STATUS OF THE KEKB PROJECT

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Abstract

KEKB, KEK B-Factory, is an asymmetric energy, two-ring, electron-positron collider for B-physics, and is now under construction at KEK. Machine study done at the accumulation ring, AR, of TRISTAN, in 1996 showed that HOM-free normal-conducting cavities, called ARES, and superconducting, single-cell, single-mode cavities being developed could be used for KEKB. Fast beam-ion instability was also studied experimentally. Installation of equipment in the tunnel started in February 1997. Commissioning of the machine will start from the upgraded injector linac in May 1998 to the two rings in October 1998. We anticipate beam collision toward the end of the year, which will be followed by the start of physics experiment in early 1999.

1.INTRODUCTION

KEKB[1][2][3] is one of the two B-Factories under construction in the world. Energies of the KEKB rings were set at 3.5 GeV for the positron ring (LER) and 8 GeV for the electron ring (HER). In order to facilitate direct injection into the rings and increase the intensity of positrons, the present 2.5 GeV linac is now being upgraded up to 8 GeV. The positron production taget will be moved from the present 0.2 GeV position to the place where 3.7 GeV electrons hit the target. A new 150 m tunnel is being constructed to accommodate transport lines between the upgraded linac and the KEKB rings.

Two rings of KEKB are housed in the TRISTAN tunnel of 3000 m circumference and installed side by side. At the center of one of the four long straight sections of the tunnel, we have an interaction point, IP, where BELLE[4] detector will be installed.

Even though we try to squeeze βy^* at IP to 1 cm, the design luminosity goal of KEKB, 10^{34}cm^{-2}s^{-1}, requires high stored currents of 2.6 A at LER and 1.1 A at HER distributed into 5000 bunches. These large currents and large number of bunches oblige us to use special higher-mode free and beam-loading proof accelerating cavities to prevent coupled-bunch instablities. Two types of cavities, normal-conducting ARES cavity and superconduction single-cell, single-mode cavity, SCC, are being developed. We adopt copper vacuum ducts for both rings that can sustain large heat load, have a smaller photo-desorption coefficient and have good self-shielding capability of synchrotron lights.

The most salient feature of KEKB is a finite-angle crossing scheme at IP. Electron beam and positron beam collide at ± 11 mrad. This crossing scheme makes any use of separation dipole magnets unnecessary; the interaction region becomes simple and facilitates the shortest bunch spacing of 0.59 m. Although simulation studies have not shown any degradation of luminosity and significant increase of tails due to synchrobetatron resonances excited by the finite-angle crossing, we are rather prudent and developing crab cavities as a backup system. Orientation of incoming bunches of electrons and positrons is tilted by crab cavities by 11 mrad; the electron and positron bunches collide head-on at IP in the center-of-mass frame.

Figure 1 shows the layout of KEKB, and Table 1 summarizes its parameters.

Table 1 Main Parameters of KEKB

Ring	LER		HER
Energy(GeV)	3.5		8.0
Circumference(m)		3016.26	
Luminosity(cm^{-2}s^{-1})		1×10^{34}	
Crossing angle(mrad)		± 11	
Tune shifts		0.039/0.052	
Beam function at IP(m)		0.33/0.01	
Beam current(A)	2.6		1.1
Natural bunch length(cm)		0.4	
Bunch spacing(m)		0.59	
Emittance(m)		$1.8\times10^{-8}/3.6\times10^{-10}$	
Energy loss/turn(MeV)	$0.81^{\dagger}/1.5^{\dagger\dagger}$		3.5
RF voltage(MV)	5 ~ 10		10 ~ 20
RF frequency(MHz)		508.887	

† without wigglers
†† with wigglers

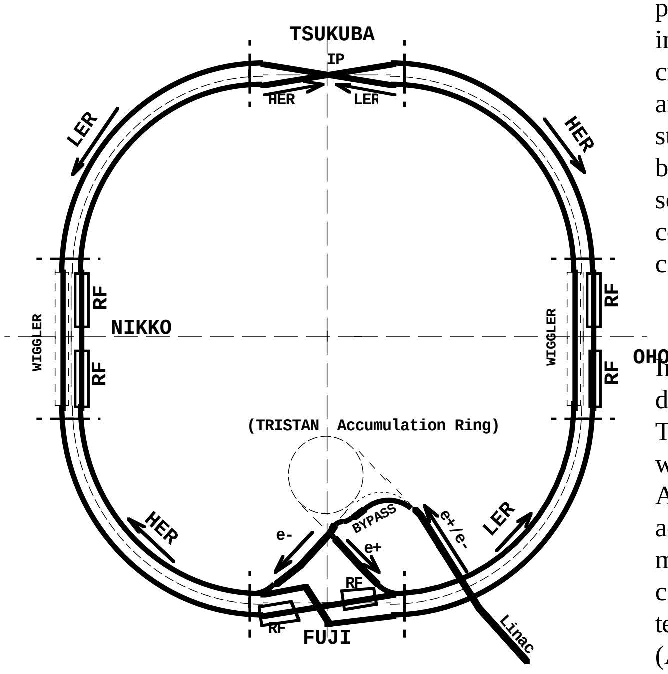

Fig. 1 Configuration of KEKB accelerator system

2. PRESENT STATUS OF CONSTRUCTION

2.1 Magnets and its installation

One thousand and six hundred main magnets and 1700 steering magnets are used at KEKB. Among them 119 dipoles and 313 quadrupoles of HER are refurbished magnets from TRISTAN. Except for small number of correction magnets and special quadrupoles near IP, all magnets have been ordered and delivery of magnets started in December 1996. Magnetic measurement systems became ready in January 1997 and have been in full operation from February. Forty magnets are measured per week.

Since two rings are installed side by side and only 1.1 m is available for transportation of magnets, we made two hovercraft-type transporters. Magnets started in late February 1977. Installation of magnets located at outer side of the tunnel will be installed first by this summer, which will be followed by the installation of magnets at inner side of the tunnel.

2.2 Vacuum system

By 1996 90% of copper vacuum ducts and their components had been ordered to companies. The delivery of the vacuum ducts started in September 1996. Vacuum ducts are baked, leak-checked, filled with dry nitrogen gas and stocked before being installed.

2.3 Interaction region

Basic iron structure of BELLE detector was completed and temporarily moved in to IP in April 1997 for surveying its position with respect to accelerator components. A pair of superconducting final-focus quadrupoles will be installed at both sides of IP inside the detector. One cryostat contains one superconducting quadrupole, one anti-solenoid, one correction skew quadrupole and two steering dipoles. The first full set of these coils have been completed and a test in a vertical cryostat will start soon. The superconducting magnet system will be completed by this summer and in September 1997 a combined test with the BELLE solenoid will begin.

3. CAVITIES AND AR BEAM TEST

In June, July and November 1996, we had a series of dedicated beam tests at the accumulation ring, AR, of TRISTAN[5]. All APS-type normal-conducting cavities were replaced with cavities of KEKB, namely, two ARESs, and one SCC. ARES consists of three cells: an accelerating cell, an energy-storage cell operated in TE013 mode, and a coupling cell that connects the accelerating cell and the energy-storage cell. Two ARESs that were tested differed from each other in that one type of ARES (ARES-95) used a choke-mode type cavity as its accelerating cell and the the other (ARES-96) had an accelerating cell with four wave-guide HOM dampers attached to the side of the cell.

Throughout the beam tests, AR was filled with electrons and operated at 2.5 GeV. We oftained the following results concerning ARES[6]:

(1) We could stably store 500 mA of the total current with both types of ARES operated at 0.5 MV. No serious HOM modes were found to be excited by beams.

(2) Power absorbed by HOM dampers attached to the accelerating cell and that absorbed by a damper attached to the coupling cell agreed well with the design.

(3) Concerning the fundamental RF property such as the detuning frequency, transient response, etc., we did not find any serious disagreement between the experiment and theoretical calculation.

The results we obtained about SCC are summarized as follows[7]:

(1) By the use of SCC operated at 1.2 MV, we could store 573 mA. This current was not limited by the cavity but by the radiation level around AR. No serious HOM modes were excited in SCC.

(2) The maximum accelerating voltage achieved was 2.5 MV that corresponded to the field gradient of 10.3 MV/m.

(3) We encountered rather frequent trips of the cavity in the July run. During summer shutdown we increased the pumping power of ducts close to the cavity and lowered the vacuum pressure by more than one order of magnitude. This worked well: in the November run, we observed almost no trips of the cavity.

(4) SCC has two cyrindrical HOM ferrite absorbers attached to the vacuum ducts at both ends of the cavity. Maximum HOM power absorbed by these absorbers amounted to 4.2 kW, which was very close to the expected value of 5 kW when the cavity is used at HER.

Encouraged by the results of the beam tests, we have decided to use both types of cavities. By the commissioning, we will install 10 ARESs at LER, and 4 SCCs and 12 ARESs at HER.

4. FAST ION INSTABILITY AND PHOTOELECTRON INSTABILITY

The following two new instabilities are expected to be serious at B-Factories.

4.1 Fast ion instability

Even though we have a long enough bunch gap at the electron ring and all ions are cleared during the gap, ions created within a passage of a bunch train excites strong coupled-bunch oscillation in the train. The amplitude of the oscillation grows as the bunch number counted from the head of the train increases. This is the fast ion instability, FII[8].

At AR we studied FII[9]. We stored 100 to 200 electron bunches in AR at 2.5 GeV and observed the spectrum of beam oscillation. If the current was high enough, strong vertical betatron oscillations were observed. After the stored current decreased and the vertical oscillations died out, we injected nitrogen gas in the ring. Strong coupled-bunch oscillations were excited again. The oscillation amplitudes of bunches in the train were registered for 1600 turns on a transient memory system. Analysis shows that the amplitude of the oscillation grows along the bunch train. The phase advance between bunches was consistent with that determinded by the ion oscillation frequency.

4.2 Photoelectron instability

In a positron ring, photoelectrons created by synchrotron lights at the inner surface of the vacuum duct are attracted by the beam. Although electrons are swept out rather quickly (within a few times ten nanoseconds), a stationary distribution of electrons (electron cloud) is established by continuous production and clearing of electrons. Transversely displaced bunches disturb the elctron cloud, which then exerts forces on subsequent bunches. The oscillations of bunches may resonantly couple via the electron cloud and lead to a coupled-bunch instability called photoelectron instability, PEI[10].

There had been only one experiment on the PEI performed at KEK PF[11]. The experiment showed that positron bunches stored at PF ring started to oscillate vertically if the current became larger than a threshold. The spectrum showed a pattern that was similar to that of oscillations excited by a wake field of 10-20 nsec range.

In order to verify the PF experiment and clarify the details of PEI, we conducted a series of experiments at BEPC of IHEP as a joint collaboration beween KEK and IHEP. These experiments clearly confirmed the result of the PF experiment[12]: The vertical betatron oscillations were observed only for the positron beam; The spectrum of the betatron oscillation was distributed around 50 MHz range that indicated that the range of force was 15-20 nsec. The study will be continued in 1997.

5. MILESTONES

We have set the following new milestones taking into account the progress of the construction. See Table 2.

Table 2 Milestones of KEKB

date		Milestones
1994	April	start of construction
1995	July	bidding for LER main equipment
	Dec.	start of dismantling of TRISTAN
1996	Mar.	end of dismantling
	June	bidding for HER main equipment and final focus sperconducting quadrupoles
	July	beam test at AR
	Oct.	beam test at AR
	Nov.	beam test at AR
	Dec.	start of bypass tunnel construction
1997	Feb.	start of installation of magnets
	Oct.	completion of bypass tunnel
1998	May	upgraded linac commissioning
	Oct.	LER and HER commissioning
1999	early	physics run starts

ACKNOWLEDGMENT

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