innovative biological research. However, there is a gap in the life sciences between the detailed molecular information that can be obtained with the above methods and the precise location of such complexes in functioning cells. There is scope for new imaging technologies. At Diamond we are exploring new beam lines that exploit coherent diffraction imaging and soft X-ray microscopy and the possibilities of new light sources.

Keywords: diamond light source, life sciences research, macromolcular complexes

MS.90.2

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A compact X-ray free electron laser at SPring-8

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Japan launched a construction project of x-ray free electron laser (XFEL) in 2006, as one of five Key Technologies of National Importance, to complete in 2010 fiscal year. The XFEL emits coherent hard x-rays which will be extremely useful for exploring the nano-world. The operation principle of the Japanese XFEL at the initial phase will be self-amplified spontaneous emission (SASE), as the precedent two projects in the U.S. and Europe. The XFEL will be composed of a linear accelerator and a long undulator in which electrons interact with photons to form micro-bunches with the period of emitted radiation. The micro-bunched electrons radiate coherent photons when they run through the undulator. The unique feature of the Japanese XFEL is the use of in-vacuum undulator. This makes the magnetic period of the undulator shorter than that of conventional out-of-vacuum undulators, leading to the reduction of the electron energy to produce certain energy of x-ray photons. Therefore, the length of the linear accelerator will be shorter, and the whole facility will be more compact. However, lower electron energy requires higher beam quality to produce lasing than is realized by a conventional laser-RF gun system. We have developed a new injector system, instead, which was fully proven in the operation of a prototype ultraviolet FEL. The present status of the project will be reported together with scientific programs using the XFEL, synergetic use of XFEL and SPring-8, and the second phase program for seeded XFEL. Some recent result from the prototype FEL will be introduced as well.

Keywords: X-ray free electron laser, coherent radiation, accelerator based x-ray source

MS.90.3

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Status of the Energy Recovery Linac (ERL) project at Cornell University

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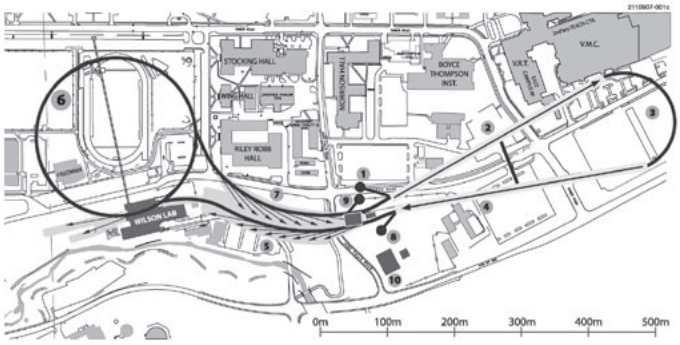
The status of the Energy Recovery Linac (ERL) project at Cornell University is summarized. ERLs are being developed as next generation synchrotron light sources. The fundamental x-ray beam properties from storage ring sources, such as the source size, spectral brightness, and pulse duration are limited by the dynamic equilibrium characteristic of the magnetic lattice that is the storage ring. Advances in laser-driven photoelectron sources and superconducting linacs allow the acceleration of electron bunches with superior properties for synchrotron radiation, and superconducting linac energy recovery allows the development of an x-ray ring without the need for electron storage. Relevant properties include x-ray beams of extraordinary spectral brightness and small source size, with concomitant high transverse coherence, sub-picosecond x-ray pulse durations, and flexibility of operation. ERLs are capable of hosting practically all experiments now being carried out at storage rings while also enabling new types of experiments. Progress is reported on development of the required high-spectral brightness photo-injector and superconducting linac. X-ray applications are discussed.



Keywords: X-ray synchrotron radiation, technology, instrument development

MS.90.4

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Electron storage ring based tabletop light source named MIRRORCLE for protein crystallography

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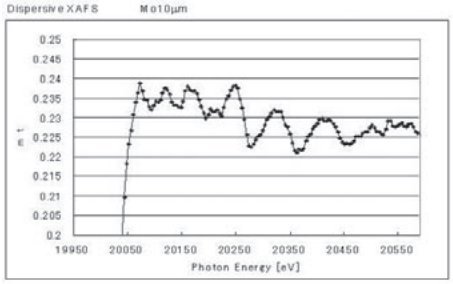
Light source based on a 20 MeV storage ring has been commissioned. The average stored beam current was more than 2A at 400Hz beam injection. We have observed an extremely short 15 ms damping time, a small 3 mm diameter beam size, and a long 1 min lifetime to this low energy and 15cm orbit radius electron storage ring. We generate X-rays by a 10 micron size target placed in this storage ring. The observed X-ray density is more than that of 1kW X-ray tube, but the spectrum is polychromatic. The X-ray energy extends up to 20 MeV and the total power is 100W when an accelerator power is applied. We have commissioned a crystal monochrometer beam line. A special configuration enabled extracting tunable monochromatic X-rays onto the fixed sample position. The 10 to 30 keV rage x-rays is extracted. We have carried out EXAFS and found that the energy resolution is satisfactory for the protein crystallography (see fig.). Due to a background radiation around the beam line and a poor performance of CCD camera, diffraction pattern is



not yet reliable. We will demonstrate the protein crystallography by June with the improved machine and reduced background.

Keywords: synchrotrons, protein crystallography, EXAFS

MS.90.5

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Integrating laser and linac technology for next generation X-ray sources

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We will discuss a superconducting linac-based compact inverse Compton scattering source of hard x-rays appropriate for a university or industry laboratory. The process of inverse Compton scattering, in which an electron of 20-50 MeV backscatters an optical photon into the hard x-ray spectral range, offers the opportunity to produce high-brilliance hard x-ray beams with a laboratory-scale facility. Using a 2-meter superconducting linac and a 1-kW laser system, the time-average brilliance of such beams will be similar to 2nd generation synchrotron facilities. Two important characteristics will make our concept unique in comparison to the best synchrotrons or other compact sources. First, beam size can be below 10 microns, and second, the pulse length can be as short as 100 femto-seconds opening up applications difficult or impossible with even 3rd generation sources. This talk will discuss the conceptual design of such a source and the scientific program it could support, including imaging and crystallography in both static and time-dependent modes.

Keywords: high-power lasers, Compton scattering, synchrotron radiation sources

MS.91.1

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Liquid state of spins and charges in geometrically frustrated spinel oxides

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Among a wide variety of structural categories of transition metal oxides, the spinel, generally ex-pressed by the chemical formula AB_2O_4, is unique in that an extremely strong geometrical frustration on both “spin” and “charge” channels is anticipated from its pyrochlore B-sublattice, a corner shared network of B-tetrahedra. We have been exploring novel liquid states of spins and charges produced by frustration using spinel structure as a play ground. In this talk, we present recent highlights of such exploration. $Na_4Ir_3O_8$ with S=1/2 Ir^{4+} was discovered. This compound crystallizes in “hyper-Kagome” structure, which can be viewed as a cation-ordered (Ir and Na) spinel structure. We show that the ground state of this system is very likely a three dimensional S=1/2 spin liquid as a consequence of geometrical frustration [1]. LiV_2O_4 spinel is a “charge” frustrated system because of the mixed-valent configuration with 1:1 ratio of V^{3+} and V^{4+}, where we found a charge analogue of spin liquid state. In this system, the ordering of charges is suppressed completely because of the geometrical frustration and, instead, a heavy-fermion metal with an effective electron mass of $100m_e$ is realized at low temperatures. [2]. A new mixed-valent spinel oxide $LiRh_2O_4$, a Rh-analogue of LiV_2O_4, was discovered [3]. We found that, in contrast to LiV_2O_4, an orbital ordering associated with cubic to tetragonal transition suppresses frustration and leads to a complex charge ordered state at low temperatures. This waork was done in collaboration with Y.Okamoto, S.Niitaka, M.Nohara, H. Aruga-Katori, P.Jonson, S.Fujiyama and K.Kanoda

[1] Y. Okamoto et al., Phys. Rev. Lett 99, 137207 (2007).
[2] P. Jonson et al., Phys. Rev. Lett.99, 167402 (2007).
[3] Y. Okamoto et al., submitted.

Keywords: spinel, geometrical frustration, liquid state of spins and charges

MS.91.2

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Local order and frustration in vanadate spinels

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Orbitally degenerate frustrated spinels, $Cd_{1-x}Zn_xV_2O_4$ were investigated using elastic and inelastic neutron scattering techniques. For the end members, x = 0 and 1, a tetragonal distortion is observed upon cooling through a Jahn-Teller coupling mechanism which leads to the formation of spin chains in the ab-plane. Upon further cooling, Neel ordering is established due to interchain coupling. In the doped compounds, bulk susceptibility shows that the macroscopic transitions to cooperative orbital ordering and long range antiferromagnetic ordering are absent. However, from the inelastic magnetic scattering measurements, it is suggested that the dynamic spin correlations at low temperatures have similar one dimensional characteristics as observed in the pure samples. The pair density function analysis of neutron diffraction data shows that the local atomic structure does not become random with doping but rather consists of two distinct environments corresponding to ZnV_2O_4 and CdV_2O_4. This suggests that short-range orbital ordering is present which leads to the one dimensional character of the spin correlations even in the low temperature cubic phase of the doped compositions.

Keywords: local symmetry, one-dimensional, orbital degeneracy

MS.91.3

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Controlling spin glass entropy - Frustrated magnetism in the spinels

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The zero point entropy of frustrated magnets is an interesting quantity, as it provides information on the degeneracy of their ground states. Indeed, much of the recent work on spin ices was triggered after the characterisation of their zero point entropies using specific