Thoughts on Final Quad Vibration in Cold ILC

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Hard vs Soft Quad Mounts in Cold ILC

Final quads in ILC need nanometer relative alignment across IP for beams to collide.

The baseline has superconducting quads with unknown vibration characteristics mounted in an unknown way in an unknown environment. The baseline has fast beam-beam steering feedback as the primary vibration control.

Normally we put accelerator components on stiff supports rather than springs. Springs make DC alignment and low-frequency motion worse rather than better. Springs increase the motion from onboard disturbances at high frequencies compared to stiff mounts.

Only if high-frequency ground motion is much greater than onboard disturbances would total vibration be less for a spring-mount than for a stiff mount.

In a cold ILC, quad vibration motion between bunches will look small and predictable to the beam-beam feedback because the sampling frequency is so high (3 MHz).

Even if spring mounts did reduce the vibration at high frequency, it's not clear that the beam-beam feedback needs the help there.

It's true that for the warm ILC, spring mounts plus active quad stabilization (augmented by slow beam-beam feedback) did seem like a sensible solution.

But I don't see how passive spring-mounts for the final quads make sense for a cold ILC with beam-beam feedback.

Final Quad Vibration Measurement in a Cold ILC?

Most of what the fast beam-beam feedback responds to will be final quad motion.

Independent information about final quad positions would be a valuable diagnostic for the vital fast beam-beam feedback system.

A weakness of pure beam-beam feedback is that the first few bunches of each train may not collide, while the feedback is converging.

Information about final quad motions between the last bunch of one train and the first bunch of the next train could greatly reduce the initial convergence time.

If the machine costs $5 billion, then getting back the luminosity from 3 bunches out of 3000 is worth spending of order $5 million.

For quads where line-of-sight to the ground is available, I'd use interferometry relative to the ground, and an accelerometer on the ground at the support base, combined using a Kalman filter with knowledge of cultural noise and support resonances.

For superconducting quads cantilevered into the detector, I'd use interferometry from the cryostat to the cold mass, interferometry from the (cantilevered) cryostat to some the detector iron, an accelerometer on the detector iron, and an accelerometer in the floor, also combined in a Kalman filter with lots of knowledge about resonances and cultural noise.

Final Quad Vibration Control in a Cold ILC?

It isn't necessary to mechanically control the quad positions (rather than fast or slow beam steering) to get the benefit of the information about their positions, unless the mechanical motions are so large that some higher order effect comes in that steering doesn't fix.

Mechanical control is hard at high frequency is hard, but easy at low frequency. If the motion were so large that mechanical control were necessary, probably most of the motion would be at fairly low frequency.

The sensible strategy would be to control the large low-frequency motions mechanically, which would get rid of the higher order effects, and let the beam-beam feedback control the residual high-frequency motion.

State-vector control theory gives a rigorous recipe for using disparate actuators like mechanical movers, slow steering, and fast steering together, rather than having separate feedbacks that may need to be carefully tuned to avoid fighting with each other.

If we want the option of fast mechanical vibration control, we should use actuators that don't degrade the passive stability of the system. I would not choose an actuator that requires the quads to be mounted on springs, or requires standing current or voltage.

Piezoelectric actuators would be a reasonable choice. They can move of tens of microns with sub-nanometer precision, but they are quite stiff if you use a reasonable cross-section. If you short them out, you can pretty much ignore them.

Interferometry Role

You can make good interferometers with a single-mode fiber or two and a corner reflector, with the laser, photodiode, etc. far away.

This would make a nice compact way to measure the cold-mass position relative to the cryostat in a superconducting quad, and the cryostat position relative to a local reference.

You need a nanometer-precision position sensor inside an accelerometer. Joe Frisch's accelerometer used a capacitive sensor, which required tight clearance to get the precision, which made spring creep and total amplitude an issue. Spring creep was dealt with by a remote adjustments of the spring, total amplitude by extra electrodes, drive electronics, and a feedback inside the accelerometer. Fiber interferometry could be used for the position sensor with millimeter clearances, which would make these problem much easier.

Interferometry used for absolute position measurements to micron accuracy, which is useful if quads get misaligned during detector accesses. Of course this is only as good as reproducibility of the other end and reference arm.