CBETA BEAM COMMISSIONING RESULTS

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Abstract

We report on the first results of commissioning CBETA with a fully closed return loop. We repeat much of our early commissioning from the fractional arc test [1, 2] , namely setting up the injection system, calibrating the main linac, and steering beam through the first splitter line. Most importantly, first results from sending the beam all the way through the Fixed Field Alternating gradient permanent magnet return arc are described.

INTRODUCTION

The construction of a high energy, high luminosity, polarized Electron-Ion Collider (EIC) remains one of the highest priorities for the nuclear physics and accelerator communities and continues to drive research and development of many state-of-the-art accelerator technologies [3]. In the case of the potential eRHIC design(s), the use of Fixed Field Alternating-gradient (FFA) recirculating loop(s) [4, 5] may provide significant cost reduction by shortening the length of the linac, as well as minimizing the number of recirculating loops required.

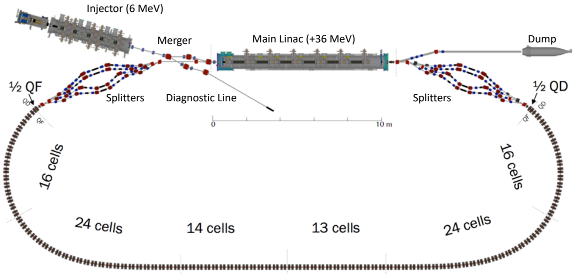

Figure 1: Layout of the CBETA machine.

As part of this development effort, the Cornell-BNL Energy recovery linac Test Accelerator (CBETA) [6], a 4-pass, 150 MeV ERL utilizing a Non-scaling Fixed Field Alternating-gradient (NS-FFA) permanent magnet return loop, is currently under design and construction at Cornell University through the joint collaboration of Brookhaven National Lab (BNL) and the Cornell Laboratory for Accelerator based Sciences and Education (CLASSE). Building on the significant advancements in high-brightness photoelectron sources and SRF technology developed at Cornell [7–9], as well as the FFA magnet and lattice design expertise from BNL [10, 11], CBETA will establish operation of a multi-turn SRF based ERL utilizing a compact FFA return loop with large energy acceptance (a factor of roughly 3.6 in energy), and thus demonstrate one possible cost-reduction technology under consideration for the eRHIC design. Moreover, successful completion of the CBETA project requires the study and measurement of many critical phenomena relevant to both the EIC and ERL communities. Examples include the Beam-Breakup (BBU) instability, halo-development and collimation, as well as Coherent Synchrotron Radiation (CSR) microbunching and energy spread growth [6].

Figure 2: Photo of the straight section of the permanent magent FFA return loop.

The final full 4-turn ER CBETA layout is shown in Fig. 1. This spring, installation of the lowest energy splitter line after the linac and permanent magnet FFA loop was completed, allowing the beam to be passed nearly all the way back to the linac. Figure 2 shows a top down view of the straight section of the FFA loop (bottom of Fig. 1). In parallel to construction, beam commissioning began in March. To date, this has included initial tune up of the injector for 5 pC bunches, as well as recommissioning of the main linac, yielding a desired energy gain of 36 MeV.

FIRST BEAM AROUND THE FFA RETURN LOOP

Tuesday May 7, 2019 saw the first attempt at threading the beam through the FFA permanent magnet return loop. This was achieved by finding the beam on the first few BPMs at the beginning of the arc. Subsequent steering of the orbit near the design position in the first section of the FFA (roughly -15 mm) caused the beam to thread through the arc very quickly, passing about 3/4 of the way through. Steering the orbit vertically finally passed the beam to the gate valve at

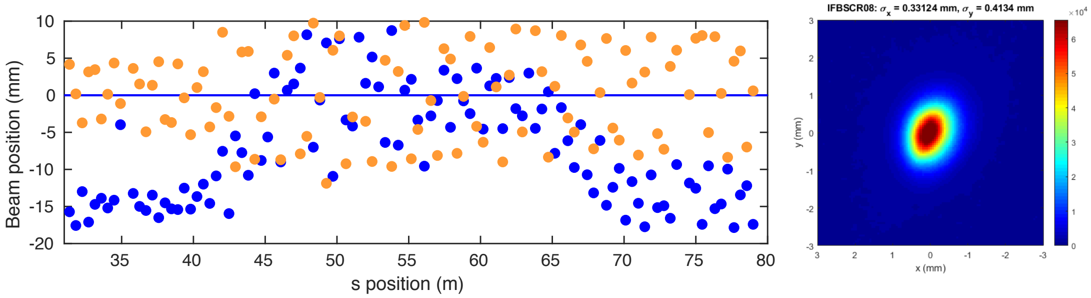

Figure 3: First beam on all of the FFA return loop BPMs (left) and at the end of the return loop (right).

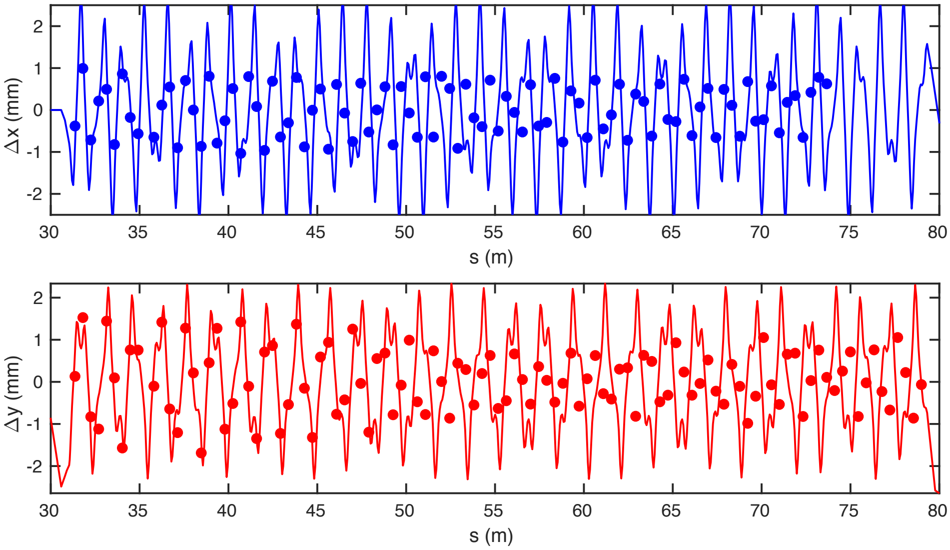

Figure 4: Horizontal (top) and vertical (bottom) difference orbits through the FFA loop.BPM data (dots), online model (line).

the end of the return loop (before the return splitter section). Figure 3 shows the BPM positions of the first beam threaded through the entire return loop, as well as an image of the beam on the final FFA viewscreen. Note the horizontal orbit positions at the entrance and exit of the arc of about -15 mm. This is the correct design orbit.

After success threading the beam around, two difference orbits were measured and compared with the online model provided by the CBETA Virtual Machine [12]. These can be seen in Fig. 4. In both cases the model agrees fairly well up to about 40 m. Taking the Fourier transform of the data in the first periodic section, and comparing the resulting horizontal and vertical phase advance per cell to the predicted values by tracking particles through 3D fieldmaps implies the beam energy was 41.7 MeV (as opposed to the assumed 42 MeV in the model). In the future, this may prove a useful way of estimating the beam energy, though results now are only preliminary.

CONCLUSION

As of this spring, CBETA beam commissioning is now well underway, with an initial beam has been sent through the permanent magnet FFA loop without the use of any corrector magnets. This represents an important milestone in the direction of establishing both single-turn, and later multi-turn energy recovery, and serves as proof of principle for the development of permanent magnet based FFA designs.

Several important measurements are now underway, including verification of orbit correction throughout the machine, recalibration of the linac cavities, performing an energy scan to determine the tunes as a function of energy and possibly the BPM offsets in certain sections of the FFA loop, commissioning the return splitter line between the FFA loop and main linac, and tune up of the beam arrival monitors before and after the linac to aid in time of flight adjustment for establishment of energy recovery.

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