# *Hard X-ray Nanoprobe (HXN) Beamline Advisory Team(BAT) Meeting*

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## *Executive Summary*

The BAT committee met to discuss the status of the HXN effort, finalize the BAT charter, and to formulate plans for monitoring the program during the design, construction and commissioning phases. Three major conclusions were reached:

1-There has been significant progress on the design of the beamline (physical layout and optics), and this portion of the effort is well funded and staffed.

2-Significant effort must be put into the design and construction of the end-station if all the capabilities of the beamline are to be used effectively. The BAT finds the amount currently allocated ($1.5M) too low, and recommends setting aside sufficient funds (core ($3.5M ) plus contingency) to accomplish this task.

3-The BAT, working with the instrument scientist and NSLS-II staff will put together a list of commissioning experiments that will guide the design and construction.

## Charter

HXN at NSLS-II is intended to produce and utilize a nanometer sized beam of hard x–ray photons. It will be a world-leading instrument, enabling spatially resolved versions of many powerful structural and spectroscopic x-ray techniques, with unprecedented sensitivity and spatial resolution. It is expected to detect fluorescence from single atoms, and to measure local structure and strain information from volumes ~$nm^3$ in size. The HXN BAT will represent the needs of the users and guide the NSLS-II staff in design and trade-offs required to enable a maximally useful and scientifically productive beamline.

## CURRENT STATUS

BEAMLINE ISSUES

Andrew Broadbent (NSLS-II) presented the budget, schedule, power management and satellite building design. This was followed by Nick Simos (BNL) , who presented the vibrational analysis of the facility

and HXN beamline. The current analysis calls for a stand-alone satellite building, with integrated vibration management, temperature and humidity control and power management for the HXN. There is a model of the complete facility and vibration sources, with single monolithic HXN satellite building floor; a comparison with EM type segmented floor is pending. The x-ray shielding in the satellite building, (suitable for monochromatic and/or white-beam) must be integrated into the planning.

Hanfei Yan and Ray Conley (NSLS-II) presented details of the 1nm R&D program and discussed the planned fabrication of the multi-layer Laue lenses, which are the front-up optics for the beamline. Significant work is underway on Laue lenses, the first technology that seems capable of reaching a 1 nm x-ray beam size, with a very solid plan of how to produce wedge lenses. This is a very exciting area of x-ray optics research, of not only learning enough about how the optics work but also how to interpret x-ray experiments where the continuum theory breaks down at some point. Extended wave models and perhaps even an atom-by-atom modeling of results might be needed to correctly interpret data.

END STATION ISSUES

Yong Chu (NSlS-II, the beamline scientist for HXN), presented the desired characteristics of the end station, and the anticipated performance of the beamline based on the IDT design. The front-up challenge is measuring fluorescence from single atoms in buried layers, followed by "diffraction" from structural volumes ~$nm^3$ in size.

Peter Siddons (BNL) presented advances in fluorescence detectors. It is now possible to have an array of such detectors on a chip with advanced signal processing built in. The best utilization of such advanced detectors would be the integration of the entire detector/ sample stage/ software system with appropriate data acquisition, analysis and storage functions. The BAT recommended that such integration should be considered during the end-station design. The following points were raised:

- fast data acquisition: high detector count rate, $2\pi$ solid angle
- deconvoluting overlapping XRF peaks: excellent energy resolution
- data readout speed: fast detector readout
- data processing: fast peak fitting
- stage positioning accuracy at 1 nm
- fast stage scanning with 1 nm step (slewscan)

It is also important to recognize that detector development efforts are underway, with possibly much better detectors to be available when NSLS-II becomes operational. Thus, any design should have modularity and upgradeability .

Martin Holt (CNM, ANL) reviewed the development of the CNM Nanoprobe at sector 26-ID-C at APS. He reiterated the difficulties of getting beamline development funds after completion of construction, and suggested that early prototyping of the end-station was essential. He also recommended that any in-

situ sample manipulation capabilities (heating/cooling, application of magnetic and electric fields, mechanical load) should be designed into the end station. This was reaffirmed by Professor Chris Jacoben who noted: "Having built three cryo microscopes, my opinion is that you need to design cryo in from the start instead of simply plopping a cryostat on there."

DISCUSSION and SUGGESTIONS

There was a vigorous debate about the satellite building and the end-station integration, and the associated budgets. The BAT felt that there was a large upfront budget for the beamline, inadequate funding for the end-station, and no budget for maintenance.

Another debate topic was the mission of the HXN. On the latter point the BAT thought that an evolving document that contains information about the advantages, disadvantages, and current and emerging competitors would be useful. This document would have the following information:

1-A list of questions that the nanoprobe work will raise (in both science and technology areas) and the answers as they are found.
2-The types of samples where the x-ray nanoprobe provides unique information compared to competing probes.
3- The first set of experiments which need the single-atom fluorescence sensitivity of the nanoprobe.

Since the XNM would be working in uncharted territory, forward modeling of the expected signals and testing of prototype assemblies are required for risk minimization. In addition, it might be helpful to stage the beam size with the first beam at 10 nm, extended to 5 nm and finally to 1 nm. These efforts should be carried out in parallel with the beamline building, and tapping into the expertise of BNL institutes might be helpful.

Defining optimal sample characteristics for HXN is also an issue. The following questions were raised:

i- At what levels can samples (biological and or material science) survive the radiation dose that can be given by the beamline. Will this put a limitation the size of beam that can be employed with the Laue lenses?
ii- What are the flux numbers that are needed for single-atom imaging? How long will it take to make images or make a near-edge scan to determine a chemical state from a near edge scan.

iii-Is there any way to make a 3-dimensional Soller slit that might select only a 20 to 50 nm width of emitted fluorescence along the depth of focus? (A polycapillary with micron dimensions working at 90 degrees to the incident beam is such a device for microbeam dimensions and can select a 20 micron length along the beam direction for confocal x-ray microscopy.)

iv-How can we change the x-ray beam diameter such that the region-of-interest can be located quickly, and then characterized?

v-How can we achieve effective pre-positioning alignment methods? For submicron x-ray microscopes around the world, a visible-light microscope with positioning references is commonly used. However, for the HXN, a visible light microscope will not be sufficient. It is important to develop a method using a higher resolution microscope such as a SEM, so that regions of interest can be located rapidly with respect to a kinematical sample mount, and then transferred to the HXN with a known location.

User education and outreach, such as having a summer school to train prospective users, a Gordon Conference for micro/nanodiffraction and related approaches were also discussed.

The BAT feels that a very high quality team is being assembled to form and staff the beamline. We have every confidence that the Nanoprobe team will ultimately reach its objective. There is, however, much work to be done.