Abstract

In support of Compton scattering gamma-ray source efforts at LLNL, a multi-bunch test stand is being developed to investigate accelerator optimization for future upgrades. This test stand will enable work to explore the science and technology paths required to boost the current 10 Hz mono-energetic gamma-ray (MEGa-Ray) technology to an effective repetition rate exceeding 1 kHz, potentially increasing the average gamma-ray brightness by two orders of magnitude. Multiple bunches must be of exceedingly high quality to produce narrow-bandwidth gamma-rays. Modeling efforts will be presented, along with plans for a multi-bunch test stand at LLNL. The test stand will consist of a 5.5 cell X-band rf photoinjector, single accelerator section, and beam diagnostics. The photoinjector will be a high gradient standing wave structure, featuring a dual feed racetrack coupler. The accelerator will increase the electron energy so that the emittance can be measured using quadrupole scanning techniques. Multi-bunch diagnostics will be developed so that the beam quality can be measured and compared with theory. Design will be presented with modeling simulations, and layout plans.

TEST STAND LAYOUT

The advanced X-band test accelerator will be an independent beamline capable of performing experiments on future improvements to the LLNL center for gamma-ray applied science. The high power RF used for the main 250 MeV linac will also be used to power an RF photoinjector and single traveling wave accelerator section [3]. The same photocathode drive laser will also be used to generate multiple photoelectron bunches [2]. The test stand is shown in Fig. 1. Beam dynamics simulations predict less than 1 mm-mrad rms emittance, as shown in Fig. 2. The parameters for the test stand and the simulation are shown in Table 1. Beamline diagnostics will include pop-in screens, ICT, energy spectrometer, and a Faraday cup. In addition, a multi-bunch diagnostic beam deflector is planned so that the properties of multiple bunches can be distinguished independently.

RF GUN DESIGN

The RF photoinjector is based on a high gradient 7 MeV 5.5 cell X-band RF gun [4, 5, 6]. Improvements specific to our application have been implemented and will be described in this paper. PARMELA simulations revealed that...
a longer first half cell, as simulated with SUPERFISH resulted in a lower final emittance for the setup planned at LLNL. As a result a full redesign of the RF gun has been performed, using a longer first half cell, lengthened from a 0.49 cell to a 0.59 cell. A schematic for the RF gun is shown in Fig. 3.

The RF gun properties required for complete design are: field balanced across all cells, mode frequency of 11.424 GHz, and a coupling $\beta$ of $\sim$1.8. The circular iris profile, cell lengths (except for the first half cell), and coupler geometry are all adapted from the design of the new X-band RF gun [6]. This new RF gun boasts an improved mode separation of $>10$ MHz, which decreases mode beating of the electric field on the cathode. The improved mode separation is demonstrated in Fig. 4. The new RF gun also employs a racetrack coupler to reduce the RF quadrupole field experienced by the electron beam. These improvements were incorporated into the design of a modified RF gun for LLNL.

Complete 3D RF design for the photoinjector was accomplished using HFSS. Each modification affects the three design criteria: field balance is primarily a function of relative cell radii; coupling is primarily a function of the coupler cell radius and coupling aperture; the frequency is primarily changed by scaling all cell radii. Each adjustment changes the primary goal being modified, but also affects the other two. Final design is achieved by successive iteration, until all parameters are simultaneously met. The final field balance is quite excellent, as shown in Fig. 5. The final coupling was achieved at 11.424 GHz, with a $\beta$ of $\sim$2, as shown in Fig. 6.

Final modification of the design is necessary to converge on a set of dimensions for engineering drawings and actual copper fabrication. Machining will be done at 20 °C, while operation is planned for 45 °C. Scaling of the design dimensions was calculated and simulated. Design numbers were then truncated to acceptable fabrication tolerances, which required readjustment of the drawing numbers to conform with optimal field balance, coupling, and frequency at the operating temperature of 45 °C. Engineering drawings have

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<th>Table 1: Test Stand Parameters</th>
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<td>Charge</td>
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Figure 5: HFSS simulation result showing field flatness of ∼1% across all cells.

Figure 6: HFSS simulation S_{11} result showing an operating mode coupling β of ∼2 and a design frequency of 11.424 GHz.

been completed, and fabrication is planned in the near future.

**FUTURE WORK**

Future modeling efforts will focus on the predicted performance of the new RF photoinjector, specifically on the multi-bunch performance of the RF gun. Simulation of beam loading will determine the predicted bunch to bunch energy spread, and drive compensation efforts. The test stand experimental program will focus on the fabrication and commissioning. Experiments will benchmark modeling results and focus future research and development on solving the technical challenges to increasing gamma-ray flux and repetition rates. The technology developed on the test stand will serve as the basis for future upgrades to LLNL’s center for gamma-ray applied science to further increase the gamma-ray production.

**REFERENCES**


