OLMAT as a HHF Facility for Testing ITER & DEMO Divertor Armor Materials

SPA midterm

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INDEX

PREVIOUS RESULTS

1.- JUDITH results reproduced

2.- Disruption cracking at WEST

OLMAT UPGRADES

1.- Beam dump

2.- CW laser

SCHEDULED EXPERIMENTS: late 2022

1.- Large holder: testing >50 samples

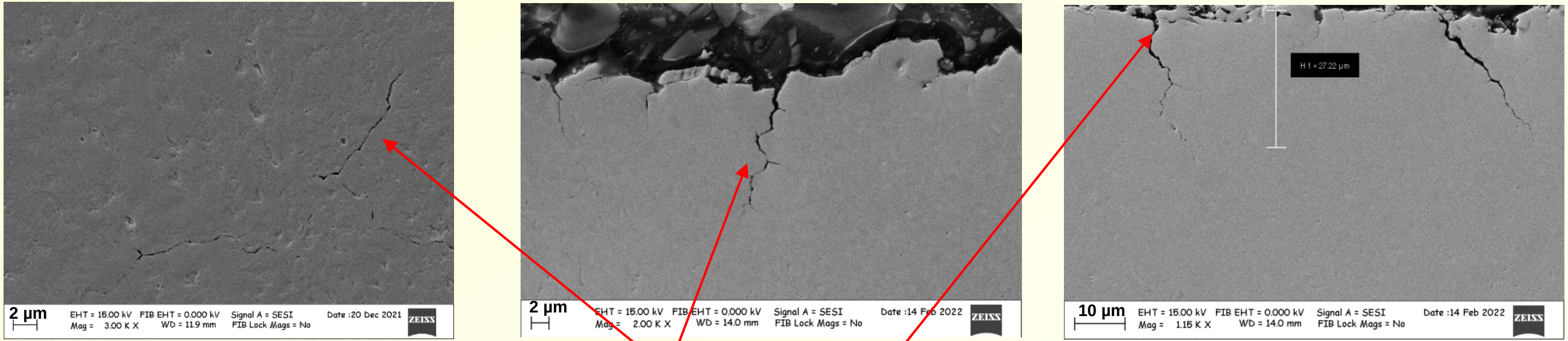
2.- Disruption-like pulses: really only 1?

SUMMARY

OLMAT: fatigue damage

As in Judith [1]. ITER-like W samples at 600-700 ºC with ΔT = 200-350 ºC:

- **641 pulses of 15±5 MW/m^2 every 45s: F_{HF} = 4.7±1.6 MW/m^{2}s$^{0.5}$**
- **Particle flux 0.62 ·10^{22} m^{-2}s^{-1}.** OLMAT range: 0.28-1.45 ·10^{22} m^{-2}s^{-1}



Small cracks

<u>At these relatively low number of pulses only damage has been found at F_{HF} =4.7</u>

- **Intergranular cracking of up to 20-30 µm deep.**

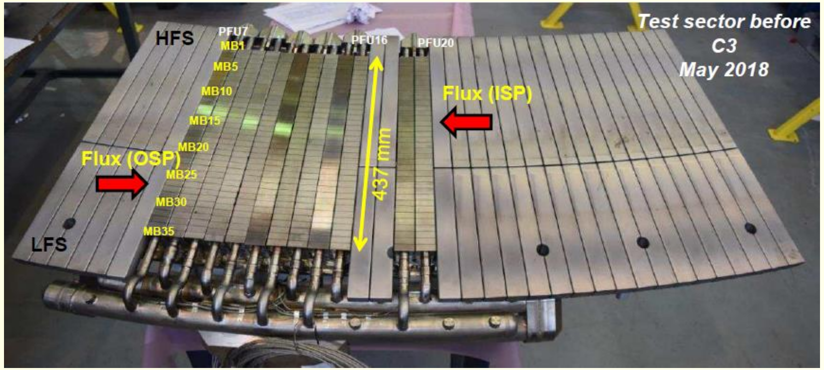
Results from Judith reproduced!

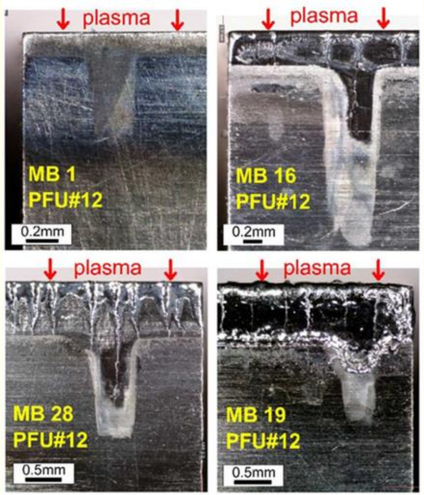
[1] M. Wirtz, et al, Nucl Mat. Ener. **12** (2017) 148

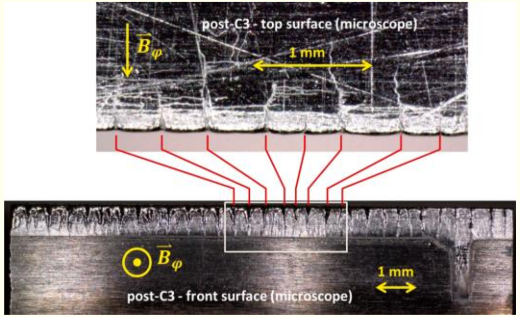
DISRUPTION CRACKING AT WEST

WEST ITER-like tiles, actively cooled [2]:

- Cracking and melting of exposed surfaces over full poloidal extent of divertor, even on areas with no steady state heat flux.
- Brittle cracking of W due to transient events?
- Consistent with cracking threshold determined in JUDITH [1] $F_{HF} = 6\ MW/m^2s^{0.5}$







[1] M. Wirtz, et al, Nucl Mat. Ener. **12** (2017) 148
[2] J.P. Gunn et al., *Nucl. Mat. Ener* **27** (2021) 100920

INDEX

PREVIOUS

UPGRADES

EXPERIMENTS

SUMMARY

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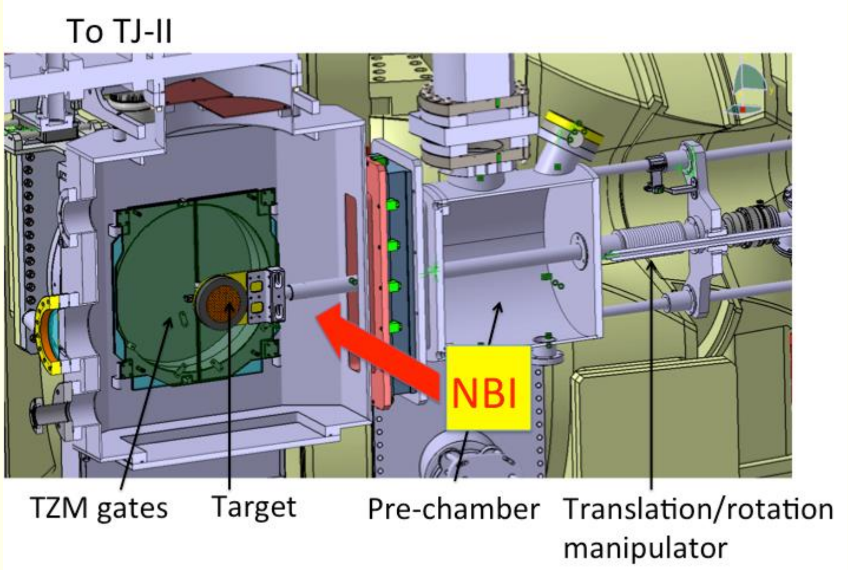
SUMMARY

UPGRADES: beam dump

Replace TZM gates by actively-cooled copper beam dump.

- **Better protection of valves and experimental time increased.**
- **Possibility of place a large (280x280 mm) sample holder.**
- **Installation November/January.**



UPGRADES: CW laser

- **Power: 930 W continuous; 9300 W pulsed.**
- **Pulses: 0.2-10 ms; 90J energy; 10-2000 Hz**

New optic head, still to be installed:

- **Circular spot: 1-15 mm (10 GW/m^2 pulsed to <10 MW/m^2 continuous)**
- **Elongated for strike point: 0.5x21 mm.** (We have still to acquire the cylindrical lens)

INDEX

EXPERIMENTS: large holder

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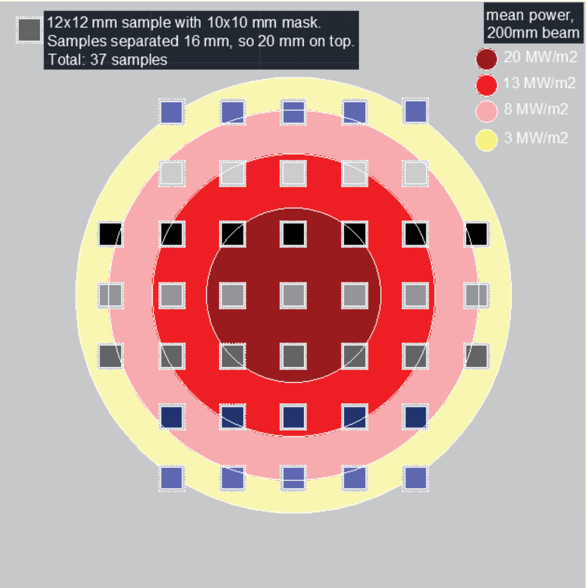
At beam dump: different materials at different conditions at the same time

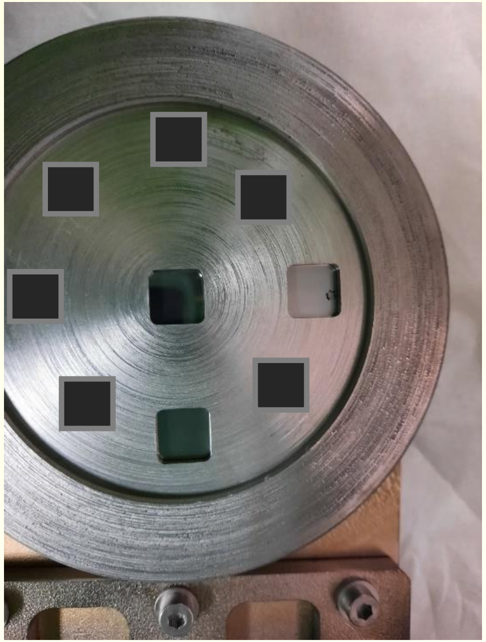
- **Use the whole OLMAT beam (20 cm) to have a power distribution** (here just an idea)
- **Changed daily to have a distribution of number of pulses: 1000, 2000, 5000, etc.**
- **Different samples irradiated at the same time *to compare its fatigue resilience*. Represented by colors in the picture:**
  - From Germany: ITER-like W, Wf/W, SMART-W
  - From Spain: SMART-W+Zr, nanostructured, 3D-print, Eurofer, etc.
  - **Open to more collaborators**
- **One sample may be irradiated by the CW laser:**
  - Pulsed: to simulate transients (0.5-10 GW/m^2)
  - Heated continuously to T > DBTT to avoid brittle fatigue.



EXPERIMENTS: laser

In WEST, it seems *just one mild disruption* (compared to DEMO) caused cracking at edges of ITER-like W [2]. Test with our CW laser.

- **Laser irradiation at edges and at 45-60 deg.**
- **Power 200 MW/m^2 for 1ms and 450 MW/m^2 for 2.5 ms: Mean disruptions in WEST. (in DEMO 10-100 GW/m^2)**
- **Just one pulse should cause cracking as WEST suggest [2].** We will test 1, 5, 10…
- **If cracking then heat up at ~600 ºC** (above DBTT, no cracking).
- **Mainly ITER-like W. Other W allows may also be tested.**



[2] J.P. Gunn et al., *Nucl. Mat. Ener* **27** (2021) 100920

INDEX

SUMMARY

PREVIOUS UPGRADES EXPERIMENTS **SUMMARY**

- Successful commissioning of OLMAT. Fatigue experiments as in Judith.
- We will start ambitious experiments.

2022 plans

- Better characterize OLMAT beam power distribution.
- Install CW laser in October. Measure the absorbed power in W (~40%)
- Install actively-cooled beam dump in November/January.
- Large sample holder to compare different materials at different powers and number of pulses. ~6 operation days in December 2022 or February 2023
- Use the new, flexible CW laser to study disruptions like in WEST.
~3 operation days in November/December 2023.

RESERVE SLIDES

CW laser for OLMAT: characteristics

PREVIOUS
UPGRADES
EXPERIMENTS
SUMMARY

- **Power: 930 W continuous; 9300 W pulsed.**
- **Pulses: 0.2-10 ms; 90J energy; 10-2000 Hz**

1. Optical characteristics

N	Characteristics	Test conditions	Symbol	Min.	Typ.	Max.	Unit
1	Operation Mode			CW / pulsed			
2	Polarization			Random			
3	CW Nominal Power		P_{nom}	900			W
4	Pulsed Nominal Power			9000			W
5	Pulse duration			0.2		10	msec
6	Pulse energy	Duty cycle 10 %, PRR = 10 Hz, Maximum power		90			J
7	Duty Cycle*	Pulsed mode				50*	%
8	Output Power Tuning Range	Pulsed mode		10		105	%
9	Emission Wavelength	Output power: 900 W	λ		1070		nm
10	Emission Linewidth	Output power: 900 W	$\Delta\lambda$		3	6	nm
11	Switching ON/OFF Time	Output power: 900 W			100	150	µs
12	Maximum Modulation Frequency	CW & Pulsed modes Output power: 900 W		2000			Hz
13	Output Power Instability	Output power: 900 W Time interval: 8 hrs (T=Constant)			±1	±2	%
14	Red Guide Laser Power				0.4	0.5	mW

**Maximum duty cycle limit is inversely proportional to peak power: 10% for 9000W, 15% for 6000 W,........, 50% for 1800W and lower*

CW laser for OLMAT: operation

PREVIOUS

UPGRADES

EXPERIMENTS

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- **Power: 930 W continuous; 9300 W pulsed.**
- **Pulses: 0.2-10 ms; 90J energy; 10-2000 Hz**

We still do not have optic head, so different possibilities:

- ❑ **Operation for hours in any mode. Independent/triggered with OLMAT**
- ❑ **ITER (or DEMO) like pulses:**
  - 10 MW/m^2 in 0.37 cm^2 area. 400s pulses, or when steady state is reached.
- ❑ **Reattachment (continuous mode)**:
  - 20-70 MW/m^2 in 0.19-0.05 cm^2 area. OLMAT 50 MW/m^2. Synergies laser+beam?
- ❑ **Mitigated (or type III) ELMs**:
  - 10 MW/m^2 in 3.7 cm^2 area. 2000 Hz. Quite important fatigue
- ❑ **Disruptions**:
  - 1-10 GW/m^2 in 0.4-4.7 mm^2 area (0.7-2.2 mm spot).