Design for the Radiation Protection of the compact ERL (cERL) in KEK

Energy Recovery Linac
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Fig. Memorial photo for arrangement completion of the cERL injector on 3/27/2013.
Accelerators in KEK

PF-AR (6.5 GeV)

PF ring (2.5 GeV)
For driving cutting-edge science and for succeeding research at the Photon Factory (2.5 GeV and 6.5 GeV rings)

Needs for future light source at KEK

3-GeV ERL light source plan at KEK

New technology
1.3 GHz (CW) operation
At first, we began to construct a low power cERL (35 MeV, 10 μA).

**Goals of the cERL**

Demonstrating reliable operations of our R&D products (guns, SC-cavities, ...)

Demonstrating the generation and recirculation of ultra-low emittance beams

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**Diagram Notes:**
- Recirculating loop
- Main superconducting cavities
- ERL test facility
- Injector
- 3GeV Energy Recovery Linac
- Injector
- 13.4MV/m (470.4m LINAC)
- Dump
### Table: Expected loss of the main beam

<table>
<thead>
<tr>
<th>Part</th>
<th>Symbol</th>
<th>Beam loss point</th>
<th>Energy (MeV)</th>
<th>Loss ratio (%)</th>
<th>Loss current (μA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recirculating loop</td>
<td>a</td>
<td>Collimator at Injector</td>
<td>5</td>
<td>0.1</td>
<td>0.01</td>
</tr>
<tr>
<td>Recirculating loop</td>
<td>b</td>
<td>Bending magnet at beam examination course</td>
<td>5</td>
<td>0.8</td>
<td>0.08</td>
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<tr>
<td>Recirculating loop</td>
<td>c</td>
<td>Injector beam dump</td>
<td>5</td>
<td>100</td>
<td>10</td>
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<tr>
<td>Recirculating loop</td>
<td>d</td>
<td>Collimator at the merger section</td>
<td>5</td>
<td>0.3</td>
<td>0.03</td>
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<tr>
<td>Recirculating loop</td>
<td>e</td>
<td>Collimator at the 1st arc</td>
<td>35</td>
<td>0.1</td>
<td>0.01</td>
</tr>
<tr>
<td>Recirculating loop</td>
<td>f</td>
<td>Collimator at the 2nd arc</td>
<td>35</td>
<td>0.1</td>
<td>0.01</td>
</tr>
<tr>
<td>Recirculating loop</td>
<td>g</td>
<td>Movable Faraday cup for beam tuning</td>
<td>35</td>
<td>100</td>
<td>0.01</td>
</tr>
<tr>
<td>Recirculating loop</td>
<td>h</td>
<td>Main beam dump</td>
<td>5</td>
<td>100</td>
<td>10</td>
</tr>
</tbody>
</table>

**Fig.** Expected beam loss points of the main beam.
Field emission from main superconducting cavities is very significant as a source of radiation. But, field emission current is unknown and different among cavities.

**Fig.** Illustration of assembly of two 9-cell cavities.

**Fig.** Photo of two 9-cell cavities.
Indirect measurement of field emission current

(1) The assembly of the main superconducting cavities was closed with SUS blind flanges.

(2) Voltage was applied to the single cavity.

(3) Dose rates from generated photons were measured at places around the cavity and on the roof of accelerator room using TLD, ionization survey meter, and NaI survey meter.

(4) Dose rates per electron current were calculated by MARS15.

(5) Field emission current was estimated from the measured dose rates and calculated dose rates per electron current.

Fig. Example of measured dose rates.

Fig. Example of calculated dose rate.
Measured results of field emission current

Currents were quite different between cavities #3 and #4.

Current was increased steeply with applied voltage.

Current was significantly large!

Fig. Estimated field emission current as a function of applied voltage.
Shielding design for cERL

On the basis of the floor space, expected beam loss ratios, and result of the field emission measurement,

1.5-m-thick concrete wall shield + 1-m-thick concrete roof shield + local shield (Fe, Pb, and concrete) around beam loss points

**Fig.** The final design of shield for cERL.

e. Beam loss at collimator at the 1st arc

g. Beam loss at Movable Faraday cup for beam tuning

**Fig.** Examples for dose rate distribution calculated by MARS15.
We wanted to construct cERL beamline and shield immediately, but...
removing EP2 beamline and shield
It took one year to remove most of EP2 beamline and shield.
December, 2010

Activated iron plates

Photo of ERL test facility
It took one more year to clean up the ERL test facility completely.
Activated area of floor was separated by painting in red to control drilling a hole in the activated floor.
Shield construction

May 2012 to August 2012

Movie
Present status and future plan of cERL

Present phase (Injector construction)

On 4/11/2013, arrangement of cERL injector was completed.

On 4/16/2013, commissioning of cERL injector (5MeV, 1μA) started.

200nA of 5-MeV electrons was successfully transferred into the beam dump in commissioning.

On 5/23/2013, cERL injector is going to be completed, then research operation will start.

Next phase (+Recirculating loop construction)

Last week, shielding design for Recirculating loop was fixed.

In this summer, arrangement of Recirculating loop will start.

Next winter, commissioning of entire cERL (35 MeV, 10 μA) will start.

Future

Energy up (35 MeV → 245 MeV)
Intensity up (10 μA → 10mA)
Energy-recovery linac (ERL) is a promising device for future X-ray light sources.

Before the construction of the 3-GeV ERL facility, a compact ERL (cERL) is being constructed on the ground level at the ERL test facility in KEK.

For the cERL, 1.5-m-thick concrete wall shield + 1-m-thick concrete roof shield + local shield (Fe, Pb, and concrete) around beam loss points was adopted on the basis of the floor space, expected beam loss ratios, and result of the field emission measurement.

In this April, commissioning of Injector started. Next commissioning of the entire cERL is going to start in the next winter.

Beam loss ratios have to be investigated using the low power cERL. The results will reflect shield design for future upgraded (energy and intensity increased) cERL and 3-GeV ERL.
Thank you for your attention in spite of unscheduled talk.