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Future Hard X-ray Nanoprobe at the Advanced Photon Source

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We are designing and constructing a new hard x-ray nanoprobe at the Advanced Photon Source. The nanoprobe will allow real space mapping of density and elemental composition through transmission; crystallographic phase, strain, and texture through diffraction; trace element analysis through fluorescence; chemical states through spectroscopy; magnetic domain structure through linear and circular dichroism; and morphology through x-ray tomography. The nanoprobe will be a versatile tool that can be applied to research in nanoscience and nanotechnology. Examples of application to research thrusts at Argonne National Laboratory include to image and track domain evolution in ferroelectric and magnetic nanostructures, to observe strains in microelectronic interconnects, to measure composition and phase distributions in layered nanoparticles for catalysis, or to determine the location, elemental composition, and chemical state of hybrid inorganic/organic nanoparticles interacting with biological systems.

We aim with the design of the x-ray nanoprobe to advance the state of the art of hard x-ray microscopy by providing the highest spatial resolution achievable from the brilliance of a third generation synchrotron radiation source such as the Advanced Photon Source. A dedicated source, beamline, and optics will be used to optimizing the capabilities of the nanoprobe. This unique instrument will not only be key to the specific research thrusts in nanoscience at Argonne National Laboratory, but will be of general utility to the broader nanoscience community. It will offer diverse capabilities in studying nanomaterials and nanostructures, particularly for embedded structures. The combination of diffraction, fluorescence, and phase contrast in a single tool will provide unique characterization capabilities for nanoscience. Current x-ray microprobes based on Fresnel zone plate optics have demonstrated a spatial resolution of 150 nm. With advances in the fabrication of zone plate optics, and using an optimized beamline design, we expect to be able to achieve 30 nm resolution. The nanoprobe will cover the x-ray energy range of 3-30 keV with a working distance between the focusing optics and the sample typically of 10-30 mm.

The x-ray nanoprobe will complement other microscopy techniques such as optical microscopy, scanning electron microscopy, transmission electron microscopy, scanning probe microscopies, and soft x-ray microscopy. In particular, the x-ray nanoprobe provides advantages such as being nondestructive, non-invasive, quantitative, requiring minimal sample preparation, providing sub-optical spatial resolution, having the ability to penetrate inside a sample and study its internal structure, and having enhanced capability to study processes *in situ*. Another important distinction compared to charged-particle probes is that x-rays are non-interacting with applied electric or magnetic fields, which is a significant advantage for in-field studies of dielectric and magnetic materials.

The nanoprobe will operate in two modes: a primary scanning probe mode, in which an x-ray spot of 30 nm FWHM is used to probe the specimen, and a full-field transmission mode, in which the full undulator beam will be used for transmission imaging with 30 nm spatial resolution. The scanning probe mode (figure 1) makes use of the high brilliance of an APS insertion device by focusing the spatially coherent fraction of the undulator beam into a diffraction-limited spot. It is suited for spectroscopy with high trace element sensitivity and strain contrast imaging. The full-field transmission mode, which will use the full photon flux provided by the undulator, will allow fast acquisition of a larger object field at high spatial resolution in amplitude or phase contrast. It can also be used as an alignment tool to allow quick, *in situ* identification of a small specimen area of interest for scanning probe studies. In full-field transmission mode, the nanoprobe will be invaluable for applications such as high-throughput 2D imaging and high-resolution tomography. The combination of both scanning probe and full-field transmission mode in a single x-ray microscope will be a uniquely powerful tool.

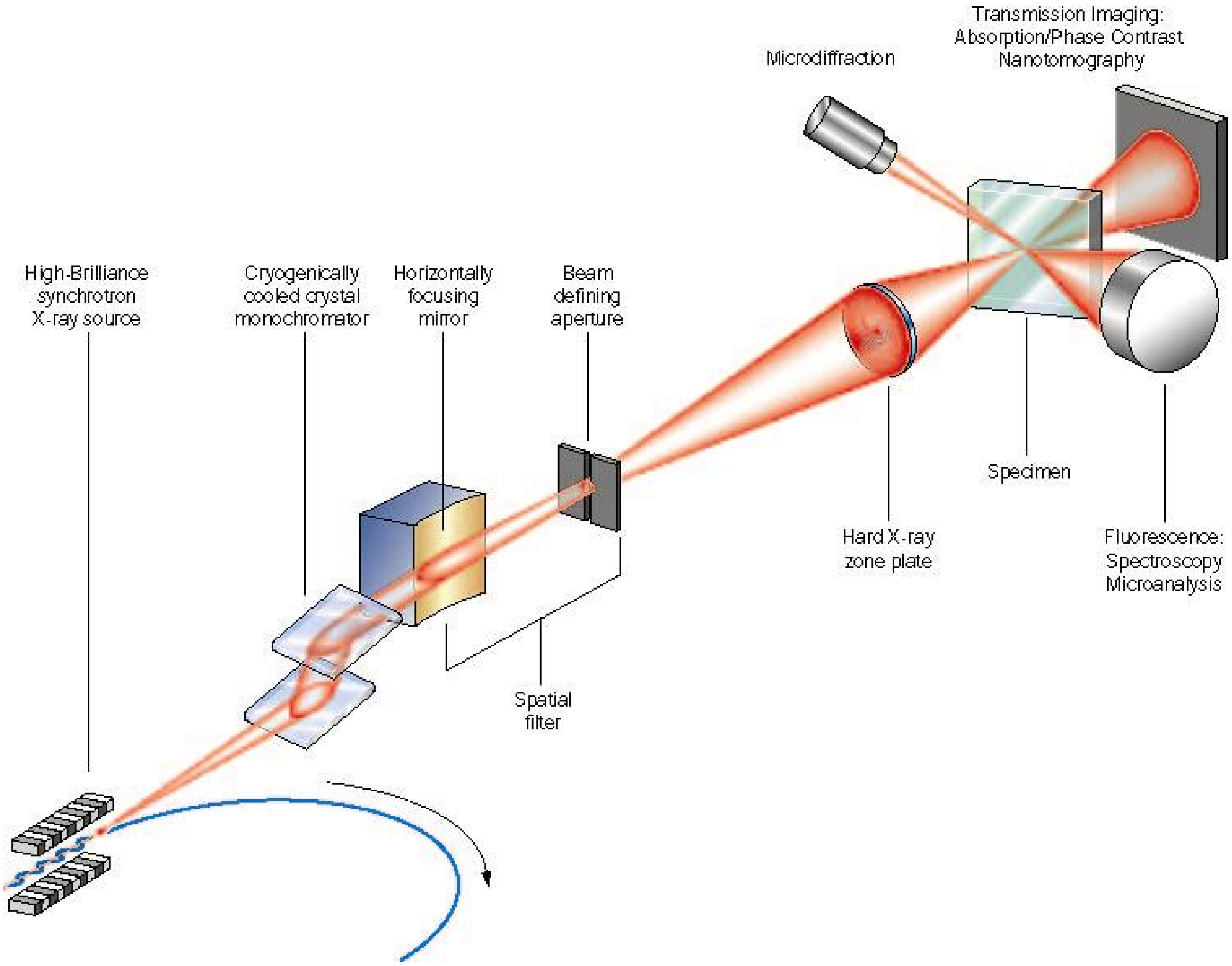

Figure 1. Conceptual layout of the planned hard x-ray nanoprobe at the Advanced Photon Source.