Flash heating of Be codeposits and implanted D

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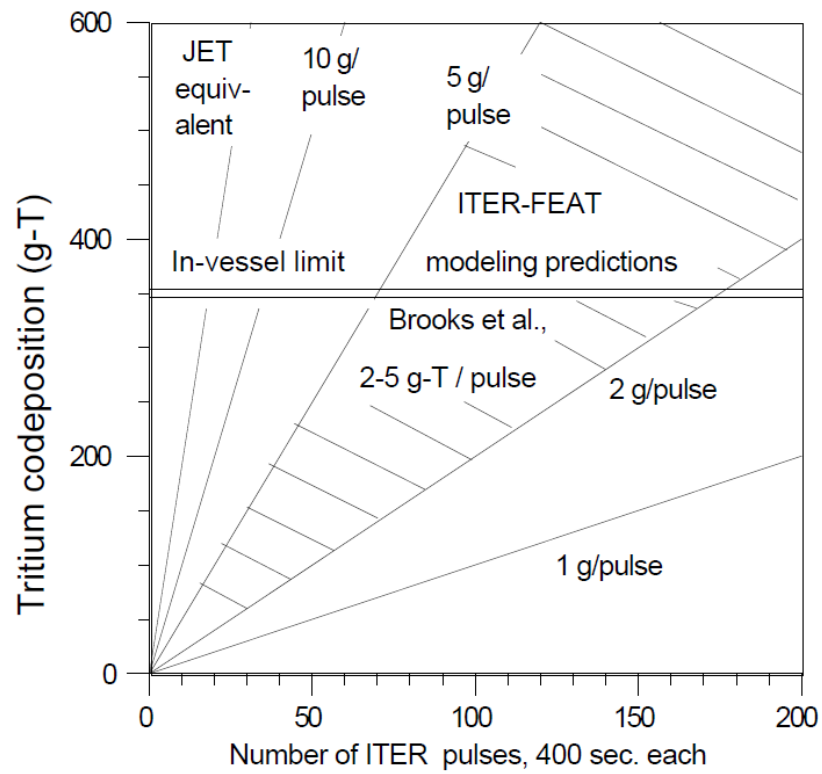
Motivation

- ITER safety regulations limit T inventory
- Tritium will be codeposited in Be layers on the main chamber wall in ITER
- Can transient heating from impurity radiation during plasma shutdown be used as a means of tritium removal in ITER?



J Brooks, A Kirschner, D. G. Whyte, D. N. Ruzic, D. A. Alman

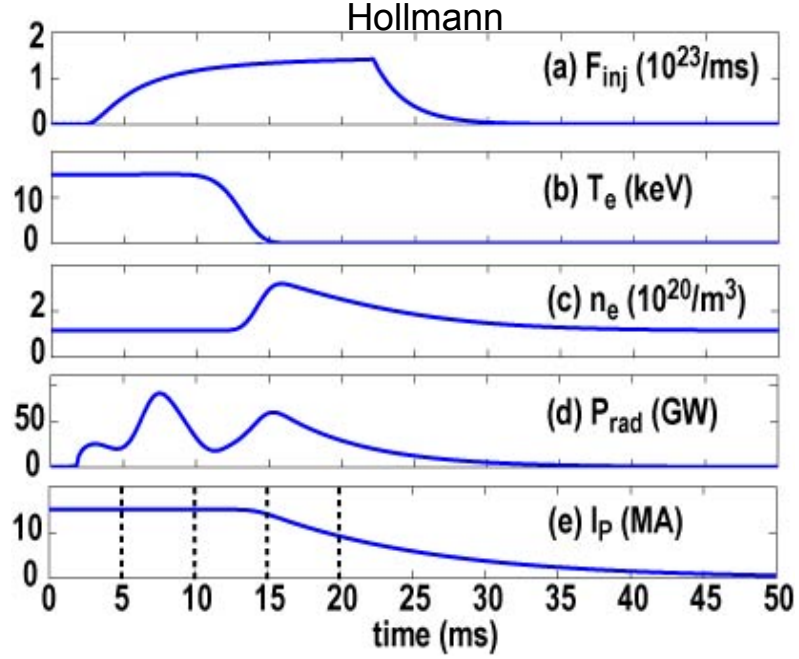
Flash parameters guided by simulation of ITER fast shutdown

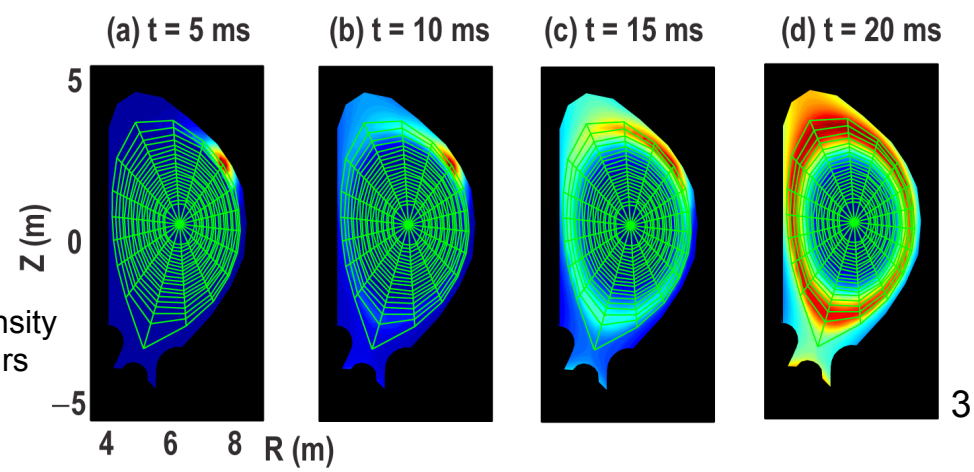
- 2E24 neon atoms injected
- Thermal energy 450 MJ radiated in ~10 ms
- ITER fast shutdown max impact factor

$$10 - 20 \frac{\mathrm{MJ}}{\mathrm{m}^2\sqrt{\mathrm{s}}}$$

Pisces laser: $20 \frac{\mathrm{MJ}}{\mathrm{m}^2\sqrt{\mathrm{s}}}$

Hollmann



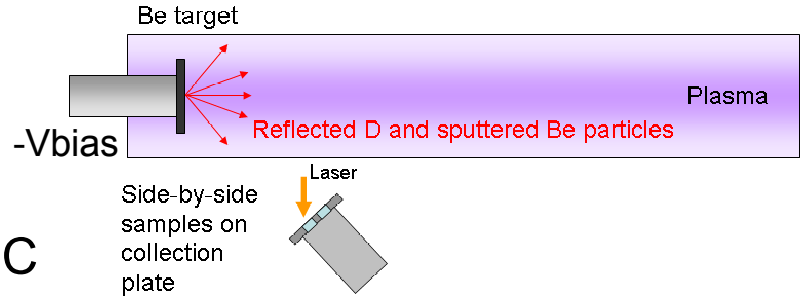


Ne density contours

Flash heating studied for three cases in PISCES

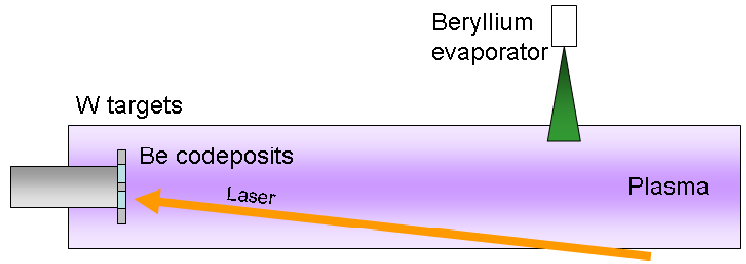
- ~100 nm thick Be codeposits on W collection plates

  ~20% D is flash-released, T_S = 900 C



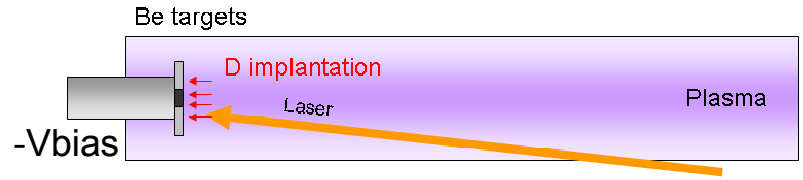
- <650 nm thick Be codeposits on W targets

  <5% D released, 450 C



- D implantation on Be target

  ~50% D released, 450 C

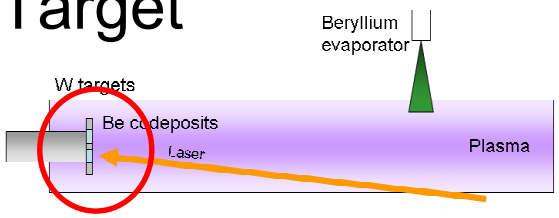


Laser Flash Experimental Procedure

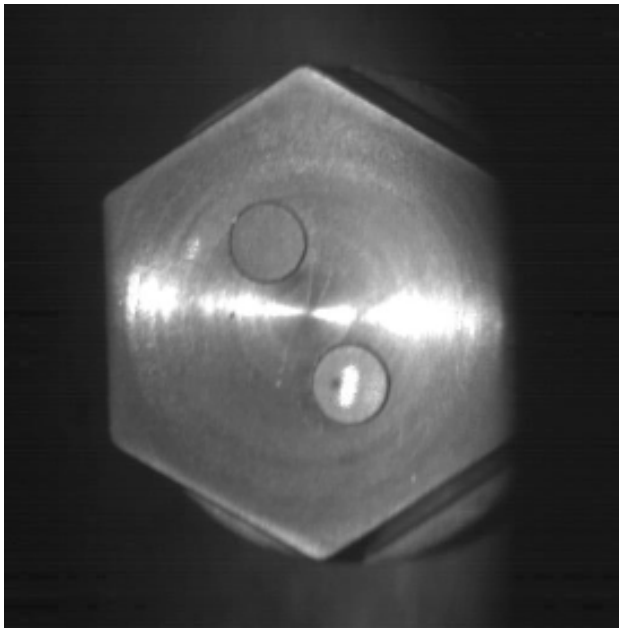
- Be codeposit formed (or target exposed) on two side-by-side samples in D plasma
- Plasma shut off, then one sample hit with welding laser (1064 nm, 50 J, 10 ms duration, 1 to 4 flashes)
- Fast pyrometer used to measure temperature
- D retention measured in both samples separately using TDS → determine amount of D removed during flash

Imaging used to verify alignment of laser on samples

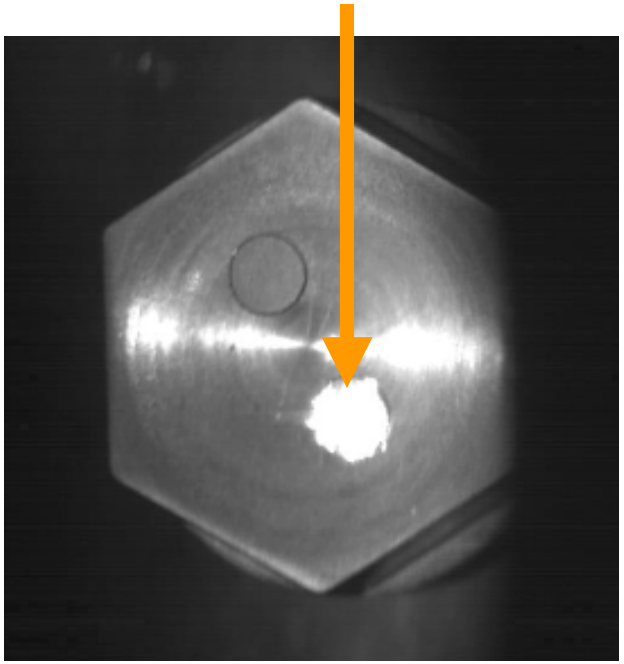
Target



Exposed sample area = 0.28 cm^2

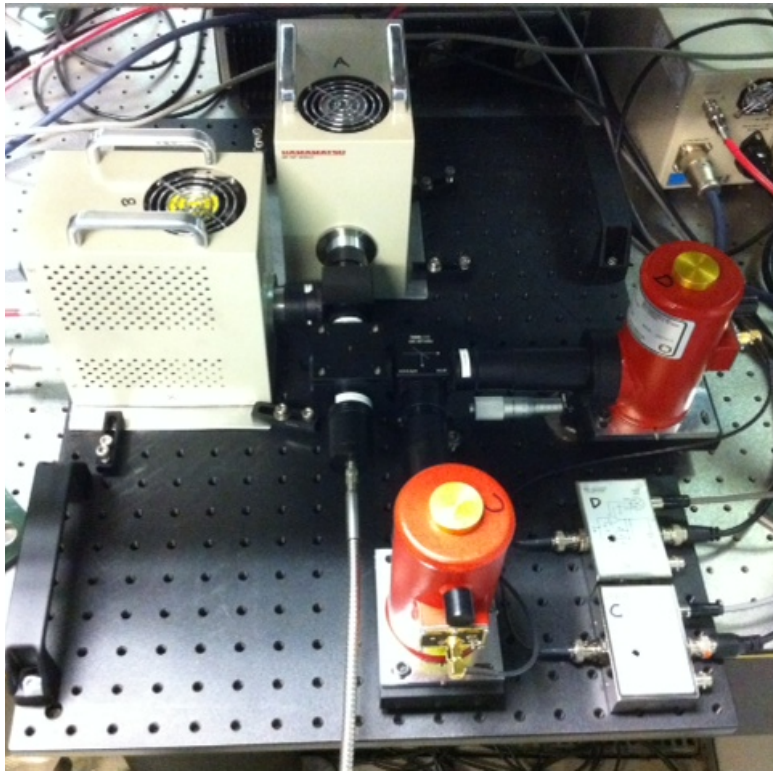


Laser

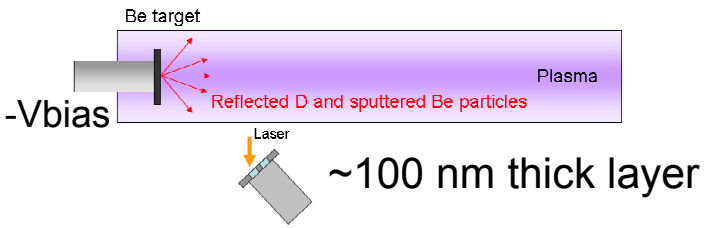


4-color pyrometer system used to measure sample temperature during flash

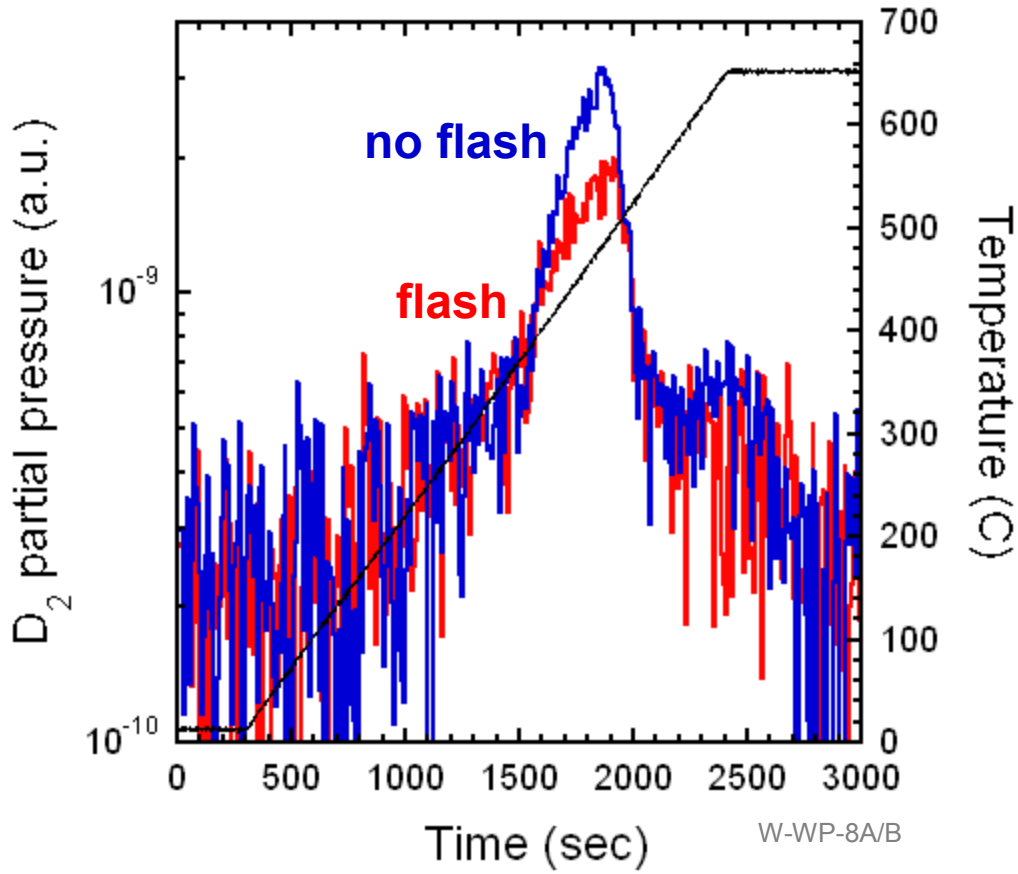
- Time resolution ~ 100 μsec
- CaF_2 viewport and IR/vis fiber
- 2 NIR PMT detectors (1.3 and 1.5 μm filters)
- 2 InSb IR detectors (2.7 and 3.5 μm filters)



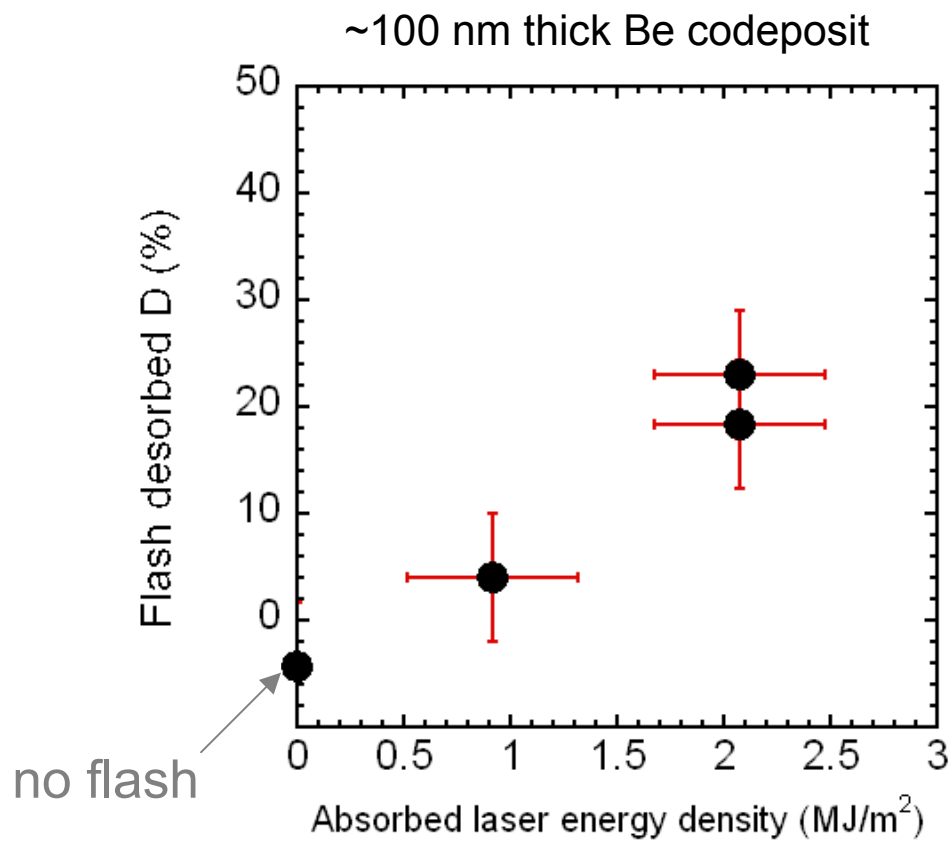
Flash heating of codeposits shows little release of D



- T_{flash} = 900 C
- Flash desorbs ~20% of D



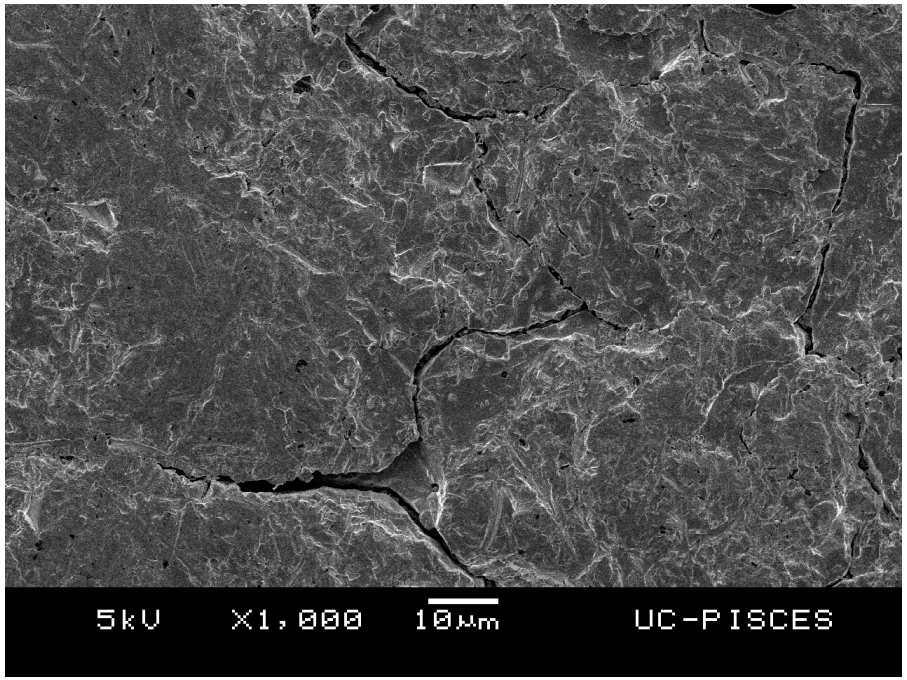
Small release (<25%) observed even at max laser power



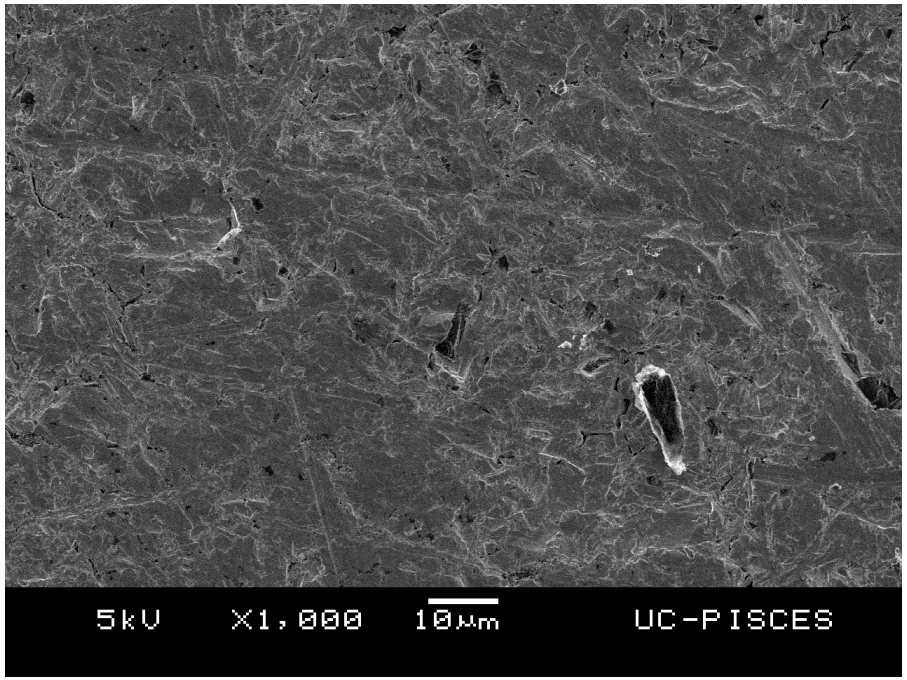
Desorbed D = 1 – ϕ_D(flash)/ϕ_D(no flash)

SEM images show signs of cracking on flashed sample

2 MJ/m^2 laser flash



No laser flash

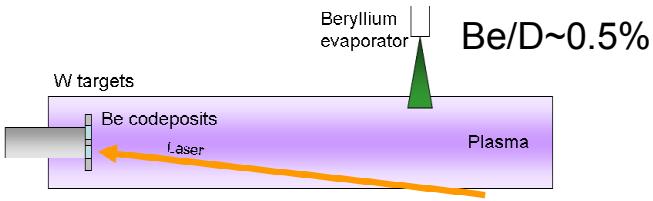


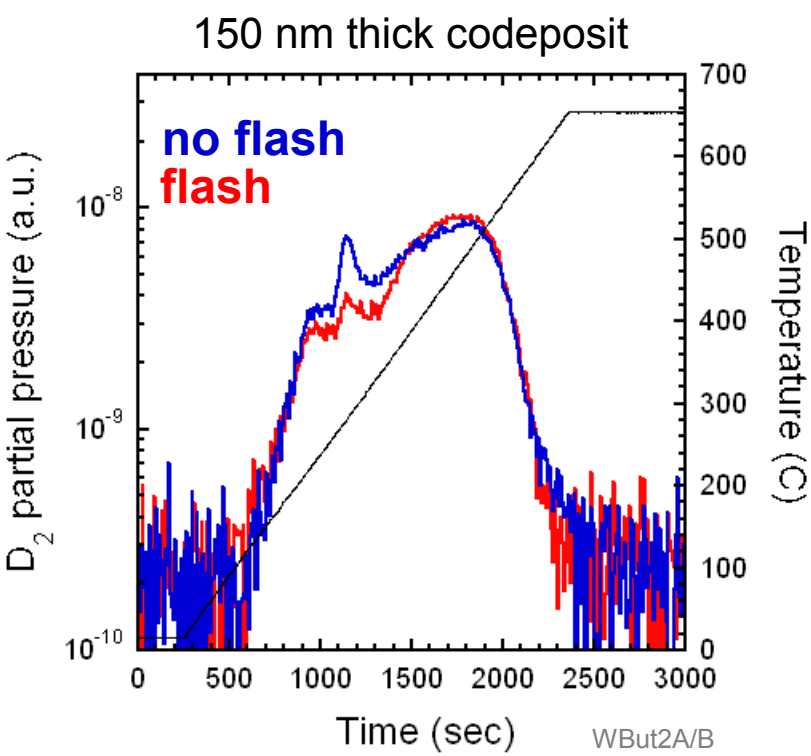
W-WP-5A/B

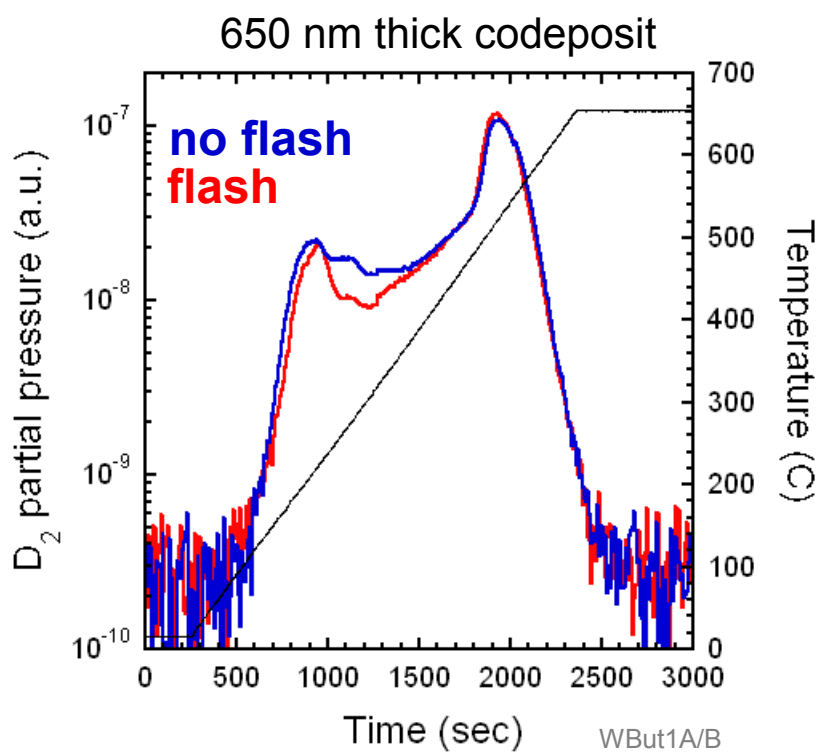
Cracking is consistent with electron beam high heat flux testing done at Julich.

Flashing codeposits created in plasma also shows small fractional release of D

- T_{flash} ~ 450 C
- T_{sample} = 50 C during deposition
- Clear reduction in peak at 290 C

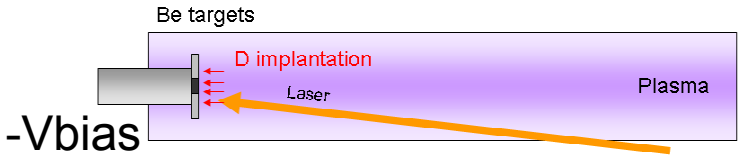




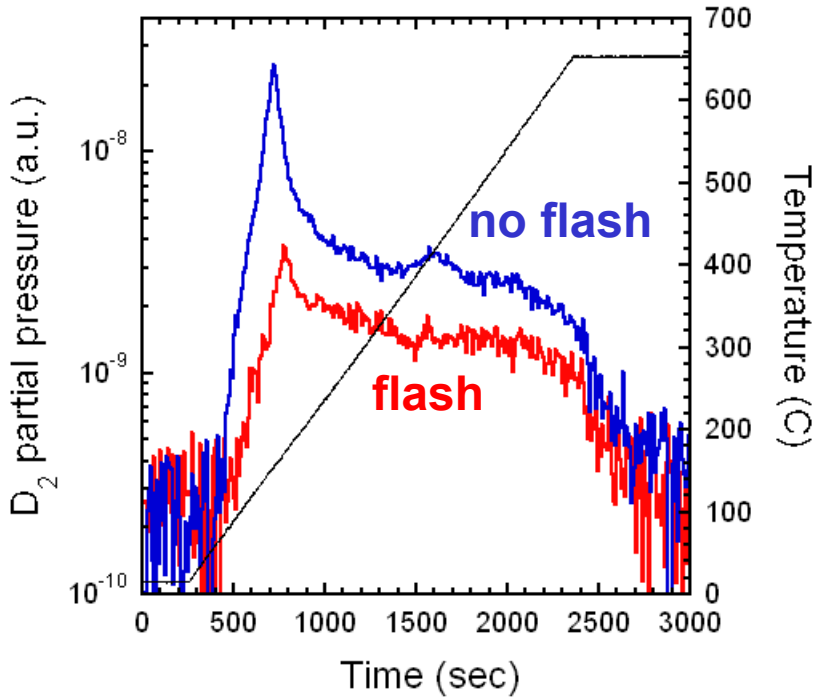


Reinelt et al. (2009) identified peak as decomposition of BeD_2

Flashing Be targets implanted with D from plasma results in larger changes than codeposits



- 50% to 60% of D released due to laser flash
- T_{flash} ~ 450 C
- T_{sample} = 30 C during exposure

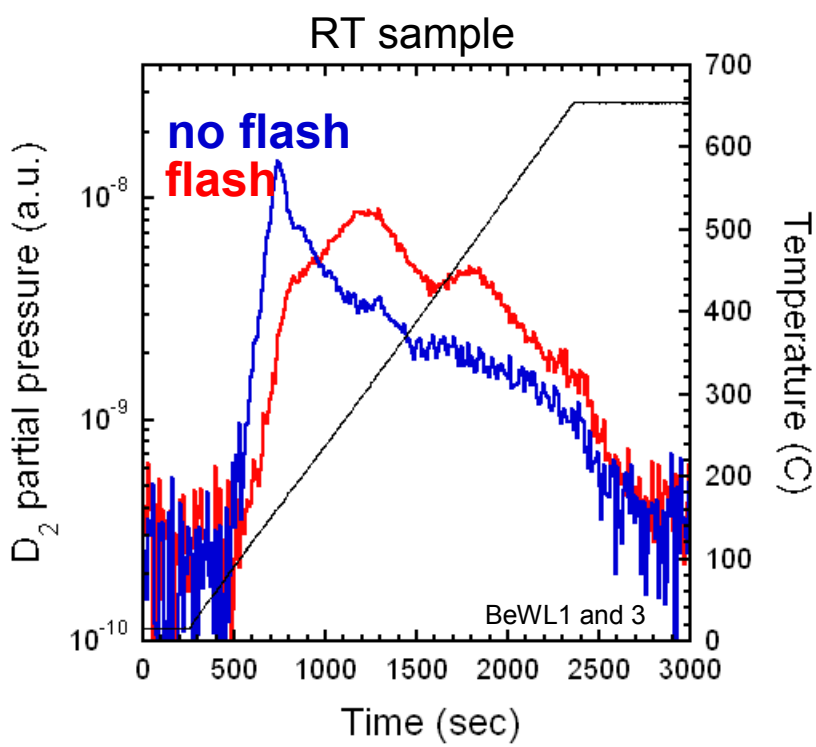


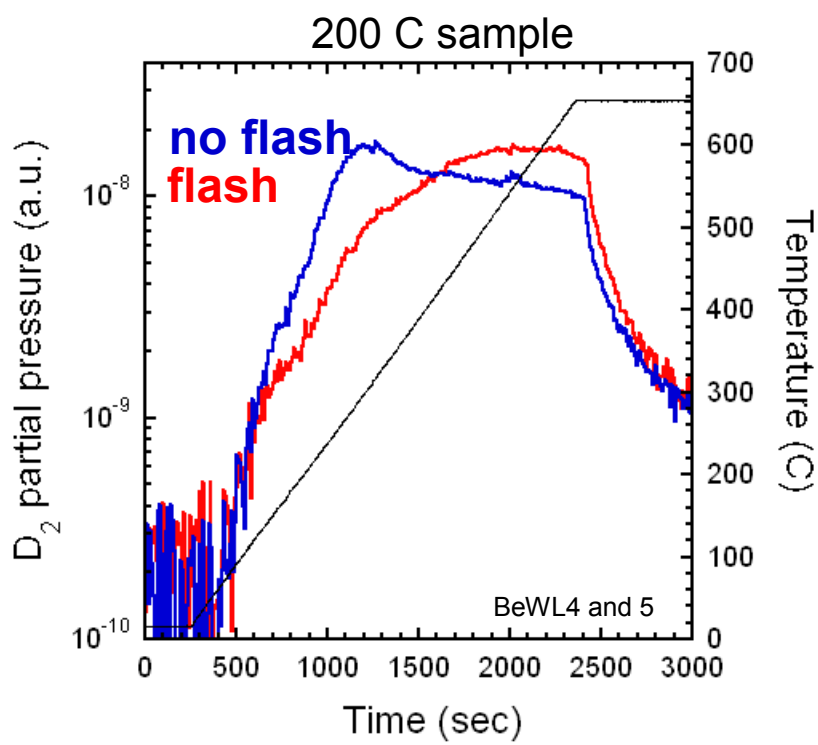
D implantation zone is order 20 nm < codeposit thickness.

Results suggest that flash desorption zone thickness (relative to codeposit thickness or D implantation depth) is relevant parameter to predict fraction of D released.

Simulate ELM heat flux to PFC using repetitive flashing (1Hz) of Be targets during implantation

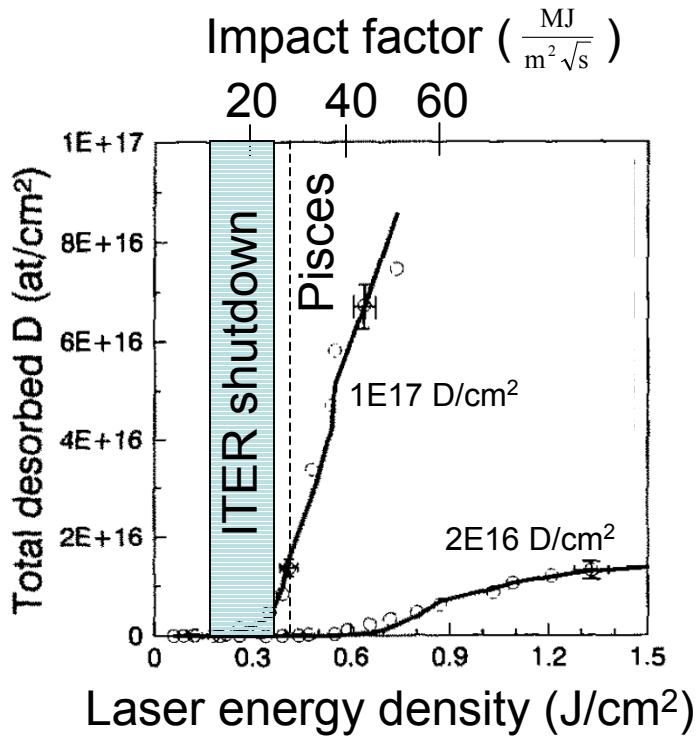
- No significant D release from ~3600 flashes, each with T_{flash} ~ 450 C
- Retention mechanism shifts due to repetitive flashing





Comparison to other work

- Fluence-dependent desorption threshold
- Two-trap desorption model reproduces data better than diffusion-limited model

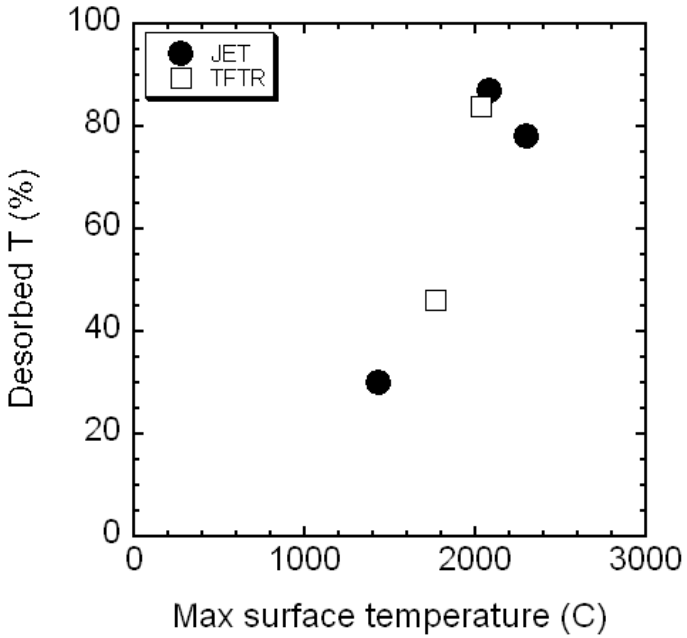


1keV D implanted into Be
Q-switched Ruby laser, 25 ns FWHM

Schiettekatte, Keroack, et al., 1994

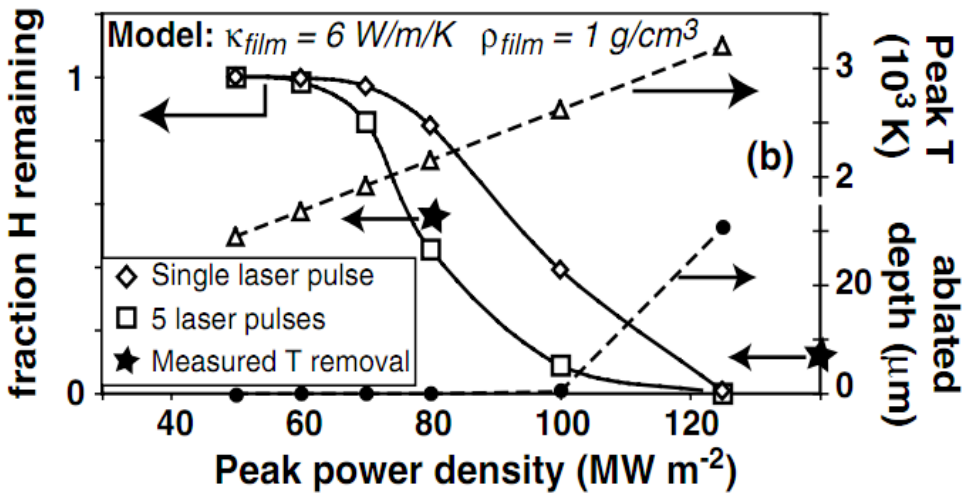
T_{flash} needs to be >2000 K for significant release of T from C codeposits

Scanning Nd laser



C.H. Skinner et al., JNM 2003

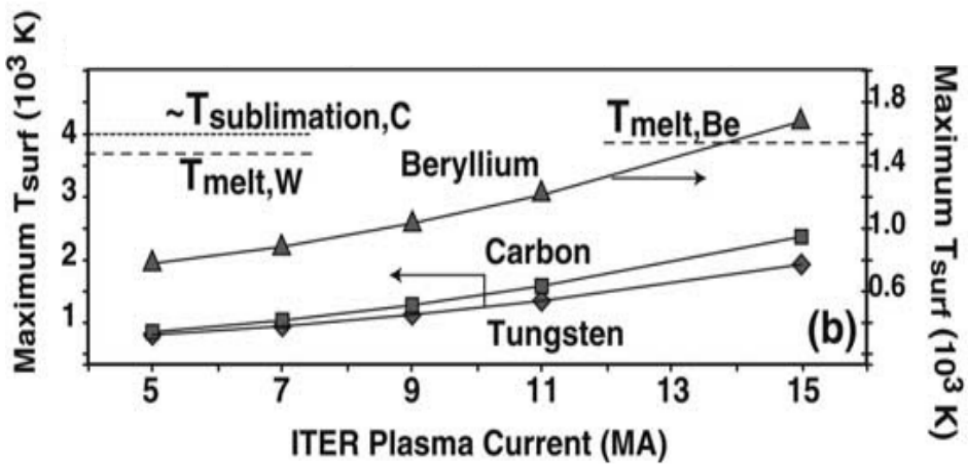
Calculated H diffusion in amorphous carbon



D. Whyte and J. Davis, JNM 2005

Modeled radiative plasma shutdown for ITER

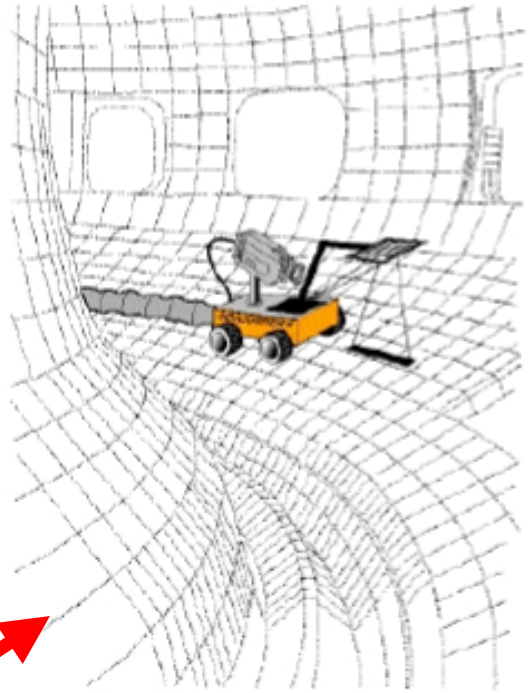
D. Whyte and J. Davis
JNM 2005



- Temperatures necessary for significant (>50%) removal of tritium can only be reached for highest I_p
- Risk melting Be wall

Other options for tritium removal in ITER

- Remove whole codeposit by ablation
  - Debris fall in remote locations
- Oxidation
  - De-condition wall
  - Possible damage to in-vessel components
- Laser heating (Skinner)
  - Still need to increase efficiency



Sojuner II

Conceptual design for laser detritiation of ITER inspired by successful SojunerI mission to Mars

Summary

- Be codeposits and Be implanted with D shows <50% of D desorption with ITER-relevant flash impact factors.
- PISCES data (T_{surf} < 900 C) suggests flash desorption zone is thin (of order 10 nm), so majority of D remains in codeposit.
- Flash removal of D during fast shutdown appears to be unrealistic in ITER, but controlled laser heating appears promising.