ACHIEVEMENT OF ATF AND ITS FUTURE PLANS *

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Abstract

The ATF (Accelerator Test Facility at KEK) International collaboration has been launched formally under the MoU (Memorandum of Understanding) from August 1, 2005, so as to maximally contribute to the world design and development efforts in the areas of particle sources, damping rings, beam focusing and beam instrumentation towards the International Linear Collider (ILC) project. I will give a talk on the achievement at ATF and its future plans, especially ATF2 project.

OUTLINE OF ATF AT KEK

The Accelerator Test Facility (ATF) at KEK comprises a multibunch-capable RF gun (with up to 20 bunches, spaced by 2.8ns, per pulse), an 1.3GeV S-band injector linac, a damping ring, and a beam diagnostic section(EXT)[1]. Each part directly contributes to the development of technologies relevant to high luminosity linear colliders. ATF at KEK is a research center for studies of issues concerning the injector, damping ring and beam delivery systems for ILC. Fig.1 shows a schematic plan view of ATF[2, 3, 4]. The multibunch scheme is essential to boost the rf-to-beam transfer power efficiency in the accelerator.

ATF generates, accelates, damps, and extracts a train of 20 bunches with 1×10^{10} electrons/bunch and 2.8ns spacing. The achievable normalized emittance is 3.8μm horizontally and 0.0125μm vertically, and an energy spread 0.08% and the bunch length 8mm for the multibunch beam. The small emittance from the damping ring has been achieved by special design of a strong focusing lattice with precise alignment of components and beam orbit control. The nonlinear behavior of the beam has to be well understood to provide enough dynamic aperture under such strong focusing conditions.

After the technology choice for ILC Main Linac, we proposed ATF2 project as a test beam line using very flat beam from the ATF damping ring to realize 37nm vertical beam size at the final focus point stably. Then, we have established an International Collaboration of ATF (including ATF2 project) with many institutes and it was launched on Aug. 1st 2005. Now several other institutes were added to join into this collaboration.

The International Collaboration of ATF is based on the Memorandum of Understanding (MoU) which defines the organization of the international collaboration to carry out the research programs at ATF and its extension ATF2, so as to maximally contribute to the world design and development efforts in the areas of particle sources, damping rings, beam focusing and beam instrumentation towards the ILC project. We are adding the MoU, the chart of the organization and related material into new ATF Web Site (http://atf.kek.jp/).

As evidence from this MoU, the construction and operation of ATF2 will be executed in the framework of the International Collaboration of ATF. The management of activities of ATF2 will be carried out under the supervising bodies as described in the later section.

I described the simplified explanation of the ATF MoU in the following sub-sections. Also, I explain the achievement of ATF and the plan of ATF2[5].

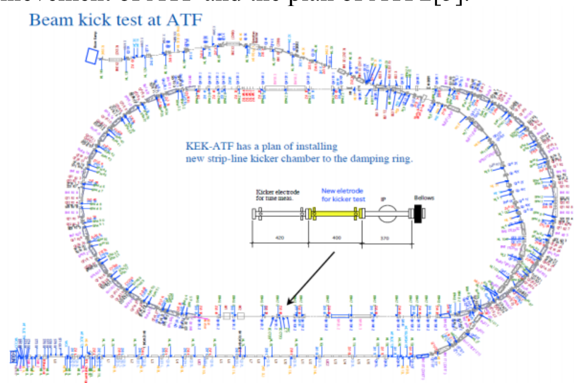

Figure 1: Schematic plan view of ATF.

MISSION OF ATF/ATF2

ATF is to establish the technologies associated with producing the electron beams with the quality required for ILC and to provide such beams to ATF2 in a stable and reliable manner.

ATF2 is effectively to use the beams extracted from ATF at a test final focus beamline which is similar to what is envisaged at ILC. The goal is to demonstrate the beam focusing technologies that are consistent with ILC requirements. For this purpose, ATF2 aims to focus the beam down to a few tens of nm (rms) with a beam centroid stability within a few nm for a prolonged period of time.

Both ATF and ATF2 is to serve the mission of providing the young scientists and engineers with training opportunities of participating in R&D programs for advanced accelerator technologies.

ORGANIZATION OF ATF/ATF2

To execute the scientific programs at ATF/ATF2, the following bodies were instituted:
- International Collaboration Board (ICB)
- Technical Board (TB)
- Spokesperson (SP) with his/her Deputies
- System/Group Coordinators (SGCs)

International Collaboration Board (ICB)

The International Collaboration Board (ICB) is the decision making body for executive matters related to the

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ATF collaboration. Each collaborating institute can delegate one member to the ICB. In addition, the ICB is joined by the three GDE Regional Directors, who represent Asian, North American and European regions.
One of the members of the ICB is to serve as the ICB Chair. The nomination of the ICB Chair is done through mutual voting by all of the ICB members.

According to the 1st ICB meeting at Snowmass 2005, an ICB meeting will be held approximately once per year. Research programs and near term schedules of the machine operation will be posted to the ATF Web Site, usually for the upcoming two weeks. If some collaborators have a need to change the schedule, SP or deputies have to coordinate it.

Technical Board (TB)

The TB consists of approximately 4~5 members from each of the Asian, North American and European regions. The members of the ATF Technical Board (TB) are nominated and appointed by the ICB. The TB serves the following tasks:

- At the request of ICB, assist the Spokesperson in formulating the ATF Annual Activity Plan, which outlines the activity plans of ATF/ATF2 including the budget and beam time allocation for each Japanese fiscal year.
- Assist the ICB in assessing the scientific progress that is being made by the ATF collaboration.

Usually schedule of ATF machine operation is divided to two blocks of operating time per year with about four months summer long shutdown. One block is from mid. of Oct. to Dec, and the other is from mid. of Jan. to mid. of June. Since there are many collaborators, we decided two meetings of TB per year in Dec. and May for review and recommendation of the research programs at ATF.

Spokesperson (SP)

The SP serves the following tasks:

- Direct and coordinate the work required at ATF/ATF2 in accordance with the ATF Annual Activity Plan.
- Report the progress made by the collaboration to the ICB and the director of KEK.
- Report the matters related to KEK budget and KEK properties to the director of KEK.

To carry out these tasks, the SP will

- Appoint, with an approval of ICB, up to three Deputies to assist his/her tasks in the areas of
  - Beam operation,
  - Hardware maintenance, and
  - Design, construction and commissioning of ATF2.
- Appoint, with an approval of ICB, the System/Group Coordinators (SGCs) on critical ATF subsystems and study programs.
- Organize a "Coordination Group" with the Deputies and System/Group Coordinators for coordinating the details of the operation and development at ATF/ATF2 on a daily (during the beam operation period) or weekly (during the maintenance and construction period) basis.

The report and the discussion are usually carried out through the ATF Web Site (http://atf.kek.jp/) with members of ICB, TB and SGCs.

System/Group Coordinators (SGCs)

- The System/Group Coordinators were appointed by the Spokesperson with an approval of ICB.
- The appointment of the System/Group Coordinators was made in a manner consistent with the ATF Annual Activity Plan.
- The System/Group Coordinators coordinate the tasks charged to the assigned Systems or Groups, and assist the Spokesperson and the Deputies coordinate the ATF/ATF2 research programs.

In case of small study groups with less than 5 members, the Spokesperson or the Deputies may assume the role of its Coordinator on an acting basis.
Simplified organization chart is shown in Fig.2.

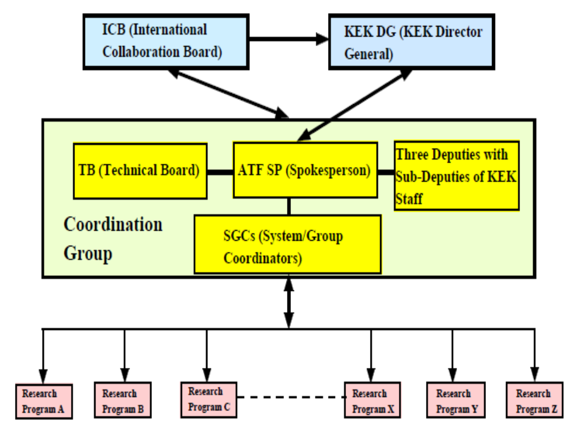

Figure 2: Simplified organization chart.

Execution of Research Programs at ATF/ATF2

The ATF Spokesperson (SP) supervises the construction and operation programs of ATF/ATF2 in accordance with the ATF Annual Activity Plan, as approved by the ICB. The ATF SP can delegate part of his/her tasks to the Deputies and System/Group Coordinators, as deemed appropriate. The planning and execution of the construction and operation programs of ATF/ATF2 must be conducted in a manner consistent with the Japanese laws, KEK internal regulations and other rules applicable in case of activities by non-KEK members of the collaboration. Details of the group structures are to be formulated in ways optimized in accordance with the technical nature of each program in question, e.g. activities such as design, simulation, testing, construction, commissioning, operation, and investigation.

Additional agreements concerning the matters related to execution of non-KEK budget, management of non-KEK properties at the premise of ATF, together with handling of KEK properties at the premises outside KEK, are to be individually dealt with in Annexes attached to the ATF MoU.

The detailed coordination of beam time allocation will be done by the Coordination Group.

An institute who has not signed on the ATF MoU may participate in part of the research programs at ATF, with an authorization of the ATF SP, in as much as the proposed activity is:

- within the ATF Annual Activity Plan,
- under the consent by the relevant Deputies or System/Group Coordinators, and
- promptly reported to the ICB.

Should a conflict of interests occur among the members or Work Groups within the collaboration, the Spokesperson will make the best efforts to resolve it in an amicable manner. When a suitable resolution cannot be reached, the Spokesperson will bring the matter to the ICB for further negotiation towards a resolution.

Membership of the Collaboration

Membership of new institutes for the ATF collaboration is subject to approval of the ICB. Institutes who desire to join the ATF collaboration shall submit a proposal to the Spokesperson, who will relay the matter to ICB.

Withdrawal of a member institute from the ATF collaboration is subject to acknowledgement by the ICB. Institutes who desire to withdraw from the ATF collaboration shall submit a notification to the Spokesperson, who will relay the matter to ICB.

ACHIEVEMENT OF ATF

There is a lot of developments on beam instrumentation at ATF since 1993. The detail report is given by reference of [6]. This report covers remained achievements.

Emittance Measurements at EXT

Intensive studies on the vertical emittance with the wire scanners in EXT have been ongoing since March(2000)[7]. An important observation we made during this time is that there appears to be a source of x-y cross plane coupling somewhere between the extraction point of the damping ring (DR) and the wire scanner region in EXT. The measured vertical emittance is approximately (1.1+/-0.1)x10^{-11} m for the beam intensity of (2.0+/-0.2)x10^{9} electrons per bunch. The emittance is found to grow to (2.2+/-0.1)x10^{-11} m at the beam intensity of (8.0+/-0.3)x10^{9} electrons per bunch, however. In these measurements, the x-y beam profile showed a tilting of a few degrees, as observed by using 10 degree wires. The quoted vertical emittance in these plots might be further reduced by re-optimizing the setting of skew magnets. Obviously, repeated measurements and careful studies are needed, and the results shown here should be considered preliminary. It appears that the following points play an important role.

1. Tuning with skew knobs in the arc sections of the DR for reducing the betatron coupling in the ring.
2. Careful corrections for residual dispersion in EXT.
3. Additional cross-plane coupling correction using a skew quadrupole magnet in EXT, upstream of the wire scanners.

Beam Tuning and Diagnostics in Damping Ring

COD and Dispersion: The program SAD is used in orbit and dispersion corrections, for calculating new setting of the steering magnets. The results of the COD correction in DR were 2mm (peak to peak) horizontally with 1mm expected from simulations and 1mm vertically. The dispersion in the DR is measured as difference of orbits with different RF frequencies. The dispersion correction in the ring worked and typical r.m.s. of the vertical dispersion after the correction was about 5 mm which is close to our target.

X-Y Coupling Corrections: To correct x-y coupling, trim coils of the all sextupole magnets are connected to produce skew quadrupole field. A global correction of the coupling is essential to achieve the smaller emittance. We tried a global coupling correction minimizing vertical COD response to horizontal steering. The orbit coupling was clearly reduced and some reduction of the vertical emittance was observed after the correction. We also tried a coupling correction by 4 dedicated skew quadrupoles and achieved some reduction in the vertical beam size at the SR source point.

Local orbit bumps were also used for low vertical emittance tuning. Setting many bumps one-by-one the vertical beam size was monitored using SR-interferometer.

We tried new coupling correction using orbit response matrix (ORM) analysis. It has been confirmed that ORM analysis is a technique used to diagnose and correct optics errors in storage rings. Recently, we achieved and confirmed the normalized vertical emittance of 0.015µm at a bunch charge of (7.0+/-0.2)x10^{9} electrons in the ATF ring by ORM analysis and the laser wire monitor [8,9].

New Extraction Kickers with a Flat-top Longer than 300ns

A project to replace the extraction kicker system in the ATF damping ring was collaboration between KEK and SLAC. A SLAC epoxy kicker system was prepared. At the same time, a modification to the kicker pulse was introduced so that flat-top of pulse lengths 340ns was achieved. This allows us to experimentally examine the implications to the beam instrumentation hardware and component stabilization issues in conditions similar to ILC. A team of accelerator physicists from KEK and SLAC succeeded in extracting 3 bunches of electron beam at 154 ns duration and 2 bunches at 336 ns duration in Fall, 2005 (Fig.3), a milestone in realizing the beam control operation mode required in the ILC.

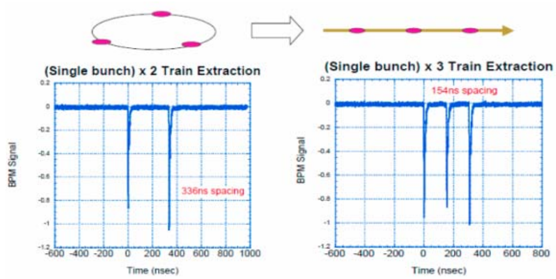

Figure 3: ILC-like beam extraction at ATF.

Polarized Positron Beam Generation

The proof of principle experiment for polarized positron beam generation based on backward-Compton scattering has been done at EXT. Almost 100% circular polarized gamma-ray was generated at about 56MeV with 2.2×10^{7} photons/collision. The polarization of the positron beam which was generated through the process of pair-creation at the gamma-ray target has been measured by the transmission method of gamma-ray related Compton scattering in magnetized iron. Detail report was published soon[10].

Development of a Fast strip-line Kicker

In the present ILC design baseline, the damping rings must store up to ~5600 bunches in a ~6 km circumference and provide the main linacs with the bunches spaced apart by ~150ns or ~300ns. Thus, the injection and extraction kickers have to realize 3.0nsec rise and fall times at a repetition rate of 3MHz or 6MHz. A collaboration was formed among KEK, SLAC, DESY, LBNL and LLNL in the Fall of 2004 to address this issue. In Spring, 2005, three flavors of pulse circuits (built by DESY, SLAC/LLNL and KEK) were used to test-drive a stripline kicker (prepared by KEK), which was installed at the ATF damping ring. Fig.4 shows a beam kick angle measured with the BPMs while scanning the kicker timing with respect to the bunch arrival. It demonstrates the rise and fall times of 2.2 ns and 3.0 ns, respectively, as achieved with two commercially available 5kV fast pulses and with two 32.7cm long strip line kickers. This R&D program will continue and will attempt to demonstrate the beam extraction, to check the stability and reliability, and to check the effects on previous and following bunches.

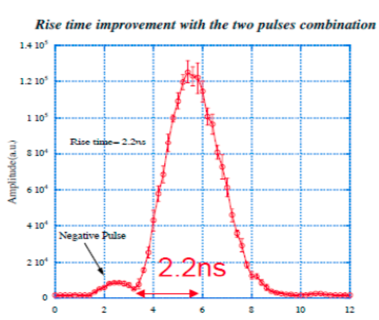

Figure 4: Beam kick amplitude vs timing.

Beam Position Monitors

Fig.5 shows the schematic design of a beam position monitor unit that has been used at the ATF damping ring. In 2005-2006, collaborators from SLAC tested a new signal processing circuit which average the BPM signals over a prescribed number of turns for improved resolution. Fig.6 overlays the measured beam position data from the BPMs with existing and test circuits. A dramatic improvement, close to a sub-micron level, has been demonstrated. We will improve all signal processing circuits of the damping ring BPM by the end of 2008 in order to reduce vertical emittance near 1pm.

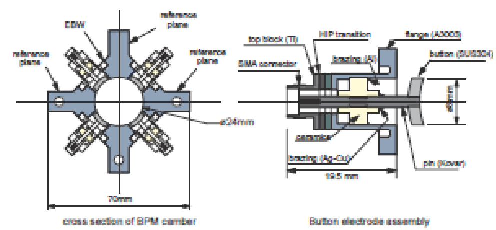

Figure 5: Schematic view of an ATF damping ring BPM.

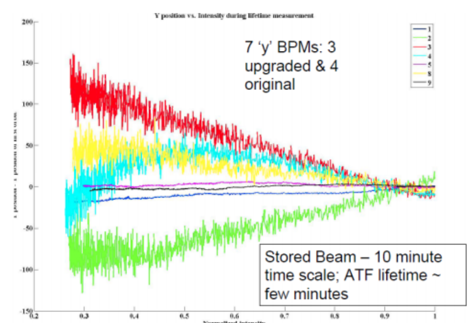

Figure 6: Position data of the stored beam, as function of the bunch intensity. Data from BPMs with the old, existing readout circuits and with new test circuits are overlaid.

FUTURE PLANS FOR ILC AT ATF/ATF2

ATF2

ATF2 is a scaled model of the ILC Beam Delivery System which transports, focuses and controls the low-emittance beam at an interaction point. Two major goals of ATF2 are: (1) to focus the beam vertically at 37nm with the local chromaticity correction scheme and (2) to control beam position with a few nm vertical jitter at the focus point, by taking advantage of the ultra-low emittance beam at ATF.

The ATF2 beam line in the latest design comprises 26 standard quadrupole magnets, a doublet of final quadrupole magnets, 5 sextupole magnets and 3 bending magnets. Fig.7 shows the layout of ATF2. Each of the quadrupole and sextupole magnets features a cavity type BPM (Beam Position Monitor, QBPM) with 100nm position resolution. In JFY2005-2006, 28 standard Q-magnets and 26 QBPM were produced by groups at IHEP (China) and PAL (Korea), respectively. The electronics of QBPMs with digital readout have been designed at SLAC and are under construction there.

The schedule of ATF2 construction and beam commissioning/operation was fixed at 3rd ATF2 project meeting and approved by ICB and TB. Fig.8 shows the final schedule of ATF2. Both the ATF and ATF2 will be managed to serve the mission of providing the young scientists and engineers with training opportunities in R&D programs for advanced accelerator technologies.

Future plans of fast kicker R&D and beam instability studies

R&D on fast kicker is going to check the performance of the system with 2.8ns 20-bunch train. Preliminary results indicate the possibility of beam extraction without kick effect into adjacent bunch. We consider more detail study of the system is necessary.

The fast ion instability, micro-wave instability and non-linear beam dynamics studies are underway to obtain important information for the ILC damping ring design. Several international groups already proposed the plan and we are discussing the details on each study soon.

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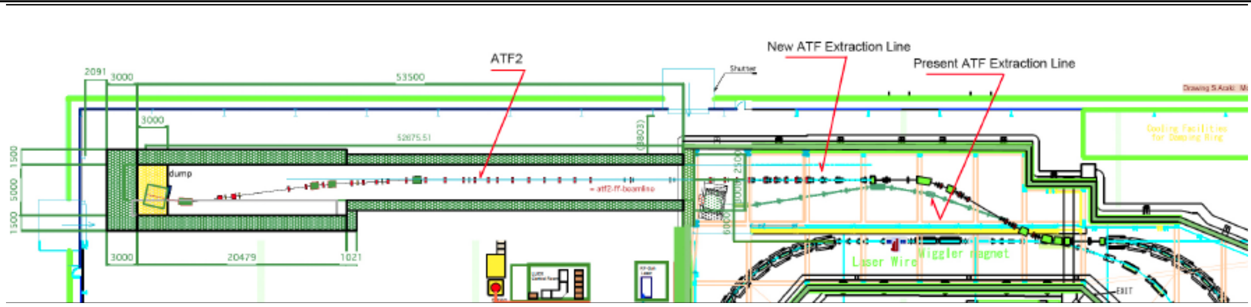

Figure 7: Layout of ATF2.

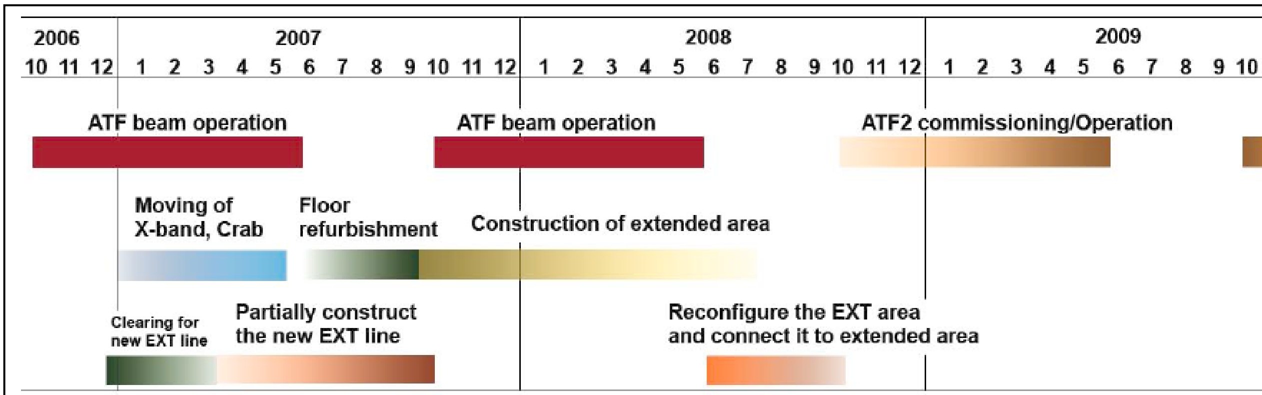

Figure 8: Schedule of ATF2 construction and commissioning/operation.