Thermal Response of Be/C Codeposits to an ITER Type1 ELM Heat Pulse

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PPPL
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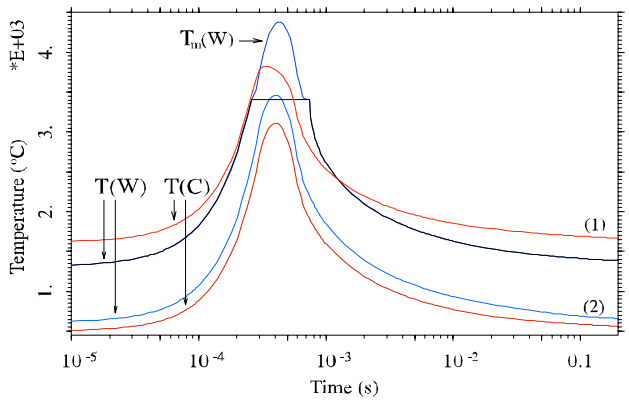
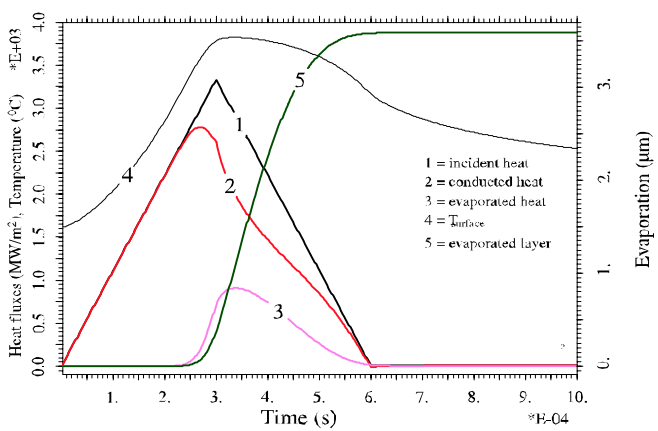
Response of PFC surfaces to ITER ELM heat pulses can proceed in two phases

- Phase 1 ($60k)
  - Examine thermal response of PISCES mixed-material samples to heat pulses at PPPL using existing laser system
  - Provide thermal response data to ITER design team
  - Reexamine behavior of surfaces modified by extreme temperature excursions to plasma in PISCES
- Phase 2 (~$200k)
  - Install new high-power laser system in PISCES to examine behavior of mixed-material surfaces during extreme temperature excursions and plasma bombardment
  - Determine stability of Be layers on ITER divertor plate

Heat loads during ITER Type1 ELMs challenge Divertor PFC Lifetime

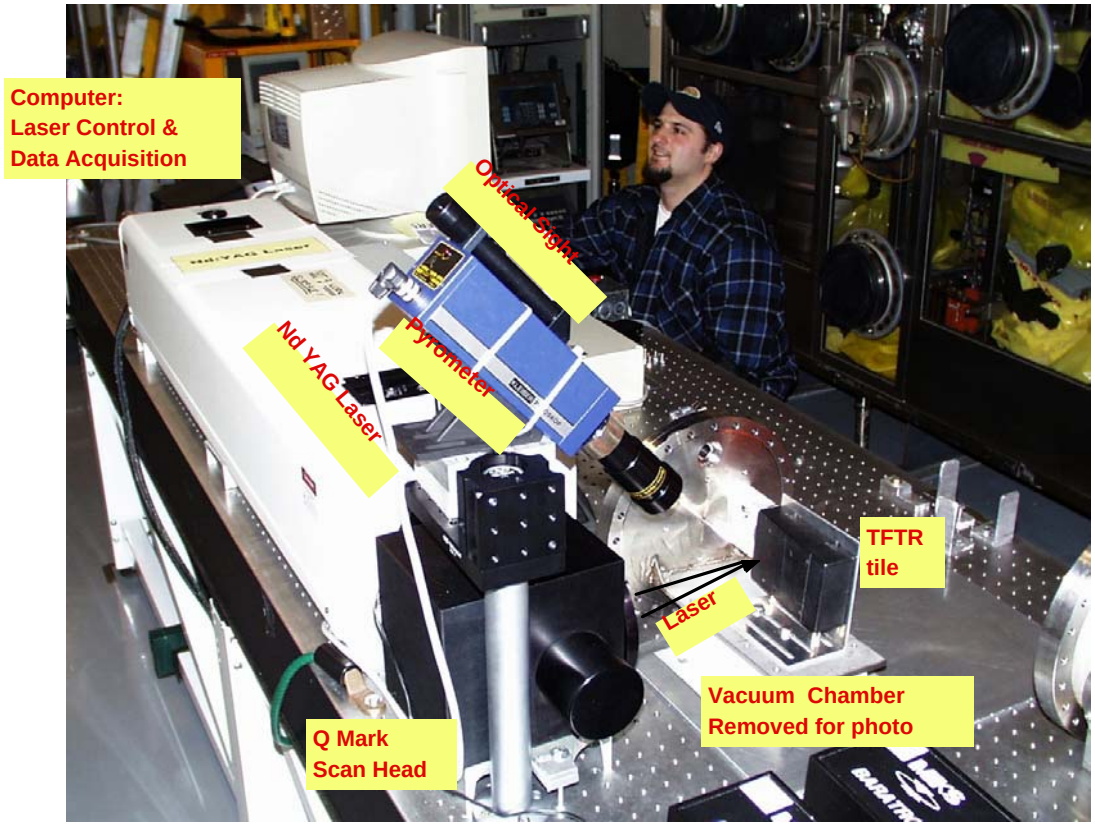


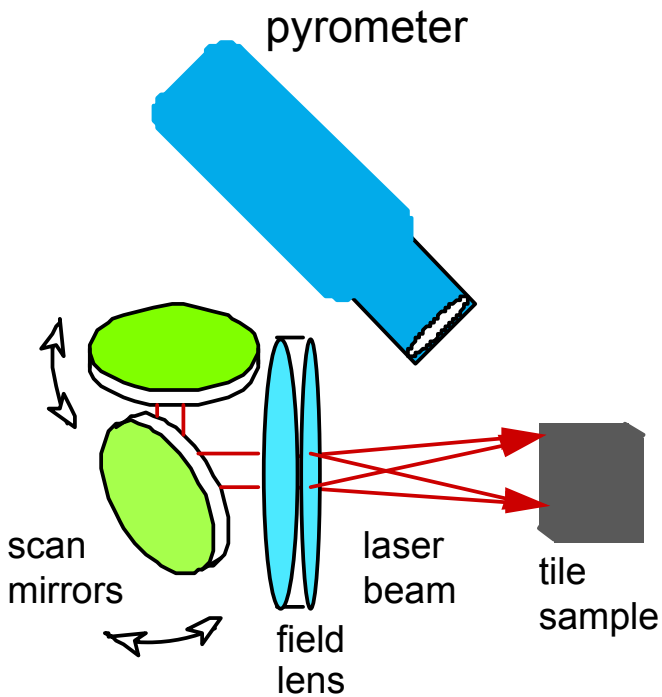


From G. Federici, et al., Plasma Phys. Control. Fusion 45(2003)1523.

- ITER ELMs increase divertor plate surface temperature to over 3000ºC
- Be diffusion into bulk may become significant and affect brittle destruction of graphite
- Equally important for W/C/Be mixed system
- Understanding the response of Be surface layers to high temperature excursions is crucial to predicting behavior in ITER

Thermal response measured during laser detritiation experiments at PPPL:



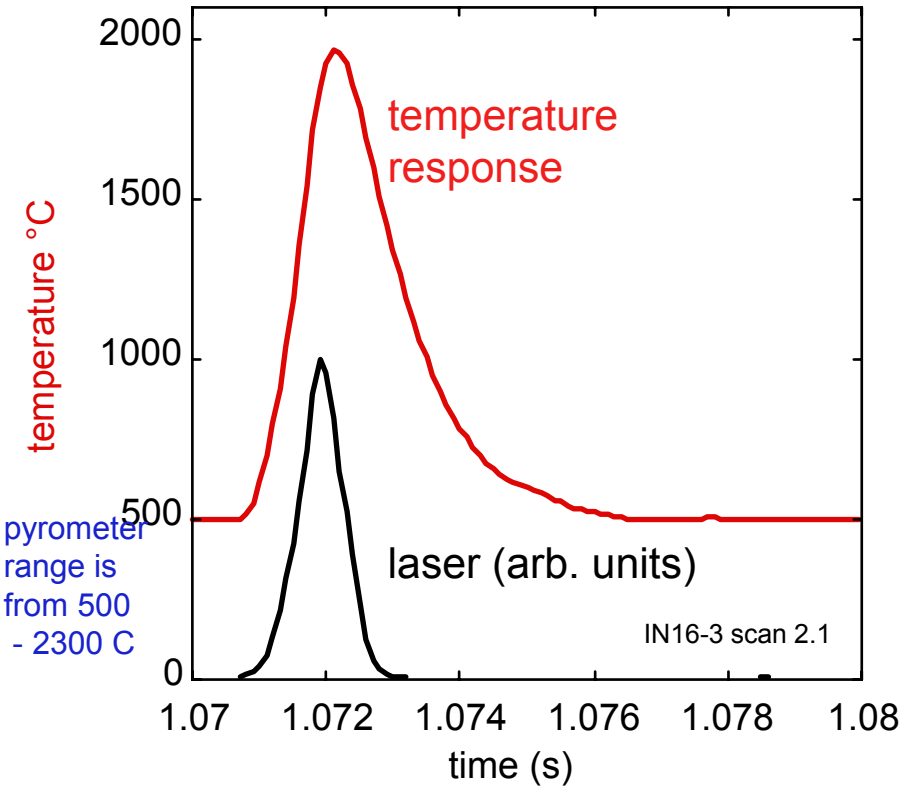


CW laser beam scanned across tile sample.
Local heat pulse 128 W/mm^2, duration was 0.8 ms or 1.6 ms (FWHM)
Deposited energy: 0.1 - 0.2 MJ/m^2,
(10% - 20% of ITER ELM-pulse; optimized for tritium removal, not to simulate ELMs)

Thermal response of Mixed C/Be materials created on JET

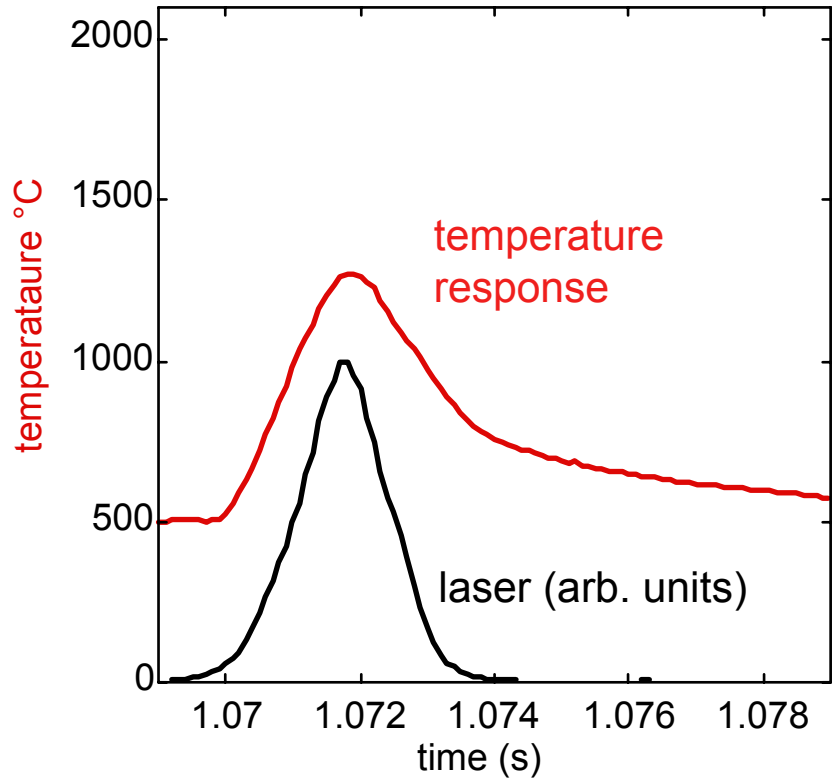
JET inner divertor tile 3 experienced Be and C deposition followed by C erosion leading to a deposit rich in Be (NRA analysis showed Be/C ≈ 1.5).

From P. Coad et al., JNM 290-293 (2001) 224.



pyrometer range is from 500 - 2300 C

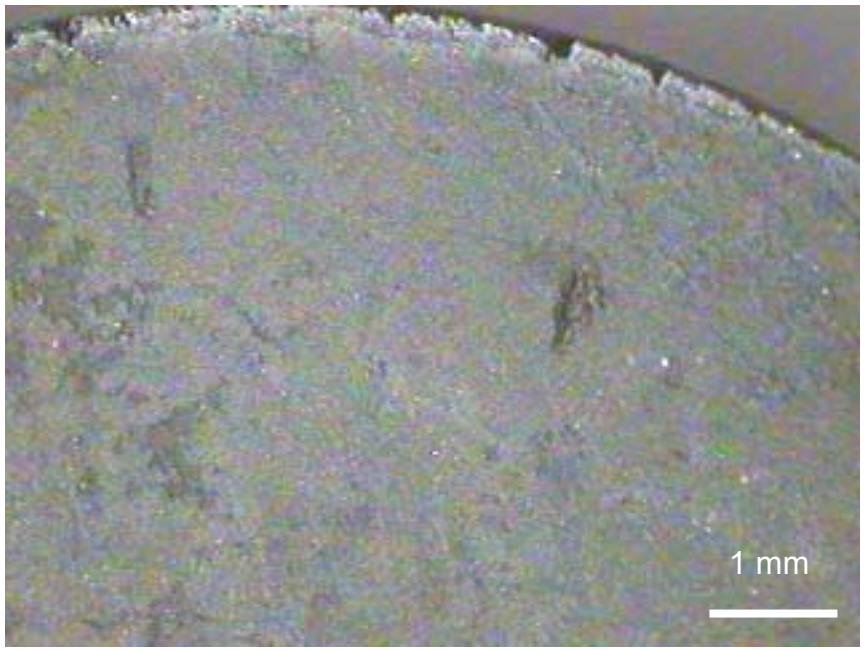
1st laser scan.
Duration over point 0.8 ms FWHM
temperature rises to 1963 C.



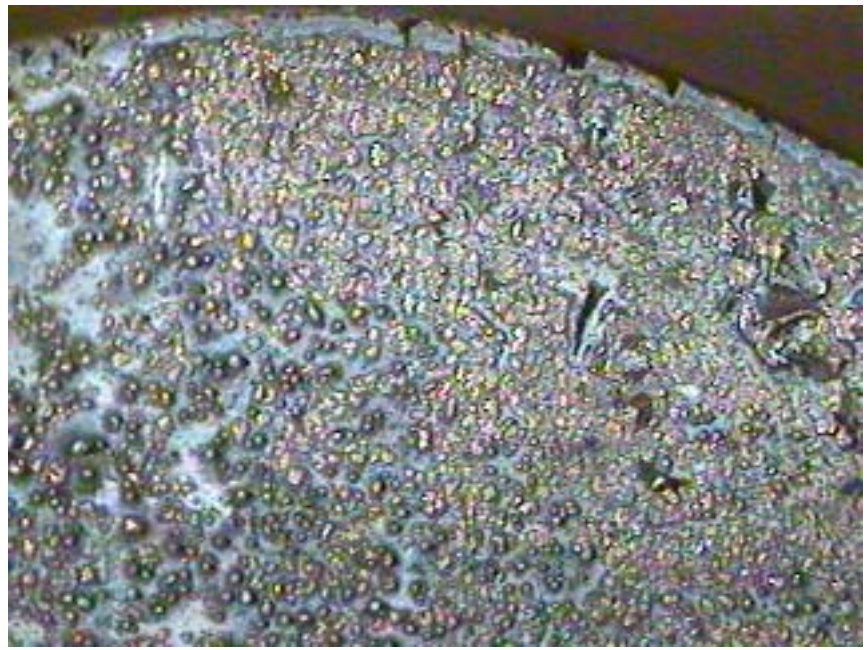
20th heat pulse over same area.
scan speed reduced x2; pulse 1.6 ms.
temperature rise only 1270 °C
- surface has changed....

Be/C layers on JET divertor tiles appear to form ‘beads’ in response to large heat flux.

IN3-16 before laser scan



IN3-16 after laser scans



‘Globules’ formed after laser heating.
21 temperature excursions above 1000 C, peak temperature 2,100 C.
Subsequent scans at same laser power and speed resulted in lower temperatures (1,601 C then 1,314 C) as layer became more thermally conducting similar to the manufactured material.
Other codeposits (without Be) did not show this major temperature decrease.

Phase 1 funding will provide thermal response data on mixed-materials to ITER

- Phase 1 - $50k will fund new focusing optics to increase surface heating and enable PPPL to measure thermal response of PISCES mixed-material surfaces
- Phase 1 – PISCES will generate and reexamine plasma interaction behavior of samples at no additional cost
- Phase 1 - $10k ($5k PPPL & $5k UCSD) will be used to design the laser/optic system for ELM simulation measurements in-situ in PISCES-B

Phase 2 funding will provide in-situ measurements of response during plasma bombardment of mixed-material layers exposed to extreme heat fluxes

- $100k will purchase high power pulsed laser and optics for installation on PISCES-B
- $50k will fund PPPL staff to participate at UCSD on ELM interaction simulation measurements
- $25k will fund laser safety system and interlocks at UCSD
- $10k ($5k PPPL & $5k UCSD) will be used to design the laser/optics system

ITER ELM simulations in PISCES will be a high profile experiment for the US PFC Community

- ITER personnel are incessantly requesting these Be layer measurements
- Opportunities for collaborations abound
  - melt layer measurements during plasma bombardment
  - modelling
  - fast surface temperature measurements
  - post-exposure sample analysis
- Could be used to bring ‘new’ money (ITER funding) into the PFC Program