The Tenth KEKB Accelerator Review Committee Report

Introduction

The Tenth KEKB Accelerator Review Committee meeting was held on February 21-23, 2005. The Committee welcomed two new members: Trevor Linnecar from CERN, an accelerator RF system expert and Heino Henke from Berlin Technical University, an RF, impedance and instability expert. In addition, since John Seeman from PEP-II at SLAC was unable to attend, Nadine Kurita, the PEP-II chief engineer, replaced him for this meeting. Oswald Gröbner and Georg Hoffstaetter were unable to attend this meeting and Masanori Kobayashi has retired. Appendix A shows the present membership of the Committee.

The tenth Committee meeting followed the usual format of oral presentations by the KEKB staff members and discussion by the Committee members. The Agenda for the meeting is shown in Appendix B. The first day concentrated on KEKB performance and, in particular, the progress on the crab cavity, and on the second day, the talks addressed the R&D towards SuperKEKB. The Committee was again impressed by the high standard of the talks, both the technical content and the presentations themselves. The recommendations of the Committee were presented to the KEKB staff members before the close of the meeting. The Committee wrote a draft report during the meeting that was then improved and finalized by e-mail among the Committee members.

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A) Executive Summary

1) Foreword

KEKB continued to make excellent progress since the last Committee meeting. The peak luminosity has increased to a new world record of 1.52 x 10^{34} $cm^{-2}s^{-1}$, 50% above the design luminosity of 10^{34} $cm^{-2}s^{-1}$ (at this time last year it was 1.16 x 10^{34} $cm^{-2}s^{-1}$). The Committee congratulates the entire KEKB project staff on this new record. Continuous injection has been in regular operation since January 2004, and has helped to increase the daily integrated luminosity by almost a factor of two since last year. The BELLE detector has accumulated 365 fb^{-1}, another world record (197.5fb^{-1} last year) and has published, or submitted for publication, a total of 120 papers in refereed journals (83 last year). Immediately before the meeting a new record was broken – accumulating 1000pb^{-1} in a single day. This is an indication of how well all facets of the operation are functioning. The first day of the meeting was devoted to the present status of KEKB and the progress with the crab cavity, while the second day covered the plans for upgrading KEKB to a luminosity of 1-5 x 10^{35} $cm^{-2}s^{-1}$. The KEKB machine group has done an enormous amount of excellent work, and is to be congratulated on the impressive results that have been achieved.

2) Summary

KEKB continued to make excellent progress over the last year, increasing all of the worldwide luminosity records: highest peak luminosity: 1.516 x 10^{34} $cm^{-2}s^{-1}$, highest daily integrated luminosity: 1.083 fb^{-1}, highest weekly integrated luminosity: 6.242 fb^{-1}, and highest 30-day luminosity: 24 fb^{-1}. A bellows in the LER near the IP was damaged on November 3. The current had to be limited to below 900 mA (it was 1650 mA before the incident) reducing the luminosity until a repair could be carried out during the winter shutdown. It is expected that the luminosity will continue to slowly increase during the year, but no large factors of improvement seem likely until the crab cavities can be installed. The KEKB team has made many hardware and tuning improvements in order to reach the peak luminosity including precision tune feedback and detection and compensation of BPM motion relative to the sextupole magnets near the interaction point. Continuous injection is now the standard operating procedure and this has helped improve the integrated luminosity.

The Belle detector has now accumulated 365fb^{-1}, and of these 168fb^{-1} were obtained this year. The Belle detector is working extremely well and has had no major difficulties. Backgrounds are low, and losses during beam injection are small. Continuous injection has been acceptable to the detector but has necessitated suppressing 3.5 ms of data taking during each injection cycle. Overall, the Belle collaboration is extremely pleased with the quality and quantity of the beam being provided by the accelerator.

3) Recommendations

Last year, the Committee made several recommendations and the KEKB staff has addressed all of them. Some of these related to the priorities of the program and are reiterated below, together with recommendations for continuing the work that has already been started.

1. The Committee believes that improving the luminosity of KEKB is the highest priority, and experimental and theoretical studies to improve luminosity should be given precedence.
2. The Committee strongly endorses the proposal to construct, test, and install one crab cavity in each ring with the highest priority. In the meantime, high priority should be given to continuing detailed studies of the beam dynamics of the ring with a single crab cavity, as well as continuing technical developments.
3. The Committee would like to encourage studies leading to increased luminosity in the short term; e.g. a study of shorter bunch spacing, fast ion instabilities, working point, improving linear and non-linear optics, etc.
4. The Committee recommends that Belle implement an azimuthally localized veto similar to that of BaBar to avoid the 3% loss in luminosity caused by the detector trigger veto during injection.
5. The Committee endorses the direction of the present studies to design a major luminosity upgrade (SuperKEKB) aimed at a luminosity of 1–5 x 10^{35} $cm^{-2}s^{-1}$ and recommends that they be continued.
6. The Committee recommends continued evaluation of all of the effects that would impact the choice of which beam goes in which ring.

The Committee has made new recommendations throughout the different sections below. Highlights of these recommendations are summarized here.

7. Coherent synchrotron radiation has the potential to have such a profound impact on the design of SuperKEKB that the Committee strongly recommends carrying out more detailed studies at KEK, and comparing the results with those of other studies at SLAC and elsewhere.
    - Prior to making any decision, the contributions from all other longitudinal impedances present in the LER should be combined with the CSR wake and the potential for partial compensation should be investigated.
    - The Committee also recommends studying the transverse effects of the CSR impedance.
    - One of the consequences of the transient shielding is a radiated field ahead of the bunch, so the effect on multi-bunch stability should also be addressed.

8. In order to clarify the reasons for the reduction of the specific luminosity with increasing numbers of bunches at the collision point, and to provide insight on the electron cloud effect on the beam as well as diagnostics relevant to the cloud density, the Committee recommends performing an experimental program for the 3-bucket spacing collisions. This would be useful for KEKB as well as for SuperKEKB.

9. The Committee strongly endorses the plans for simultaneous injection in all four rings, including the crystalline tungsten positron target.
10. The Committee notes the problems encountered in achieving high gradients in the C-band structures and recommends studying alternative solutions in parallel with the present solution.
11. A new conceptual design for a movable mask was presented which is ‘electrically invisible’ (rod with ceramic support) and has a much lower loss factor, but a significant amount of R&D remains to demonstrate a reliable, operational movable mask with a reduced loss factor. The Committee recommends pursuing this R&D work and subsequent beam tests with high priority.
12. The Committee feels that HOMs will be one of the limiting factors in increasing the current. Detailed studies of the vacuum components including proper damping and component cooling should be carried out.

B) Findings and Recommendations

1) KEKB performance and near term plans

KEKB has progressed very well over the past year and more than reached its goals. The luminosity has reached 1.5 x 10^{34} cm^{-2} s^{-1}, a new world's record. The accelerator continues to set integrated luminosity records, for example, 1.08fb^{-1} per day and 24fb^{-1} in 30 days. The total integrated luminosity over the life of KEKB has reached 363fb^{-1}.

The horizontal tune of the Low Energy Ring (LER) operates very close to the half integer tune (0.505) which, with the use of IP tuning knobs, gives higher luminosity. The change this year was to apply a more precise feedback on the bunch tunes, which has greatly stabilized colliding beam operation.

KEKB now operates with about 1,200 bunches but with beam currents near the design values. This high bunch charge is well tolerated by the beam-beam interaction and, as a result, gives more luminosity. The design number of bunch (5,000) would allow for more current and luminosity in the future. However, the number of bunches is presently limited in the LER by the Electron Cloud Instability (ECI). The KEKB staff is looking at measures to increase the current and specific luminosity.

The high bunch currents and short bunch lengths have stressed several vacuum chambers with high temperatures and forces. Several vacuum leaks have occurred, and these chambers have been replaced and upgraded. The Committee suggests continued vigilance watching for the "next" chamber to have problems.

The number of beam aborts has averaged about four per day in each ring since May 2002. Since continuous injection has been implemented, the beam aborts have had a noticeable impact on the average luminosity (~5%). The causes have been carefully documented and assigned to different categories. It would be interesting to study these beam aborts in more detail to try and eliminate them. This would be good for the present KEKB and, more importantly, provide useful information for SuperKEKB.

2) BELLE status and plans

The Belle detector has made full use of the 363fb^{-1} delivered by KEKB, with 166 in the past year. The Committee congratulates the Belle collaboration on the effective use of detector and storage ring. From this nearly doubled number of BBbar pairs 60 contributed papers and 24 talks were presented at ICHEP04 alone.

The Belle data have now confirmed direct CP violation with a 3.9 σ signal, improving to 5 σ when combined with BaBar data. This result provides convincing support for the Kobayashi-Maskawa mechanism. CPV isospin analysis has confirmed Belle's previous result establishing an unexpected large branching ratio of 2.32×10^{-6} for $B^0 \rightarrow \pi^0\pi^0$ with a 6 σ signal. Time dependent CPV analysis has reduced the error on sin $2\varphi_1$ to 5%.

Hints of new physics come from $B^0 \rightarrow \varphi Ks$ and $B^0 \rightarrow \varphi K^0$ and other decays showing significant deviations from Standard Model predictions. Earlier significant differences from BaBar on $B^0 \rightarrow \pi^+\pi^-$ results have been reduced significantly, but still there remains a 2.3 σ discrepancy. Several new decay modes have been found with some candidate explanations proposed. We look forward to confirmation with an increased data set.

The next doubling of Belle's data set will likely require at least two years. We expect a refining of the results presented in the mean time, and encourage exploring all avenues of analysis. These results will provide the physics case, which will be needed to justify SuperKEKB.

3) BPM issues

A novel and very clever scheme to check good transmissions from all 4 buttons of a BPM was presented. Horizontal and vertical positions can be derived from all 4 electrodes, but it has been discovered that in fact any combination of 3 out of the 4 electrodes is sufficient to calculate a position estimate. If all 4-button signal transmissions are perfect, the four 3-button position estimates should be identical. The consistency is defined as the standard deviation of the four different position estimates and is usually better than 0.1 mm for a 'good' BPM.

Various BPMs have had degraded consistencies due to bad connectors, imperfect contact with connectors, and thermal drift in cable impedance, broken cables. Bad BPM have thus been identified, and bad connections identified using TDR and fixed.

Correct and stable BPMs are essential for KEKB operation due to the global orbit correction scheme. Daily variations in consistency have also been identified as caused by sunshine heating BPM cables and reduced by thermal insulation. Publication of this simple and clever scheme is encouraged.

Thermal motion of BPM positions following an abort is a serious problem. For 21 BPMs downstream of twin bends in the HER, this thermal motion has been reduced by an additional support.

Movement of BPMs at LER local correction sextupoles cause tune changes due to thermal motion. Electrostatic position sensor with 1 μm resolution shows a good correlation with the resulting tune changes, and correction of BPM data with position sensors has dramatically reduced the tune excursions caused by thermal motion after an abort. This improvement may be necessary for all sextupoles in the future.

4) Beam observations

Bunch-by-bunch spectra of vertical oscillations of the positron beam have been measured using the feedback BPM and the Beam Oscillation Recorder. In the bunch train with 4-bucket bunch spacing, above the threshold current of the vertical beam blowup, an upper sideband of the vertical betatron tune is detected in the spectra of the bunches with numbers >5; the sideband peak becomes more pronounced in the following bunches through the tail of the bunch train. While it has been suspected for a long time that the emittance blow-up in the LER above a certain threshold was caused by a coherent instability associated with the strong and very fast short range electron cloud wake, this is the first time a coherent signal associated with this instability has been recorded.

The betatron tune was made visible by lowering the feedback gain down to the stability margin. The vertical tune and the sideband peak both increase in tune along train, saturating near the 40th bunch. The difference between the tune and the peak also increases, then saturates near the 40th bunch. The sideband can be reduced or eliminated by turning the solenoid field on. The sideband appearing in correlation with the vertical beam size blowup due to the electron cloud in LER can be interpreted as a signature of the strong head-tail (or transverse mode coupling) instability causing the blowup, and caused by the strong, fast and short range wake of the electron cloud. The presence of the sideband and its intensity may serve as a diagnostic tool for the electron cloud density on the beam axis.

Similar spectra are observed by the optical diagnostics of coherent oscillations using the PMT setup. The latter technique also provides the vertical beam size data. Their correlation with the burst-like coherent oscillation signal reveals the relaxation behavior of the strong head-tail instability.

Important information can be obtained by measuring these spectra as a function of the chromaticity, as the next step of the study. A considerable effort should be invested in the detailed quantitative analysis of the measured spectra.

The frequency offset and calculations with a realistic short-range electron cloud wake suggests that the mode frequencies merging at threshold are the m = 1 and m = 2 head tail modes. While a reactive feedback system was effective in PEPII to raise the mode coupling threshold caused by the broadband transverse impedance wake (raising the merging threshold of the m = 0 and m = 1 modes by shifting the m = 0 mode frequency), it seems difficult to raise the mode coupling threshold much for the electron cloud wake due to the high frequencies involved.

The Committee encourages further activities providing insight in the electron cloud effect on the beam, as well as diagnostics relevant to the cloud density. In particular, the same measurement is recommended with the 3-bucket separation in the train as a way to understanding the reasons limiting the number of bunches at present.

5) Beam-beam experiments

A comprehensive set of experiments relevant to the beam-beam effects was performed during the past year. These include measurements of the beam-beam kick during a scan of the horizontal offset at the collision point, the coherent beam-beam tune shifts, and the dynamic beta. In everyday performance the KEKB team achieved very high values of the beam-beam parameter, and routine tuning of the collision has become a state-of-the-art activity.

One of the goals of this experiment was to understand why the optimum luminosity is reached with a certain horizontal offset of the beams at the interaction point. The offset is believed to result from a combination of the beam-beam and electron cloud effects. Accurate measurements of the "egure" picture provide a solid experimental basis for future simulation and theoretical studies.

The dynamic beta and emittance can be reliably computed as a function of the beam-beam parameter by an optics code with appropriate model optics of the machine. Therefore, measurement of these parameters provides a diagnostics for the beam-beam parameter that is complementary to the coherent beam-beam tune shift measurement.

However, in the presented experiments the approach was different. The dynamical change of the horizontal beam size at IP was measured from the beam-beam kick measurements. These measurements are made with pairs of detectors providing resolution of 10 mm in position and 0.05 degrees in phase. Hence, the relation between the horizontal beam-beam parameter and horizontal emittance was obtained. The latter is consistent with the measured tune shift value.

In order to clarify the reasons for the reduction of the specific luminosity with increasing numbers of bunches at the collision point, the Committee recommends performing a similar experimental program for the 3-bucket spacing collisions.

6) ARES status

The ARES concept is a very convincing approach to increase the stored energy in order to reduce the cavity detuning under beam loading, which is necessary to suppress the longitudinal coupled bunch instability. Three cavities, accelerating, coupling and storage cavity, are driven in the pi/2-mode. This assures a high stored energy for a given accelerating voltage, while the losses are low because the coupling cell is only weakly excited. The two other modes, 0- and pi-mode, are damped in the coupling cell. The pi/2-mode is also the most stable against detuning of the accelerating cavity by beam loading.

20 cavities are installed in the LER ring and 12 in the HER ring, together with 8 superconducting cavities. So far, operation has been very stable with only 1 trip per cavity every 3 months. In the LER ring the beam current is up to 1.8A with a cavity voltage of 0.4MV, an input power of about 300KW and HOM power of 5KW. In the HER ring the beam current is around 1.2A with a cavity voltage of 0.34MV. Most of the initial problems have been overcome. In 2 cavities, multipacting was observed in the coaxial part of the RF input coupler. After replacing 2 couplers one worked fine, the other still showed multipacting. The reason why some couplers show multipacting is not known. Studies are going on to determine whether to coat the coupler or to modify the shape. We believe that this problem will be solved.

In the meantime, numerical multipacting studies have been performed and operational regions found with no multipacting. An RF phase feedback has been installed which provides rapid crossing of the multipacting regions and maintains the cavity in a safe zone during operation with beam.

This is an elegant solution that nevertheless can give operational restrictions. We encourage the continuation of studies on coupler shaping and coating to remove this problem at the source. In conclusion, the ARES seems to be in a very good condition and we congratulate the RF people for this nice idea and the solid realization.

7) Injector Upgrade

Providing different beams to four rings simultaneously is an ambitious goal. Top-up injection of both electrons and positrons is currently adopted for KEKB operations. In other words, the injector linac is fully occupied for KEKB operation. However, it must also provide electron beams of 2.5 GeV to the Photon Factory and 3.0 GeV to the Photon Factory Advanced Ring a few times per day. In the near future, these rings will also require top-up operation.

In the first phase, electron beams of 8.0 GeV for KEKB and 2.5 GeV for the Photon Factory will be provided using a DC bending magnet to switch between the two beams, until a pulsed magnet is ready. The injector group obtained 2.5 GeV beams by decelerating 5.7 GeV beams by electronic control of the RF phases. This is really an excellent and effective way of operating the 8 GeV linac. In order to have necessary space, the last accelerating section will be removed, so a C-band pulse compressor will be used to compensate for the lost acceleration.

This Committee praises this excellent idea and the initial experimental results. For electronic control of the positron production, a crystalline tungsten target with a hole will be installed this summer. When electron beams are required, the primary electron beam is deflected through the hole in the target. Even though it would be a complicated operation scenario, the Committee encourages the proposed scheme of operations.

8) Crab cavity overview

Considerable additional progress has been recorded in the evolution of the crab cavity concept into detailed engineering design. Specific locations in "Nikko" with existing cryogen supply have been identified and cavities have been ordered. Indeed, the half-cells have recently been deep-drawn. The order for cryostats will soon be placed, and a schedule has been established that leads to cavity installation in February 2006.

The cavity design, which originated in 1991-2 as a part of a KEK-Cornell collaboration, retains the original concept, but has benefited from numerous refinements in the intervening period, including transfer of the crab mode rejection filter to the warm beam pipe, provision of transverse support stubs and the implementation of a cavity tuner based on the variable insertion of the coaxial coupler. The tuner includes a capability for differential movement to correct transverse misalignment. Engineering design is well advanced and appropriate for procurement of components. A stress analysis of critical components shows acceptable stresses and strains. Further analysis to update the understanding of the present design in the areas of cavity multipactor performance, allowable HOM Q's and anticipated dynamic losses would be beneficial.

A development program for a niobium-coated copper coaxial coupler was only partially successful, with issues of inadequate niobium coating of the end of the coupler that there was insufficient time to address. The fallback position of fabricating the coupler entirely from niobium has been adopted. There are no problems foreseen with this approach, although it will be somewhat more expensive.

A somewhat unexpected issue has arisen with the need to obtain government certification of the pressure-vessel aspects of the design. Interactions with the licensing Review Committee have been very positive, with members of the Committee offering valuable suggestions for design improvements.

Although the schedule for completion of this activity is aggressive, it is being vigorously pursued and the Committee looks forward to hearing about a successful installation on its next visit.

9) Crab Cavity HOM Damper

There are two HOM dampers, one on the large beam pipe and the other in the coaxial line formed by the beam pipe and the coaxial coupler. These absorb unwanted modes generated in the crab cavity by the beams. A systematic analysis to optimize the damping of the different modes has been carried out (HFSS) and a set of design values for the different elements have been found such that the beam remains stable transversely and longitudinally. The ferrites used as the absorbing material in the dampers are formed in an isostatic press and electron beam welded to the beam and coaxial line tubes. The HOM power with the calculated impedances is estimated to be 18 kW, below, but close to, the limits of the capabilities of the ferrites as extrapolated from measurements. This should be clarified.

10) Input/ coaxial coupler

The input coupler for the crab cavity, with its T-stub support structure, needs to provide 100kW. It has successfully been tested at all RF phases of reflection up to 200 kW incident power. We support the initiative to complete the test set-up so that the couplers can be tested at even higher power, for all phases, during a long period. Most of the components are ready, but a 90° bend has still to be built.

The coaxial coupler inside the beam tube to the right of the crab cavity serves as a means for separating out the higher order modes to be damped while maintaining a high quality factor for the crab mode. It also serves as the tuning element for the cavity, being moveable axially. The original idea to use Niobium film on copper has been rejected for the moment in favor of a solid Niobium solution. This was due to a lack of time for the R&D necessary for the resolution of issues concerned with producing an even layer of Niobium. Both the design of the stub support in the coaxial coupler (which has to reject frequencies to beyond 950 MHz) and the design of the notch filter (which reflects energy in the line at the crab mode frequency while allowing all other modes to pass to the ferrite HOM) have been fully studied and optimized dimensions have been found. One estimation that should be revisited and should be measured on the prototype is that concerning the amount of power that could be coupled down the lines in the event of the ~ 1m long coaxial line tilting off-axis. The bellows that allow the coaxial line to be moved longitudinally should also be checked for their HOM impedance and the resulting power dissipation.

11) Cryostat for the Crab Cavity

The present state of the design of the crab cavity cryostat and its components was presented. Simulations of the effect of stress on the cavity and the He jacket and the resulting stress contours and buckling modes were shown. The cavity/jacket ensemble appears mechanically stable under normal operating conditions.

The whole design is now nearly complete, including the Helium jacket, vacuum vessel and magnetic shield. The cavity has a unique tuning system using a moveable inner coaxial coupler, cooled by liquid He at its tip, and supported by a cooled stub. One issue, that has been mentioned elsewhere, concerns the allowed horizontal deflection of the central tube, which may occur over time or when moving the tuner. The excess power that would then be absorbed in the 80 K copper bellows or the 300 K mode damper should be estimated, then verified and measured on the prototype.

Significant progress has been made on the manufacture of many components of the cryostat, and a prototype is under construction. Static losses in the cryostat have been calculated in detail. Dynamic losses due to the RF in the cavity are estimated at 50W, but these, and the required HOM damping, seem to be based on the original design published in 1992. The estimates should be updated to reflect improvements that have since been made to the design. Particular attention may need to be paid to the TM_{010} mode, which depends for it's damping on sufficient insertion of the coaxial coupler, even though the latter's position will be defined by the crab mode frequency. A list of the required damping for all cavity HOMs, as defined by the beam dynamics requirements, should be provided for comparison with the measured values.

Losses due to the presence of the beam in the cavity, whether it is on or off-axis, should also be estimated. The cavity itself will be tested horizontally in a specially prepared pit, but using an existing test bench. This is a good milestone towards the final construction.

12) Refrigeration system for the Crab Cavity

The locations in "Nikko" selected for the crab cavities are in close proximity to, and will be supported by, the liquid helium refrigerator originally installed for the TRISTAN cryomodules. With an installed capacity of 8 kW at 4.4 K, the refrigerator is presently supplying liquid helium to 8 superconducting cavities that are using less than 50% of its capacity. The remaining capacity will be more than enough for the two crab cavities and for a crab cavity test stand also to be located in this area.

13) RF control for the Crab cavity

The beam loading aspects of a crab cavity (K. Akai et al, EPAC 96) was reviewed. The influence of the loaded Q and the horizontal position error Δx in the crab cavity has an important influence on the required power.

As a crab cavity phase error will produce a horizontal displacement at the IP, the required phase tolerance and phase jitter is determined by the acceptable horizontal displacement at the IP, which has been determined from beam-beam simulations. It turns out that the correlation time of the jitter is important: <1% of σ_x is required for a 1-turn correlation while <5% of σ_x is required for a 10-turn correlation. The bunch position shifts caused by the accelerating cavity transients due to the 5% abort gap also translate into horizontal shifts at IP but are mostly compensated as it has the same direction for the two rings.

With the available power in existing 500 MHz klystrons, a target Q_L of 2 x10^5 has been adopted. This appears reasonable and results in a power requirement of typically 100 kW.

The feedback system is similar to that used for the superconducting accelerating cavities: tuning loop, direct RF feedback, phase lock and gain loop for klystron, and amplitude and phase loop for V_c.

Slow phase drift is compensated through the continuous closed orbit correction system (CCC). In addition, a local orbit feedback is planned for the crab cavity insertion to minimize horizontal orbit excursions in the crab cavity. This local feedback loop may possibly receive position reference information from the crab cavity power level.

The coupled bunch growth rates due to the fundamental mode were calculated by Akai et al. in 1996 for a Q_L of 1 x10^6, and depend strongly on tuning error. For the lower Q_L currently proposed, and with the addition of direct RF feedback, the acceptable tuning range is even smaller, but should easily be maintained by the tuning loop.

Since the direct RF feedback loop has a significant influence on the effective transverse coupling impedance of the crabbing mode, correct and precise phasing of the direct RF feedback loop is also very important.

The crab cavity amplitude tolerance is fairly relaxed and easily achievable.

In brief, the tolerances looks achievable, the crab cavity RF control system looks reasonable, and the Committee is looking forward to successful operation of the crab cavities with beam some time in 2006, without too many bad surprises.

14) Crab optics and dynamics

Since the previous Committee, changes were adopted in locations of the two crab cavities, both in LER and HER. The appropriate modification of the crab optics was done.

Following the previous Committee recommendations, a study of the crab cavity effects on the collective motion was performed. The conclusion is that the head-tail instability is not a problem, provided that high beta values are avoided in the high-impedance elements.

The effects of imperfect optics on the dynamic aperture have been simulated. The results do not reveal any serious reduction of the dynamic aperture as long as the parasitic horizontal dispersion at the crab cavity is within 0.2 m, and the existing optics correction technique is capable of keeping the parasitic dispersion below 0.05 m. No contribution to the $2\nu_x + \nu_s =$ integer resonance was found from the crab cavity.

A side effect of rotational misalignment of the crab cavity or of x-y coupling might be a vertical crabbing angle at the interaction point. Simulations showed that the former could be cured with the existing iBump correction, while the latter can be compensated by the "r_1" coupling coefficient knob.

The Committee recommends continuing the studies of collective effects, including the current-dependent contribution to the crabbing angle, and simulation of the electron cloud effect on bunches that are crabbing all around the ring. We also suggest continued examination of single beam stability issues related to the crab cavity, including transient beam motion in the cavity and operating with the cavity detuned.

15) Magnets, installation, orbit control

An upgrade of the magnet system has been designed to maintain the horizontal beam orbit at the crab cavities, including the installation of four new magnets, exchanging the positions of some steering magnets and realignment of the chicane magnets. The relevant power supply modifications are also been carefully evaluated.

It is planned to control the horizontal orbit to within ±1 mm in the crab cavities to avoid loss of control of the crabbing mode field due to beam loading. A crab orbit feedback similar to the iBump, the EPICS based collision feedback system, will be employed, using 4 horizontal steering magnets in each ring to make an offset bump, and by using 4 BPMs around the crab cavity to monitor the orbit offset.

All of the upgrade issues have been addressed and scheduled. A test of the control system is planned this spring, and magnet installation will be done during summer 2005. This provides a good opportunity to test the feedback system in the fall without crab cavities but with "crab optics".

16) Super KEKB overview update

A concerted effort by the KEKB team gathered much momentum last year culminating in a Letter of Intent for SuperKEKB. This letter has been published and was distributed to the Committee before this meeting.

The Committee welcomes this effort and considers it a demonstration of technical confidence as well as a determination to produce the maximum output of B-physics research at KEK. At this point, the Letter of Intent includes a substantial amount of useful information, indicating a range of luminosity potentially achievable by Super KEKB, i.e. 1-5 x 10^{34}. The Committee concurs with the great potential of the Super KEKB as proposed by the KEKB team, and further agrees with the estimated range of luminosity achievable. A tentative cost estimate of 465 oku-yen was mentioned. A timetable has also been suggested that ends with SuperKEKB starting Physics in 2011.

The KEKB team identified several technical items as requiring further R&D, both in terms of accelerator physics studies and hardware design and development. These items, as well as the Committee's views on them, will be discussed in the following sections. The highlights of these discussions have been given in the recommendations section. The uncertainty in the outcome of these R&D items has been reflected in the range of achievable luminosity given above. The Committee recommends strongly that R&D of these items be carried out in a timely fashion, and hopes that appropriate and strong support from the KEK laboratory is forthcoming.

17) Beam-beam update

Beam-beam limit is studied using a 3D PIC simulation code. Following the recommendations of the 2004 MAC, an extensive survey of various lattice error tolerances has been done. It was found that near the beam-beam limit of ξ=0.1, the beam-beam interaction accompanied by either of the 4 components of the linear coupling in the arc can significantly perturb particle motion, and it was suggested that the underlying mechanism could be due to Arnold diffusion. The Committee finds this study to the point, but is not yet convinced of the mechanism suggested, and encourages continuation of the study.

The PIC simulation also showed that the parasitic collisions have only minimal effect on the beam-beam limit provided that the working point is optimized, even for a bunch pattern with every bucket filled. Therefore, the choice of very large crossing angle of ±15mrad is justified. The Committee finds this result and conclusion encouraging.

18) Vacuum upgrade

The vacuum system is very challenging with HER and LER vacuum currents of 4.1A at 8 GeV and 9.4 A at 3.5 GeV respectively. The design is further constrained by impedance and HOM issues due to the high bunch current and short bunch lengths. Although there have been significant studies of secondary electron emissions, the real impact of the electron cloud could still be a limiting effect.

The conceptual design of the copper antechamber addresses several of the key issues for the vacuum system. It significantly reduces the broadband impedance because the beam does not see synchrotron radiation masks and pumping holes. It also reduces the electron cloud effect by keeping the secondary electron production further away from the positron beam. Also, as shown by the secondary electron yield studies, the copper material can create a carbon layer that protects itself from multipacting, however the results presented by S. Kato do not agree with the data in this presentation. Collaboration is recommended here to determine how the secondary electron yield studies performed by Kato can be applied to the vacuum system. Also the vacuum group should consider last year's comment on a design that uses a clearing electrode.

The thermal analysis of the vacuum chambers including synchrotron radiation heating was not presented during the Review. The chamber sees 28 W/mm on the back wall of the antechamber, which could create unacceptable peak temperatures and stresses. Copper data indicates that the re-crystallization temperature could be less than 200ºC depending on the cold work of the material. Optimization of the cooling scheme will also be required. Two smaller cooling channels would probably be much more effective than 1 large channel and, with proper placement, can reduce deformation of the vacuum chamber during temperature excursions. The thermal motion should be considered in order to achieve the required BPM stability. The ability of the comb style bellows to manage the operational travel requirements and alignment of the system should be evaluated.

Since a synchrotron radiation ray trace study was not presented, it was unclear whether the critical components such as bellows and flanges are masked from a direct synchrotron radiation strike. The molybdenum flange on the wiggler chamber has a temperature rating of 150ºC and a synchrotron radiation strike could cause leaks in the vacuum system. Also, since the vacuum sealing surface is at the inner wall of the vacuum chambers, it is possible that the HOM thermal losses could create a large enough thermal gradient to open the flanges during operation.

Mis-steering should be considered when designing the antechamber-style chambers. The vertical position and angle steering could be limited by the height of the slot and synchrotron radiation may be able to hit the entrance of the slot. Thermal-stress calculations should be done to determine if cooling is needed here. Orbit interlocks could be applied at higher currents if needed.

No pressure profile for the new vacuum system was presented. The chamber is conductance limited by the screen and therefore optimization of the pumping screen should be addressed. The cost impact of drilling more holes should be compared with the improved vacuum performance. Also, the diameter (4 mm) and depth of the holes should be reviewed for HOMs to prevent heating of the NEG strips. The issue of the capacity or frequency of regeneration of the NEG was not discussed.

NEG material can produce dust and it is therefore possible that NEG particles may fall to the bottom of the chamber and migrate into the main beam channel. Dust particles have already been mentioned as a potential cause for beam instabilities in KEKB. The pump screens in the wiggler style chambers that have a pump port opposite the synchrotron radiation mask could be angled to prevent secondary scatter from striking the NEG strips and producing dust.

The beam stay clear or magnet clearance of the vacuum chambers was not presented. Sufficient space should be allowed for manufacturing tolerances and alignment of these long vacuum chambers. Also the size of the chambers is dependent on many parameters. The injection acceptance of the beam chamber requires a specific vertical height. The single bunch instability is reduced with a very small vertical height and the tune shift is reduced with a round aperture. The Committee recommends that the aperture should be agreed upon by all disciplines so that the vacuum group can proceed with a design.

If a 28 mm radius chamber is adopted, it is unclear if the fields produced by the beam are still unaffected by the 18mm high slot. If the chamber diameter is greatly reduced, the antechamber might affect the single bunch instability or tune shift.

The comb prototype was installed and found to reduce the HOM power at the convolutions. This is an innovative solution that successfully reduces the HOM power into the cavity space behind the shield. However, the test results still showed that some power leaks past the comb, and this power will increase with increased bunch current and shorter bunch lengths. The small bunch length keeps driving the size of the slots down to prevent transverse (TE) mode leakage into the bellows cavity, but the use of absorbing tiles and fans may still be necessary.

An acceptable impedance budget for the vacuum system should be specified including acceptable tapers and steps.

The designs for specialty equipment such as SR light monitors, transverse and longitudinal feedback kickers and collimators should be started. The Committee strongly recommends that a prototype of the moveable mask be installed in KEKB.

The Committee encourages continued prototyping of the vacuum chambers. A copper extrusion with a welded antechamber may be less expensive and provide a dimensionally reliable alternative.

Given the complexity of the technical issues influencing the vacuum component design, the Committee recommends a formal procedure for technical approval, including a review of synchrotron radiation power handling and impedance characteristics (including frequency dependence, resistive wall, HOM, and coherent synchrotron radiation).

19) ARES upgrade

With the increased current and the resulting increase in beam loading, the cavity detuning should increase from –20KHz for KEKB to –200KHz for SuperKEKB. A larger ratio of the stored energies in the storage and accelerating cavity of 15 will bring the detuning back down., and to do this the opening of the coupling iris between the coupling and accelerating cavity will be enlarged.

At the same time the input power and the HOM load increase.

The input coupler, which shows several multipacting zones at 150-190KW, has to operate reliably at 800KW. A 50nm thin coating with TiN is foreseen. In addition, we recommend studying active graphitization and a longitudinal shaping of the outer coaxial line. The coupler will be tested in an upgraded test stand with a 1MW klystron, two couplers, a storage cavity and a water load.

The copper plating of the storage cavity is going to be improved using the J-PARC facility. The first results are excellent with no degradation of the theoretical Q-value.

The increased HOM load requires multiple changes. The monopole and vertical dipole modes in the accelerating cavity are coupled out via four waveguide dampers and damped by bullet-shaped SiC absorbers. SiC tiles in the grooved beam pipe absorb the horizontal dipole modes. If the waveguide absorbers cannot stand the estimated 80KW losses, their number will be increased. The grooved waveguide may be replaced, if necessary, by a winged chamber with directly water-cooled tiles able to absorb 20KW. Tests will be performed on a newly established L-band test stand with a 1.2MW klystron. In summary, although many changes of the actual ARES will be required, work is well under way and qualified solutions have been found.

20) SCC upgrade

Experience with operation of the SCC systems in KEKB has been very encouraging, significantly exceeding design requirements, specifically in RF power transferred to the beam and in HOM power extracted to the beam-line ferrite absorbers.

The RF power that must be transferred to the beam of SuperKEKB increases to an average of 460 kW per cavity. Operation of the input coupler at 500 kW has been demonstrated in traveling wave conditions in a test stand, which is a good basis for confidence that the requirements of SuperKEKB can be achieved. The increase in beam current also requires a reduction of Q_{ext}. A 30% reduction has been achieved by mounting the input coupler with a thinner gasket, which causes the coupler to protrude further into the beam pipe for higher coupling. Further reductions, if needed, could be achieved without further modification of the coupler by the installation of an external waveguide matching network (iris).

A more challenging requirement is the increase in HOM power to be removed from 16 kW to 60 kW. A test stand is being established to investigate the limits of existing coupler designs and to evaluate proposed improvements. To date, dampers have successfully handled the equivalent of 43 kW without damage. One change being considered is a reduction in the thickness of the ferrite layer to 2-3 mm, to decrease the thermal impedance from the heated ferrite through the copper wall to the cooling water. In addition, damper fabrication processes that determine the integrity of the joint between the copper jacket and either the ferrite or silicon carbide material are being reviewed. Prospects for a successful resolution of this issue seem good.

21) Lattice and Dynamic aperture

The present successful performance of KEKB is due, in large part, to the merits of its optics. In KEKB the arc lattice design, with a $5\pi/2$ phase advance per cell and non-interleaved sextupole pairs connected by I' transformations, provides independent tuning of the momentum compaction and horizontal emittance. The sextupoles are mounted on x- and y-movers; their pair wise displacement (either ++ or +–) is used for correcting beta-beat, horizontal dispersion (by x-displacements) and also vertical dispersion and coupling (y-displacements). The chromaticity correction is not accompanied by a nonlinear kick limiting the dynamic aperture.

For these reasons, the present arc optics is adopted for the SuperKEKB. However, the IR lattice had to be extensively modified to meet the SuperKEKB design goals.

With the new optics and a random model of magnet alignment and steering errors, the ability to correct betas, dispersions and xy-coupling has been successfully checked. However, the application of local vertical bumps in SuperKEKB arcs is now limited by the need to keep the synchrotron radiation fans within the antechamber.

A dynamic aperture study has been done with the new optics, showing only a small reduction compared with the present KEKB optics.

The Touschek lifetime in the LER is estimated to be 50 minutes, with the momentum aperture calculated in the dynamic aperture study. Although the dynamic aperture can be considered reasonable for injection purpose, its effect on the Touschek lifetime is serious. It is suggested that ways of improving the momentum aperture be pursued by first determining the underlying mechanism presently limiting the observed momentum aperture.

The dynamic aperture study should continue as more mechanisms and error effects are added. In particular, synchro-betatron effects in the presence of crab cavities, IR magnet multipole errors, and parasitic collisions are among the next effects to be included in the simulation.

In simulating the effect of the beam-beam kick on the dynamic aperture, the Committee suggests using the form of the beam-beam kick resulting from a non-Gaussian transverse distribution shape such as the one obtained in the strong-strong beam-beam simulations, and to take into account the final bunch length.

22) Interaction Region (IR) overview

The Super KEKB IR parameters have been chosen aggressively, but carefully, to optimize the performance of the machine. The vertical and horizontal interaction point beta functions are 3 and 200 mm respectively. Dynamic and physical apertures are maintained by building new QCS magnets with superimposed compensating solenoids placed close to the interaction point. A larger crossing angle (increased from ±11mr to ±15mr) provides space for the necessary focusing elements.

The design of the interaction region is complicated by the large dynamic beam-beam effects that more than double the horizontal emittance and reduce β^*_x to keep the beam size at the interaction point approximately the same. The vacuum chambers are designed to have no synchrotron radiation striking within 5m (LER) or 8m (HER) downstream of the interaction point, although the effect of vertical deflections due to the solenoid field have not yet been considered. The QCS quadrupoles alone generate nearly 250 kW of synchrotron radiation. At least as challenging is the disposition of more than 100 kW of higher order mode power that are expected to be deposited near the interaction region. Experiment backgrounds will be more than an order of magnitude larger than at present.

The interaction region is the most difficult design challenges of a collider. The Super KEKB interaction region now has a basic design covering the critical areas. However, there is much work to be done before one can be certain that all of the desired parameters can be realized.

As noted above, the synchrotron radiation fans must be completely calculated, including vertical extent and the effects of allowed orbit bumps (and a means of limiting them). Radiation impinging on the interaction region from the incoming beam should be rechecked. The HOM generation has to date only been approximately scaled from KEKB estimates, and the dissipation has not been addressed yet. Vacuum pumping and instrumentation needs to be laid out. A beam-stay-clear map should be made available. Magnet design and analysis is not yet complete (particularly realistic multi-poles).

The KEK staff has made good progress on the IR design, but there is still much work to be done. We strongly encourage a well coordinated and focused effort on the tasks listed above.

23) IR vacuum chamber

The preliminary design of the vacuum system is underway.

The interaction region vacuum is one of the most challenging systems. The Committee commends the KEKB staff for extrapolating their past experience to help define the design tasks and improvements. The design presented is preliminary, so the following comments do not address specific issues.

A 3-D graphical and analytical solution for the synchrotron radiation (SR) fans should be done as soon as possible and should include the vertical deflection from the solenoid field. It is critical to determine if the SR fans can strike the 1 cm proposed vertex chamber and the walls of the other vacuum chambers. If SR power strikes the vacuum chambers close to the interaction point, the power densities could be difficult to manage and could impact the backgrounds. The vacuum group needs to work closely with the background group to determine the placement and acceptable slopes for the masks. The design of the crotch mask should be started soon to determine if the SR power is reasonable. A mis-steering envelope should be defined to ensure that the vacuum chamber does not intercept SR power that could damage the chambers.

Another important issue is the HOM heating in this area. Analysis needs to be done here to determine the amount of HOM heating expected. The staff needs to consider where the power could go (bellows, resistive wall components, etc.) when designing this area. Also, the comb bellows may still require absorbing tiles or convective cooling on the bellows corrugations due to the increased HOM power from the short bunch lengths and high bunch currents.

Since the IR geometry creates a trapped volume and the crotch mask is a HOM generator, the staff should consider designing a HOM damper near the crotch so the modes can be absorbed in a location that is designed for high power. Understanding the trapping mechanism for HOM power generated in the space between the crotch and the central beam pipe is urgent. Absorbing this power safely could impact the design of other components in this region.

Thermal analysis on the vertex chamber from resistive and HOM power should be performed.

A magnet prototype is underway, but the conceptual design of the vacuum system has only just started. Caution is advised not to allow the magnet group to lock the vacuum system into an insufficient space. It is essential to provide enough space between the beam stay clear and magnet stay clear for the vacuum chamber, cooling and pumping. With the smaller βy^* in the interaction point the beam stay clear could get large outboard of the interaction point and could lead to background problems. Beam stay clear ellipses need to be mapped in this area using defined values for σ_x and σ_y.

A preliminary BPM design is needed to determine if it can be installed near the interaction point in the QSR magnet. Presently, it appears that the space is too limited. It will be important to decide how critical these BPMs are for steering the beams into collision. Two sets of BPMs separated by a fraction of the BPM processing wavelength might be considered so that both beams can be independently measured.

Finally, pressure specifications for different distances from the interaction point should be provided to the vacuum group based on the background effects. The interaction region area will have space limitations for pumping, so instrumentation in this area is also critical to help understand the backgrounds.

24) Secondary electron yields from vacuum materials and *in situ* surface characterization

Studies by S. Kato et al. on the mechanism for the conditioning of copper to lower secondary electron yields (SEY) have shown that carbon, initially dissolved in the bulk material, plays a critical role. The Committee was highly impressed by this work, both by its thoroughness, and by its relevance to a phenomenon critical to the operation of high intensity colliders as well as other applications.

This team has found that carbon in its graphite form has a very low SEY without any conditioning. By careful examination of copper surfaces using XPS spectra and measurement of SEY, carbon from the bulk material was observed to migrate to the surface under electron bombardment. This process also served to drive off oxides, water, and other surface-bound substances. The carbon formed into a "rough" graphite structure with the low SEY properties. Other metals, nickel, stainless steel, as well as Titanium Nitride and Chromium Oxide, were measured though only the extensive study of copper was reported.

The researchers propose a conditioning procedure that avoids coating with Titanium Nitride or other materials. The process starts with carbon enrichment if necessary, then surface roughening and electron irradiation (< 1 keV, 10C/cm^2). The resulting surface has low SEY which is maintained during venting.

The Committee enthusiastically applauds this work and strongly encourages continued study of the properties of surfaces in accelerator environments and the development of surface preparation and conditioning techniques.

25) QCS

The QCS design takes into account the Belle experience on required shielding and wiring space. It adopts a non-magnetic metal, tungsten alloy, for shielding and eight rods to support the cryostat. The rods would be adequate for weight, EMF, and heat losses. The Committee would like to remind the design team of the safety margin of the ES fields and the multipole components due to conductor displacement errors.

26) Background

A comprehensive review of background sources in the Belle detector was presented to the Committee. These included synchrotron radiation, beam-gas scattered beam particles, Touschek scattered particles, and neutrons and electrons from radiative Bhabha events. The ease with which the detector can be damaged was emphasized by an event in summer, 1999 when a mis-steered beam caused fatal damage to the vertex detector. Backscattered radiation originating from the incoming HER beam in the QCS now accounts for 1/3 of SVD and CDC background, though the dominant background in the detector comes from beam-gas or Touschek scattered particles (the small beam emittance in all 3 dimensions aggravates Touschek scattering). The azimuthal distribution of radiation on the SVD has been reasonably well predicted by simulation.

All background levels will be higher for Super KEKB. More synchrotron radiation is predicted to increase backscattered sources by a factor 6. Radiative Bhabha electrons will be a larger source of background (a factor 19) with the more closely spaced QCS quadrupoles planned for Super KEKB, though polyethylene shielding could lower this. With the smaller beam emittance the Touschek scattering rate will increase by a factor 97.

Shielding, both heavy metal and polyethylene, might limit this factor to 10~20. However, if the central beam pipe is reduced in radius from 1.5 to 1 cm, the SVD rates could increase dramatically. A statement was made that the detector will be upgraded to work with 20 to 30 times the background rates. If this and the predictions above are true, then the increases in background in Super KEKB may be manageable.

There was no presentation of backgrounds during injection. We recommend study and optimization of detector backgrounds and minimization of detector dead time during continual injection. We also recommend continued refinement and calculation of background calculations using parameters confirmed by machine designers.

27) Impedance

The shorter bunches (σ_z = 4 mm) and higher currents (I_{LER} = 9.4 A) result in a dramatic increase in HOM power dissipation in SuperKEKB. A substantial effort has been devoted to categorize and minimize the HOM heating for various vacuum chamber components. As an indication of the severity of the problem, it is noted that after this round of minimization, the resistive wall is one of the strongest heating sources (1 MW).

Loss factors for a number of new vacuum components designed for SuperKEKB have been estimated by the MAFIA T3 simulation code: pumping ports, photon masks, connection flanges, RF shields for bellows. All these components occur in large numbers in SuperKEKB.

These components have all been redesigned to have a much smaller loss factor than the current KEKB components: photon masks and pumping ports are now located in the antechamber, helicoflex gaskets are replaced by smooth MO-type OFC flanges, and finger type bellow shields are replaced by smooth nested comb teeth shields (reducing HOM heating by a factor of 3 to 0.7 MW).

There is a reasonably good agreement between estimated loss fact for the current KEKB LER and the measurements (LER 2000, Ieri-san), which gives confidence in the calculations.

The 16 movable masks in each ring of the current design (which so far have gone through many versions!) have a large loss factor, currently estimated to be k (3 mm) = 16 * 2 [V/pC] = 32 [V/pC] which extrapolates to P_{HOM} = 5.7 MW for SuperKEKB LER, a very large number, even larger than the total RF system HOM power loss.

A new conceptual design with an ‘electrically invisible’ movable mask (a rod with ceramic support) having a much lower loss factor was presented, but a significant amount of R&D remains to demonstrate a reliable operational movable mask with a reduced loss factor. The Committee recommends pursuing this R&D work and subsequent beam tests with high priority.

The loss factors of RF cavities (ARES and SCC) are well known, power measurements agree well with estimated loss factors, and R&D is in progress to address the higher power levels anticipated in SuperKEKB. Tests on the ferrite HOM dampers of SCC so far did not damage them, but have caused outgassing.

The HOM power in the interaction region is estimated to be a few 100 kW with most of the heating coming from the recombination chambers. It is expected that a large number of absorbers will be needed in the interaction region to absorb these HOMs. An effective solution will require knowing where the HOM power will be deposited. This is a difficult but unfortunately also unavoidable task. The Committee recommends dealing with this problem systematically at the earliest possible time.

While the vacuum components mentioned above look very promising, there are still a number other components (BPMs, IR chamber, IR mask, recombination chamber, high current crab cavity, longitudinal and transverse feedback kickers, accidental trapped modes, etc) that need to be addressed in terms of loss factors and HOM power handling capacity.

Furthermore, in addition to the HOM study, a study of the more general problem of single- and multi-bunch collective instabilities should be carried out using the impedances found.

28) Coherent synchrotron radiation

The near field of the Coherent Synchrotron Radiation (CSR) was computed with a code available at KEK. Transient shielding due to a perfectly conducting beam pipe with a square cross section was assumed. To evaluate the resulting longitudinal wake in the LER, the ring was represented by a simplified model with about 100 straight and bent periods. The square cross-section of the beam pipe was kept uniform around the orbit. In the next step, it is planned to include wiggler sections.

The resulting wake was used in a longitudinal tracking code with radiation damping and quantum excitation. The bunch distribution stays stable with increasing bunch current, while the bunch length grows slowly. But above a certain threshold, both the length and the energy spread of the bunch start to grow fast, ending up in a saw-tooth oscillation. The threshold clearly increases as the size of the shielding pipe is reduced.

The conclusion of this study is that to prevent serious lengthening (<10%) of a 3 mm bunch, as specified for SuperKEKB, the beam pipe cross-section should not be larger than 56x56 mm^2 compared with the present 94x94 mm^2. The implication of the reduced beam pipe size on the other impedances has not yet been considered.

However, there is a common understanding among the Committee members that, prior to making any decision, the contributions from all other longitudinal impedances present in the LER should be combined with the CSR wake and the potential for partial compensation should be investigated.

The Committee also recommends studying the transverse effects of the CSR impedance. One of the consequences of the transient shielding is a radiated field ahead of the bunch, and its effect on the multi-bunch stability should also be addressed.

This effect has the potential to have such a profound impact on the design of SuperKEKB that the Committee strongly recommends carrying out more detailed studies at KEK, and comparing the results with those of other studies at SLAC and elsewhere.

29) C-band R&D status for SuperKEKB

A C-band test module was installed last year. It consists of a booster klystron, a modulator, a 43MW, 2μs klystron with pulse compressor and an RF window, an accelerating cavity, and a load. After some initial breakdown and heating problems, the klystron and modulator operate with no trouble. The RF window was tested up to 300MW in a resonant ring and has a VSWR below 1.05 with 4% bandwidth. A SLED-type pulse compressor, operating in the TE_038 mode, provided 200MW output power in a test stand and had a power multiplication factor of 4.7. A 1m long, half-scale S-band accelerating structure was powered and showed a gradient of 42MV/m at 56MW input power. Breakdown occurred at the input coupler, and severe damage of the coupler iris and the first structure iris were found.

In order to make efficient use of the available power, it is planned to change the accelerating structure. It will be a 2m long, constant gradient structure with the group velocity varying from 3 to 1% and a single-sided coupler. An input power of 80MW will create a gradient of 42MV/m. Since this is at the limit of what we consider to be reliable due to breakdown and pulsed heating, we strongly recommend preparing backup solutions, e.g. a single input, two-sided coupler and a 1m long structure with lower group velocity.

30) Tungsten mono-crystalline target for a high-intensity positron source

A preliminary study of a new type of the positron source using a mono-crystalline target has been carried out at the KEKB injector linac. This source is expected to become one of the bright, new schemes for a high intensity positron source.

More experimental data are expected to clearly understand the physical interaction processes of the Channeling Radiation (CR) and the Coherent Bremsstrahlung (CB), since a full simulation taking into account both CR and CB has not yet been carried out.

The experimental setup was installed at the 3rd switchyard in the linac beam line, including the target system, the primary electron beam monitor system and a simple positron spectrometer. Some preliminary experimental results have been obtained with incident electron energies of 4 and 8 GeV and with different thickness of the target. It is reported that the absolute positron yields with the crystal target were enhanced by about 26% for a positron energy of 20MeV/c and by 15% and 18% for electron energies of 4 and 8 GeV respectively, averaging over the positron momentum range of 5 – 20 MeV/c, compared with the maximum e+ yield with the amorphous target.

The Committee recommends that this experiment be continued to improve the understanding of the positron yield, and to obtain a precise alignment of the crystal axis, since it is expected to be used in the linac upgrade plan for simultaneous injection scheme to the four rings.

31) KEKB controls: Status and upgrade plan

The KEKB control system is working well and there have been few problems. However, like most control systems, it is based on equipment that is either obsolete, or is expected to become obsolete in the near future. Plans are under way to evaluate all the components and develop plans for upgrading those that are the most vulnerable. All the upgrades will certainly be needed if it is decided to go ahead with SuperKEKB. If KEKB continues in it's present configuration, it can be expected that some fraction of the components will be upgraded each year as part of a continuous improvement effort.

There are currently no plans to make major changes in the software, other than those that are driven by hardware upgrades. In the high-level applications there will also continue to be new algorithms required to support the new accelerator physics initiatives.

Overall, the Control system seems to be in good shape.

Appendix A

KEKB Accelerator Review Members

Andrew Hutton	JLab Chairman
Alexander Chao	SLAC
Warren Funk	JLab
Oswald Gröbner	CERN (retired) – unable to attend
Heino Henke	Technical University, Berlin
Nadine Kurita	SLAC (replacing John Seeman for this meeting)
Trevor Linnecar	CERN
Won Namkung	POSTECH
Flemming Pedersen	CERN
Eugene A. Perevedentsev	BINP, Novosibirsk
David Rice	Cornell
John Seeman	SLAC – unable to attend
Wang Shuhong	IHEP, Beijing
Katsunobu Oide	KEK Secretary, Accelerator
Shin-ichi Kurokawa	KEK Secretary, Accelerator

Agenda of the Tenth KEKB Accelerator Review Committee

Feb. 21(Mon.)		
8:30- 9:00	Executive session	
9:00- 9:05	Welcome	Y. Totsuka
Status report		
9:05- 9:20	Overview of KEKB project	K. Oide
9:20-10:00	KEKB performance & near term plans	H. Koiso
10:00-10:30	Belle status and plans	Y.Sakai
10:30-10:50	Break	
10:50-11:10	BPM issues	M. Tejima
11:10-11:30	Beam observations	J. Flanagan
11:30-11:50	Beam-beam experiment	T. Ieiri
11:50-12:15	ARES status	T. Abe
12:15-13:30	Lunch	
13:30-13:55	Injector upgrade	M. Satoh
Crab cavity		
13:55-14:25	Crab cavity overview	K. Hosoyama
14:25-14:50	HOM damper	Y. Morita
14:50-15:15	Input/Coaxial coupler	K. Nakanishi
15:15-15:40	Cryostat	H. Nakai
15:40-16:00	Break	
16:00-16:15	Refrigeration system	H. Nakai
16:15-16:40	RF control	K. Akai
16:40-17:05	Crab optics & dynamics	A. Morita
17:05-17:30	Magnets, installation, orbit control	M. Masuzawa
17:30-18:30	Executive session	
18:30-20:00	Reception	
Feb. 22 (Tue.)		
SuperKEKB		
8:30- 9:00	SuperKEKB overview update	T. Mimashi
9:00- 9:20	Beam-beam update	M. Tawada
9:20- 9:45	Vacuum upgrade	Y. Suetsugu
9:45-10:10	ARES upgrade	T. Abe
10:10-10:30	break	
10:30-10:55	SCC upgrade	T. Furuya
10:55-11:20	Lattice and dynamic aperture at SuperKEKB	Y. Ohnishi
11:20-11:40	IR overview	Y. Funakoshi
11:40-12:05	IR vacuum chamber	K. Kanazawa
12:05-13:25	lunch	
13:25-14:00	***IR vacuum system upgrades plus a short status of PEP-II***	***N. Kurita***
14:00-14:25	Secondary electron yields from vacuum materials and in-situ surface characterization	S. Kato
14:25-14:45	QCS	N. Ohuchi
14:45-15:10	Background	O. Tajima
15:10-15:30	Impedance	K. Shibata
15:30-15:45	break	

15:45-16:05	Coherent radiation	T. Agoh
16:05-16:30	C-band R&D status for SuperKEKB	T. Kamitani
16:30-16:50	Tungsten mono-crystalline target for a high-intensity positron source	T. Suwada
16:50-17:10	KEKB controls: Status and upgrade plan	N. Yamamoto
17:25-18:30	Executive session	
18:30-20:00	Working dinner	
Feb. 23 (Wed.)		
8:30-10:30	Executive session	
10:30-11:00	Interaction with KEKB staff members	
11:00-11:30	Closing	