Overview of OFES LLNL Fusion Program

Fusion Power Associates
30th Anniversary Meeting and Symposium
Fusion Energy: Status and Prospects
December 2-3, 2009

Don Correll
Fusion Energy Program Leader (acting)
LLNL’s Fusion Energy Program is dedicated to advancing the science required for fusion’s viability – MFE and HEDLP/IFE

FEP engages the OFES fusion community through multiple collaborations:

- DIIIID
- NSTX
- Edge Simulation Laboratory
- Fusion Simulation Project
- SciDAC FACETS (Core-Edge Transport)
- SciDAC Center for the Study of Plasma Microturbulence
- Heavy Ion Fusion Sciences VNL
- FSC for Extreme States of Matter
- FI Advanced Concepts Exploration
- Virtual Lab for Technology
FEP reflects our OFES major deliverables, commitments to collaborative partnerships, and LLNL’s fusion energy vision.

FEP FY10 Funding
~ 12.5M$ OFES
~ 0.8M$ DIIIID ARRA
~ 0.6M$ NDCXII ARRA
~ 0.3M$ U.S ITER Project
~ 0.2M$ NSTX Spectrometer ARRA

Don Correll
FEP Leader (acting)
Wayne Meier
FEP DPL

Dave Hill
DIIIID Deputy Director

John Barnard
HIFS-VNL Deputy Director

Harry McLean
ACE FI
LLNL Leader

DIID and NSTX
Steve Allen

HEDLP/HIFS-VNL
Alex Friedman

HEDLP/Fast Ignition
Prav Patel

Theory/Modeling
Bruce Cohen

Technology/Materials
Wayne Meier
LLNL FEP – GA DIII-D collaboration has been an effective science partnership since 1986; recent accomplishments . . .

- $800K ARRA funding for IR & Visible periscopes for DIII-D
  - ITER prototype
  - Previous U.S. ITER contracts
  - 3 fast IRTV systems
- Motional Stark Effect
  - 64 channel, fast DIII-D system
  - ITER optical design
- Comparison of Edge Plasma and Divertor models with new data
  - Edge flow (with Australia University)
  - Heat flux

DIII-D and NSTX
Steve Allen

LLNL IRTV Design for ITER

LLNL ITER MSE Optical Design

ELM heat Flux Versus Time
FEP theory and modeling continues to advance plasma understanding in MFE and HEDLP/IFE (>100 pubs 2006 - 2009)

- Theory and simulation of LPI for NIF and FI
- Support for DIII-D
- Simulation of tokamak core microturbulence
- SSPX spheromak fast photo of kink
- NIMROD MHD spheromak simulation
- ITER Controller Simulation
- Tokamak edge simulation and theory
FEP personnel are contributing to important fusion technology R&D needs

- Superconducting magnets including ITER central solenoid
- Multi-scale modeling of radiation damage to fusion materials
- Safety analyses in support of future fusion power plants and experimental facilities including ITER
- Chamber design and systems modeling & analyses for laser IFE

Central Solenoid Model Coil (ITER prototype)

Modeling divertor vacuum pipe break in ITER

Harnessing Fusion Power Theme for MFE ReNeW
FEP has a key role in the HIFS-VNL’s NDCXII project

- FEP staff members lead
  - WDM theory and simulations effort
  - Machine physics design effort
- Innovative design using LLNL’s ATA induction cells led to large costs savings

### Comparison of NDCXI and NDCXII

<table>
<thead>
<tr>
<th>Parameter</th>
<th>NDCXI</th>
<th>NDCXII (projected)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ion species</td>
<td>K⁺ (A=39)</td>
<td>Li⁺ (A=7)</td>
</tr>
<tr>
<td>Ion energy</td>
<td>300-400 keV</td>
<td>1.5 MeV &amp; more</td>
</tr>
<tr>
<td>Focal radius</td>
<td>1.5 - 3 mm</td>
<td>0.5 mm</td>
</tr>
<tr>
<td>Pulse duration</td>
<td>2 - 4 ns</td>
<td>0.5 - 1 ns</td>
</tr>
<tr>
<td>Peak current</td>
<td>~ 2 A</td>
<td>~ 10 A &amp; more</td>
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FEP HEDLP/Fast Ignition is developing experimentally validated ‘state of the art’ 3D computational tools

<table>
<thead>
<tr>
<th>State-of-the-art codes</th>
<th>Experimental benchmarking</th>
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</thead>
<tbody>
<tr>
<td>3D Rad-Hydro code—HYDRA</td>
<td>TITAN LLNL 200J, 0.5ps in 1 beam</td>
</tr>
<tr>
<td>Hydrodynamics, radiation transport, EOS, ionisation</td>
<td></td>
</tr>
<tr>
<td>3D PIC code—PSC</td>
<td>OMEGA EP LLE 5.2kJ, 10ps in 2 beams</td>
</tr>
<tr>
<td>Relativistic laser absorption, electron generation, electromagnetic fields</td>
<td></td>
</tr>
<tr>
<td>3D Hybrid-PIC—LSP</td>
<td>NIF ARC LLNL 10kJ, 10ps in 8 beams</td>
</tr>
<tr>
<td>Self-consistent electron transport, field generation, large-scale plasmas</td>
<td></td>
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</tbody>
</table>

Next Speaker:
Overview of Fast Ignition at LLNL
Prav Patel
FEP Associate Program Leader for HEDLP/FI
FEP staff members are engaged in helping achieve ignition on NIF (e.g. ‘tuning beam wavelength’ result)

**Recent NIF symmetry**

Two laser beam transfer ener...some of the

Earlier this year energy transfer some of the

**Lasnex simulations with an energy transfer model show controlled cross-beam transfer**


**FEP’s Pierre Michel, Laurent Divol et al.**

**Phys. Rev. Lett. 102, 025004 (Jan 2009)**

A symmetric implosion was achieved without changing the laser energy, by simply tuning the wavelength shift by a few Angstroms between the inner and outer beams
**Early Career PI’s of interest to OFES reside not only in FEP but other LLNL fusion research areas**

FEP helped LLNL submit six proposals to OFES in response to the DOE SC Early Career solicitation

<table>
<thead>
<tr>
<th>Name</th>
<th>Area</th>
<th>Proposal Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bayramian, Andy</td>
<td>NIF</td>
<td>World’s First High Average Power Petawatt Laser for Fusion Neutron Generation, Particle Acceleration, and X-ray source for Fusion Materials Science</td>
</tr>
<tr>
<td>Kemp, Andreas</td>
<td>FEP</td>
<td>Integrated multi-scale simulation tool for intense laser-matter interaction - modeling plasma physics from near vacuum to 1000 times solid density</td>
</tr>
<tr>
<td>Marian, Jaime</td>
<td>Condensed Matter and Materials</td>
<td>Computational Modeling and Design of Nano-structured Materials for enhanced Radiation Resistance in Fusion Environments</td>
</tr>
<tr>
<td>Shverdin, Miro</td>
<td>NIF</td>
<td>Precision monoenergetic gamma-ray (MEGa-ray) source for time-resolved phase-space measurement of plasmas</td>
</tr>
<tr>
<td>Soukhanoedkii, Vlad</td>
<td>FEP</td>
<td>High Flux Expansion Divertor Program on the National Spherical Torus Experiment</td>
</tr>
<tr>
<td>Tang, Vincent</td>
<td>Engineering</td>
<td>Experimental and Numerical Study of Wave-Plasma Interactions at ITER Relevant Parameters</td>
</tr>
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