1 ERL Project Overview

The energy recovery linac (ERL) is a future X-ray light source designed on the basis of state-of-the-art superconducting linear accelerator technology, which will offer significantly better performance than existing storage ring technologies. The high repetition rate, short pulse, high spatial coherence, and high brightness of ERL will enable the filming of ultrafast atomic-scale movies as well as the determination of the structure of nanoscale heterogeneous systems. These unique capabilities of the ERL will drive a distinct paradigm shift in X-ray science, from the study of "static and homogeneous" systems to "dynamic and heterogeneous" systems; in other words, from the study of "time- and space-averaged" analysis to "time- and space-resolved" analysis.

This paradigm shift will make it possible to directly observe the behavior of heterogeneous functional materials in real time and space. It will also enable predictions to be made for the design and innovation of better functional materials. These advances will contribute to solving the grand challenges of society and will support life in the future. Such functional materials will continue to be used in indispensable technological tools such as catalysts, batteries, superconductors, biofuels, random access memories, spintronic devices, and photoswitches. Life itself is an intrinsically heterogeneous and dynamic system; structural biology based on existing storage ring technology has greatly contributed to rational drug design by providing the static atomic coordinates of proteins. The ERL will further 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 critical gaps in our understanding of material science and technology.

In addition, the continuous improvement of linear accelerator technology will result in significant advances 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, the X-ray beam from a SASE-XFEL is not fully coherent in the temporal domain. It is proposed that the unprecedented electron beam quality of the ERL will make an X-ray free-electron laser oscillator (XFEL-O) feasible when used with a Bragg diamond cavity configured for lasing in the X-ray region. The construction of an XFEL-O is scheduled to take place during the second phase of the ERL project.

KEK established the ERL Project Office in April 2006. Because a GeV-class ERL machine had not been constructed anywhere in the world, it was necessary to first construct a compact ERL (cERL) with energy of 35 MeV that could be used for the development of several critical accelerator components such as a high-brilliance DC photocathode electron gun and superconducting cavities for the injector and main accelerator. In the 2012 fiscal year, such main accelerator components were successfully installed in an ERL test facility; performance of these could be checked by the end of the 2012 fiscal year.

We published the "Conceptual Design Report for 3-GeV ERL" at the 2nd ERL symposium (http://pfwww.kek.jp/ERLoffice/detabase/ERL%20CDR_0807.pdf). We organized an International Advisory Committee (IAC) to evaluate our 3-GeV ERL project according to the Conceptual Design Report and provide critical comments on the project. The members of the committee were as follows: Ingolf Lindau (Chair) from Stanford Univ., Thomas Tschentscher from Euro XFEL, Kwang-Je Kim from APS, Zhao Zhentang from SSRF, Junichiro Mizuki from Kwansei Gakuin Univ., Masahiro

Figure1: Group photo of the International Advisory committee for 3-GeVERL project.

Kato from UVSOR, and Alfred Baron from Riken. Unfortunately, Dr. Thomas Tschentscher could not attend the IAC. Figure 1 shows a group photo of the committee members, presenters, and directorates of the ERL project. A summary of the IAC meeting is available at the web site [1]. In particular, we asked the IAC members to give us critical comments for the following four questions.

1) Question 1 – Are the scope and strategies of the 3-GeV ERL project including the further upgrade of XFEL-O satisfactory as the future light source in KEK?

2) Question 2 – The Science Case for the 3-GeV ERL project

A. Is the scope of the science case of the 3-GeV ERL reasonable and also satisfactory?

B. Is the effort to brush up the science case enough?

C. Further recommendation for this item

3) Question 3 – Development for accelerator technologies

A. Is the technical development for the accelerator components for the cERL sufficient?

B. Is there anything to check the technical problem in cERL before construction of the 3-GeV ERL?

4) Question 4 – Construction of 3-GeV ERL

A. Is the construction of the 3-GeV ERL feasible under the R&D planning of accelerator development?

B. Further recommendations for this item

For Question 1, the IAC gave us positive comments; for example: *"The ERL, with the XFEL-O, is a logical step in the development of next generation accelerator-based photon sources. It will have unprecedented characteristics, and will be complementary to high-gain FELs and ultimate storage rings. Going far beyond present state-of-the-art, and ERL will open up major new research areas. The ERL is therefore an exceedingly strong and logical candidate as a future light source at KEK."* For Question 2, the IAC mentioned that *"the scientific case for a 3-GeV ERL is mature and is solidly anchored in both the Japanese and the international scientific community. The Preliminary Conceptual Design Report has an impressive expose of the breadth of novel scientific opportunities an ERL source offers."* Also, the IAC recommended that *"PF/ERL-team play an active role in promoting the evolution of the scientific case with workshops, symposia, etc. and also the ERL team should continue to pursue further advanced capabilities, such as sub-femtosecond pulse generation via echo-enhanced harmonic generation, and fold these into the scientific case."* For Question 3, *"the IAC was very impressed by the advanced status and the rapid progress of the cERL project."* The committee also mentioned that *"the strategy to construct the cERL as a precursor to the 3-GeV ERL is critical since the cERL has the main technology components required for the 3-GeV ERL."* For Question 4, we presented that the cERL was expected to be operational and commissioned at the end of 2012 and that the experience from this endeavor would be the basis for a design plan scheduled to be largely finalized in 2014. *"The IAC fully supports this approach".* Also, The IAC stressed the importance that *"this plan must be scrutinized by outside review committees with appropriate technical background."* The IAC also fully supported the fact that *"a continuous R&D effort of the gun/laser is necessary and in parallel with the ERL construction, extending into the commissioning/operational phase."* The IAC mentioned that *"the proposed construction time, with completion of the 3-GeV ERL in 2021, is timely and feasible, given sufficient resources."* The IAC recommended that *"a careful study is done to make sure that the chosen layout is optimal, with particular care that there is enough space for future expansion."* A complete and detailed of the summary of the IAC's comments can be found online at the URL mentioned above.

Figure 2: Logo of ERL project, designed on the basis of the logo of the Photon Factory and the motif of a pearl.

After the IAC meeting, the *"Energy Recovery Linac Conceptual Design Report"* was partially revised and finalized as the KEK report and opened on a website [2].

In March 2013, the nickname and logo of our ERL project were settled and opened at the Photon Factory Symposium. The nickname was PEARL (Photon Factory ERL Advanced Research Laboratory) and the logo is shown in Fig. 2. The nickname PEARL inherits the name of the Photon Factory as well as research centers with a synchrotron radiation facility. In addition, the pearl is a gem popular in the traditional technology of Japan, and it emits the brightness of the seven colors. These features characterize the pearl as a symbol of science and the radiation accelerator technology to be produced by the ERL project. The logo design was developed from the logo of the Photon Factory as well as the motif of a pearl.

REFERENCES

[1] http://pfwww.kek.jp/ERLoffice/detabase/ERL_AC/ERL_iac3gev/index.html

[2] "Energy Recovery Linac Conceptual Design Report", *KEK Report* 2012-**4**, http://ccdb5fs.kek.jp/tiff/2012/1224/1224004.pdf