PERFORMANCE IMPROVEMENTS OF THE SLAC LINAC FOR THE FACET BEAM*

F.-J. Decker, N. Lipkowitz, E. Marin, Y. Nosochkov, J. Sheppard, M. Sullivan, Y. Sun, M.-H. Wang, G.R. White, U. Wienands, M. Woodley, G. Yocky, SLAC, Menlo Park, CA 94025, USA

Abstract

Two thirds of the SLAC Linac is used to generate a short, intense electron beam for the FACET experiments. The emittance growth along the Linac is a major concern to finally get small spot sizes for these experiments. There are two different approaches to get the required small emittances: a) lengthy iterative global tuning technique, and b) trying to identify locations of the main sources of the emittance growth and reducing their effect locally. How these approaches help to get good beam performances is discussed.

INTRODUCTION

Since the last FACET run a few improvements were done to get better emittance and small spot sizes at the final focus (FF). They include two major strategies: (1) Lower the betatron functions in the FACET chicane and lower the high peaks before the FF, which increases the linear betatron sizes at the FF and (2) tune the whole linac up with a fixed set of parameters. The first step seems counterproductive, but the higher value means 12 µm instead of 4 µm linear size, which was actually including higher orders a 20 µm size. The second point made more effective use of the long tuning times, so that experiments could follow after some iteration. Since the reproducibility of a machine setup depends strongly on local compensation of emittance growth effects, we discuss some of these techniques in more detail.

QUAD SHUNTING TECHNIQUE

By changing the strength of a quadrupole in the linac (e.g. ΔQ = 1.9 kG, see Fig. 1), the beam experiences a kick $\Delta Q \cdot x$, where x (or y) is the beam offset in the quadrupole. By fitting the kick strengths and comparing it with the expected kick from the measured orbit position (orbx), you can calculate the offset of the quadrupole (dxq) with respect to the beam position monitor (BPM). This procedure is very fast, since it doesn't involve lengthy corrector scans like the Bowtie method [1].

Observations

Some of these oscillations seem to start from the wrong place and by introducing big orbit offsets by makng some oscillations it was found that in Sector 7 the power supplies of the first two quadrupoles were switched with the next two, caused by a wiring problem inside the power supply box.

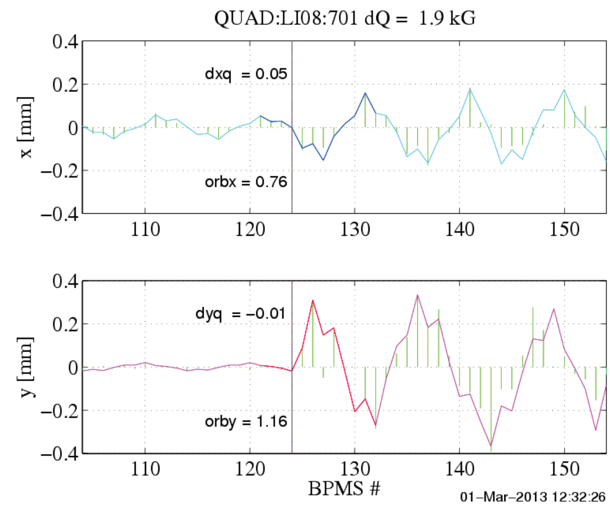

Figure 1: Quad shunt technique. A quadrupole at the location of the vertical line is changed and the resulting orbit change is fitted with a kick (blue and red), the cyan and magenta parts are extrapolations.

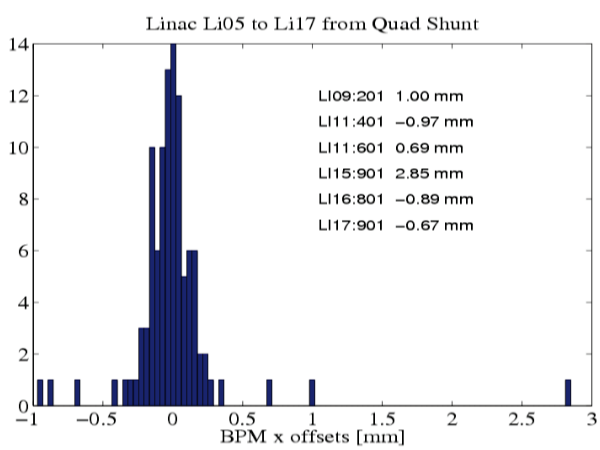

Figure 2: Distribution of the horizontal BPM to quadrupole offsets from quad-shunting.

Numbers

Plotting the distribution of the BPM to Quad offsets (Fig. 2) we get a width of about 150 um, but with a few big flyers which mostly could be traced back to BPM processor problems. Another way to check the offset is to calculate: XCor/Q – $BPMx$, when this quantity is zero the corrector compensates the quadrupole kick due to the orbit. Figure 3 shows that this distribution is about 2.5 as wide, pointing to quadrupole misalignments.

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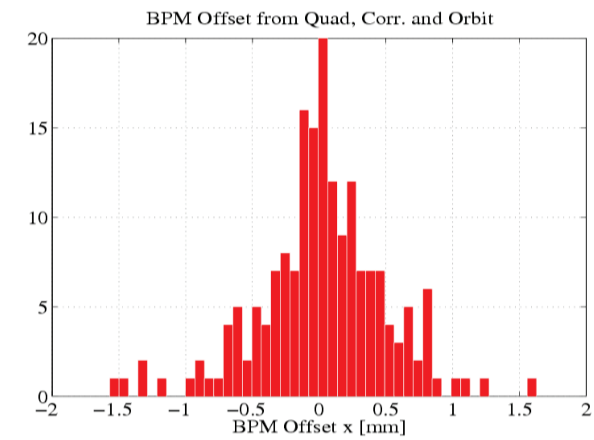

Figure 3: Distribution of the BPM offsets in x calculated from the strengths of quads, correctors and the orbit.

ALIGNMENT

The linac got aligned at the beginning of 2012 using the data from the movable targets in the linac light pipe [1]. It was recognized that the correctors in the second half of the linac were stronger (Fig. 4) and even some vertical correctors maxed out at the end of Sector 14.

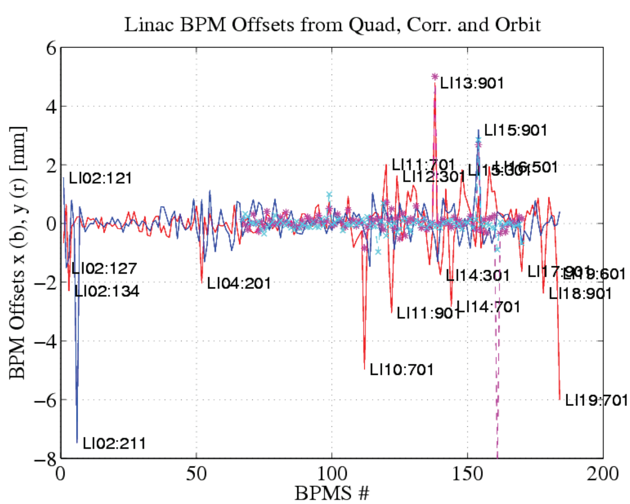

Figure 4: BPM offset along the linac. Stronger correctors seen as apparent BPM offsets show up in the second half.

Measuring the dispersion by switching a klystron off and on and plotting the difference orbit, a big dispersion wave was observed, which could be reduced with a -3mm three corrector bump, see Fig. 5.

Quantifying Misalignments

Corrector strengths and BPM orbit information give a hint about big misalignments, but RF kicks from the accelerator structures and hysteresis from the correctors (Fig. 6) can bias the measurement, which would lead to a wrong alignment. A ballistic measurement, where correctors are degaussed, RF klystrons and quadrupoles are off, a straight beam defines a line to which the BPMs read, seeing -2.5 mm at BPM Li14 901 (Fig. 7).

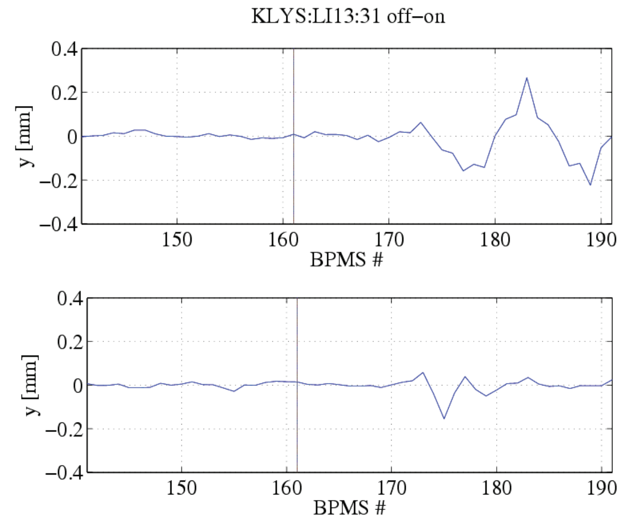

Figure 5: Vertical difference orbit for klystron 13-3 off-on shows the generation of a big dispersion wave at BPMs #175 (Li14 901), top. While a -3 mm orbit bump there cancels the downstream wave considerably, bottom.

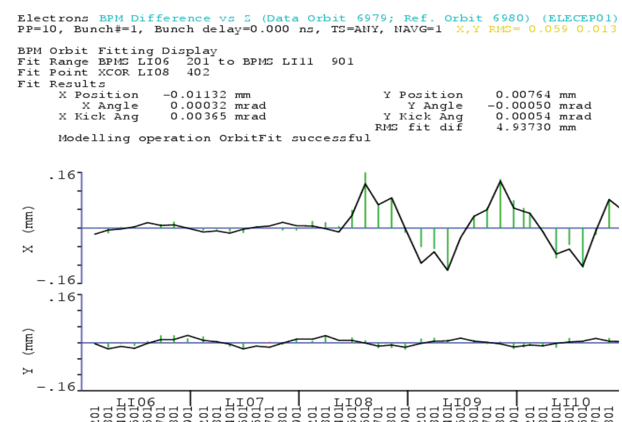

Figure 6: Corrector hysteresis: XCOR LI08 402 all up and back (orbit), minus all down and back up (reference). The 3.65 µrad kick in x correspond to1.5 kG-mm or 4.4% of the maximum corrector strength.

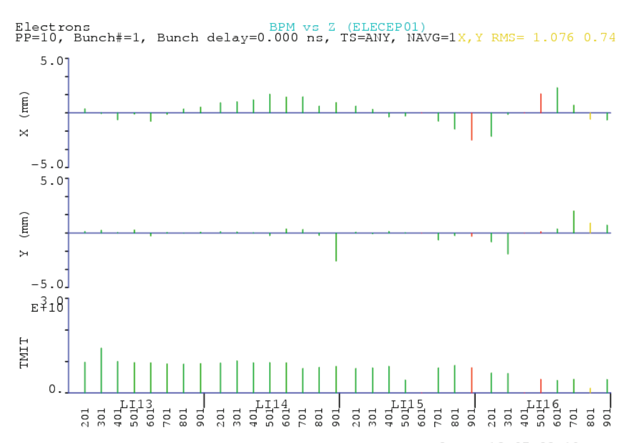

Figure 7: Ballistic orbit (all off) in Li14 to Li16.

EMITTANCES

The beam emittances at the end of the linac at the experiment have to be good. Any blow up along the linac should be reduced as close as possible to the source. Figure 8 shows the emittance development and the mismatch parameter along the linac.

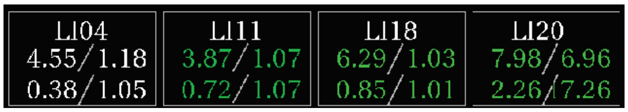

Figure 8: Normalized emittances in *x* and *y* along the linac in units of E-5 m-rad.

Typically the *x*-emittance blows up from 3.0 E-5 m-rad to 6 E-5 m-rad, and the *y*-emittance from 0.3 E-5 m-rad to 1.2 E-5 m-rad. In the experimental area five OTR (optical transition radiation) screens and three wire scanners can measure the beam sizes around the plasma interaction region. Fitting the squared sizes with a parabola the emittance is calculated, see Fig. 9.

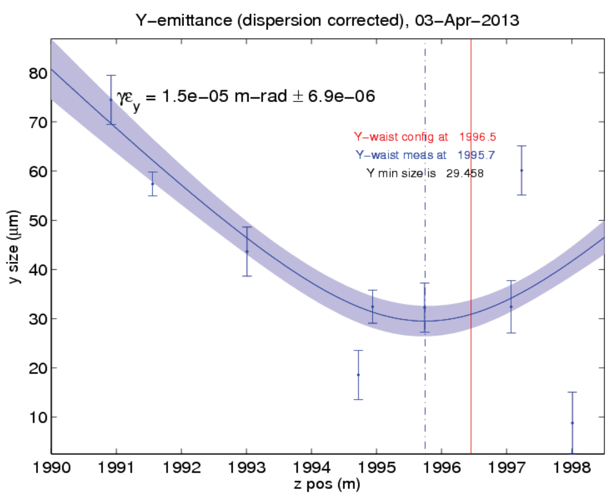

Figure 9: Vertical beam size measurements in the FACET experimental area giving an emittance of 1.5 E-5 m-rad.

First the measured emittance was three times bigger at 4.5 E-5 m-rad and the measured waist was 5 m early, due to the fact that the dispersion wasn't fully corrected. Subtracting the measured dispersion sizes in quadrature the plot in Fig. 9 was achieved pointing out the importance of dispersion correction. Some of the beam sizes look therefore extremely small (10 µm).

STABILTY

A few pulse to pulse jitter sources were identified and fixed, especially the compressor klystron phase jitter. Another concern is the daily temperature stability. Here the injection phase into the linac (PHASRMP) has to be tightly controlled by operators. Figure 10 shows the difference of this phase minus the beam arrival phase in Li02 versus the outside temperature. By measuring this temperature and using it in a feed-forward the injection phase was stabilized. The problem is a slight phase lag (seen as loops in Fig. 10) which is big enough so that the operators prefer to tune it directly.

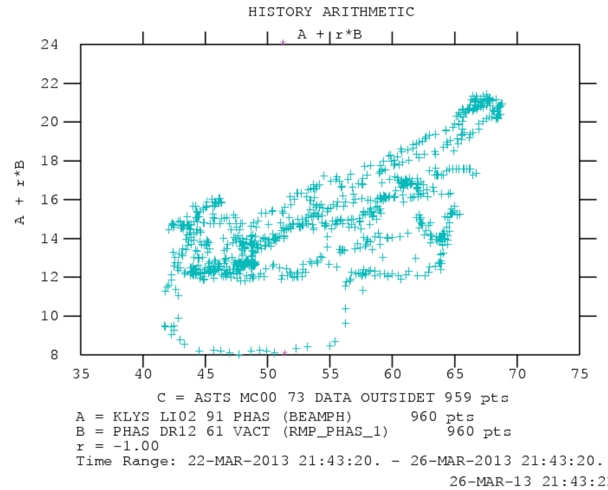

Figure 10: The variation of the linac injection phase minus measured beam phase versus the outside temperature.

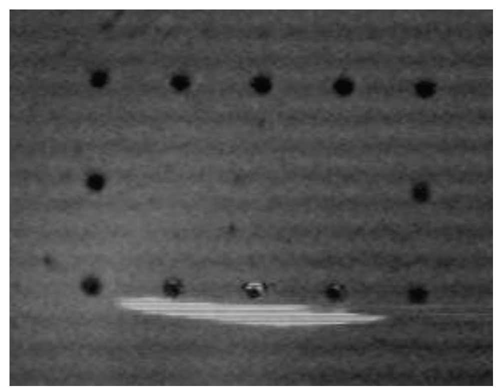

Figure 11: Energy spread (horizontal) and a clean beam in *y* with not much structure along the bunch.

The stretched out beam at the first dispersion region has a flat beam profile which nearly is the size of the screen holes as it should be (Fig. 11).

SUMMARY

The beam performance for the FACET experiments has greatly improved from last year's run. Identifying and fixing alignment issues, tuning for one setup, and a relaxed chicane and final focus lattice are the major contributors.

REFERENCES

[1] F.-J. Decker et al., "Intensity Effects of the FACET Beam in the SLAC Linac," IPAC12, New Orleans, May 2012, WEPPR040.

[2] F.J. Decker, et al., "Emittance Control for Different FACET Beam Setups in the SLAC Linac," LINAC12, Tel Aviv, Sep. 2012, MOPB001.

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