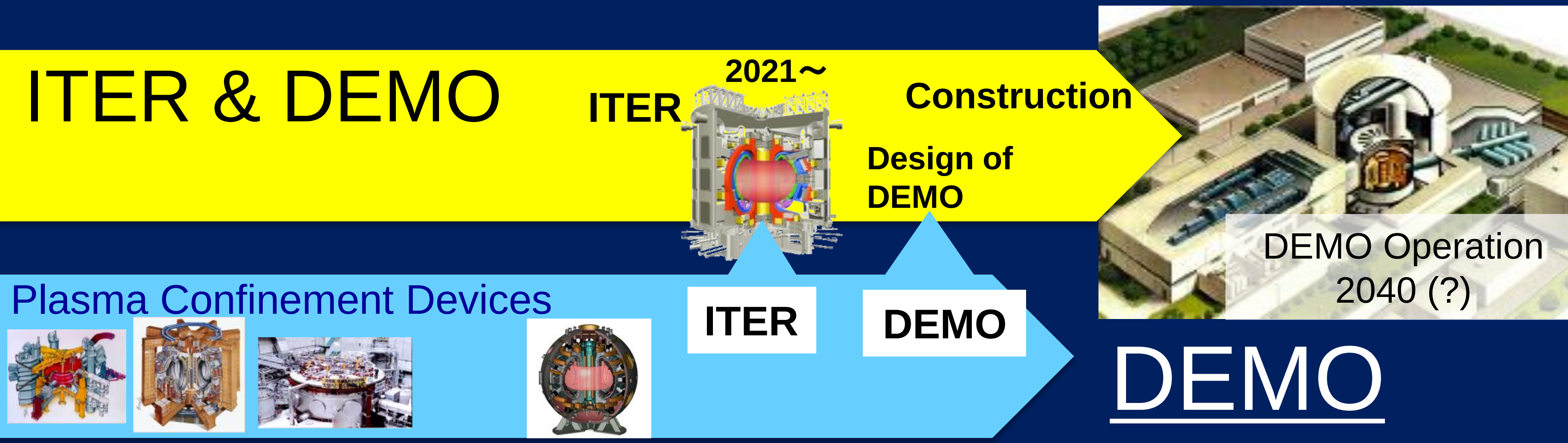
PWI合同研究会
筑波大学国際会議室, 2014.07.31

国内国外直線･照射装置研究の展開

筑波大学プラズマ研究センター
坂本瑞樹

Road Map to DEMO



Researches on plasma confinement devices such as tokamaks and stellarators are important to design and operate ITER and DEMO, since the topology of the magnetic field plays an important role and non-linear dependence between wall and plasma performance must be addressed.

M. Sakamoto, 2nd IAEA DEMO Workshop, Dec. 2013

Power & Particle Handling

ITER

100MW

10 MW/m^2
(stationary)

20 MW/m^2
(non-stationary)

DEMO

500MW

< 8 MW/m^2

(SlimCS*)

- Power handling has a direct impact on machine protection.

Need to disperse the power

- Particle handling relates to plasma performance.

Need to concentrate the particles

Compatibility of power and particle handling is crucial for steady state operation.

There exists a large step towards DEMO

A large step from now to ITER and DEMO

	JET	ITER	DEMO*
P/R (MW/m)	11	25	94-130
W_{th}/R (MJ / m)	3	X 20 → 60	125-395
operation time (s/ yr)	$4.0\cdot10^4$	$4.0\cdot10^5$	X 60 → $2.4\cdot10^7$
Averaged neutron fluence (FW) (MW a / m^2)	~0	~0.3	X 30 → ~10
T_{wall} (K)	500	500	X 2 → 1000

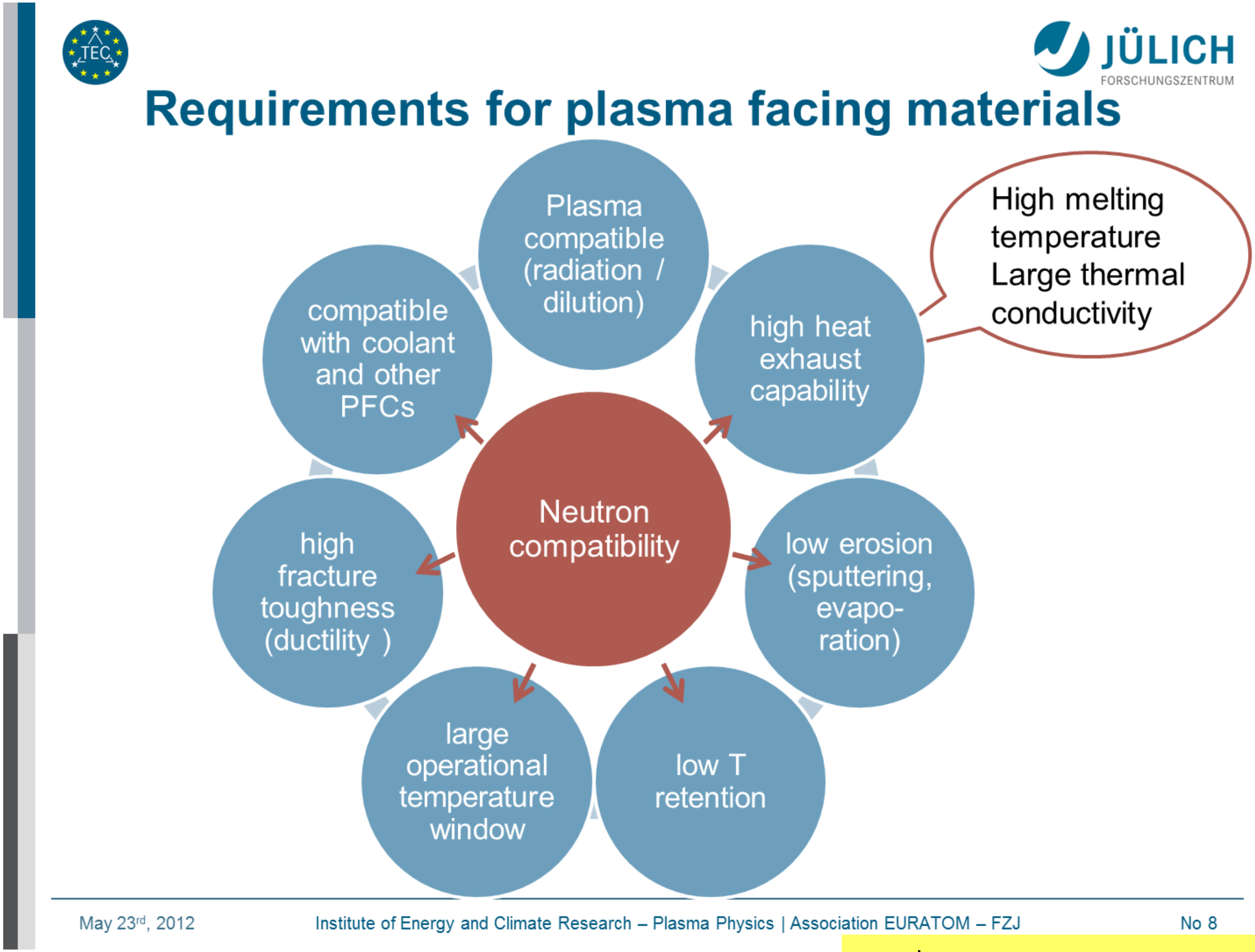
*Range given by different models within EFDA- PPCS (2005) [D. Maisonnier *et al* 2007 *NF* **47** 1524]

- **New challenges for all issues related to *<u>fluence</u>*, *<u>neutron damage</u>* and *<u>wall temperature</u>* *(last two will indirectly affect all others via material issues)***

M. Sakamoto, 2nd IAEA DEMO Workshop, Dec. 2013

20th PSI (2012) B. Unterberg

Neutron compatibility will be required



20th PSI (2012) B. Unterberg

M. Sakamoto, 2nd IAEA DEMO Workshop, Dec. 2013

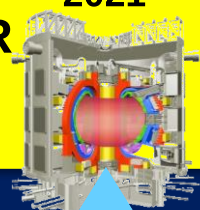
Road Map to DEMO

Integrated performance

ITER & DEMO

ITER

2021～

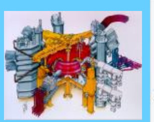


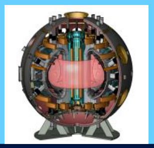
Construction

Design of DEMO

DEMO Operation
~ 2040

Plasma Confinement Devices





ITER

DEMO

DEMO

Steady State Operation

"Complementary studies"

Contribution

Linear Plasma Devices

What is necessary?

PSI-2

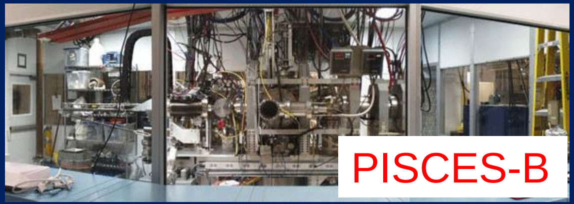
GAMMA 10/PDX

MAGNUM-PSI

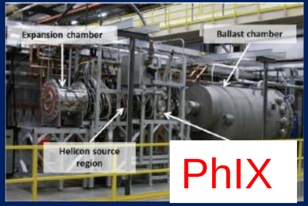
Extrapolation using simulation

Fundamental study

NAGDIS-II



PISCES-B

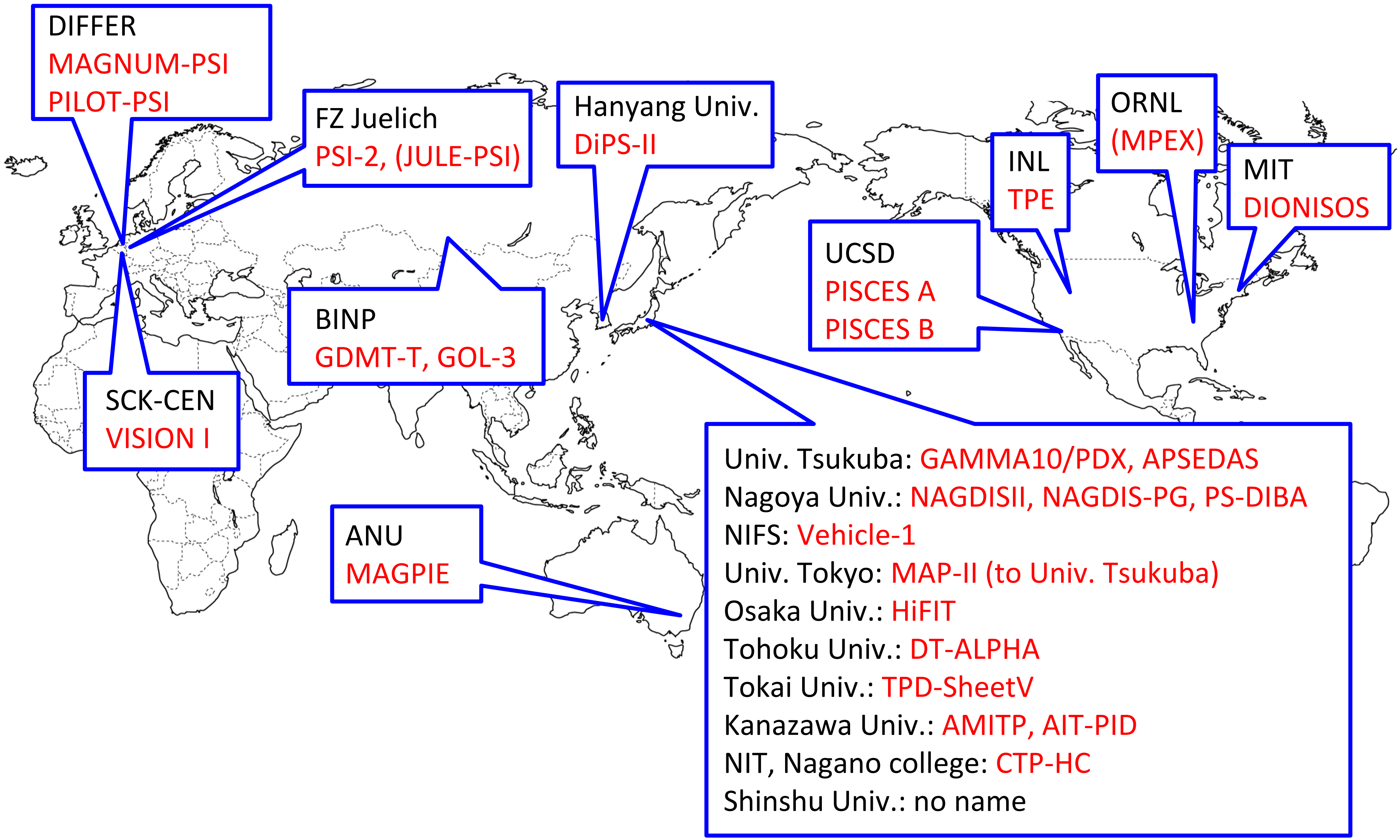


PhIX

Innovation
New findings

M. Sakamoto, 2nd IAEA DEMO Workshop, Dec. 2013

Linear plasma devices for divertor simulation and PWI in the world



Excellent researches on divertor simulation and PWI have been done in linear plasma devices by utilizing characteristics (uniqueness and innovative ideas) of each device

Existing devices for example

- PISCES-B: Beryllium
- MAGNUM-PSI, PILOT-PSI:
  High B field and transient heat load
- TPE: Tritium and radioactive material
- NAGDIS: W nanostructure, arcing etc.
- PS-DIBA: In situ measurement of dynamic & static retention
- TPD-SheetV: Sheet plasma, Omegatron mass Sprctrometer
- GAMMA 10/PDX: High ion temperature

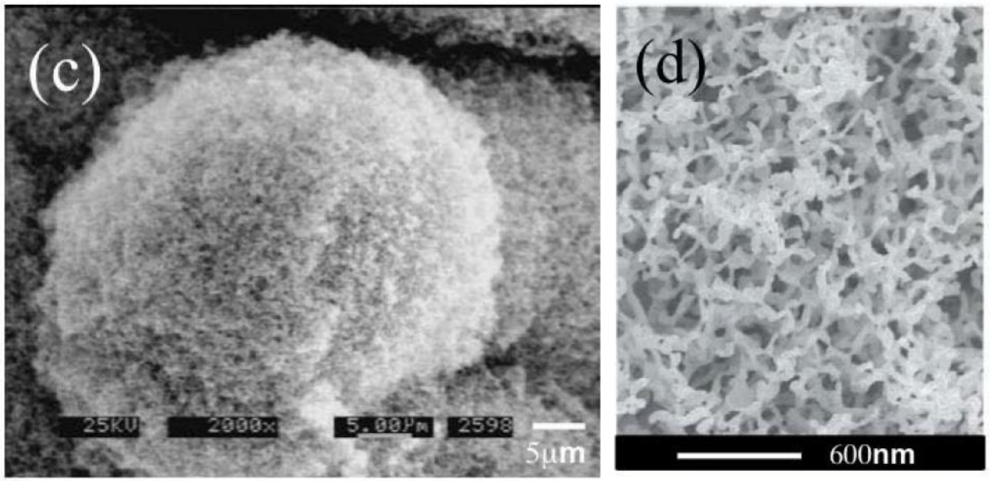
New Project

- JULE-PSI (FZ-Juelich)
- MPEX (ORNL)
- Japanese activity under NIFS bilateral collaboration
  (Nagoya Univ., Tohoku Univ., etc.)

Ref: N. Ohno, PMIF 2013

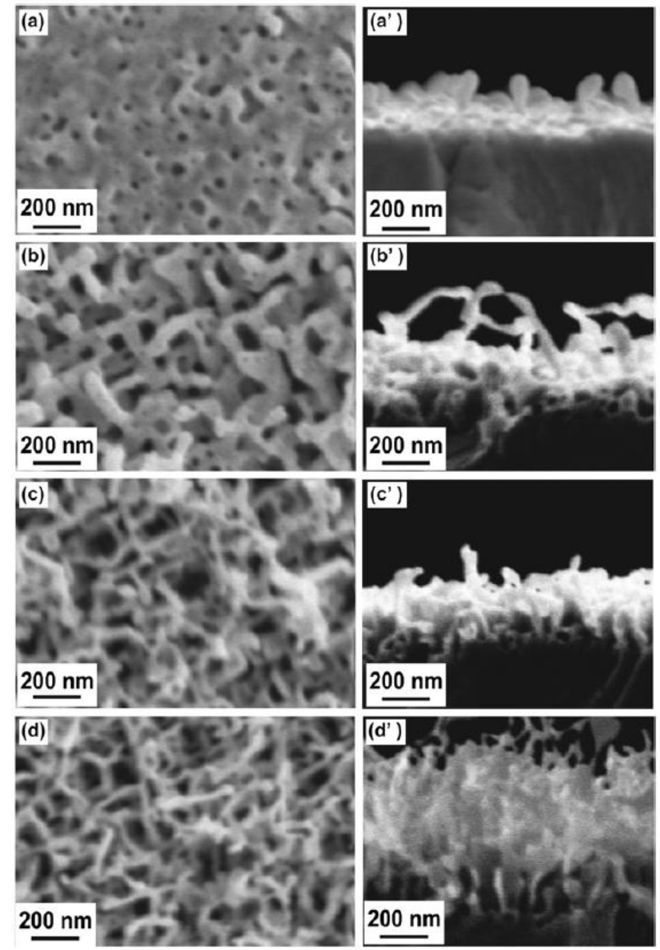
Tungsten nanostructure (fuzz) was firstly found in linear plasma devices

NAGDIS-II



S. Takamura et al. PFR, Vol. 1 (2006) 051.
http://www.jspf.or.jp/PFR/PDF/pfr2006_01-051.pdf

Incident ion energy and W temperature are critical parameters for formation of nano-structure.

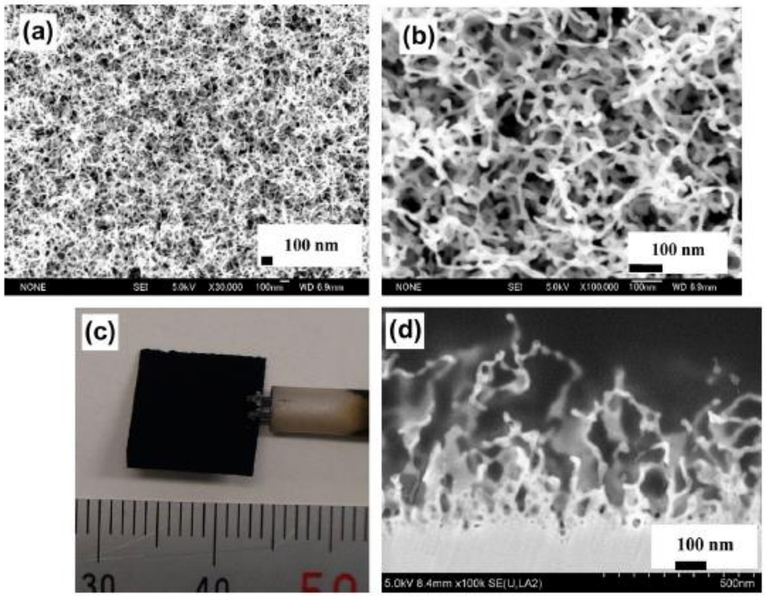


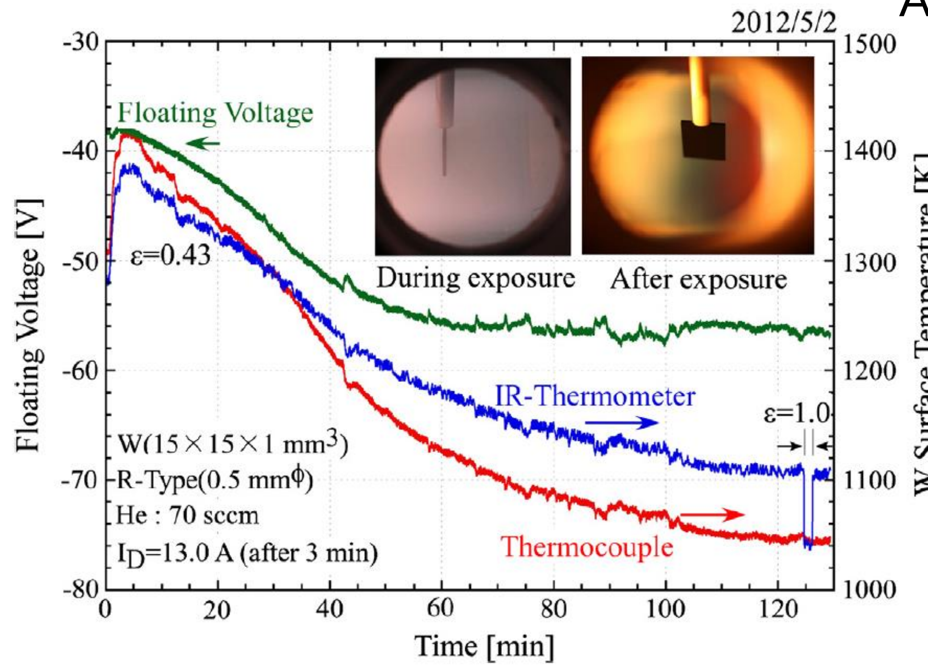
E=50 eV, Ts=1400 K,
He fluence: (a) 6×10^{24} m^{-2}, (b) 1.1×10^{25} m^{-2} (c) 1.8×10^{25} m^{-2}, (d) 2.4×10^{25} m^{-2}

S. Kajita et al., Nucl. Fusion **49** (2009) 095005.

Formation of W nanostructure leads to cooling of W target

AIT-PID



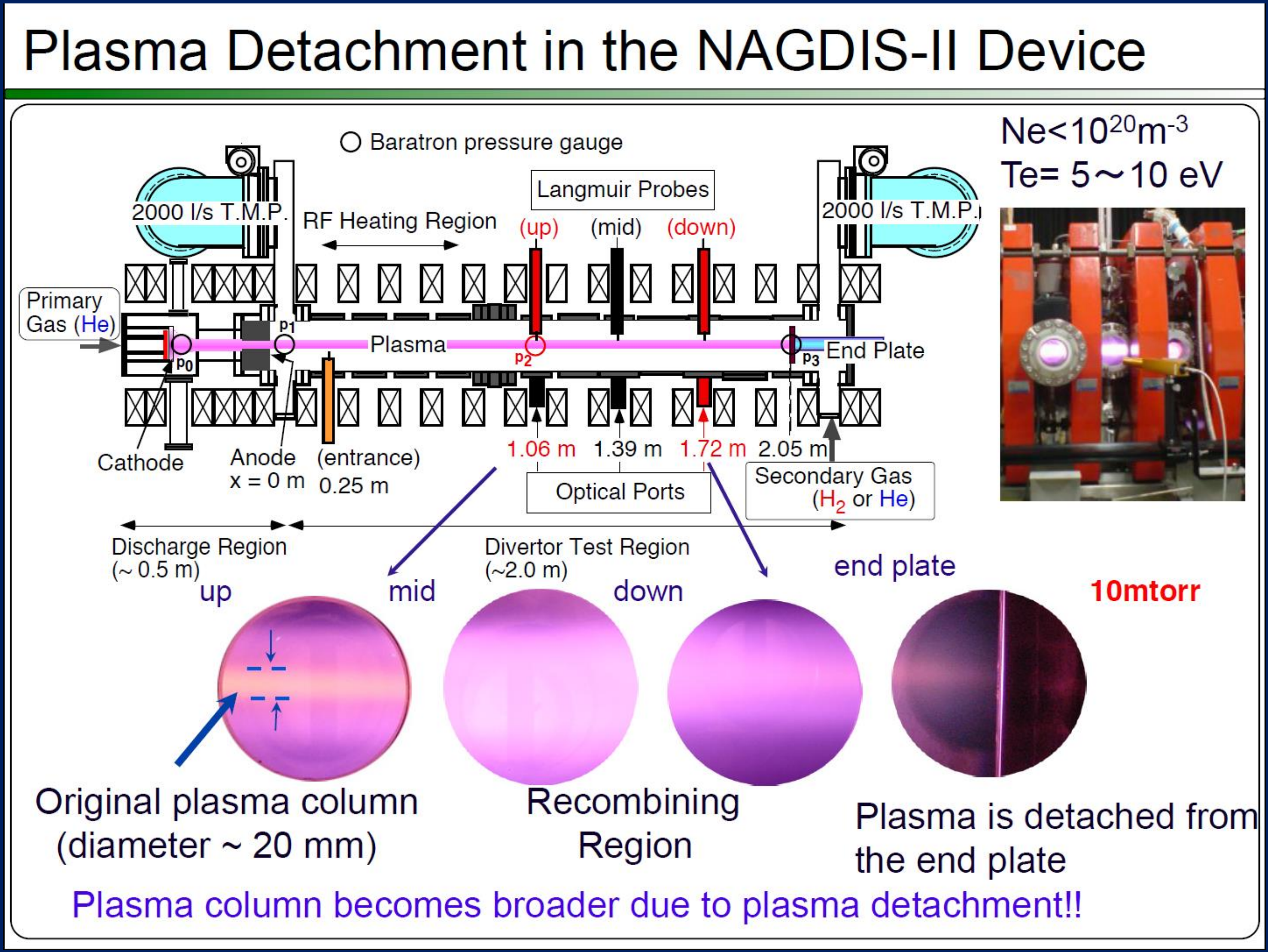


- W surface temperature decreased as nanostructure was formed on the surface. Total emissivity increased from 0.18 (non-damage) to 0.45-0.55 (nanostructure).
- The cooling comes mainly from an increase in the total emissivity of blackened tungsten. In addition, a deepening of floating potential due to suppression of secondary electron emission also contributes to such a temperature reduction.

S. Takamura et al., JNM 438 (2013) S814.

Plasma detachment was firstly demonstrated in a linear plasma device

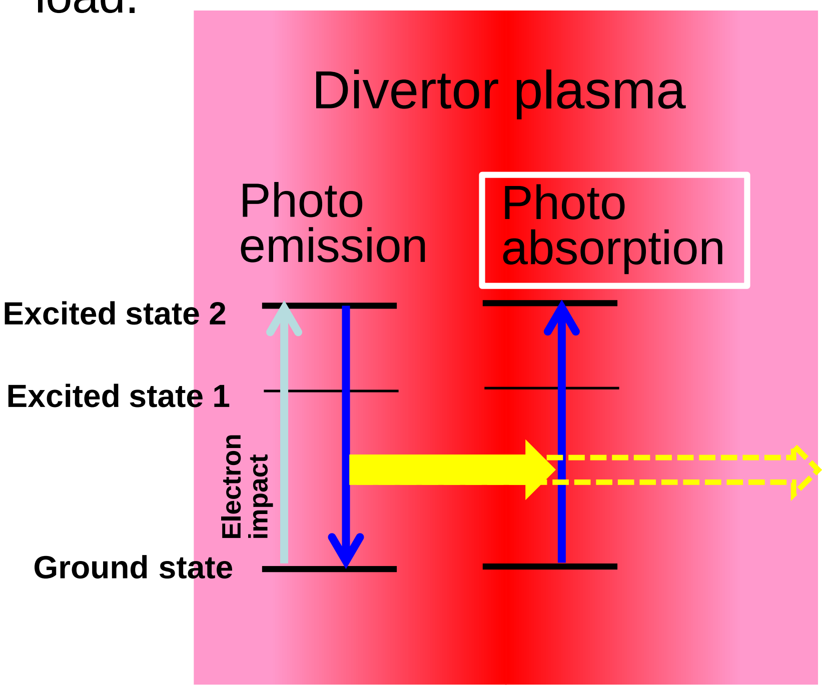
QED: W.L. Shu et al., PRL 49 (1982) 1001.
PISCES-A: L. Schmitz et al., JNM 176-177 (1990) 522.

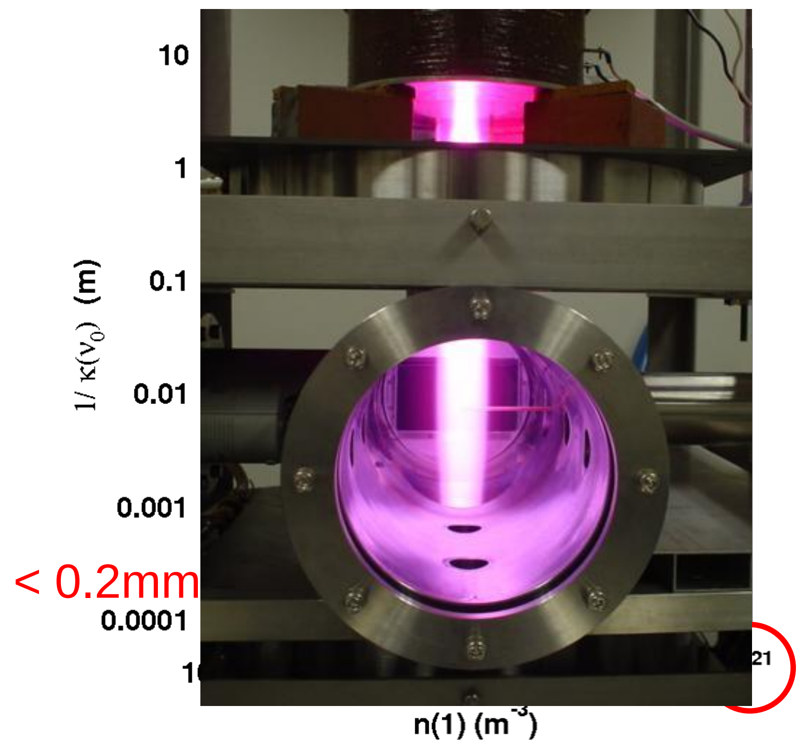


Radiation transport will play a significant role in DEMO

In the case of high density divertor plasma like DEMO (i.e. > 10^{21} m^{-3}), the radiation transfer will play a significant role, since the plasma will be optically thick. The mean free path for Lα photons can be shorter than 0.2 mm.

Effective ionization rate coefficient will be increased and radiation cooling will be reduced. Small uncertainty of prediction of P_{rad} leads to large effect on target heat load.

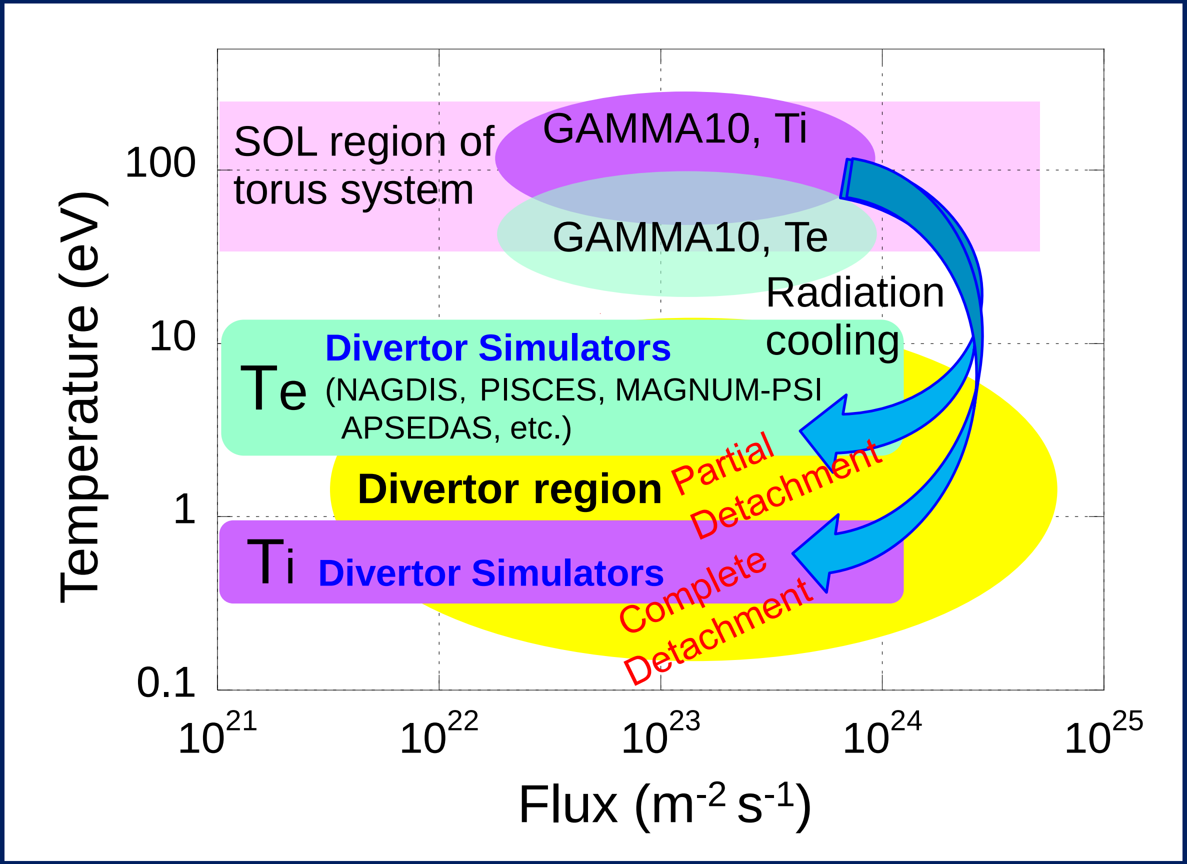




Fundamental study using a linear plasma device is important for validation of the model and getting an accurate database, since the plasma is well defined.

M. Sakamoto, 2nd IAEA DEMO Workshop, Dec. 2013

Process of decreasing in electron and ion temperatures in SOL & divertor region and effect of transient plasma event like ELM are important to study the divertor detachment.



プラズマ・核融合学会誌8月号小特集

J. Plasma Fusion Res. Vol.90, No.8 (2014) ●-●

小特集

DEMOに向けた直線型装置を用いた境界プラズマ，プラズマ・壁相互作用研究

1．直線型プラズマ生成装置の現状と
DEMOのダイバータ設計における課題

坂本瑞樹、大野哲靖、
朝倉伸幸、星野一生

2．ダイバータにおける熱流制御とプラズマ材料相互作用

菊池祐介、澤田圭司、高村秀一、
上田良夫、永田正義

3．直線型プラズマ生成装置を用いたプラズマ・壁相互作用研究

波多野雄治、宮本光貴、島田 雅、
上田良夫、時谷政行

4．まとめにかえて

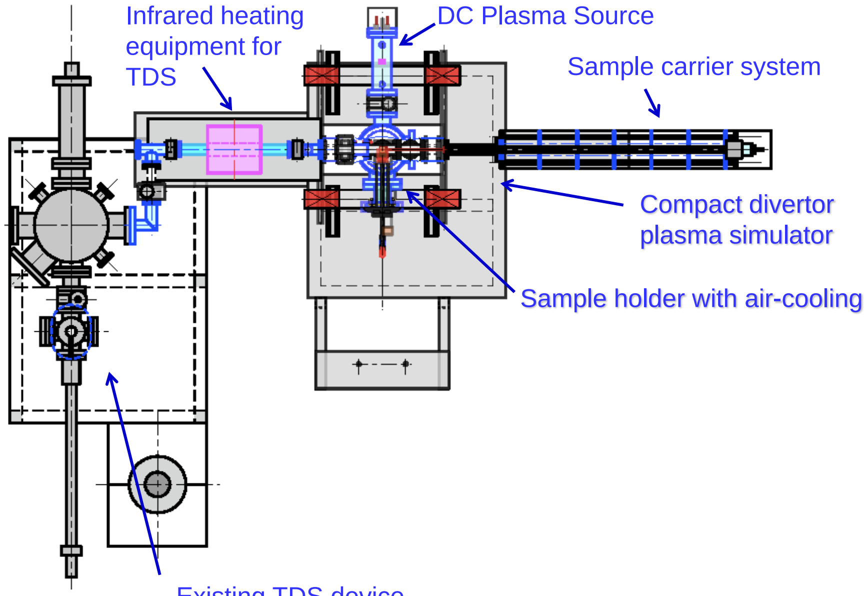
中嶋洋輔

Japanese activity under NIFS bilateral collaboration

International Research Center for Nuclear Material Science (IRCNMS), Institute for Materials, Tohoku Univ. has a long history to conduct neutron irradiation tests using nuclear reactors overseas (BR2) as well as in Japan (JMTR, JOYO, JRR-3)

→ Many neutron-irradiated samples already exist in IRCNMS

A compact divertor simulator with a TDS device is constructing in Nagoya Univ (Prof. Ohno).



Ref: N. Ohno, PMIF 2013

DEMOに向けた国内の直線型装置の研究連携の仕組みが重要