EMITTANCE MEASUREMENTS IN THE ALS BOOSTER SYNCHROTRON[*]

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Beam emittance measurements in the Advanced Light Source Booster Synchrotron are presented. Electrons are injected at 50 MeV and extracted at various energies ranging from 150 MeV to 1,520 MeV. The extracted beam is then transported in the Booster-to-Storage-Ring beam transfer line where the emittances are measured. Beam sizes are measured at 7 locations using scintillators and CCD cameras. The measured emittances are then compared with the theory based on intra-beam scattering, betatron coupling, radiation damping, and radiation excitation.

I. INTRODUCTION

The Advanced Light Source (ALS) is a third-generation synchrotron radiation source for UV and soft X-rays at LBL [1]. The Injector consists of a 50 MeV Linac and 1.5 GeV booster synchrotron. Recently several proposals to utilize the Booster synchrotron were made.

One such experiment is the Compton side scattering experiment [2] whereby a femtosecond laser beam collides with the circulating booster beam and generates femtosecond X-rays. The other experiment is to extract the beam at 150 MeV to a specially designed transport line where the feasibility of the optical stochastic cooling will be studied [3].

The following emittance measurements were made on the beam at booster extraction, at various energies, and also at various points in the Booster-to-Storage Ring transfer line (BTS) at a fixed energy. These data were acquired to provide verification of beam characteristics and to obtain data the proposed experiments.

All these proposals use the Booster as a damping ring whereby the beam is ramped to a certain energy where the sychrotron radiation damping is significant, wait at this energy for several damping times to reduce the beam emittance and the energy spread, and ramp down to the desired energy to perform experiments before either the emittance grows too much due to intrabeam scattering or the beam is lost due to Touschek scattering.

II. INSTRUMENTATION

The scintillators used here are 6 % chromate doped alumina (Chromox 6 manufactured by Morgan Matroc Limited in the UK). Linearity of this type of scintillator is not known and expected to be dependent upon the spectral region involved. We did not use any special filters. In the present data analysis, we assumed that the response is linear. CCD cameras are known to have a large linear dynamic range if we do not saturate the pixels. Under the circumstances, the resolution of the measurements is basically the pixel defined image size.

At each BTS scintillator-TV monitor location the image was measured and scaled for pixel to millimeter conversion from the fiducials on each screen The result in each case is on the order of 0.1 mm/pixel. This results in a resolution in emittance for x and y of 1.2E-10 and 2.0E-9 m-rad respectively.

III. EXTRACTED BOOSTER BEAM EMITTANCE AT VARIOUS ENERGIES.

Electrons are injected into the Booster at 50 MeV and then ramped in energy to 1.5 GeV. The beam emittance in the Booster is determined dynamically by the mechanisms comprising synchrotron radiation excitation and damping, intrabeam scattering and adiabatic damping. Intrabeam scattering is negligible during normal operation but might become important for experiments with denser beams, as is proposed for the stochastic cooling experiment.

Initially beam emittances damp adiabatically and above 400 MeV synchrotron radiation damping becomes significant, at energies above 800 MeV quantum excitation causes the emittances to grow. Beam spot size measurements were made on the first scintillator-TV monitor in the BTS at various Booster extraction energies. This monitoring point is immediately after extraction and before any significant transport elements. The emittances were determined from the relationship of beam spot size and the beta functions at TV locations. The measured horizontal emittance, shown in Fig 1, shows a variation consistent with theory.

The larger values at low energy are probably due to mis-matches, energy jitter and kicker fluctuations of the Linac beam into the Booster. Agreement is better at higher energy, where the emittance is dominated by radiation damping rather than initial conditions. The scatter in the data is caused by variations in day-to-day/pulse-to-pulse performance, as well as a sensitivity to beam intensity.

Measured and calculated vertical emittance are shown in Fig 2. In the vertical plane the agreement between measured and predicted values are better at lower energies, suggesting a better match from the Linac into the vertical plane of the Booster (as might be expected from the horizontal injection system).

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[*] This work was supported by the director, office of the Energy Research, Office of the Basic Energy Science, Mterials Science Division, of the U.S. Department of Energy under contract no. DE-AC03-76SF00098.

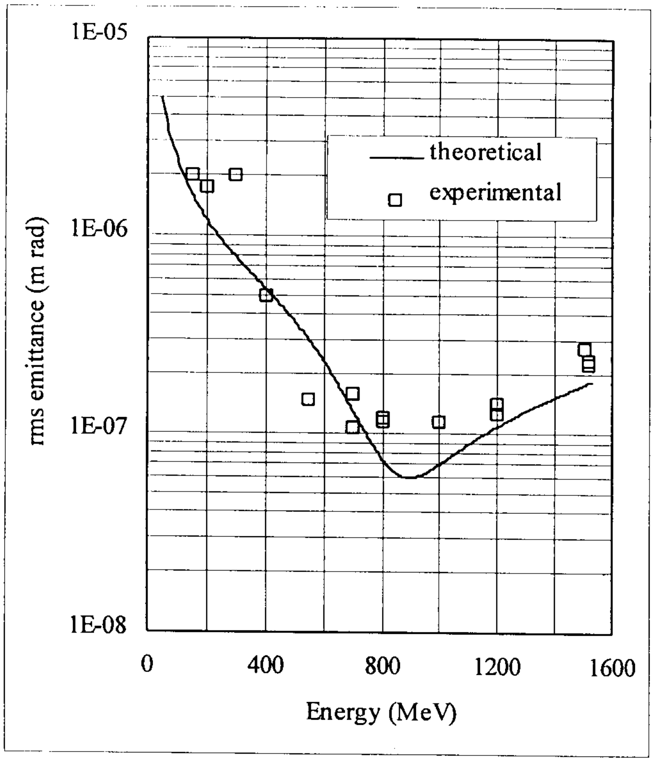

Figure 1. Comparison of measured and calculated transverse emittance as a function of energy.

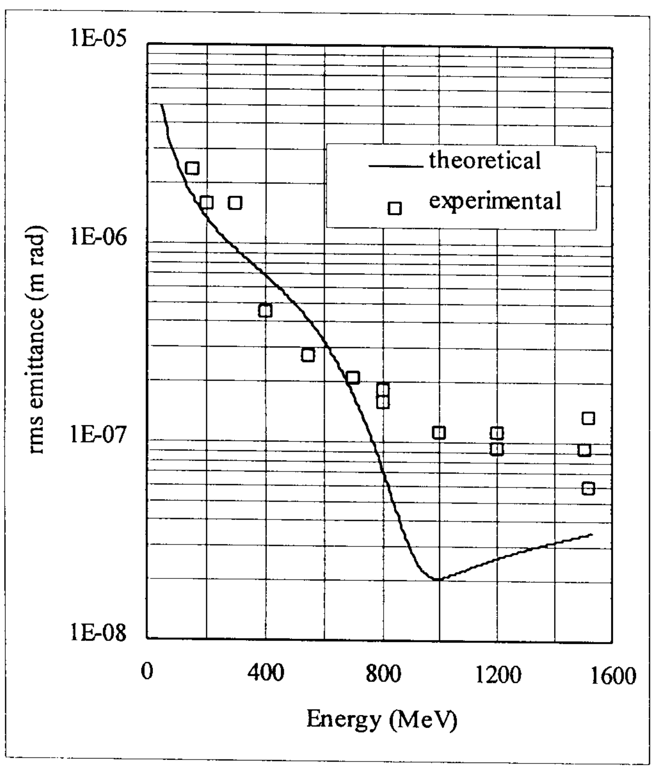

Figure 2. Measured and calculated vertical emittance as a function of energy.

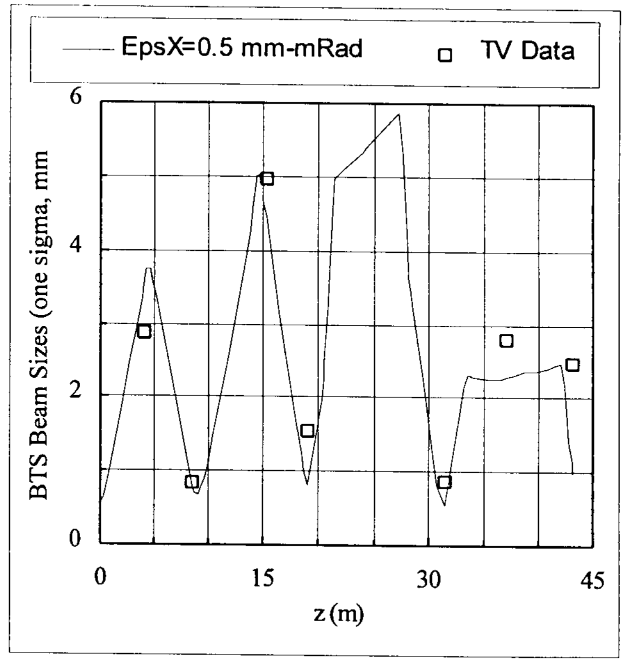

Figure 3. Beam spot size in the horizontal plane at various locations in the transport line.

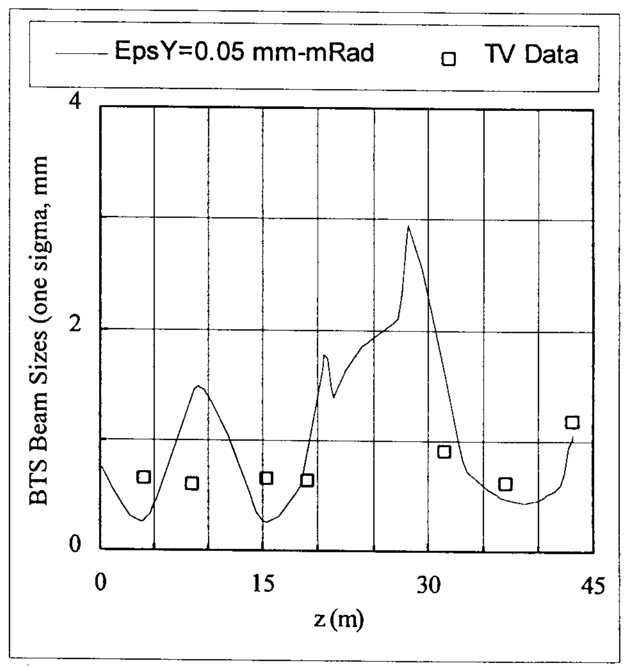

Figure 4. Beam spot size in the vertical plane at various locations in the transport line.

IV. EXTRACTED BOOSTER BEAM SPOT SIZE AT VARIOUS POSITIONS IN THE BTS

Beam spot size measurements were made on the seven scintillator-TV monitors in the BTS and Storage Ring (SR) during typical single bunch operation at the nominal 1.52 GeV level for comparison with theoretical results for optimum transport.

Beam size is fairly consistent with theoretical values in the horizontal plane as shown in Fig 3.

The measured beam spot sizes do not compare as well with theoretical values in the vertical plane, shown in Fig 4.

V. CONCLUSIONS

We have expected that the horizontal-to-vertical emittance coupling is less than 1 % because we used the same techninique that we used for the storage ring to align the booster ring. In the calculation we assumed 10 % coupling to fit the data better.

We notice that the agreement between measurements and the theoretical predictions are good except when the expected spot size is small. This may be due to the fact that the scintillator non-linearity may result in values larger than the actual beam size.

VI. REFERENCES

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[3] A. Zholents, et al., "Analysis of Optical Stochastic Cooling," in these proceedings.