Short-pulsed K_α X-ray source based on high-intensity femtosecond laser-solid interaction: generation and applications

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Table-top plasma X-ray sources driven by high-peak power (fs) laser sources are of high applicative interest for imaging and material science [1,2] because of their capability to provide hard energetic jitter-free point-source pulsed X-ray sources suitable for phase-contrast imaging and (time-resolved) X-ray diffraction. We thus study the characteristics of a hard K_α X-ray source (Figure 1) produced by a high intensity femtosecond laser interacting with a solid molybdenum or copper target for a wide range of laser intensity (I ~ 10^{17} - 2.8×10^{19} W/cm²) and for four values of the temporal contrast ratio (6.7×10^{7} < CR < 3.3×10^{10}). Results demonstrate that increasing the laser intensity leads to enlargement of the X-ray source size and this phenomenon is emphasized when the temporal contrast of the laser driving pulse is deteriorated (Figure 1). To explain these observations, we developed dedicated experiments and hydrodynamic simulations (in collaboration with CEA-DIF, [3]) to estimate the impact of laser absorption mechanisms and hot electron scattering inside the solid on the evolution of both the X-ray source size and the K_α photon number. Benefiting of knowledge and control of this unique high-rep-rate (100 Hz, [4]) X-ray source, we further successfully apply it to diverse X-ray materials (Mo@17.48 keV and Cu@8.04 keV) and applicative fields, providing observation of biological specimen (in collaboration with CEA-LIST, [2]) and inert materials and demonstrating its capability for imaging (figure 2a) and time-resolved material science (figure 2b).

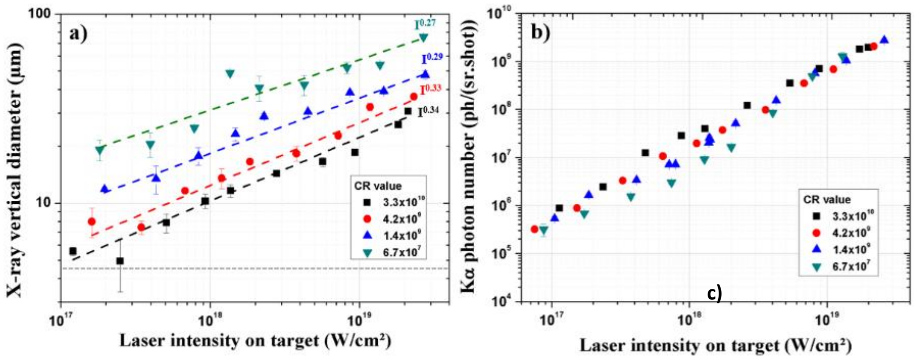

Figure 1. *Data provided for Mo X-ray converter target. a) FWHM X-ray vertical diameter versus laser intensity on target. Fitting power functions in form of I^ε with ε varying with the contrast ratio value are shown by dashed lines. The grey horizontal dashed line is the FWHM vertical laser focal diameter (~4.6 µm). b) K_α photon number versus laser intensity on target.*

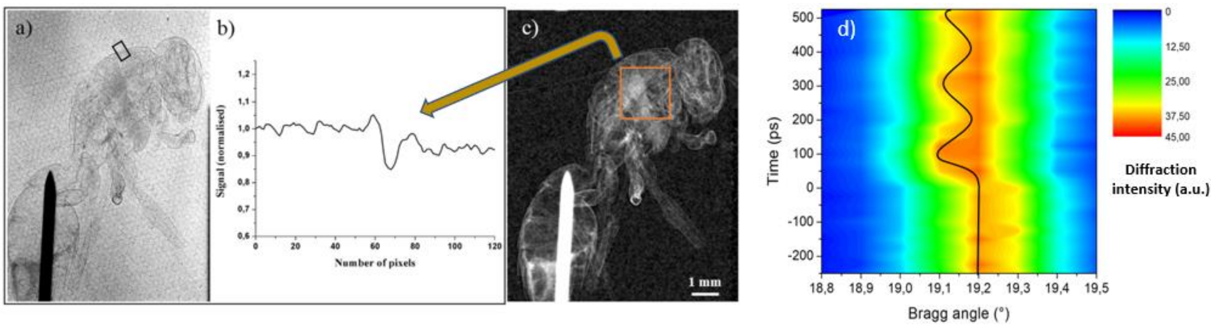

Figure 2. *a-c) Phase-contrast X-ray imaging of a wasp (2s time of exposure, I ≃ 1.3×10^{19} W/cm²) [2]. d) Observation of transient phonon oscillations in gold excited by ultrashort laser pulses through X-ray diffraction (in collaboration with ELI-Beamlines).*

References

[1] R. Schoenlein et al., Phil. Trans. R. Soc. A **377**: 20180384 (2019).
[2] M. Gambari et al., Sci. Rep. **10**, 6766 (2020).
[3] M. Gambari et al., Sci. Rep. **11**, 23318 (2021).
[4] Y. Azamoum et al., Opt. Lett. **43**, 3574 (2018).