1 ERL Project Overview

The ERL is a future X-ray light source designed based on state-of-the-art superconducting linear accelerator technology, which will offer far higher performance than the existing storage ring. The high repetition rate, short pulse, high spatial coherence and high brightness of the ERL will enable the filming of ultrafast atomic-scale movies and determination of the structure of heterogeneous systems on the nano-scale. These unique capabilities of the ERL will drive forward a distinct paradigm shift in X-ray science from “static and homogeneous” systems to “dynamic and heterogeneous” systems, in other words, from “time- and space-averaged” analysis to “time- and space-resolved” analysis.

This paradigm shift will make it possible to directly witness how heterogeneous functional materials work in real time and space, and will enable predictions to be made in order to design and innovate better functional materials which will eventually solve the grand challenges of society and support life in future. Such functional materials will continue to be used in indispensable technologies such as catalysts, batteries, superconductors, biofuels, random access memories, spintronics devices and photoswitches. On the other hand, life itself is an intrinsically heterogeneous and dynamic system. Structural biology based on the existing storage ring technology has greatly contributed to determining the static atomic coordinates of proteins which are useful information for rational drug design. The ERL will contribute to biological science and biotechnology by shedding light on the heterogeneity and complexity of cellular functions. In short, the ERL will be an unprecedented tool that will bridge the critical gaps in our understanding of material science and technology.

In addition, continuous improvement of linear accelerator technology will result in further quantum leaps in X-ray science in the future. One possibility is the realization of a fully coherent X-ray free-electron laser. Although self-amplified spontaneous emission X-ray free-electron lasers (SASE-XFELs) have been constructed around the world, the X-ray beam from SASE-XFEL is essentially not fully coherent in the temporal domain. By configuring a Bragg diamond cavity for lasing in the X-ray region, it is proposed that an X-ray free-electron laser oscillator (XFEL-O) will be feasible by taking full advantage of the unprecedented electron beam quality of the ERL. The XFEL-O is planned to be constructed in the second phase of the ERL project.

As a future project of the KEK Photon Factory, we propose to construct a 3-GeV ERL that can be upgraded to become the X-FELO. The conceptual layout of the 3-GeV ERL is shown in Fig. 1. In the first stage of the project, we construct a 3-GeV ERL which comprises an injector linac, a superconducting main linac, and a return loop. In the return loop, we will install 20 to 30 insertion devices which are used to emit synchrotron radiation. Using state-of-the-art undulator technology, we cover a broad spectrum range of synchrotron radiation from vacuum ultra-violet (VUV) to hard X-rays. In the second stage of the project, we will build an X-FELO system which comprises a long undulator and an X-ray resonator. To deliver high-energy beams for the X-FELO system, we change the path length in the return loop by a half RF wavelength of 115.3 mm. The beams are then accelerated again (without energy recovery) through the main linac up to 6 GeV. Then, the beams are used to drive the X-FELO. The details of the 3GeV-

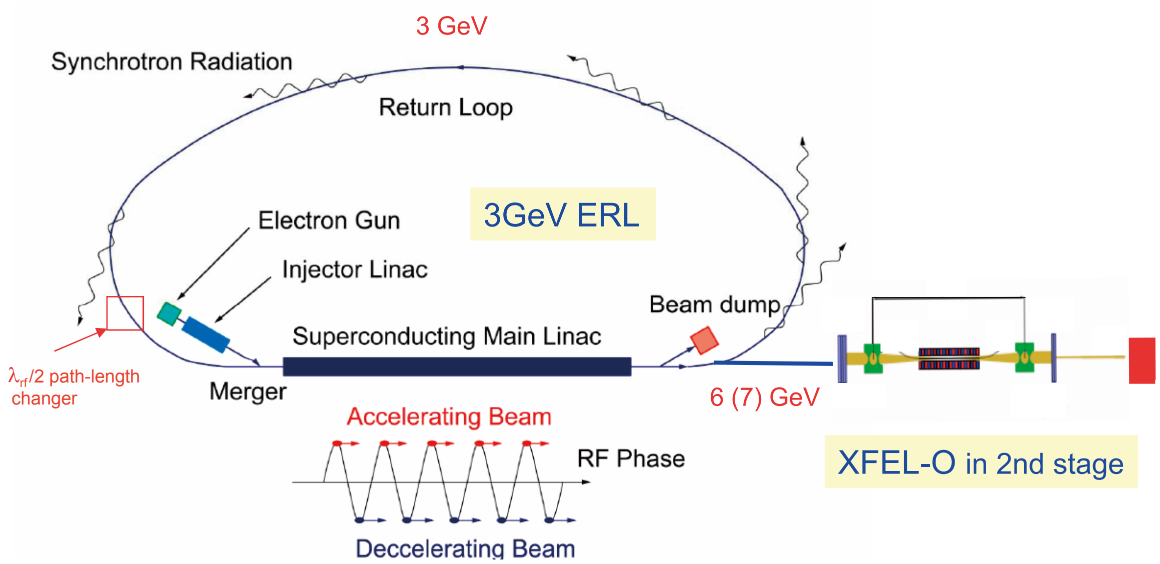

Figure 1
Conceptual layout of 3-GeV ERL plan integrated with an X-ray free electron-laser oscillator (XFEL-O).

ERL design are described in the following section.

KEK established the ERL Project Office in April 2006. Because a GeV-class ERL machine has not been constructed anywhere in the world, it is necessary to first construct a compact ERL (cERL) with an energy of 35 MeV that can be used for developing several critical accelerator components such as a high-brilliance DC photocathode electron gun and superconducting cavities for the injector and main accelerator. In fiscal 2011, such main accelerator components were successfully developed and operation of the beam will start at the end of fiscal 2012.

KEK and JAEA organized the ERL2011 from October 16 to 21, which was the 50th ICFA Advanced Beam Dynamics Workshop on Energy Recovery Linacs to discuss accelerator technologies and applications based on the ERL (Fig. 2). The workshop was a success with 140 participants from 9 countries worldwide. The number of overseas participants was 61, including 26 from the USA, 13 from Germany, 11 from China, 4 from the UK, 3 from Russia, 2 from Switzerland, 1 from Korea, and 1 from Slovenia. All of the presentation files were posted on the ERL2011 Indico-page of the Scientific program at the ERL 2011 site [1]. The next ERL workshop is to be held in BINP, Novosibirsk in 2013.

Science case which is opened by the ERL project was also discussed by the ERL Science Workshop II (April 2011), first ERL symposium (July 2011), IMSS symposium 2011 (December 2011), and second ERL symposium (March 2012). The sub-title of both ERL symposiums was “Synchrotron radiation to realize the sustainable society”, and Dr. Hiroshi Komiyama, former president of the University of Tokyo, and Prof. Ei-ichi Negishi of Purdue University, who won the Nobel Prize for Chemistry in 2010, gave special plenary talks at each symposium. In addition to the plenary talk by Prof. Negishi, addresses (video letters) from Prof. Keith Hodgson of SSRL, Dr. Helmut Dosch of DESY and Prof. Maury Tigner of Cornell University gave presentations at the second ERL symposium (Fig. 3).

Figure 2
Group photo of the ERL2011 (October 16-21), which was the 50th ICFA Advanced Beam Dynamics Workshop on Energy Recovery Linacs.

(a) (b)

Figure 3
(a) Prof. Ei-ichi Negishi of Purdue University, Winner of the Nobel Prize for Chemistry in 2010 and (b) Prof. Keith Hodgson of SSRL, at the occasion of the second ERL symposium (March 2012).

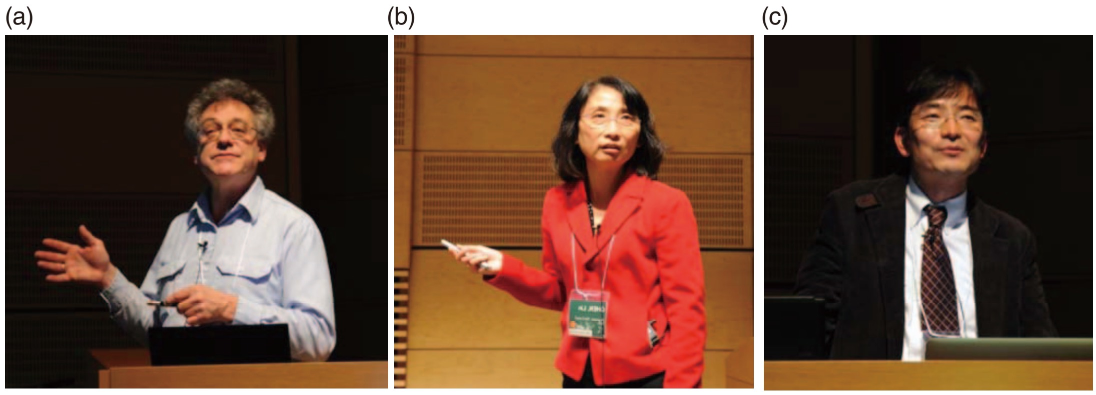

Figure 4
Photographs of Dr. Sol Gruner (Cornell University) (a), Dr. Lin X. Chen (ANL) (b) and Dr. Ryu Abe (Hokkaido University) (c) at the IMSS symposium.

We invited Dr. Sol Gruner (Cornell University), Dr. Lin X. Chen (ANL) and Dr. Ryu Abe (Hokkaido University) to the IMSS symposium in December 2010 to provide scientific updates (Fig. 4) Dr. Gruner presented the summary talk of the XDL2011 workshop, which was a series of workshops devoted to the science of diffraction-limited high repetition rate, hard X-ray sources, and was held at Cornell University during the month of June 2011. The Photon Factory was one of the co-organizers of the workshop [2]. Dr. Lin X. Chen presented her work on time-resolved X-ray absorption spectroscopy on photo-exited transient states by using APS with time resolution of several pico seconds. Then she emphasized the importance of femto-second time resolution in order to clarify the dynamics of materials. Dr. Ryu Abe presented the chemistry of visible-light-responsive photo-catalysts for the production of hydrogen from solar power. He also summarized the future challenges for development, such as direct observation of the photo-catalyst reaction itself and the carrier recombination process.

We published the Preliminary Conceptual Design Report for the 3GeV-ERL upon the occasion of the second ERL symposium [3]. According to the CDR, we will organize the International Advisory Committee to evaluate our 3GeV-ERL project and also to obtain critical comments for the project next fiscal year.

REFERENCES

[1] http://erl2011.kek.jp/scientific_program/index.html
[2] http://erl.chess.cornell.edu/gatherings/2011_Workshops/index.htm
[3] http://pfwww.kek.jp/ERLoffice/detabase/ERL_Preliminary_Design_Report_web.pdf