PISCES Laser Transient Systems

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Overview

- Introduction
- Use of Laser Heat Pulses
- PA Short Pulse Update
- PA Long Pulse Initial Results
- PB Long Pulse Install

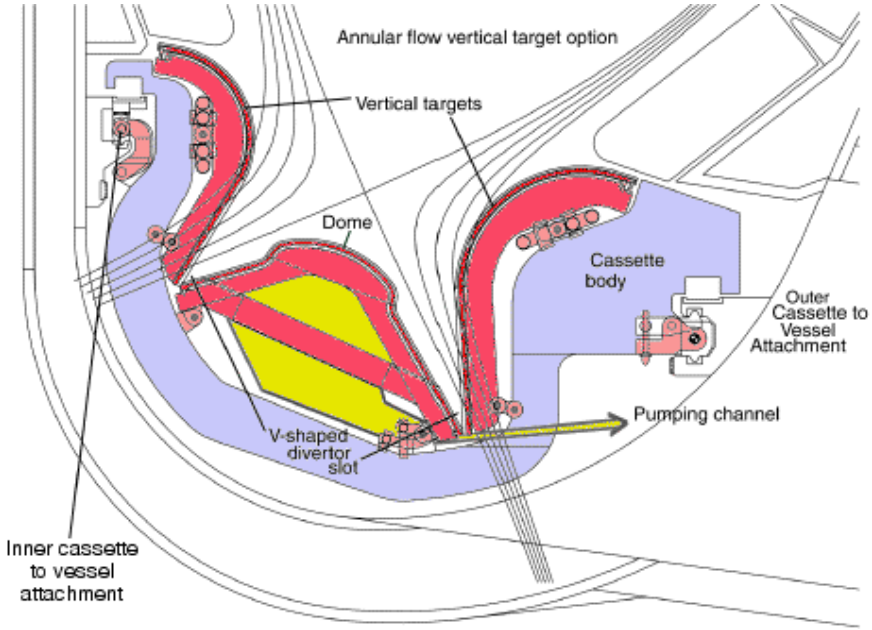
Introduction

When an ELM occurs in tokamaks, up to 30% of the pedestal energy can be deposited on the plasma facing boundary

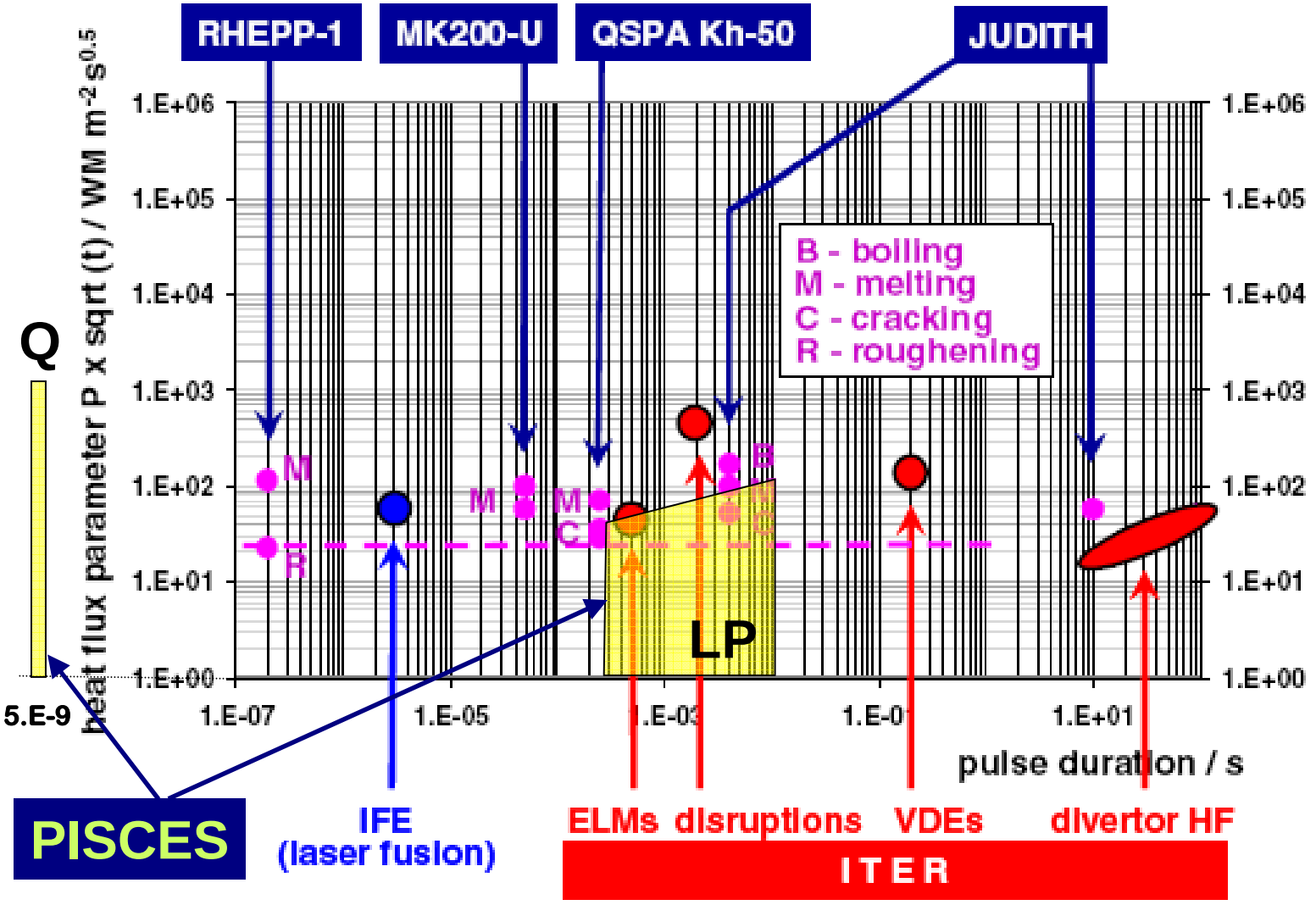
Result is heating & material loss due to sublimation, evaporation and melt splashing of plasma facing components

and

Expansion of the ejected material into the plasma



IFE/MFE Transients & Experiments



J. Linke, F. Escourbiac, I.V. Mazul, R. Nygren, M. Rodig, J. SchlosseR, S. Suzuki, J Nucl. Mat. 367–370 (2007) 1422–1431

PISCES A & Beam Delivery

PISCES A

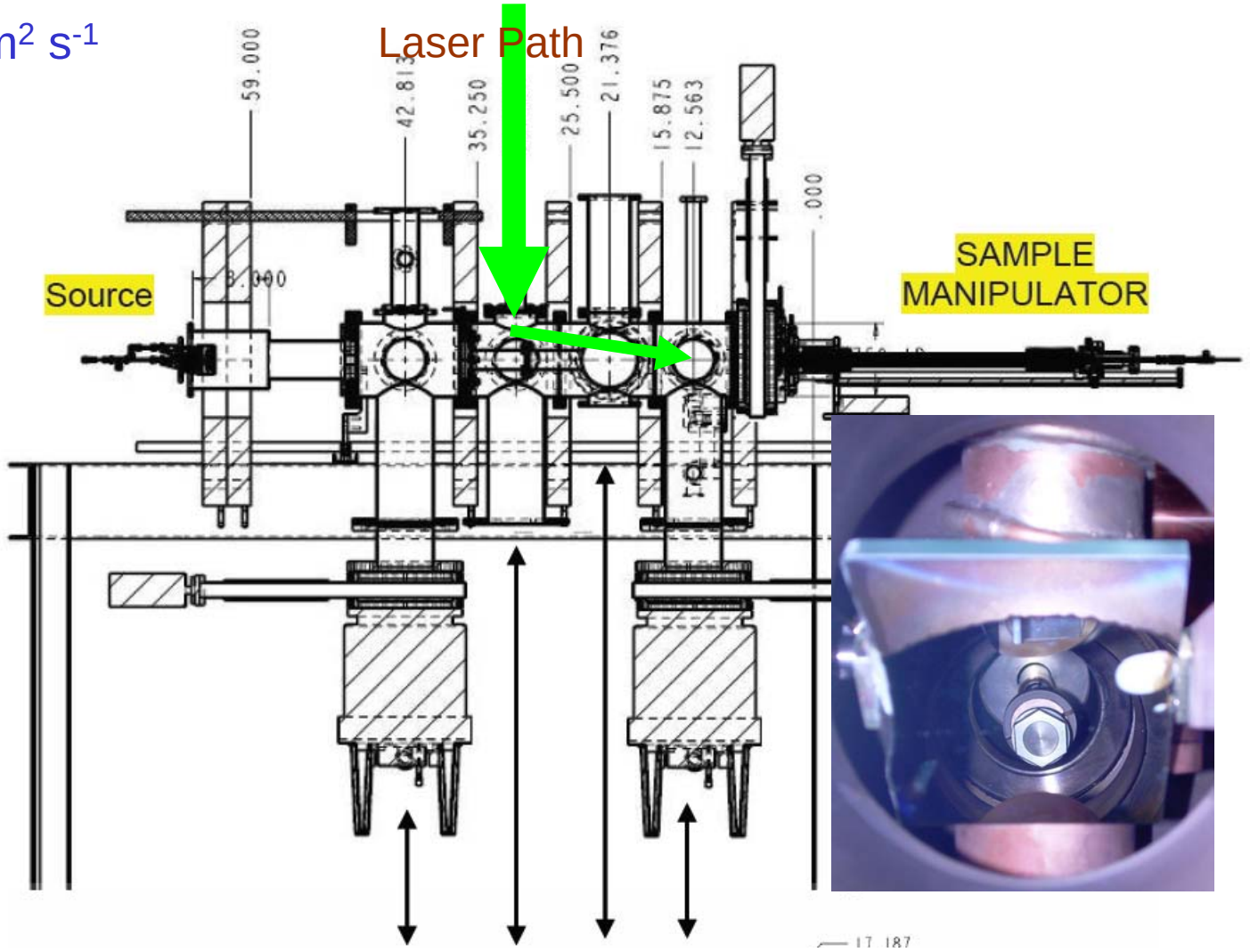
$\Gamma \sim 10^{17} - 10^{19}$ D^+/cm^2 s^{-1}

$n \sim 10^{12}$ D^+/cm^3

$Te \sim 5\text{-}10eV$

$V_{bias} \sim$ up to 250V

$R_p \sim 4cm$



Introduction

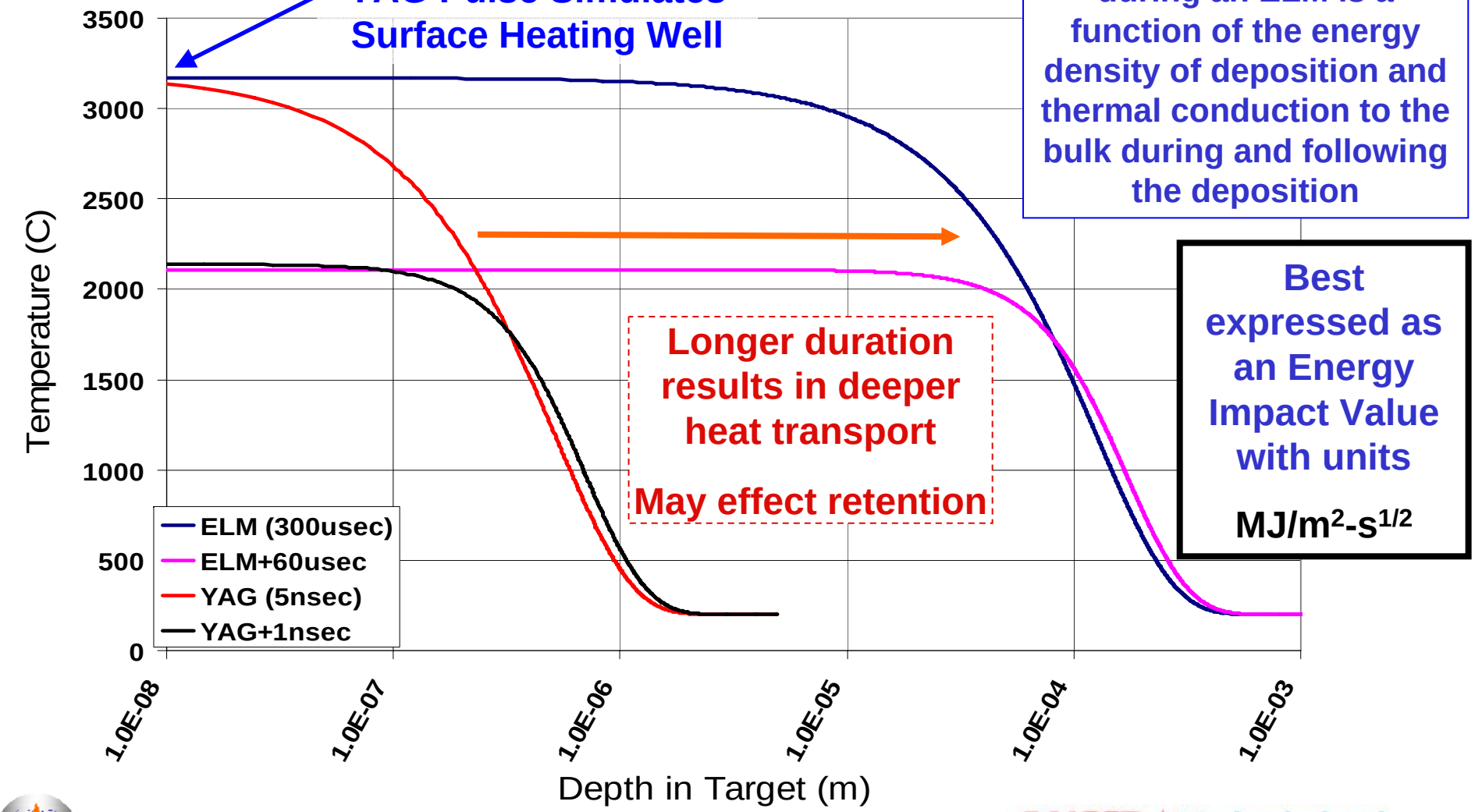
Calculations indicate that a pulsed laser system can be used to simulate the surface effects of the heat pulse of ELMs

Surface temperature during an ELM is a function of the energy density of deposition and thermal conduction to the bulk during and following the deposition

$$\Delta T(z,t) = \frac{2H}{k}\sqrt{\alpha t}\left\{ierfc\left[\frac{z}{2\sqrt{\alpha t}}\right] - ierfc\left[\frac{\sqrt{z^2+a^2}}{2\sqrt{\alpha t}}\right]\right\}$$

Lasers of varied pulsewidth can be utilized to mock transients such as ELMs and IFE wall impacts.

Q-Switch Nd:YAG as ELM Mimic



Mimic of ELM Transient on W

Laser Exposure of W at 200C for 60min

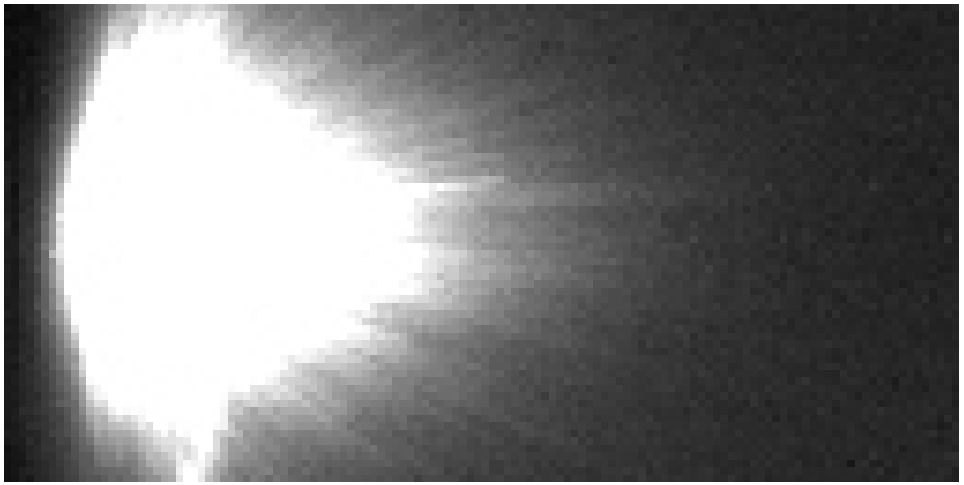
- Laser Parameters
  - 5nsec
  - 4mm spot
  - 166mJ per Shot
  - ~10^8 W/cm^2
  - 1200 Pulses

Absorbed Energy Impact ~58 MJ/m^2 s$^{1/2}$

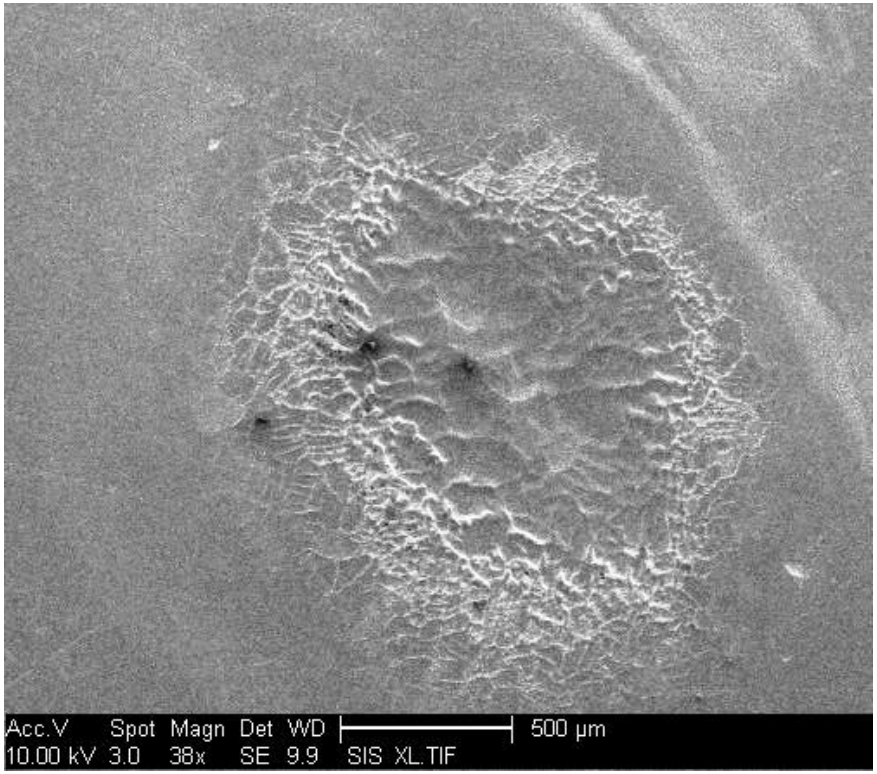
$\mathcal{R}_{W\ (\lambda=1064nm)}$ **~ 70%**

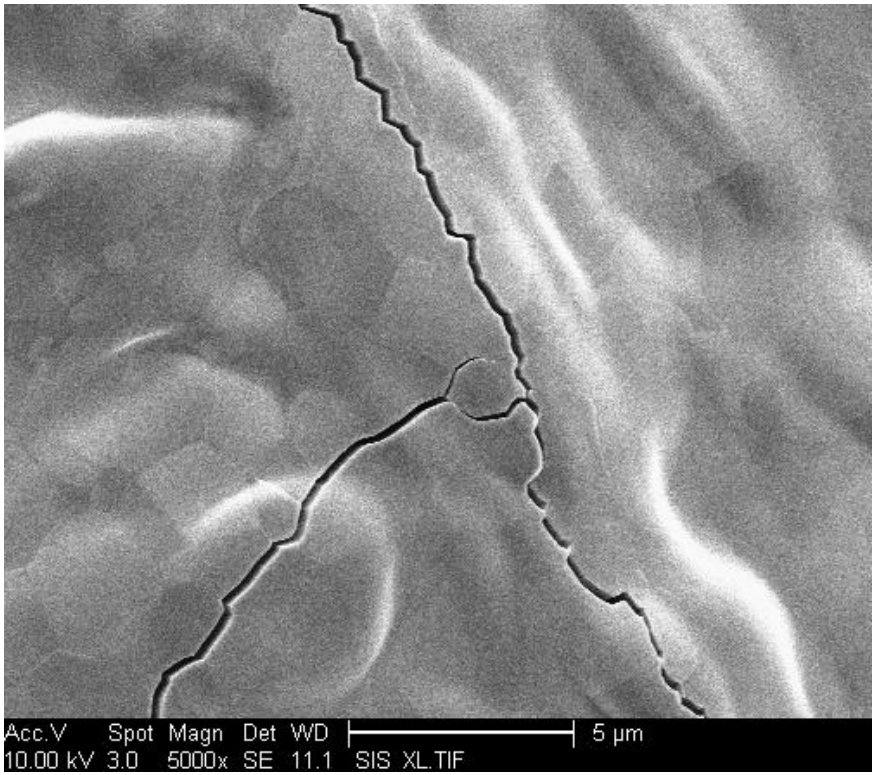
ELM Equivalent 1MJ/m^2 @ 0.3msec

- Plasma Parameters
  - Total Fluence **~ 10^{26} D^+/m^2**
  - Ion Energy ~100eV



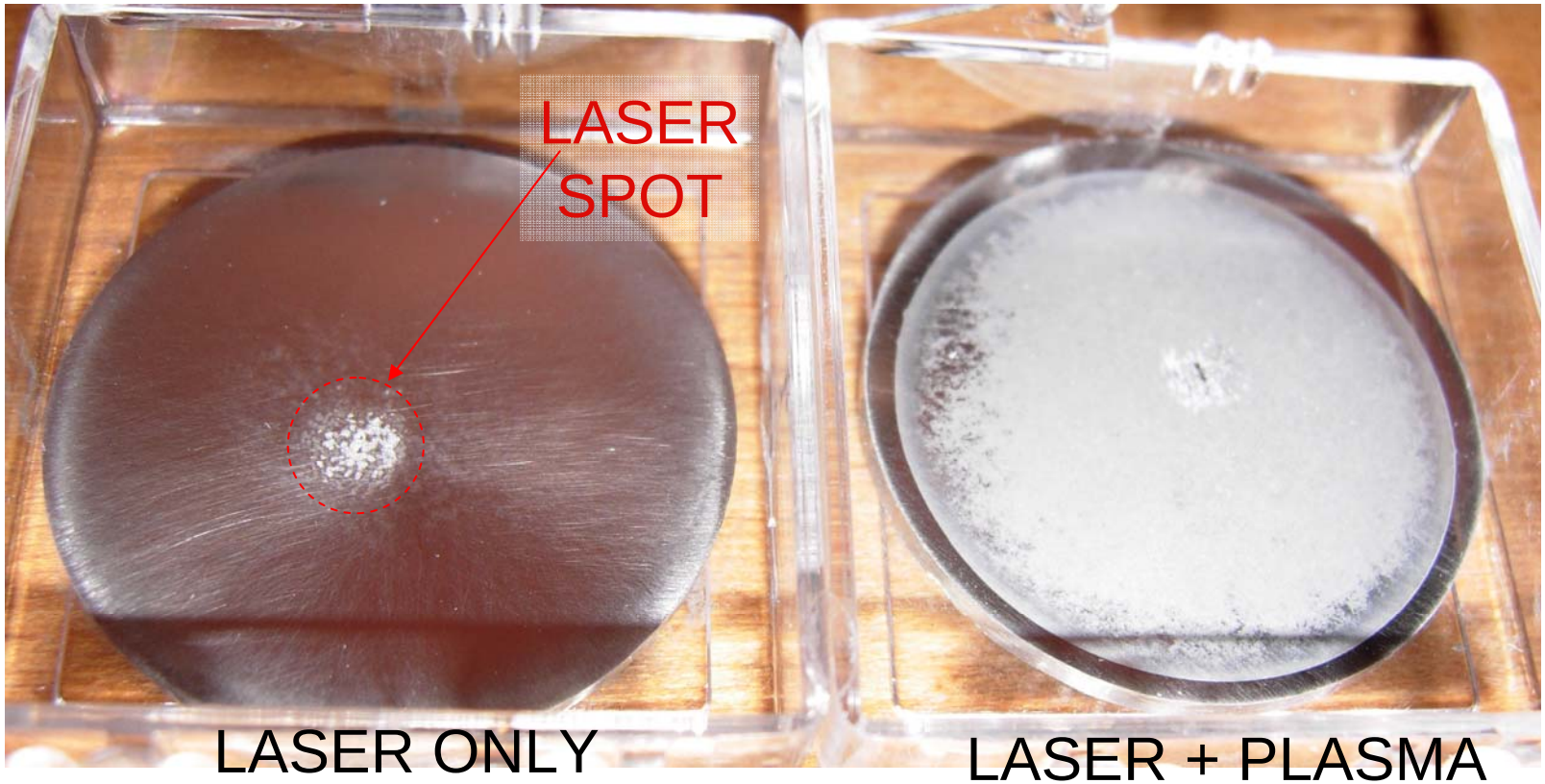
SEM Surface Analysis





Plasma + Heat Pulse Enhancement

Absorbed Energy Impact ~45 MJ/m^2 s$^{1/2}$ + $F \sim 10^{26}$ D$^+$/m^2, $T_{surf} \sim 50^oC$

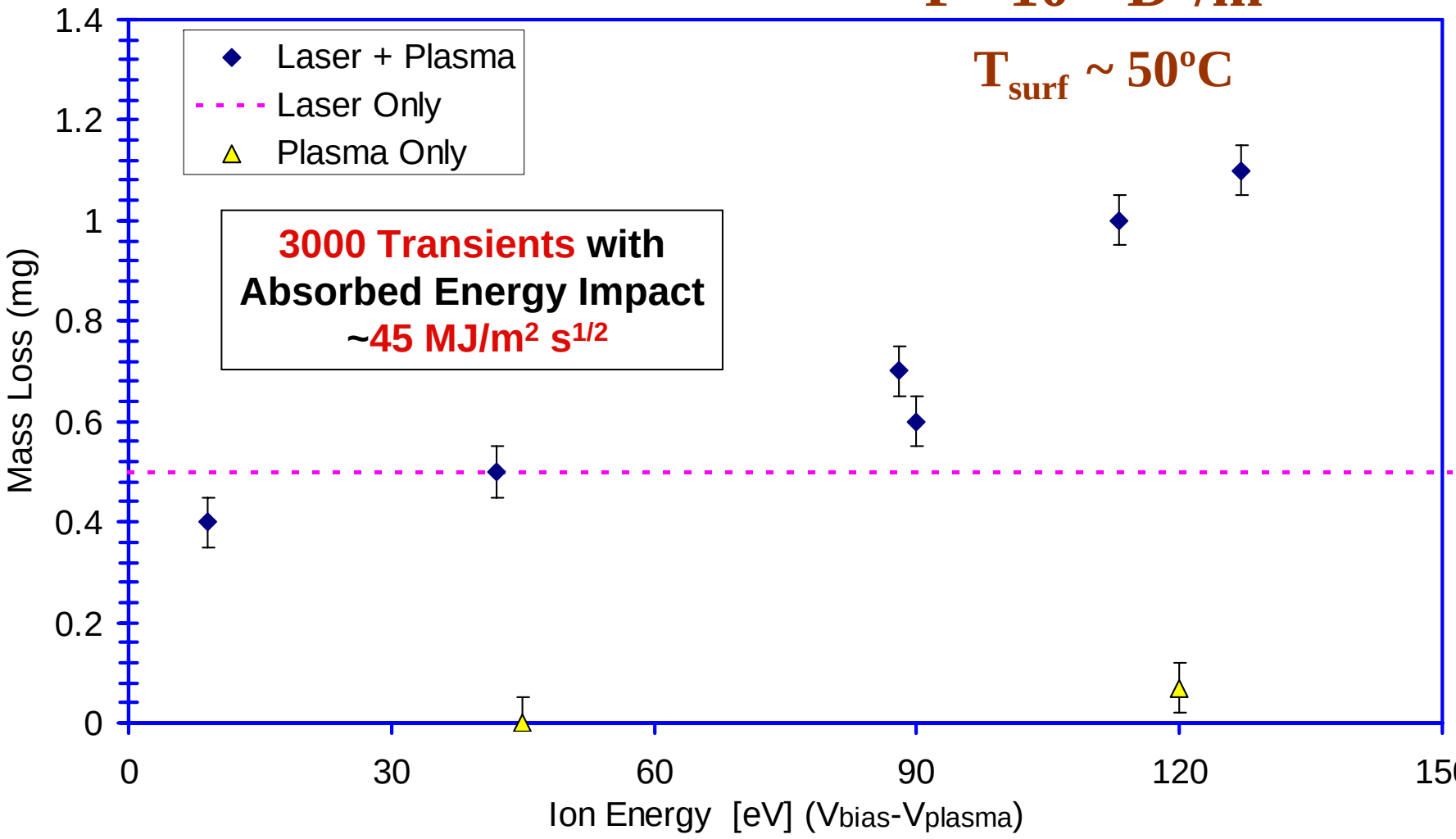


Erosion of W PFC under Simulated ELM Transients at High Repetition Rate

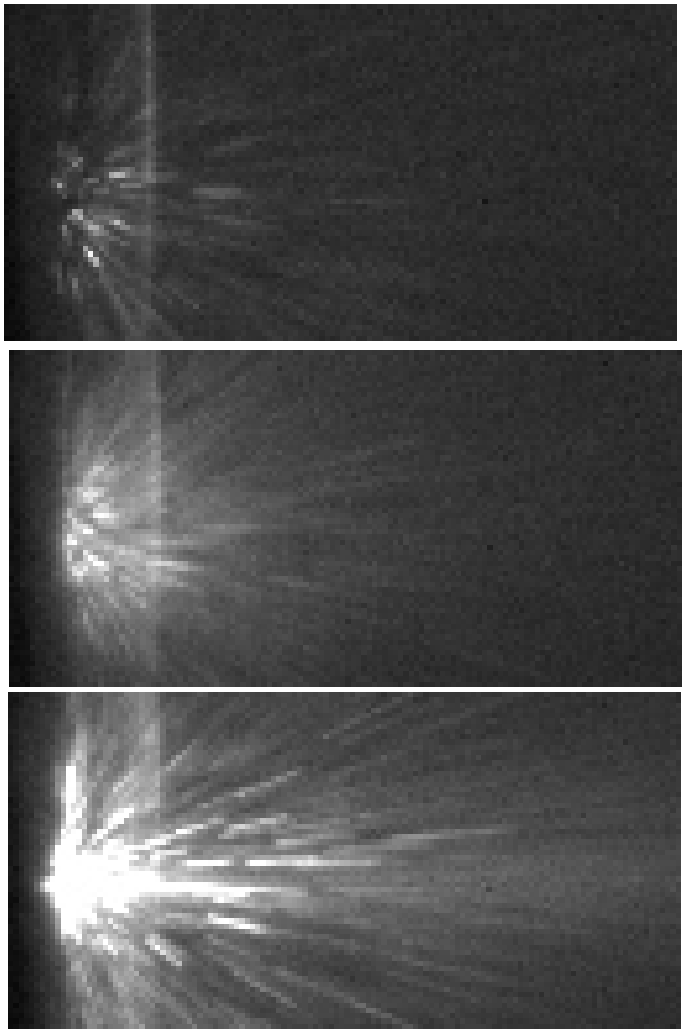
(low fluence between ELMs)

F~ 10^{26} D^+/m^2

T_{surf} ~ 50°C



Effects of D Loading on Damage



$F = 5 \times 10^{22}/m^2$

$F = 5 \times 10^{23}/m^2$

$F = 2 \times 10^{24}/m^2$

Fluence to surface between heating transients

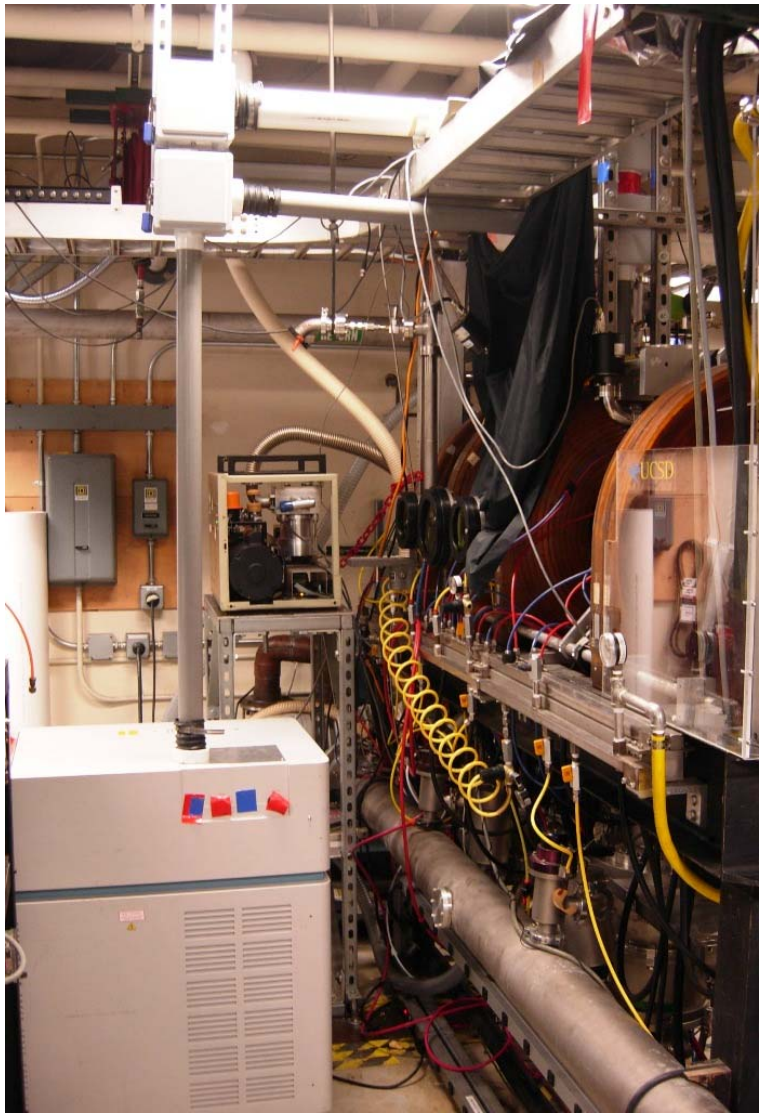
V_{bias}=125V
Γ=2x10^{22}/m^2-sec
T_e=11eV
n_e=2x10^{24}/m^3

Summary of Observations

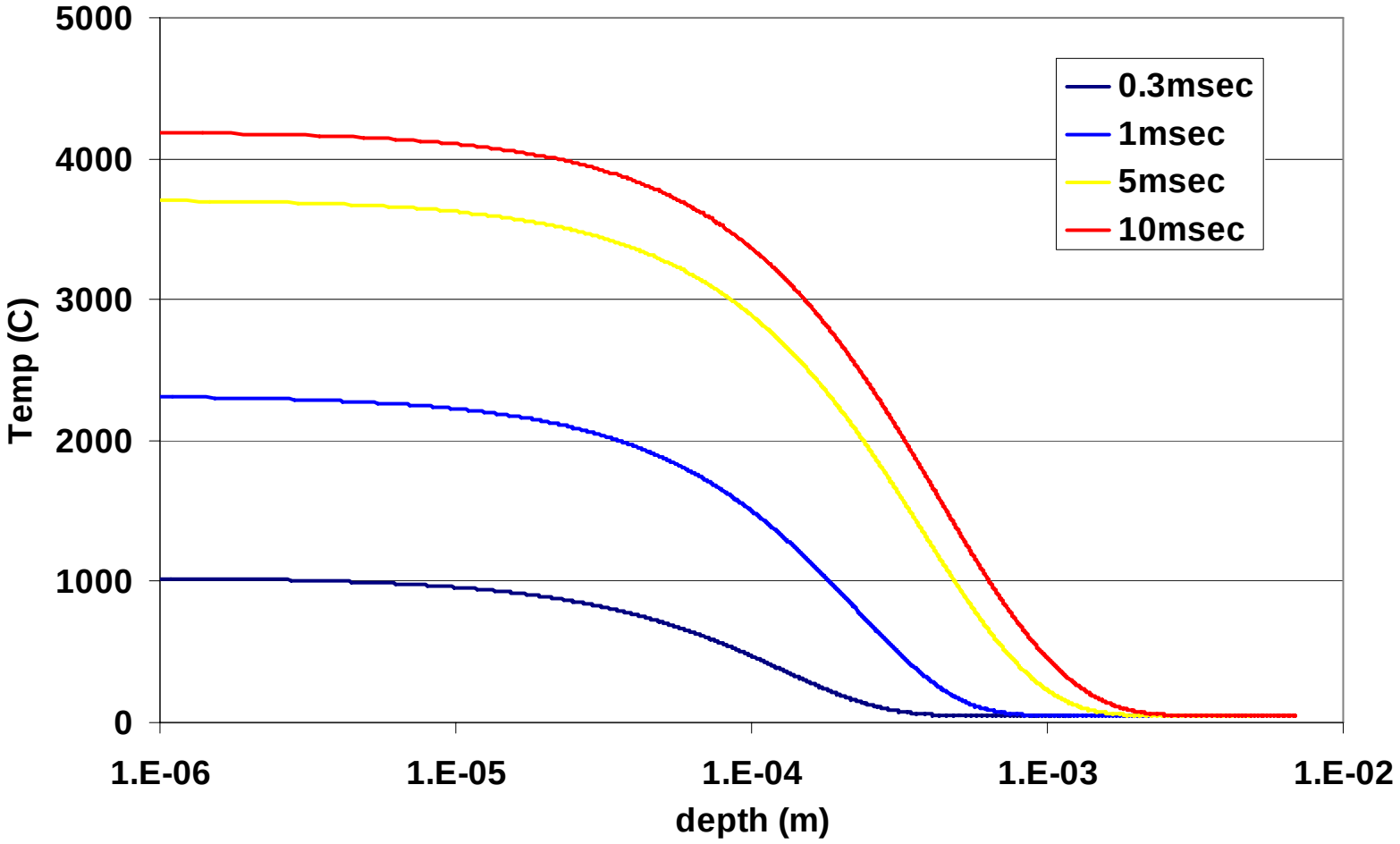
- **Fluence to PISCES-A targets between transients greater than operating tokamaks - approaching ITER**
- **Neutral and Ionized W found in range of mm to several cm in front of surface – *allows study of transport & redeposition***
- **Synergistic effect between thermal transients & plasma exposure leads to enhanced material removal**
- **Synergistic effect depends upon D fluence between transients**

Long Pulse Laser

- New Laser System
  - 0.3 - 20msec pulse
  - E_{pulse} = 1.5 - 50 J
- Installation on PISCES A
  - Compare results to short-pulse results
  - Test diagnostic systems
- Installation on PISCES B for Mixed Materials Studies –
  - Alloying of Materials
  - Effect on Surface "Nanostructures"



Long Pulse Nd:YAG as ELM Mimic



Maximum system parameters at each pulse duration

PA Long Pulse

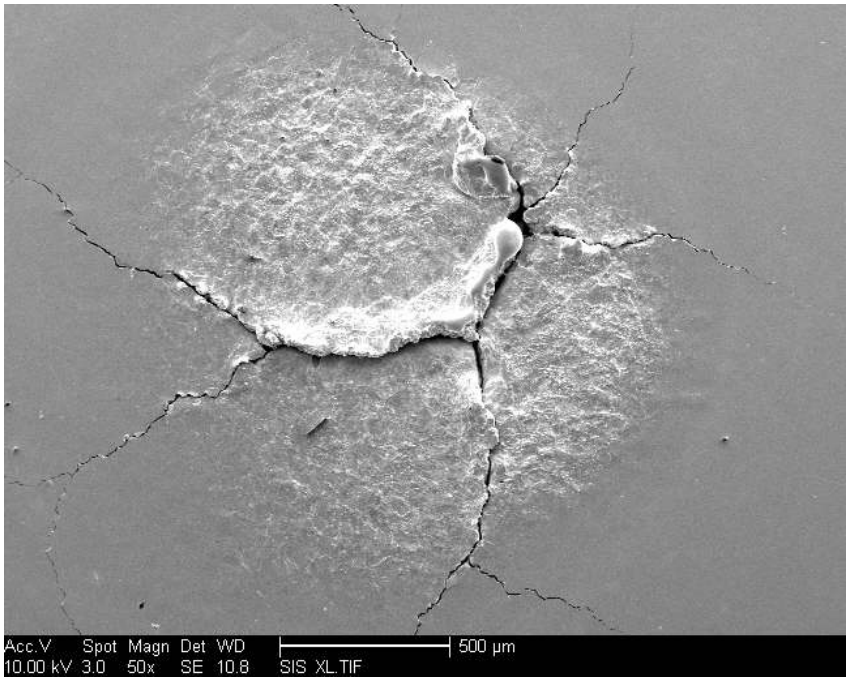
- Output beam collimated (divergence reduced)
- Laser safety windows installed
- Beam entirely enclosed outside vacuum

“No goggle operation”

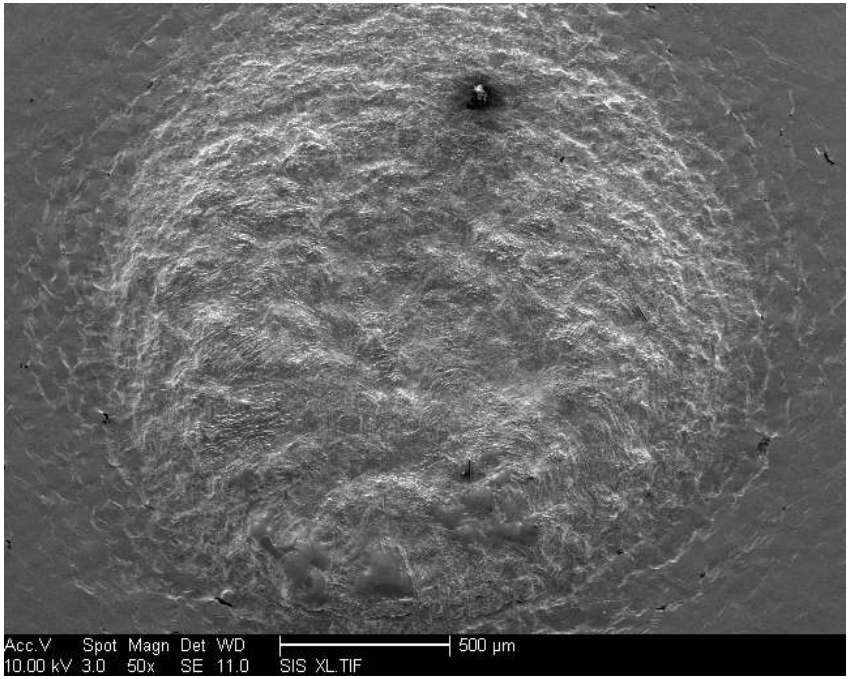
- Heat exchanger repaired
- Aux air cooling added (AC)
- Triggering system for remote/camera operation

Initial Experiments

- 25J – 5msec - 1200 Laser Pulses @1/3 Hz
  - 5 kW – 50MJ/$m^2s^{1/2}$
- 75V Bias – Total Fluence ~10^{26} D^+/m^2

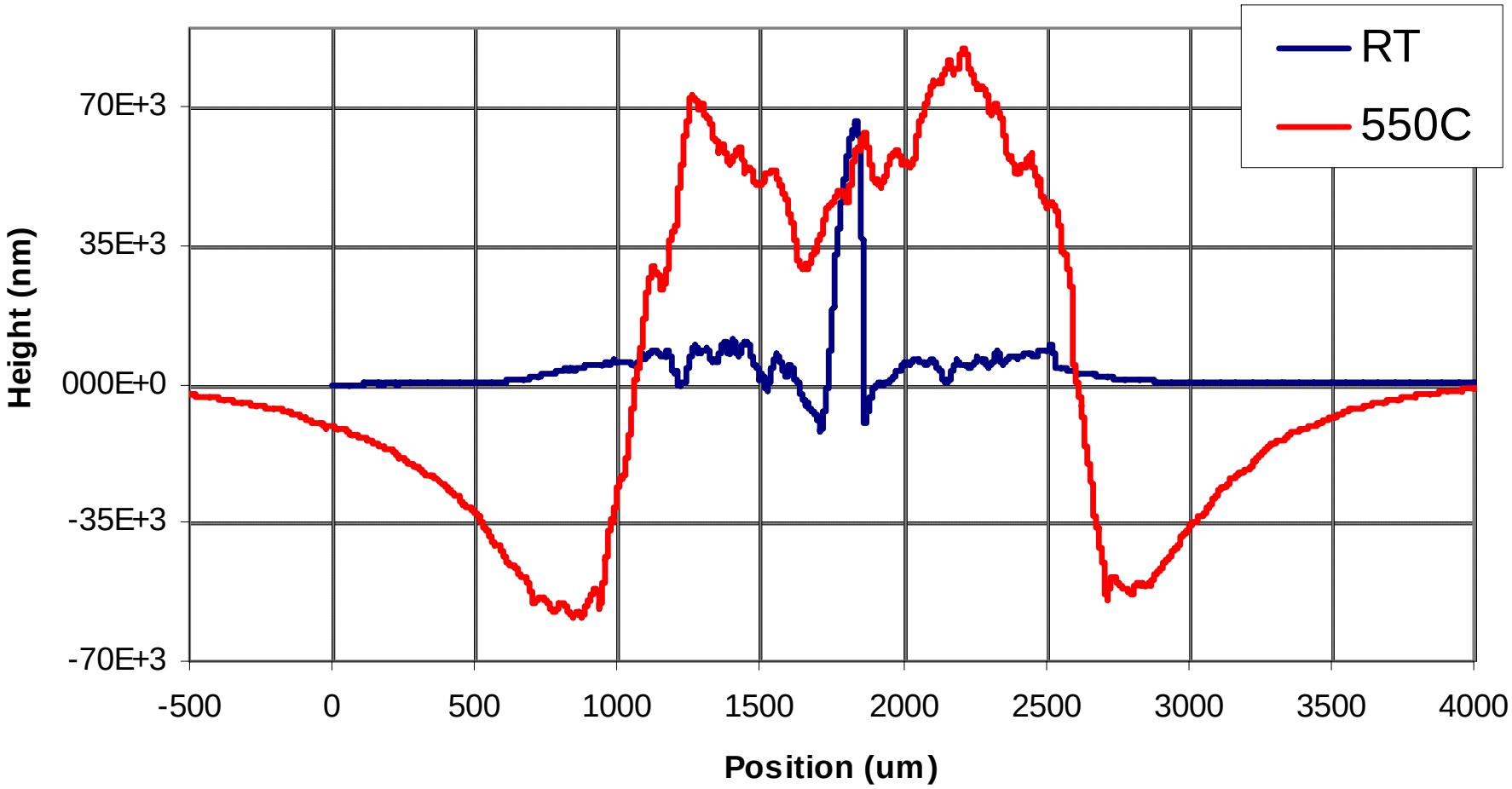


Room Temperature

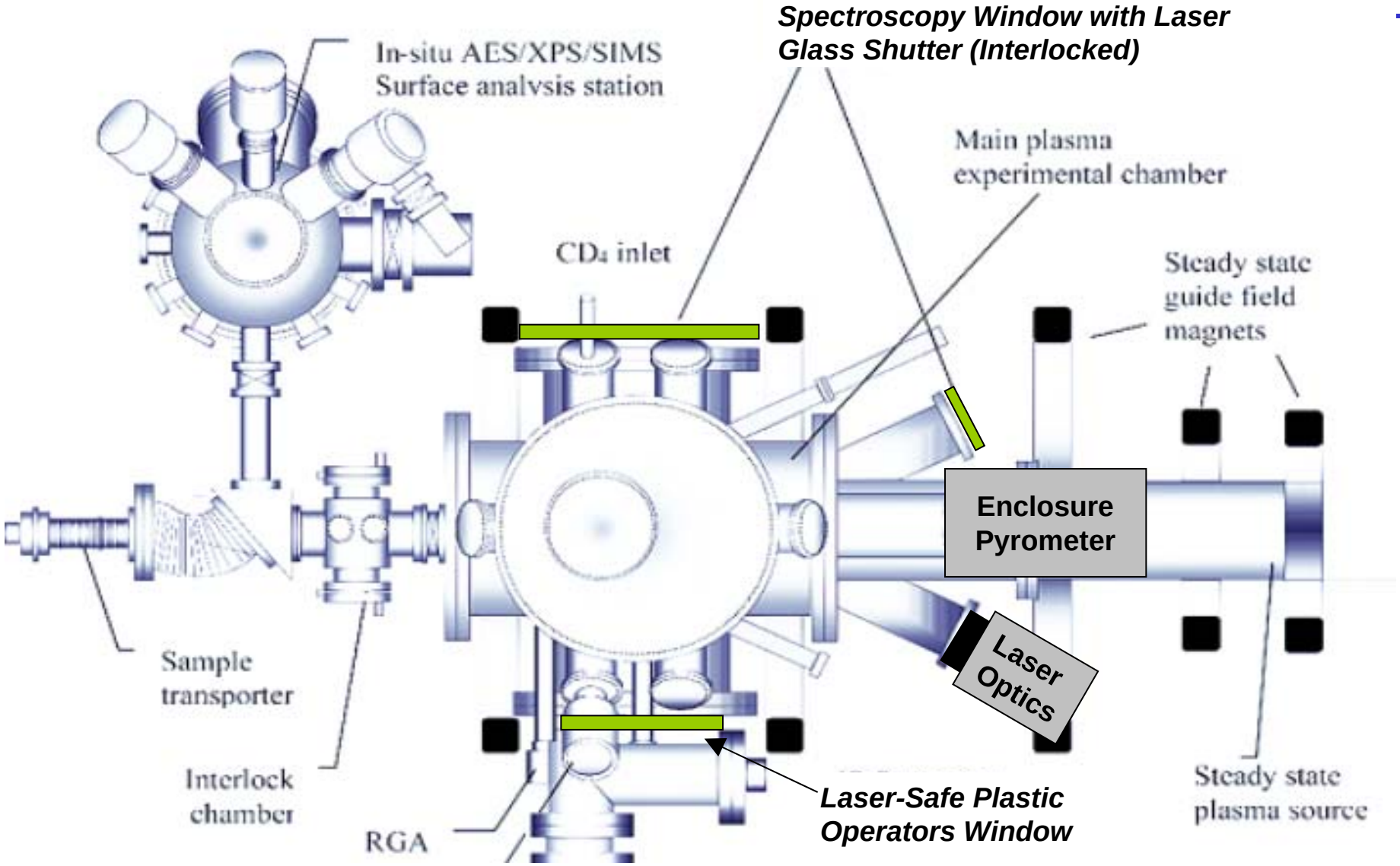


>500ºC

Surface Profiles



PB Implementation Update



Questions

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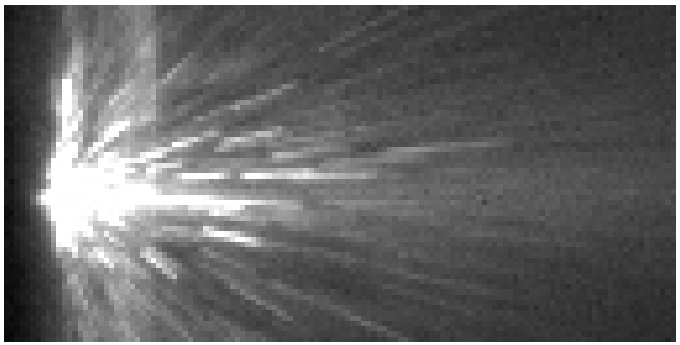

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