Low Emittance Tuning: Summary of Working Group Discussion

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Low Emittance Tuning: Discussion Agenda

1. Compare the techniques presently used to characterise alignment and optics.
   - What does the technique tell you? What data are needed? What instrumentation are needed to produce the data? What are the strengths, and limitations?
   - How do we use the techniques (in combination?) to best effect?
   - What other techniques may be possible?
2. What development is needed for instrumentation?
3. What needs to be done to achieve the emittance goals at CesrTA and ATF?
4. What needs to be done to specify the relevant design features of the ILC damping rings?

1. Low-emittance tuning techniques

- Tuning for low vertical emittance involves identifying and correcting sources of vertical dispersion and betatron coupling.
- Issues for low-emittance tuning techniques include:
  - requirements for functionality and performance of instrumentation;
  - sensitivity to instrumentation characteristics (e.g. BPM tilts);
  - time taken for data collection.
- To achieve and maintain ultra-low vertical emittance, storage rings depend on highly stable environmental conditions, and a variety of techniques to characterise instrumentation, and correct dispersion and coupling…

1. Low-emittance tuning techniques

- Techniques in use in operating storage rings include:
  - BPM-quad alignment
  - Beam-based alignment of magnets
  - BPM gain calibration
  - Closed-orbit response measurement and analysis
  - Turn-by-turn trajectory measurement and analysis

Techniques: BPM-quad alignment

- The offset of a BPM with respect to the center of an adjacent quadrupole is determined by observing the orbit change with respect to variation in the quadrupole strength.
  - The goal is to help achieve a planar orbit...
  - ...but if the coupling is small, a planar orbit may be achieved based on vertical dispersion measurements. Therefore, some tuning strategies (e.g. at KEKB) may not depend on BPM-quad alignment.
- High performance BPMs (good resolution; good stability; low systematic errors) can make a big difference.
- How well do we need to know the BPM-quad alignment? It depends on how the results will be used...
- Generally, DC quadrupole shunts are used. Could there be some advantage to using AC strength variations (though this will generally require additional hardware)?

Techniques: Beam-based alignment of magnets

- Closed orbit with all correctors at zero (or with reduced strength) provides information on the relative alignment of storage ring magnets.
- Not as widely used as BPM-quad alignment; but has been used to identify magnets for realignment.
  - SRS, CESR…
- Effectiveness may be limited by other errors (e.g. dipole tilts) and degeneracies.
- May be useful in combination with survey data, and other techniques (dispersion measurements, use of closed-orbit bumps in CESR to identify dipole tilts).

Techniques: BPM gain calibration (Satoh-Tejima)

CALIBRATION OF KEKB BEAM POSITION MONITORS

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Abstract

This paper first proposes a practical model for output signals of BPM electrodes. The model is based on a definition of the geometric center of a BPM head, and on the assumption that the character of the head can be specified only by a small number of parameters, the relative gains of electrodes. On the basis of the model, calibration was done to find the relative gains of all KEKB LER BPM heads. The paper reports and discusses the calibration results.

1 INTRODUCTION

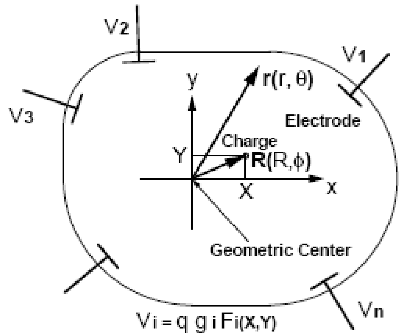

Figure 1: Coordinate system and an image of the model monitor.

- Determine the gain on individual BPM buttons by means of measurements with beam at different positions within the BPM.

Techniques: Closed-orbit response

- The change in closed orbit in response to a change in an orbit corrector magnet is used to determine the lattice optics and instrumentation characteristics.
- Application may involve the complete set of correctors and BPMs, or just a limited number.
- In widespread use, with good experience at many machines:
  - e.g. at ALS, used to minimise the coupling, helping to reduce the vertical emittance to < 5 pm.
  - Beta-beat can be reduced to < 1% (with benefits e.g. for lifetime).
- Issues include:
  - time taken for data collection (if using complete set of correctors, several hours), and potential difficulty in application to large machines;
  - optimal selection of components; possible degeneracies in the fit variables; difficulty in choosing optimal fit conditions.

Techniques: Turn-by-turn trajectory analysis

- Turn-by-turn BPM readings are collected following a beam “kick”, or during resonant excitation. The data can be analysed to determine lattice optics (including dispersion/crabbing) and instrumentation characteristics.
- Requires some means of kicking or resonantly-exciting the beam (with PLL to fix the excitation frequency to the tunes); and BPMs capable of recording beam position over several (or many) thousand turns, with resolution of a few 10’s microns.
- Relationships between different approaches to data analysis (e.g. at CESR, and at PEP-II) still remain to be fully understood.
- Potential advantages include the speed of data collection (~ ms or seconds); and the fact that perturbations on the beam are small compared to those used in closed orbit measurements.
- Further development needed fully to exploit potential e.g. for characterising instrumentation.

Techniques: Further remarks...

- Some techniques attempt an "all-in-one" correction...
  - e.g. LOCO analysis of closed-orbit response to characterise optics and instrumentation in a single step;
- ...but there can be benefits in an iterative approach, separating different aspects of machine performance as far as possible.
  - e.g. KEKB; or the approach to turn-by-turn trajectory analysis at CESR.
- A variety of other "standard" techniques can be useful, for example:
  - characterising resonance strengths by tune-approach measurements;
  - measuring the variation of beam size, lifetime etc. with proximity of working point to resonances in tune space.
- There are some other possibilities for development:
  - Combined use of closed-orbit response and turn-by-turn trajectory data (under way at CesrTA).
  - Model-independent analysis.

2. Instrumentation development

- Beam position monitors:
  - Digital receivers, e.g. Echotek or Libera, seem to show sufficiently good performance.
  - Useful functionality includes phase and amplitude detection (for turn-by-turn trajectory measurement and analysis) within the electronics.
- Beam size monitors/emittance diagnostics:
  - Good progress with sub-micron beam size monitors using synchrotron radiation.
  - Some work still needed on fast (turn-by-turn) monitors.
  - There are still some open questions:
    - What is the trade-off between speed and resolution?
    - How to determine how many monitors (and of what type – speed; resolution...) are needed for a particular machine?
- Longitudinal diagnostics:
  - Streak cameras…

3. Tasks outstanding: CesrTA

- Develop phase-advance analysis for characterisation of BPMs (David Sagan/Jim Shanks).
- Application of Satoh-Tejima technique for BPM gain calibration (David Rubin/David Sagan/Mike Billing/Matt Rendina).
- Apply procedure developed to achieve low-emittance operation and understand the results [requires micron-resolution beam-size monitor] (CesrTA collaboration…).
- Explore AC measurement of dispersion (David Rubin/Yiton Yan).
- Optimisation of tuning based on closed-orbit response data; investigation of combined use of orbit response data and phase advance data (Jim Shanks/Rohan Dowd?).
- Explore tuning using coupling/dispersion bumps (Mike Billing/David Rubin).
- Understand relationship between PEP-II and CESR techniques for analysis of turn-by-turn trajectory data (David Sagan/Yiton Yan/Mike Billing).
- Investigation of machine stability (Mike Billing/…).
- Explore possible use of beam-based alignment techniques to identify magnets requiring re-alignment.
- Investigation of performance of new survey equipment (in-hand: CesrTA survey group).

An invitation to participate in CesrTA

- All those interested in the CesrTA programme are invited to:
  - participate in the monthly collaboration (WebEx) meetings;
  - participate in experimental shifts and data analysis (remote participation is a possibility that can be investigated…)

3. Tasks outstanding: ATF

- Develop and implement a plan for low-emittance tuning.
  - Consider previous experience at ATF, and techniques used in other machines, e.g. KEKB (Satoh-Tejima BPM calibration technique; use of coupling/dispersion bumps).
- Continue with the upgrade programme for the BPMs.

4. Specifications for the ILC damping rings

- Specifications are required for:
  - magnet supports, alignment and environmental stability (temperature, ground motion/vibration);
  - instrumentation and diagnostics (types, numbers, locations, functionality and performance);
  - tuning techniques and procedures.
- As usual, we need to balance cost and technical risk.
- In one possible approach, we could adopt (with minimal modifications) the specifications for an operating facility, e.g. SLS – but this could prove expensive.
- Specifications need to be supported by extensive simulations to optimise for cost, and justify modifications from existing systems.

Points for discussion with Project Managers

- Have we identified all the important issues and priorities for CesrTA and ATF?
  - Low-emittance tuning studies are needed in each case, both because of direct relevance for ILC damping rings; and to support other studies, e.g. electron cloud and ion effects.
  - See slides 12 and 14.
- Are plans for future coordination and communication appropriate and sufficient (as far as presently developed)?
  - Twice-monthly ILCDR collaboration meetings, coordinated with monthly CesrTA collaboration meetings.
  - R&D workshops to be integrated into ILC workshops, beginning with Chicago, November 2008.
- How do we proceed with specification and design work for the DRs?
  - All available effort needs to be focused on CesrTA and ATF.