Interoffice Memo

From : L. Emery
Subject : Hardware Improvement Priority for APS Storage Ring
To : R. Gerig
Copy to : G. Decker, R. Klaffky

Purpose:

The purpose of this memo is to list some of the SR improvements that require a significant hardware design and construction effort and are related to enhancing the SR as a light source. Priorities are given in terms of short term (this year), medium term (maybe next year), and long term (2 years and longer). The statuses of the improvements range from almost completely installed to only a partial concept. This memo will outline what parts of each improvement need to be done .

I don't mention SR improvements that involve software, such as automated injection tuning scripts and feedback orbit correction software upgrades, and those that involve procedures, such as calibrating all power supplies against a single standard, or realigning girders. Also there are many improvements to the storage ring related to maintenance and reliability, which I won't mention.

The information data presented for each improvement are present status, new components, specifications, R&D required, aspects no specified yet.

This year's hardware improvements:

Upgrade of the BTS bpms. Will be complete this shutdown (1/2003). The new bps have lower electronic noise than the previously installed bps (15 μm instead of 1500 μm). This great improvement will speed up the trajectory correction in general, analyze booster extraction septum regulation and particularly help diagnose injection problems during top-up.

- Present status: To be complete this shutdown.
- New components: Electronics
- Specifications: Electrical noise to be at least as good as SR bpms in single pass mode.
- R&D required: None (anymore)
- Unknown aspects: None.

Increase the number of narrow-band bpms to help improve the long term stability of the

orbit. We have enough units available to replace the monopulse receiver electronics of the P1 bpms with narrowband electronics.

- Present status: Straightforward to execute. Can install one or two pairs every two weeks. Need to update OAG application software to recognize that narrowband electronics can be installed at bpms other than P0s.
- New components: Electronics
- Specifications: Install at P1 button location. Measure offset after installation.
- R&D required: None
- Unknown aspects: None.

Replace present beam position limit detectors (BPLD) with digital version (DBPLD) to reduce spurious trips and improve functionality.

- Present status: Five DBPLD pairs have been installed. Replacement is straightforward to execute. Can install one or two pairs every two weeks.
- New components: Electronics
- Specifications: Install and validate at narrowband bpms locations. Can install at P1 location if the electronics are replaced with narrowband bpms.
- R&D required: None
- Unknown aspects: None.

Replace the ceramic chambers with a new design by ME group to eliminate part of the bump mismatch during injection. The ME group is planning an installation in April 2003 (or in the next shutdown).

- Present status: Ceramic chambers delivered and magnetic field response measured by C. Doose. Best group of 4 to be selected by L. Emery by examining the best 4 waveforms.
- New components: Ceramic vacuum chambers, separate bellows.
- Specifications: Resistivity of coating within 2% of the average. The tolerance was not met, though it was known in advance that it was difficult.
- R&D required: Develop method to adjust the effective resistivity in house.
- Unknown aspects: None.

Kicker pulse output history for injection post-mortem. Occasionally, there is a beam dump at the instant the injection kickers fire. The current output history with time stamp will reveal whether a kicker misfired.

- Present status: Just an idea. Several other systems have histories: bpm, correctors, video data of beam images.

- New components: None.
- Specifications: Record the kicker output at 0.5 second interval with time stamp.
- R&D required: None
- Unknown aspects: None

Redesign vertical scrapers to reduce HOM heating and improve the collimation properties. OAG and PHY staff are currently determining the specifications, i.e. geometry based on higher-order modes (HOM) and collimation.

- Present status: In design stage.
- New components: Scraper assembly.
- Specifications: Change geometry to reduce HOM heating by a large factor, which has not been determined yet.
- R&D required: Calculate impedance using MAFIA, optimize thickness of Tungsten from simulations.
- Unknown aspects: Effectiveness as collimator, i.e. low number of secondary particles.

*Stabilize the booster extraction septum magnets t*o reduce pulse-to-pulse jitter in the beam trajectory in the BTS. (Applicable to SR injection septum magnets.)

- Present status: ES group removed external regulator and used internal regulation of new HV power supply. This eliminated the occurrence of low-amplitude first pulse. Set-up was tested only in booster extraction thin septum magnet.
- New components: HV power supply, modified circuit.
- Specifications: Stability of 1 part in 1500 for all pulses.
- R&D required: Circuit modification. Since high regulation level of HV supply is difficult to measure on bench we need beam studies to measure the combined contribution of both septums.
- Unknown aspects: None.

Design and implement small skew quadrupole correctors at all IDs.

- Present status: Just an idea.
- New components: Short electromagnets of the type used in ID4-CPU, power supplies.
- Specifications: Skew quadrupole maximum magnetic field not determined yet.
- R&D required: Construction of skew quadrupole magnets.
- Unknown aspects: Free space in straight section for these magnets.

Corrector regulation improvement for reduced rms beam motion.

- Present status: Data was taken in August 2002 of rms beam motion with correctors in different running conditions. Orbit motion spectrum produced by the 38 correctors with steel vacuum chambers has been characterized, and will be used to set the specifications.
- New components: 76 PS regulators at first, then maybe the rest.
- Specifications: RMS noise output spectrum not yet specified.
- R&D required: Develop the regulators
- Unknown aspects: Whether the regulators of correctors with Al chambers need improvement.

Next year's hardware improvements:

Longer straight sections. Phase 1.

Phase 1 increases the available space for undulators by 2.6 m to 7.6 m instead of the usual 5.0 m. This involves removing the Q1 and H1/V1 magnets and extending the ID chamber at both ends up to the H2/V2 magnet close to the Q2 magnet. It is assumed that the same 0.536 m is necessary for the bellows, vacuum chamber transition box and gate valve on each side of the ID vacuum chamber.

- Present status: Users are expecting this to happen. During studies we demonstrated the feasibility of setting up one sector with Q1 quadrupole set to zero current for the high-emittance and the low-emittance lattice respectively, which guaranteed the feasibility of the optics.
- New components: ID vacuum chamber extrusion, new piece of standard SR vacuum chamber extrusion, a new transition box, and possibly new girders #5 and #1.
- Specifications: Long straight section should fit in a third undulator. Minimum vertical aperture is not known, probably not 5 mm, perhaps 8 mm.
- R&D required: Synchrotron radiation masking should be re-examined at EA5 which will be moved 1.3 m upstream. It is probable that the displacement of the absorber downstream (EA6) is not critical. Numerical studies on optics matching flexibility may be required, as we now have only 2 quadrupoles instead of 3 quadrupoles for matching lattice functions.
- Unknown aspects: None

Make adjustments to the kicker power supplies for making identically scaled waveforms as a function of amplitude as much as possible. Seems difficult according to ES group. OAG will further discuss with ES group.

- Present status: Kicker power supplies currently have an amplitude dependence. A

long tail is produced when operating above 50% of maximum range.

- New components: Unknown
- Specifications: Normalized waveforms to be within 1% of average.
- R&D required: Unknown
- Unknown aspects: Perhaps specification can be relaxed with a secondary kicker applying a corrective kick.

Design a centroid bunch waveform-programmable kicker system to correct the betatron oscillation of non-targeted stored bunches over the length of the injection kicker pulse. Wait for specification until new chambers are installed.

- Present status: just an idea.
- New components: Two kicker striplines or magnets. Two amplifiers.
- Specifications: Kicker bandwidth about 10 MHz, strength about 5% that of injection kicker
- R&D required: Development of kicker magnet.
- Unknown aspects: Some way to program a fast kicker. Perhaps a transverse feedback system may be able to perform this task, though feedback systems typically have very high bandwidth at the expense of strength.

A vertical wiggler to adjust the vertical emittance for lifetime requirements. For best injection the vertical dispersion should be zero everywhere and the coupling minimized. But this minimizes the vertical emittance as well and makes the lifetime small. To recover the lifetime we increase the vertical emittance again, but in a way that doesn't generate a beam loss, which is with a vertical wiggler.

- Present status: Just an idea.
- New components: Electromagnetic wiggler magnet, special absorber for strong radiation. Vacuum chamber with vertical slot.
- Specifications: Horizontal aperture of ± 20 mm. Zero horizontal dispersion. Long period to generate vertical dispersion and emittance.
- R&D required: Radiation absorber.
- Unknown aspects: Need a straight section from some sector. Future requirements for higher vertical emittance. Tolerance of emittance change accepted by the users.

A horizontal wiggler to compensate the variation of horizontal emittance due to changes in the ID gaps around the ring. In high-emittance lattice, the zero dispersion in the straight section makes closing the IDs a source of extra damping with no additional quantum excitation, which reduces the emittance by 10%. The effect is much less (1%) for the low emittance lattice, and may not be necessary if users are not sensitive.

Interoffice Memo: Hardware Priority for APS Storage Ring Improvements

- Present status: Just an idea.
- New components: Electromagnetic wiggler magnet, special absorber for strong radiation.
- Specifications: Need zero-dispersion straight section for either lattice. Wiggler specification not known yet. Emittance range not known yet, but can be estimated from history.
- R&D required: Radiation absorber.
- Unknown aspects: Need a straight section. Tolerance of emittance change accepted by the users. With the lower emittance lattice, there is a lesser effect of ID gap on the emittance of the beam. Perhaps it is not necessary to have this device.

Implement upgrade of BPM memory scanner with proper decimation which will eliminate aliased frequencies from the readings. Various averaging time will be available simultaneously for history, orbit correction, glitch logging and long term data logging.

- Present status: Ideas have been developed by diagnostic group. Low priority. Project stalled.
- New components: Electronics
- Specifications: Several simultaneous averages should be available.
- R&D required: Unknown
- Unknown aspects: None,

Upgrade real-time feedback system (RTFB) to include all bpm types.

- Present status: RTFB uses only orbit information from a set of 8 monopulse receiver bpms. The signals from all bps in each sector is available at the RTFB sampling rate on the reflective memory. Need to rewrite the feedback ioc software to make all data available to the software. Presently all bpm data is available to the "DSP scope" software.
- New components: None.
- Specifications: All bpm signals to be available for use by RTFB.
- R&D required: None.
- Unknown aspects: None

Upgrade datapool orbit correction with second processor.

- Present status: Datapool orbit correction runs at 10 Hz in each plane using one DSP processor. A second DSP will split the work, and possibly increase the correction rate to 20 Hz in each plane.
- New components: DSP board.

- Specifications: Double the effective correction rate of DC orbit correction to 20 Hz.
- R&D required: None.
- Unknown aspects: Possible.

Improved resolution of 35 BM beam image processing with 3-m pinhole. Present pinhole is located about 10 m downstream of source. Reducing the distance will increase magnification and resolution. Though not strictly needed for present-day user operation, the better resolution would be needed now for optics correction during machine studies.

- Present status: ME group has done much design work.
- New components: Pinhole jaws. Probably new vacuum chamber for 35BM beamline.
- Specifications: Not determined yet, but probably more difficult than the 3-m pinhole is capable of delivering.
- R&D required: Jaw design work is mostly done, I think.
- Unknown aspects: Maybe

Improved resolution of 35ID beam image processing with a zone plate.

- Present status: Unknown. Need input from B. Yang.
- New components: Zone plate.
- Specifications: Not determined yet.
- R&D required: Unknown
- *Unknown aspects: Maybe*

Increase the stability of the dipole supply by factor ten to improve bunch cleaning effectiveness. Also tune measurements could then be made with less averaging, which would be important for some lattice studies.

- Present status: ES group considered this but waiting for specification. Present stability is measured by beam at 1 part in 20,000 in the spectrum range DC to 1 Hz.
- New components: Regulator
- Specifications: To be determined, but probably 1 part in 65,000 is sufficient.
- R&D required: None
- Unknown aspects: None

Transverse feedback system for single bunch instability. If such a system were in place one could reduce the chromaticity and obtained a slightly higher lifetime. We already have two unused striplines, which can be the pickup and the drive.

- Present status: Just an idea

- New components: Amplifier, electronics to process the beam signal into a correction signal.
- Specifications: Not known yet.
- R&D required: Many such systems exist in other light sources. So R&D will be minimal.
- Unknown aspects: Whether feeding back on centroid motion alone is sufficient in reducing the instabilities when the chromaticity is reduced at the operating bunch currents.

Three-screen diagnostic system for BTS line. Modify BTS transfer line (by moving quadrupoles and perhaps adding new quadrupoles) and add 3 high-resolution screens in a long drift space to make a clean emittance measurement.

- Present status: Just an idea, but concept has been implemented in the linac.
- New components: 1 or 2 quadrupoles, high-resolution screens, perhaps CTR screens.
- Specifications: Resolution not known yet, around 10 μm.
- R&D required: Optics matching.
- Unknown aspects: None

Modify the regulation of the booster extraction and storage ring septums to reduce the need for feedforward setpoint adjustments. At present, the supplies are voltage regulated. As the coils heat up from operation, their resistance change and the current driving the magnetic field is reduced slightly. Current regulation would be more appropriate, as this would guarantees a constant magnetic field.

- Present status: Just an idea.
- New components: More sophisticated regulator.
- Specifications: About 1 part in 2000.
- R&D required: Unknown
- Unknown aspects: How this fits with improved HV stability that reduced jitter.

Longer-term hardware improvements:

Dipole with gradient for lower emittance cell. The emittance achieved is 1.2 nm-rad, and effective emittance 1.8 nm-rad and tunes are nux=46.20 and nuy=32.27. The necessary gradient is -0.17 $1/m^2$. We have a choice of building new dipole magnets with canted pole faces or adding pole face windings to existing magnets to add the gradient. In order to add the pole face windings, the aperture of the SR extrusion may have to be reduced significantly.

- Present status: just an idea
- New components: Dipole magnets or high-current windings attached to pole faces. Probably new SR curved extrusion.
- Specifications: Gradient of magnet determines angle of pole faces and current through windings (not calculated). Alignment of dipole magnet.
- R&D required: Feasibility analysis of pole face windings. Feasibility analysis of canted pole face. Nonlinear analysis of low emittance cell. Whether dipoles can be setup one pair at a time and still operate normally..
- Unknown aspects: Which approach is easier. Perhaps a sufficiently lower emittance can be obtained in a different way (i.e. rf frequency shift of +500 Hz as shown in studies)

Longer straight sections. Phase 2.

The final phase would a total of 10.6 m for the undulators by extending the ID chamber further at each end by 1.5 m. To do this the length of the closest dipole magnets would have to be reduced by factor 2 and their strength increased by a factor 2 to maintain the same bend angle, which seems feasible. The Q2 and Q3 can then be moved towards the dipole by 1.5 m to take up the available space. Changing the dipole length will have a large impact on the ring, since the geometry of the beam axis is changed. The straight section will move inwards (a new hole in the ratchet wall may be necessary), and the rf frequency will be increased.

- Present status: Just an idea.
- New components: Dipole, possibly new crotch absorbers (since synchrotron power has increased by a factor 4), 4 new girders for the magnets. The dipole strength may be increased by a combination of smaller gap and extra coils. If a smaller gap is used, then a new design for a SR VC extrusion with smaller vertical aperture is required.
- Specifications: Long straight section should fit four undulators. Minimum vertical aperture is not known, probably not 5 mm, perhaps 8 mm.
- R&D required: Same as in phase 1 plus dipole magnet.
- Unknown aspects: How this could be combined with dipole with gradient.

High-Conductivity Chambers. Coating the ID vacuum chamber with Cu will reduce the resistivity and the impedance of the chambers by a factor or 1.6. This can benefit operations in one of two ways: increasing the single bunch limit for fixed sextupole strength, or decreasing the necessary sextupole strength for fixed bunch current. The improvement to these quantity is not known. If we choose to reduce sextupole strength,

then the lifetime might increase a bit as seen in some studies.

- Present status: Just an idea.
- New components. None. Reuse ID chambers.
- Specification required: Thickness of Cu coating from physics consideration.
- R &D required: Find method to deposit Cu coating.
- Unknown aspects: Vacuum issues of Cu.