

X-ray Fluorescence Microprobe (XFM): A three-pole wiggler X-ray fluorescence microprobe beamline for characterization of materials in an "as-is" state.

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A. Science Case

The X-ray Fluorescence Microprobe (XFM) Beamline will address many of the most pressing questions in earth, environmental, and life sciences, in energy technology and materials studies, and in paleontology and cultural heritage sciences specifically focusing on spatially-resolved characterization of elemental abundances and speciation in “as-is” samples that are heterogeneous at the micrometer scale. Key scientific drivers for XFM include the following: Molecular Speciation of Contaminants in the Environment at the Microscale; Genetic Control of Metal Ion Uptake, Transport and Storage in Plants Relevant to Agriculture and Bioenergy, Mineral-fluid Interface Reactions Relevant to Carbon Sequestration; Biogeochemistry of Nanotoxins in the Environment; Metal Ions in Health and Disease, Early Solar System Properties Inferred through Analysis of Extraterrestrial Materials, and Characterization of Paleontological, Archeological and Cultural Heritage Artifacts.

XFM will have capabilities for microbeam applications of X-ray fluorescence (XRF), X-ray absorption fine structure (XAFS) spectroscopy, X-ray diffractions (XRD) and fluorescence computed microtomography (fCMT). Worldwide, there is strong demand from the user community for X-ray microprobes with these capabilities. In particular, additional facilities optimized for microfocused Extended X-ray Absorption Fine Structure (μ EXAFS) spectroscopy are needed to provide detailed information on the local environment of the target atom, co-ordination numbers and bond lengths, including the characterization of these properties in-situ within environmental chambers. Currently, few beamlines routinely offer this capability and the broadband nature of NSLS-II’s three pole wigglers (3PW) make these excellent sources for μ EXAFS with spatial resolutions between 1-10 μ m and flux densities up to two orders of magnitude higher than currently achievable at NSLS’s microprobe beamlines. Such an instrument is proposed here.

XFM will be a much needed complementary beamline to the Hard X-ray Nanoprobe (HXN) and Sub-micron Resolution X-ray spectroscopy (SRX) project beamlines by allowing more flexibility in sample configuration (e.g., ability to accommodate large sample sizes and customized environmental chambers) at the expense of elemental sensitivity and spatial resolution. Both of the project beamlines aim for ultra-high spatial resolution using multilayer Laue lenses, KB mirrors and/or zone plates on undulator sources. Utilizing such small beams will place constraints on sample size and will make high precision spectroscopies challenging because of the requirement to maintain beam stability at a fraction of the beam size during energy scans. XFM will trade-off beam size and flux for sample configuration flexibility and more readily achievable stability constraints for spectroscopies. For biological samples XFM will offer a complementary microprobe for high-throughput imaging of biological tissues at a cellular resolution. Experience at existing synchrotron facilities has demonstrated that access to X-ray fluorescence probes with complementary capabilities is highly effective and efficient in tackling these scientific problems. The XFM beamline represents a transition opportunity for the current X26A and X27A microprobe user communities while providing NSLS-II a platform to attract new communities to synchrotron research.

Molecular Speciation of Contaminants in the Environment at the Microscale

A major scientific challenge is defining the health hazards posed by contaminated materials which reside close to areas of human activity, such as residential areas. Such materials derive as by-products of human activity itself, such as weapons production, precious metal mining, agricultural activity, industrial residues from manufacturing and pathogens released to the environment. Potential hazards include migration into the drinking water and food supplies, inadvertent digestion of soil and inhalation of wind-blown particulates. In many cases these contaminants are heterogeneously dispersed at the micrometer scale and their toxicity and bioavailability is often highly dependent on the molecular species present. Arsenic in particular is receiving attention in situations of large scale groundwater contamination, such as Bangladesh. The mechanisms by which these contaminants are bound and transported in the environment and the pathways for human uptake (bioavailability and bioaccessibility) need additional detailed study.

Redox reactions on the surfaces of particulates and the specific contaminant speciation are the crucial properties. Highly focused X-ray probes are indispensable resources in evaluating questions about what controls the surface area of materials in surface and subsurface settings and the chemical state of the

contaminants. In-situ spectroscopy under natural conditions allows interrogation of metal surface complexes and products that form on mineral surfaces and humic substances. Within reactive transport studies, the X-ray microprobe has been essential in numerous applications including understanding Se transport and reduction at water-sediment boundaries¹, Cr diffusion and reduction in soil aggregates², coupling of Cr and Mn redox in soil³, coupling of U and Fe redox in sediments during bioremediation⁴ and diffusion of U into soils exposed to acidic and alkaline waste solutions⁵.

Providing high-quality μ EXAFS is also necessary to further our understanding of these processes on particulate surfaces to understand the mechanisms that play a profound role in controlling the cycling of toxic metals in the environment. For environmental chemists EXAFS spectroscopy has become the principal synchrotron technique for inferring contaminant speciation (local electronic and structural configuration). XFM will allow these users to apply these techniques in-situ with micrometer spatial resolution, permitting investigation of samples in as close to an “as-collected” state as possible, maintained at ambient conditions and in the presence of water. This research will aid scientists in identifying what complexes are bound to what specific solids (surface complexes, metal–ligand bonds, surface precipitates) and how the molecular geometry and coordination environment of the element is controlled by its microscale environment⁶⁻⁸. This capability is a major advantage to biological and environmental science studies that strive to understand the chemical heterogeneity of samples in a natural state, yet this potential is rarely taken full advantage of since conventional “bulk” EXAFS requires a homogenized sample.

Genetic Control of Metal Ion Uptake, Transport and Storage in Plants Relevant to Agriculture and Bioenergy

Opportunities to examine how genetic variations in organisms affect their interactions with the environment are driven by the rapidly increasing quantity of nucleotide sequence data that has been provided by the Department of Energy’s Genomes-To-Life (GTL) program. Synchrotron-based X-ray imaging techniques are extremely well suited to aid in the evaluation of how specific genes influence the uptake of nutrients and contaminants in plants. This is done by imaging these interactions at the cellular and subcellular level, yielding non-destructive, three dimensional characterization of elemental distribution potentially in-vivo. These types of studies require the application of high-throughput elemental analysis technologies and their integration with both bioinformatic and genetic tools. For example, biofortification involves developing plants that store higher concentrations of bioavailable nutrients in the seed. To do this, functions of the ion transport and storage genes need to be known. Another example is in phytoremediation (specifically phytoextraction), which involves using metal-accumulating plant species to remove elements of toxicological relevance from contaminated soils⁹. Our ability to characterize the function of genes involved in elemental homeostasis will be more rapid and comprehensive with instrumentation suitably configured to provide this information in-vivo; identifying the organelle in which a particular element accumulates will allow us to rapidly target the genes responsible.

The relevant data can be obtained using whole-plant, high resolution X-ray fluorescence computed microtomography (fCMT)¹⁰⁻¹², which XFM will provide. Three-dimensional fCMT gives users a non-invasive, spatially resolved and multi-elemental analysis technique that images the metal concentration of specific cell layers and organelles in plants as close to their natural state as possible. Also important, since the chemical form of the metal in question strongly influences bioavailability or toxicity, XFM’s strengths in μ XAFS will let us characterize in-vivo the valence state, coordination chemistry and nearest neighbor identity of the metal of interest. Complexation of nutrient metals such as iron to phytate (inositol-hexakisphosphate), for example, renders the mineral non-bioavailable; enhancing iron phytate accumulation will not be beneficial for biofortification, therefore speciation is critical in these studies.

Ultimately, the high-quality, three dimensional chemical imaging and microspectroscopy that XFM will provide on live organisms at micrometer spatial resolutions will be wonderfully complemented by the higher resolution, sub-micrometer elemental imaging NSLS-II’s undulator-based probes will provide on sectioned samples, providing sub-cellular characterization of metal homeostasis. In the future, reliance on plants for energy as well as food will place a strain on the already scarce prime agricultural land, shifting plant production to nutrient-limited soils. Optimizing nutrient acquisition and use to support bioenergy

production in marginal soils will rely on information about the genetic control of metal ion uptake, transport and storage. Beamlines such as XFM will play a significant role in helping researchers develop these technologies.

Mineral-fluid Interface Reactions Relevant to Carbon Sequestration

The behavior of water and solutes in geologic formations containing multiple fluid phases (water-air, water-oil, brine-CO₂) in pores and fractures is strongly dependent on the content (saturation) of each phase, with flow and transport rates at low water saturation levels being controlled by properties of water films. Needs for understanding physical-chemical processes of brines and condensed (liquid and supercritical) CO₂ in pores and fractures are rapidly growing because of the growing importance of geological CO₂ sequestration. These immiscible fluid phases have complex interactions in geologic formations that ultimately control the effectiveness of subsurface CO₂ sequestration. Basic properties of brine films under geologic CO₂ sequestration in need of investigation include the dependence of film thickness on chemical potential of water, flow of these brine films, and reactions between film solutes and mineral surfaces. There is also significant interest in what trace metals that may be present in CO₂-rich industrial flue gases (i.e., Hg, As, Se) and/or naturally occurring Ca²⁺-enriched brines (Sr, As, Cr, etc.). Such characterization is required in understanding the interaction of supercritical CO₂ (injected into the subsurface) and with minerals and waters in the confined aquifers that are hoped to be used for sequestration.

Characterization of aqueous films (ranging from a few nm's to hundred nm's thickness) in geologic media involves overcoming several basic experimental challenges. Unlike films investigated in materials sciences, water films in geologic media typically coat mineral surfaces that are topographically rough at multiple scales, making them difficult to investigate by reflectivity-based methods. Additionally, in the case of CO₂, experiments require use of high pressures (> 30 atm). Work at NSLS X26A with aqueous solutions containing Rb⁺, SeO₄²⁻, and Br⁻, shows that monochromatic X-ray beams with spot sizes in the 100 to 500 μm range can be used to obtain measurements of average water film thicknesses, relying on X-ray fluorescence of high Z tracers^{13,14}. New experimental chambers will allow measurement of the hydraulic properties of brine films adsorbed on mineral surfaces under confinement with supercritical CO₂. This new experimental system will rely on a monochromatic hard X-ray beam for determining concentrations of fluorescing tracers contained in the brine films. XFM's versatility in sample handling will also allow us to utilize these XRF-based imaging and spectroscopy techniques tomographically to measure tracer concentration and speciation in-situ along the grain surfaces of sediment samples confined in experimental cells¹⁰. Similarly, tomographic μXRD imaging will allow us to visualize three-dimensionally the change in pore volume and mineralogy as the brines interact with grains in the cell^{10,15}. Again, the characteristics of the proposed XFM beamline (flux at high energies, spot size, and working distance) are well suited for this application and will be an important resource in meeting DOE Office of Fossil Energy's goals for transforming the fundamental science of carbon sequestration into a portfolio of practical, affordable and safe technologies and mitigation strategies.

Biogeochemistry of Nanotoxins in the Environment

Specific information on chemical speciation and chemical species transformations is prerequisite to the development of a comprehensive understanding of toxic element and manufactured nanomaterial behavior in the environment. Furthermore, molecular-level information is required to properly predict contaminant fate, to develop effective and rational remediation strategies, or to provide realistic and accurate risk assessments. Synchrotron-based X-ray microanalytical techniques have emerged as powerful tools for determining the chemical speciation of a wide variety of toxic elements in soil samples, waste-forms, and biological specimens with little or no chemical pretreatment at detection limits that, on the average, exceed those of conventional methods by several orders-of-magnitude¹⁶.

Spatially-resolved XRF and XAFS allow for the determination of element distributions in environmental samples such as soil and biota, as well as for the interrogation of molecular-level processes occurring at critical geochemical and biogeochemical boundaries, such as along mineral grain and mineral assemblage boundaries, along fractures and pore linings, at the plant root/soil interface, and at microbe/mineral

assemblage interfaces. The illumination of the spatially variable nature of contaminant metal and metalloid distribution in soil samples has greatly increased our understanding of coupled biogeochemical processes occurring in soil that influence contaminant fate and transport as well as bioavailability and toxicity^{17,18}. More recently, insights into key chemical transformations of manufactured metal and metal oxide nanomaterials released to the environment as well as on their bioavailability and distribution within tissues of various ecoreceptors have been provided via spatially resolved synchrotron-based techniques and the need for this information is expected to increase dramatically in the future¹⁹. High quality spatially resolved EXAFS will be especially needed to probe the biogeochemical transformations of manufactured nanomaterials in waste water streams, biosolids and in soil, which is a primary repository of nanomaterials released to the environment.

Metal Ions in Health and Disease

In biology metal ions are essential for a wide range of biological functions; yet these same “essential” metals are also involved in disease processes. The disease often arises due to an altered distribution of metal ions in subcellular organelles, which can extend to organ-wide changes in ion distribution. Thus, understanding these diseases requires both knowledge about how individual metal ions bind to and/or regulate subcellular processes (nm) and visualizing the interactions between various cell types in a tissue (μm). For example, metabolic diseases such as Wilson’s and Menkes’ result from errors in expression and/or function of Cu-transport proteins²⁰. A number of neurodegenerative diseases, including Alzheimer’s, Parkinson’s, and Lou Gehrig’s disease, involve the accumulation of metal ions in misfolded protein aggregates and may play a direct role in redox-mediated neuron toxicity²¹⁻²⁴. Metal-containing aggregates have also been found in immunodeposits in autoimmune diseases including Systemic Lupus Erythematosus (kidney deposits), Rheumatoid Arthritis (joint deposits), and Grave’s disease (thyroid deposits).

Many non-essential metals are toxic to cells even at extremely low concentrations and in most of these cases, the toxic burden on the body depends on the efficiency by which these contaminants are absorbed, i.e. the chemical form of the element, which is nicely assessed by μXAFS . Metal-containing compounds are used as therapies in many areas of medicine, such as anticancer drugs²⁵⁻²⁸, anti-inflammatories²⁹, and diabetes medications³⁰. While high resolution nm imaging is important for understanding how these drugs interact with organelles in the target cells, rapid μm screening studies are equally necessary to characterize the effects of different drugs at a cellular level with tissue³¹ and for visualizing the mechanisms of disease progression between cells or within an entire organ. XFM will play an important role in assessing the target location, distribution, and concentration of metal ions in tissue and will be an invaluable to life sciences research.

Early Solar System Properties Inferred from Analysis of Extraterrestrial Materials

NASA collects interplanetary dust particles (IDPs), ~ 5 to $50 \mu\text{m}$ -size fragments from asteroids, comets, and the Earth’s stratosphere. Some of these IDPs are the most “primitive” (least altered by aqueous or thermal processing) samples of the early dust from our Solar Nebula³². Bulk elemental and speciation analyses of these particles, which are best performed with a beamspot adjusted to match the particle size, provide constraints on the composition and oxygen fugacity of the Solar Nebula. This is important to probe the conditions of the Nebula 4.5 billion years ago, at the time the first dust was forming.

Meteorite samples from the asteroid belt, Mars, and the Moon contain minerals in the $1 \mu\text{m}$ to mm size range as well as minerals which exhibit zoning at the μm to tens of μm scale. XFM analyses of these samples are critical to the understanding of the geochemical conditions on these bodies at the time the minerals formed. For example, it has been suggested that the outer layers of the zoned carbonate structures in the ALH84001 Mars’ meteorite formed by thermal decomposition of the inner core carbonate, but μXRF showed there is not enough Cr or V in the core carbonate to account for the abundances of these elements in the rim material³³.

μXRF analyses can also provide the elemental analysis of small (10^3 ’s of μm ’s) fluid inclusions, recently discovered in salt crystals in the Monahans meteorite. This would provide the first opportunity to directly determine the nature of the fluids responsible for aqueous processing on some asteroids.

XFM will also support NASA sample return missions such as Stardust. Synchrotron μ XRF, μ XRD and μ XAFS analysis of comet dust collected by Stardust provided new insights into the origin of comets and the solid grains that form dust disks around other stars. It also demonstrated that there was large-scale transport of dust from the inner to the outer Solar System early in its history³⁴⁻³⁶. In the upcoming decade NASA anticipates additional sample return missions. Two of the New Frontiers spacecraft are sample return missions to a primitive asteroid and to the unexplored lunar polar basin region; NASA has just announced the competition for the next Discovery spacecraft, which will almost certainly include sample return proposals; and Mars' sample return remains a NASA priority. These extraterrestrial samples are generally expected to be small and well matched for early characterization using XFM. Stardust returned hundreds of particles but they totaled less than 0.3 mg of comet dust, and may also have collected as much as 10 femtograms of interstellar dust. Synchrotron-based analyses of these samples are generally highly productive because the beamspot can be well-matched to the sample size XFM will provide.

Characterization of Archeological, Paleontological, and Cultural Heritage Artifacts

Synchrotron microspectroscopy beamlines offer paleontologists, archeologists and art historians a unique combination of analytical capabilities particularly well-suited for the chemical and mineralogical analysis of museum artifacts. The methods provided by X-ray microprobes are non-invasive, have low detection limits, afford high lateral resolution and provide exceptional chemical sensitivity. These characteristics are highly desirable for the chemical characterization of these precious, heterogeneous and complex materials³⁷.

In particular, XFM's chemical and mineralogical mapping capability with variable spatial resolution will provide researchers unique insights into the chemical history and future of these artifacts. For example a better understanding of the chemistry involved in both the object's history (that is, during fabrication³⁸⁻⁴⁰) and future (during preservation and restoration treatments⁴¹) can be addressed. μ XRF, μ XAFS and μ XRD can provide insight into craft skills that were mastered years, decades, or centuries ago but were lost over the course of time. For example, how the optical properties of historical glasses or ceramics reflect the molecular environment of relevant chromophores^{42,43}. As a forensic tool, such measurements can reveal chemically ancient texts and art long considered lost by overprinting and recycling^{44,45} and provides non-destructive methods for artifact authentication. In paleontology, state-of-the-art synchrotron rapid scanning XRF imaging can reveal striking new details about the chemical preservation of soft tissue, elemental distribution patterns related to an organism's life processes, insights into the chemistry of the fossilization process, and details of curation history.⁴⁶ These instruments can also be invaluable in helping conservationists characterize unwanted reactions that can dramatically alter an object's original visual properties. This is particularly important in considering the stresses that atmospheric pollutants in urban areas impose on unique irreplaceable museum artifacts.

The design of most existing X-ray microspectroscopy beamlines makes imaging large samples impractical. XFM with its variable focus and collimation, coupled with dramatic advances in ultrafast, large solid-angle energy dispersive detectors being developed at BNL^{47,48} is ideal for these studies⁴⁹. The beamline should allow for signals from multiple elements to be read out at intervals of several milliseconds per pixel during bidirectional scans covering meters. Incorporating large format translation stages and environmentally controlled hutches in the design will allow for analysis of whole objects including panel paintings, sculpture, and archaeological materials.

The European synchrotrons, ESRF in particular, currently lead the world in the application of synchrotron-based analysis of cultural heritage objects. Although museum scientists from across the country and the world would be regular users of the proposed beamline, the proximity of the NSLS-II to many of the country's largest and most scientifically capable museums raises the real possibility of transporting whole art objects to the facility for in situ analysis. In some instances, the appointment of a specific liaison to the cultural heritage community has facilitated use of synchrotron sources in conservation science and art historical research and should be considered for NSLS-II. The very recent announcement that the Smithsonian Institution, the premier cultural center in the USA, is pairing with SOLEIL for

synchrotron-based analysis of cultural heritage materials, shows the lure of a 3rd generation synchrotron source for museum based research

B. Beamline Concept & Feasibility

To meet the stated scientific goals, the beamline must produce and maintain stable strongly focused microbeams while varying incident beam energy smoothly over at least 1 keV within the energy range from 4-20 keV. NSLS-II's 3PW source is well-suited to meet these technical challenges. The principal technical requirements are the following:

- ***Variable incident spot sizes between 1 μm and 1 mm.*** The lower limit is defined by the smallest likely spot size that is useful in imaging sub-cellular components in many organisms and fine-grains in geological aggregates. The larger limit is defined by the largest beam diameter that will likely be used for "bulk" fluorescence analysis, is a convenient pixel size with high sensitivity for imaging physically large samples and for XRD analysis permits more powder-like diffraction when needed. The instrument must allow the user to easily trade spot size for flux.
- ***Maintain beam position to better than 5% of beam size with systematic noise in the I0-normalized EXAFS spectrum below 0.1%.*** EXAFS requires a precise measure of $\mu(E)$ and optimal EXAFS measures oscillations less than 0.1% of the edge-step signal. This requires a fairly precise and accurate measurement of $\mu(E)$ so as not to degrade or even destroy the EXAFS. For microbeam fluorescence measurements this can be challenging, especially for very low concentration samples. It requires noise in the I0-normalized EXAFS to vary smoothly by not more than 0.1% over the energy scan and that the focused beam (and sample) not drift spatially by more than 5% (optimally less than 1%) of the beam area during an energy scan.
- ***Tunable and scannable energy range between 4-20 keV.*** With a particular emphasis on XAFS, this energy range covers at the lower energy range the K-edge of Ti, an important element in earth, environmental, biological, and materials science studies. The higher energy end covers the L-edges of important actinide elements, which is crucial for environmental remediation studies.
- ***Combined microfocused X-ray fluorescence, absorption spectroscopy and diffraction analysis.*** To best characterize the heterogeneity observed in natural materials, most users demand that modern hard X-ray microprobes be designed for near simultaneous μXRF , μXAFS and μXRD . These combined methodologies are extremely important, giving users the capability to synchronize elemental maps and phase maps, evaluate how variability in molecular speciation couples to mineralogy, and the ability to identify a phase by simultaneously looking at its chemical signature and its diffraction pattern.
- ***Large working distance to enable analysis of bulky materials and the use of environmental chambers.*** While the instrument should be capable of achieving spatial resolutions below 10 μm , choices for focusing optics should allow for sufficient working distances to enable versatility in analysis. For example, samples within bulky environmental cells that can flow gases and solutes, analysis of samples under controlled and variable pressure and temperature, in-situ analysis of live organisms (i.e. small plants) actively transporting and cycling nutrients or toxins and sufficient distance to enable 3D fluorescence tomography of objects a few millimeters in diameter.
- ***Accommodations for the analysis of physically large samples with positional stability.*** A unique aspect of this beamline will be to enable analysis of physically large samples with dedicated instrumentation. This will foster the growth of emerging synchrotron communities, particularly in the analysis of cultural heritage materials, paleontological samples, and large manufactured objects, such as battery cells, in an "operational" state.

The design goals for such a beamline are best met on a broadband X-ray source that utilizes a compound focusing optical layout to produce an extremely stable secondary source. A schematic of a suitable layout

that will meet the scientific requirement is shown in Figure 1 and described in more detail in Appendix A.4. The 3PW sources at NSLS-II are well suited to achieving these goals. The low emittance of the NSLS-II storage ring means that even at relatively long distances from the 3PW source, a compound focusing optical design can be effectively employed to produce a highly collimated monochromatic source that can be variably focused/collimated to spot sizes between 1 μm and 1 mm at the sample position. The broadband nature of this source between 4 and 20 keV will allow very smooth energy scanning over this energy range with high energy resolution and stability. Pre-focusing optics downstream of the shield wall will be utilized to gather maximum photon flux to be delivered to the instrument for spectroscopy and fluorescence analysis. A horizontally deflecting toroidal mirror gathers sufficient radiation in both vertical and horizontal directions within an acceptable spot size to a downstream collimating mirror. This mirror will deliver a small highly collimated beam to a secondary source aperture (SSA). The SSA provides a highly stable secondary source to a double-crystal monochromator that allows the user to trade flux for spot size (1-10 μm FWHM focused, ~ 1 mm collimated) by simply varying the SSA diameter. The microprobe will then utilize grazing-incidence mirrors in a Kirkpatrick-Baez geometry to provide the wide energy range required with a high degree of achromaticity while scanning energy. Since these optics re-image the source using two successive elliptical mirrors that are perpendicularly arranged, much of the astigmatism encountered in the optical design can be effectively suppressed.

Such a design provides relatively long working distances from the final focusing optic to the sample, long enough to very effectively allow placement of experimental chambers where materials can be characterized in-situ while environmental parameters such as gas or fluid composition, pressure, temperature, or electrical charge are varied. The long-working distances and variable spot size can be further exploited to allow for characterization of the chemical variation in natural samples three-dimensionally using tomographic methods (for example within plants and other moderately sized organisms^{12,11} or within soil columns of small size¹⁰) and for the analysis of physically large samples up to meters in size.

The pre-conceptual design presented here (Appendix A.4) demonstrates that a reasonable optical layout is feasible that will satisfy the scientific requirements using this source with a photon flux of up to 2×10^{11}

NSLS-II

XFM Versatile Hard X-ray Microprobe

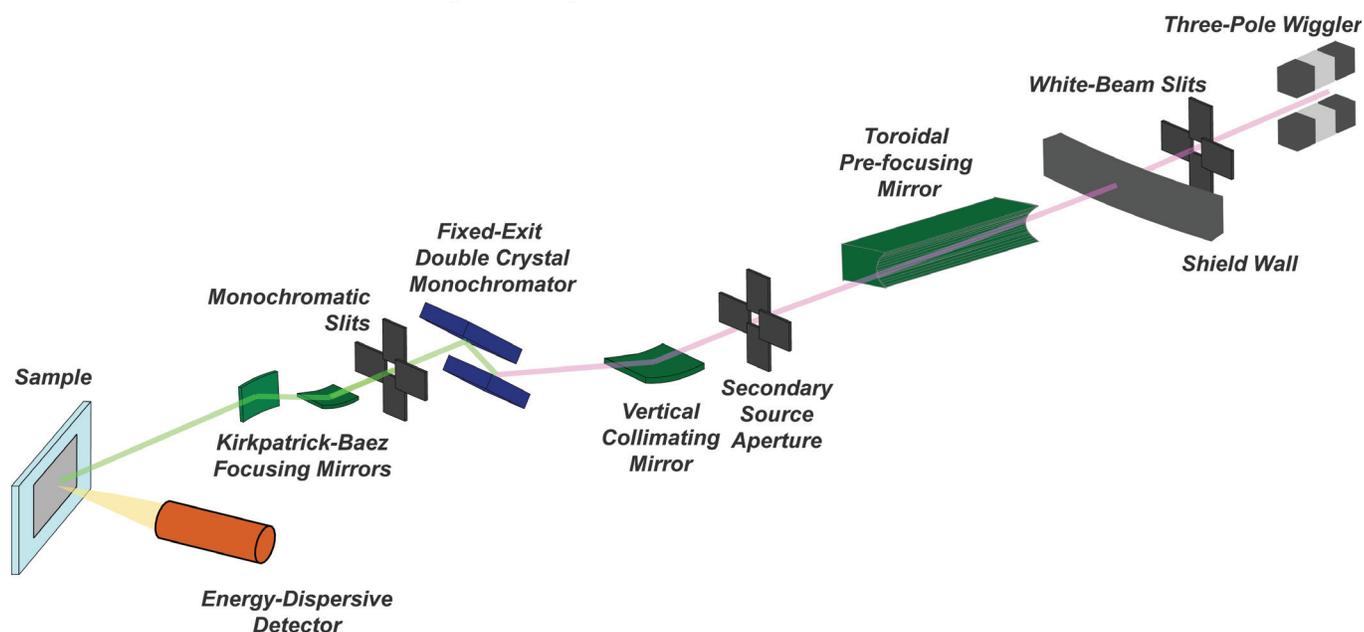


Figure 1. Schematic pre-conceptual layout of XFM optical components (downstream direction right to left).

ph/sec/0.1%bw in a 10 μm focal spot. This is a flux density up to two orders of magnitude higher than the existing bending magnet microprobes at the NSLS currently deliver to the sample. The spot can be reduced

to as small as 1 μm by reducing the SSA size with an associated hit in flux. Such a facility incorporating all these parameters will impact a very broad scientific user community and be unique in the United States.

XFM Endstation Considerations

The scientific requirements of XFM to enable spatially resolved EXAFS will necessitate careful control of the final focusing optics and sample environment to maintain beam stability to better than 5% of the focused spot size. This will require careful moderation of hutch temperature, humidity and airflow. These specifications will complement our needs to build a hutch that fully supports and engages the cultural heritage community with an environmentally controlled, airlocked and security-enabled enclosure with particulate filtering suitable for conservation science.

The types of samples that the user community will wish to examine using XFM will be extremely variable, reflecting the high degree of versatility the beamline will be designed to support. Therefore the specimen mounting, environment and manipulation apparatus must have significant flexibility. It is likely that the majority of the experiments will operate at the highest available spatial resolution with specimens cm's in size. However, a critical goal for XFM is to provide sufficient flexibility to accommodate high-impact experiments of large specimens up to meters in size supporting large travel dimensions. These customized stages must be capable of supporting samples m's in size and weighing in excess of 50 kilograms. These large stages must raster scan through a micron diameter beam precisely and reproducibly. Some specimens will also need to be studied whole without sectioning utilizing tomographic methods by rotating samples about the focal point (θ). A variety of sample environments is also required to be supported including cryogenic capabilities to minimize radiation damage.

We envision that for many X-ray fluorescence analyses, XFM will utilize the next generation of the BNL-CSIRO Maia detector system based on silicon-drift diode arrays. This system will dominantly operate in a continuous scanning mode capable of rapid on-the-fly XRF acquisition. This is required to allow for imaging of large sample areas while maintaining high pixel resolution, for minimize radiation dose to photo-redox sensitive samples and for enabling the next-generation of μXAFS experiments that collect data in an image-stack modality. This system will efficiently support the fast readout, fast raster scan, on-the-fly acquisitions required in a normal incidence geometry and with large solid angles. In addition to allowing the greatest beam demagnification, this approach will reduce the horizontal footprint of the beam on the sample and place the microscope optic axis coincident with (or at least parallel to) the X-ray beam. This is also optimal for analysis of physically large specimens. We also plan to investigate the possible utility of confocal XRF in the analysis of large, flat samples⁴⁵.

Coupled μXRD analysis is a core technique at modern X-ray microprobes and will be fully enabled at XFM by incorporating high sensitivity, low noise area detectors with relatively large 2θ coverage and along-beam adjustable position for optimizing angular range and phase-contrast. XFM will also be required to support complementary microfocused tomographic modes of fluorescence, absorption and diffraction imaging. This will require rapid fluorescence detectors, calibrated photodiodes with high sensitivity to measure absorption, as well as high sensitivity and rapid readout CCD area detectors for diffraction imaging and tomography.

C. Required Technical Advances (if any)

We are confident that the stated goals of XFM are achievable utilizing currently available technologies. We do foresee that XFM will benefit, however, from improvements in mirror figuring, further development of energy dispersive detectors and the design of precise, long travel stages.

D. User Community and Demands

This proposal is an outgrowth of the following workshops held over the past few years by various user communities to specifically identify future analytical resources that must be developed to advance our understanding of complex natural systems:

- Workshop on STXM and X-ray Nanoprobe Capabilities and Needs in the Environmental, Geological, and Biomedical Sciences, Stanford University, Jul. 9-10, 2007.

- NSLS-II User Workshop, Environmental and Life Sciences, BNL, Jul. 17-18, 2007.
- Workshop for Assessing the Synchrotron Radiation Needs of the Molecular Environmental Science and Low-temperature Geochemistry Community (EnviroSync), Rockville, MD, Jul. 23-24, 2007.
- Medical Applications of Synchrotron Radiation, Saskatoon, Canada, Aug. 26 - 30, 2007.
- Biological Applications of X-ray Microprobes, Chicago, IL, Nov. 15-16, 2007.
- NSLS/NSLS-II Life Sciences Strategic Planning Workshop, BNL, Jan. 15-16, 2008.
- NSLS/NSLS-II Earth and Environmental Sciences Strategic Planning Workshop, BNL, Jan. 22–23, 2008.
- Cultural Heritage Secrets Unveiled with Synchrotron Radiation, BNL, May 18, 2009.
- Future Prospects in Synchrotron X-ray Fluorescence Microprobe Analysis, American Chemical Society Annual Meeting, San Francisco, CA, Mar. 21, 2010.
- Biological Applications of X-ray Fluorescence Microscopy, Chicago, IL, Aug. 13-14, 2010.

These workshops identified a clear need for higher intensity focused X-ray probes to enable the next generation of research. Recommendations for NSLS-II included focused beam XRF instruments providing a broad range of photon energy from 4-25 keV with the ability to tune the energy to enable μ XAFS spectroscopy and capability for simultaneous μ XRD.

This beamline will coalesce research groups interested in the application of highly focused X-ray fluorescence, spectroscopy, diffraction, and microtomography in geochemistry, molecular environmental sciences, cosmochemistry, life sciences, paleontology and cultural heritage sciences. Worldwide, X-ray microprobe beamlines are consistently some of the most oversubscribed with high user demand and publication rates. The NSLS hard X-ray microprobes have together averaged an oversubscription rate of 250% based on days requested versus days allocated. Appendix A.5 gives a list of user groups which have utilized microprobe instruments at the NSLS and APS managed by members of XFM's BDP team.

E. Proposal Team Expertise and Experience

This proposal team was organized to include individuals with vast experience in the application of X-ray fluorescence microprobes in earth, environmental, life, and cultural heritage science research and individuals with decades of experience in the design and operation of these instruments. The current membership is listed below (alphabetical) and brief biographies are provided in Appendix A.2:

- **Paul Bertsch:** Professor, Department of Plant and Soil Sciences, Univ. of Kentucky. Paul is recognized internationally for research contributions in developing minimally invasive recovery strategies for contaminated sites. He pioneered the application of X-ray microprobe methods in the environmental sciences. He will provide guidance on XFM application to soil sciences.
- **Eric Dooryhee:** Physicist, NSLS-II Project, BNL. Eric has been a world-renowned advocate in promoting the use of synchrotron radiation techniques in Art and Archaeology over the past 10 yrs. He is chair of Synchrotron Radiation in Art & Archaeology (<http://www.sr2a.ua.ac.be/>) and was a member of the IPANEMA group at SOLEIL. He will provide expertise in the application of XFM to Cultural Heritage studies.
- **George Flynn:** Professor of Physics, State Univ. of New York at Plattsburgh. George has a long history of studying the chemistry of meteorite and cosmic dust samples and in the utilization of X-ray microprobes for the analysis of extraterrestrial particles. He was team leader for NASA Stardust's chemical composition team. He will provide guidance on beamline development with respect to utilization for the analysis of extraterrestrial materials.
- **John J. Flynn:** Frick Curator of Fossil Mammals & Dean, Richard Gilder Graduate School, Division of Paleontology, American Museum of Natural History. Author of more than 110 scientific publications, John's research focuses on the evolution of mammals and Mesozoic vertebrates, geological dating, plate tectonics, and biogeography. He will provide guidance on beamline development with respect to utilization for the analysis of paleontologic samples.

- **Matthew Ginder-Vogel:** Director, Process and Analytical Chemistry, Calera Corporation. Matt has significant experience in utilizing XAFS for studying the dynamics of nutrients and contaminants within the environment. At Calera Corporation he directs analytical studies related to Calera's Mineralization via Aqueous Precipitation (MAP) process for sequestering greenhouse gases. Matt will provide guidance on beamline design for XAFS studies and CO₂ capture related studies.
- **Antonio Lanzirotti (Leader):** Senior Research Associate, Univ. of Chicago. Tony has expertise in design, operation and application of X-ray microprobes and will be the BDP leader.
- **Matthew Marcus:** Beamline Scientist, Advanced Light Source, Lawrence Berkeley National Laboratory. Matthew is the chief beamline scientist at the 10.3.2 microprobe beamline at the ALS and will provide instrument design guidance.
- **Lisa Miller:** Biophysical Chemist, NSLS & NSLS-II, BNL. Lisa has broad expertise in design and application of beamlines for biomedical research. She will provide scientific guidance for the life sciences research.
- **Paul Northrup:** Associate Environmental Scientist, Stony Brook Univ. Paul has expertise in beamline design and management, environmental science applications and capabilities of NSLS-II. He will provide technical expertise.
- **Tracy Punshon:** Research Associate Professor, Dept. of Biological Sciences, Dartmouth College. Tracy is a leading plant biologist that has pioneered the use of synchrotron microprobe techniques for studying metal homeostasis in plants, in particular in the development of fluorescence microtomography methods. She will provide guidance for plant biology studies and tomographic techniques.
- **Mark Rivers:** Senior Scientist, Univ. of Chicago. Mark has broad expertise in beamline design and operation especially in beamline controls and data acquisition. Mark will provide guidance in beamline design, beamline controls and instrumentation control.
- **David Peter Siddons:** Physicist, BNL. Peter is an award winning physicist with experience in the development of X-ray optics, detectors and synchrotron instrumentation. In collaboration with CSIRO he developed the Maia detector system and is currently designing stages and instrumentation for cultural heritage studies. He will provide guidance on beamline and detector design.
- **Gregory Dale Smith:** Senior Conservation Scientist, Indianapolis Museum of Art. Greg oversees the Conservation Science Laboratory at the IMA. He has significant expertise in the application of state-of-the-art technologies to conservation science and the development and testing of innovative conservation treatments. He will provide expertise in the application of microprobe methods in cultural heritage studies.
- **Stephen Sutton:** Senior Scientist, Univ. of Chicago. Steve has broad expertise in microprobe design, management and operation including microprobe data analysis. Steve will provide guidance in overall scientific direction and microprobe design.
- **Ryan Tappero:** Research Associate, NSLS, Brookhaven National Laboratory. Ryan is beamline scientist of the X27A X-ray microprobe beamline at the NSLS and has expertise in microprobe operations. He was also a pioneer in the application of X-ray tomography methods to understanding element cycling in the rhizosphere and in plants and has broad expertise in EXAFS.
- **Tetsu Tokunaga:** Senior Scientist, Hydrogeology Department, Lawrence Berkeley National Laboratory. Tetsu has significant expertise in studying the physicochemical basis of environmental transport processes using synchrotron methods. He has developed synchrotron methods for direct measurements of diffusion-limited precipitation of cations in variable redox sediments. He will provide guidance on the development of fluid and environmental cell methods for XFM.

F. Suggestions for BAT Membership

None.

G. Funding and Management

Type I proposal.

Appendices

A.1	References.....	A-1
A.2	Beamline Proposal Team Biographies.....	A-4
A.3	JPSI Letter of Support for XFM Beamline.....	A-21
A.4	Details of Pre-Conceptual Optical Plan for XFM	A-22
	Table 1: Predicted XFM flux at sample position as a function of energy.....	A-24
	Table 2: XFM comparison to other microprobes.....	A-25
	Figure 2: XFM Horizontal & Vertical Optical Layout & Ray-Tracing.....	A-26
A.5	Lists of Potential Users.....	A-27

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Appendix A.2. XFM Beamline Proposal Team Biographies (alphabetical)

Paul M. Bertsch

Education:

B.Sc. Plant and Soil Sciences (1978) University of Connecticut

M.Sc. Soil Chemistry (1980) Virginia Tech Thesis: "Lime-Aluminum Interactions and Phosphorus Relations with Selected Coastal Plain Soils, 208 pp. (Thesis advisor: Mark Alley and Lucian Zelazny)

Ph.D. Soil Physical Chemistry and Mineralogy (1983) University of Kentucky. Dissertation: The Behavior of Aluminum in Complex Solutions and its Role in the Exchange Equilibria of Soils, 252 pp." (Thesis advisor: G.W. Thomas)

Research Experience (abbreviated):

2009-present Director of the Tracy Farmer Institute for Sustainability and the Environment

University of Kentucky, Lexington

2008-present Professor of Environmental Chemistry and Toxicology

Department of Plant and Soil Sciences, University of Kentucky, Lexington, KY

2008-present Georgia Power Professor of Environmental and Soil Chemistry Emeritus

University of Georgia, Athens, GA

1984-2008, Assistant, Associate and Professor of Biogeochemistry

Savannah River Ecology Laboratory, University of Georgia

1999-2007 Director

Savannah River Ecology Laboratory, University of Georgia

2001-present Faculty of the Marine Biomedicine and Environmental Sciences Program

Medical University of South Carolina, Charleston, SC

Professional Societies:

American Geophysical Union, Geochemical Society, Soil Science Society of America, American Association for the Advancement of Science, American Chemical Society, Clay Minerals Society, EnviroSync

Professional Activities (since 2002):

Chair -U.S. National Committee for Soil Science; NAS; Member-Committee for Earth Resources, NAS; President, Soil Science Society of America; Member, Scientific Advisory Committee, Advanced Photon Source; Chair, Division of Soil Chemistry, Soil Science Society of America; Associate Editor, Vadose Zone Journal; Associate Editor, Soil Science Society of America Journal

Awards:

Fellow, Soil Science Society of America; Fellow, American Society of Agronomy; Fellow, International Union for Pure and Applied Chemistry; Jackson Award for excellence in research and teaching in soil chemistry and mineralogy, SSSA. 1996.; UGA Excellence in Undergraduate Research Mentoring Award, 2001

D.W. Brooks Award for Research Excellence, UGA, 2004; Career Achievement Award – Soil Science Research Award –Soil Science Society of America. 2004.

Selected Publications:

Unrine, J., O. Tsyusko, S. Hunyadi, J. Judy, and P.M. Bertsch. 2010. Effects of particle size on chemical speciation and bioavailability of Cu to earthworms (*Eisenia fetida*) exposed to Cu nanoparticles. J Environ Qual In Press.

Ma, H.B., P.M. Bertsch, T.C. Glenn, N.J. Kabengi, and P.L. Williams. 2009. Toxicity of manufactured ZnO nanoparticles in the nematode *Caenorhabditis elegans*. Environ. Toxicology and Chemistry 28:1324-1330.

Jackson, B.P., P.L. Williams, A. Lanzirrotti and P.M. Bertsch. 2005. Evidence for biogenic pyromorphite formation by the nematode *Caenorhabditis elegans*. Environmental Science and Technology. 39(15) 5620-

Jackson, B.P., J.F. Ranville, P.M. Bertsch and A.G. Sowder. 2005. Characterization of colloidal and humic-bound Ni and U in the "dissolved" fraction of contaminated sediment extracts. Environmental Science and Technology 39:2478-2485.

Bertsch, P.M. and D. B. Hunter. 2001. Applications of Synchrotron-Based X-ray Microprobes. Chemical Reviews 101:1809-1842.

Eric Dooryhee

Present situation: Powder Diffraction beamline group Leader at NSLS-II

Education:

M.Sc. Hard Condensed Matter Physics and Crystallography (1985) University of Paris (Jussieu)

Ph.D. Radiation Physics (1987) University of Paris (Orsay). Dissertation: "ESR study of high-energy ion induced defects in silica" (Thesis advisor: Y. Langevin)

Research Experience:

2009-present Staff Scientist, Brookhaven National Laboratory, National Synchrotron Light Source II, NY

2001-2009 Senior Scientist, Neel Institute, CNRS Grenoble, France

1996-2000 Beamline Scientist, BM16 (now ID31), European Synchrotron Radiation Facility, France

1990-1995 Senior Scientist, Interdisciplinary Research Center with Ions and Lasers, CNRS Caen, France

1988-1989 Post-doctoral Fellow, Synchrotron Radiation Source, Daresbury, UK.

Research Interests:

Diffraction science: x-ray synchrotron, interfacial diffusion and strain in perovskite thin films and superlayers, structure solving and refinement, applications to art and archaeology (SR2A).

Professional Societies:

Member of the International Union of Crystallography and of the French Association of Crystallography.

Professional Activities (since 2000):

Co-supervision of 4 PhD students (and >20 graduate trainees); organization of a European Marie Curie training course 2007; member of the organizing committee of the European School HERCULES; member of the Scientific Advisory Committee of SR2A; member of the CNRS Scientific Advisory Board (2004-2008); membership in PhD examination panels; lecturing; chair of the IUCr commission CrysAC; member of the International Program Committee of the IUCr; editing duties.

Selected Publications (from over 90):

E. Dooryh e, C.R.A. Catlow, et al. A study of cation environment and movement during dehydration and reduction of nickel-exchanged zeolite-Y by X-ray absorption and diffraction. *J. Phys. Chem.* 95 (1991) 4514.

E. Balanzat, S. Bouffard, A. Cassimi, E. Dooryh e, L. Protin, et al. Defect creation in alkali-halides under dense electronic excitations: experimental results on NaCl and KBr. *Nucl. Inst. and Methods B91* (1994) 134.

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S. H emon, V. Chailley, E. Dooryh e, C. Dufour, F. Gourbilleau, F. Levesque, E. Paumier. Phase transformation of polycrystalline Y₂O₃ under irradiation with swift heavy ions. *Nucl. Inst. and Methods B122* (1997) 563.

Ph. Walter, P. Martinetto, G. Tsoucaris, R. Breniaux, M-A. Lefebvre, G. Richard, J. Talabot, E. Dooryh e. Making make-up in Ancient Egypt. *Nature* 397 (1999) 483.

E. Dooryh e, J-P. Duraud, R.A.B. Devine. Structure and Imperfections in Amorphous and Crystalline Silicon Dioxide, eds. R.A.B. Devine, J-P. Duraud, E. Dooryh e (J. Wiley & Sons Ltd, Chichester, 2000)

P. Pinheiro, M-C. Schouler, P. Gadelle, et al. Effect of hydrogen on the orientation of carbon layers in deposits from the carbon monoxide disproportionation reaction over Co/Al₂O₃ catalysts. *Carbon* 38 (2000) 1469.

R.W. Cheary, E. Dooryh e, P. Lynch, N. Armstrong. X-ray Diffraction Line Broadening from Thermally Deposited Gold Films. *J. Appl. Cryst.* 33 (2000) 1271-1283.

O. Masson, E. Dooryh e, A.N. Fitch. Instrument line profile synthesis in high-resolution synchrotron powder diffraction. *J. Appl. Cryst.* 36 (2003) 286-294.

E. Dooryh e, M. Anne, I. Bardi es, J-L. Hodeau, P. Martinetto, S. Rondot, J. Salomon, G.B.M. Vaughan, Ph. Walter. Non destructive synchrotron X-ray diffraction mapping of a Roman painting. *Appl. Phys. A* 81 (2005) 663-667.

Martinetto P, Terech P, Grand A, Ramasseul R, Dooryh e E, Anne M. Molecular structure of a D-homoandrostanyl steroid derivative: Single crystal and powder diffraction analyses *J. of Physical Chemistry B*110 (2006) 15127.

M. Nemoz, E. Dooryh e, J-L. Hodeau C. Dubourdieu, H. Roussel, et al. Sensitivity of synchrotron radiation x-ray diffraction to the chemical ordering in epitaxial perovskite multilayers. *J. Appl. Phys.* 100 (2006) 124110.

Lemee N., Dooryh e E., Bouyanfif H., Le Marrec F., et al. Synchrotron x-ray scattering evidence for interlayer structural coupling in (PbMg_{1/3}Nb_{2/3}O₃)_(1-x)(PbTiO₃)_x superlattices. *Physical Review B*78 (2008) 140102.

Bleuet P., Welcomme E., Dooryh e E., Susini J., Hodeau J.-L., Walter P. Probing the structure of heterogeneous diluted materials by diffraction tomography. *Nature Materials* 7 (2008) 468-472.

Design and commissioning of a wide-angle analyzer crystal for powder diffraction. Patent WO2008/125450.

Dr George J. Flynn:

Professor of Physics, State Univ. of New York at Plattsburgh. (518) 564-3163. george.flynn@plattsburgh.edu.

Dr. Flynn received B.S. and M.S. degrees in Physics from the Massachusetts Institute of Technology in 1972, and a PhD in Physics from Washington University, where he participated in projects involving elemental characterization of interplanetary dust and meteorites, fission track dating of lunar samples, and a search for super-heavy elements in the Allende meteorite, in 1982. He has been actively involved in the chemical analysis of interplanetary dust particles since 1978. He served as the leader of the Elemental Analysis Preliminary Examination Team for the Wild 2 samples collected by the Stardust spacecraft, and he currently serves as a member of the Stardust Interstellar Particle Preliminary Examination Team. Dr. Flynn is a member of the Curation & Analysis Planning Team for Extraterrestrial Materials (CAPTEM) and is a Fellow of the Meteoritical Society.

Selected Recent Publications:

Flynn, G. J., Lanzirotti, A., and Sutton, S. R. (2009) Elemental and Mineralogical Compositions of Cluster IDPs, *Lunar and Planet. Sci. XXXIX*, Lunar and Planet. Inst., A.#1166.

Flynn, G. J., L. P. Keller, S. Wirick and C. Jacobsen (2008) Organic matter in interplanetary dust particles, in *Proc. Int. Astron. Union*, Symposium S251, February 2008, 267-276.

Bajt, S.; Sandford, S. A.; Flynn, G. J.; Matrajt, G.; Snead, C. J.; Westphal, A. J.; Bradley, J. P. (2009) Infrared spectroscopy of Wild 2 particle hypervelocity tracks in Stardust aerogel: Evidence for the presence of volatile organics, *Meteoritics & Planetary Science*, 44, 471-484.

Flynn, G. J., Lanzirotti, A., and Sutton, S. R. (2008) Elemental Compositions of Large Cluster IDPs, *Lunar and Planetary Science XXXIX*, Lunar and Planetary Institute, 1146-1147.

Flynn, G. J. (2008) Physical, Chemical, and Mineralogical Properties of Comet 81P/Wild 2 Particles Collected by Stardust, *Earth, Moon, and Planets*, 102, 447-459.

Lanzirotti, A., S. R. Sutton, G. J. Flynn, M. Newville, and W. Rao (2008) Chemical Composition and Heterogeneity of Wild 2 Cometary Particles determined by Synchrotron X-ray Fluorescence, *Meteoritics and Planetary Science*, 43, 187-213.

Cody, G. D.; Ade, H.; O'D. Alexander, C. M.; Araki, T.; Butterworth, A.; Fleckenstein, H.; Flynn, G.; Gilles, M. K.; Jacobsen, C.; Kilcoyne, A. L. D.; Messenger, K.; Sandford, S. A.; Tylliszczak, T.; Westphal, A. J. (2008) Quantitative organic and light-element analysis of comet 81P/Wild 2 particles using C-, N-, and O- μ -XANES, *Meteoritics & Planet. Sci.*, 43, 353-365.

Matrajt, G.; Ito, M.; Wirick, S.; Messenger, S.; Brownlee, D. E.; Joswiak, D.; Flynn, G.; Sandford, S.; Snead, C.; Westphal, A. (2008) Carbon investigation of two Stardust particles: A TEM, NanoSIMS, and XANES study, *Meteoritics & Planetary Science*, 43, 315-334

Gallien, J.-P.; Khodja, H.; Herzog, G. F.; Taylor, S.; Koepsell, E.; Daghlian, C. P.; Flynn, G. J.; Sitnitsky, I.; Lanzirotti, A.; Sutton, S. (2008) Characterization of carbon- and nitrogen-rich particle fragments captured from comet 81P/Wild 2, *Meteoritics & Planet. Sci.*, 43, 335-351.

Flynn, G. J. et al. (2006) Elemental Composition of Comet 81P/Wild 2 Samples Collected by Stardust, *Science*, 314, 1731-1735.

Pizzarello, S., G. W. Cooper, and G. J. Flynn (2006), The Nature and Distribution of Organic Matter in Carbonaceous Chondrites and Interplanetary Dust Particles, in *Meteorites and the Early Solar System II* (eds. D. S. Lauretta and H. Y. McSween Jr.), Univ. of Arizona Press, 625-652.

Keller, L. P., S. Messenger, G. J. Flynn, S. Clemett, S. Wirick, and C. Jacobsen (2004) The nature of molecular cloud material in IDPs, *Geochim. Cosmochim. Acta*, 68, 2577-2589.

Flynn, G. J.; Keller, L. P.; Feser, M.; Wirick, S.; Jacobsen, C. (2003) The origin of organic matter in the solar system: evidence from the interplanetary dust particles, *Geochimica et Cosmochimica Acta*, 67, 4791-4806.

Dr. John J. Flynn, Biography

Richard Gilder Graduate School and Division of Paleontology, American Museum of Natural History, New York, NY 10024

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PROFESSIONAL PREPARATION

Yale University	B.S., Geology and Geophysics (cum laude)	1977
Columbia University	M.A., Geological Sciences	1979
Columbia University	M.Phil., Geological Sciences	1980
Columbia University	Ph.D., Geological Sciences	1983

PROFESSIONAL APPOINTMENTS

Dean, Richard Gilder Graduate School (Jan 2007-present) & Chairman (2005-present) and Frick Curator of Fossil Mammals (2004-present), Division of Paleontology, American Museum of Natural History

Adjunct (voting) Professor, Columbia U (Earth & Environmental Sci.); Adjunct (voting) Prof., City U. of NY (Biology, Earth Sciences); Resource Faculty, NY Consortium Evol. Primatology.

Chair (1993-2001) and MacArthur Curator (1995-2004), Department of Geology, Field Museum of Natural History; Curator of Fossil Mammals (1992-2004); Assoc. Curator (1988-1992)

U. of Chicago- Associate Chair (1995-2004) & Lecturer (1990-2005), Committee on Evolutionary Biology; Chair of Exec. Comm., NSF Biodiversity Training Grant. Biological Sci. Collegiate Div., Lecturer.

Adjunct Professor, Univ. of Illinois at Chicago, Biological Sciences (1995-2004)

Fellow, John Simon Guggenheim Memorial Foundation (July 2001-2002)

Professor Visitante, Universidad de Chile, Departamento de Geología, (2001-2002)

Assistant Professor, Rutgers University, Geological Sciences (1982-1987)

Yale University, Lecturer, Department of Geology and Geophysics (1982)

AWARDS

Clara Jones Langston Lecturer in Vertebrate Paleontology, University of Texas at Austin, 2010.

Fellow, American Association for the Advancement of Science (elected Fellow in the Geology & Geography Section, by the AAAS Council, 18 December 2009).

Joseph T. Gregory Award, Society of Vertebrate Paleontology, Austin, Texas, October 2007, for "outstanding service to the Society of Vertebrate Paleontology).

Fellow, John Simon Guggenheim Memorial Foundation, New York, July 2001-2002. "*The interplay of evolution and geologic change in South America*"; research, writing, and exploration in Chile.

Premio "Roberto Araya" (Roberto Araya Prize), Sociedad Geológica de Chile, April 2002; for the best presentation of the year, "*Vertebrados fósiles en Chile*", 16 October 2001.

Golden Muse Award, First Place for *Dino Documentary* (Field Museum Public Relations and RPM Advertising produced 30 second public service announcement of 1997 summer exhibit *Dino Families*; featured scientist), 8th Annual Muse Awards (1998; American Assoc. Museums); also awarded Bronze Telly (national award for advertising excellence).

First Place, Science Category, 6th Annual Muse Awards (1996; American Association of Museums), for "*Life Over Time News/The Evolutionary Broadcasting Network*" series (scientific content specialist on Development team).

Alfred Sherwood Romer Prize (4th Annual), Soc. of Vertebrate Paleontology, October, 1982.

William R. Belknap Prize (Excellence in Geology), Special Distinction in the Major, Hammer Award for Oral Presentation of Senior Thesis, Yale University, May, 1977.

Author of more than 110 scientific publications, and awarded ~\$5 million in grants for research, collections, labs, and education, Flynn's research focuses on the evolution of mammals, Cenozoic and Mesozoic faunas, geochronology, plate tectonics, and biogeography. His research has been published in *Science*, *Nature*, *PNAS*, *Evolution*, and journals and books spanning the earth sciences, biology, anthropology, etc. Flynn also has contributed articles to *Scientific American*, *Natural History*, and *National Geographic*, provided scientific expertise for several popular science books, and been featured in numerous television and radio shows (A&E, National Geographic Explorer, Today Show, Early Show, CNN, 20/20, NPR, etc.), newspapers and magazines. Dr. Flynn has led more than 50 paleontological expeditions to Chile, Perú, Colombia, Madagascar, India, Angola and the Rocky Mountains, supported by the National Science Foundation, National Geographic, NASA, and other organizations. Flynn serves on the Advisory Board of the Yale Peabody Museum and was President (1999-2001) and member of the Board/Executive Committee (1993-2002) of the Society of Vertebrate Paleontology, the world's largest organization of professionals in this field.

MATTHEW GINDER-VOGEL, Ph.D.

CONTACT INFORMATION

Calera Corporation
14600 Winchester Blvd.
Los Gatos, CA 95030

EDUCATION

2000, B.A. **Carleton College**, Northfield, MN, Chemistry
2006, Ph.D. **Stanford University**, Stanford, CA, Department of Geological and Environmental Sciences, Soil and Environmental Biogeochemistry Group

PROFESSIONAL POSITIONS

2010- Director, Process and Analytical Chemistry, Calera Corporation
2006 - 2010 Post Doctoral Associate, Department of Plant and Soil Sciences,
Center for Critical Zone Research and Environmental Soil Chemistry Group, University of Delaware
2001-2006 Graduate Research Assistant, Department of Geological and Environmental Sciences, Soil and
Environmental Biogeochemistry Group, Stanford University
2001-2004 Graduate Teaching Assistant, Department of Geological and Environmental Sciences, Soil and
Environmental Biogeochemistry Group, Stanford University
2000-2001 Graduate Research Associate, Structural Inorganic Chemistry Group, Los Alamos National Laboratory

Journal Reviewer: Environmental Science and Technology, Geochimica et Cosmochimica Acta,
Water Research, Vadose Zone Journal, Journal of Environmental Quality,

Guest Editor:

Environmental Science and Technology, Special Issue on Biogeochemical Redox Chemistry

Awards:

Excellence in Review for Environmental Science and Technology (2010)

Select Publications:

1. Zhu, M., M. Ginder-Vogel & D. L. Sparks (2010) Ni(II) Sorption on Biogenic Mn-Oxides with Varying Mn Octahedral Layer Structure. *Environmental Science & Technology*, 44, 4472-4478.
2. Zhu, M., M. Ginder-Vogel, S. J. Parikh, X.-H. Feng & D. L. Sparks (2010) Cation Effects on the Layer Structure of Biogenic Mn-Oxides. *Environmental Science & Technology*, 44, 4465-4471.
3. Shimizu, M., M. Ginder-Vogel, S. J. Parikh & D. L. Sparks (2010) Molecular Scale Assessment of Methylarsenic Sorption on Aluminum Oxide. *Environmental Science & Technology*, 44, 612-617.
4. Landrot, G., M. Ginder-Vogel & D. L. Sparks (2010) Kinetics of Chromium(III) Oxidation by Manganese(IV) Oxides Using Quick Scanning X-ray Absorption Fine Structure Spectroscopy (Q-XAFS). *Environmental Science & Technology*, 44, 143-149.
5. Ginder-Vogel, M., B. Stewart & S. Fendorf (2010) Kinetic and Mechanistic Constraints on the Oxidation of Biogenic Uraninite by Ferrihydrite. *Environmental Science & Technology*, 44, 163-169.
6. Borch, T., R. Kretzschmar, A. Kappler, P. V. Cappellen, M. Ginder-Vogel, A. Voegelin & K. Campbell (2010) Biogeochemical Redox Processes and their Impact on Contaminant Dynamics. *Environmental Science & Technology*, 44, 15-23.
7. **Ginder-Vogel, M.;** Fischel, J.S.; Landrot, G.; Sparks, D.L. Quantification of rapid environmental redox processes using quick-scanning X-ray absorption spectroscopy (Q- XAS). *Proceedings of the National Academy of Sciences*. **2009**, 106(38), 16124-16128. (Published online)

Dr. Antonio Lanzirotti, Ph.D.

Education:

B.Sc. Geology (1985) New Mexico Institute of Mining and Technology

M.Sc. Geochemistry (1988) New Mexico Institute of Mining and Technology. Thesis: “Geology and Geochemistry of a Proterozoic Supracrustal and Intrusive Sequence in the Wet Mountains, Colorado” (Thesis advisor: Kent Condie)

Ph.D. Geochemistry (1995) State University of New York at Stony Brook. Dissertation: “U-Pb Dating of Metapelites” (Thesis advisor: Gilbert N. Hanson)

Research Experience (abbreviated):

2007-present Senior Research Associate

Center for Advanced Radiation Sources, University of Chicago, Chicago, IL

1999-2006 Microprobe Scientist

Center for Advanced Radiation Sources, University of Chicago, Chicago, IL

1998-1999 Laboratory Manager

Professional Service Industries Analytical Services, Oakbrook Terrace, IL

1997-1998 Adjunct Assistant Professor

Queens College, City University of New York

1995-1997 National Science Foundation Post-Doctoral Fellow

The University of Massachusetts at Amherst

1993-1997 Isotope Geochemistry Laboratory Manager

State University of New York at Stony Brook.

Professional Societies:

American Geophysical Union, Geochemical Society, American Mineralogical Society, American Chemical Society,

Professional Activities (since 2002):

National User Facilities Organization Vice-Chairman, 2010-2011; National Synchrotron Light Source Users’ Executive Committee Chairman, 2003-2004 and 2010-2011; Chairman of Beamline Advisory Team for the NSLS-II Submicron Resolution X-ray Probe project beamline 2008-present; Proposal Oversight Panel Chairman, National Synchrotron Light Source 2007-present; Proposal Allocation Panel Member, National Synchrotron Light Source 2005-present; Proposal Review Panel Member, National Synchrotron Light Source 2000-2002, Advanced Light Source 2008-present; Co-organizer, Environmental Molecular Sciences Workshop, National Synchrotron Light Source 2000 Annual Meeting; Co-organizer, Synchrotron Environmental Sciences III Meeting, 2005;

Selected Publications:

Cottrell, E., Kelley, K., Lanzirotti, A., and Fischer, R. (2009) High-Precision Determination of Iron Oxidation State in Silicate Glasses Using XANES, *Chemical Geology*, v. 268, p. 167-179.

Flynn, G., Sutton, S., and Lanzirotti, A. (2009) A Synchrotron-Based Facility for the In-Situ Location, Chemical and Mineralogical Characterization of ~10 micrometer Particles Captured in Aerogel, *Advances in Space Research*, v. 43, p. 328-334.

Flynn, G., et al. (2006) Elemental Compositions of Comet 81P/Wild 2 Samples Collected by Stardust. *Science*, v. 314, p. 1731-1735.

Kim, S., Punshon, T., Lanzirotti, A., Li, L., Alonso, J., Ecker, J., Kaplan, J., and Guerinot, M.L. (2006) Localization of Iron in Arabidopsis Seed Requires the Vacuolar Membrane Transporter VIT1. *Science*, v. 314, p. 1295-1298.

Lange, K., Rowe, R., Jamieson, H., Flemming, R., and Lanzirotti, A. (2010) Characterization of geosynthetic clay liners using micro-analytical methods, *Applied Geochemistry*, v.25, p.1056-1069.

Lanzirotti, A., Tappero, R., and Schulze, D. (2010) Practical applications of synchrotron-based hard X-ray microprobes in the soil sciences. In Grafe, M. and Singh, B. (eds.), *Advances In Understanding Soil Environments By Application of Synchrotron-Based Techniques*. Elsevier.

Lanzirotti, A., Sutton, S., Flynn, G., Newville, M., and Rao, W. (2008) Chemical Composition and Heterogeneity of Wild 2 Cometary Particles Determined by Synchrotron X-ray Fluorescence. *Meteoritics and Planetary Science*, v. 43, p. 187-214.

Punshon, T., Guerinot, M. and Lanzirotti, A. (2009) Using Synchrotron X-ray Fluorescence Microprobes in the Study of Metal Homeostasis in Plants, *Ann. Bot.*, v. 103, p. 665-672.

Reeder, R., Schoonen, M., and Lanzirotti, A. (2006) Metal Speciation and Its Role in Bioaccessibility and Bioavailability. In Sahai, N. and Schoonen, M., eds., *Reviews in Mineralogy and Geochemistry* v. 64: *Medical Mineralogy and Geochemistry*, p. 59-113.

Sutton, S. R., Bertsch, P. M., Newville, M., Rivers, M., Lanzirotti, A., and Eng, P. (2002) Microfluorescence and microtomography analyses of heterogeneous earth and environmental materials. In Fenter, P., Rivers, M., Sturchio, N., and Sutton, S., eds., *Reviews in Mineralogy and Geochemistry* v. 49: *Applications of Synchrotron Radiation in Low-Temperature Geochemistry and Environmental Science*.

Dr. Matthew Marcus, Ph.D.

Education:

Ph.D. Physics (1978) Harvard University, Cambridge, MA.

B.Sc. Physics (1972) City College of New York, New York, NY.

Research Experience (abbreviated):

2001-present Microprobe Scientist; Director-Advanced Light Source 10.3.2

Advanced Light Source, Lawrence Berkeley National Laboratory, Berkeley, CA

1998-2001 Systems Engineer (Physicist)

KLA-Tencor, Milpitas, CA

1978-1998 Physicist

Bell Laboratories (Lucent), Murray Hill, NJ

Patents:

"Article Comprising A Multiport Variable Capacitor", to issue on 06/05/2001, as U.S. Patent Number 6242989.

"Internal gettering by metal alloy clusters" Buonassisi, A., Heuer, M., Istratov, A., Pickett, M. D., Marcus, M. A., Weber, E. R., US Patent 20060289091

Professional Societies:

Materials Research Society

Selected Publications:

Marcus, M. A. (2010) "X-ray photon-in/photon-out methods for chemical imaging" Trends in Analytical Chemistry 29,508-517

Toner, B., Fakra, S. C., Manganini, S. J., Santelli, C. M., Marcus, M. A., Moffett, J. W., Rouxel, O., German, C. R., Edwards, K. J. (2009) "Preservation of iron(II) by carbon-rich matrices in a hydrothermal plume" Nature Geoscience

Bargar, J. R., Fuller, C. R., Marcus, M. A., Brearly, A. J., Perez De le Rosa, Webb, S. M., Caldwell, W. A. (2009) "Structural characterization of terrestrial microbial Mn oxides from Pinal Creek, AZ" Geochimica et Cosmochimica Acta 73,877-1222

Marcus, M. A., Westphal, A. J., Fakra, S. C (2008) "Classification of Fe-bearing species from K -edge XANES data using two-parameter correlation plots" J. Synchrotron Radiat. 15,463-468

Manceau, A., Nagy, K., Marcus, M. A., Lanson, M., Geoffroy, N., Jacquet, T., Kirpichtchikova, T (2008) "Formation of metallic copper nanoparticles at the soil-root interface", Environmental Science&Technology, 42 (5), 1766-1772

Arai, Y., Marcus, M. A., Tamura, N., Davis, J. A., Zachara, J. M. (2007) "Spectroscopic Evidence for Uranium Bearing Precipitates in Vadose Zone Sediments at the Hanford 300-Area Site", Environmental Science&Technology, 41 (13), 4633-4639

Yano, J., Robblee, J. Pushkar, Y., Marcus, M. A., Bendix, J. Workman, J., Collins, T. J., Solomon, E. I., DeBeer George, S., Yachandra, V. K. (2007), "Polarized X-ray absorption spectroscopy of single-crystal Mn(V) complexes relevant to the oxygen-evolving complex of Photosystem II" J. Am. Chem. Soc. 129, 12989-13000

Aruguete, D. M., Marcus, M. A., Li, L.S., Williamson, A., Fakra, S., Gygy, F., Galli, G, A, Alivisatos, A. P. (2007) "Surface structure of CdSe nanorods revealed by combined X-ray absorption fine structure measurements and ab Initio calculations", J. Phys. Chem. C 111(1),75-79

Marcus, M. A., MacDowell, A. A., Celestre, R., Manceau, A., Miller, T., Padmore, H. A., Sublett, R. E (2004): "Beamline 10.3.2 at ALS: a hard X-ray microprobe for environmental and materials sciences", J. Synchrotron Radiation, 11, 239-247

Manceau, A., M.A. Marcus, and N. Tamura (2002), *Quantitative Speciation of Heavy Metals in Soils and Sediments by Synchrotron X-ray Techniques* In: Applications of Synchrotron Radiation in Low-Temperature Geochemistry and Environmental Science, P. Fenter, M. Rivers, N.C. Sturchio, S. Sutton Eds., Mineralogical Society of America, Washington DC, pub., 49, 341-428

Lisa M. Miller

EDUCATION

John Carroll University (Cleveland, OH)	B.S.	1989	1.1	Chemistry
Georgetown University (Washington, DC)	M.S.	1992		Chemistry
Albert Einstein College of Medicine (Bronx, NY)	Ph.D.	1995		Biophysics

POSITIONS AND EMPLOYMENT

2007 - present	Life & Environmental Sciences Division Head, NSLS, Brookhaven National Lab
2007 - present	Adjunct Associate Professor, Dept. of Chemistry, SUNY Stony Brook
2002 - present	Adjunct Associate Professor, Dept. of Biomedical Engineering, SUNY Stony Brook
1999 - present	Staff Biophysicist, National Synchrotron Light Source, Brookhaven Nat'l Lab
1997 - 1999	Instructor, Dept. of Physiology and Biophysics, A. Einstein College of Medicine
1995 - 1997	Postdoctoral Fellow, Advanced Light Source, Lawrence Berkeley National Lab

PROFESSIONAL EXPERIENCE AND PROFESSIONAL MEMBERSHIPS

2010 - present	Science Advisory Committee, Australian Synchrotron
2008 - present	Science Advisory Committee, Stanford Synchrotron Radiation Laboratory
2007 - present	Science Advisory Panel, BioCAT, Advanced Photon Source, Argonne National Lab
2005 - present	Proposal Review Panel, Elettra Synchrotron, Trieste, Italy
2008 - present	Proposal Review Panel, Advanced Photon Source, Argonne National Lab
2004 - 2008	Scientific Advisory Committee, Canadian Light Source
2005 - 2009	Proposal Review Panel, Advanced Light Source, Lawrence Berkeley National Lab
2002 - 2007	Section Head, Scientific Information and Outreach (NSLS-BNL)

PROFESSIONAL MEMBERSHIPS

Member of American Chemical Society (since 1990), Biophysical Society (since 1992), American Society for Bone and Mineral Research (since 1996), Society for Applied Spectroscopy (since 2002)

HONORS AND AWARDS

2005	Brookhaven Town Award for Outstanding Service to the Community in Science
2002	Department of Energy Outstanding Mentor Award

SELECTED PUBLICATIONS (FROM A TOTAL OF 79)

- L.M. Miller, R.J. Smith. Synchrotrons vs. Globars, Point-Detectors vs. Focal Plane Arrays: Selecting the Best Source and Detector for Specific Infrared Microspectroscopy and Imaging Applications. (2005) *Vibrational Spectroscopy*, **38**: 237-240.
- L.M. Miller, Q. Wang, T. Telivala, R. Smith, A. Lanzirrotti, J. Miklossy (2006). Synchrotron-Based Infrared and X-Ray Imaging Shows Focalized Accumulation of Cu and Zn Co-localized with Beta-Amyloid Deposits in Alzheimer's Disease. *J. Struct. Biol.*, **155** (1): 30-7.
- M.E. Ruppel, D.B. Burr, L.M. Miller (2006). Chemical composition of microdamaged bone differs from undamaged bone in control and bisphosphonate-treated dogs. *Bone*, **39** (2): 318-24.
- L.M. Miller, P. Dumas (2006). Chemical imaging of biological tissue with synchrotron infrared light. *Biochim Biophys Acta*. **1758** (7): 846-57.
- L.M. Miller, Q. Wang, R.J. Smith, H. Zhong, D. Elliott, J. Warren (2007). A New Sample Substrate for Imaging and Correlating Organic and Trace-Metal Composition in Biological Cells and Tissues. *Analytical & Bioanalytical Chemistry*, **387**(5):1705-15.
- L.M. Miller, W. Little, A. Schirmer, B. Busa, S. Judex (2007). Accretion of Bone Quantity and Quality in the Developing Mouse Skeleton, *J Bone Miner Res*. **22**(7): 1037-45.
- A.L. Leskovjan, A. Lanzirrotti, L.M. Miller (2009). Amyloid plaques in PSAPP mice accumulate less metal than plaques in human Alzheimer's disease. *NeuroImage* **47**(4): 1215-20.
- A. C. Leskovjan, A. Kretlow, L.M. Miller (2010). Unsaturated Lipid Content is Reduced in the Hippocampus of the PSAPP Mouse Model of Alzheimer's Disease. *Anal. Chem.* **82**: 2711-2716.

Paul Northrup

Department of Geosciences, Stony Brook University

Education:

Dowling College	Biology	B.A., 1989
Stony Brook University	Earth and Space Sciences	M.S., 1992
Stony Brook University	Geology	Ph.D., 1996
Bell Laboratories	Post-Doctoral Associate	1996-1998

Appointments:

2009-present	Lecturer and Research Scientist, Department of Geosciences, Stony Brook University
2004-2009	Assistant, Associate Environmental Scientist, Environmental Sciences Department, BNL
2003-2004	Research Scientist, Department of Geosciences, Stony Brook University
1998-2003	Physicist, Member of Technical Staff, Bell Laboratories, Lucent Technologies

NSLS:

2003-present	Spokesperson and Program Director, Beamline X15B
1996-present	Beamline Scientist, Participating Research Team (PRT), X15B
2004-2009	Contributing User Group Beamline Scientist, X27A Microprobe
2004-2009	PRT member, X11A and X11B EXAFS beamlines
2005-2008	Scientist, Center for Environmental Molecular Science, an NSF/DOE Center at BNL and Stony Brook

NSLS-II Project:

2009-present	Beamline Development Scientist (25%), NSLS-II Submicron Resolution X-ray (SRX) Beamline
2008-2009:	Group Leader (interim), SRX Beamline
2008-present	Beamline Advisory Team member, SRX Beamline
2007-2008	Group Leader, NSLS-II Project Beamline for XAS

Selected Relevant Publications:

- P. Northrup, "X-ray Absorption Spectroscopy Beamline", Part 2, Chapter 5, in *NSLS-II Preliminary Design Report (PDR)*, NSLS-II, 2008.
- P. Northrup and R. Reeder, "Evidence for the importance of growth-surface structure to trace element incorporation in topaz" *Am. Min.*, 79, 1994.
- F. Einsiedl, T. Schäfer, and P. Northrup, "Combined sulfur K-edge XANES spectroscopy and stable isotope analyses of fulvic acids and groundwater sulfate identify sulfur cycling in a karstic catchment area" *Chemical Geology* 238, 268-276, 2007.
- P. Bingham, A. Connelly, R. Hand, N. Hyatt, P. Northrup, "Incorporation and Speciation of Sulphur in Glasses for Waste Immobilization" *Glass Technol.*, 50(3), 135-138, 2009.
- P. Northrup, A. Lanzirrotti, A. Celestian, "Growth of Environmental Science at the NSLS" *Synch. Rad. News*, 20:3, 2007.
- P. Voyles, P. Citrin, D. Chadi, D. Muller, J. Grazul, P. Northrup, H.-J. Gossmann, "Evidence for a New Class of Defects in Highly n-doped Si: Donor-pair-vacancy-interstitials" *Phys. Rev. Lett.*, 91, 125505, 2003.
- P. Citrin, P. Northrup, R. Birkhahn, A. Steckl, "Local Structure and Bonding of Er in GaN: A Contrast with Er in Si" *Appl. Phys. Lett.*, 76: 2865, 1999.

Synergistic activities:

- Beamline design:** a) current X15B Helium-atmosphere endstation, design, construction and commissioning, b) NSLS-II beamline for bulk/microbeam XAS, full preliminary design, c) NSLS-II SRX Beamline, collaborator on initial BAT design, adaptation to NSLS-II Project constraints, ongoing design effort.
- Beamline management and program development:** X15B.
- User community:** NSLS User Executive Committee representative for imaging. Workshops, short courses and seminars.
- Facility strategic planning:** Participation in NSLS/NSLS-II scientific and facility strategic planning workshops, and development of white papers.

Dr. Tracy Punshon, Ph.D.

Education

B.Sc. (hons) Applied Biology (1992) Liverpool John Moore's University, UK.

Ph.D. Biology (1996) Liverpool John Moore's University. Thesis "Heavy metal resistance in *Salix*" Advisor: Nicholas M. Dickinson

Research Experience (abbreviated)

2008-Present Research Assistant Professor Department of Biological Sciences, Dartmouth College, Hanover, NH.

2005-2008 Research Associate B Department of Biological Sciences, Dartmouth College, Hanover, NH.

2004-2005 Program Coordinator University of Georgia, Savannah River Ecology Laboratory, Aiken, SC.

2000-2004 Research Faculty Rutgers University, Piscataway, NJ.

1998-2000 Post-Doctoral Fellow University of Georgia, Savannah River Ecology Laboratory, Aiken, SC.

1996-1998 Experimental Officer Liverpool John Moores University, UK.

Professional Societies

American Society of Plant Biologists

Selected Professional Activities

Editorial Committee Member, International Conference on the Biogeochemistry of Trace Elements

Selected Publications

Punshon T, Guerinot ML, Lanzirotti A. Using synchrotron X-ray fluorescence microprobes in the study of metal homeostasis in plants. *Annals of Botany*. 2009;103:665-72.

Kim SA, Punshon T, Lanzirotti A, Liangtao L, Alonso JM, Ecker JR, et al. Localization of iron in *Arabidopsis* seed requires the vacuolar membrane transporter VIT1. *Science*. 2006;314(5803):1295-8.

Punshon T, Lanzirotti A, Harper S, Bertsch PM, Burger J. Distribution and speciation of metals in annual rings of black willow. *Journal of Environmental Quality*. 2005;34:1165-73.

Punshon T, Jackson BP, Lanzirotti A, Hopkins W, Bertsch P, Burger J. Application of synchrotron X-ray microbeam spectroscopy to the determination of metal distribution and speciation in biological tissues. *Spectroscopy Letters*. 2005;38:343-63.

Punshon T, Jackson BP, Bertsch PM, Burger J. Mass loading of nickel and uranium on plant surfaces: Application of LA-ICP-MS. *Journal of Environmental Monitoring*. 2004;6(2):153-9.

Dr. Mark L. Rivers, Ph.D.

Education:

University of California Berkeley PhD, Geology and Geophysics, 1985

Harvard College A.B summa cum laude, Geological Sciences, 1976

Research Experience:

1993-present Co-direct the design and construction of the GeoSoilEnviroCARS sector at the Advanced Photon Source. Experimental capabilities include high-pressure diffraction, X-ray microprobe and X-ray absorption spectroscopy.

2001-present Senior Scientist, Department of the Geophysical Sciences and Center for Advanced Radiation Sources, The University of Chicago.

1989-present Associate Director, Center for Advanced Radiation Sources, The University of Chicago

1988-2001 Senior Research Associate, Department of the Geophysical Sciences, The University of Chicago.

1984-1988 Research Associate, Department of the Geophysical Sciences, The University of Chicago.

1984-1993 Designed, constructed, and operated a synchrotron X-ray fluorescence microprobe at the National Synchrotron Light Source. Conducted research on trace element geochemistry of minerals, melt and fluid inclusions.

Professional Societies:

American Geophysical Union

Professional Activities:

Member of COMPRES Facilities Committee. 2002-present, Chair 2003-present.

Member of United States National Committee for Crystallography. 1997-1999

Member, NSF Proposal Review Panel, Earth Sciences Instrumentation and Facilities Program, 1994-1997

Member of APS User's Organization Steering Committee. 1992-1995, 2003-present. Chair 2003-2004.

Develop national synchrotron user facilities for earth science research.

Develop beamline controls and data analysis software that are widely used at X-ray synchrotrons around the world (see <http://cars.uchicago.edu/software>).

Awards:

R&D 100 Award for X-ray Microprobe/Microscope, Co-winner (1989)

Selected Publications:

J.R. Royer, E.I. Corwin, A. Flior, M.L. Cordero, M. Rivers, P. Eng, H.M. Jaeger, "Formation of granular jets observed by high-speed X-ray radiography," *Nature Phys.* 1 (2), November, 164-167 (2005).

D. Wildenschild, J.W. Hopmans, M.L. Rivers, A.J.R. Kent, "Quantitative Analysis of Flow Processes in a Sand Using Synchrotron-Based X-ray Microtomography," *Vadose Zone J.* 4, 112-126 (2005).

M.L. Rivers, Y. Wang, T. Uchida, "Microtomography at GeoSoilEnviroCARS," *Proceedings of SPIE : Developments in X-Ray Tomography IV*, Ulrich Bonse, eds., 5535, SPIE (2004), 783 - 791.

Y. Wang, Y., G. Shen and M. L. Rivers (2002), High Pressure Research at Third Generation Synchrotron Sources, in *Third Generation Hard X-ray Synchrotron Radiation Sources*, D. M. Mills ed, Wiley, 203-236.

Sham, T. K. and M. L. Rivers (2002). A brief overview of synchrotron radiation. In *Reviews in Mineralogy & Geochemistry: Applications of Synchrotron Radiation in Low-Temperature & Environmental Science*, Mineralogical Society of America, Vol 49, 117-147.

L. Bai, D.R. Baker, M.L. Rivers, "Experimental study of bubble growth in Stromboli basalt melts at 1 atm," *Earth Planet Sci. Lett.* 267 (3-4), 533-547 (2008). DOI: 10.1016/j.epsl.2007.11.063

P. Eng, M. Newville, M. Rivers, S.R. Sutton, "Dynamically figured Kirkpatrick Baez X-ray micro-focusing optics," *X-ray Microfocussing: Applications and Technique*, I. McNulty, eds., SPIE, (1998), 145 - 155.

Kirk G. Scheckel, Rebecca Hamon, Laurence Jassogne, Mark Rivers, Enzo Lombi, "Synchrotron X-ray absorption-edge computed microtomography imaging of thallium compartmentalization in Iberis intermedia," *Plant Soil* 290 (1-2), 51-60 (2007). DOI: 10.1007/s11104-006-9102-7

D. Peter Siddons

Biographical Information:

Born 17th May, 1947 in England. Married with three children.

Education:

M.Sc. in Physics from University of Bristol, England in 1976

Ph.D in Physics from University of London, Kings College, England in 1979.

Experience:

2000–present.

Group Leader, Detector Development . A new group formed to improve the capabilities of NSLS beamlines through the development of advanced detectors.

1998–1999.

Sabbatical leave, ESRF Grenoble, France.

1994 – 1998.

Group Leader of NSLS Beamline R&D and User Support group. The group consisted of ten scientists and ten support staff, and was responsible for the development of new facilities and capabilities at NSLS, in addition to providing support for users of over 15 beamlines, including spectroscopy, scattering and imaging instruments across the spectrum.

Professional Activities

Chair, European XFEL Detector Advisory Committee, Hamburg, Germany.

Science Advisory committee for the Diamond Light Source, UK.

Facilities Advisory Committee for LCLS, Stanford CA.

Photon Sciences Advisory Committee for DESY, Hamburg, Germany.

Founder member of DetectorSync organization to promote detector development for synchrotron radiation applications.

Awards

R&D100 awards:

Wavefront-dividing IR interferometer, 1990

Sagittal focusing Laue monochromator for high-energy x-rays, 2006.

BNL Science & Technology Prize, 2006.

Elected Fellow of the American Physical Society, 2009.

Patents

Method and apparatus for micromachining using hard X-rays. United States Patent 5679502

Recent Publications.

High-throughput X-ray fluorescence imaging using a massively parallel detector array, integrated scanning and real-time spectral deconvolution. C.G. Ryan^{1,6,7}, D.P. Siddons², G. Moorhead^{3,6}, R. Kirkham³, G. De Geronimo⁴, B.E. Etschmann^{1,7}, A. Dragone², P.A. Dunn³, A. Kuczewski², P. Davey³, M. Jensen³, J.M. Ablett^{2,8}, J. Kuczewski², R. Hough¹ and D. Paterson⁵. 9th International Conference on X-Ray Microscopy. IOP Publishing, Journal of Physics: Conference Series 186 (2009) 012013

Development of a silicon drift detector array: an x-ray fluorescence spectrometer for remote surface mapping. Jessica A. Gaskin, Gabriella A. Carini, Wei Chen, Gianluigi De Geronimo, Ronald F. Elsner, Jeffrey W. Keister, Georgiana Kramer, Zheng Li, Brian D. Ramsey, Pavel Rehak and D. Peter Siddons. Proc. SPIE, Vol. **7441**, 744118 (2009); doi:10.1117/12.826389

X-Ray Diffuse Scattering Measurements of Nucleation Dynamics at Femtosecond Resolution. A. M. Lindenberg et al., Phys. Rev. Lett. 100, 135502 (2008)

Formation of secondary electron cascades in single-crystalline plasma-deposited diamond upon exposure to femtosecond x-ray pulses JM. Gabrysch et al. Appl. Phys. 103, 064909 (2008); doi:10.1063/1.2890158

Dr. Gregory Dale Smith, Ph.D.

Education:

B.Sc. Chemistry/Anthropology/Sociology (1995) Centre College of Kentucky

Ph.D. Analytical/Physical Chemistry (2000) Duke University: "Step-Scan Fourier Transform Infrared Time-Resolved Spectroscopy of Polypyridine Transition Metal Complexes" (Thesis advisor: Prof. Richard A. Palmer)

Research Experience (abbreviated):

2010-present Senior Conservation Scientist

Indianapolis Museum of Art, Indianapolis, IN

2005-2010 Andrew W. Mellon Professor of Conservation Science

Art Conservation Dept., Buffalo State College, Buffalo, NY

2003-2004 Samuel Golden Postdoctoral Research Fellow

National Gallery of Art, Washington, DC

2002-2003 Postdoctoral Fellow

National Synchrotron Light Source, Brookhaven National Lab, Upton, NY

2000-2001 Marshall Sherfield Postdoctoral Fellow

University College London, London, England

Professional Societies:

American Institute for Conservation (AIC)

Professional Activities (since 2002):

Chairman, Research and Technical Studies Specialty Group, American Institute for Conservation, 2009-2010

Member, Education and Training Committee, American Institute for Conservation, 2008-2010

Associate Editor, *Journal of the American Institute for Conservation*, 2008-2010

Associate Editor, *Annali di Chimica*, 2005-2008

Awards:

Distinguished Young Alumnus Award (Centre College), 2009

SUNY Research Foundation Incentive Grant, 2006-2008

Buffalo State College Provost's Incentive Grant, 2006

United University Professionals Individual Development Award, 2006

National Science Foundation International Postdoctoral Research Fellow, Israel, 2001 (declined)

British Marshall Sherfield Postdoctoral Fellow, 2000-2001

National Science Foundation Graduate Fellow in Archaeological Science, 1996-1999

Selected Publications:

Palmer, R. A.; Smith, G. D.; Chen, P. "Breaking the Nanosecond Barrier in FTIR Time-Resolved Spectroscopy." *Vibrational Spectroscopy*, **1999**, *19*, 131-141.

Palmer, R. A.; Smith, G. D.; Litvinenko, V. N.; Edwards, G. "Fourier Transform Infrared Picosecond Time-Resolved Spectroscopy with a UV Free Electron Laser Pump and Synchrotron IR Probe." *Proceedings of SPIE*, **1999**, *3775*, 137-144.

Smith, G. D.; Palmer, R. A. "Fast Time-resolved Mid-Infrared Spectroscopy Using an Interferometer," in *Handbook of Vibrational Spectroscopy*, Vol. 1, J. M. Chalmers and P. R. Griffiths (Eds.), John Wiley & Sons: Chichester, **2002**, 625-640.

Smith, G. D.; Clark, R. J. H. "Raman Microscopy in Art History and Conservation Science." *Reviews in Conservation*, **2001**, *2*, 92-106.

Smith, G. D.; Clark, R. J. H. "A Note on Lead(II) Oxide in Mediaeval Frescoes from the Monastery of San Baudelio, Spain." *Applied Spectroscopy*, **2002**, *56*, 804-806.

Smith, G. D.; Firth, S.; Cardona, M.; Clark, R. J. H. "First- and Second-Order Raman Spectra of Galena (PbS)." *Journal of Applied Physics*, **2002**, *92*, 4375-4380.

Miller, L. M.; Smith, G. D.; Carr, G. L. "Synchrotron-based Biological Microspectroscopy: From the Mid-Infrared through the Far-Infrared Regimes." *Journal of Biological Physics*, **2003**, *29*, 219-230.

Smith, G. D. "Infrared Microscopy Using a Synchrotron Source for Arts-Science Research." *Journal of the American Institute of Conservation*, **2003**, *42*, 399-406.

Chaplin, T. D.; Clark, R. J. H.; Jacobs, D.; Jensen, K.; Smith, G. D. "The Gutenberg Bibles: Analysis of the Illuminations and Inks Using Raman Spectroscopy" *Analytical Chemistry*, **2005**, *77*, 3611-3622.

Smith, G. D.; Klinshaw, R. J. "The Presence of Trapped Carbon Dioxide in Lapis Lazuli and Its Potential Use in Geo-sourcing Natural Ultramarine Pigment" *Journal of Cultural Heritage*, **2009**, *10(3)*, 415-421.

Stephen R. Sutton

Education

B.S. Physics (1971) Washington University, St. Louis, MO

Ph. D. Earth and Planetary Sciences (1984) Washington University, St. Louis, Mo.

Research Experience (abbreviated)

2001-present: Senior Scientist, Dept. Geophys. Sci. and Center for Adv. Rad. Sources, Univ. of Chicago

2009-present: Research Associate, Department of Geology, The Field Museum, Chicago, IL

1990-present: Associate Director-CARS/Co-Project Leader for GeoSoilEnviroCARS at the APS, Center for Advanced Radiation Sources (CARS), University of Chicago, Chicago, IL

1996-present: Beamline Spokesperson, X26A Microprobe Beamline Participating Research Team, NSLS, NY

1988-2001: Senior Research Associate, Dept. of the Geophysical Sciences, University of Chicago, Chicago, IL

Professional Societies

American Geophysical Union; American Chemical Society, Geochemical Society, EnviroSync

Service (since 2002)

DOE-BER Environmental Remediation Science Division Strategic Planning Workshop Member (2002); NASA-Cosmochemistry Proposal Review Panel Member (2002); MSA/GS Short Course, Reviews in Mineralogy & Geochemistry: Applications of Synchrotron Radiation in Low-Temperature & Environmental Science, Mineralogical Society of America, Vol 49, organizing committee and co-editor (2002); DOE Workshop on Geosciences User Facilities, organizer (2004); APS Workshop on Future Directions in Synchrotron Environmental Science, co-organizer (2004); NASA-Stardust Participating Scientist Review Panel Member (2005); APS General User Proposal Review Panel, Imaging Panel Chair (2005); Elements magazine, guest editor (2006); NASA Stardust Oversight Committee, member (2006-present); Advanced Photon Source Proposal Review Panel, member (2005-2007); Ninninger Meteorite Award (judge; 2007-present); University of Delaware DENIN External Advisory Board (2007-present); APS Renewal Geology, Environmental and Planetary Science Team (2008); NSLS-II SRX Beamline Advisory Team (2008-); NASA New Frontiers Review Panel (2009); Delaware Environmental Institute External Advisory Board (2009-); NASA-CAPTEM Stardust Curation Review Committee (2009-2010); X-ray Microscopy 2010, Local Organizing Committee (2009-2010).

Awards

Undergraduate Scholarships (1967-1971); McDonnell Graduate Fellowships (1980-1984); Ninninger Meteorite Award (1982-1983); R&D 100 Award for X-ray Microprobe/Microscope, Co-winner (1989)

Selected Publications

Karner, J. M., J. J. Papike, S. R. Sutton, P. V. Burger, C. K. Shearer, L. Le, M. Newville, and Y. Choi (2010) Partitioning of Eu between augite and a highly spiked martian basalt composition as a function of oxygen fugacity (IW-1 to QFM): Determination of $\text{Eu}^{2+}/\text{Eu}^{3+}$ ratios by XANES. *American Mineralogist* 95, 410-413.

Kashiv, A. M. Davis, R. Gallino, Z. Cai, B. Lai, S. R. Sutton and R. N. Clayton (2010) Extinct ^{93}Zr in Single Presolar SiC Grains from Low Mass Asymptotic Giant Branch Stars and Condensation from Zr-Depleted Gas. *Astrophysical Journ.* 713, 212-219.

Pearce, D. C., K. Dowling, A. R. Gerson, M. R. Sim, S. R. Sutton, M. Newville, R. Russell, and G. McOrist (2010) Arsenic microdistribution and speciation in toenail clippings of children living in an historic gold mining area. *Science of the Total Environment* 408, 2590-2599.

Rao, M.N., L.E. Nyquist, S.R. Sutton, G. Dreibus, D.H. Garrison, and J. Herrin (2009) Fluid-evaporation records preserved in salt assemblages in Meridiani rocks. *Earth and Planetary Science Letters* 286 (3-4), 396-403.

Lanzirotti, A., S. Sutton, G. Flynn, M. Newville, W. Rao (2008) Chemical composition and heterogeneity of Wild 2 cometary particles determined by synchrotron X-ray fluorescence. *Meteoritics & Planet. Sci.* 43, 187-214.

Berry, A. J., L. V. Danyushevsky, H. St. C. O'Neill, M. Newville and S. R. Sutton (2008) Oxidation state of iron in komatiitic melt inclusions indicates hot Archaean mantle. *Nature* 455, 960-964.

Tokunaga, T., J. Wan, Y. Kim, S. Sutton, M. Newville, A. Lanzirrotti, W. Rao (2008) Real-Time X-ray Absorption Spectroscopy of Uranium, Iron, and Manganese in Contaminated Sediments During Bioreduction. *Environ. Sci. & Technol.*, 42: 2839-2844.

Alderden, R. A., H. R. Mellor, S. Modok, M. D. Hall, S. R. Sutton, M. G. Newville, R. Callaghan, and T. W. Hambley (2007) Elemental tomography of cancer-cell spheroids reveals incomplete uptake of both platinum(II) and platinum(IV) complexes. *Jour. Am. Chem. Soc.* 129 (44), 13400-13401.

Simon, S., S. R. Sutton and L. Grossman (2007) Valence of Titanium and Vanadium in Pyroxene in Refractory Inclusion Interiors and Rims. *Geochim. Cosmochim. Acta* 71, 3098-3118.

Flynn, G. J., et al. (2006) Elemental Compositions of Comet 81P/Wild 2 Samples Collected by Stardust. *Science* 314: 1731-1735.

Sutton, S. R., Karner, J. M., J. S. Delaney, J. J. Papike, C. K. Shearer, M. Newville, M. Rivers, P. Eng, M. D. Dyar (2005) Vanadium K Edge XANES of Synthetic and Natural Basaltic Glasses and Application to Microscale Oxygen Barometry. *Geochim. Cosmochim. Acta*, Vol 69/9 pp 2333-2348.

Sutton, S.R., P. M. Bertsch, M. Newville, M. Rivers, A. Lanzirrotti, P. Eng (2002) Microfluorescence and Microtomography Analyses of Heterogeneous Earth and Environmental Materials, Reviews in Mineralogy & Geochemistry: Applications of Synchrotron Radiation in Low-Temperature & Environmental Science, Mineralogical Society of America, Vol 49, 429-483.

Dr. Ryan Tappero, Ph.D.

Education:

A.Sc. Geology (1998) Sierra College, Rocklin, CA.

B.Sc. Soil Science (2001) California Polytechnic, San Luis Obispo, CA. Senior thesis: "Assessment of nitrate loading into a creek adjacent to a Lake Tahoe golf course" (Thesis advisor: Thomas Ruehr)

M.Sc. Soil Chemistry (2003) California Polytechnic, San Luis Obispo, CA. Thesis: "Phytoextraction of chromated copper arsenate (CCA) contaminated soil using Sunflower, Hemp, and Brake Fern" (Thesis advisor: Thomas Ruehr)

Ph.D. Environmental Soil Chemistry (2008) University of Delaware, Newark, DE. Dissertation: "Microspectroscopic study of cobalt speciation and localization in hyperaccumulator *Alyssum murale*" (Thesis advisor: Donald Sparks)

Research Experience (abbreviated):

2008-present Microprobe Scientist

National Synchrotron Light Source, Brookhaven National Laboratory, Upton, NY

2004-2007 United States Department of Agriculture (USDA) Fellow

USDA-ARS, Beltsville, MD and University of Delaware, Newark, DE

2001-2003 Intern Geochemist

CA Regional Water Quality Control Board, Land Disposal Unit, San Luis Obispo, CA

1999-2001 Earth and Soil Science (ESS) Laboratory Manager

California Polytechnic, San Luis Obispo, CA

Professional Societies:

Geochemical Society of America (GSA), American Chemical Society (ACS), Soil Science Society of America (SSSA), Soil and Water Conservation Society (SWCS), Golden Key National Honor Society

Selected Publications:

Lanzirotti, A., R. Tappero, and D.G. Schulze. 2010. Practical application of synchrotron-based hard X-ray microprobes in Soil Sciences. In: Singh, B and M. Gräfe (Eds.) *Developments in Soil Science* 34: 27-72. Elsevier ISBN 9780444532619.

Gräfe, M., R. Tappero, M.A. Marcus, and D.L. Sparks. 2008. Arsenic speciation in multiple-metal environments: I. Bulk-XAFS spectroscopy of model and mixed compounds. *J. Colloid Interface Sci.* 320:383-399.

Gräfe, M., R. Tappero, M.A. Marcus, and D.L. Sparks. 2008. Arsenic speciation in multiple-metal environments: II. Microspectroscopic investigations of CCA-contaminated soil. *J. Colloid Interface Sci.* 321:1-20.

Tappero, R., E. Peltier, M. Gräfe, K. Heidel, M. Ginder-Vogel, K.J.T. Livi, M.L. Rivers, M.A. Marcus, R.L. Chaney, and D.L. Sparks. 2007. Hyperaccumulator *Alyssum murale* relies on a different metal storage mechanism for cobalt than for nickel. *New Phytologist* 175:641-654.

Tappero, R., D.H. McNear, M. Gräfe, M.A. Marcus, and D.L. Sparks. 2006. (In situ) Elemental distributions, associations, and molecular speciation in plant material using synchrotron X-ray fluorescence (μ -SXRF) imaging and X-ray absorption fine-structure (XAFS) spectroscopy. In: Luster, J. and R. Finlay (Eds.) *Handbook of Methods Used in Rhizosphere Research*. Birmensdorf, Swiss Federal Research Institute WSL. pp. 209-210

McNear, D.H., R. Tappero, and D.L. Sparks. 2006. Quantitative elemental compartmentalization in plant tissues using synchrotron-based X-ray fluorescence and absorption-edge computed microtomography (F-CMT and AE-CMT). In: Luster, J. and R. Finlay (Eds.) *Handbook of Methods Used in Rhizosphere Research*. Birmensdorf, Swiss Federal Research Institute WSL. pp. 204-205

Dr. Tetsu K. Tokunaga, Ph. D.

Earth Sciences Division (MS 70-108B) Lawrence Berkeley National Laboratory, 1 Cyclotron Road, Berkeley, CA 94720.
510-486-7176, tktokunaga@lbl.gov

Education:

Ph.D., 1986, Soil Science, University of California, Berkeley
B.A., 1979, Soil Resource Management, University of California, Berkeley

Research Interests:

Tetsu Tokunaga's research combines soil physics with related disciplines of environmental biogeochemistry and multiphase flow. His research includes studies on reactive transport of metals and radionuclides (chromium, selenium, vanadium, and uranium) in sediments, and studies of multiphase fluid flow in geologic media (film flow in fractures, unsaturated hydraulic scaling).

Professional Experience:

1990, 1992: Lecturer, Department of Soil Science, University of California, Berkeley
1988 -1993: Scientist, Earth Sciences Division, Lawrence Berkeley National Laboratory
1993 -2001: Staff scientist, Earth Sciences Division, LBNL
2001 -present: Senior staff scientist, Earth Sciences Division, LBNL

Service:

Associate editor, Vadose Zone Journal (2008- current)
Associate Editor, Water Resources Research (2009- current)

Selected Publications (from over 60):

- Tokunaga, T.K., G.E. Brown, Jr., I.J. Pickering, S.R. Sutton, and S. Bajt. 1997. Selenium redox reactions and transport between ponded waters and sediments, *Environ. Sci. Technol.* 31, 1419-1425.
- Tokunaga, T.K., and J. Wan. 1997. Water film flow along fracture surfaces of porous rock. *Water Resour. Res.*, 33, 1287-1295.
- Tokunaga, T.K., S.R. Sutton, S. Bajt, P. Nuessle, and G. Shea-McCarthy. 1998. Selenium diffusion and reduction at the water-sediment boundary: Micro-XANES spectroscopy of reactive transport. *Environ. Sci. Technol.*, 32, 1092-1098.
- Tokunaga, T. K., J. Wan, and S. R. Sutton. 2000. Transient film flow on rough fracture surfaces. *Water Resour. Res.*, 36, 1737-1746.
- Tokunaga, T. K., J. Wan, M. K. Firestone, T. C. Hazen, E. Schwartz, S. R. Sutton, M. Newville. 2001. Chromium diffusion and reduction in soil aggregates, *Environ. Sci. Technol.*, 35, 3169-3174.
- Tokunaga, T.K., K.R. Olson, and J. Wan. 2004. Conditions necessary for capillary hysteresis in porous media: Tests of grain-size and surface tension influences. *Water Resour. Res.* 40, w05111.
- Tokunaga, T. K., J. Wan, J. Pena, S.R. Sutton, and M. Newville, 2004. Hexavalent uranium diffusion into soils from concentrated acidic and alkaline solutions. *Environ. Sci. Technol.* 38, 3056-3062.
- Tokunaga, T.K., J. Wan, A. Lanzirotti, S.R. Sutton, M. Newville, and W. Rao. 2007. Long-term stability of organic carbon-stimulated chromate reduction in contaminated soils, and its relation to manganese redox status. *Environ. Sci. Technol.* 41, 4326-4331.
- Tokunaga, T.K., J. Wan, Y. Kim, S.R. Sutton, M. Newville, A. Lanzirotti, W. Rao. 2008. Real-time X-ray absorption spectroscopy of uranium, iron, and manganese in contaminated sediments during bioreduction. *Environ. Sci. Technol.* 42, 2839-2844.
- Tokunaga, T.K., Y. Kim, and J. Wan. 2009. Potential remediation approach for uranium-contaminated groundwaters through potassium uranyl vanadate precipitation. *Environ. Sci. Technol.* 43, 5467-5471.
- Tokunaga, T.K. 2009. Hydraulic properties of adsorbed water films in unsaturated porous media. *Water Resour. Res.* 45, W06415, doi:10.1029/2009WR007734.

Appendix A.3. JPSI Letter of Support of XFM BDP



STONY BROOK UNIVERSITY
CHEMISTRY BLDG, ROOM 405
STONY BROOK, NY 11794-3400
631-632-8196
JPSI@SUNYSB.EDU

June 21, 2010

Ladies and Gentlemen:

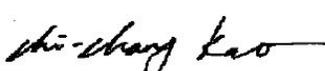
The Joint Photon Sciences Institute (JPSI) was established at Brookhaven National Laboratory (BNL) and Stony Brook University (SBU) in the fall of 2008. The mission of JPSI is to exploit the properties of advanced photon sources to address the nation's most critical scientific and technical problems. In particular, JPSI will explore the opportunities offered by the unprecedented brightness of the National Synchrotron Light Source II (NSLS-II).

Specifically, JPSI will create an innovative environment where researchers from universities, industries, and government laboratories can work together to identify major scientific and technological opportunities, create device solutions using the most advanced research tools, and catalyze discovery to deployment. The key element of JPSI's strategy is to leverage the presence of thousands of researchers from the more than 400 companies, universities, and government laboratories that carry out research at the NSLS today and will continue to do so at NSLS-II. In addition, JPSI has formed a strategic alliance with the National Institute of Standards and Technology to promote the usage of synchrotrons by industry.

So far, JPSI has focused its program on four themes: microelectronics, energy storage, extreme environments, and solar energy. In each area, leaders from universities, government laboratories and industries were invited to a focused workshop where major technology challenges and capabilities of advanced research tools were presented, new scientific opportunities identified, and collaborative teams formed. These activities have led to major funding from New York State in energy storage, beamline upgrades at the NSLS for microelectronics research, and a new beamline proposal at the NSLS and NSLS-II for advanced lithography. In parallel, JPSI has launched basic research programs in coherent diffraction imaging and nano-diffraction.

As the Directors of JPSI, we are writing in support of the X-ray Fluorescence Microprobe: A three-pole wiggler based x-ray fluorescence microprobe beamline for characterization of materials in an "as-is" state (XFM) beamline proposal. The proposed beamline is part of the suite of scientific capabilities identified in the four major workshops. It is the intention of JPSI to engage NSLS-II in a partnership agreement to develop these capabilities and to share the stewardship of these beamlines. The aim is to maximize their impact by engaging the intellectual expertise within JPSI and its research partners in these techniques, and to continue to expand these successful research programs at the NSLS today and NSLS-II tomorrow.

Sincerely yours,


Chi-Chang Kao, Director


John B. Parise, Co-Director



Appendix A.4. Details of Pre-Conceptual Optical Plan for XFM

A schematic showing a proposed layout for optical components along the XFM beamline is shown in Figure 1 with upstream components on the right and downstream components progressively further left. The proposed design is based on the design of beamline 10.3.2 at the Advanced Light Source⁵⁰, a design which has repeatedly demonstrated exceptional microfocused beam stability suitable for μ EXAFS studies. The NSLS-II 3PW source should provide a broadband source of radiation suitable for fluorescence-mode absorption spectroscopy. X-ray energies and photon flux provided by this source will accommodate the scientific requirements for investigators interested in utilizing X-ray microprobes for earth, environmental, life, and materials science research. The challenge for an X-ray microprobe using this source is to deliver a relatively high flux-density to the sample. White beam slits located in the front-end will be set to accept the central 0.112 mrad of the horizontal on-axis 3PW radiation while accepting the full 0.250 mrad of vertical radiation. This aperture size is the maximum that can likely be collected horizontally by placing the first optical element downstream of the shield wall at a reasonable pitch but also should eliminate much of the structure that is observed in the side lobes of the 3PW fan.

The first optical element of XFM will be a horizontally-deflecting toroid sitting at roughly 24.5 m from the source. This mirror will focus at unit magnification and, since the focusing mirrors in the hutch can only accept a limited amount of solid angle, will only need to be 1 m long and will only require indirect water cooling. As a rhodium-coated optic, this mirror set at a 2.75 mrad fixed pitch will accept and focus the full 0.112 x 0.250 mrad (H x V) fan of radiation supplied by the white beam slits. A reasonable inherent slope error of 0.5 μ rad *rms* (assuming a bent cylinder) for this type of mirror affects mainly the already-wider horizontal source size while preserving the excellent vertical source size of the 3PW. The figure error of this mirror is most easily visible at the SSA, which is apparent in preliminary ray-tracings we have conducted for this proposal (Fig. 2).

The figure error on the toroid can be low enough to not make a significant blurring in the horizontal plane at the SSA. Since the sagittal slope error can be scaled by the incident angle for this type of optic, it is not a limiting factor in focusing. Rather it will be the aberrations from the toroid that limits performance. We recognize this and encourage a thorough evaluation of other pre-focusing optic types. However, we foresee that the increased flux provided by the toroid will likely provide the best balance between excellent flux density for micro-spectroscopy with manageable aberration.

This toroidal mirror will focus to a Secondary Source Aperture (SSA) located 49.0 m from the source with a spot size of 380 μ m (H) x 70 μ m (V) FWHM. This source aperture will require water-cooling since it will see pink beam and we envision these could be a set of polished tungsten roll slits that will allow the user to reduce the effective diameter of the source, thereby reducing the spot size on the sample at the cost of flux. This design decouples the final focused beam from the actual source and any motion that it may experience, significantly enhancing stability for spectroscopy.

The next optical element will be 200 mm long collimating mirror sitting at 51.5 m from the source. This will be a flat silicon mirror utilizing a bender to provide vertical collimation and with both bare silicon and rhodium stripes for harmonic rejection. It is reasonable to assume that mirrors of this length with an *rms* slope error of 0.2 μ rad should be available. This collimating mirror can be optimized to balance vertical acceptance of the mirror with respect to the demagnification of the final Kirkpatrick-Baez (KB) focusing optics in the experimental hutch, independent of the horizontal SSA-to-KB optimization.

A fixed-exit, double-crystal monochromator (DCM) will sit downstream of the collimating mirror at 51.9 m from the source. Incorporating both Si(111) and Si(311) crystals, the monochromator will provide near ideal energy resolution due to vertical collimation provided by the collimating mirror. This will provide excellent performance for spectroscopy by minimizing angular divergence on the DCM. The beam footprint on the mono will also be very small, less than 1 mm in both dimensions. Although the power density on the first crystal of the DCM will be high, only indirect water-cooling should be required. It should also be noted that in utilizing such an optical design the thermal distortion of the DCM will have less impact due to short SSA-to-sample distance, although standard considerations for thermally-induced mismatches in d-spacing between 1st and 2nd DCM crystals need to be considered and evaluated. Another

significant advantage of this design is that this provides either a highly collimated monochromatic beam or pink beam to the hutch (assuming suitable accommodations for moving the DCM and/or KB optics out of the beam path are made). The diameter of this beam is readily varied by changing the width of the SSA and can supply an unfocused beam up to 1 mm in diameter for fluorescence analysis of physically large samples not requiring spatially resolved beams or for “bulk” spectroscopic analysis.

The DCM then will illuminate a set of bender-type, Rh-coated silicon KB mirrors to provide optimal harmonic rejection with variable mirror pitch. The mirrors will both be 200 mm in length with the vertically focusing mirror sitting at 53.8 m from the source and the horizontally focusing mirror at 54.0 m. This will provide a horizontal demagnification of 25.0 and a vertical demagnification of 6.25. These optics should deliver an ideal spot size to the sample sitting at 54.2 m from the source of $10 \times 5 \mu\text{m}$ with the SSA fully open (preliminary ray tracing shown in Figure 2). This is assuming, again, slope errors of $0.2 \mu\text{rad rms}$ for these 200 mm long optics. An ultimate focus of ~ 1 micron will be achievable with a flux of 1×10^9 by closing the SSA to $36 \times 14 \mu\text{m}$.

Bear in mind that a typical EXAFS spectrum scans an energy range of about 1000 eV, a requirement that for a μEXAFS beamline means that the energy dependence of the vertical beam position be reduced⁵¹. It is expected that the proposed design for XFM will eliminate or at least strongly reduce vertical beam offsets while scanning without having to mechanically follow the X-ray beam.

Table 1 shows a preliminary set of calculations of the likely delivered flux to the sample at various energies with the SSA fully open (in a $10 \times 5 \mu\text{m}$ spot) and at smaller spots achieved by closing the SSA. This also accounts for the likely absorption by beryllium windows and air paths in this design. Table 2 shows a listing of comparable microprobes worldwide utilizing both dipole sources (in gray) and undulator sources (in blue) in comparison to the proposed XFM beamline on an NSLS-II 3PW source (in yellow).

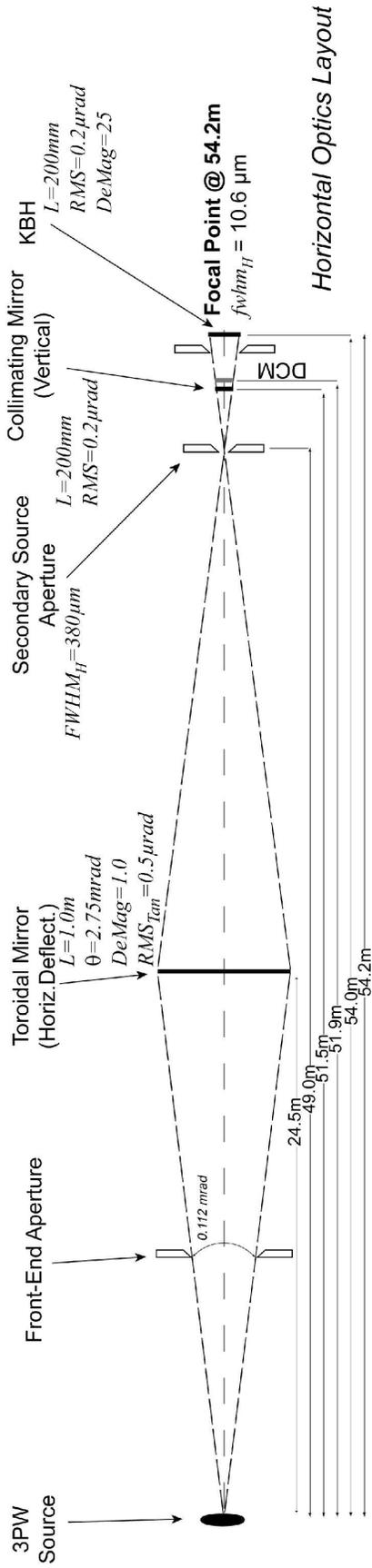
What is apparent from this comparison is that for a dipole-based microprobe XFM has the potential of delivering the highest flux density in a sub- $10 \mu\text{m}$ spot than any comparable beamline in the world, in fact two orders of magnitude more flux to the sample than the current NSLS microprobes at a comparable spatial resolution. While the XFM 3PW source doesn't have a brightness comparable to that available to microprobe beamlines at 3rd generation sources that utilize undulator sources, it is interesting to note that the compound focusing design proposed for XFM here in fact yields a total delivered flux in less than $10 \mu\text{m}$ that is in many cases comparable. With an emphasis on exceptional beam stability and smooth energy scanning over extended energy ranges, XFM promises to be one of the world's best beamlines for microspectroscopy.

Table 1. Predicted XFM flux at sample position as a function of energy

Energy	Source flux	Flux at sample position*		
	(0.33HxfullV)	10 x 5	5 x 5	1 x 1
keV	Ph/s/0.1%bw	μm	μm	μm
4	1.1E+13	2.E+11	8.E+10	3.E+09
5	9.5E+12	2.E+11	1.E+11	4.E+09
6	8.8E+12	2.E+11	1.E+11	4.E+09
7	8.0E+12	2.E+11	9.E+10	4.E+09
8	7.2E+12	2.E+11	9.E+10	4.E+09
9	6.5E+12	2.E+11	8.E+10	3.E+09
10	5.8E+12	1.E+11	7.E+10	3.E+09
11	5.1E+12	1.E+11	6.E+10	3.E+09
12	4.6E+12	1.E+11	6.E+10	2.E+09
13	4.1E+12	1.E+11	5.E+10	2.E+09
14	3.6E+12	9.E+10	5.E+10	2.E+09
15	3.3E+12	8.E+10	4.E+10	2.E+09
16	3.0E+12	8.E+10	4.E+10	2.E+09
17	2.6E+12	7.E+10	3.E+10	1.E+09
18	2.4E+12	6.E+10	3.E+10	1.E+09
19	2.2E+12	6.E+10	3.E+10	1.E+09
20	2.0E+12	5.E+10	3.E+10	1.E+09

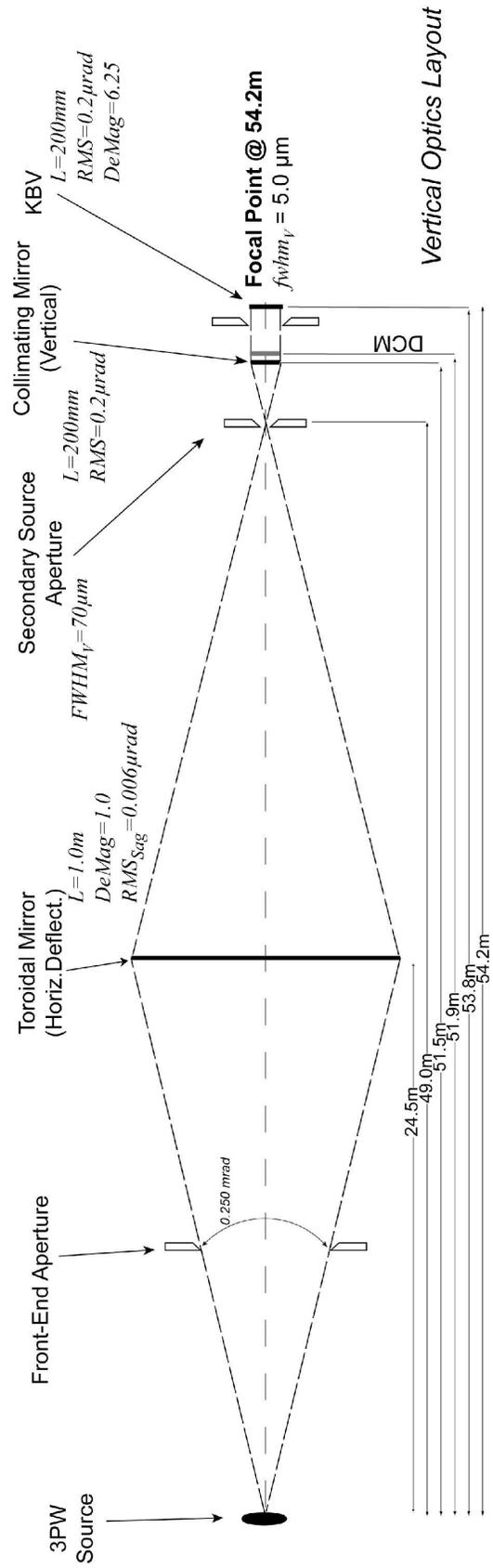
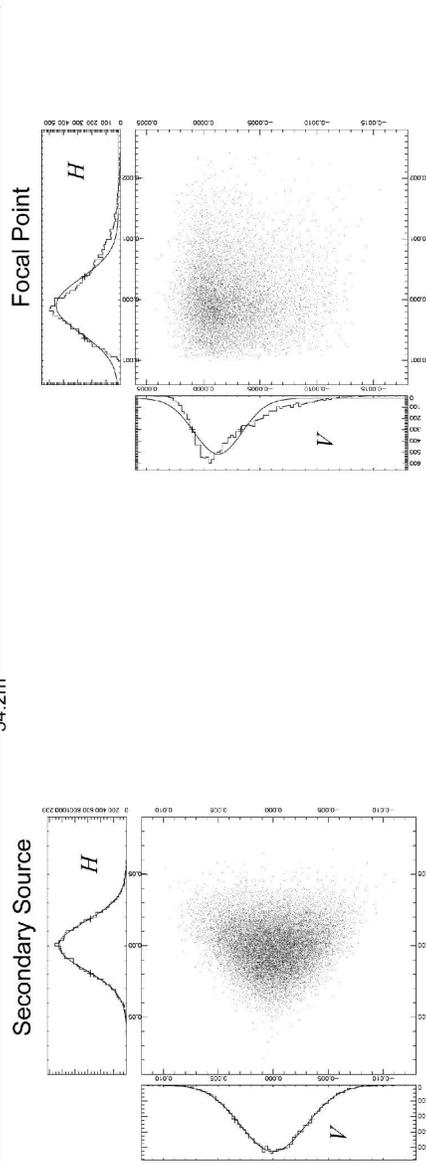
*Fixed aperture (0.112 x 0.25 mrad acceptance); Si(111) bandpass; 12.5 μm Be window; 5 cm air absorption

Table 2: XFM comparison to other microprobes			
Beamline	Energy range (keV)	Spot size (μm^2)	Max Photon flux in spot
XFM @ NSLS-II	4 - 20	1 x 1 – 10 x 5	2×10^{11}
X26A @ NSLS	4.5 - 20	6 x 5	3×10^9
X27A @ NSLS	4.0 - 30	14 x 7	5×10^9
10.3.2 @ ALS	3 - 17	5 x 5 - 16 x 7	9×10^9
BM05/29 @ ESRF	6 - 13	1.5 x 1.4	2.5×10^7
SRX @ NSLS-II	4.65 - 23.2	0.1 x 0.1	5×10^{12}
ID21 @ ESRF	2 - 7.5	0.2 x 0.2 - 1 x 1	$10^8 - 10^9$
ID22 @ ESRF	6.5 - 18	3.5 x 1.5	10^{12}
2-ID-B @ APS	2 - 4	0.06 x 0.06	10^9
2-ID-D @ APS	5 - 30	0.2 x 0.2	4×10^9
2-ID-E @ APS	7.5 - 10	0.5 x 0.3	5×10^9
13-ID-C,D @ APS	4 - 45	2 x 2	10^{11}
20-ID-B,C @ APS	4.3 - 27	2 x 2	10^{11}
XFM @ AS	4 - 25	0.06 x 0.06	10^{10}
MicroXAS @ SLS	5 - 20	1 x 1	2×10^{12}
LUCIA @ SOLEIL	0.8 - 8	2.5 x 2.5	2×10^{11}

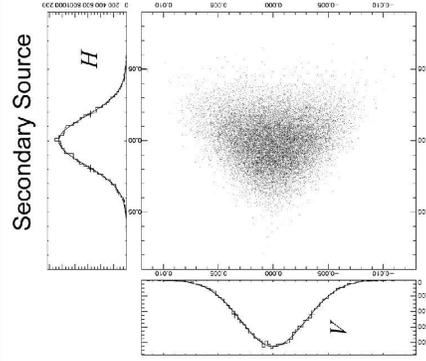


Horizontal Optics Layout

Figure 2. Horizontal (top) and vertical (bottom) optics layout and scatter plots for the Secondary beamline at the Secondary Source Aperture and at the final focus point produced by KB focusing mirrors as described above. Distances to major optical components are shown.



Vertical Optics Layout



Appendix A.5. Lists of Potential Users

These are lists of users for the X26A and X27A microprobes at the NSLS and the GSECARS (13ID) microprobe at the APS. Proposal team members are spokespersons for these instruments.

Table A.5.1: Beamline X26A (since 2005), NSLS, Spokesperson Steve Sutton (Last Name, First Name, Institution)

Table A.5.2: Beamline X27A (since 2006), NSLS, Spokesperson Lisa Miller (Last Name, First Name, Institution)

Table A.5.3: 13ID GSECARS XRM and XAFS Users, APS (since 1998) Spokespersons Steve Sutton and Mark Rivers (Last Name, First Name, Institution)

Table A.5.1: Beamline X26A Users since 2005

Andrade	Claudio	Queen's University (Canada)	Flynn	George	SUNY @ Plattsburgh
Appel	Michael	Brookhaven National Laboratory	Frank	Mark	Northern Illinois University
Arai	Yuji	U.S. Geological Survey	Frappier	Amy	Boston College
Bailey	Scott	USDA Forest Service	Frodsham	Aaron	Stony Brook Univ.
Becker	Udo	University of Michigan	Fuhrmann	Mark	Brookhaven National Laboratory
Bertsch	Paul	Univ. of Kentucky	Gao	Weimin	Brookhaven National Laboratory
Bostick	Benjamin	Dartmouth College	Gao	Xiaodong	Purdue University
Bowman	Kimberley	Princeton University	Gillow	Jeffrey	Brookhaven National Laboratory
Brearley	Adrian	University of New Mexico	Ginder-Vogel	Matthew	University of Delaware
Brinkmeyer	Robin	Texas A&M University	Glimcher	Melvin	Harvard Medical School
Cano	Katherine	George Mason University	Gough	Kathleen	University of Manitoba
Casey	Erin	Savannah River Ecology Laboratory	Graham	Lila	Children's Hospital - Boston
Chazen	Caitlin	Brown University	Greenberg	Michael	American Museum of Natural History
Cheng	Min-Wen	Purdue University	Grey	Clare	Stony Brook Univ.
Cooper	Matthew	Princeton University	Guerinot	Mary-Lou	Dartmouth University
Corriveau	Madeleine	Queen's University (Canada)	Gunter	Mickey	Univ. of Idaho
Cottrell	Elizabeth	Smithsonian Institute	Guest	Christopher	University of Vermont
Davis	Mark	Schott Industries	Hakala	Jacqueline	Ohio State University
DeFilipis	Luigi	Roma Tre University (Italy)	Hanson	Jonathan	Brookhaven National Laboratory
Delaney	Jeremy	Rutgers University	Harding	Jevon	Princeton University
Devicharan	Chidambaram	Brookhaven National Laboratory	Harrington	Laura	Princeton University
Dimasi	Elaine	Brookhaven National Laboratory	Harris	Clinton	Washington Math Science Tech Publ
Dobrzhinetskaya	Larissa	Univ. of California Riverside	Hawkins	Samantha	Charter High
Dodge	Cleveland	Brookhaven National Laboratory	Hay	Michael	Westinghouse Savannah River Co.
Doherty	Owen	Stony Brook Univ.	Hendricks	Gerald	U.S. Geological Survey
Dong	Bin	SFA Inc.	Hendy	Erica	University of Delaware
Donkervoort	Laura	Queen's University (Canada)	Herzog	Gregory	Bristol University
Duff	Martine	Westinghouse Savannah River Co.	High	Whitney	Rutgers University
Dyar	Melinda	Mount Holyoke College	Hirschmann	Marc	University of Colorado
Eaton	Michael	Colorado School of Mines	Huber	Don	Univ. of Minnesota
Ebel	Denton	American Museum of Natural History	Hunter	Douglas	Purdue University
Elzinga	Evert	Rutgers University	Jackson	Brian	Westinghouse Savannah River Co.
Emerson	Erica	Mount Holyoke College	Jamieson	Heather	Dartmouth College
Falini	Giuseppe	University of Bologna	Johnson	Erik	Queen's University (Canada)
Feng	Huan	Montclair State University	Jones	Keith	Brookhaven National Laboratory
Flinn	Jane	George Mason University	Jones	Blair	Brookhaven National Laboratory

Kabengi	Nadine	University of Georgia	Mishra	Bhoopesh	University of Notre Dame
Kaste	James	Dartmouth College	Morel-Kraepiel	Anne	Princeton University
Kastyak	Marzena	University of Manitoba	Mullen	Emily	University of Washington
Kelley	Kathernine	Univ. of Rhode Island	Murray	Soren	Kingsborough Community College
Kennerly	Michael	Rensselaer Polytechnic Institute	Myneni	Satish	Princeton University
Kerker	Prasad	SUNY @ Stony Brook	Naftel	Steven	University of Western Ontario
Khaokaew	Saengdao	University of Delaware	Nemec	Joseph	George Mason University
Knowles	Emily	Univ. of Colorado-Boulder	Northrup	Paul	Brookhaven National Laboratory
Komlos	John	Princeton University	Nuessle	Patterson	Westinghouse Savannah River Co.
Kretlow	Ariane	Brookhaven National Laboratory	Oyerinde	Oyenike	Princeton University
Kretlow	Ariane	Brookhaven National Laboratory	Parsons	Michael	Natural Resources Canada
Kupper	Joseph	University of Kentucky	Perry	Eugene	Northern Illinois University
Kwak	Se Young	Brookhaven National Laboratory			Centre National de La Recherche
Lac	Don	University of Massachusetts	Pouschat	Pricilla	Scientifique
Lange	Karina	Queen's University (Canada)	Punshon	Tracy	Dartmouth College
Lanzirotti	Antonio	University of Chicago	Quicksall	Andrew	Dartmouth College
Larsen	Joern	Lawrence Berkeley National Laboratory	Quigg	Antonietta	Texas A&M University
Layton-			Rak	Malgorzata	University of Manitoba
Matthews	Daniel	Queen's Univ. (Canada)	Ranville	James	Colorado School of Mines
Leri	Alessandra	Princeton University	Rao	William	University of Kentucky
Leskovjan	Andreana	SUNY @ Stony Brook	Rasbury	Troy	SUNY @ Stony Brook
Lev	Steven	Towson Univ.	Reeder	Richard	SUNY @ Stony Brook
Linkous	David	George Mason University	Reich Morales	Martin	University of Michigan
Lorenz	Emily	SUNY @ Stony Brook	Rivers	Mark	University of Chicago
Lovett	Rebecca	University of Arkansas	Sanchez-Roberts	Rosa	Stony Brook Univ.
Low	Paul	University of Massachusetts			Centre National de La Recherche
Ma	Hongbo	University of Georgia	Rose	Jerome	Scientifique
Martin	Keisha	SRS Technologies	Ross	Donald	University of Vermont
		Centre National de La Recherche	Saad	Fawzy	Children's Hospital - Boston
Masion	Armand	Scientifique	Schroth	Andrew	Dartmouth College
Mccanta	Molly	Brown University	Schulze	Darrell	Purdue University
McDonald	Louis	West Virginia University	Seaman	Sheila	University of Massachusetts
McDonald	Jason	SUNY @ Stony Brook	Seiter	Jennifer	University of Delaware
Mcnear Jr.	David	University of Kentucky	Shimizu	Masayuki	University of Delaware
Meghan	Ruppel	SUNY @ Stony Brook	Sitnitsky	Iлона Leanela	Plattsburgh State University
Melancon	Sonia	University of Windsor	Smeaton	Christina	University of Windsor
Miller	Lisa	Brookhaven National Laboratory	Smith	Randy	Brookhaven National Laboratory

Sparks	Donald	University of Delaware
Sutton	Stephen	University of Chicago
Szeghalmi	Adriana	University of Winnipeg
Tang	Yuanzhi	SUNY @ Stony Brook
Templeton	Alexis	Univ. of Colorado-Boulder
Tappero	Ryan	University of Delaware
Thomas	Jay	Rensselaer Polytechnic Univ.
Telivala	Tejas	SUNY @ Stony Brook
Tokunaga	Tetsu	Lawrence Berkeley National Laboratory
Tsyusko	Olga	University of Georgia
Unrine	Jason	University of Kentucky
Vazquez	Gustavo	Brookhaven National Laboratory
Walker	Stephen	Queen's University (Canada)
Wang	Qi	Brookhaven National Laboratory
Wang	Yunpeng	Academy of Sciences (China)
Weisener	Christopher	University of Windsor
Wichard	Thomas	Princeton University
Willis	Alexander	Princeton University
Willner	Marjorie	Princeton University
Witting	Ian	Cornell Univ.
Wrye	Lori	Queen's University (Canada)

Table A.5.2: Beamline X27A Users since 2006

Ablett	James	Soleil	Dvorak	Joseph	Science
Acerbo	Alvin	Stony Brook Univ.	Elzinga	Evert	Brookhaven National Laboratory
Adams	Monique	U.S. Geological Survey, Denver CO	Etschmann	Barbara	Rutgers University
Arai	Yuji	Clemson Univ.	Feng	Huan	CSIRO
Adler	Adriana	SUNY @ Stony Brook	Fitts	Jeffrey	Montclair State University
Arnason	John	SUNY @ Albany	Flinn	Jane	Brookhaven National Laboratory
Ba	Xiaolan	SUNY @ Stony Brook	Fokin	Maria	George Mason University
Bain	Jeffrey	University of Waterloo	Frumberg	David	SUNY @ Stony Brook
Bainbridge	Cynthia	Natural Resources Canada	Fuhrmann	Mark	Cornell University
Beauchemin	Suzanne	Natural Resources Canada	Gao	Weimin	Brookhaven National Laboratory
Beg	Mirza	SUNY @ Stony Brook	Gao	Xiaodong	Brookhaven National Laboratory
Blowes	David	University of Waterloo	Gibson	Blair	Purdue University
Bolanos	Lenaye	SUNY @ Stony Brook	Gideons	Erin	University of Waterloo
Bolotnikov	Aleksey	Brookhaven National Laboratory	Gilchrist	Sivajini	George Mason University
Borkiewicz	Olaf	Miami University	Gillow	Jeffrey	Rutgers University
Bourassa	Megan	Stony Brook Univ.	Gillow	Jeffrey	Brookhaven National Laboratory
Bousquet	Pierre	University of Waterloo	Grafe	Markus	Arcadis G&M Inc.
Broadhurst	Catherine	USDA	Gunsinger	Michael	CSIRO (Australia)
Bronson	Scott	Brookhaven National Laboratory	Guo	Qiang	University of Waterloo
Bruner	Steven	Boston College	Halada	Gary	University of Waterloo
Butko	Vladimir	Brookhaven National Laboratory	Hanson	Albert	SUNY @ Stony Brook
Camarda	Giuseppe	Brookhaven National Laboratory	Hossain	Anwar	Brookhaven National Laboratory
Cano	Katherine	George Mason University	Huang	Jenny	Brookhaven National Laboratory
Chaney	Rufus	USDA	Hylton	Shavonne	Cornell University
Chattop	Madhuri	UCLA	Jackson	Brian	SUNY @ Stony Brook
Chen	Zhiqiang	New Jersey Institute of Technology	Jamieson	Heather	Dartmouth College
Chidambaram	Devicharan	Brookhaven National Laboratory	Jones	Keith	Queen's University (Canada)
Christianson	Carl	Boston College	Jones	Blair	Brookhaven National Laboratory
Clodius	Jennifer	Brookhaven National Laboratory	Kaczmarek	Janet	USGS
Constantine	Lynn	PriceWaterHouseCoopers	Kirkham	Robin	SUNY @ Stony Brook
Crosson	Garry	Brookhaven National Laboratory	Kissell	Marianna	CSIRO
Dehipawala	Sunil	Queensborough Community College of CUNY	Kretlow	Ariane	SUNY @ Stony Brook
Dimasi	Elaine	Brookhaven National Laboratory	Krycka	Kathryn	Brookhaven National Laboratory
Dodge	Cleveland	Brookhaven National Laboratory	Kuczewski	Anthony	NIST
Donepudi	Venkateswara	Japan Society for the Promotion of	Kuczewski	John	Brookhaven National Laboratory

Kwak	Se Young	Brookhaven National Laboratory	Singh	Balwant	University of Sydney
Kwiatek	Wojciech	Institute of Nuclear Physics	Smith	Randy	Brookhaven National Laboratory
Lam	Phoebe	Woods Hole Oceanographic Institute	Soo	Yun-Liang	National Tsing Hua University
Lanzirotti	Antonio	University of Chicago	Sparks	Donald	University of Delaware
Lekki	Janusz	Institute of Nuclear Physics	Tang	Yuanzhi	SUNY @ Stony Brook
Leskovjan	Andreana	SUNY @ Stony Brook	Tappero	Ryan	University of Delaware
Lindquist	William	SUNY @ Stony Brook	Tyson	Trevor	New Jersey Institute of Technology
Lindsay	Matthew	University of Waterloo	Unrine	Jason	University of Kentucky
Lorenz	Emily	SUNY @ Stony Brook	Wang	Qi	Brookhaven National Laboratory
Luo	Yun	Miami University	Wei	Rui	SUNY @ Stony Brook
MacKinnon	Edward Ted	Natural Resources Canada	Woicik	Joseph	NIST
Martin	Ronald	University of Western Ontario	Yang	Lin	Brookhaven National Laboratory
McDonald	Jason	SUNY @ Stony Brook	Yang	Ge	Brookhaven National Laboratory
Miller	Lisa	Brookhaven National Laboratory			
Moorhead	Gareth	CSIRO			
Moreels	David	Brookhaven National Laboratory			
Morrison	Jean	U.S. Geological Survey, Denver CO			
Mortensen	John	Garden City High School			
Naftel	Steven	University of Western Ontario			
Northrup	Paul	SUNY @ Stony Brook			
Ozaki	Takuo	Japan Atomic Energy Agency			
Pace	Heather	Colorado School of Mines			
Perez Garrido	Carlos	Universidad Complutense de Madrid			
Rakovan	John	Miami University			
Rasbury	Troy	SUNY @ Stony Brook			
Reeder	Richard	SUNY @ Stony Brook			
Roeper	Donald	SUNY @ Stony Brook			
Ruppel	Meghan	SUNY @ Stony Brook			
Ryan	Christopher	CSIRO			
Schirmer	Anne	SUNY @ Stony Brook			
Schoonen	Martin	SUNY @ Stony Brook			
Seiter	Jennifer	University of Delaware			
Sheridan	Michael	George Mason University			
Sherrell	Robert	Rutgers University			
Siddons	David	Brookhaven National Laboratory			

Table A.5.3: APS GSECAR 13ID Users since 1998

Last Name	First Name	Affiliation
Ackermann	Sonia	University of Freiburg
Afton	Scott	University of Cincinnati
Alderden	Rebecca	The University of Sydney
Allison	Nicky	University of Brighton
Anderson	Alan	St. Francis Xavier University
Antonio	Mark	Argonne National Laboratory
Arai	Yuji	University of Delaware
Ardau	Carla	University of Waterloo
Bai	Liping	McGill University
Bain	Jeff	University of Waterloo
Bajt	Sasa	Lawrence Livermore Nat. Laboratory
Baker	Lucas	Kansas State University
Beak	Douglas	Ohio State University
Berry	Andrew	Imperial College of Sci. Tech. and Med.
Bertsch	Paul	Savannah River Ecology Lab.
Bhatia	Naveen	ANSTO
Biedron	Sandra	Argonne National Laboratory
Bishop	David	Indiana University
Bishop	James	Lawrence Berkeley Nat. Laboratory
Blowes	David	University of Waterloo
Blute	Nicole	Malcolm Pirnie
Bodendiek	Imke	Brookhaven National Laboratory
Bodnar	Robert	Virginia Polytechnic Institute
Bommannavar	Arun	Carnegie Institution of Washington
Booth	Corwin	Lawrence Berkeley Nat. Lab.
Borch	Thomas	Stanford University
Borch	Thomas	Stanford University
Bostick	Benjamin	Dartmouth College
Bosze	Stephanie	Miami University
Brabander	Daniel	Massachusetts Inst. Technology
Breit	George	U.S. Geological Survey-Denver
Brown	Sally	University of Washington
Brown	Gordon	Stanford University
Brugger	Joel	Univ of Adelaide
Byrne	Robert	University of South Florida
Cabri	Louis	Natural Resources Canada
Carroll	Susan	Lawrence Livermore Nat. Laboratory
Carter	Brandon	Lawrence Berkeley Nat. Laboratory
Catalano	Jeffrey	Argonne National Laboratory
Caulder	Dana	Lawrence Berkeley Nat. Laboratory
Cavallaro	Giuseppe	University of South Australia
Celestian	Aaron	SUNY-Stony Brook
Chandra	Anand	Univrsity of South Australia
Channell	James	University of Florida
Chappell	Mark	U.S. EPA
Charnock	John	Daresbury Laboratory
Chen	Chia-chen	Ohio State University
Cheng	Likwan	Argonne National Laboratory
Chimnery	Nicholas	Daresbury Laboratory
Choi	Sunkyung	University of Arizona
Chorover	Jon	University of Arizona
Chou	I-Ming	U. S. Geological Survey
Chow	Paul	Carnegie Institution of Washington
Ciston	James	Illinois Institute of Technology
Cohen	David	ANSTO
Collard	Zachary	Southwest Missouri State University
Cordova	Carmen	Stanford University
Comelius	Andrew	University of Nevada, Las Vegas
Corriveau	Madeline	Queen's University - Canada
Coughlin	Jessica	Savannah River Ecology Laboratory
Cross	Julie	Argonne National Laboratory
Daniel	Million	University of Nevada, Las Vegas
Davidson	Mark	University of Florida
Davis	Katherine	University of Maryland
Davis	Linda	Washington and Lee University
Delaney	Jeremy	Rutgers University
Dera	Przemyslaw	Carnegie Institution of Washington
Dion	Heather	Savannah River Ecology Lab.
Downs	Robert	University of Arizona

Duff	Martine	Savannah River Ecology Lab.
Dyar	Darby	Mount Holyoke College
Ebbs	Stephen	Southern Illinois University
Etschmann	Barbara	CSIRO
Evans	Katharine	Australian National University
Everhart	Jeffery	University of Delaware
Falconer	Ruth	University of Abertay Dundee
Fan	Rong	University of South Australia
Farquhar	Morag	University of Manchester
Fendorf	Scott	Stanford University
Fenter	Paul	Argonne National Laboratory
Field	Jason	University of Arizona
Fifarek	Richard	SIU-Carbondale
Finch	Adrian	University of St Andrews
Flynn	George	SUNY-Plattsburgh
Foran	Garry	Australian National University
Forsyth	Adrian	University of Windsor
Foster	Andrea	U.S Geological Survey
Fowle	David	University of Windsor
Gelabert	Alexandre	Stanford University
Gerson	Andrea	University of South Australia
Gibson	Blair	University of Waterloo
Gilbert	Ben	University of California, Berkeley
Ginder-Vogel	Matthew	University of Delaware
Glatz	Rebecca	Stanford University
Goldblum	Linda	Northern Illinois University
Gonzalez	Carolina	University of New Hampshire
Goddell	Carmen	University of California, Berkeley
Gray	Julian	Georgia State University
Grossman	Larry	University of Chicago
Guest	Chris	Purdue University
Gunsinger	Michael	University of Waterloo
Guyodo	Yohan	University of Minnesota
Ha	Juyoung	Stanford University
Haack	Elizabeth	McMaster University
Hack	Alister	Australian National University
Hall	Matthew	University of Sydney
Hambley	Trevor	University of Sydney
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Hemond	Harold	Massachusetts Inst. Technology
Hendricks	Gerald	University of Delaware
Herbel	Mitchell	Stanford University
Hettiarachchi	Ganga	The University of Adelaide
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Huber	Don	Purdue University
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Ilgen	Anastasia	University of Alaska-Fairbanks
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Jackson	Brian	Savannah River Ecology Laboratory
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Jamieson	Heather	Queen's University - Canada
Jassogne	Laurence	The University of Western Australia
Jayanetti	Sumedha	Southwest Missouri State University
Jones	Linda	Northern Illinois University
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Kamer	James	University of New Mexico
Kashiv	Yoav	University of Chicago
Keller	Nicole	Australian National University
Kelly	Shelly	Argonne National Laboratory
Keon	Nicole	Massachusetts Inst. Technology
Khaokaew	Saengdao	University of Delaware
Kim	Christopher	Chapman University
Kinman	William	University of Notre Dame
Kiser	Jon	San Francisco State University

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Knight	Kim	University of Chicago
Kocar	Benjamin	Stanford University
Koven	Charles	University of California, Berkeley
Kretlow	Ariane	Robert Koch-Institut
Kretzschmar	Ruben	NASA-Johnson Space Technology
Kumar	Ravhi	University of Nevada, Las Vegas
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Lagroix	Fance	University of Minnesota
Lam	Phoebe	Lawrence Berkeley National Laboratory
Lawlor	Matthew	University of Chicago Lab. School
Layman	Adam	St. Francis Xavier University
Le	Loan	NASA-Johnson Space Center
Lefticariu	Liliana	Indiana University
Lentini	Chris	Chapman University
Leskovjan	Andreana	Brookhaven National Laboratory
Lindsay	Matthew	University of Waterloo
Linnen	Robert	University of Waterloo
Liu	Weihua	CSIRO
Lombi	Enzo	CSIRO
Lundin	Scott	Massachusetts Institute of Technology
Lundstrom	Craig	Univ. of Illinois Urbana-Champaign
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Mailhot	Christian	Lawrence Livermore Nat. Lab.
Majzlan	Juraj	University of Freiburg
Mallmann	Guilherme	Australian National University
Manning	Bruce	San Francisco State University
Manning	Craig	University of California-Los Angeles
Marques	Joao	Purdue University
Masue	Yoko	Stanford University
Mavrogenes	John	Australian National University
Mayanovic	Robert	Southwest Missouri State University
McArthur	Alan	Aviex LLC
McDaniel	Sonya	Southwest Missouri State University
McKinley	James	Pacific Northwest Nat. Lab.
McLaughlin	Mike	University of Adelaide
McNear	David	University of Kentucky
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Miller	Noah	University of Maryland
Miller	Stefanie	Chapman University
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Morin	Guillaume	Laboratoire de Minéralogie
Mueller	Seth	USGS
Murray	Karen	Stanford University
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Pierzynski	Gary	Kansas State University
Polizzotto	Matthew	Stanford University
Qin	Gang	Malcolm Pirnie
Quinn	Kelly	University of South Florida
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Rollo	Hugh Andrew	Queen's University - Canada
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Rytuba	James	USGS
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Schlossman	Mark	University of Illinois, Chicago
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Stark	Alexander	University of Manchester
Straka	Alison	University of Maryland
Strawn	Daniel	University of Idaho
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Telivala	Tejas	Brookhaven National Laboratory
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