2 Expected Scientific Cases

2-1 Introduction

As described in the preceding chapter, the ERL can provide photon beams that are much more intense, brilliant, coherent and shorter pulses than beams from 3rd-generation storage rings. The excellent scientific cases for these characteristics of the PF-ERL are described in the following sections.

2-2 Scientific Subjects Opened by Short Pulses

The electron bunch length in the ERL can be much shorter than that in an electron storage ring. A typical bunch length in the time domain is about 1 ps and it can be shortened further to 0.1 ps with bunch compression at the accelerator. This feature is one of the outstanding qualities of the ERL light source. Sub-picosecond time-resolved measurements in X-ray diffraction, photoemission spectroscopy, small angle scattering, X-ray absorption fine structure (XAFS) and magnetic circular dichroism (XMCD) and so on will provide us with various new and interesting information about the non-equilibrium dynamics of matters. Figures 1 and 2 show two typical examples of such time-domain science with synchrotron radiation. Time-resolved X-ray diffraction and small angle scattering will give us information about the dynamics of the structural changes for various reactions such as photo-induced phase transitions, chemical reactions in polymer and biological systems. Time-resolved XAFS will give us information about the dynamics of charge transfer, electronic state and local structure during chemical reactions, especially, photochemical reactions such as photocatalysis. In atomic and molecular science, one of the interesting time-domain experiments would be the molecular alignment

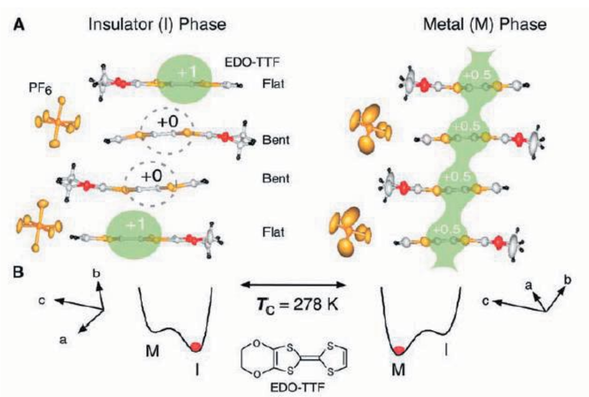

Figure 1
Schematic view of the lattice and electronic structural changes accompanied by the photo-induced metal-insulator phase transition in $(EDO\text{-}TTF)_2PF_6$ at sub-picosecond time range.

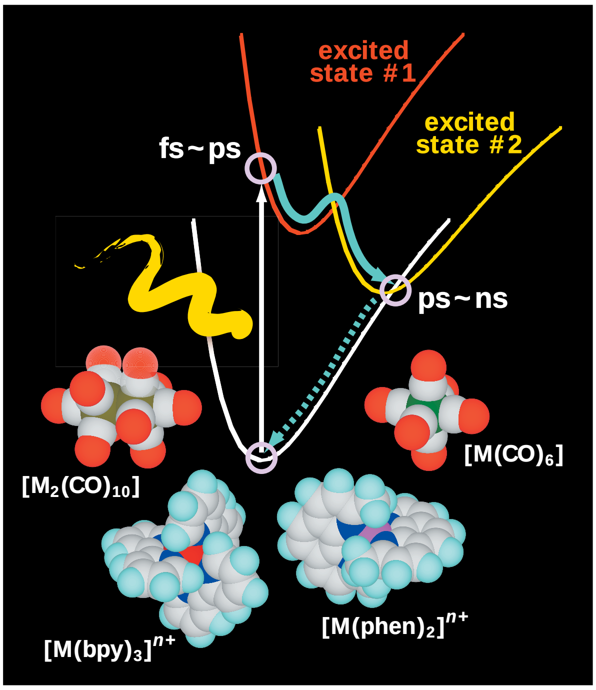

Figure 2
Light-induced excited states of metal complexes as examples of time domain sciences with a sub-picosecond time resolution.

with an intense optical laser field and to carry out the follow-up investigations of the structural changes over the lapse of time. Such studies can be performed by time-resolved measurements using electron-ion coincidence spectroscopy. The time-resolved XMCD and PEEM methods have brought us information about the magnetization dynamics of nano-scale magnetic systems. The sub-picosecond time resolution of the ERL will give us further information about the dynamics of spin-precession relaxation mainly in ferromagnetic materials.

2-3 Scientific Subjects Opened by Coherent X-Rays

The ERL will provide X-rays with much higher coherence compared to the 3rd-generation storage rings. For example, the coherent flux will be almost two orders-of-magnitude greater than in storage rings such as SPring-8. Figure 3 shows some typical new methodologies that will be opened by coherent X-rays. One is an application to phase-contrast imaging and microscopy. The highly coherent X-rays would reduce the exposure time by orders of magnitude and also improve both resolution and contrast. This will open new possibilities in flash-imaging studies of soft matters such as biological tissues. The next are scientific subjects related to X-ray coherent scattering such as X-ray photon correlation

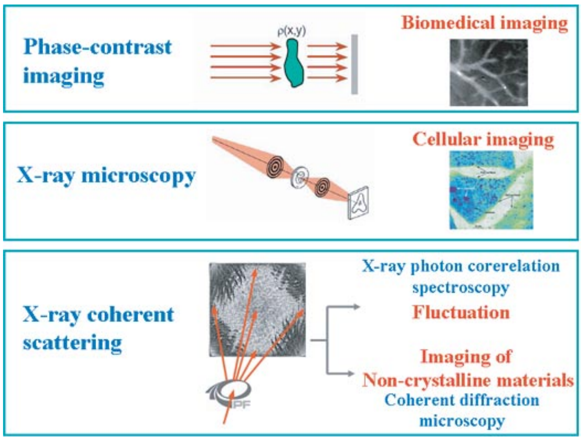

Figure 3
Typical scientific subjects which will be opened by use of coherent X-rays.

spectroscopy and coherent diffraction microscopy. Coherent diffraction microscopy might be one of the most exciting technological developments by utilization of coherent X-rays, because it will become possible to study the structure of biological matter and other non-crystalline materials. Utilizing the X-ray photon-correlation spectroscopy, studies of the dynamic speckle patterns can give us information about the fluctuation of domain size, domain shape, and domain-domain distance during the domain-formation process in materials near the phase transitions. This technique can also be applied to the investigation of vibration modes in biological systems.

2-4 Scientific Subjects Opened by Nano-Beams

The partially coherent synchrotron radiation emitted from the ERL can be focused down to the diffraction limit in both the vertical and horizontal directions, i.e., a round beam with several tens of nm diameter. Various new applications can be opened by the availability of high-intensity nano-beams, such as micro-diffraction, spectro-microscopy and micro-spectroscopy to investigate local atomic structures and/or local electronic structures.

X-ray diffraction with nano-beams will enable a local atomic structural analysis of nano-materials, fine mosaic materials and very small sub-µm crystals. For example, in the area of the macromolecular structure analysis, the highly intense beam with a diameter of several hundred nm will enable us to solve the structure of crystals whose diameter is just sub µm. This achievement will make it possible to accomplish structural analyses of large complexes and membrane proteins important in biological science. The extremely small beam size will also allow us to investigate structures under ultra-high pressure environments that can be realized only within a very small volume of diamond anvil cells. This should lead to a drastic progress of Earth-planetary science. Photoelectron emission spectroscopy with nano-beams will also give us information on local electronic structures of interesting nano-materials with position-by-position measurements.

Typical sciences expected to be opened by ERL are summarized in Fig. 4.

Scientific cases at PF-ERL

- **Scientific subjects opened by short pulse (sub-pico second)**
  #Investigation of non-equilibrium dynamics.
  #Study of spin dynamics in material.
  #Chemical reaction with catalysts .
  #Photo-induced phase transition, and related materials
  #Reaction processes of proteins (life science)
- **Scientific subject opened by coherent X-rays**
  #Structure analysis of non-crystalline materials
  #Phase contrast imaging
  #Investigation of the fluctuation of several domains by means of X-ray photon correlation spectroscopy
- **Scientific cases opened by nano beam**
  #Combination with other general experimental method.
  ↓
  Local structural analysis, Local electronic state, Microscopic studies, Structural analysis of small crystals (~100nm), etc.

Figure 4
Representative new sciences opened by use of ERL.