3 PF-AR

3-1 Operation summary

In FY2013, the construction of the tunnel for the direct beam transport (BT) line was almost completed. The lattice design of the 6.5-GeV BT line has been finished, and the production of DC magnets, kicker and septum magnets, pulsed bending magnets, and vacuum ducts was started. Details of the project to realize the full-energy top-up injection will be described in the next section.

In summer 2013, 16 power supplies of the quadrupole magnets were updated. We have continued to update aged power supplies year by year. There are eight power supplies still waiting to be updated, while there are a total of 28 quadrupole power supplies operating in the PF-AR.

Figure 1 shows the full history of the operation time. The operation statistics are summarized in Table 1. The total operation time has remained at about 4000 h and the user time was much less than the required 4000 h in these three years. The insufficient operation time was due to the unavoidable factors of budget circumstances and higher electricity bills. The accelerator group made an effort to reduce the time for accelerator conditioning and to keep a high user time ratio at around 90%.

The numbers of failures by source are summarized in Table 2 for recent years, and are classified by down time as a pie chart in Fig. 2. In FY2013, failures in beam injection including ramping up and those in beam instrumentation (control/monitor) increased.

The 30-year-old analog detection circuits of the beam position monitor (BPM) caused repeated troubles for COD measurement and emergency repair was necessary. To improve the BPM system, new signal transmission cables are being prepared, and the detection circuits are planned to be renovated by the end of FY2014.

Construction of the new BT tunnel near the present BT line might disturb the condition of the beam injection. When the full-energy injection is realized in future, most of the beam instabilities affecting the injection will be resolved, and stable, efficient injection is expected. The dust-trapping decreased drastically in FY2013. This is thought to be a side effect of the reduced stored current due to the insufficient injection condition.

The total down time in FY2013 amounted to about 100 h, which is unfortunately the worst result in recent years. The longest down time was a 24-hour cancellation of user time in order to secure radiation safety for the construction site of the BT tunnel. The other long down time was a 20-hour interruption because of an initial defect in a quadrupole power supply installed in summer 2003.

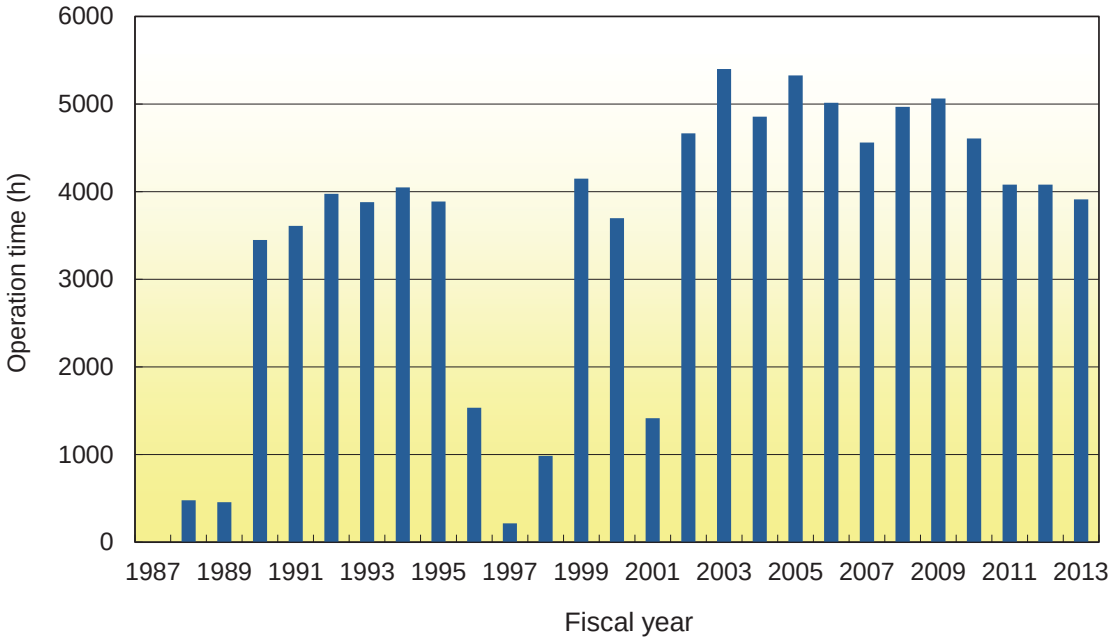

Figure 1: Full history of the operation time of the PF-AR.

Table 1: Operation statistics and mean time between failures (MTBF) during FY2005 – FY2013.

Fiscal year	2005	2006	2007	2008	2009	2010	2011	2012	2013
Total operation time (h)	5313	5016	4561	4969	5063	4608	4080	4080	3912
Scheduled user time (h)	4456	4032	3624	4344	4392	4032	2904	3672	3478
Ratio of user time (%)	83.9	80.4	79.5	87.4	86.7	87.5	71.2	90.0	88.9
Number of failures	79	51	60	40	41	74	49	33	47
Total down time (h)	69.3	55.1	45.2	41.7	91.0	73.7	38.7	29.7	99.6
Failure rate (%)	1.6	1.4	1.2	1.0	2.1	1.8	1.3	0.8	2.9
MTBF (h)	56.4	79.1	60.4	108.6	107.1	54.5	59.3	111.3	74.0
Mean down time (h)	0.9	1.1	0.8	1.0	2.2	1.0	0.8	0.9	2.1

Table 2: Classification of failures by source of trouble.

Fiscal year	2005	2006	2007	2008	2009	2010	2011	2012	2013
RF	12	10	1	4	8	10	5	4	5
Magnet	4	1	1	2	2	10	8	3	4
Injection	4	3	8	9	1	6	4	3	18
Vacuum	2	6	2	0	2	1	0	1	0
Dust trap	37	24	39	15	16	24	20	13	3
Insertion devices	0	1	0	0	0	0	0	0	0
Control / Monitor	4	0	1	1	1	2	1	2	8
Cooling water	5	1	0	3	4	4	1	0	2
Safety / Beamline	9	4	5	5	7	17	3	4	3
Earthquake	2	0	1	0	0	0	5	3	1
Electricity	0	1	2	1	0	0	2	0	3
Total	79	51	60	40	41	74	49	33	47

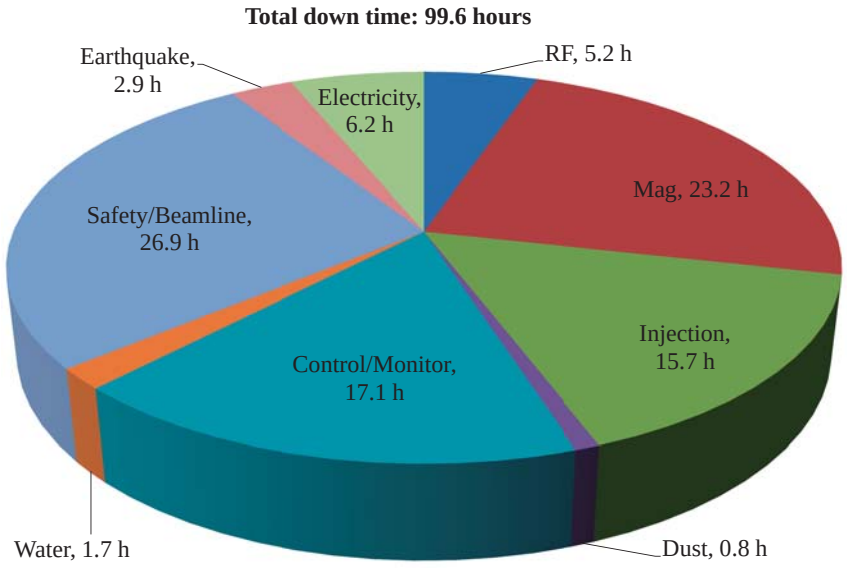

Figure 2: Pie chart of the down time in FY2013.

3-2 New PF-AR Transport Line

Construction of a new beam transport line (BT) for the Photon Factory Advanced Ring (PF-AR) started at KEK's Tsukuba campus in April 2013. This new BT will enable 6.5-GeV full energy injection and top-up operation for the PF-AR. At present, the beam injection is carried out with beam energy of 3 GeV, and the accumulated beam with a beam current of 60 mA is ramped up to 6.5 GeV. Then, the user operation starts. Beam injection is done twice a day and it takes about 15 minutes for each injection. So far, the PF-AR has used the common BT with the KEKB (8-GeV electrons) as shown in Figure 3. During the PF-AR beam injection, the BT was optimized for the PF-AR and the KEKB beam injection was pending.

Fast switching injection with 50 Hz from the KEK LINAC to the three rings, the PF-ring (2.5 GeV) and the KEKB LER (3.5 GeV) / HER (8 GeV), has already been achieved. In the upcoming SuperKEKB project, the estimated beam lifetime is as short as 10 minutes, so fast switching injection to the PF-AR is required by the start of the physics run at SuperKEKB in January 2016. Therefore, the new BT is separated from the SuperKEKB BT at the end of the KEK LINAC using a pulsed bending magnet as shown in Figure 3. The separated beam for the PF-AR passes through a new tunnel, about 200 m long, and is injected to the PF-AR.

Construction of the tunnel was started in April 2013, and will be completed in FY2013. Figure 4 shows the precursor tunnel and the inside of the tunnel. The construction of infrastructure (cooling water, etc.) will begin in April 2014 and end in September 2014. The accelerator components such as the magnet, vacuum and monitor systems were fabricated in FY2013 (Figure 5). The components will be adjusted and the infrastructure of electric devices and the cooling water system will be constructed in FY2014. Installation of the accelerator components and beam commissioning of the direct BT are scheduled for FY2015. Optical parameters from the end of the injector linac to the injection point of the PF-AR are shown in Figure 6.

Figure 4: Upper photograph: the precursor tunnel in November 2013. Lower photograph: the inside of the tunnel before painting.

Figure 5: Fabricated magnets.

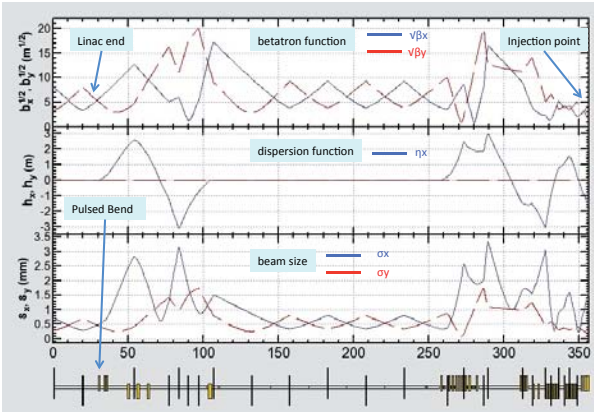

Figure 6: Optical functions from the end of the injector linac to the injection point of the PF-AR. Blue and red lines represent the horizontal and vertical parameters, respectively.

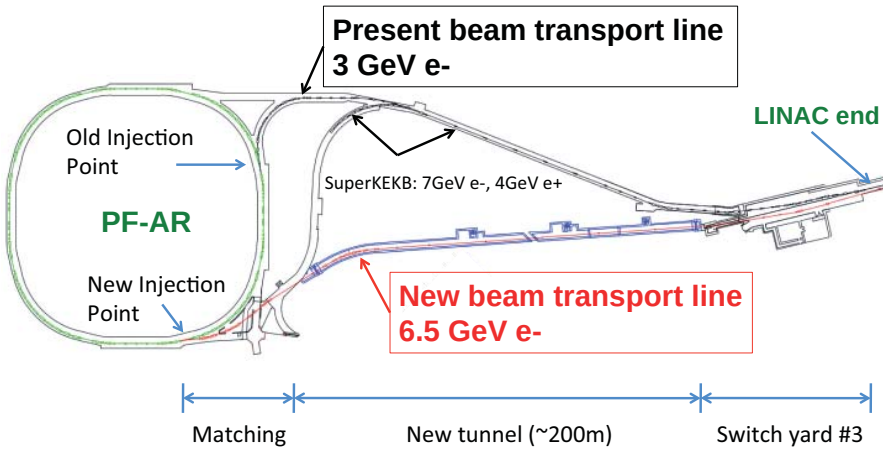

Figure 3: New beam transport line (red) for the PF-AR. The black line shows the present beam transport line; the blue area is the new tunnel.