X-Ray Nano Computed Tomography Systems and Application in the Laboratory

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Computed tomography (CT) with X-rays is a well-established imaging technology in medical, research and industrial applications. It allows creating a 3-D representation of an object by spatially mapping its X-ray attenuation coefficient. Until recently, resolutions of laboratory CT systems were limited to the micrometer scale, or were realized with X-ray optics. In the latter case, the usable X-ray energy range as well as the achievable field of view are limited. In this work, we aim at nano-CT systems that use strong geometric magnification (500-times and larger) to push the resolution limits compared to available technology. Thanks to new developments in component technology and advances in system integration, these systems enable resolutions down to 150 nm, with an energy range up to 60 kVp and flexibility for the samples similar to a micro-CT device.

In an X-ray imaging system, the resolution limiting factor usually is the penumbral blurring of the focal spot of the X-ray tube. The size of the focal spot is typically limited by the design of the electron optics in combination with the design of the target. Furthermore, in order to achieve a high spatial spot stability, which is crucial in nano-CT imaging, sophisticated cooling and shielding is required. In this work, improvement in the electron optics, focusing technology and development of a tungsten-diamond target will be presented to enable resolution of 150 nm line and spaces.

For optimal signal/noise performance, Hybrid Photon Counting detectors (HPC) were used. In HPC detectors, each pixel of a dedicated readout chip is directly bonded to a semiconductor X-ray sensor [1]. With a dedicated signal processing circuitry on each pixel, the energy of an X-ray event is analyzed and compared to a threshold energy. For events exceeding the chosen threshold, a digital counter is incremented by one. This makes the detector virtually noise-free, enables long acquisition times and assures highest signal-to-noise ratios.

This work will present the advances made on the component side, and then present implementations of Nano-CT systems using these components. The achievable spatial resolution is demonstrated using characterization with a Siemens star. Examples of Nano CT measurements of several model samples are presented to evaluate the performance of the system.

[1] C. Brönnimann, P. Trüb (2015) Hybrid Pixel Photon Counting X-Ray Detectors for Synchrotron Radiation. In: Jaeschke E., Khan S., Schneider J., Hastings J. (eds) Synchrotron Light Sources and Free-Electron Lasers. Springer, Cham; DOI https://doi.org/10.1007/978-3-319-04507-8_36-1