Status of TRISTAN-II Project

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Abstract

TRISTAN-II (B-Factory) is a 3.5 x 8 GeV, two-ring, electron-positron collider in the existing TRISTAN tunnel and aims at detecting the CP-violation effect at B-mesons. The final goal of the luminosity is 10^{34} $cm^{-2}s^{-1}$. Progress of design work and the present status of R&D are reported.

I. INTRODUCTION

The design of the B-Factory at KEK has converged to that on the basis of existing TRISTAN[1], hence the name TRISTAN-II: Two rings of the TRISTAN-II are to be installed in the existing TRISTAN tunnel and the infrastructure of TRISTAN will be maximally utilized. For the moment we plan to have only one interaction point in the rings where electrons and positrons collide with each other. The 2.5 GeV electron linac will be upgraded to 8 GeV in order to inject 3.5 GeV positrons and 8 GeV electrons directly into TRISTAN-II.

We plan to increase the luminosity of TRISTAN-II in two steps[2]. We will first employ a small-angle (± 2.8 mrad) crossing scheme (step 1), where we will fill every fifth bucket with beam. Three meter bunch spacing in this case (the RF frequency of TRISTAN-II is 508 MHz the same as that of TRISTAN) is long enough to install beam separation equipment, such as separation dipole magnets. The luminosity of step 1 is 2×10^{33} $cm^{-2}s^{-1}$. In the second step, we will fill every bucket with beam by introducing a large-angle crossing (~± 10 mrad) with crabbing[3,4]. The luminosity will be increased by a factor 5 to 10^{34} $cm^{-2}s^{-1}$. The machine parameters for both steps are essentially unchanged except the bunch spacing and the total current.

As shown in Fig.1 the detector will be installed at Fuji Experimental Hall of TRISTAN. Electrons and positrons are injected from the upgraded linac to TRISTAN-II at straight sections on both sides of the collision point. Two rings of TRISTAN-II will be installed side by side.

II. LATTICE DESIGN

A. Beam Parameters

The main parameters of the TRISTAN-II accelerators are given in Table 1. The values in parentheses correspond to those for step 1. The high-energy ring, HER, and the low-energy ring, LER, have the same circumferences, emittances, and the beta functions at IP. The large current, the large number of bunches and the small value of beta function at the interaction point are the salient features of TRISTAN-II.

B. Chromaticity Correction

It is desirable if we can inject beams into TRISTAN-II without changing the optics at injection from that of collision; we have been studying a non-interleaved sextupole chromaticity correction scheme expecting that this scheme enables us to have sufficient dynamic apertures at injection[5]. Between a pair of sextupoles no other sextupoles exist and the betatron phase advance is π in both horizontal and vertical planes. This scheme cancells the geometric aberrations of the sextupole by the -I transformation in a pair.

C. Low-α Lattice

In order to reduce the necessary accelerating RF voltage, V_c, we are studying another lattice with small values of α (the momentum compaction factor). The α's of LER and HER are 2.5×10^{-4} and 3.5×10^{-4}, respectively and corresponding V_c's 4.4 and 18 MV. The small synchrotron tunes in this case (0.017 in LER and 0.025 in HER) might mitigate the synchrobetatron resonances.

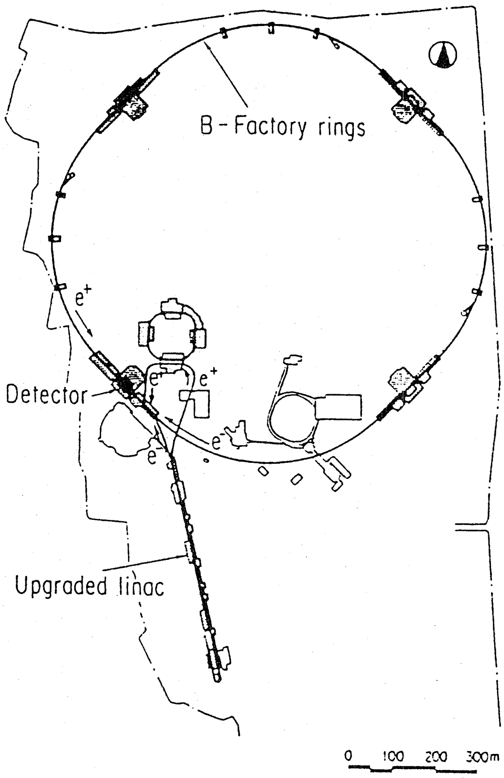

Fig. 1. Layout of TRISTAN-II within the KEK site.

III. COUPLED-BUNCH INSTABILITIES AND RF SYSTEM

A. Sources of Coupled-Bunch Instabilities

Large currents, many bunches and short distance between bunches cause strong coupled-bunch instabilities both in the

Table 1 Main parameters of TRISTAN-II

	LER	HER	
Energy	3.5	8.0	GeV
Circumference	3018		m
Luminosity	$1\times10^{34}(2\times10^{33})$		$\mathrm{cm}^{-2}\mathrm{s}^{-1}$
Tune shifts	0.05/0.05		
Beta function at IP	1.0/0.01		m
Beam current	2.6 (0.52)	1.1 (0.22)	A
Natural bunch length	0.5		cm
Energy spread	7.8×10^{-4}	7.3×10^{-4}	
Bunch spacing	0.6(3.0)		m
Particles/bunch	3.3×10^{10}	1.4×10^{10}	
Emittance	19/0.19		10^{-9}m
Synchrotron tune	0.064	0.070	
Betatron tune	~ 39	~ 39	
Momentum compaction	8.8×10^{-4}	1.0×10^{-3}	
Energy loss/turn	0.91	4.1	MeV
RF voltage	20	47	MV
RF frequency	508		MHz
Harmonic number	5120		
Damping decrement	2.6×10^{-4}	5.1×10^{-4}	
Bending radius	15.0	91.3	m
Length of bending magnet	0.42	2.56	m

Values in parentheses are for step 1.

transverse and longitudinal directions. Three sources of coupled-bunch instabilities are identified: (1) higher-order modes (HOM) of RF cavities (transverse and longitudinal); (2) accelerating mode of RF cavities (longitudinal); and (3) resistive wall of vacuum ducts (transverse).

B. Normalconducting RF cavity

To prevent the coupled-bunch instabilities due to HOMs we need special cavities with small HOM impedances. We have been studying a two-cell damped cavity[6], where the HOM fields are guided to waveguides attached to the side of the cavity through slots cut on the disk between cells; the cutoff frequency of the waveguides is set higher than the fundamental accelerating mode frequency.

The first prototype damped cavity has been completed and a low-power test is going on. Q-values of the most dangerous modes, TM110-π and TM011-π, were found to be as small as 41 and 14.

As an alternative of the two-cell damped cavity, the design of the choke-mode cavity[7] is under way at KEK.

C. Superconducting RF Cavity

The superconducting cavity for TRISTAN-II is a single-cell cavity with two large-aperture beam pipes attached to the cell (see Fig. 2). HOMs propagate toward the beam pipes, since their frequencies are above the cut-off frequencies of the beam pipes. The diameter of the one pipe is made larger than that of the other in order to make a few transverse modes otherwise trapped propagate. The iris between the cell and the larger beam pipe prevents the fundamental mode from propagating toward the beam pipe.

After having determined the optimized shape of the cavity by computer calculation, a full-size aluminum model was manufactured and resonance spectra of the cavity were measured with and without ferrite absorbers (TDK IB-004). The loaded Q values of HOMs were ~ 100 or less with absorbers, except two harmless quadrupole modes, TM210 and TE211.

A full-size Nb model with this optimized shape was constructed (see Fig. 2) and tested in a vertical cryostat. The maximum accelerating field obtained was 11 MV/m with a Q value of 10^9.

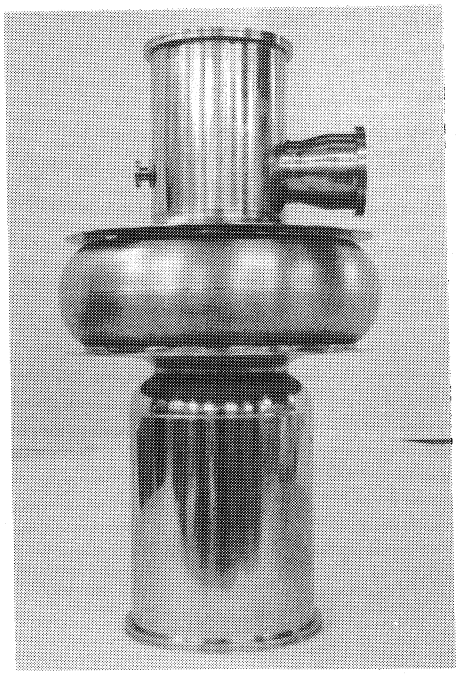

Fig. 2 Full-size Nb model cavity.

D. Coupled-Bunch Instability due to Fundamental Mode

Extremely heavy beam loading to the cavity, together with the small revolution frequency, leads to a quite violent longitudinal coupled-bunch instability. As the beam current increases, the resonant frequency of the fundamental mode should be moved down to minimize the reflection power from the cavities. The amount of frequency detuning Δf is given by

$$\frac{\Delta f}{f_{RF}} = \frac{I}{2\,\frac{V_c}{N_{cell}}}\,\frac{R_s}{Q_0}\,\sin\phi \quad ,$$

where I denotes the total beam current, V_c the total RF voltage, N_{cell} the number of cells, R_s the shunt impedance per cell, Q_0 the unloaded Q value and ϕ the synchronous phase. At LER the necessary detuning frequency is more than three times as large as the revolution frequency. The unstable coupled-bunch instability modes lie at the frequency, $Nf_0 + f_s$, where N is an integer, f_0 the revolution frequency and f_s the synchrotron frequency; the resonant frequency of the cavity passes three coupled-bunch instability modes as the beam current increases. The growth time becomes as small as 4.8

μs in the worst case.

The most straightforward way to avoid this instability is to employ superconducting cavities. The detuning frequency for superconducting cavities is much smaller than that for normalconducting cavities because of a high field gradient and a low R_s/Q_0 value. This small detuning frequency together with the large loaded Q value of superconducting cavities make the growth time of the coupled-bunch instability as long as 23 ms (loaded Q of 2.5×10^5 is assumed). Another possible cure for this instability is so-called RF feedback system[8].

E. Energy Storage Cavity

T. Shintake of KEK proposed to add an low-loss energy storage cell to a normalconducting accelerating cavity cell in order to suppress the coupled-bunch instabilities due to the fundamental mode[9]. This storage cell effectively enlarge the stored energy and the loaded Q value and reduces the R_s/Q_0. The growth time becomes long enough to make RF feedback unnecessary even for normalconducting cavities. We are investigating the feasibility and applicability of the idea to TRISTAN-II[10].

IV. VACUUM SYSTEM

Copper has some advantages over Al as a material for vacuum ducts for TRISTAN-II. It shows a small photodesorption coefficient, η, compared with Al, and has good radiation shielding capability.

A trial model Cu duct was fabricated. The duct is straight and 3.7 m long and consists of a beam channel (100 mm in width and 50 mm in height), a pump channel and a cooling channel. The duct material is Oxide Free Copper provided from HITACHI Cable, Ltd. Each channel was independently extruded in a circular-pipe shape with a proper size and then extracted to its design shape. They were welded each other by EBW. The thermal gas desorption rate and photodesorption coefficient of the duct were measured. New models with a simplified shape are now under construction.

V. SEPARATION DIPOLE MAGNET

The separation superconducting dipole magnets will be installed close to the vertex detector and the precision drift chamber. In order to reduce the leakage field, this magnet has two layers of cosθ windings[11]. The maximum leakage field at the surface of the cryostat is less than 50 Gauss. The first prototype magnet is under construction.

VI. LINAC UPGRADE

The 2.5 GeV linac will be upgraded by adding accelerating structures and replacing 20 MW klystrons with 60 MW ones. SLEDs are used to increase the field gradient. After this upgrade, the linac can accelerate 8 GeV electrons, which will be injected directly into HER. Positrons are produced by 4 GeV electrons and accelerated up to 3.5 GeV before being injected directly to LER. The intensity of positrons after this upgrade will be 3.2×10^9 per pulse; this corresponds to 1000 sec injection time to LER with a 50 Hz repetition rate.

VII. MACHINE STUDY PLAN

A. Beam Test of RF Cavities and Feedback Systems at the TRISTAN AR

Three-month long beam test is planned to be held in 1995 by the use of TRISTAN Accumulation Ring (AR). We plan to store more than 500 mA electron beam in AR with a multibunch mode at 2.5 GeV. The bunch spacing is 10 nsec and the total number of bunches amount to 128. To accumulate this high current, the existing APS type RF cavities will be removed temporally from the ring and a normal conducting damped cavity and a single cell superconducting cavity will be installed. The transverse and longitudinal feedback systems will be also installed.

B. Dynamic Aperture Study

Since the non-interleaved sextupole scheme has never been adopted in real machines, we must be very careful introducing this scheme. We have a plan to carry out a machine study on this scheme in this autumn at TRISTAN which needs a dedicated machine time of about a month. Measured and calculated dynamic apertures will be compared.

VIII. PROSPECTS

We envision that construction of TRISTAN-II will start from April 1994 and by the end of 1998 the commissioning will take place.

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