Characterization of Megahertz X-ray laser Beams by Multishot Desorption Imprints in PMMA

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INTRODUCTION

- Here we present the first characterization of defocused MHz 13.5-nm beam (FLASH) using method of multi-pulse desorption imprints to PMMA [1].
- Diagnostics of intense FEL X-ray pulses is important for:
  - experimental works
  - beamline optics (overheating damage) [2]
- Material removal is not linearly proportional to total dose delivered by multiple pulses
  (direct beam fluence profile recovery from desorption imprint is not possible).
- We have developed a NoReFry algorithm which calculates the material response function and so the correct beam fluence profile.

RESULTS

- The NoReFry algorithm was applied to WLI data obtained from ablation (34 profiles) and MHz desorption (8 profiles) imprints.

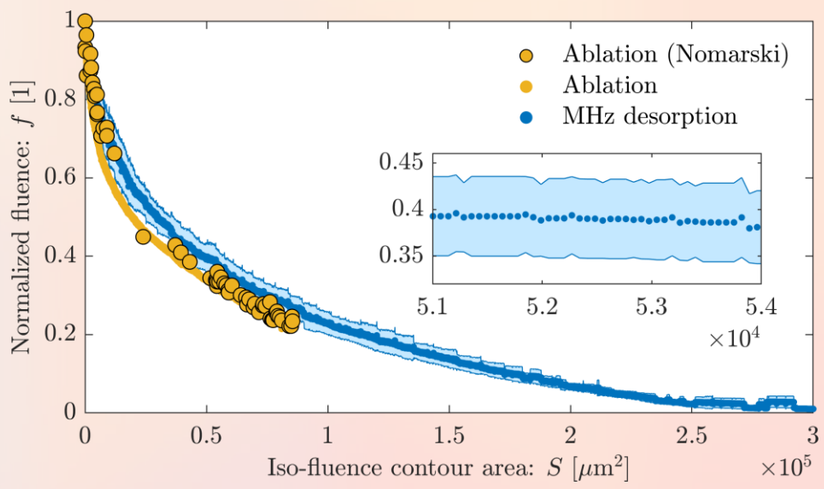


Figure: Retrieved fluence scans and ablation contour areas (solid circles) measured from Nomarski images. The error bar was obtained from the NoReFry.

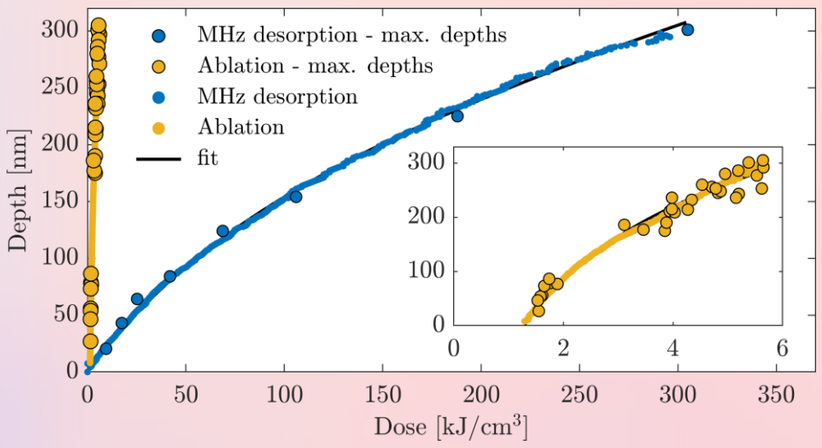


Figure: Maximum depths of imprints and recovered response functions fitted by a theoretical desorption resonse function model [4].

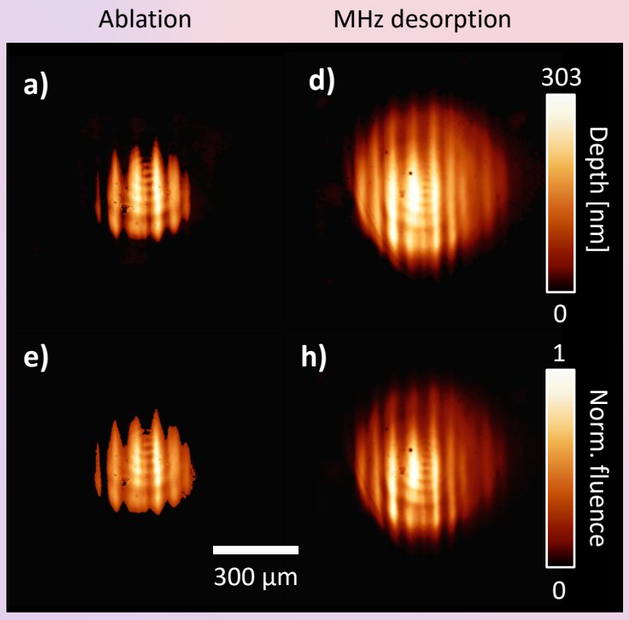
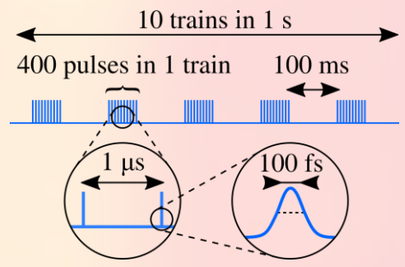


Figure: WLI depth profiles of ablation and desorption imprints. Threshold character of ablation process is clearly visible in the left image.

Figure: Corresponding beam profiles recovered using calibration curves (i.e. inverse response functions).

EXPERIMENT



- Experimental data from BL2 at the FLASH [3]
  (100 uJ, 13.5 nm, 100 fs)
- Ablation imprints: single-shot operation
  (1 pulse from train)
- MHz desorption imprints: open shutter regime
  (deposition of multiple pulse on the same spot)

Ablation imprints

- Single-shot induces large damage.
- One imprint provides an iso-fluence contour.
- Fluence profile can be obtained from multiple imprints at different attenu-ation levels.
- Low-intensity wings below the damage threshold remain unexplored.

Desorption imprints

- Accumulation of multiple shots at the same spot.
- Energy of each shot is below the ablation damage threshold.
- Fluence profile can be obtained from one single imprint (depth monotonously increas-es with deposited dose).
- Calibration curve (response function) must be known!

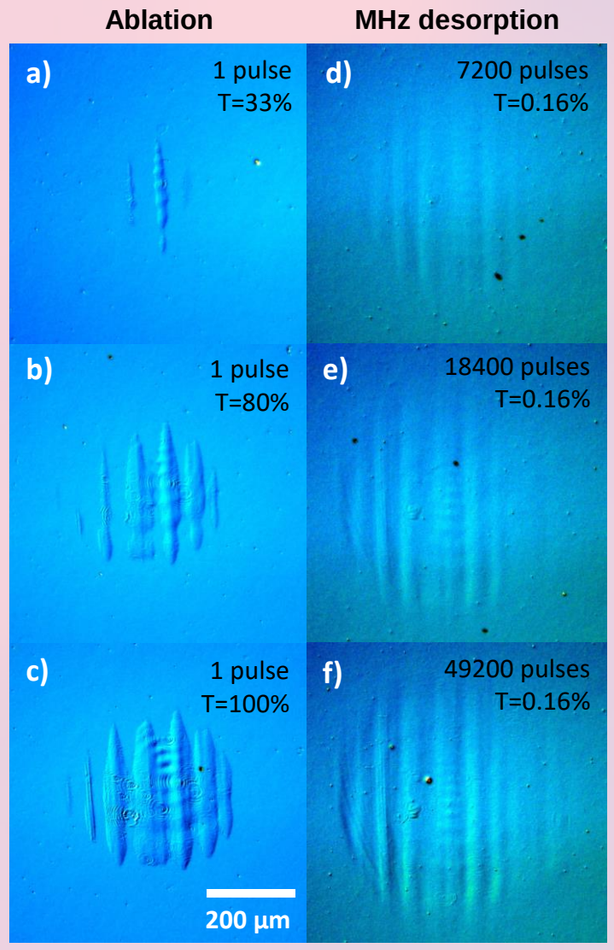
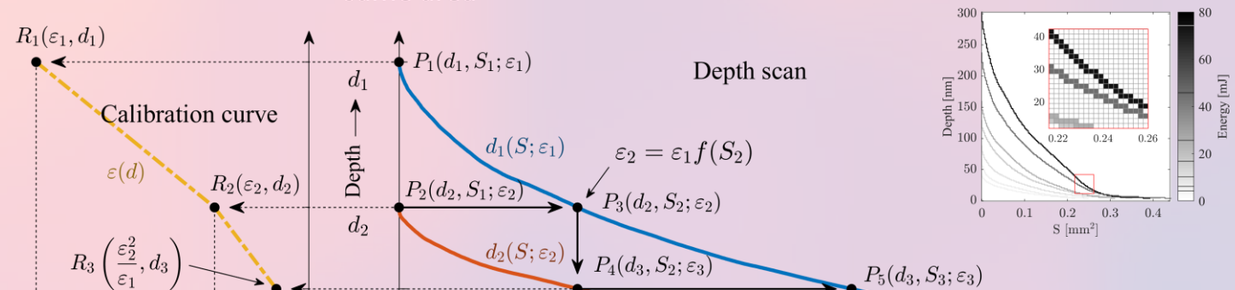
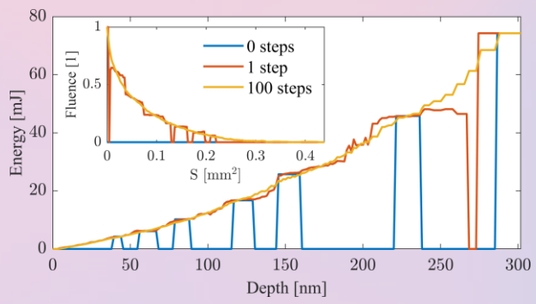


Figure: Nomarski images of ablation imprints (at different attenuation levels) and desorption imprints (different number of deposited pulses).

Non-linear Response Function Recovery (NoReFry)

- **Aim:** Extraction of the calibration curve (dependence of depth on total absorbed dose) from multiple desorption imprints
- **Two assumptions:** 1) Response function monotonically increases with accumulated dose
  2) Iso-depth contour coincides with the beam iso-dose contour of the same area





Top: Schematics of the algorithm showing a calibration curve and fluence scan recovery from two desorption imprints.
Left: The algorithm convergence is very fast and stable solution is found within tens of iteration loops.
Top right: Matrix composed from 7 imprint profiles.

CONCLUSION

- We have developed a method to reconstruct beam profile from desorption imprints regardless of repetition rate.
- NoReFry is applicable wherever the response function monotonically but non-linearly increases with the deposited dose.
  (e.g. fluorescence signal acquired from an exposed LiF crystal, luminescence signal from a saturating Ce:AYG screen)
- Effect of the 3rd harmonic, intrinsically present in each FEL spectrum, can be suppressed by a proper choice of attenuators.
- PMMA could be used as an absolutely calibrated dosimeter. More information about this work will be available in [5].

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