APS April Meeting 2008 in St. Louis, MO
  - Bruce Remington has been asked to be the Chair
- There will be a special session on DOE Research on High Energy Density Plasmas in this year's DOD Annual Directed Energy Symposium of the Directed Energy Professional Society in Huntsville, AL
  - Francis Thio has been asked to Chair the session
- We will be holding a HEDLP Town Hall Meeting at the APS DPP Meeting in Nov 2007.
  - Cris Barnes is the host for the meeting
- We will be issuing a Solicitation for new proposals in spring 2008 competing for new money in FY 2009
- On-going grants in the program will be re-competed with new proposals when the grants are due for renewals
- Detailed plans are being discussed between SC and NNSA

OFES is consolidating several ICC projects with HED content within the HEDLP Program

- Several of the ICC projects are exploring the science of HED plasmas including high Mach-number, high flux density plasma jets
- These projects have been moved out of the ICC program into the HEDLP program, increasing the OFES budget for the Joint Program for HEDLP from 12.22M to 16M in FY 2008.