Ablation damage characterizes non-Gaussian beam profiles – extension of Liu's method

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We utilized the ablation imprints method [1] to thoroughly characterize fluence distributions [J/cm^2] of focused non-Gaussian laser beam profiles. This method is derived from Liu's method [2], which is commonly applied to determine beam widths of Gaussian beams and ablation threshold fluences of studied targets. However, Liu's method requires a Gaussian beam, which is often not the case for x-ray and EUV laser pulses generated by Free-Electron Lasers (FEL) and sometimes for Vis and NIR laser pulses. To address this limitation, the ablation imprints method was developed for x-ray and EUV spectral domains [1]. It has since become well-established as a reliable tool to determine the interacting beam fluence distribution, a crucial information for laser induced damage threshold (LIDT) studies.
We expanded the ablation imprints method into Vis and NIR spectra with 1st generation targets of PbI_2 layer on poly(methyl methacrylate). We present its comparison with the conventional beam characterization of projecting a magnified image of the focal spot onto a camera. The analysis of ablation imprints provided additional information on the lower fluence tails (≈ 10^{-3}) of the fluence distribution leading to a more accurate determination of peak fluence because a non-negligible part of pulse energy is carried in the beam tails. While traditionally this higher dynamic range came at the cost of tens of human-hours spent on segmentation of imprint images, recent advancements have automated and accelerated this process to machine-minutes by employing the convolutional neural network U-Net [3]. We also present results from beam characterization and LIDT studies in x-ray spectral domain gathered at European XFEL to highlight the potential of the method following several generations of target improvements.

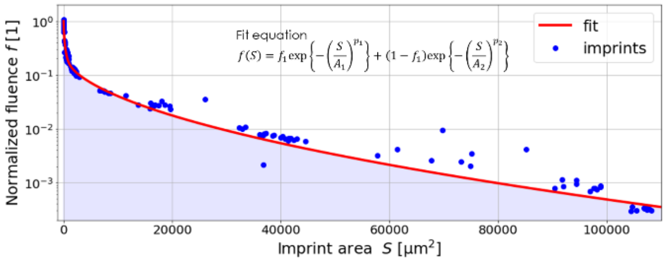

Figure: Plot of normalized fluence against imprint area (= area of beam profile cross section) for a non-Gaussian focused x-ray laser beam measured at European XFEL.

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References: [1] J. Chalupský, T. Burian, V. Hájková, L. Juha, T. Polcar, et al., "Fluence scan: an unexplored property of a laser beam," Opt. Express 21, 26363-26375 (2013); [2] J. M. Liu, "Simple technique for measurements of pulsed Gaussian-beam spot sizes," Opt. Lett. 7, 196-198 (1982); [3] J. Chalupský, V. Vozda, J. Hering, J. Kybic, T. Burian, et al., "Deep learning for laser beam imprinting," Opt. Express 31, 19703-19721 (2023)