SUMMARY & DISCUSSION OF KEY MATERIALS SCIENCE PROBLEMS IN LASER INERTIAL FUSION ENERGY (IFE)

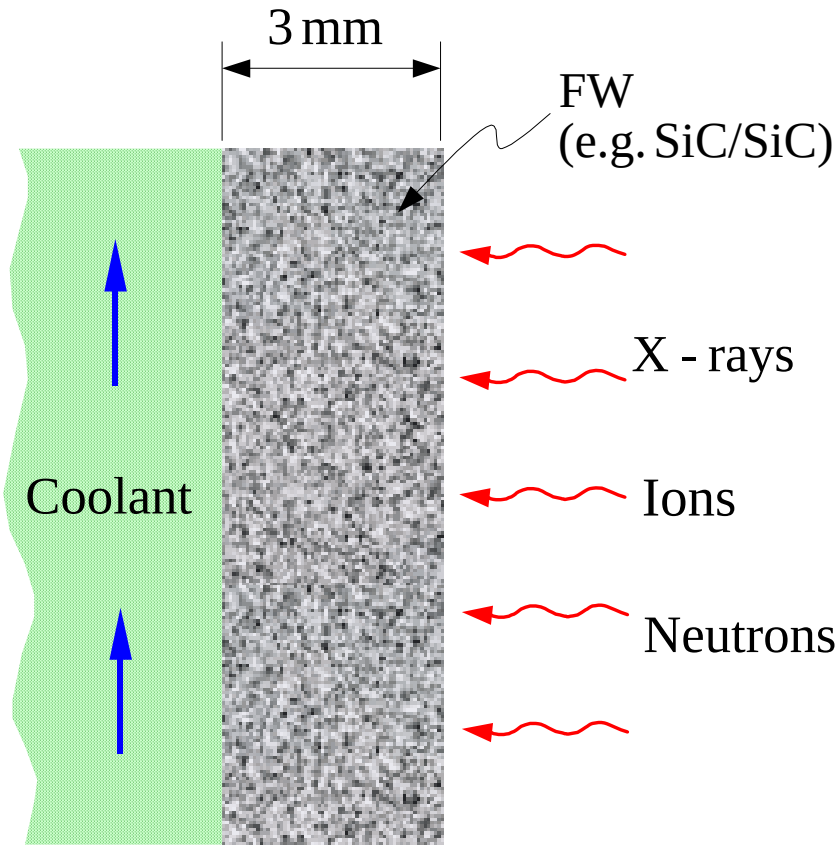
N.M. Ghoniem (UCLA) and L. Snead (ORNL)

US Fusion Materials Science Program

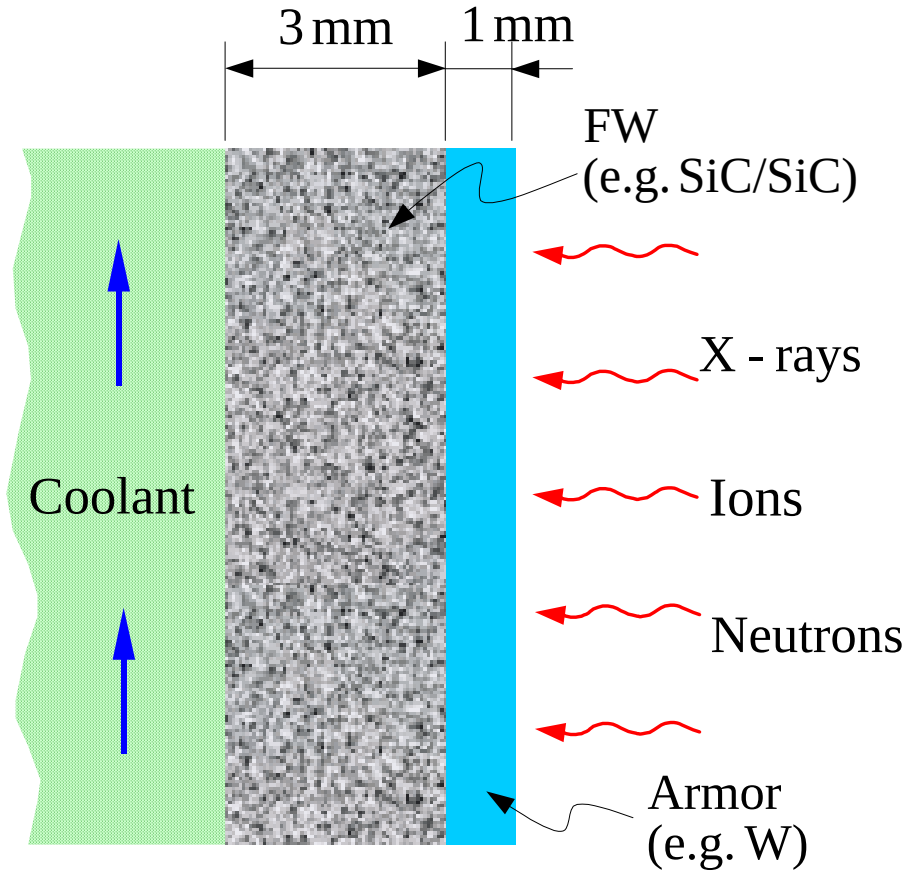
Strategic Planning Meeting

August 26-30, 2002

Material Systems-I

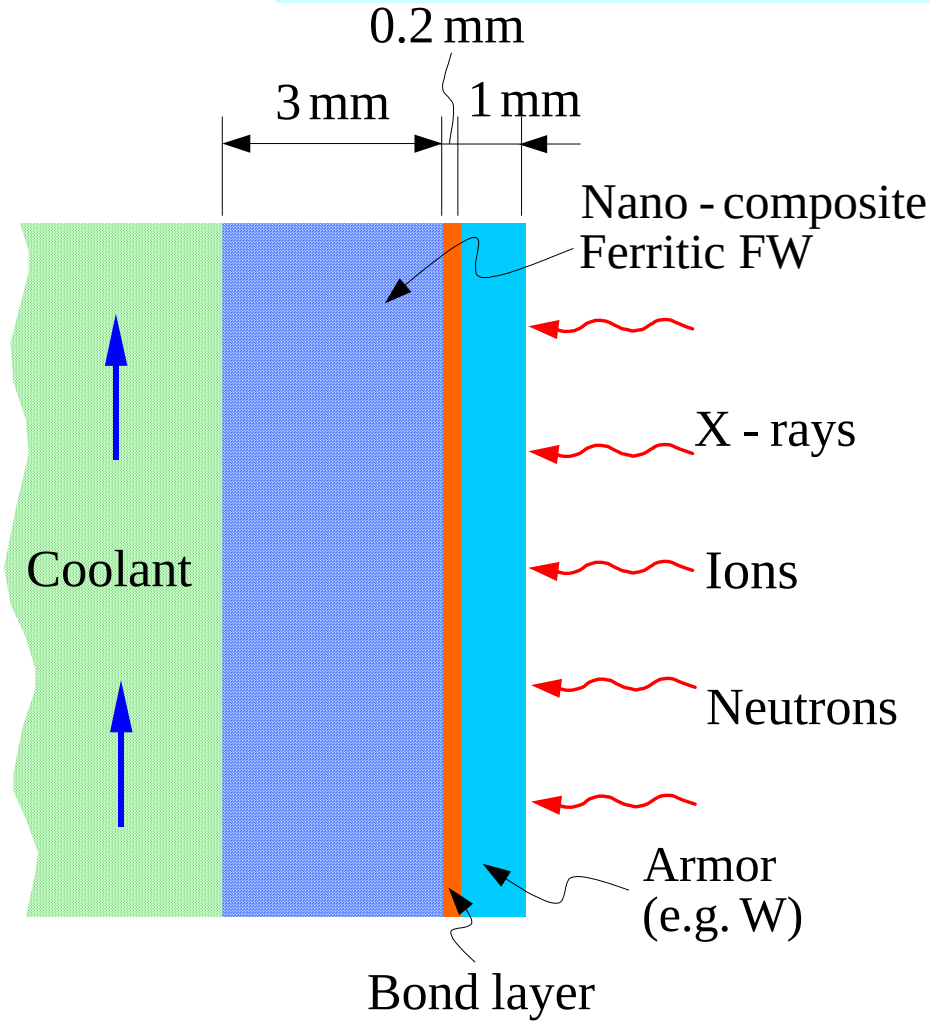


Monolithic composite FW

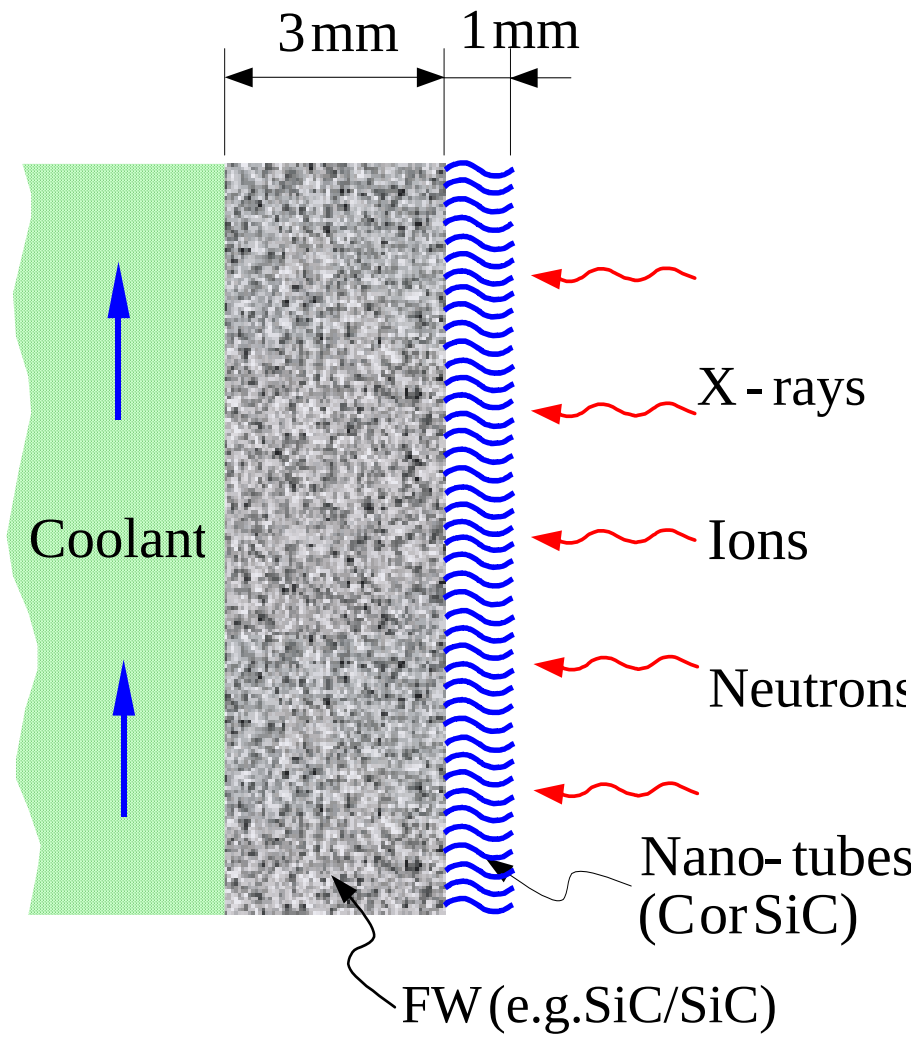


Armored composite FW

Material Systems-II

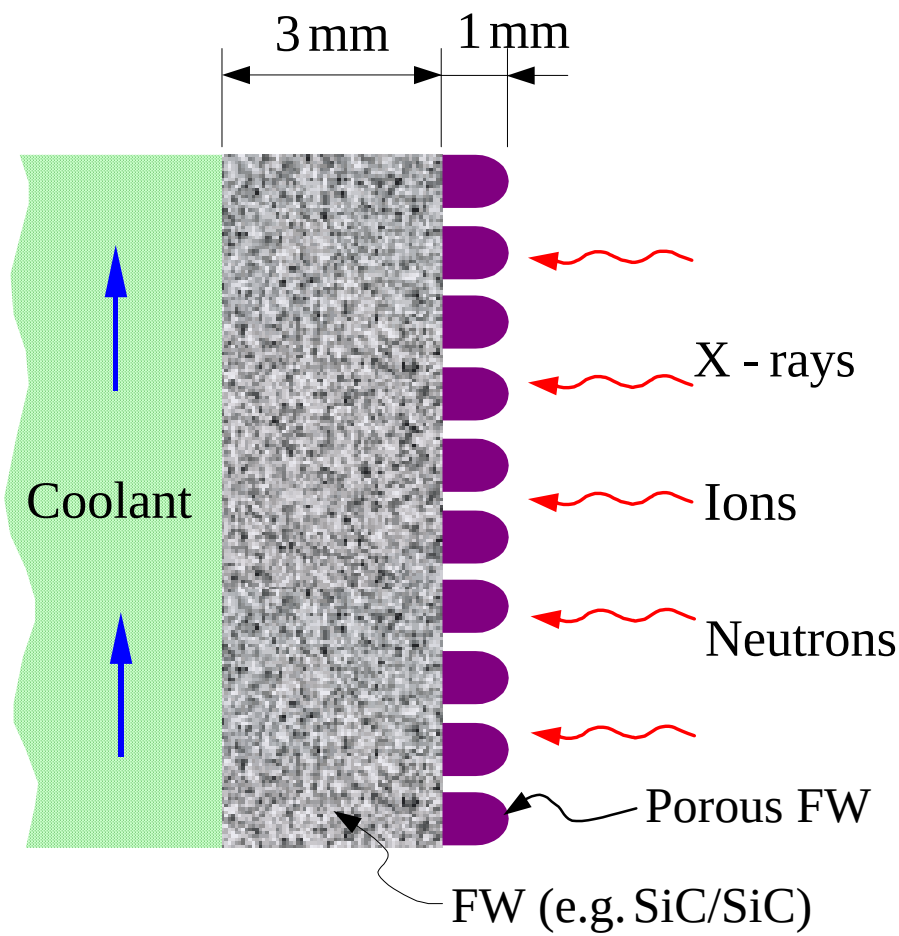


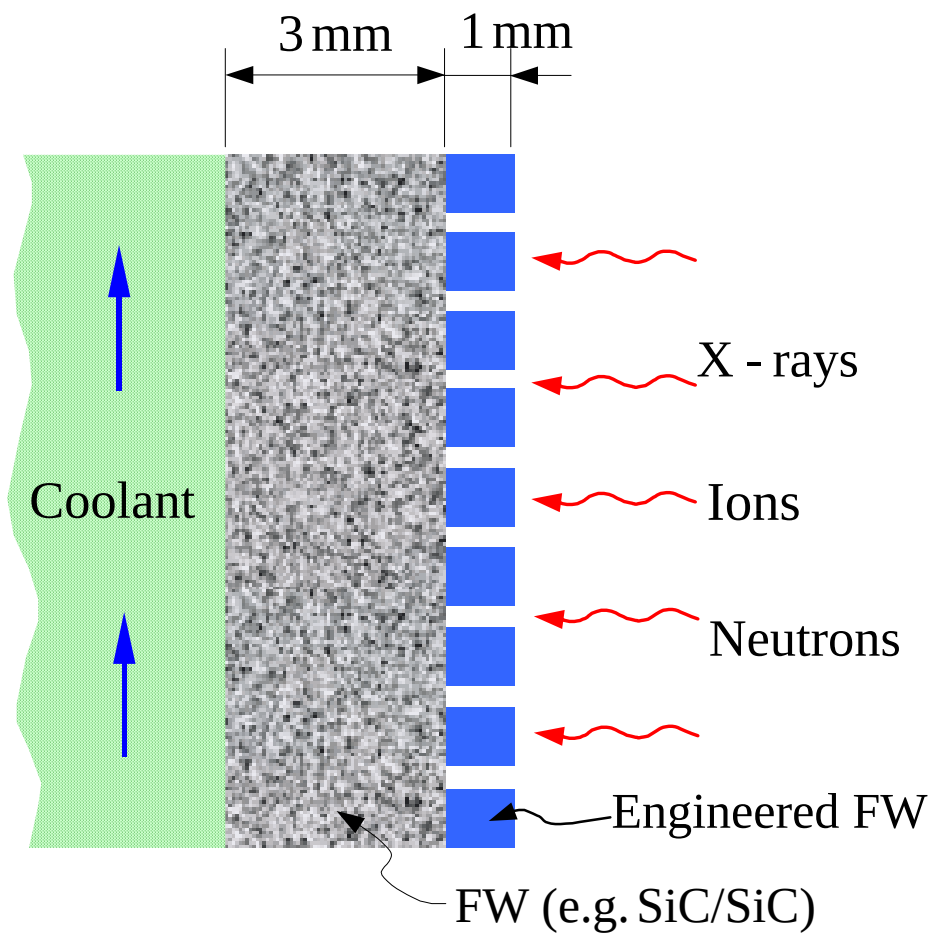
Armored nano - composite Ferritic FW



Engineered FW

Material Systems-III





KEY SCIENCE & TECHNOLOGY CHALLENGES-1

(1) Pulsed Neutron Effects on Material Degradation:

- **Key Issue:** Effects of damage rate (6-7 orders of magnitude larger than MFE) and inter-pulse transients on microstructure & properties.
- **Common Issues with MFE:**
  - High rates of gas generation in C/ SiC;
  - Burnup and stoichiometric changes;
  - SiC: Degradation of K_{th}, micro-cracking, differential swelling, hermiticity.
  - C: Dimensional stability (i.e. shrinkage/ swelling);
- **Questions:** (1) property extrapolation; (2) materials engineering; (3) effects of pulsed irradiation & excessive gas generation.

KEY SCIENCE & TECHNOLOGY CHALLENGES-2

(2) Pulsed X-Ray Effects on Surface Ablation:

- Mechanisms of Radiation Enhanced Sublimation (RES) in intense non-equilibrium conditions;
- Surface modification technologies for materials engineering;
- Photon-surface interaction processes:
  - Threshold events;
  - Effects of surface defects, segregation & contamination;
- Cumulative X-ray pulsing effects on sub-threshold events;
- Effects on degradation of optics.

KEY SCIENCE & TECHNOLOGY CHALLENGES-3

(3) Synergistic Neutron & Thermomechanical Damage to Structural Components;

- Transient pressure and surface loading effects:
  - Stress waves, vibrations;
  - Gradual destruction of fiber/ matrix/ interphase properties.
- Degradation of strength by neutrons/ thermo-mechanical loads;
- Realistic lifetime and reliability limits, which account for damage evolution mechanisms;
- Integration of component design is necessary.

KEY SCIENCE & TECHNOLOGY CHALLENGES-4

(4) Control of Macroscopic and Microscopic Surface Deformation of Reflective Optics:

- Multiple length-scale deformation by: differential swelling, thermal expansion, gravitational & mechanical loads, sub-surface defects & fatigue-induced dislocation motion;
- Macroscopic deformation: >> control via deformable mirrors and active control loops;
- Microscopic deformation: >> control via materials design, layered structures and coatings.
- <u>Issues:</u>
  - Length-scale limit for active deformation control ?
  - Function separation into optics & mechanical?

KEY SCIENCE & TECHNOLOGY CHALLENGES-5

(5) Mechanisms of Laser-Induced Damage in Reflective Optics:

- LIDT is caused by surface and near-surface defect generation. For a single-shot ~ 1-10 J/cm^2.
- Amorphous & engineered coatings can improve LIDT for single shot (amorphous Ni >> 40 J/cm^2).
- Data and models on multiple-shot LIDT are lacking. Limited data shows a factor-of-ten reduction after 10000 shots.
- Role of microstructure engineering (e.g. coatings, surface modification techniques & nano-structured multi-layers)?
- Effects of dust, debris and neutrons?

KEY SCIENCE & TECHNOLOGY ISSUES-6

(6) Mechanisms of Optical Absorption in Transmissive Optics:

- Mechanisms of oxygen-deficient centers (F-centers), strained Si-O bond centers, E+ centers and non-bridging hole centers have been determined.
- Fluence limits for concentration buildup of color centers?
- Annealing kinetics, agglomeration & interaction with H, T, and He?
- Transmutation effects? (e.g 27.5 appm/FPY H, 69.1 He, 54 C, 2 N, 15 Mg, and 4 Al)
- Transient effects: in-situ versus ex-reactor behavior?

KEY SCIENCE & TECHNOLOGY ISSUES-7

(7) Safety and Environmental Impact of Materials:

- The interaction of tritium with ceramic fiber composites (graphite and SiC) and refractories ?
- The attachment, release and diffusion of hydrogen isotopes in graphite and SiC?
- Safety and environmental limits on alloy compositions can be leveraged from MFE studies.