KEK-LS MAC Close-out Comments

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1. *Is the KEK-LS design consistent with the present state-of-the-art in mid-size light source designs? If not, describe any improvements that should be considered.*
    a. Based on the brightness curves shown, the projected performance of KEK-LS is only slightly better than MAX IV, which is now considered a conservative design. Hence, the committee feels that the proposed KEK-LS design could be more ambitious. A key factor is the strong effect of IBS. Direct optimization of x-ray brightness, instead of proxies like emittance, is strongly encouraged.
    b. The various DQBA configurations show fairly low emittance, but also have different beta function values at the straights, which invalidates simple comparisons based on emittance. A direct comparison of x-ray brightness needs to be made. Still, scaling the APS-U lattice gives ~80-pm natural emittance, while scaling ALS-U suggests significantly smaller values.
    c. Elimination of the short straights, use of anti-bends, use of a strictly achromatic design, use of state-of-art magnet strengths, use of more than 20 cells, use of more dipoles per cell, use of round beams to control IBS, use of on-axis injection, and use of state-of-the-art insertion devices all suggest themselves as routes to higher brightness within a ~500-m circumference.

1. *Is the KEK-LS design consistent with the present state-of-the-art in mid-size light source designs? If not, describe any improvements that should be considered.*
    d. The fact that sufficient DA exists for accumulation strongly suggests that the lattice can be pushed toward lower emittance. The fact that the magnet designs are relatively relaxed compared to other designs strongly suggests that further optimization is possible. A design that pushes magnet parameters to match those from other facilities should be prepared. This will allow more compact cells, and hence more dipoles per cell or more cells per unit circumference.
    e. Suite of planned insertion devices are not state-of-the-art, which significantly reduces the potential brightness improvement. More advanced devices should be considered as base-line devices.

2. *Describe any issues with the feasibility of the KEK-LS design, including in particular any potentially fatal problems.*
    a. The approximate computation of Touschek lifetime may produce misleading results, since it is not based on the local momentum acceptance (LMA). Use of LMA is a standard approach available in several easily obtained codes.
    b. Calculations of bunch lengthening from higher-harmonic cavities (HHCs) needs to be extended to include bunch-by-bunch charge variation, camshaft bunches, longitudinal impedance, etc. These results need to be used as input to thorough lifetime calculations based on LMA.
    c. Tracking does not include systematic or random multipole errors in the magnets. Given the small magnet bores and large claimed DA, this must be included.
    d. Even without geometric wakes, instability growth rates are very high. Preparation of a complete impedance model and use of tracking to assess injection efficiency and instability thresholds is a high priority.

3. *What are the most urgent technical issues to be addressed to ensure that KEK-LS will reliably achieve its specified performance?*
    a. Apply modern nonlinear dynamics optimization methods, which can provide very significant improvements in lifetime and DA. Several less computationally-intensive methods have recently been developed.
    b. Perform a technical comparison of the merits of using the KEK linac, a new booster, an accumulator ring, etc. Choose the scheme that allows driving KEK-LS to the highest possible brightness. Relevant considerations are emittance, bunch charge, bunch train capability, and longitudinal mismatch.
    c. Explore larger emittance ratios to suppress IBS and increase Touschek lifetime. Brightness may in fact increase. Flux through narrow beamline apertures will increase.
    d. Include the effect of the harmonic cavity in all calculations, particularly IBS and Touschek lifetime. Check calculations of bunch lengthening, as a 6-fold increase seems incorrect even in the ideal case. Ensure that the bucket height is held fixed.

3. *What are the most urgent technical issues to be addressed to ensure that KEK-LS will reliably achieve its specified performance?*
    e. Perform an accurate computation of the Touschek lifetime based on the local momentum acceptance, including actual bunch distributions in the presence of the HHCs and bunch-train gaps.
    f. Prepare an impedance model including geometric and resistive contributions. Use this in tracking simulations to assess instability thresholds at injection, for stored beam with gaps, and to establish chromaticity requirements.
    g. Start iterating lattice, magnet, and vacuum designs early with emphasis on photon beam extraction from the storage ring for all ID and BM sources over a wide energy and polarization range.
    h. Define any requirements for short bunch lengths and particular filling patterns to accommodate time-resolved experiments. Carefully evaluate these using the impedance model, cavity transients, and rf feedback systems.

4. *How does the PF-MAC evaluate the proposed insertion devices? Are there other types of insertion devices that should be considered?*
   a. Overall ID designs appear to be too conservative. E.g., SCUs and CPMUs are not included.
   b. Devices with small horizontal chamber dimension could be considered if on-axis injection is employed. These are superior to standard EPU designs.
   c. The need for SCW(s) must be carefully examined with the input from users. Carefully consider the impact on beam properties and dynamics.
   d. 5-m long IVU in 5.6-m straight appears not to leave enough space for transition regions, BPMs, correctors and other components. CPMU or SCU should be considered to reduce the length of necessary device while maximizing brightness.
   e. Similarly, the 1.2-m straight appears not to be long enough to accommodate a 0.6-m long in-vacuum ID.
   f. Consider further reducing the gap value of in-air devices. E.g., APS-U will have an 8.5-mm magnetic gap for such devices.
   g. Cooling water of 25C +/- 1C is inadequate. It is preferable to reduce the mean temperature and the fluctuation.
   h. LN2 lines can be installed in the ring area in order for CPMUs to be constructed more easily.

6. *Other comments and suggestions?*

Lattice and beam dynamics

1. Perform a scaling study including IBS, RF power limits, and other practical considerations to determine the optimum beam energy, rather than assuming 3 GeV.
2. The lattice momentum acceptance is low compared to the available RF acceptance, but also in terms of the resulting Touschek lifetime. State-of-the-art optimization methods can dramatically improve this.
3. Optimize lattices based on x-ray brightness using a standard set of IDs, rather than based on emittance. Include bunch lengthening and IBS.
4. Consider whether using canted devices in the long straights provides a workable, higher-brightness alternative to the short straights, that also allows more cells in the lattice.
5. No information was provided on the field quality of the magnets. The designs are based on 2D simulations, which will produce misleading results for saturated magnets.

6. *Other comments and suggestions?*

<u>Lattice and beam dynamics</u>

6. Conduct beam tracking study including ID kickmaps and lattice errors.
7. Carefully consider and evaluate methods of compensating for the effects of IDs on beam dynamics, e.g., correction of tune errors and lattice function beats.
8. Include operating at positive chromaticity in the beam dynamics calculations.
9. The 5.6-m space available for injection appears insufficient for conventional injection including an extra quadrupole.
10. Investigate an alternate injection scheme using, e.g., injection at an angle in a septum at the upstream end and a nonlinear kicker at the downstream end.
11. On-axis injection does not necessarily require swap-out or an accumulator ring. On-axis, off-momentum injection is another option.

6. *Other comments and suggestions?*

Magnets

1. Push magnet designs to state-of-art level to enable a truly leading LS design. Magnet designs should aim for greater compactness, to reduce costs, reduce coil overhang, etc.
2. Consider using a permanent magnet longitudinal gradient dipole (a la ESRF) for energy saving.
3. Include space for beam exit pipes for various sources (e.g., an EPU in vertical linear mode) in the design.
4. A 15-mm bore radius seems overly generous considering 10-mm DA without errors. Reducing the magnet gap is a simple and efficient path towards less expensive magnets with lower power consumption. Magnet gap choice should ultimately be driven by required vacuum chamber cross-section (for impedance and pumping).
5. Will the sextupole magnets incorporate steering and skew-quadrupole correction? If so, don’t neglect the multipole errors that result.

6. *Other comments and suggestions?*

RF

1. The choice of using room temperature cavities with solid state RF amplifier emphasizes system reliability. However, KEK has excellent SRF infrastructure and 500-MHz cavity module experience, a full SRF system with fundamental RF frequency of 500-MHz is a valid choice with the consideration of beam transient effects.
2. Make a comparison with lower frequency RF system, for example 166.7-MHz as main RF frequency and 500-MHz as third harmonic RF frequency, to see if it can help to improve beam lifetime, rf heating, and collective beam effects, including ions in particular.
3. The third harmonic cavities have damping effects on the beam instabilities in the storage ring, but also suppress the synchrotron tune, which may make instabilities worse. An analysis should be conducted for the KEK-LS case.

6. *Other comments and suggestions?*

RF

4. In the choice of 500-MHz normal conducting cavity, consider also the BESSY-type HOM-damped cavity
5. A thorough analysis of the benefits of active vs. passive HHCs for actual user modes (including hybrid mode) should be carried out.

6. *Other comments and suggestions?*

<u>Vacuum</u>

1. Define where the 10 per cell horizontal + vertical fast corrector magnets will be located and the relevant flanged/welded vessel interfaces, compatible with the magnet layout
2. Check PSD assumptions against those of other labs
3. Consider use of NEG-coated Al extrusion for ID vessels as this is commonly used around the world
4. NEG coating for elliptical chamber may require a separate setup to achieve proper in-house coating on ID chamber.
5. Investigate NEG-coating imperfections such as local defects, uneven coating, and roughness.

6. *Other comments and suggestions?*

Diagnostics

1. The target for the fast orbit feedback should be higher than 100-200 Hz. 450 Hz was recently demonstrated in a developmental system at APS.
2. Consider alternatives to Libera BPM electronics which could offer better performance and reduced cost, keeping in mind the life-cycle cost as well as up-front costs.
3. Include a second pinhole camera on a bending magnet with different dispersion to allow evaluation of energy spread as well as emittance.
4. Allocate space for high-precision ID BPMs for very sensitive beamlines.

6. *Other comments and suggestions?*

Diagnostics

5. Consider additional pickups, for example 10 more, 200 dedicated for COD measurement, one for bunch charge monitor, one for dedicated tune monitor, two for bunch-by-bunch feedback, six reserved for future application, 200+10.
6. Recommend two photon BPMs (in this way both position and angle can be easily measured) for each beamline. Carefully consider complexity of photon BPMs for EPUs.
7. Small diameter (4mm) of button with 0.5mm of gap size may introduce some beam impedance. Consider a larger button size and smaller gap (for example 5mm button + 0.25mm gap size) as an alternative solution.
8. Calculate RF heating in the BPM button with worst-case filling pattern.

6. Other comments and suggestions?

Beamlines

1. Carry out wave-optics simulations especially for high coherence beamlines.
2. Prepare requirements for the photon sources in detail earlier including any future upgrade possibilities. (For example, higher harmonics degradation, gap scanning speed requirement, degree of taper, etc.)
3. The use of the Er(20%) criterion in beamline designs seems problematic if each of several effects is allowed to separately produce a 20% degradation in performance.
4. Because PF has no experience on 3rd and 4th generation machines, it is strongly recommended to send beamline scientists and engineers to other facilities for training.
5. R&D on the beamline components and vibration issues at PF are important. KEK should support these activities.

6. *Other comments and suggestions?*

Facilities

1. If the storage ring and experimental hall are on a piled foundation, consider making the building support on a pad foundation to reduce vibration coupling.
2. Measure background vibration levels where KEK-LS will be built; localize any significant vibration sources and try to eliminate.
3. +/- 1 deg.C temperature stability is insufficient; it is recommended to aim at +/- 0.1 deg. C, bearing in mind that this is the local stability; the temperature around the ring can vary +/- 1 deg. C.
4. To access the inside of the ring, a bridge might be a better solution than an underpass.
5. LN2 lines are needed for many beamlines and possibly for some IDs.

6. *Other comments and suggestions?*

R&D

1. Diversify the sources of funding department/agencies including Institute of Materials Structure Sciences, Grants in Aid for Scientific Research, Japan Science and Technology Agency, etc.
2. Development of challenging ring designs that are genuinely state-of-the-art will require a significant investment by KEK, but will have far-reaching positive consequences on an international stage.

Conclusion

The MAC genuinely appreciates the hard work behind the many interesting and thoughtful presentations.

KEK has the opportunity to build a light source that is not only the best of its kind in Japan, but that will compete on the international stage for decades. A good start has been made on a design based on decades of experience and expertise. The committee encourages KEK to be even bolder to create a truly world-leading light source.