3 To Realize the PF-ERL

3-1 Preliminary Design Study of the PF-ERL

Feasibility studies of the ERL have been continued at the KEK Photon Factory and Accelerator Laboratory for several years and the "Study Report on the Future Light Source at the Photon Factory — Energy Recovery Linac and Science Case —" (in Japanese) was published in March, 2003. A plan view of the proposed ERL shown in Fig. 1 and its principal parameters are given on Table 1. The detailed structure of the PF-ERL as the future light source, however, has not been decided yet. It will be determined as the construction and the demonstration of the 150-300 MeV class ERL prototype proceed during the next several years.

ERLs are different from conventional storage rings in that the transverse emittance is not determined by the balance of the quantum excitation and the radiation damping but instead determined by the "adiabatic damping". Specifically, excitation of the transverse motion due to the emission of synchrotron radiation is negligibly small in the ring where the electrons pass through only once, and the normalized emittance of the beam emitted from the electron gun is conserved if no growth of the emittance occurs in the route including the pre-accelerator, main acceleration structures, arcs etc. The electron beam must be accelerated up to its final energy at once in such a ring and must be dumped every time after circulating the ring once. Therefore, a high-field superconducting linac is essential for this kind of a ring. Furthermore, because the beam energy of several GeV is required as discussed below, the total power of the beam is tremendous and the energy must be withdrawn from the beam back to the linac. This is the reason why this kind of a ring is called "Energy Recovery Linac". We expect to develop an electron gun with a normalized emittance of 0.1 mm·mrad in a few years. This value is not unrealistic in the case of a small emission current. If the electron beam from such a gun can be accelerated up to 5 GeV (γ =10000) without any emittance growth, the emittance of 10 pm·rad at 5 GeV could be achieved. This value fulfills the condition for the diffraction limit in the X-ray region as discussed in the preceding chapter.

In the case of usual storage rings, the bunch length in time domain is limited by the balance of quantum excitation and radiation damping, and ranges from several tens of ps to several hundreds of ps. It is very difficult to obtain light pulses with time lengths less than 1 ps at a reasonable beam current (e.g. a few mA). On the other hand, in the case of the ERL, short electron bunches emitted from a gun can be transported without elongating. In addition, they can be compressed further in the longitudinal direction, and it does not seem to be difficult to obtain light pulses with time lengths less than 1 ps. Thus the condition for the light pulse length discussed above can also be satisfied.

Table 1 Principal parameters of the ERL proposed in 2003.

Beam energy	2.5-5 GeV
Injection energy	10 MeV
Circumference	1253 m
Maximum current	100 mA
Normalized emittance	0.1 mm.mrad
Energy spread	5×10^{-5}
Bunch length	1-0.1 ps
Acceleration frequency	1.3 GHz
Acceleration gradient	10-20 MeV/m

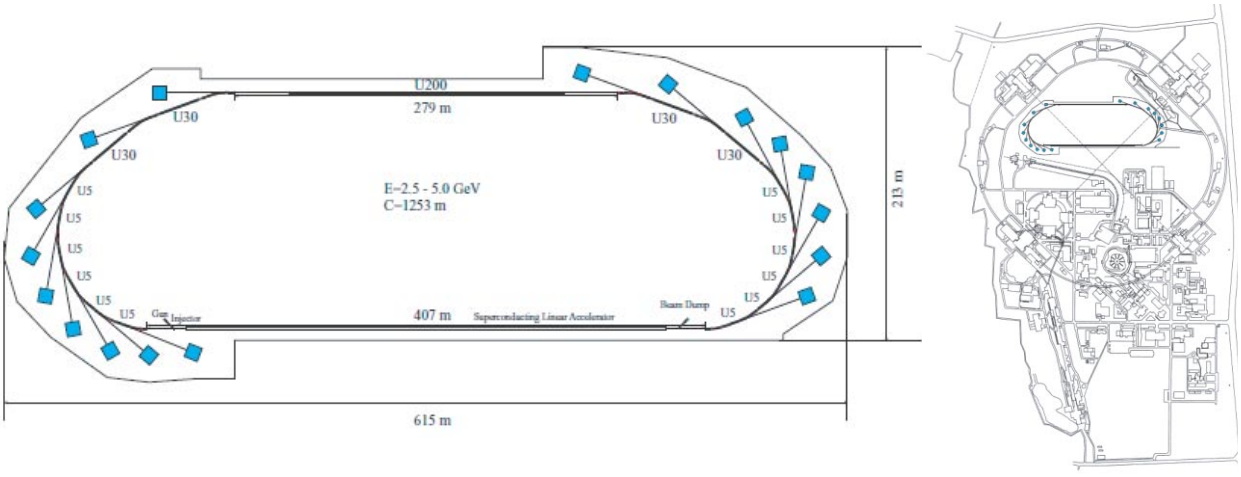

Figure 1
Plan view of the ERL as proposed in March, 2003, whose energy is 2.5-5 GeV with the circumference of 1253 m.

3-2 The Prototype ERL

To realize the 5-GeV ERL, the development of many components would be necessary and investigations of beam dynamics are also indispensable. The technical issues to be resolved before the construction of the 5-GeV ERL light source are listed below.

1) Effects that spoil energy recovery.
2) Instabilities that break conservation of normalized emittance.
3) Effects that elongate the bunches.
4) Effects of the so-called coherent synchrotron radiation.
5) "Beam gymnastics" in the longitudinal phase space.
6) Achievable acceleration gradient.
7) Technical issues on the superconducting acceleration structure.
8) Development of an electron gun with the required specifications.

etc.

In order to resolve these issues and investigate the beam dynamics, we plan to construct an ERL prototype machine. As shown in Fig. 2, the experimental hall previously used for cold neutron science on the KEK Tsukuba campus will be available for the R&D of ERL. Although the area is not entirely satisfactory for our eventual purpose, it is sufficient for the construction of a prototype 150-200 MeV class ERL in it. Moreover, there is a building for a cryogenic system nearby. Although part of the cryogenic system is also moving to the Tokai campus (J-PARC site), we expect that the rest of it and the building can be used for our purpose. According to the provisional layout of the prototype in the hall, a straight section with a length of about 25 m should be available for a superconducting linac. The maximum energy obtained by the linac depends on the capacity of the cryogenic system. We expect an energy of 150-200 MeV. When a powerful cryogenic system (kW class at 2 K) becomes available, the prototype can be converted into a practical light source for the VUV region. In this case, insertion devices will be installed in the other straight sections.

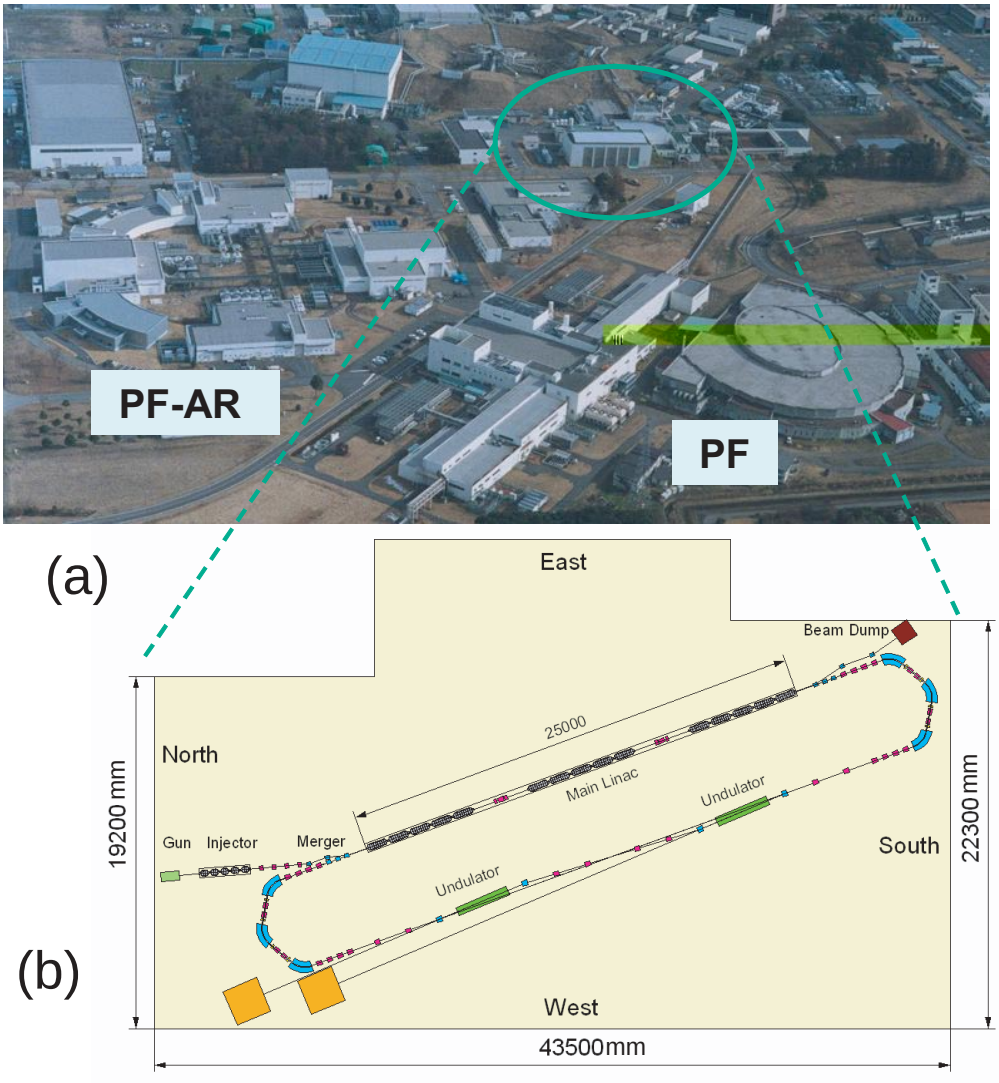

Figure 2
(a) The building which will be used for the construction of the prototype ERL.
(b) Schematic drawing of the prototype ERL with a straight section for a superconducting linac whose length will be about 25 m.

3-3 The Time Schedule for the PF-ERL Project

We have just started organizing an R&D group to investigate the ERL. We aim at designing, constructing and testing a 200-MeV prototype accelerator during the years 2006-2009 and then hope to start the construction of the main 5-GeV ERL machine from 2010. In addition to the Photon Factory staff members, the Accelerator Laboratory of KEK is now officially involved in this project. We have also started collaboration with the JAEA (previously JAERI) group which has already built a low-energy (17 MeV, 10 mA) ERL and is also proposing the construction of an ERL-based light source.

The official organization of the ERL Project Office at KEK started at the beginning of April in 2006. As the first step, we have started a design study of the prototype 200-MeV ERL in collaboration with accelerator scientists from other synchrotron-radiation facilities in Japan such as ISSP (Institute of Solid State Physics, Univ. of Tokyo), UVSOR (Institute for Molecular Science) and JASRI/SPring-8. We hope to complete the construction of this prototype ERL by the end of FY2008 and gain operational experience in 2009. Tentative time schedule of the ERL project is shown in Fig. 3.

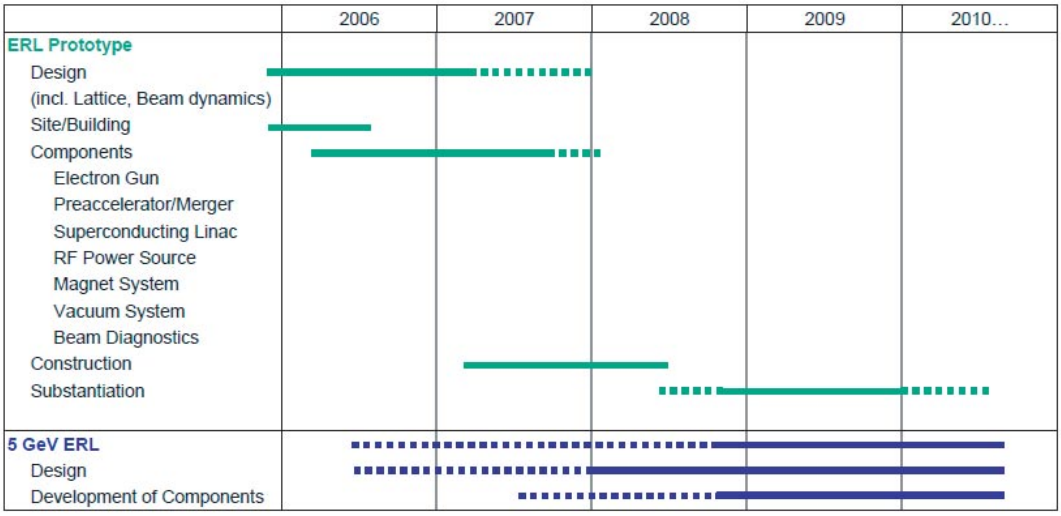

Figure 3
Tentative time schedule for the PF-ERL project.