The Fifth KEKB Accelerator Review Committee Report

Introduction

The fifth KEKB Accelerator Review Committee meeting was held on February 10-12. Appendix A shows the membership of the committee.

As before, the fifth committee meeting comprised oral presentations by KEKB staff members and discussion by the committee members. The agenda of the meeting is shown in Appendix B. For the first time, a new session where the committee reported its recommendations to the KEKB staff members was held before the close of the meeting. The committee wrote a draft report during the meeting, which was then improved and finalized by E-mail communication among the committee members.

Contents

Executive Summary

Foreword:
The 5th meeting of the Machine Advisory Board for the KEKB facility was qualitatively different from previous meetings. KEKB was put into operation about a year ago and a wealth of information and observations has now been accumulated. In a 2-day meeting with 13 hours of oral presentations, there was little time left for the committee members to digest and discuss all the new information. The challenge to fully understand and continuously improve the performance of KEKB triggered in the KEKB machine group a phenomenal activity in all areas. One cannot fully do justice to that major effort in a 2-day meeting.

During the first year of operation KEKB reached a remarkable level of performance (peak luminosity 7 x 1032cm-2s-1, integrated luminosity in a 24 hour period of 25 pb-1, total accumulated luminosity in the first 4 months of physics research 0.5 fb-1. The present difficulties and limitations are clearly identified and a vast program is under way to overcome these limitations. What can be said at this moment with certainty is that no “show stoppers” have materialized, and that the chosen approach by the KEKB group to make further rapid progress seems to be perfect.

Summary:

Commissioning of KEKB started Dec. 1, 1999, and the first electron beam was stored in the 8 GeV high energy ring of KEKB on Dec. 13. On Jan. 10, 1999 positrons were injected into the 3.5 GeV low energy ring and subsequently stored. By the middle of April 1999, 524 mA of e- and 514 mA e+ were accumulated and stored in the 2 KEKB rings.

At the beginning of May 1999 the BELLE detector was moved into place, and one month later the first hadronic events were produced in e+e- collisions and observed in BELLE. The time during the second half of the year was spent on HEP (3 months), component installation, and a number of repairs (vacuum leaks and one magnet failure).

By Feb 8, 2000, 0.5 fb-1 of luminosity had been accumulated and analysis started on the large number of multi-hadron events, which were produced.

The most problematic machine physics issue, which manifested itself during the initial runs, was an increase in positron beam size with increasing positron beam current. The biggest technical challenges were failures of masks that are used for background reduction of the BELLE detector.

The positron beam blows up, displaying some of the predicted characteristics of the photoelectron instability, but the observations are not conclusive. A number of solutions to this problems were discussed, but at this stage it may be too early to determine the best way of attacking this problem.

An incredible amount of detailed observation and analysis of the machine optical parameters of KEKB were carried out, and comparison with the design was made. In the course of this work, some new innovative methods were used. Subsequent correction of some of the observed parameters makes KEKB one of the best-understood high-energy machines. Except for the vertical beam size increase of large positron current in the low energy ring, no other significant instabilities limit the present beam current or reduce luminosity so far. To a large extent, this is due to the transverse single-bunch feedback systems that work perfectly.

The angular crossing of the two beams in KEKB worried the machine designers, because it might reduce the tolerable beam-beam tune shift and seriously limit the attainable luminosity. Although at this stage it is still too early to quote observed beam-beam tune shift limits in the chosen geometry, one can already safely say that there does not seem to be a significant luminosity degradation.

Crossing beam geometries make much simpler interaction region setups possible compared to head-on beam geometries. This may be one reason for the modest background rates in the BELLE detector, which seem to be smaller than predicted.

A number of critical and complicated components worked surprisingly well, often much better than anticipated. The final superconducting quadrupoles close to the interaction point work perfectly without any problems. Another very complicated system is that of the RF acceleration, consisting of 26 of the new and innovative ARES acceleration cavities and 8 superconducting cavities. Power levels of up to 380 kW were transferred to the beam through a single superconducting cavity. This surely represents a world record in superconducting acceleration technology.

Another area of very successful commissioning was that of the electron pre-acceleration and injection into the high-energy ring as well as the positron production, acceleration and injection into the low energy ring. The achieved, overall injection rates of 1.2 mA/s in both rings are close to the design. In particular, the complicated switching between 4 modes of linac operation (8 GeV electron injection in KEKB, 2.5 GeV injection into the photon factory, 2.5 GeV electron injection into the accumulator ring AR, and 3.5 GeV positron injection into KEKB) works perfectly with typical switching times of two minutes.

The machine control system, using the world’s largest application of EPICS, works perfectly, as does the extensive beam monitor system.

Finally the machine vacuum system deserves praise: In spite of the fact that the KEKB machine in this early stage of the game has been let up to air quite frequently, average pressures in the 10-8 to 10-9 Torr are attained in the presence of large stored currents. Beam life times between 1 and 10 hours are observed. Vacuum conditions will further improve with “beam scrubbing”, i.e. beam-induced gas desorption.

The amount of work done during this first year of operation, and the accomplishments of the KEKB machine group are most impressive and deserve the highest praise.

Findings and Recommendations

A) KEKB Commissioning Status

The commissioning of KEKB has been a phenomenal success. Achieving a luminosity of 7.3 x 1032cm-2s-1 after just over a year of commissioning is a great achievement for the KEKB staff. This is indicative of a well-designed accelerator and an excellent commissioning team. It is difficult for the committee in two days to delve into all facets of commissioning, but it is hard for the committee to imagine the commissioning team doing any more than they have in the past year. Congratulations!

There have been significant successes: the luminosity reached 7.3 x 1032cm-2s-1; the positron injection rate is nearing 100% and has reached 1.7 mA/sec; the backgrounds in the BELLE detector are manageable and are not a major hindrance to machine operation; a peak integrated luminosity per day of 25/pb was achieved; the RF, feedback, control, vacuum, and magnet systems work nearly to design. Overall, everything is functioning well.

However, the committee shares with the commissioning team their primary areas of concern for future work:

A) The positron beam enlargement with current has limited present performance and future studies and hardware changes will be needed. The committee feels that the evidence for enlargement along the positron train from the photoelectron instability (PEI) needs to be confirmed, and the studies extended to make sure the growth rates and physics mechanisms are understood as well as possible. The proposed solutions should be tested on a short section of the LER as soon as possible. Full computer simulations of the exact conditions of the KEKB experiments should be carried out.

B) The beam size in the HER enlarges at high currents. Studies should continue to determine the cause, and to develop a solution.

C) Studies of the electron injection rate, which is only about 30% efficient, should concentrate on finding the sources of inefficiency and improving the tuning techniques.

D) The various methods of measuring the luminosity, either by direct measurement or by calculation using measured beam sizes and currents, do not agree within a factor of two. Continued studies are encouraged to reduce this discrepancy.

E) The effects of shorter bunch lengths on the luminosity should receive further study as crossing angle issues may manifest themselves in these tests.

F) The tuning of the interaction region to make small spot sizes has been successful but further tuning of the x-y coupling is needed.

B) Beam Optics Issues

Beam optics work in KEKB has concentrated on beta function, dispersion, and x-y coupling correction in the two rings. Several standard and some newly developed beam optics correction techniques have been used with good success. The spurious dispersion has been reduced to 2 cm and beta functions are within 10% of the design values. The rings were successfully de-coupled to a few percent. This is a very satisfactory position to be in for a project at this stage of development.

During recent beta measurements, the phase advance data in the LER lattice indicate that there is a systematic betatron phase error on one side of the Tsukuba interaction straight. The source of this phase error should be investigated.

The local optics corrections near the interaction region, which are needed to make high luminosity, have also been fairly successful. However, to finish the interaction region corrections, several new techniques need to be refined or practical methods developed. These techniques include fine-tuning of the x-y coupling and reducing the vertical dispersion to sub-mm levels.

Perhaps from these studies, insight into the discrepancy between the spot size measurements and those predicted by the measured luminosity will emerge.

C) Beam Instability Issues

Considering the relatively short time since commissioning started, the amount of experimental data related to beam instability issues is very impressive. Longitudinal and transverse broadband impedances have been measured by observing single bunch effects. The measured impedances are significantly larger than the design goals, but are still far from being limiting factors for KEKB performance at the nominal single bunch currents. Transverse coupled bunch instabilities (CBI) were also observed early in KEKB commissioning, and both bunch-by bunch feedback and large positive chromaticity have proven necessary to suppress these. At present, CBI does not limit the LER current, while in the HER some beam loss occurs in the tail of a series of trains at about 435 mA. The exact cause of this loss does not seem to be fully understood at present.

The Bunch Oscillation Recorder is very useful for measuring the growth rates of coupled bunch instabilities after turn-off of the feedback system, as well as recording all the characteristic signatures of the Fast Beam-Ion Instability in the HER.

By far the most harmful beam instability observed is the vertical beam blow-up in the LER, suspected to be caused by the Photoelectron Instability (PEI). At present, this is one of the most serious problems limiting the luminosity of the KEKB. A number of observed characteristics of this blow-up supports the hypothesis that it is due to a fast build-up of an electron cloud around the positron beam, and that the neutralizing electron cloud line density reaches a saturation value close to full neutralization after a passage of about 20 bunches. This behavior has been supported by tune shift measurements versus bunch position in a train. In addition the average vertical beam size versus the length of the bunch train has been measured by the interferometer, and a fast gated camera made a less precise measurement of the beam size versus bunch number. These measurements indicate that the trailing bunches are blown up compared with the leading bunches. In apparent contradiction with this are the observations of bunch-by-bunch luminosity in BELLE, which do NOT show the expected higher luminosity for the first 10 or 20 bunches. Soon (March 2000), simultaneous use of the interferometer and the fast gated camera will be possible which will make measurements available with beams in collision.

A substantial fraction of the arcs was equipped with permanent magnets in an attempt to confine the photoelectrons. Although a measurable effect was observed under certain conditions, the effect was not dramatic. Many different fill patterns have also been attempted but with only partial success.

A number of measurements are being actively pursued, such as: i) measuring the photoelectron current in the BPMs, ii) measurements of the reflectivity and the energy distribution of photoelectrons in a test vacuum chamber at the Photon Factory, iii) increasing the number of permanent magnets, and iii) construction of solenoids with Bz = 30 – 50 Gauss for installation in the field free regions of the arcs.

It would be very important to be able to directly observe the coherent signals of the instability itself to get a more thorough agreement between observations and simulation. Early simulations considered only long range wakes excited by a rigid dipole displacement of a bunch (chromaticity $\xi = 0$, head-tail mode number $m = 0$), while more recent simulations include much shorter range wakes. Ideally, growth rates and instability thresholds should be calculated for all possible head-tail mode numbers m, as well as for different values of chromaticity, and the results compared with experiments. As has already been done for the single bunch case, the frequency shifts of m = 0 and m = -1 modes could be measured for the multi-bunch case with significant electron neutralization. These simulations should be compared with experiment, and agreement between simulation and observed modes and thresholds obtained. It may be worthwhile constructing transverse pick-ups sensitive at microwave frequencies. Due to the large difficulties and uncertainties associated with the simulations, the committee feels that experimental observation of mode frequencies, thresholds and growth rates would be extremely useful to be able to evaluate whether the feedback systems could help in curing this harmful instability.

For zero chromaticity, the feedback system is only sensitive to the m = 0 head-tail modes. However even for $m \neq 1$, a center of gravity component is produced at low frequencies for non-zero chromaticity, which may make the feedback system effective even for high frequency modes.

Measures to reduce the production of photoelectrons in the beam pipe are also discussed in the vacuum section.

The dipole signals from the Fast Beam-Ion Instability in the HER are effectively suppressed by the bunch-by-bunch feedback system. Nevertheless a substantial growth in vertical beam size occurs when the number of bunches and average beam current is increased. There is no threshold and the increase in vertical beam size is proportional to current. This effect is not yet fully understood. Although at present this effect is far from being as severe as the PEI in the LER is, it is important that the nature of this blow-up be understood. Unlike the electron cloud in the LER, which is large compared to the beam size, the ion cloud in the HER is expected to have a distribution comparable to the beam size, and therefore can excite efficiently higher order modes like the transverse quadrupolar modes (width oscillation). This was the case for the classical beam-ion instability observed in the CERN AA. Suppression of the dipolar instability was effective by means of transverse feedback, but the beam blow-up due to coherent beam-ion instability remained. After installation of a quadrupolar pick-up, the instability was clearly identified as being a quadrupolar instability, which is very difficult to cure with feedback.

D) Beam-Beam Issues

Studies of the beam-beam effect in KEKB are well advanced. The steady increase of the luminosity with time testifies that beam-beam issues are about as expected for this stage of KEKB. With the beam sizes being enlarged both by single beam effects as well as by beam-beam effects, studies of beam-beam issues have been made more complicated. However, the KEKB team has learned a lot about the beam characteristics in collision. The waist scans, beam-beam deflection scans, RF phase scans, closed orbit feedback, and IP x and y position feedback systems all work well.

In all e+e- colliders, the beam sizes are enlarged at high currents due to beam-beam forces. The accelerator physics efforts are typically directed towards improving the beam conditions so that the beam-beam tune shifts, and ultimately the luminosity, are increased.

Further studies of the beam-beam effect at KEKB should include the effects of x-y coupling corrections, low versus high emittance lattices, short versus long bunches, new tune locations, wiggler on versus wiggler off in the LER, dispersion adjustments, crossing angle studies, different bunch spacings and bunch train configurations.

Additional studies, using a few bunches around the ring and no single-beam enlargement should reveal the basic beam collision parameters. Then, further studies are encouraged where more and more bunches are added leading to increasing beam size enlargement. The tune shift limits may change.

Furthermore, colliding with bunches in every third RF bucket may be illuminating. Alternating which beam is “weaker” may indicate which optics corrections are needed. Efforts to study how to further maximise the average luminosity are needed. Studies to determine how soon the CRAB RF system is needed are in order. Tests of violating energy transparency conditions may lead to higher luminosity. The most obvious one is trying unequal tunes.

The temporary use of the lower emittance collision lattice may allow a higher average luminosity while machine studies are on-going to find a cure for the single beam blow-up in both rings, and in particular the LER.

Overall, the committee was very impressed with the progress on understanding the beam-beam effects, and concurs with the commissioning team that the next luminosity goal should be to exceed 1033cm-2s-1.

E) Background

The background in Belle has been a major source of concern from the beginning of the project. The BEAST detector was used during the commissioning to evaluate the different sources of background and the results indicated that the SVD could expect a dose of 220 krad during initial operation, roughly equal to the maximum tolerance of the silicon detectors.

In order to protect the detector, PIN photodiodes were installed around the beam-pipe for instantaneous dose monitoring and alarm; MosFets monitor the dose accumulation around the SVD, and CsI crystals detect beam loss during injection.

The background from the LER is due almost exclusively to lost particles, and is improving as the vacuum improves upstream of the detector. The background from the HER is not only due to lost particles but also due to high-energy synchrotron radiation back scattered from downstream and low energy synchrotron radiation from upstream.

Despite all the precautions, a steering mistake in the early commissioning destroyed a large portion of the SVD, so a Taskforce was set up to address all of the background issues. Limits were placed on the steering magnet strengths near the detector; a downstream aluminium vacuum chamber was replaced by a copper chamber with a factor 10 less reflectivity, an upstream mask was added, and some pumping improvements were made upstream of the detector in the HER.

These improvements have been very successful, reducing the total dose in the detector to 14 krad since October 1999 (an integrated luminosity of 0.5fb-1). This is still not sufficient, so a program to improve the vacuum upstream of the detectors should be initiated. It is recommended that the ion pumps in this region be systematically switched off (or the NEG pumps heated so that they out-gas) to determine which areas would benefit from increased pumping.

At present, the users are relatively content with the background levels. Nevertheless, since the beam currents are still a factor 5 (2) below the nominal in the LER (HER), now is the time to make the improvements that will eventually be needed.

F) IR Hardware (QCs and IR Quads)

In the interaction region, there is a very complicated superconducting magnet system including SC compensation solenoids, SC quads, SC skew quads, and SC dipole correctors. All the components of this system have been working very well. Even though there was an incident by a positron beam, the system recovered quickly, and the associated cryogenic system shows a remarkable operation record of more than 8,000 hours without any problems. The committee would like to congratulate the dedicated work done by the IR group members.

On the other hand, there was an unexpected accident with the septum quadrupole magnet, QC1LE. The power feed to one of 16 coils melted due to a blockage of the cooling water pipe. It is not uncommon for water cooled coils to become clogged up due to accumulation of copper oxide inside the cooling lines. We recommend that action be taken to prevent this kind of accidents in the future, for example, by adding a nitrogen blanket to the water system.

G) IR Vacuum System

The vacuum chamber design in the interaction region is complicated. Two serious accidents damaged the vacuum quality, i.e., the intense synchrotron radiation from the QCS magnet overheated the vacuum pipe, and an iron plate cut the BPM near the collision point.

The interaction region vacuum pressure would still not be good enough. The gas load is at least ten times higher than expected. To obtain the designed vacuum pressure, the vacuum group proposed a revised design in which they increased the conductance of the pumping slit and added a larger capacity NEG pump. There is evidence that the gas load includes not only photo-desorption but also thermal desorption, because heating-up of the bellows and vacuum chamber near the colliding point was observed. After monitoring the temperature of the vacuum chambers in the interaction region section, a reinforced cooling water channel should be added on the modified vacuum chamber. The committee recommends that if a newly designed vacuum chamber is required, it should be installed as soon as possible.

H) Vacuum System

The vacuum system in the arc sections of both rings is operating well in both performance and reliability, and the performances are close to the design. Beam cleaning process progresses satisfactory in both rings, so NEG activation has been carried out on the schedule expected by the vacuum group. This shows that the evaluation of the gas load was correct and that the surface treatments were suited for mass production.

The main problem in the vacuum system has been the movable masks that are required to minimize lost particle background in the detector. The RF finger contacts at the shaft of several of the masks have broken, and, in some cases, created a vacuum leak. The vacuum group recognizes the severity of this problem, and they have proposed to upgrade all of the masks with an improved design. One (ver.4) is a movable vacuum pipe with no shaft, in which the only moving parts are the upstream and downstream bellows. According to the design, the bellows deformation is less than 1.5 degree, so the bellows should work reliably. A different mask design (ver.5) is proposed for the straight section close to the interaction region where space is at a premium. In this design, by the use of SiC absorbers, HOMs excited by beam are effectively damped out. RF finger contacts are placed at a position where HOMs are already absorbed by SiC absorbers. The current density on the finger contact is reduced, and the reliability should be higher. The committee expects the new versions of the masks to work better.

In the recovery process, a mistake with a roughing pump increased the vacuum pressure in its vicinity during NEG pump activation, so additional activation time was required. To avoid this kind of mistake, the vacuum group should prepare a roughing pump system with a programmed system operation.

To store higher beam current, the bunch current and the number of bunches will be increased. This requires that vacuum monitoring system should be enhanced. In addition to the vacuum pressures, the temperatures of the vacuum ducts and bellows should be monitored with sufficient speed. The pressures and temperatures that are monitored should be arranged and displayed in the B-factory control room, with an active alarm system.

A more fundamental problem is the photoelectron trapping in the positron beam, which causes the positron beam to blow up. The importance of secondary, scattered photons has been recognized through the experiment that two kinds of magnet array did not work as well as expected.

Only theoretical simulations were presented, but experimental tests have not yet been carried out. It is not easy to measure the reflectivity of photons at grazing incidence, because the measurement or counting of photons requires rather complicated instruments. Thus in the experimental tests, it is better to measure the photoelectrons than the photons. In the LER, the vacuum pipes downstream of the bending magnets have BPMs, so photoelectron currents could be measured in every electrode of the BPM along the vacuum chamber, and compared with the calculated photon intensity. By using a test chamber in the beam line, the scattered photon distribution could be evaluated by measuring the photoelectron distribution with different surface conditions, for example, a smooth, shiny surface and a saw-tooth surface.

An antechamber structure would be effective in reducing the number of photoelectrons in the beam chamber, and it seems a good candidate for solving the problem. We note that the antechamber structure requires a larger opening of the QD magnets, with the consequent higher cost of the magnets and their power supplies. The committee recommends that the project team evaluate the options carefully and precisely before taking a decision, given the importance of the problem.

I) Bunch-by-Bunch Feedback Systems

The bunch-by-bunch feedback systems quickly turned out to be essential to reach high average bunch currents. Although some minor commissioning problems have been identified and are being rectified (increased vacuum pressure near the kickers, damage to power amplifiers, tuning of the transition between high and low frequency systems for the HER transverse damper), the systems work well and at present are not limiting the available luminosity.

The Bunch Oscillation Recorder that is used for transient analysis with the feedback off, is a very important beam diagnostic tool. Fast Beam Ion Instability patterns have been recorded, which clearly identifies this instability in the HER. Mode analysis of coupled-bunch instabilities has also been performed. The bunch-current monitor and the bunch-by-bunch tune measurements are also extremely valuable diagnostic tools.

The exact reason why both the feedback systems and a substantial positive chromaticity are required to stabilize the beams is not yet fully understood, and should be further investigated. A possible explanation would be that in addition to the $m = 0$ head-tail modes, higher-order modes may also be harmful. For non-zero chromaticity, these higher order head-tail modes also have a center-of-gravity dipole component, which makes it possible for the feedback systems to act on them and to stabilize them. Various experiments can be proposed to confirm this, such as trying to identify the modes which occur when the chromaticity is reduced to close to zero, or attempting to identify the mode patterns and head-tail mode number when the feedback is turned off with a high positive chromaticity.

J) Crab Cavities

The Committee commends the KEK staff on the excellent progress they continue to make on this complex system. The crab cavities have been developed as a technical contingency, since their need (or the lack thereof) has not yet been established. As a contingency, the level of resources devoted to this activity has appropriately been lower than has been the case for systems required for the initial turn-on of KEKB.

A test has now been made on a full-scale crab cavity with the center conductor installed, and the gradient achieved has exceeded the design value. This test has also established that multipacting is not a significant problem.

KEK has also made a copper model on which a number of important measurements will be made. One of these measurements will be to determine the acceptability of the spatial harmonics of the deflecting mode to ensure that they are acceptable; this measurement is important because of the significant "squashing" of the cavity shape. Another measurement will verify that the damping of all higher modes is adequate. The copper cavity can be used to determine the degree of centering of the center conductor required to prevent transmission of an unacceptable amount of power down the line. It can also be used to confirm that the one-theta waveguide mode (as opposed to the normal TEM mode) is adequately cut-off (note that the one-theta mode is directly coupled to the deflecting mode in the cavity, whereas the TEM mode is not coupled at all if the center conductor is perfectly centered).

The Committee believes that performing the test with the notch filter installed on the superconducting cavity will be an important milestone. This test will verify that the notch filter can be adequately cleaned and rinsed. The test will also verify that the amount of deflecting mode power reaching the coaxial absorber is acceptable, and that the apparatus for moving the center conductor to control its centering and to control the cavity resonant frequency works acceptably.

Analyses of the requirements on the phase and amplitude control of the crab cavities, and on the betatron phase shift between the crab cavities, have been done in the past. Since current plans call for completion of the crab cavities in about two years, it will soon be time to begin translating the control requirements into control and instrumentation designs appropriate for meeting the requirements.

The plan to use a satellite refrigerator for the crab cavities appears to be the most practical approach. KEK is to be commended for anticipating the potential problems associated with multiple changes in vertical elevation in a liquid nitrogen system, and in taking measures to avoid this problem.

Overall, progress on the crab cavity system continues to be excellent.

K) RF System Overview

At present, the Low Energy Ring (LER) is equipped with 16 ARES cavities (required for their large stored energy per square megavolt), yielding up to 6 MV total operating voltage. The High Energy Ring (HER) contains 10 ARES units and 4 superconducting cavities, giving 11 MV total voltage. Plans are under discussion for completion of the installation in October 2000, by adding 4 more ARES units into the LER, and adding 2 more ARES units plus 4 more superconducting cavities in the HER.

The entire RF system has been outstanding - in performance as well as reliability. At no time has the peak performance of KEKB been limited by the RF system, nor is this to be expected in the future. The presently installed system can support beam currents of 1.5 A in the LER and 0.7 A in the HER. However, the ARES cavities have been tested at 170 kW beam power per cavity (close to the full design value of 225 kW) and the superconducting cavities have been run at a record beam power of 380 kW each, well above the design value of 250 kW. In ARES, these power levels were achieved by suitable phase adjustments, concentrating power in some cavities at the expense of others. The ARES cavities have been conditioned to 0.4 MV per cavity (compared with the design maximum value of 0.5 MV), while only 0.31 MV is required at the moment. The superconducting cavities have been conditioned to 2.2 MV, well above the design value of 1.5 MV.

The reliability of the entire RF system is excellent, as exemplified by a total loss of beam time due to RF of only 10 hours in a 34-day physics run. It is noteworthy that up to two ARES units can trip off without beam loss, and that a tripped unit can be turned on again safely while beam is circulating, once the problem is solved.

The stability of the RF phase and the control of the synchronous phase are such that no significant collision-point shift in the BELLE detector has ever been observed. At the beginning of operations, random 0-mode synchrotron oscillations of about ±0.5 degrees were observed, caused by noise in the drive system (and the concomitant synchrotron sidebands). This was not a Robinson instability, since it was current independent. The effect was cured by the addition of a damping feedback system.

L) ARES and Superconducting Cavities

In judging the performance of both systems, it should be borne in mind that RF systems for high-intensity electron storage rings are very difficult items and notorious as potential sources of trouble during commissioning. In fact, the number of problems encountered in both systems has been astonishingly small, and they have all been solved promptly.

M) Beam Instrumentation

The beam instrumentation is very complete, and has been particularly valuable since most of it was available at the start of commissioning. The Instrumentation Group is to be congratulated on this accomplishment.

The beam position monitors have been carefully calibrated and the beam has been used to find their electrical centres with respect to the adjacent quadrupoles. The offsets were larger than expected (sigmas of 0.6 mm for everything except the HER horizontal offset which was up to 1 mm). The resultant orbit distortions had an rms of 0.3 mm, about half of that prior to the calibration, showing that the algorithm is correct and converging. 37 BPMs around the Interaction Region have still not been corrected and these are important to improve the optical function corrections at the IP. Priority should be given to completing these calibrations.

Most of the BPMs have a resolution of about 3 micron. However, some of the monitors are much noisier with resolutions up to 18 micron. It is worth following up on these, but at a lower priority than completing the calibrations.

Complete orbits can now be taken in both rings within 2 seconds – a factor two better than last year. This is an excellent result that is very useful to the commissioning team.

The octopos eight-electrode BPMs near the interaction point are working, although not yet as well as hoped, probably due to higher order modes.

The synchrotron light monitor has been a wonderful success. The interferometer was available in the control room from the initial commissioning day and has been used extensively to measure the beam sizes under many operating conditions. The studies of the beam blow-up in the LER would not have been possible without this monitor.

The gated camera has been used to measure the bunch by bunch blow-up. Unfortunately, this data still has to be de-convoluted for the diffraction, so the results for the first few bunches are probably significantly over-estimated.

Some work is still needed to provide the variable slit separation and simultaneous gated camera and interferometer measurements. Completing these installations (foreseen for March) will make the synchrotron light monitor one of the forefront instruments in the world.

The bunch current monitoring system is working well and, combined with the injection system, enables bunches to be filled to the same current within a few percent.

The tune measurement system is working well, controlled by EPICS, and available online in the control room.

The turn-by turn monitor is available to assist in optimising the injection. The injection still needs some tuning as the data shows that beam energy oscillations at injection exceed the acceptance of the ring.

Overall, the performance of the beam instrumentation has been remarkably good, which has contributed significantly to the successful commissioning of KEKB.

N) Injector Linac, Beam Transport Line and Injection System

At this meeting, the Injector Linac Group reported a remarkable achievement in improving the stability and reproducibility of the injector operation. It is a very tough duty for a machine to support 4 rings with very different beam parameters. The time required to switch from one mode to another was reported to take 2-3 minutes, a great improvement from a time of about ten minutes reported last year.

For KEKB physics experiments, the injector is presently able to provide electron beams of 8 GeV with 1.2 nC/bunch and positron beams of 3.5 GeV with 0.62 nC/bunch. The design goal of 0.64 nC/bunch for positron beams has therefore been achieved. The average injection rate into the LER is now 1.2 mA/sec, including losses in the transport lines and the ring injection system.

The committee congratulates the Injector Linac Group for their dedicated work in upgrading the injector subsystems, and in automating the parameter changes needed for each operating mode.

The electron injection efficiency to HER is reported to have a lower value of 30-40%. Therefore, the committee would like to recommend that the KEKB team carry out further studies on this subject. The committee was informed of plans for a new project to build a separate bypass transport line for 2.5 GeV electron beams to the Photon Factory (PF) and the Accumulator Ring (AR). The committee recommends further studies on this issue, taking into account the fact that it would simplify the operation of the injector linac.

O) Control System

The control system has now grown to be the largest EPICS user in the world, based on the number of records. This has happened in a short time and with very few problems. The hardware choices have proved to be reliable and few bugs have been reported.

Particularly impressive is the number of application programs that are available (almost half of them in SAD). The commissioning would not have been anywhere near as fast without these high-level tools to make complex measurements, calculate corrections and apply them. It is remarkable how many of these tools were presented by the different speakers in the course of the review, none of whom expressed any surprise at being able to perform such complicated operations on such a young machine.

The controls group is to be commended for its performance.

Appendix A

KEKB Accelerator Review Committee Member List

Gustav-Adolf Voss DESY Chairman
Alex Chao SLAC
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Dave Gurd LANL
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Appendix B

Agenda of KEKB Accelerator Review Committee

Date: February 10-12, 2000
Place: Large Meeting Room in Administration Building

Feb. 10
8:30- 9:30 Executive session
9:30- 9:45 Introduction S. Kurokawa

9:45-10:30 Overview of commissioning status K. Oide
10:30-11:15 Beam optics issues H. Koiso
11:15-12:00 Beam instability issues H. Fukuma
12:00-13:00 Lunch
13:00-13:45 Beam-beam issues Y. Funakoshi
13:45-14:30 Beam background issues and IR vacuum cambers J. Haba, K. Kanazawa
14:30-15:00 IR hardware (QCs and IR quads) issues N. Ohuchi, M. Tawada
15:00-15:45 Vacuum issues Y. Suetsugu
15:45-16:15 Feedback system M. Tobiyama
16:15-16:45 Crab cavity system development K. Hosoyama
17:00-18:00 Executive session
18:00-19:30 Reception

Feb. 11
8:30- 9:15 Executive session
9:15- 9:35 BELLE status M. Yamauchi
9:35- 9:50 RF system overview K. Akai
9:50-10:05 ARES T. Kageyama
10:05-10:20 SCC S. Mitsunobu
10:20-10:50 Beam instrumentation S. Hiramatsu
10:50-11:20 Linac A. Enomoto
11:20-11:40 Injection M. Kikuchi
11:40-12:00 Control N. Yamamoto
12:00-13:00 Lunch
13:00-15:00 KEKB tour
15:00-20:00 Executive session with dinner

Feb. 12
9:00-11:00 Executive session
11:00-11:30 Session with KEKB staff members*
11:30-12:00 Closing

* In this session, Review Committee Members explain the contents of report to KEKB staff members and accept questions and comments from them.