Material System Thermomechanics Interactions (cont'd)

- **International Collaboration: Role / Impact / Recognition**
  - **Serves a unique role in IEA program on R&D for Ceramic Breeders; Gives US access to the much larger world R&D program**
  - **FZK and JAERI supplied their favorite ceramics for measurements at UCLA; Scientists from JAERI and Japanese Universities came periodically to participate in experiments**
  - **Japan is providing funds to the US under JUPITER-II (starting April 2001) for joint research on thermomechanic interactions for SiC/Ceramic Breeder/beryllium (recognition of unique role, high scientific/engineering quality, and effectiveness)**
  - **Has provided key input to solid breeder blanket designs (in ITER and conceptual reactor designs)**
- **Excellent Engineering Science and Ph.D. Thesis Topics / Scholarly Publications**
  - **The research is mostly organized around Ph.D. thesis topics**
  - **"Science-based" research to serve practical applications**
  - **Excellent connections to other fields: Ph.D. graduates in high demand; successful careers**
  - **Eight comprehensive scholarly journal papers in 3 years in the Journal of Nuclear Materials, International Journal of Heat & Mass Transfer, Fusion Technology, and Fusion Engineering & Design (based mostly on Ph.D. thesis research)**

JUPITER-II

Started: April 2001

JUPITER-II: Introduction/Overview

- **JUPITER is an acronym for Japan-US Collaborative Program for Materials Irradiation, Theory, and Experimental Research**

- **JUPITER-II is a new phase of US-Japan (DOE-Monbusho) collaboration**

  Collaboration began in July 1987 as Annex I to DOE-Monbusho Exchange of Letters of Cooperation in Fusion Research and Development

  JUPITER-II has just begun (April 2001) for a period of 6 years

- **JUPITER-II is broader in scope than previous phases of collaboration**

  JUPITER focused on irradiation effects in structural materials

  JUPITER-II will address issues of structural and non-structural materials and their interactions for a broad spectrum of thermal, chemical, magnetic, and irradiation environmental conditions

JUPITER-II: Introduction/Overview

- **JUPITER- II leverages US resources**

  Cost of tasks is shared equally by US and Japan at about $1.3M per year total from each side; US funds come from Fusion Tech. and Materials Research programs

  Tasks are conducted in "unique" US facilities (i.e. not available in Japan)

  Funds from Japan essentially double the resources for experiments in US

  Participation in experiments by Japanese scientists increases research personnel

- **JUPITER- II addresses key scientific issues of candidate materials systems for magnetic fusion (molten salt, lithium, and He cooling) and inertial fusion (molten salt cooling)**

  Molten salt cooling issues: FLiBe tritium/chemistry and thermofluid flow

  Liquid lithium cooling issues: V alloy coatings and behavior in fusion environments

  He cooling issues: SiC thermomechanics and behavior in fusion environments

- **JUPITER- II involves many Japanese Universities and several US organizations (ORNL, ANL, PNL, INEEL, UCLA, SNL)**

  Key Persons: DOE: Sam Berk, Program Coordinators: Zinkle, Sze

Chamber Technology is a Key Part of JUPITER-II

- **Chamber Technology Elements under JUPITER-II:**
  1. Thermofluid
     (Tohoku Univ. / Kyoto Univ. / UCLA / SNL / PPPL / ORNL / ANL)
  2. Thermomechanics
     (Kyoto Univ. / Yamanashi Univ. / JAERI / UCLA / ORNL)

- **Including Chamber Technology in JUPITER-II (while none was in earlier JUPITER), and the interest of Japan in providing resources for joint experiments on US Chamber facilities is a recognition of uniqueness, role, and quality of US Chamber Research**

  - Given that US facilities are "small-scale" laboratory experiments at a university (UCLA), constructed with modest funding, is a very strong indicator of the effectiveness, resourcefulness, and excellence of US Chamber researchers

- **Extensive joint technical planning was conducted for over a year. Tasks defined are of great value to both Japan and the US.**

  - Brief information will be provided today in the presentations by Morley (thermofluids) and Ying (thermomechanics)

Thermofluid Task Objectives

(JUPITER-II)

1. Understand underlying Science and Phenomena for Flibe (and other low conductivity, high Prandtl No. liquid) flow and heat transfer through:
    - **a. Conducting experiments using Flibe simulant**
    - **b. Modeling and analysis of fundamental phenomena**
2. Compare experimental and modeling results to provide guidance and database for designs and next generation stage of larger experiments
3. Identify and assess new innovative techniques for enhancement of Flibe heat transfer (a major feasibility issue for Flibe designs)

JUPITER-II

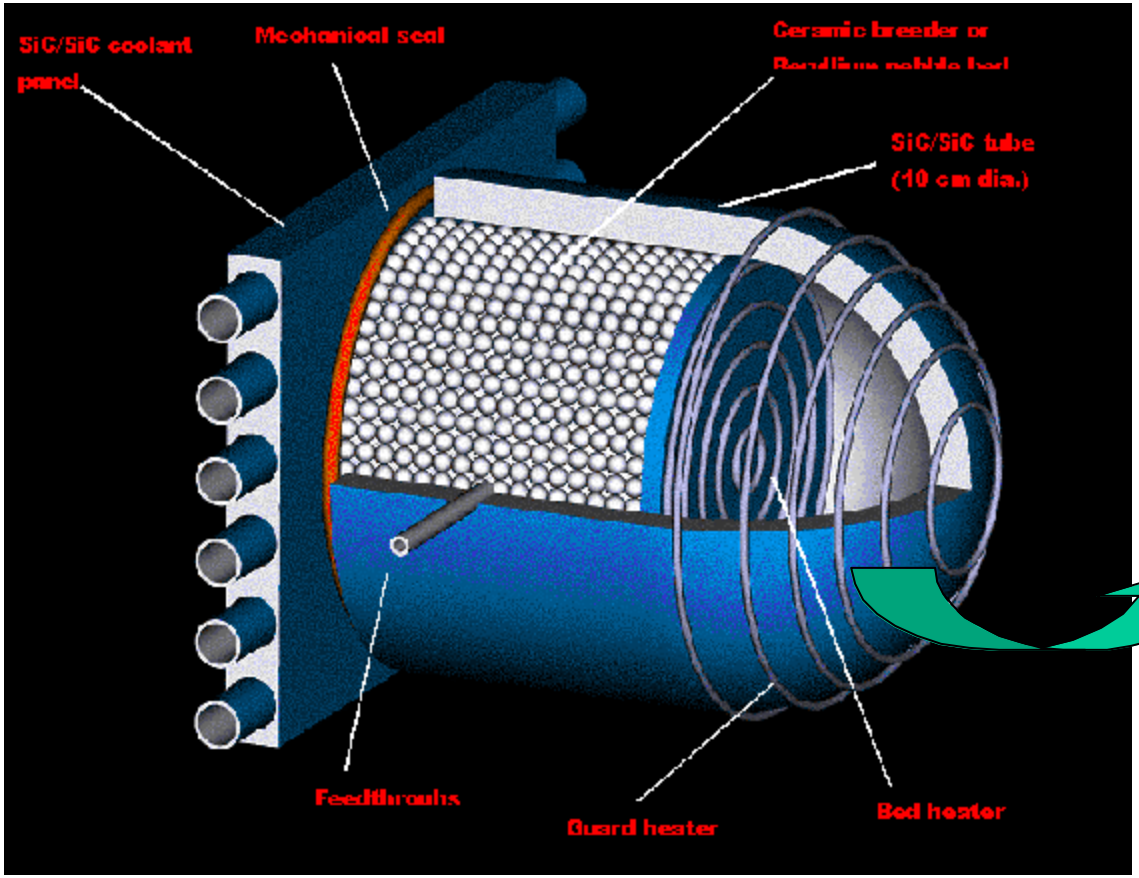
Thermomechanics for SiC/SiC/He with Be and ceramic breeders

- Extends the present thermomechanics modeling and experiments to SiC/SiC, helium-cooled systems with ceramic breeders and beryllium
- Objectives/Scope: experiments and models for:
  - *Thermomechanic interactions of SiC/SiC with Be and ceramic breeders*
  - *Short-term temperature effects on chemical compatibility*
  - *Thermomechanical performance at elevated temperatures (>800 C at interfaces)*
  - *Provide important scientific and engineering input to*

    a) the design of irradiation experiments, b) reactor studies
- Although SiC is a strong candidate structural material for fusion:
  - *Key fundamental data is lacking. Interface thermal conductance is a feasibility issue to keep SiC above the minimum temperature for radiation induced thermal conductivity degradation*
  - *Also, fabrication and joining techniques are in early stages*
  - *Japan will provide the SiC needed for the experiments from their R&D program (in addition to funds*)
- Collaborative efforts between (UCLA, ORNL) and (Kyoto Univ, Univ of Yamanashi, JAERI)

Potential Shaping Techniques Were Identified for SiC to Fabricate JUPITER-II Solid Breeder/SiC Material System Test Articles

JUPITER-II Collaboration between UCLA and University of Kyoto



PIP + RS processing

JUPITER tests will also be very useful in:

- **Integrating a number of technical disciplines and technical issues**
- **Providing boundary conditions for SiC based on Be/Ceramic Breeder consideration (and vice versa)**
- **Providing an opportunity for scientists and engineers in the material and blanket communities to work together**

Important Contributions from US Neutronics Community

(at modest funding)

University of California-Los Angeles (UCLA)

Measurements and Analysis of Integral Experiments
Safety Factors/Design Margins Quantification

USDOE/JAERI Collaborative Program on Fusion Neutronics (1984-1993)- Completed
ITER Task 218 Shielding Experiments and Analysis (1994-1997)-Completed
IEA Co_Operative Program on Fusion Nuclear Technology, Sub-Task "Neutronics"(1995-2002)-On-Going

TSI Research

Nuclear Data Needs and Prioritization (On-Going)
Coordination of New Data Evaluations (On-Going)

Radiation Safety Information Computational Center (RSICC)

Codes/Data Implementation on National Energy Research Super Computing (NERSC) Facility (On-Going)

University of Wisconsin (UW)

Code Development for Activation and Application (On-Going, unfunded)

Summary

- **The MFE Chamber Research Program serves well the goals of the Fusion Program:**

  Advancing Science, Innovation, Progress in the Near-Term, More Attractive Vision for the Long-Term, Contributions to and Interactions with other Scientific and Engineering Fields

- **APEX is effectively organized as a partnership between physics and all elements of the technology program.**

- **Excellent connections to other scientific fields and engineering applications have been established; particularly on free surface, MHD flows**

- **Excellent record of publications (and comprehensive website)**

  In 5 years: 130 Journal Articles, 140 Conference Papers/Reports

- **Trained many graduate students and post-docs who became leaders in fusion and other fields in the US and abroad**

➢ Excellent and rapid progress has been made in exploring and advancing liquid walls:

Presentation

- **Free surface, turbulent, MHD flow control and interfacial transport** — Morley
  - *extended state of the art CFD codes to free surface, MHD flows*
  - *planned, designed and constructed M-TOR and FLIHY small scale experiments to study phenomena and verify models*
- **Plasma-liquid surface and bulk interactions** — Kaita
  - *extended state of the art plasma edge and physics codes*
  - *data from experiments on plasma devices (DIII-D, CDX-U, etc.)*
  - *new resistive MHD code and LM schemes for plasma stabilization*
- **NSTX liquid surface test module (and C-MOD)** — Ulrickson
  - *Physics and engineering planning, analysis, and design*
- **Practical Engineering Issues and Analysis** — Nelson
  - *new fluid candidates (e.g. Sn, SnLi) for better compatibility with plasma at elevated temperatures*
  - *several innovative schemes for "flow control" and enhancing interfacial transport*
  - *many creative innovations to develop practical engineering solutions*

➢ Remarkable Progress on Extending the Capabilities of Advanced Solid Walls and Evolutionary Concepts:

Presentation

- **Innovative Schemes for extending the capabilities of solid walls to higher power density and high temperature using W alloys and novel heat transfer scheme for vaporization of Lithium (EVOLVE)** — Wong
- **Comprehensive material assessment of high-temperature refractory alloys and other structural materials for liquid and solid walls** — Ghoniem
- **The material system Thermomechanics Interactions program has made remarkable achievements in modeling and small-scale experiments and gained for the US access to the much larger international R&D program on evolutionary concepts** — Ying
- **Part of the new JUPITER-II program will utilize US facilities for chamber thermofluids and thermomechanics. Japanese funds double US resources and are a recognition of the quality and effectiveness of our research program**

(Included in presentations by Morley and Ying)