APPROACHES TO BEAM STABILIZATION IN X-BAND LINEAR COLLIDERS*

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Abstract

In order to stabilize the beams at the interaction point, the X-band linear collider proposes to use a combination of techniques: inter-train and intra-train beam-beam feedback, passive vibration isolation, and active vibration stabilization based on either accelerometers or laser interferometers. These systems operate in a technologically redundant fashion: simulations indicate that if one technique proves unusable in the final machine, the others will still support adequate luminosity. Experiments underway for all of these technologies have already demonstrated adequate performance.

STABILIZATION OVERVIEW*

The NLC X-band linear collider is designed to operate at a 120Hz train rate with 192 bunches spaced at 1.4 nanoseconds per train. The linacs each contain approximately 600 quadrapoles containing beam position monitors, and 40 feedback corrector magnets. Beam position monitors and correctors are distributed throughout the beam delivery system. Beam stabilization simulations are described elsewhere [1], here we only quote results. Beam stabilization can be characterized with respect to its timescale, in this paper we primarily discuss feedback on relatively short timescales:

Beam Based Alignment

On approximately one month timescales, the effective centers of the Linac beam position monitors relative to the quadrapole magnetic centers are found through either quad shunting, or dispersion free steering [2].

On several hour timescales, the Linac quadrapoles are moved based on a global optimization algorithm to minimize the orbit errors in the BPMs, to minimize the corrector strengths, and to overall center the beam.

The accelerator structures contain beam position monitors (using signals from the higher order mode ports). Mechanical movers on the structures are used to minimize the transverse wakes when the quadrapoles are aligned.

Beam Based Feedback

Feedbacks distributed throughout the accelerators operate on a pulse to pulse basis at the 120Hz repetition rate of the accelerator[1]. These feedbacks are cascaded, allowing each to have information about the operation of the upstream feedbacks[3].

The beam / beam deflection at the Interaction Point provides information on the beam separation. This deflection signal is used in a 120Hz feedback in the final focus to maintain beam collisions.

Vibration feedback

The final doublet magnets have the tightest vibration tolerances of any of the machine components [4] with an approximately 1:1 response of beam motion to magnet motion. As the 120Hz beam rate limits the effective frequency of feedbacks to frequencies below a few Hz, several options for mechanical stabilization of the final doublets have been considered, including passive, inertial based, and interferometer based feedback. To date most of the work has been directed to using accelerometers mounted on the doublets, with force feedback to control the magnet positions. The loop speed is typically 1-2 kilohertz, providing gain at frequencies from approximately 1-100 Hz. Current status of this work is described in [5], and the results are used here.

Fast Intratrain Feedback

A fast beam position monitor and kicker located near the interaction point can provide closed feedback on a timescale of tens of nanoseconds[6]. This feedback operates essentially independently from the other beam feedbacks (due to the different timescale), and can significantly improve luminosity under noisy beam conditions.

STABILIZATION STUDIES

The beam stabilization studies use a combination of real and simulated data to provide an estimated luminosity. The simulations are described in [7]. The basic procedure is:

- A series of initial machines with random errors (BPM offsets, magnet positions, etc) based on design tolerance are constructed.
- A <u>simulated</u> ground motion model, in this case the model “B”, power spectrum shown in figure 1 is applied to the beamline components EXCEPT for the final doublet. [8].
- An additional 15nm of random jitter is applied to the linac quadrapoles to simulate, for example, water flow induced vibration . An addition 5nm of random jitter is added to the beam delivery quadrapoles.
- 120Hz linac beam feedbacks are <u>simulated</u>
- Final doublet positions are taken from <u>measured</u> data from the vibration stabilization test system [5] – a

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mechanical model of a final focus doublet. Since there is only a single stabilization test system, data from two different times is taken to represent the motion of the two doublets – any motion correlations in the real system are ignored (pessimistic assumption).

- The resulting calculated beam / beam separation at the IP is used as the signal for a simulated beam feedback modeled in LIAR, whose gain is shown in figure 6.
- The resulting beam / beam separation is simulated [9] through a model of the intratrain "FONT" feedback system, based on the measured FONT system delay as tested at the NLCTA [10].
- Lumonisity from the final beam / beam separation is calculated.

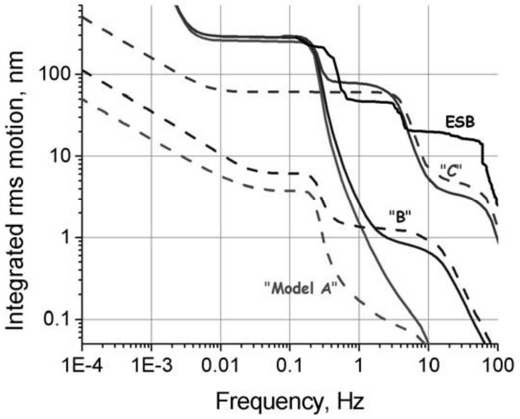

Figure 1: Ground Motion Models. Solid lines are single point motion, dashed are differential motion for 50M separation . "B used". ESB is the measured vibration at the high noise location where the vibration stabilization tests were performed.

Ground Motion Assumptions

There are large variations in ground motion between different possible accelerator sites. Model B used in the simulations roughly corresponds to ground motion in the (shallow) SLAC tunnel under quiet conditions. Figure 2.

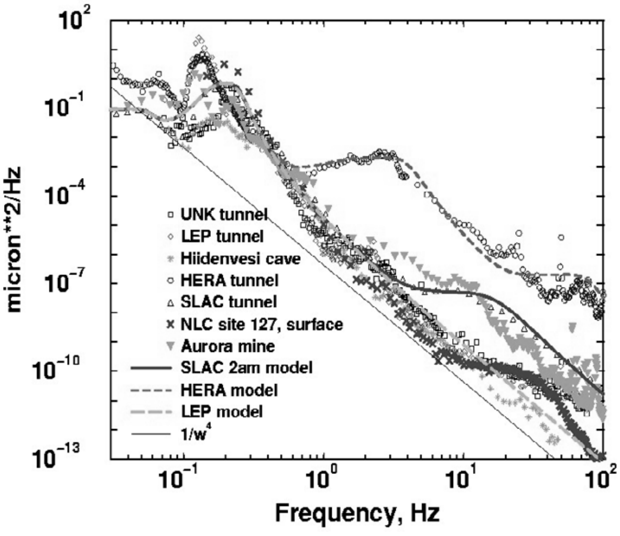

Figure 2: Ground Motion at Various Sites

Vibration Stabilization Assumptions

The final doublet stabilization experiments [5] were performed in a very noisy environment, End Station B, as shown by the line ESB in figure 1.

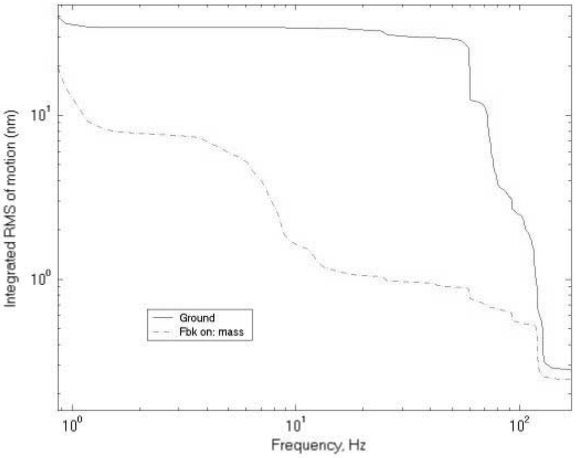

Figure 3: Ground and stabilized magnet spectra

Intratrain Feedback Assumptions

The intratrain feedback calculations assumed the system had the time delay measured in the FONT experiments conducted at the NLCTA (figures 4, 5).

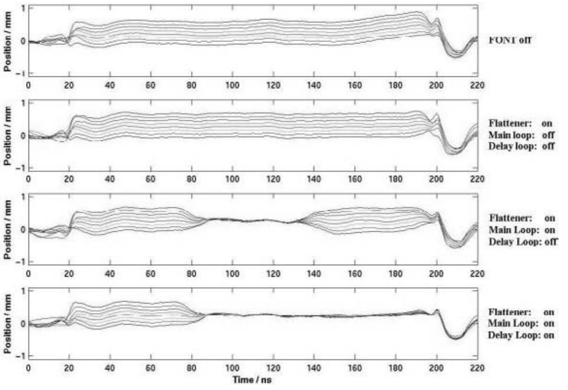

Figure 4: Intratrain feedback demonstration at NLCTA

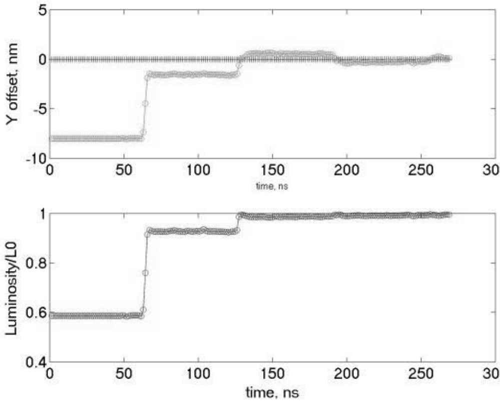

Figure 5: Calculated response of intratrain feedback to an 8 nm offset, based in measured 62ns response

Beam – Beam Feedback Assumptions

The 120Hz beam feedback at the IP is based on the beam – beam deflection which amplifies the offset to a level easily read by BPMs. A variety of algorithms are possible, the frequency response curves for two cases are shown in figure 6. The simulations were performed with a feedback similar to the design with high gain at low frequency.

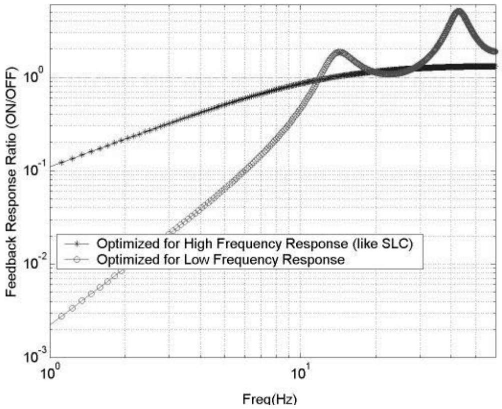

Figure 6: Design responses for 120-Hz intertrain feedback. The SLC-type design (*) is optimized for high frequency noise. An alternative design (o) is optimized for improved low frequency response.

LUMINOSITY CALCULATIONS

The luminosity of the NLC was simulated under a variety of conditions for the final focus. All simulations discussed here used the ground motion "B" model for the linac, with additional jitter applied to the quadrapoles. Statistical errors are approximately +/- 1%. In the following results.

Case 1: 30% nominal luminosity
Doublet motion taken from measurements of the motion of the triplets at the SLD: 20nm RMS.
No active vibration stabilization.
No Intratrain FONT feedback.

Case 2: 66% nominal luminosity
Doublet motion as expected from ground motion "B" model: 4nm RMS.
No active vibration stabilization
No Intratrain FONT feedback

Case 3: 71% nominal luminosity
Doublet motion measured from vibration stabilization test system: ~6nm RMS
No Intratrain FONT feedback
Note: spectrum is different from case 2.

Case 4: 93% nominal luminosity
Doublet motion measured from vibration stabilization test system: ~6nm RMS
Intratrain FONT feedback simulated with measured delay

These results indicate that reasonable luminosity can be obtained without active vibration feedback or fast intratrain feedback with nominal site ground motion levels. At a noisy site, luminosity can be recovered using the demonstrated performance of the feedback systems. In addition, the performance of both the FONT intratrain feedback, and the vibration stabilization system are expected to continue to improve.

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