SYNCHROTRON-TOMOGRAPHY WITH MICRO, NANO AND HIGH TEMPORAL RESOLUTION FOR INDUSTRIAL AND ACADEMIC USE

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Summary: Three-dimensional imaging with high spatial resolution is a powerful tool for materials characterization. Microtomography (micro-CT) and nanotomography (nano-CT) setups have been developed and optimized since years at The European Synchrotron (ESRF), in Grenoble (France). A complete service is available, including fast data acquisition with possibility of sample environments, 3D reconstructions and 3D parameter extractions on demand [1] can be proposed for industrial customers.

1. INTRODUCTION

Since 20 years, instruments for tomographic imaging are developed at the ESRF. Micro-CT is now the main three-dimensional (3D) imaging technique of the 150 m-long beamline ID19 and nano-CT has been recently established on the new 190 m-long beamline ID16. At ID19, pixel sizes from 50 down to 0.16 micrometers can be provided. ID16 is composed of two branches, working in parallel. ID16A is dedicated to ultimate resolution, under vacuum, with a smallest achievable pixel size of 10 nm. ID16B operates in air with pixel sizes between 200 and 25 nm and sample environments have been envisaged. Both ID19 and ID16B allow 3D imaging of regions of interest inside flat, plate-like objects by laminography. Recently a furnace operating in the range from 400 to 1000°C has been developed on ID16B for the purpose of studying solidification in metallic alloys and ceramics sintering. The complementarity of the different beamlines is very useful for studies in fields such as metallurgy, petrology, food industry, cosmetics, pharmaceutics, or biology.

2. EXPERIMENTAL SETUPS

Within the context of the ESRF upgrade program (Phase 1: 2008-2015), ID19 underwent a substantial refurbishment: both medium (50-3 micrometers) and high (1.6-0.16 micrometer) resolution imaging setups have been optimized, exploiting as much as possible the specificities of a 3rd generation synchrotron light source with 6 GeV ring energy. Especially the coherence properties and a high photon flux at high X-ray energies (10 to 250 keV) are beneficial for micro-CT with respect to other synchrotron sources and laboratory instruments. X-ray phase contrast imaging, in combination with (single-distance) phase retrieval using a modified version of Paganin's approach [2] are available in a routine manner. New samples stages have been introduced to accept very large objects (up to half-meter range) or two-dimensionally extended plate-like objects. A transfocator (combination of Be compound refractive lenses) has been implemented in the optics hutch to gain flux at high resolution.

All these possibilities lead to develop *in situ* experiments to add a fourth dimension to studies (e.g., time, temperature, solicitation). Samples can be investigated *in situ,* employing different sample environments like tensile stress [3], compression, fatigue devices, low or high temperature, hygrometry control, and more recently high temperature under controlled atmosphere (Fig. 1(a)). Moreover, a strong demand has also emerged to employ this potential for time-resolved *in situ* experiments, decreasing the acquisition time to less than 1s (down to 0.2s per 3D

image with 1.1 micrometer pixel size, achieved for glass solidification studies [4]), using a commercial CMOS-based camera (pco.dimax, PCO AG, Germany) [5].
As a user facility, the main role of the ESRF is to provide micro/nano-CT services for both academic and industrial users. ID19 is generating a so huge amount of data (projections and reconstructions), so that a pipeline has been developed to minimize the number of processing steps and speed up the availability of the reconstructed slices (TIF file format, 16bit depth), with ring artefact correction and other basic treatments on demand.

3. PERSPECTIVES

Our micro and nano imaging setups are in a constant evolution, which is a huge advantage, compared to conventional source systems, even if customization is also a new trend for such systems. The ESRF upgrade program (Phase 2: 2016-2020) consists in building a new storage ring. This project is called EBS for Extremely Brilliant Source. The new ESRF synchrotron should be delivered in 2020. In addition, a new imaging beamline project has been recently proposed to our SAC (Scientific Advisory Committee) taking full advantage of the new source and so enlarging our high energy, high coherence (Fig. 1(b)) and large beam properties, among 7 other projects. The final decision is supposed to be taken in June 2017.

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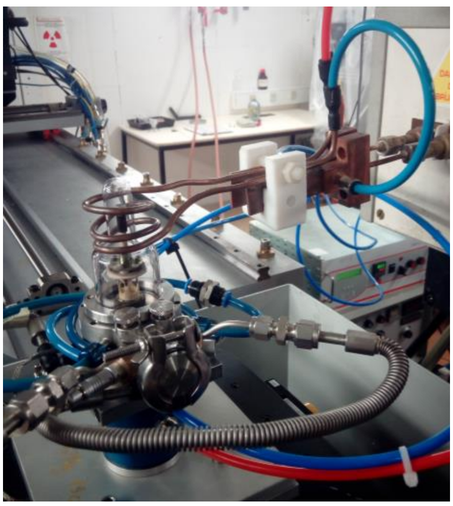

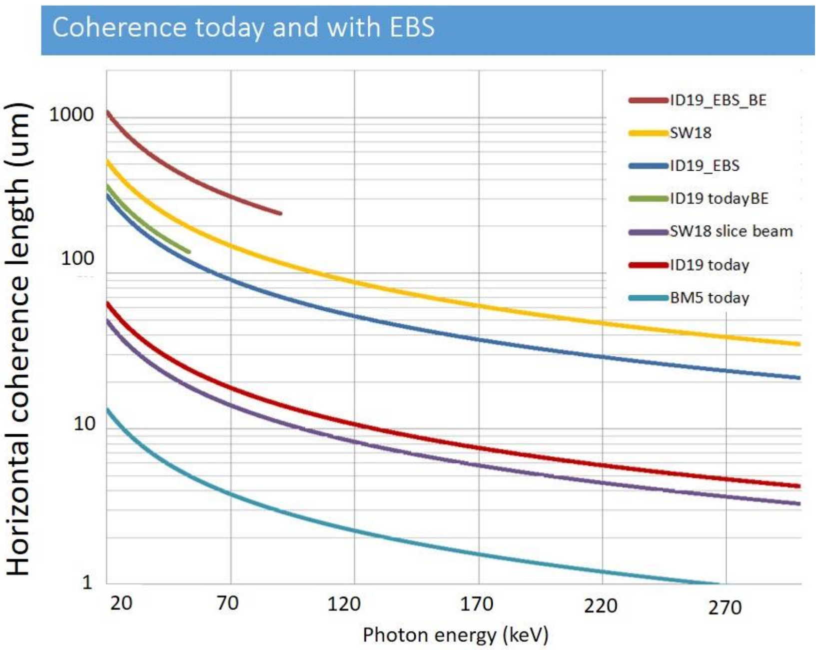

(a) (b)

Figure 1: (a) Photograph of the induction furnace with possible controlled atmosphere, developed by the ESRF sample environment team, coupled with a slip ring for fluids allowing continuous rotation (b) Level of coherence obtained with the future ESRF synchrotron source.