1. HAPL Chambers and Materials Effort Introduction

2. Chamber Tasks Coordination

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Step 1: Choose a Concept

Tungsten armor on low activation ferritic steel

- High melting temperature of tungsten
- Known, nuclear qualified materials
- Experience in fabrication and joining
- Compatibility with most coolants
- Ability to engineer tungsten if needed
- Can test a lot of the key issues now
Step 2: Identify Key Issues

- **Armor/FW Critical Issues**
  1. Viable Material Structures
  2. Helium and Hydrogen Isotope Diffusion.
  3. Ablation (ions & X-rays including surface roughening)
  4. Thermomechanical Fatigue and Fracture Toughness
  5. Thermophysical Properties (including irradiation effects)

- **Other Issues to be addressed later depending on blanket and system (e.g. need for barrier coating, corrosion...)**
Step 3: Set Up Coordinated Plan of Attack

**Chamber Tasks Coordination (CTC)**
- Armor/First Wall
- Blanket
- System
- Integrated design effort

**Materials Working Group (MWG)**
- Materials Development
- Properties
- Fabrication methods
- Constraints (e.g. temp. limits)

**Combination of modeling and experimental R&D**

Credible case that in-reactor components will provide required performance and lifetime in an integrated environment prototypical of a power plant
Develop Overall Chamber Program Milestones in Support of HAPL Program Goals

Path to develop Laser Fusion Energy

Chamber Program Milestones

Phase I: Basic Fusion Science & Technology
1999-2005

Credible case that dry wall is viable for laser IFE for Phase II

Phase II: Full Scale Components (IRE)
2006-2014

Complete study of wider range of W/FS types and downselect for further multi-effect testing

Select best armor/FW/chamber unit for ETF and start fabrication and final qualification testing (Also for chamber test modules)

Phase III: ETF
2014-

Armor/FW/chamber ready for ETF + at least one chamber test module
Develop Tasks/Deliverables to Achieve Overall Chamber Milestones

• Focus on first major milestone (within 12-18 months):
  ”Make credible case that dry wall is viable for laser IFE for Phase II”

• CTC discussion and meeting to evolve top level goals and tasks & deliverables in support of this (to be described in subsequent view graphs)

• Assumptions should be consistent with materials Time Line, in particular:
  - Assumed material maturation period appropriate for a flat plate or simple engineered (eg castellated, graded) first wall. More complex “engineered” structures will likely take longer.
  - Critical issues resolved no later than FY-06 (or before, as assumed here)
    - Sub-threshold ablation
    - Stability of LAF-W system
    - Helium management
  - Detailed structural analysis/optimization of first wall structure complete in Phase-1.
  - Push off radiation effects and modeling until mid Phase-2. This adds some risk.
Armor/First Wall: (1) Viable Material Structures

Top-Level Goal: Develop a W/LAF structure with good bond integrity and thermal stability

Deliverables

(1.i) Complete initial screening through bend testing and thermo-mechanical testing. 
~ 6 months

(1.ii) Down select to ~3 material combinations that look the best. 
~ 1 year

(1.iii) Assess and select most promising engineered structure(s) (including pre-testing in RHEPP, XAPPER, DRAGONFIRE Lab, He-testing) 
~1 year

(1.iv) Complete bonding and similar pre-screening and testing for engineered structure 
~2-3 years
Armor/First Wall: (2) Helium and/or Hydrogen Isotope Management

Top-Level Goal: Demonstrate zero armor exfoliation.

Deliverables

(2.i) Model development (refinement) for He behavior in tungsten. ~6 months

(2.ii) Monoenergetic He testing. ~1 year

(2.iii) Spectrum testing (with foils). ~1 year

(2.iv) Synergetic effect (He+H). ~1 year

(2.v) Implantation/anneal to prototypic FS/W structure ~ 2 years

(2.vi) Similar testing as (2.ii) to (2.v) for engineered W ~ 2-3 years
Top-Level Goal: Demonstrate that armor should have acceptable lifetime of about 3 years.

Deliverables --> Complete:

(3.i) Engineering modeling (including validation) in support of short-term experimental results ~6 months

(3.ii) Development of long term predictive capability (understanding mechanisms such as roughening) ~ 2 years

(3.iii) Demonstration testing (RHEPP, DRAGONFIRE, XAPPER)
- Cook and look experiments (scoping) ~6 months
- Model validation experiments ~ 1 year
- Full range of testing to enable prototypical evaluation (in conjunction with modeling) ~ 2 years
- Same range of tests for engineered materials ~2-3 years
Armour/First Wall: (4) Thermomechanical Fatigue and Fracture Toughness

Top-Level Goal: Demonstrate that for a nominal stress level fatigue-induced cracks will not propagate in the underlying structure and delamination will not occur.

Deliverables - Complete:

(4.i) Modeling of temporal stress state of W/FS interface
- Fully dense material ~ 6 months
- Engineered material ~ 6 months

(4.ii) Thermomechanical fatigue testing of bond and fatigue crack growth
- Fully dense material ~ 1.5 years
- Engineered material (depending on availability) ~ 2 years

(4.iii) IR thermal-fatigue of selected coupons >2 years
Top-Level Goal: Compile baseline property data base (including irradiation effects).

Deliverables - Complete:

(5.i) Compilation of relevant MFE material properties ~6 months

(5.ii) Identification of data need ~6 months

(5.iii) Development of plan to measure missing properties if possible (including irradiation effects) ~1 year

(5.iv) Compilation of Materials Handbook ~1 year
Blanket

Top-Level Goal: Develop at least one credible and attractive blanket concept compatible with the choice of armor (W) and structural material (FS).

Deliverables - Complete:

(B1.i) Scoping study and down selection of blanket concepts (choose 1-2 concepts for detailed study) ~1-1.5 years

(B1.ii) Detailed design study of selected blanket concept(s) ~2-3 years
System Studies

**Top-Level Goal:** Develop an integrated systems code that can be used to investigate a variety of laser-IFE design options and configurations.

**Deliverables - Complete:**

(S1.i) Integrated chamber/blanket/power cycle model for 2-3 blanket options, including cost estimates.  
~6 months

(S1.ii) Development and inclusion of performance and costing models for KrF and DPSSL drivers.  
~2 years

(S1.iii) Inclusion of cost scaling models for remaining power plant systems.  
~3 years
Chamber Interfaces

- Evolution of chamber environment and characterization of the chamber conditions prior to each shot is a key interface issue:
  - Target injection and survival requirements
  - Laser propagation and focusing
  - Armor protection

Top-Level Goal: Develop a multi-dimensional gas dynamic model for the IFE chamber (SPARTAN).

Deliverables:
(i) Explore need for and possibility of including 3-D. ~1-1.5 years

(ii) Add multi-species capability. ~1-1.5 years

(iii) Detailed parametric studies to characterize chamber conditions prior to each shot as a function of chamber size, yield, and gas type and density. ~1-1.5 years