OBSERVATION OF INDUCED BEAM OSCILLATION FROM ACTIVELY DISPLACED RF ACCELERATING STRUCTURES

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At high beam currents the alignment of the accelerating structure in a linear collider relative to the lattice quadrupoles and position monitors dominates all other alignment issues. These structure misalignments drive wakefield emittance growth. Consequently, great efforts have been spent at SLAC to align the accelerating structure[1] of the Stanford Linear Collider (SLC). As an accelerator test, remote controlled mechanical movers have been installed on several RF structures to study wakefield effects. Experimental tests of induced beam wakefields and the resulting oscillations downstream generated by these remotely displaced structures have been performed. The observed wakefield and have been compared with a computer model. The results from displacements at the beam's betatron frequency are particularly exciting as that frequency strongly excites emittance growth. In general, a control mechanism can be made to move the structure at that spatial frequency, thus providing sine and cosine adjustments for cancellation of alignment errors in the accelerator of a future collider[2]. A similar method to control emittance growth by changing the beam trajectory has already been tested and is in daily use[3].

I. STRUCTURE DISPLACEMENTS

A displaced accelerating structure produces beam wakefields which ultimately increase the emittance of the beam and reduce the luminosity of a linear collider. A schematic of this effect is seen in Figure 1. The equation of motion for particles[4] in the beam which are deflected by wakefields within the beam and by displaced accelerating structures is given by

$$\frac{d^2}{ds^2}x(z,s)+k^2x(z,s)=$$

$$\frac{r_e}{\gamma(z,s)}\int_z^\infty dz'\,\rho(z')W(z'-z)[x(z',s)+X(s)]$$

where x is the transverse displacement of the particles in the bunch, s the distance along the accelerator, z the longitudinal displacement along the bunch, k the lattice focusing, γ is the particle energy, r_e the classical radius of the electron, ρ the longitudinal particle density in the bunch, W the transverse wake potential, and X the structure displacement. If the accelerating structure also has RF fields inside then there will be deflections due to those fields as well.[5] In the considerations and measurements here we will keep the RF fields turned off.

The SLAC accelerating structure is made with 12 m long girders which are supported at the ends. We have placed motorized jacks in the center which are eccentric CAMs with a stoke of +/- 1 mm. These are remotely controllable. The geometry of the girders is shown in Figure 2 and a close-up of the remote mover CAM is shown in Figure 3. These movers have located in a 100 m section of the linac at about 500 m from the beginning where the beam energy is about 6 GeV. Eight adjacent girders have been equipped with these movers in both the horizontal and vertical planes.

II. OBSERVATIONS

The SLC beam has been made to pass through displaced accelerator structures and the ensuing oscillations observed. The measured displacements are emphasized by subtracting a nominal trajectory from the displaced trajectory. The observed oscillations are on the order of a few hundred microns for a single offset of about 1 mm over about the center half of the girder. The resolution is about 20 microns for individual BPM readings. The SLC beam has about 3 x 10^{10} electrons in a single bunch with a length of about 1 mm. The energy spread is about 1.5% at this location due to the need for BNS damping. The longitudinal head of the bunch has a higher energy than the tail by about 3%.

Moving a single girder from its nominal location produces a deflection as seen in Figure 4. The effect of the displacement can be seen along the linac as oscillations persist to the end. The deflections depend on the sign of the displacement, i.e. the placement of the CAM, as seen in Figures 5 and 6. Vertical and horizontal displacements show similar results in their respective planes.

A simulation of the effect of these accelerator displacements has been made and the results of the displacement of the girder of Figure 5 are shown in Figure 7. The measured displacements agree with the simulation to about 20%. A detailed knowledge of the energy spread along the accelerator is needed to produce an exact comparison over a long distance.

If multiple movers are used to produce a deflected beam, significantly different effects can be seen. First, if two adjacent movers are displaced together the observed deflection is roughly twice as large, as expected. However, if the displacements are spread over a full betatron wave length, the beam displacements can have internal mixing

* Work supported by US Department of Energy contract DE-AC03-76SF00515.

of the transverse offsets along the bunch so that the average displacement of the entire bunch can show trajectory beats downstream as seen in Figure 8. This means that the different longitudinal slices at the end of the displaced sections of the linac are on different sides of the nominal center line of the original beam or have significantly different angular trajectories. A more detailed analysis of these multiple mover trajectories is under way.

III. CONCLUSIONS

Displacements of an electron beam have been observed from displaced accelerating structures. The deflections agree quantitatively with the predictions. Significantly more complicated trajectories can result from a coherently produced deflections using several (eight) movers spread over a betatron wavelength. Finally, the effects of RF deflections will be added in the on-going analysis as they are expected to further complicate the observed trajectories.

IV. ACKNOWLEDGMENTS

The authors wish to thank the SLC Operations Group for providing the beam and Diana Roger for her help in producing this document.

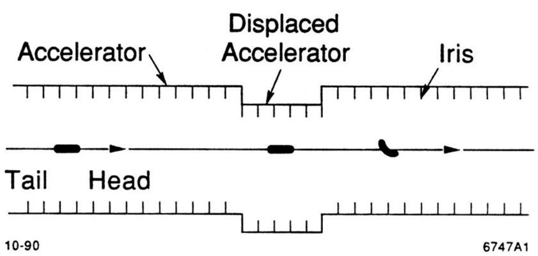

Figure 1: Schematic view of a displaced accelerating structure inducing wakefield effects in a bunch.

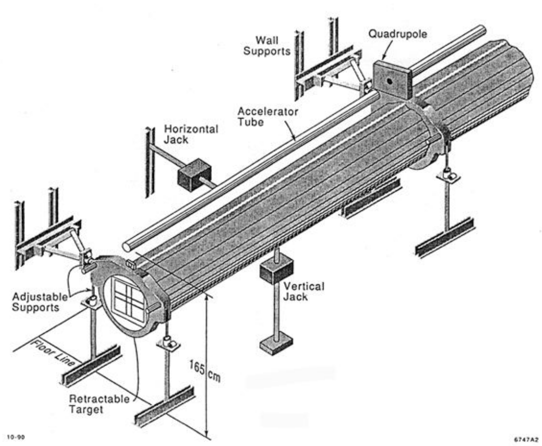

Figure 2: Schematic view of the SLAC accelerator girder with vertical and horizontal movers. The movers produce a "bow" in the girder, i.e. the ends are fixed and the center is displaced. One klystron feeds one of these girders.

Figure 3: Close-up photograph of the remotely control motorized CAM to move the accelerating structure center by +/- 1 mm. Both vertical and horizontal movers have been placed on 8 adjacent RF girders covering 100m of the SLAC linac.

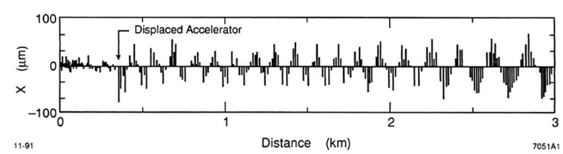

Figure 4: Measured displacement of a beam from a moved accelerator structure.

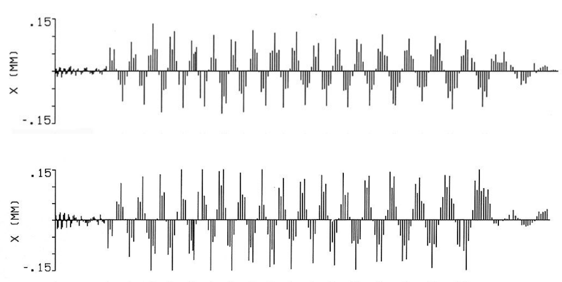

Figure 5: Examples of the beam trajectory produced by up and down single displacements of a 12 m long accelerator in Sector 5 of the SLAC linac. The upper plot results from an downward girder movement and the lower plot from an upward girder movement.

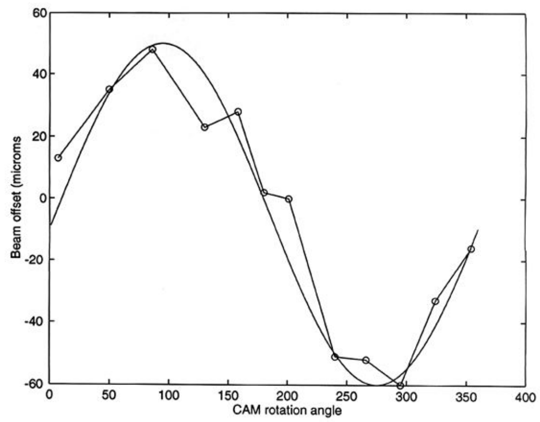

Figure 6: Displacement of an SLC bunch downstream (about 90 degrees in betatron phase) on a single position monitor from a displaced mover in Sector 5 as a function of the rotation angle of the CAM mover. The mover peak amplitude is 1 mm.

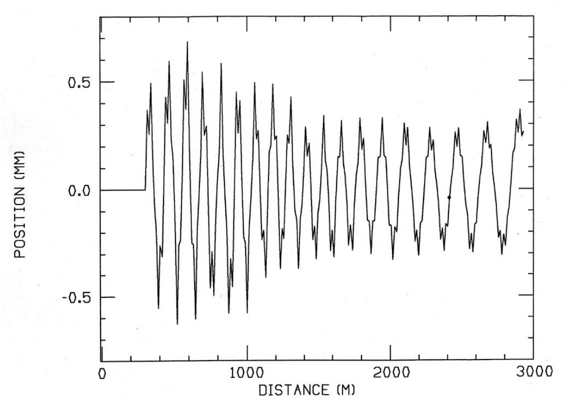

Figure 7: Simulated displacement of an SLAC beam using the accelerator displacement of Figure 3 using a 25 particle (longitudinal) model . The scales between the two plots are not the same.

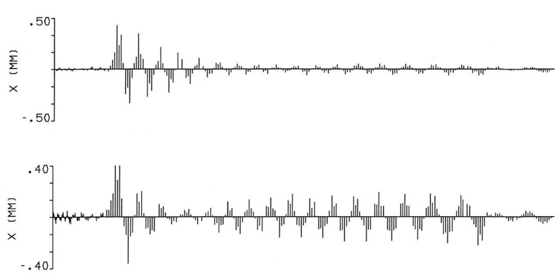

Figure 8: Examples of two trajectories produced by combined accelerator displacements. The upper plot corresponds to eight movers displaced in a sine wave pattern at the betatron frequency (~100m). The lower plot shows an example with eight movers displaced with the first six at +1 mm and the last two at -1 mm.

V. REFERENCES

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