MHz - Tomoscopy

D3.3

Report on technical requirement analysis of future applications

Project information

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1.0	20.05.2025	Antonio Bonucci	
1.1	28.05.2025	Patrik Vagovic	Little adaptions
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1. Introduction

This deliverable examines how future applications may redefine the technical requirements of MHz-TOMOSCOPY, building on the high-speed multi-view X-ray imaging capabilities developed and validated within the MHz-TOMOSCOPY project.
Recent radiographic studies have demonstrated the system's suitability for investigating ultra-fast fluid dynamics across a variety of domains, including materials science, energy systems, and biological environments. Building on these results, current efforts are directed towards the development of complete tomoscopic workflows specifically tailored to the needs of these application areas.

Future applications are primarily envisioned in the field of applied science. Given the broad range of possible use cases for MHz imaging, this report focuses on those with particular industrial interest.

This activity is embedded within a broader strategy for industrial exploitation, aiming to pioneer innovative applications of MHz-rate tomographic imaging technologies. The exploitation framework is structured along two complementary pathways:

Route 1: Building an innovation ecosystem through direct partnerships with industrial users.

Route 2: Engaging expert academic groups within Europe to act as a technological bridge to industry and stimulate further innovation.

This review summarizes the progress achieved during the second reporting period, with particular emphasis on applications of industrial relevance beyond cavitation peening, especially within the scope of Route 2.
While the technical specifications do not impact the fundamental design of the MHz-TOMOSCOPY apparatus itself, they do influence the experimental setup and the handling of the sample environment. The main description of future improvements of specification is in D1.5 but no specific adjustment seems to be required for the application.

2. Identified Industrial Applications

Ultrasound Liquid Exfoliation

Real-time dynamics of graphite exfoliation were captured using MHz-rate X-ray imaging at the European XFEL. The study involved the participation of an industrial ultrasonic device manufacturer (Hielscher).

Reference:

Jiawei Mi et al., Ultrasound cavitation and exfoliation dynamics of 2D materials revealed in operando by X-ray free electron laser megahertz imaging, arXiv:2305.08538.

https://doi.org/10.48550/arXiv.2305.08538

Biomedical and Medical Device Applications

Experimental studies focused on drug delivery and investigation of tissue damage mechanisms in ultrasound applications through the imaging of cavitation bubbles in opaque media.

References:

Christiane Contino-Pépin et al., Perfluorocarbon nanodroplets as potential nanocarriers for brain delivery assisted by focused ultrasound-mediated blood–brain barrier disruption, Pharmaceutics, 2022, 14, 1498.
https://doi.org/10.3390/pharmaceutics14071498

Manolis Gavaises et al., Numerical investigation of shock-induced bubble collapse dynamics and fluid–solid interactions during shock-wave lithotripsy, Ultrasonics Sonochemistry, 2023.
https://doi.org/10.1016/j.ultsonch.2023.106393

Cavitation Erosion

Studies on cavitation-induced material damage, relevant for components such as turbine blades and injector nozzles.

References:

Fabian Reuter, Supersonic needle-jet generation with single cavitation bubbles, Applied Physics Letters, 118, 134103 (2021).
https://doi.org/10.1063/5.0045705

David Greif, Alexander Morozov, Ernst Winklhofer, Reinhard Tatschl, Experimental and Numerical Investigation of Erosive Effects Due to Cavitation Within Injection Equipment, Proceedings of 4th ICCHMT, May 17–20, 2005, Paris-Cachan, France, Paper No: ICCHMT'05–257 (AVL List GmbH).

E. Parkinson, N. Gervais, S. Lais, A. Karakolcu, Th. Weiss, “New trends in operation and maintenance challenges for Pelton turbines”, HYDRO 2015 - ADVANCING POLICY AND PRACTICE - 26 to 28 October 2015 ~ Bordeaux, France,
https://de.scribd.com/document/360584203/Andritz-Hydro-2015-Om-Pelton-Mnto

Permeation in Porous Systems

Wetting dynamics in porous media offer a wide range of industrial applications and have attracted industrial interest, particularly in the field of energy storage.

Reference:

Patrik Huber et al., Wafer-Scale Fabrication of Hierarchically Porous Silicon and Silica by Active Nanoparticle-Assisted Chemical Etching and Pseudomorphic Thermal Oxidation, Small,
https://doi.org/10.1002/smll.202206842