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DESIGN OF THE NSLS-II LINAC FRONT END TEST STAND

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DESIGN OF THE NSLS-II LINAC FRONT END TEST STAND *

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Abstract

The NSLS-II operational parameters place very stringent requirements on the injection system. Among these are the charge per bunch train at low emittance that is required from the linac along with the uniformity of the charge per bunch along the train. The NSLS-II linac is a 200 MeV linac produced by Research Instruments Gmbh. Part of the strategy for understanding to operation of the injectors is to test the front end of the linac prior to its installation in the facility. The linac front end consists of a 100 kV electron gun, 500 MHz subharmonic prebuncher, focusing solenoids and a suite of diagnostics. The diagnostics in the front end need to be supplemented with an additional suite of diagnostics to fully characterize the beam. In this paper we discuss the design of a test stand to measure the various properties of the beam generated from this section. In particular, the test stand will measure the charge, transverse emittance, energy, energy spread, and bunching performance of the linac front end under all operating conditions of the front end.

INTRODUCTION

The NSLS-II linac is a 200 MeV linac with a 100 kV DC gun and thermionic cathode which is required to produce 15 nC in 80-150 bunches separated by 1 ns with less than 10% charge variation along the train.[1] These parameters have not been achieved at an operating list source.[2] In order to understand and test the linac gun and bunching system, we are producing a test stand that will be used to measure the beam produced by the linac gun. Once the gun is installed in the linac, the test stand can operate as a test stand for future gun development.

In this paper we will discuss the linac front end, produced by Research Instruments Gmbh, and its expected performance. Then we will discuss the design of the test stand. Finally we'll show simulations of the beam transport through the test stand. The test stand will be produced by Radiabeam Technologies

NSLS-II LINAC REQUIREMENTS

As mentioned above, the bunch train requirements have not been demonstrated at an operating light source. Much of the challenge lies in the pulser electronics that drive the cathode grid, the low energy of the beam, and the bunching process. Therefore, we want to test front end of the linac prior to its installation.

The goals for any test stand will be two fold. The first is a test bed for the pulsing electronics. We will need sufficient beam diagnostics to measure the time structure of the electron beam. This will allow us to compare the output of the gun pulser and the beam delivered from the gun. We can then do any necessary tuning to the system that is necessary. The second goal is to fully characterize the electron beam under a variety of operating conditions. This will provide us with data that we cannot otherwise obtain during operation or future study time, as not all of the requisite diagnostics will be in place. Our models can be compared to our measurements and any inadequacies can be addressed.

Once the linac front end experiments are completed, the test stand can be used as a gun test stand for future upgrades to NSLS-II. One such upgrade that is being considered is the addition of a second gun and low energy section that would operate exclusively in short bunch mode. The gun for this section could be fully characterized prior to installation with this stand

LINAC FRONT END

The linac is being produced by Research Instruments Gmbh. As part of the procurement strategy they will deliver the linac front end ahead of the rest of the linac for testing. The linac front end is defined as the electron gun, 500 MHz subharmonic prebuncher, focusing solenoids, correctors, two flags, a retractable faraday cup, one wall current monitor, one beam position monitor that are all installed on the first table of the NSLS-II linac along with the associated electronics and power supplies This assembly will attach directly to the bunching section of the linac, and is shown in Figure 1.

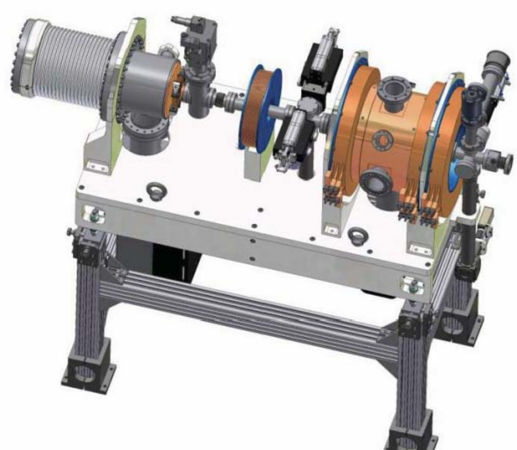

Figure 1: The NSLS-II linac front end produced by Research Instruments Gmbh. [3]. The gun is on the left with the subharmonic buncher on the right.

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TEST STAND

The linac front end test stand is designed to complement the diagnostics in the linac front end to fully characterize the electron beam. This includes charge, transverse emittance, energy, energy spread, bunch spacing, bunch length, and train uniformity. It must also provide solenoidal focusing for the low energy beam and correction coils to compensate for the earth's field. Figure 2 shows a drawing of the test stand.

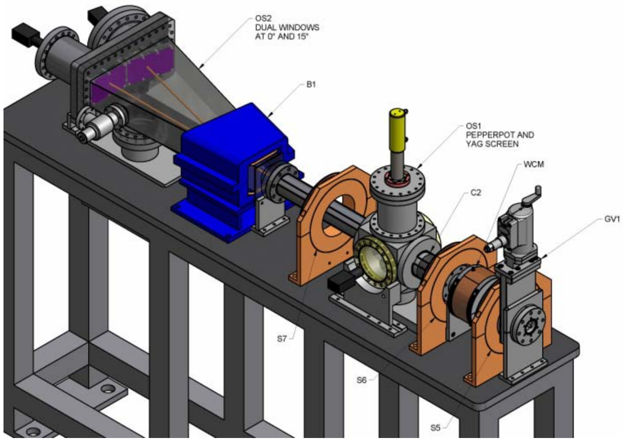

Figure 2: Conceptual design of the Linac Front End Test Stand. The LFE attaches at the gate valve on the lower right.

The wall current monitor is placed as close as possible to where the bunch length is a minimum with the buncher operating at nominal parameters. In the linac this will correspond for the location of the 3 GHz prebuncher. The bunch length will vary from 1 ns full width with no bunching to 90 ps full width when the buncher is operating. The anticipated bandwidth of the wall current monitor is not enough to measure the bunch length, but is enough to see the effect of the bunching process and to measure the bunch spacing.

The transverse emittance will be measured with a pepperpot. The unnormalized transverse emittance of the beam from the linac front end is on the order of 0.02 m-rad. The large emittance means that the imaging screen be close to the pepperpot with the holes spaces far apart. Furthermore, the need for constant focusing because of the low beam energy mean the the emittance measurement system be compact. The pepperpot will be a disk with a 5 cm diameter covered with 250 μm holes that are spaced 1 mm apart. A fluorescent screen will be placed 2.5 cm behind the pepperpot to intercept the beamlets. A 45 degree mirror reflects the light out of the vacuum chamber. This is mounted on a single pneumatic actuator which will retract the assembly from the vacuum chamber. This pepperpot screen assembly is shown in Figure 3. This design draws heavily for the design used on the test stand of the ANKA gun. [4]

A dipole with a maximum field of 23 Gauss and magnetic length of 20 cm will bend the beam through a 15 degree angle to measure the beam energy and energy spread. A 40cm drift length follows the dipole. This choice was based on a compromise between bending the beam enough to measure the energy spread with reasonable accuracy when the buncher operates, and the beam size increase that occurs from the natural defocusing of the beam. The large beam size makes it impractical to design a chamber that has two branches, so a fan shape was chosen.

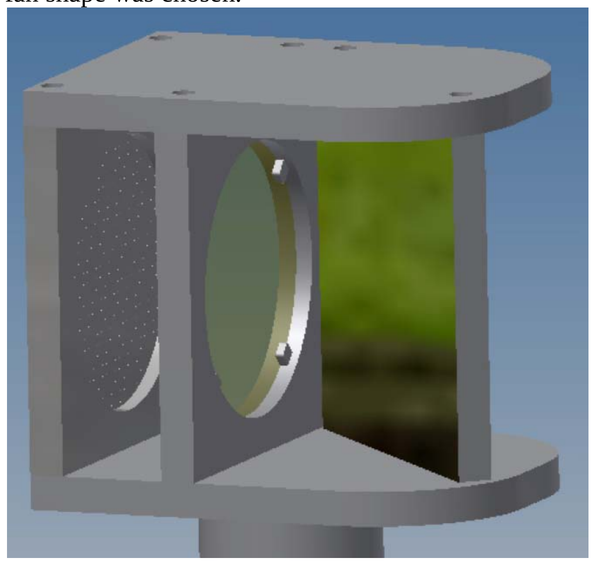

Figure 3: Conceptual Design of the pepper pot, florescent screen and 45 degree mirror assembly. The beam strikes from the left.

At the end of the chamber is a long florescent screen which will be used to measure the beam size. Two optical ports behind the screen allow a camera to image the beam. The kinetic energy spread is 3% when the buncher is not used and cannot be measured with this system. When the buncher is used, the kinetic energy spread will be 18%. The horizontal beam size should increase a factor of 1.75 due to dispersion alone. However, horizontal beam size will actually increase 2.2 times because of chromatic effects in the solenoids as well as dispersion. So taking the difference of the beam size with and without the buncher will give a larger energy spread than what nominally exists. Since the focussing is symmetric through the test stand, including the dipole, we measure the energy spread by taking the difference of the horizontal and vertical beam size.

The screen is made of conductive glass that is electrically isolated from the rest of the chamber and connected to a vacuum feedthrough. The low energy of the electron beam allows us to use the screen as a faraday cup to measure the charge of the bunch train. We do not anticipate having the ability to measure the individual bunch charge. The bunch train uniformity will be measured with the wall current monitor.

The large beam emittance requires almost constant focussing to maintain a reasonable beam size. The low beam energy allows one to use solenoids for focussing which has the added advantage of maintaining spherical symmetry. We have modelled our solenoids after the linac solenoids taking advantage of the fact that we can make ours with a smaller radius since we don't need to fit them about large RF cavities. The air core design has advantages as the fields from the solenoids will extend passed beyond it and overlap, so we can use many short solenoids which are easier to produce. The air core has the added benefit of allowing us to use small but long correction windings outside of the vacuum chamber to correct for the earth's field. The solenoids for the test stand will produce a maximum field of 250 G with a diameter of 12.7cm, and a similar magnetic length. They are air cooled.

The placement of the solenoids was chosen to maintain the beam size less than 0.6 cm rms allow sufficient room to place the pepperpot in a low field region and provide the requisite focussing for the energy spread measurement.

SIMULATIONS

We have done simulations using TStep to understand hte beam dynamics through the LFETS and optimize the design.[5] Figure 4 shows the three sigma beam size from the cathode though the end of the linac front end test stand with the prebuncher turned off. The solenoidal focusing and the dipole edge angles maintain the spherical symmetry of the beam through the apparatus.

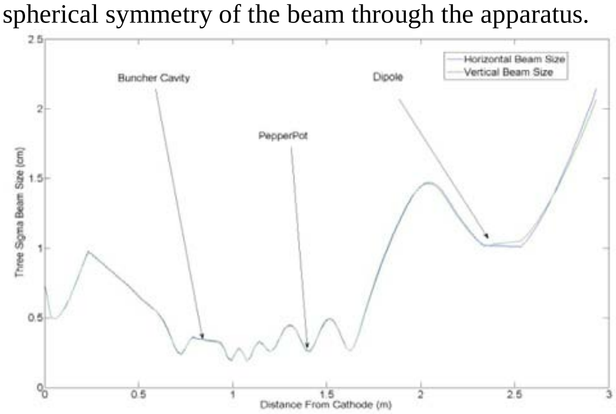

Figure 4: The three sigma beam size through the LFETS with the buncher turned off.

Figure 5 shows the evolution of the beam size with the buncher turned on. The buncher introduces a correlated kinetic energy spread of 18% to achieve bunching in the linac. This results in increased beam size before the dipole because of chromatic effects and after the dipole from dispersion.

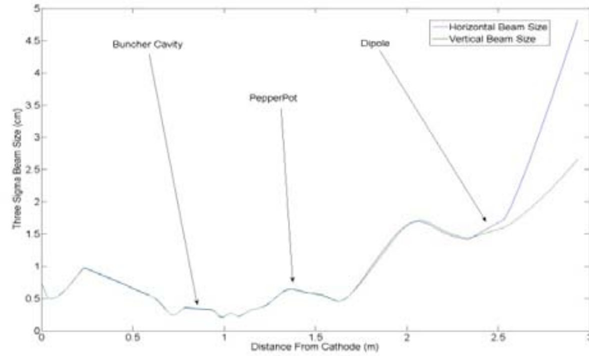

Figure 5: The three sigma beam size through the LFETS with the buncher turned on.

The effect of the buncher cavity on the beam is shown in Figure 6. Without the buncher cavity, the bunch length grows as it traverses the test stand due to space charge. The buncher cavity redues the rms beam size a factor of 8. We have placed a wall current monitor as close to this minimum as possible. This would be the location of the 3 GHz prebuncher followed by the buncher cavity which would continue to bunch the beam. In the test stand this does not exist, so the bunch length continues to increase since there is nothing to contain the bunch at this point.

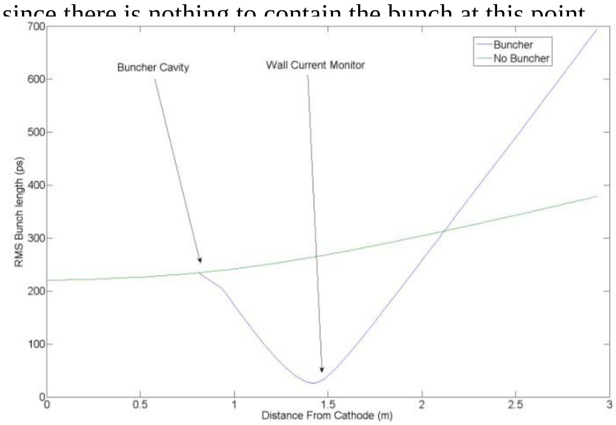

Figure 6: The rms bunch length through the LFETS with and without the buncher.

CONCLUSION

We have provided a conceptual design of a test stand for the linac front end experiment. This test stand provides the necessary diagnostics to measure all of the beam parameters produced by the linac gun. One the experiments on the NSLS-II linac front end are completed the linac front end test stand will be used as a gun test stand for any future studies and upgrades to the NSLS-II linac.

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