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CONSTRUCTION STATUS OF SUPERKEKB

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Abstract

SuperKEKB consists of 7 GeV electron and 4 GeV positron main rings (HER and LER), a newly built positron damping ring (DR) and an injector linac. Construction of SuperKEKB is progressing on schedule, and beam commissioning is scheduled in 2015. Fabrication, treatment and installation of vacuum components, magnets and power supplies, and beam diagnostic and feedback systems are ongoing. Improvement of RF system and strengthening of cooling system for magnets and beam pipes are also underway. Detailed design of the interaction region has been finalized, and final focus superconducting magnets are under production. The damping ring tunnel and buildings have been completed, and the installation of the accelerator components has started. The upgrade of the injector linac is also progressing. This paper describes construction status of SuperKEKB main rings and the damping ring as well as recent design progress.

INTRODUCTION

SuperKEKB was approved by the Japanese government as an upgrade of KEKB partially in 2010, and fully in 2011. The target luminosity is 8×10^{35} $cm^{-2}s^{-1}$, which is 40 times higher than that achieved at KEKB. The design of SuperKEKB is based on the Nano Beam Scheme [1]. In this scheme, a large horizontal crossing angle between the beams at the interaction point (IP) is introduced to shorten the longitudinal crossing region, which makes it possible to reduce β_y^*. At the same time, the stored beam currents in both rings will be approximately double that of KEKB. Design parameters and important features of the SuperKEKB design are shown elesewhere [2-4].

CONSTRUCTION STATUS

Commissioning Scenario

Based on the discussion between the accelerator group and the Belle II detector group, the commissioning will be performed in three phases.

- Phase 1: The LER and HER will be commissioned without final focus superconducting magnets (QCS) and the Belle II detector. Basic machine tuning, low emittance beam tuning and sufficient vacuum scrubbing of both rings will be performed. After about five months operation the machine will be temporarily stopped for the installation of QCS and Belle II roll in.
- Phase 2: Beam operation resumes with QCS and Belle II, but no vertex detectors. Collision tuning by gradually squeezing β_y^* and background studies will be performed.
- Phase 3: Physics run starts with the vertex detectors. Beam current will be increased by adding more RF stations. Beam tuning will continue to increase the luminosity.

Construction Schedule

With various boundary conditions such as budgetary profile, design progress, technical issues and civil engineering, the construction of SuperKEKB is optimized to meet the commissioning scenario described above as much as possible. The construction of the LER and HER for the Phase 1 commissioning is in the final stage, and will be completed in Japanese fiscal year (JFY) 2014, as scheduled. (JFY is from April to March.) Subsequently, preparation works to start the beam operation, including high-power conditioning of RF cavities and final alignment of magnets around the ring, will be conducted prior to the Phase 1 commissioning. Meanwhile, production of the QCS and other components needed for Phase 2 is ongoing to be in time for the Phase 2 commissioning.

The construction of the DR is underway and the commissioning will start before Phase 2, when the DR is indispensable to reduce the emittance of the positron beam before injecting into the LER with a small aperture around the IP of Phase 2.

Arc and Wiggler Sections

Vacuum System The mass production of beam pipes at companies and surface treatment such as TiN coating and baking performed at the Oho laboratory in KEK are near completion. More than 850 beam pipes have been TiN-coated; the goal is about 1000 beam pipes. The installation of aluminum antechamber-type beam pipes in the LER arc sections (Fig. 1 (left)) and cupper antechamber-type beam pipes for the wiggler sections in the LER and HER has been finished. The connection of bellows chambers started in JFY2013, and some of the sectors were already evacuated.

Magnet System Production of more than 500 new magnets as well as field measurement of most of them has been completed. The old 1m length 100 main dipole magnets in the LER arc sections were replaced with new 4m length ones, as shown in Fig. 1 (upper right). The rearrangement of the LER wiggler sections with new half pole and single pole magnets added to the existing double pole ones has been completed. The installation of reuse LER wiggler magnets into the HER has also been completed (Fig. 1 (lower right)). Twenty-four sextupole magnets have been modified to mount on the tilting tables, which makes it possible to tilt the magnets by ± 30 degrees.

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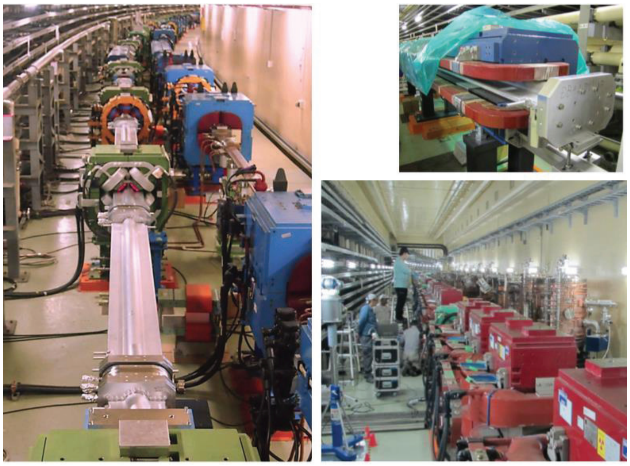

Figure 1: (left): The alminum antechamber-type beam pipes installed in the LER arc section. (upper right): A new dipole magnet in the LER with an antechamber inside. (lower right): Wiggler magnets for the HER and the ARES cavities in the LER moved from the HER.

Interaction Region

Tsukuba Straight Section The magnets and beam pipes of both rings in the Tsukuba straight section that extend about 100 m to either side of the IP were completely removed to build new beam lines. The installation of new magnets in this section has been finished (Fig. 2) except for several magnets close to the IP, which are currently being installed. The beam pipes in the Tsukuba section will be installed in JFY2014.

The beam pipes, radiation shielding and support structure close to the IP have different designs for Phase 1 (without collision) and Phase 2 (with QCS and Belle II). Construction of those for Phase 1 will be completed in JFY2014. The detail design of those for Phase 2 is ongoing.

Figure 2: Magnets installed for new beam lines in the Tsukuba straight section.

Final Focus Superconducting Magnets Eight superconducting main quadrupole magnets are utilized as doublets for vertical (QC1's) and horizontal (QC2's) focus. The QC1LP, QC1LE and QC2LP magnets for the left side of the IP have been completed. Field measurements of these magnets at 4K in KEK [5] showed the required performances. Each main magnet has correction coils fabricated under the BNL/KEK collaboration program [6]. The 20 corrector coils for the left system were completed in JFY2013. The field qualities of the corrector coils were measured at room temperature in BNL, and the excitation performances at 4K were conformed in KEK. Cryostats for the left side magnets [7] will be completed in JFY2014. The main coils for the right side of the IP have also been fabricated, and the cryostats will be completed by the summer of 2015. Figure 3 shows six of eight main quadrupole magnets.

In order to calculate the magnetic field profile precisely in the IR, the 3D model are now being built [8].

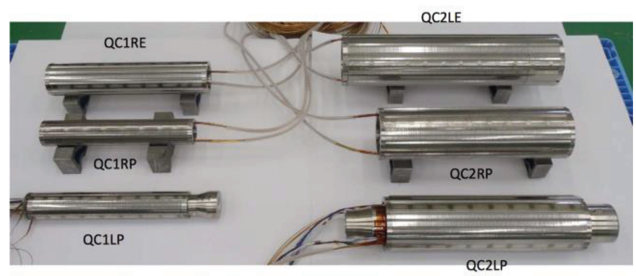

Figure 3: Final focus superconducting magnets.

RF, Monitor and Control

RF System The RF system needs to be more intensified for the higher beam currents and larger beam power than KEKB. In order to feed more power to each ARES cavity, the RF stations are changed to a new scheme, where one klystron powers one ARES cavity. (In KEKB, each klystron drived two ARES cavities.) The rearrangement of ARES cavities has been done. Construction of five new RF stations is near completion. More RF stations will be added after Phase 2.

A new low-level RF (LLRF) control system, which is composed of μTCA-platformed FPGA boards with embedded EPICS-IOC, has been developed. Nine LLRF stations among thirty stations will be replaced with new systems before the Phase 1 commissioning [9].

Monitor and Control System One hundred and twenty 509MHz narrowband detectors for BPMs have been fabricated. Gated turn-by-turn BPM detectors have also been fabricated. Most of the components for the bunch-by-bunch feedback system have been installed. The improvement of mirrors for the visible SR monitor and development of X-ray monitor for beam size measurement are ongoing. Improvements of computers, network system and control software are also underway [10].

Damping Ring

Facility and Infrastructure Construction of the tunnel for the DR and new beam transport lines for the injection from the Linac to the DR and for the extraction from the DR to the Linac was completed in JFY2012 (Fig. 4).

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Construction of a new building that houses power supplies for magnets, a klystron and high power RF system and control systems and another building for cooling water system has been completed in JFY2013. These facilities are now ready to install accelerator components.

Accelerator components for DR A newly designed accelerating cavity for the DR based on HOM-damped structure of the ARES cavity has been successfully high-power tested; stable operation exceeding the design voltage of 0.8 MV/cavity was confirmed. The second production cavity has been completed, and high-power test is underway. Production of other components such as magnets, power supplies, beam pipes, monitors and control systems are ongoing. The installation of magnets and cables into the tunnel started in May 2014.

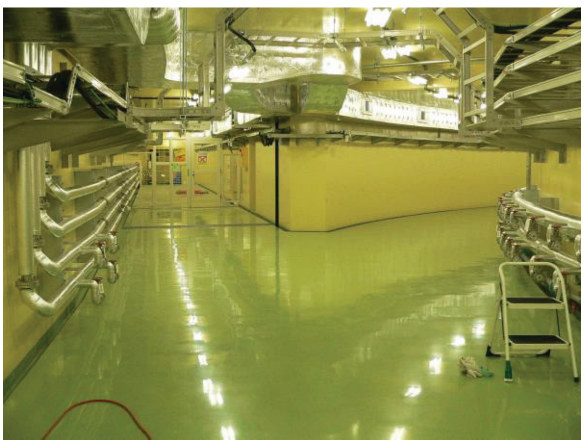

Figure 4: Damping ring tunnel.

RECENT DESIGN PROGRESS

Because of very small β_y^*, the transverse dynamic apertures of both LER and HER are mainly limited by nonlinear magnetic fields around the IP. Higher-order (sextupole, skew sextupole, and octupole) corrector coils of QCS are carefully arranged from the viewpoint of error correction and dynamic aperture optimization [11].

In recent simulation studies, it has been found that the beam-beam interaction also significantly reduces the transverse dynamic aperture, in particular around the on-momentum region [12]. By re-optimizing sextupole and octupole fields, the dynamic aperture of the HER is almost recovered to keep the Touschek lifetime acceptable (~600 sec). On the other hand, the LER dynamic aperture has not yet been recovered well so far, even with searching a better working point of the betatron tunes in addition to the optimization of the nonlinear fields.

The crab waist scheme [1] is being considered as one of the countermeasures against the dynamic aperture reduction. In simulations, the ideal crab waist without introducing any additional nonlinearities has considerably improved the dynamic aperture with the beam-beam interaction.

However, realistic lattice design for SuperKEKB has not yet been found. In an example lattice for the crab waist as shown in Fig. 5, cancellation of the nonlinearity between the crab waist sextupoles does not fully work because of the nonlinear fields around the IP, thus the dynamic aperture is drastically decreased. Any substantial improvements on the crab waist lattice and other various countermeasures are now being studied.

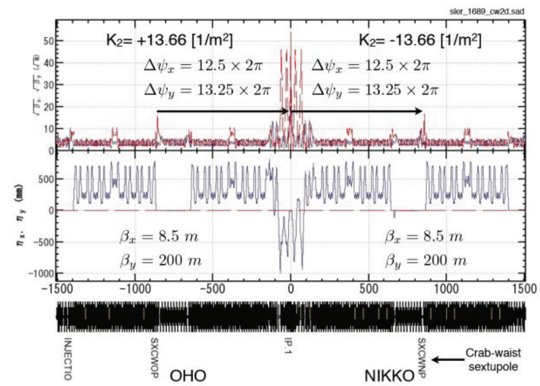

Figure 5: Example of the crab waist lattice (Y. Ohnishi et al.).

SUMMARY

Construction of SuperKEKB main rings (LER and HER) and the positron DR is progressing on schedule. The Phase 1 beam commissioning will be started in 2015. Countermeasures to recover the transverse dynamic aperture reduction due to the beam-beam interaction are being studied.

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