Summary of Japan-US Collaboration PHENIX Project and PSI Studies in IMR-Oarai

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1. Japan-US PHENIX Project (2013–2018)
2. Additional Japan-US Collaboration (D-Be-He mixture plasma exposure in PISCES, UCSD and microstructure analysis in Shimane University)
3. PSI studies in the International Research Center for Nuclear Materials Science, Institute for Materials Research (IMR-Oarai), Tohoku U.
4. Summary

ICFRM-17 Tungsten IEA Meeting, October 12, 2015, Aachen, Germany

1. Japan-US PHENIX Project (2013–2018)

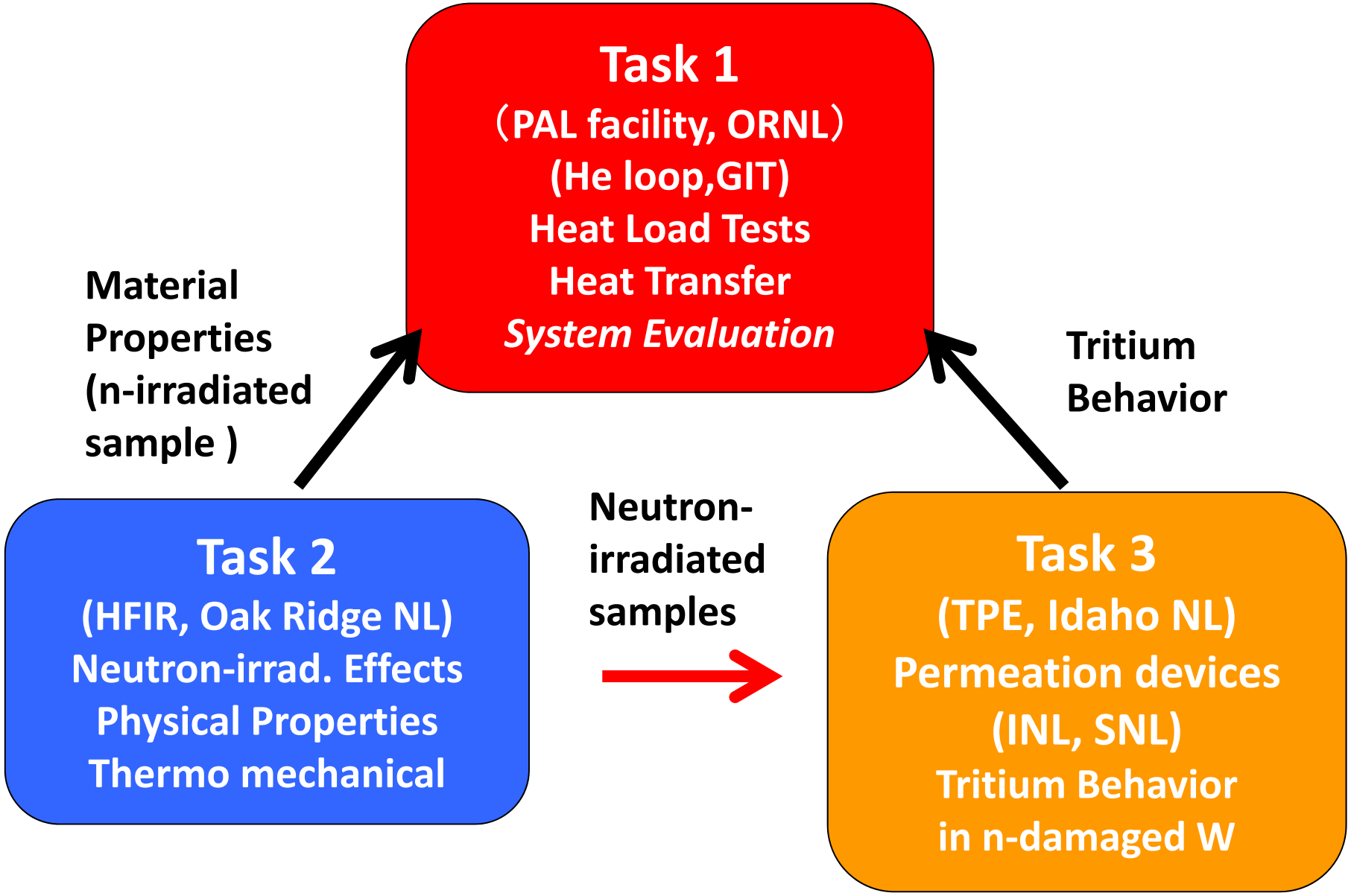
PHENIX

PFC evaluation by tritium Plasma, HEat and Neutron Irradiation eXperiments

The goal of this project is to evaluate the feasibility of He gas-cooled divertor with tungsten material armor for DEMO reactors.

	Japan	USA
Representative	Yoshio Ueda (Osaka U.)	Barry Sullivan (DOE)(interim)
Coordinator	Yuji Hatano (U. Toyama)	Barry Sullivan (DOE)(interim)
Task 1	Takehiko Yokomine (Kyoto U.) Yoshio Ueda (Osaka U.)	Adrian Sabau (ORNL) Minami Yoda (GT)
Task 2	Tatsuya Hinoki (Kyoto U.) Akira Hasegawa (Tohoku U.)	Yutai Katoh (ORNL) Lauren Garrison (ORNL)
Task 3	Yasuhisa Oya (Shizuoka U.) Yuji Hatano (U. Toyama)	Masashi Shimada (INL) Dean Buchenauer (SNL)

Structure of this Project



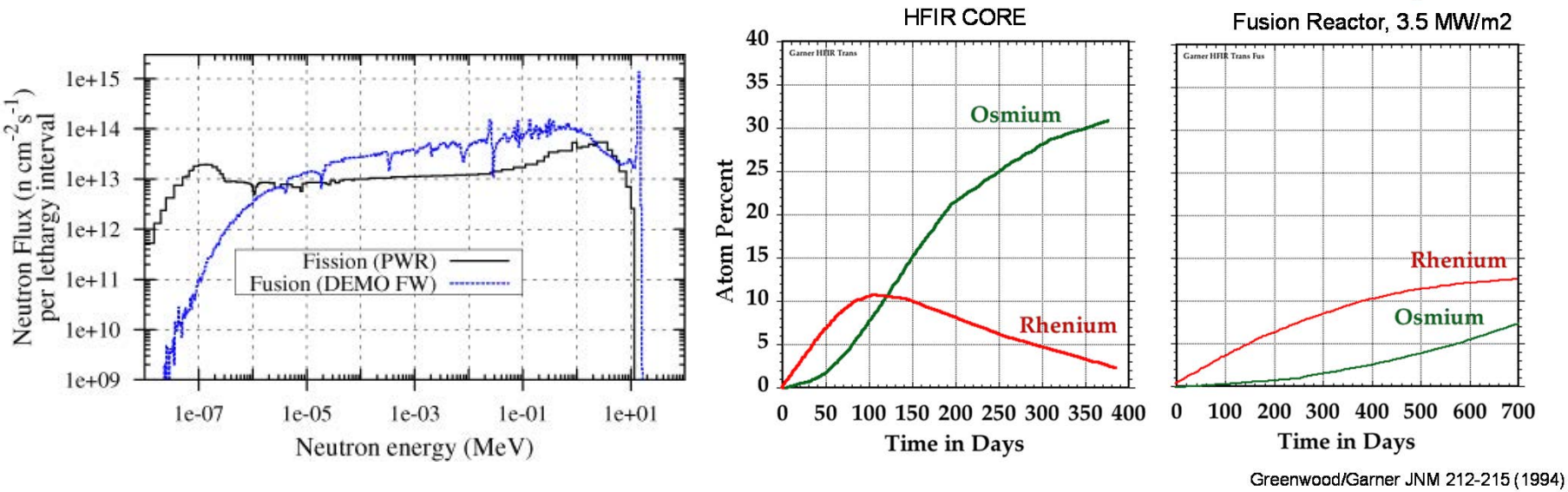
Characteristics of PHENIX neutron irradiation in High Flux Isotope Reactor (HFIR), Oak Ridge National Laboratory

- ✓ Irradiation temperature: 500, 800 and 1200 ˚C.
- ✓ Irradiation dose: 1–1.5 dpa.
- ✓ Thermal neutron shielding (Gd)

  Thermal neutron shielding is essential for fusion-relevant transmutation.
- ✓ Specimens for hydrogen isotope retention and permeation measurements

  ϕ 6 x 0.5 mm or ϕ 10 x 0.5 mm, W, W-Re, K-doped W-Re, UFG-W, Layered materials

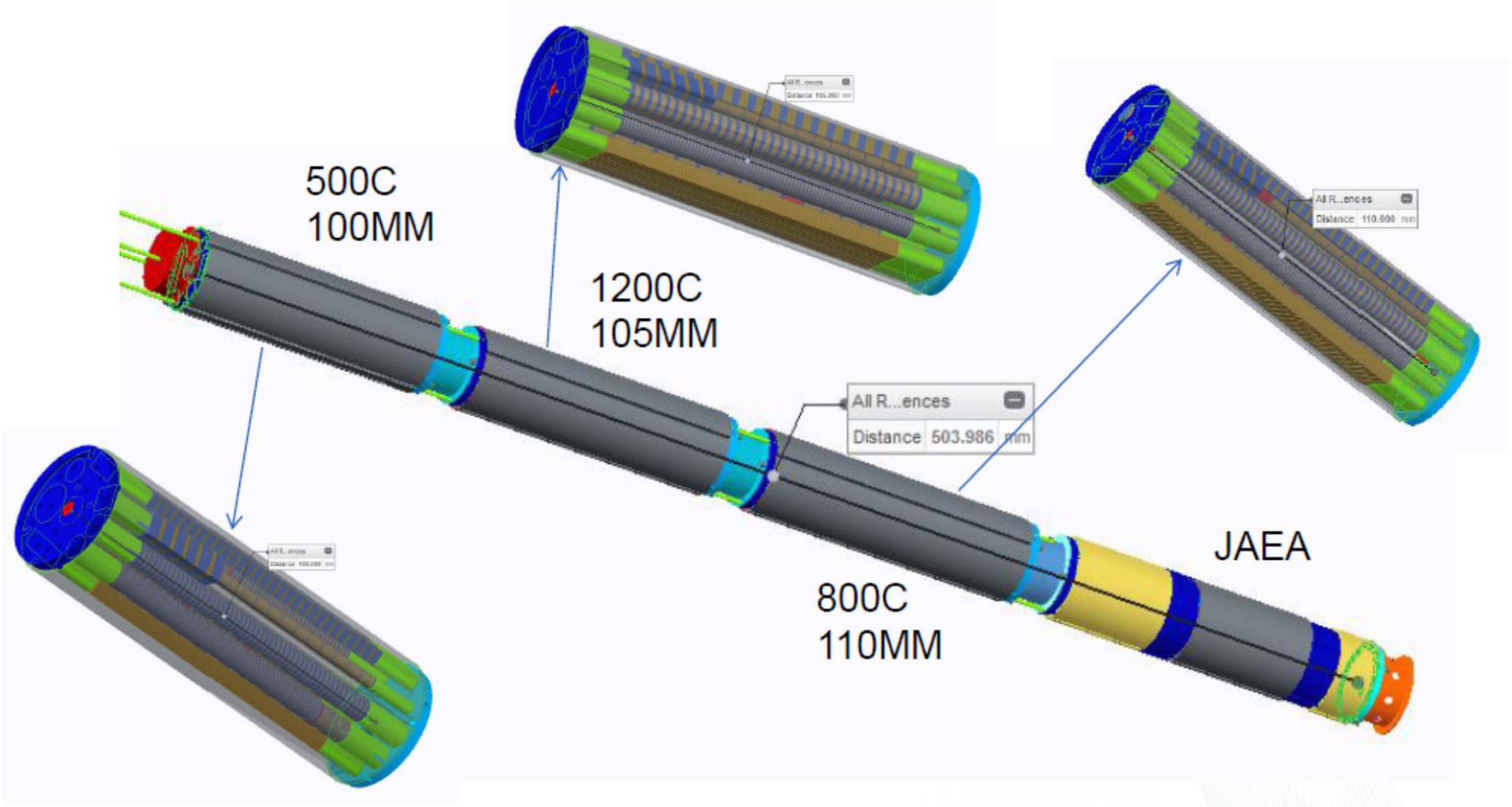
After L. Snead



Greenwood/Garner JNM 212-215 (1994)

Difference in neutron spectrum and transmutation between fusion and fission.

Preliminary Design Layout of RB* Irradiation Capsule 19J



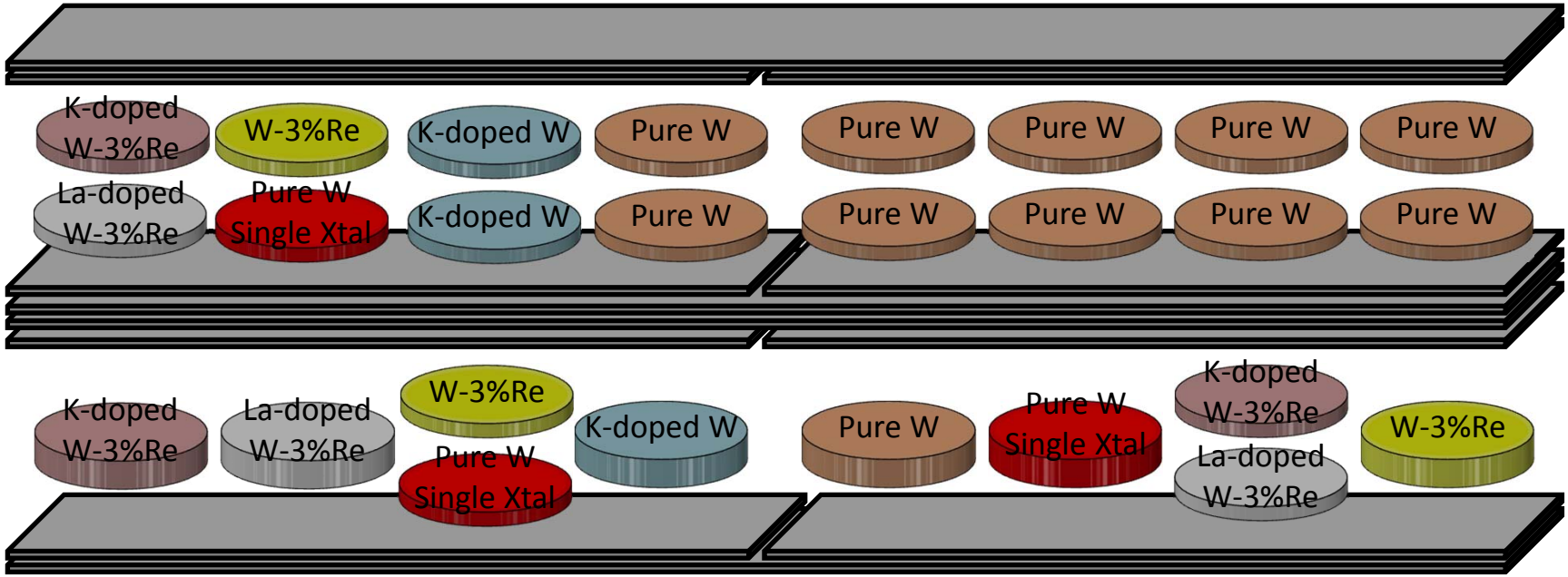
Thermal neutron shield : Gd

RB19J Irradiation Schedule

- Capsule design complete – June 2015
- All specimens received at ORNL – July 2015
- Capsule assembly – August 2015
- Capsule irradiation – February 2016
- Last irradiation cycle – March / Apr 2017 (TBC)
- Remove from HFIR and hot cell disassembly – July 2017
- PIE – August 2017 to ~March 2019 (~20 months)

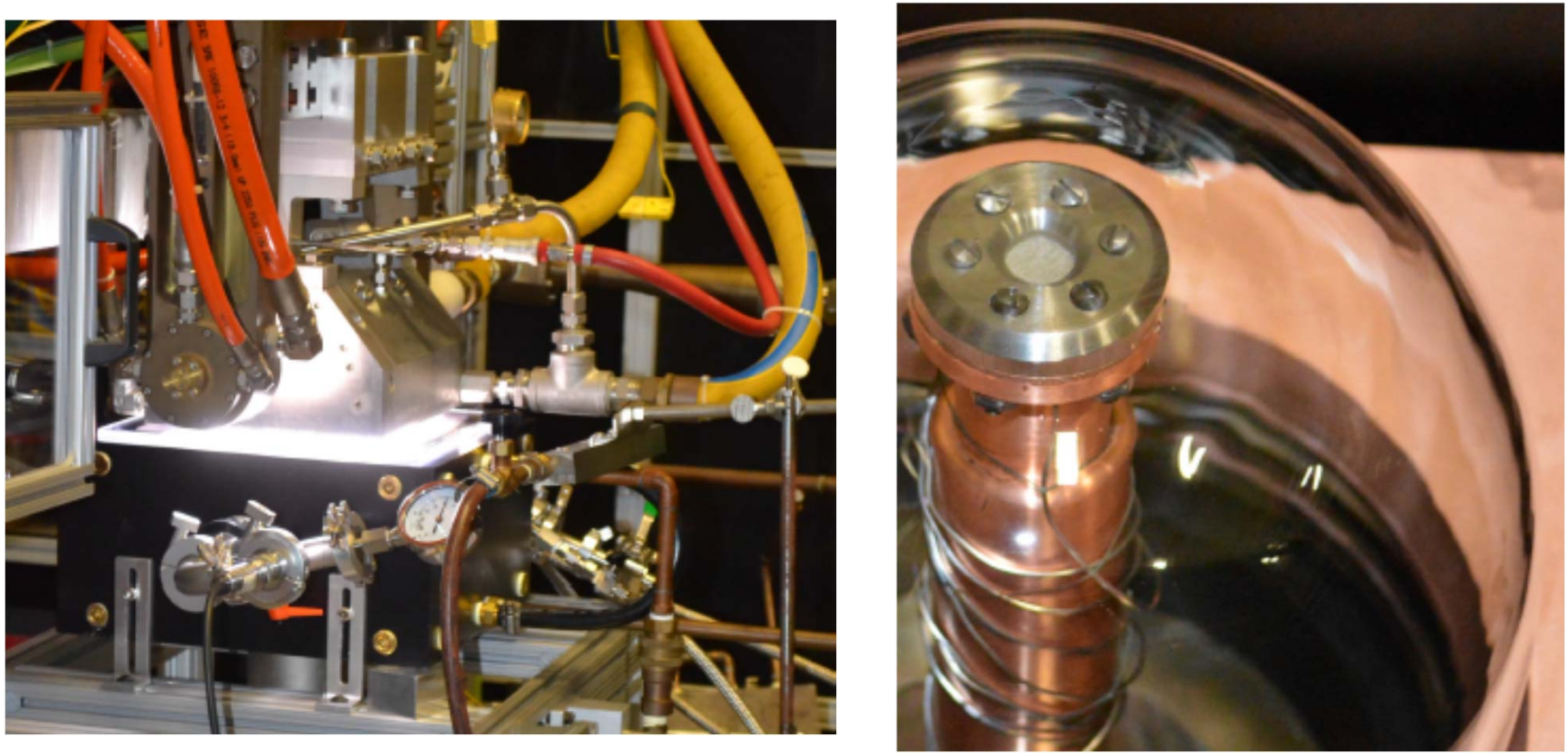
Low-dose rabbit capsule irradiation (~0.5 dpa) at 800 and 1100 °C has been completed. PIE will starts in 2016.

Task	Material	TD (φ6, t1)	MD (φ6, t0.5)
Task 2	Pure W	3	6
	K-doped W	3	6
	K-doped W-3%Re	3	6
	La-doped W-3%Re	3	6
	W-3%Re	3	6
	Pure W(Single Crystal)	3	6
Task 3	Pure W	0	18
Total		18	54
		72 (including a spare)	



Task 1

Task 1 performs heat load tests for n-irradiated W materials using Plasma Arc Lamp (PAL) Facility in ORNL, as well as thermal conductivity measurements.



PAL Facility and sample holder for n-irradiated W

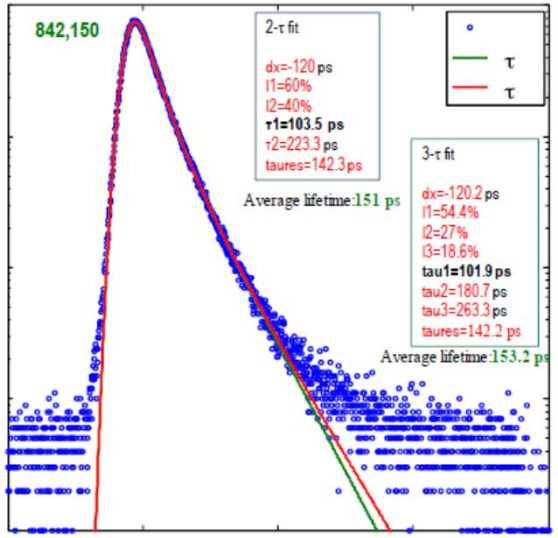
The maximum heat load is ~20 MW/m^2.

In addition, heat transfer tests and numerical modeling are performed using He-loop in Georgia Institute of Technology.

Task 2

New JEOL TEM

γ-ray detectors for positron annihilation spectroscopy



Positron lifetime spectrum

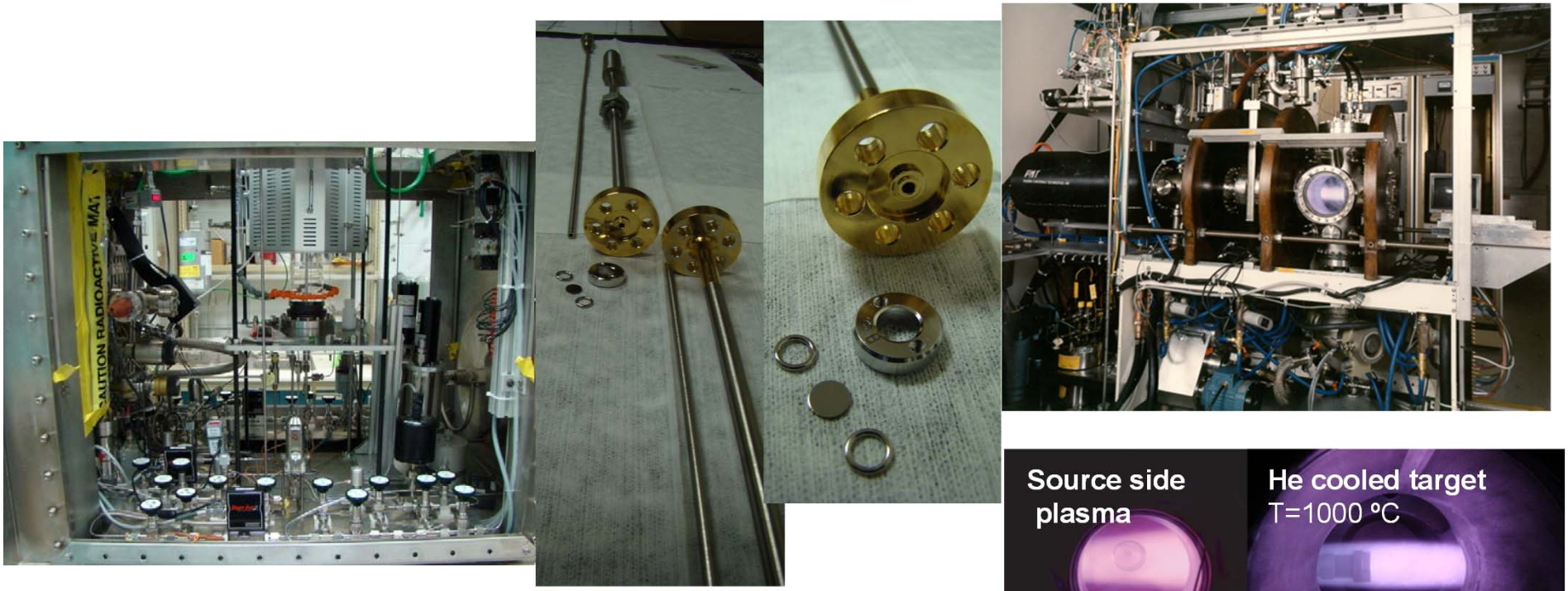
New FEI Versa

Task 2 performs

- ✓ Neutron irradiation for all tasks
- ✓ State of art microstructure analysis of n-irradiated samples using TEM, FIB, Positron annihilation spectroscopy etc.
- ✓ Mechanical property tests including hardness measurements, tensile tests and torsion tests (layered materials).

Task 3

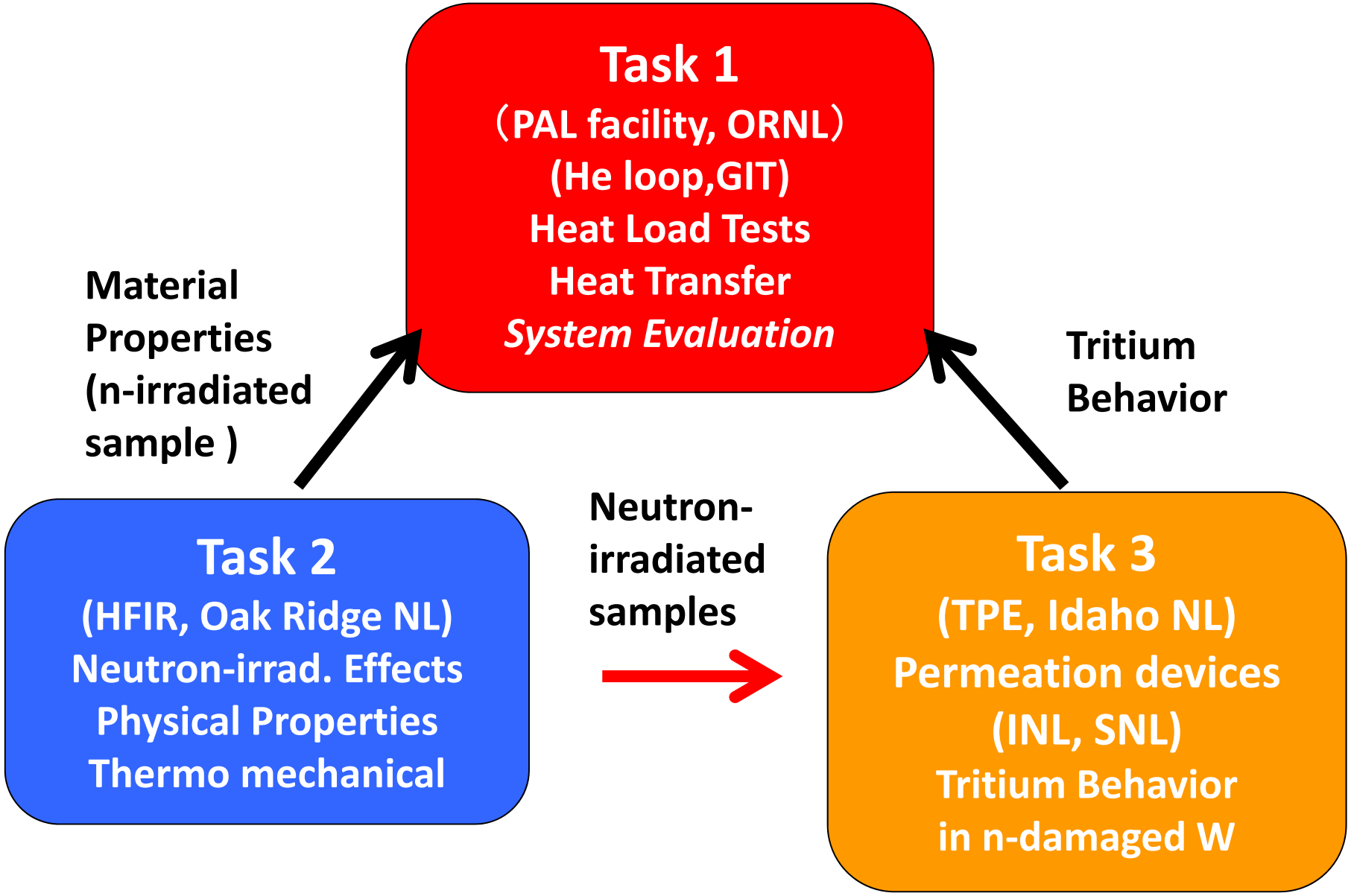
Measurements of D, T retention after exposure to high-flux plasma (10^{23} $m^{-2}s^{-1}$) of n-irradiated W materials in TPE are performed in INL, as well as permeation tests in Tritium Gas Absorption and Permeation (TGAP).



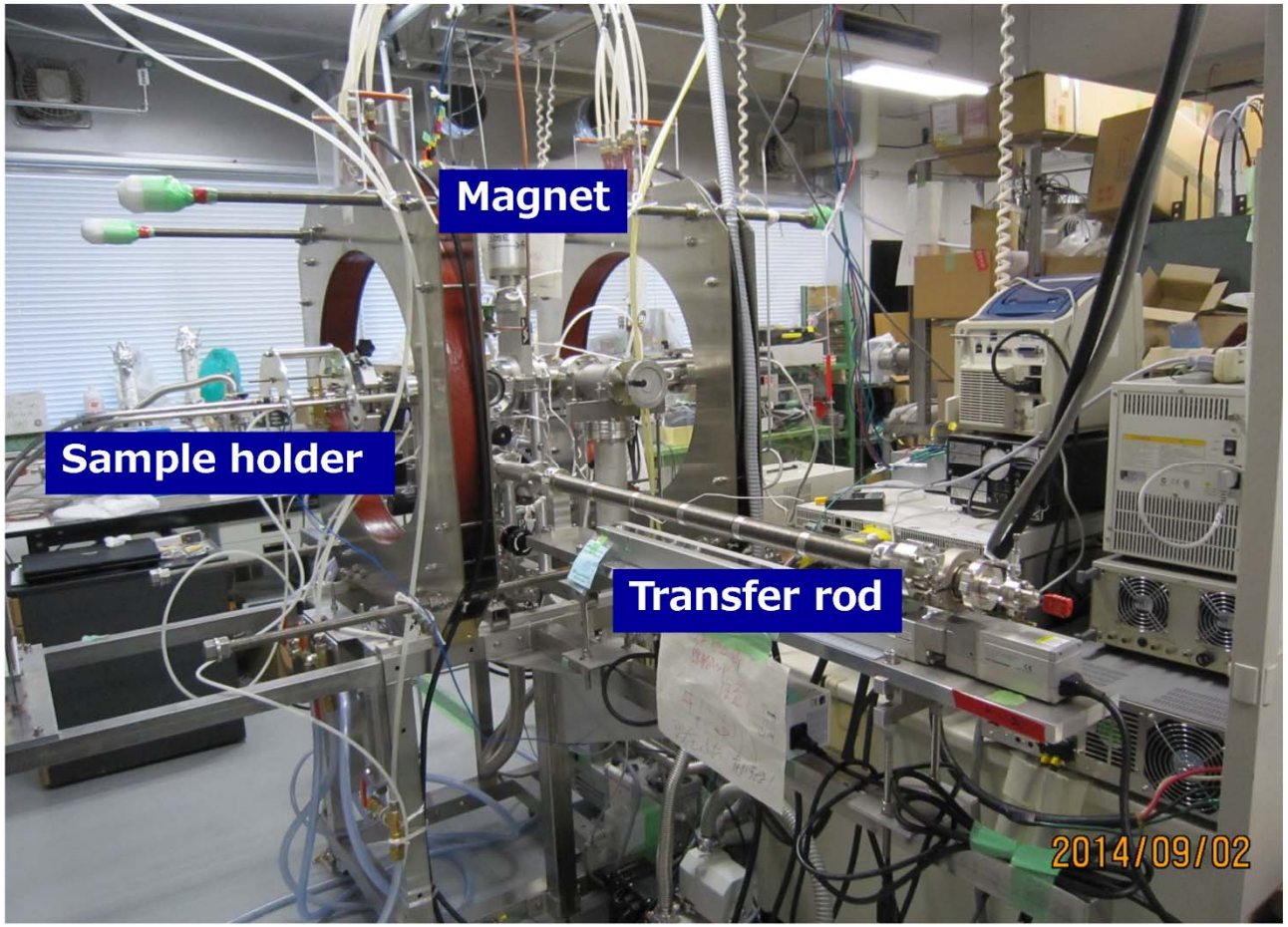
Permeation setup (TGAP) built in INL.

Famous linear plasma generator, TPE.

Structure of this Project

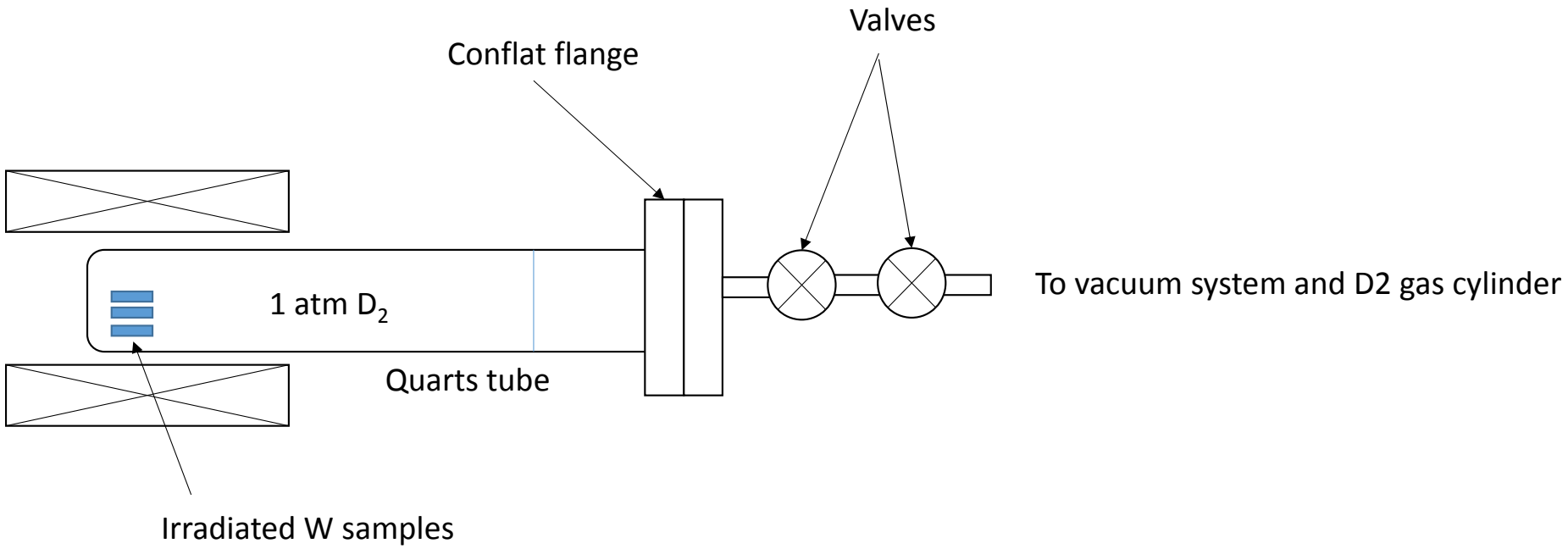


3. PSI Studies in IMR-Oarai, Tohoku University



The compact divertor plasma simulator (C-DPS) has been installed in the radiation-controlled area of IMR-Oarai.

- ✓ C-DPS Flux:10^{24} D $m^{-2}s^{-1}$, Incident Energy: 20–140 eV, Sample temperature control feedback system Currently under test operation and real experiment will start soon.
- ✓ Long-term D_2 gas exposure experiments (several hundreds hours) in a sealed capsules have been performed to examine long-range diffusion of D and vacancy-type defects under the presence of D.
- ✓ Microstructure analysis (FIB-TEM, Positron annihilation spectrometry) and thermal desorption spectrometry for D.



4. Summary

- ✓ Construction of irradiation capsule for PHENIX project has been started. The characteristic points of this capsule is thermal neutron shielding by Gd layer for appropriate transmutation. Irradiation will be performed at 500, 800 and 1200 C to 1–1.5 dpa. PIE will starts in the summer of 2017.
- ✓ Shimane University and UCSD work together on interactions of D+Be+He plasmas with W surfaces.
- ✓ The new compact linear plasma device and long-term gas exposure system have been constructed in International Research Center for Nuclear Materials Science, Institute for Materials Research, Tohoku University. Lower-dose neutron irradiation (0.02–0.04 dpa, and consequently low Re and Os) in BR2 reactor at 290 ^{o}C has been completed. PIE will start in this autumn.

Please visit Po 3-93, Po 4-82 and Po 4-93