STATUS OF THE BNL ENERGY RECOVERY LINAC INSTRUMENTATION*

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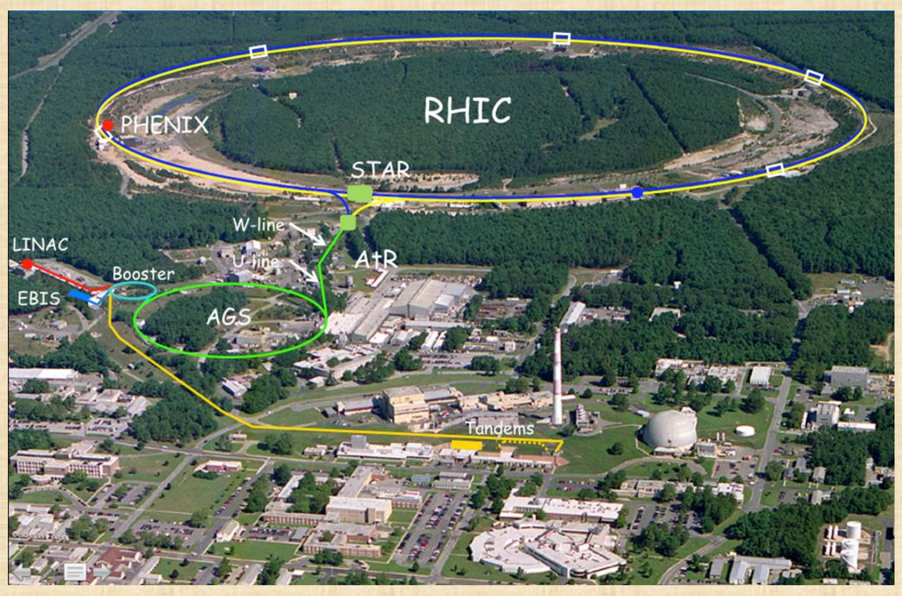
Abstract

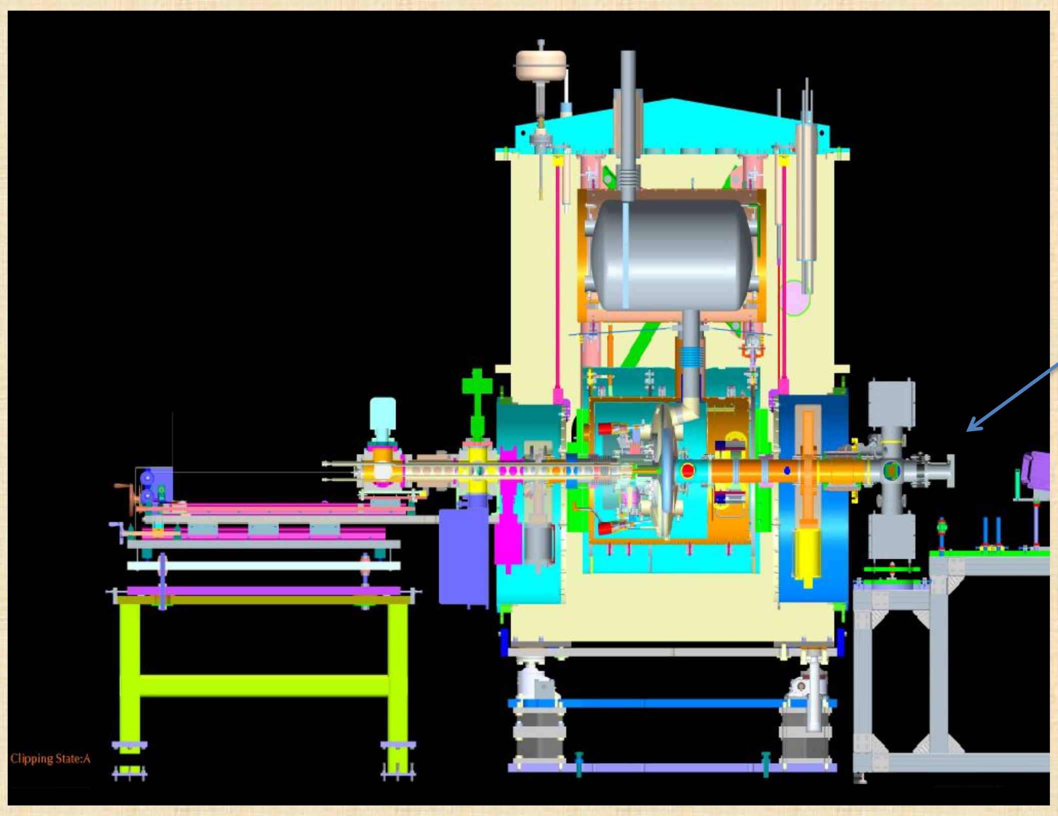
The Energy Recovery Linac (ERL) project is currently under construction at the Brookhaven National Laboratory. Energy recovery operations are expected with high intensity beams that have current up to a few hundred milliamps, while preserving the emittance of bunches with a charge of a few nC produced by a high current SRF gun. To successfully accomplish this task the machine will include beam diagnostics that will be used for accurate characterization of the beam phase space at the injection and recirculation energies, transverse and longitudinal beam matching, orbit alignment, beam current measurement, and machine protection [1]. This paper describes the recent progress and present status of the systems that will be used to meet these goals. We expect first electron beams later this year.

Introduction

The diagnostics requirements have been in several previously published papers [2,3,4]. There is a progression of ERL facility stages planned in order to move forward towards achieving full energy recovery. The diagnostics system configurations vary for each stage. The initial stage for beam testing includes the 2MeV SCRF gun, a straight beam transport to an in-flange ICT, then to an isolated blank CF flange acting as a Faraday Cup. After gun testing with different cathodes we will extend the straight transport to include a pepper pot emittance station. When the beam parameters are acceptable we will connect the transport to the injection zig-zag and deliver beam to a low power dump after the 5-cell Linac. The early commissioning stages are limited to 70W operation by the relatively small temporary beam dumps. The full complement of all of the ERL planned instrumentation subsystems, including devices in the energy recovery loop and high power beam dump, are shown in the figures to the right.

Aerial view of RHIC





Short beam line for first beam tests

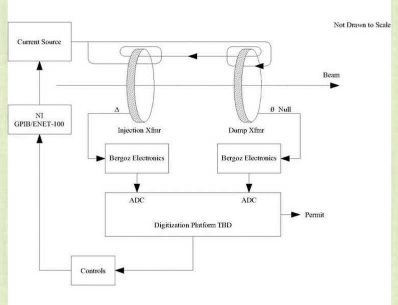
Above image is a 3D cut-away view of the ERL SCRF Gun and short beam line transport to a CF flange for initial gun commissioning with e-beam.

Beam Current Monitors

High precision DC current measurements will be made using a matched set of Bergoz NPCT-S-115 DC current transformers (DCCT) and standard NPCT electronics.

There will be one of each installed in the injection and extraction transport beam lines. These DCCTs are configured in a nulling mode [5] where their calibration windings are joined in a single loop, and driven opposite the beam by a low-noise Khronhite model 523 current source. The output level of the dump DCCT is fed back as a reference to the current source to drive the dump DCCT output to zero. The output of the gun DCCT is then a differential current measurement.

The DCCT signal processing will be done using a National Instruments PXI-1042 8 slot 3U chassis with a PXI-8115 Core i5-2510E 2.5GHz controller and a set of PXI-6289 625 kS/s, 18-bit digitizers for handling system tasks that include absolute and differential measurements. Drift (magnetic field, thermal, and gain) compensation will be automatically removed by periodic nulling without beam. The anticipated sub-micro-amp resolution may permit using this diagnostic as a second layer of the machine protection system [7] in the case the beam loss monitors fail to detect beam losses.

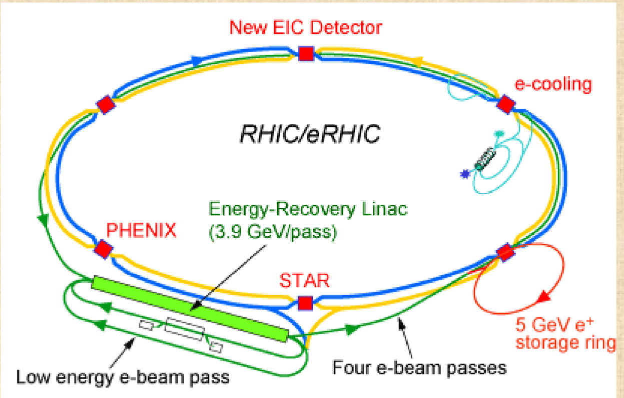


Differential DCCT Block Diagram

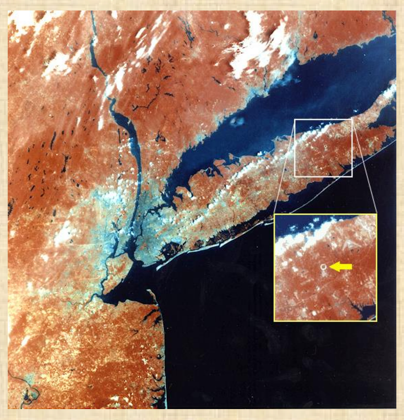
Bunch-by-bunch & bunch train charge will be measured by a Bergoz in-flange Integrating Current Transformer (ICT) part number ICT-CF6-60.4-070-05:1-H-UHV-THERMOE, located in the upstream injection line. This ICT assembly has an internal type E thermocouple for bake-out temperature monitoring; this feature was added by request.

ICT signals will be processed by Bergoz BCM-IHR Integrate-Hold-Reset electronics that have the 10 kHz repetition rate feature. A VMIC 3123 16-bit digitizer with a beam synched trigger will be configured using the double-channel digitizing method to increase the acquisition rate to 200 kS/s.

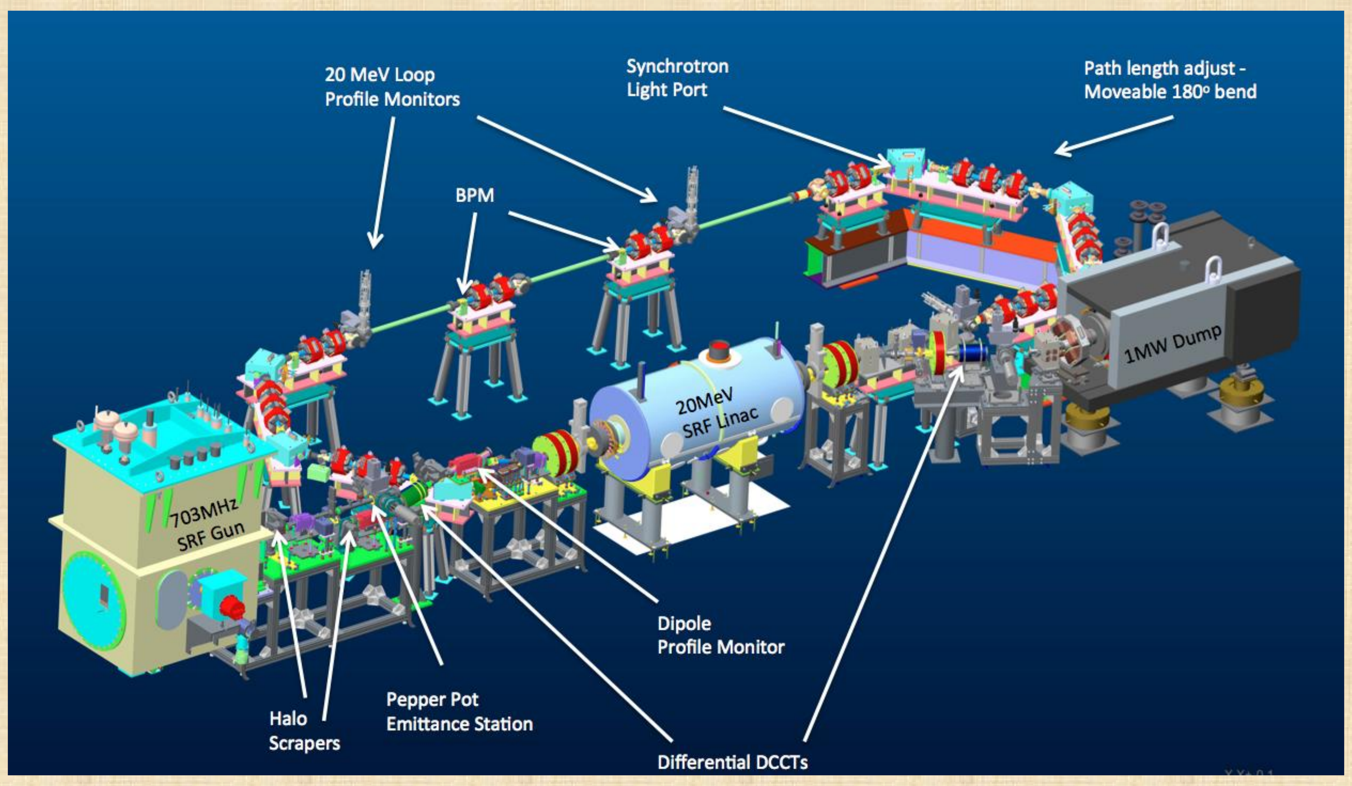
Proposed eRHIC Layout



Satellite view of RHIC at BNL on Long Island in New York.



The technology developed at the BNL R&D ERL will be applied to the future eRHIC (high energy electron-ion collider) that is presently being designed.

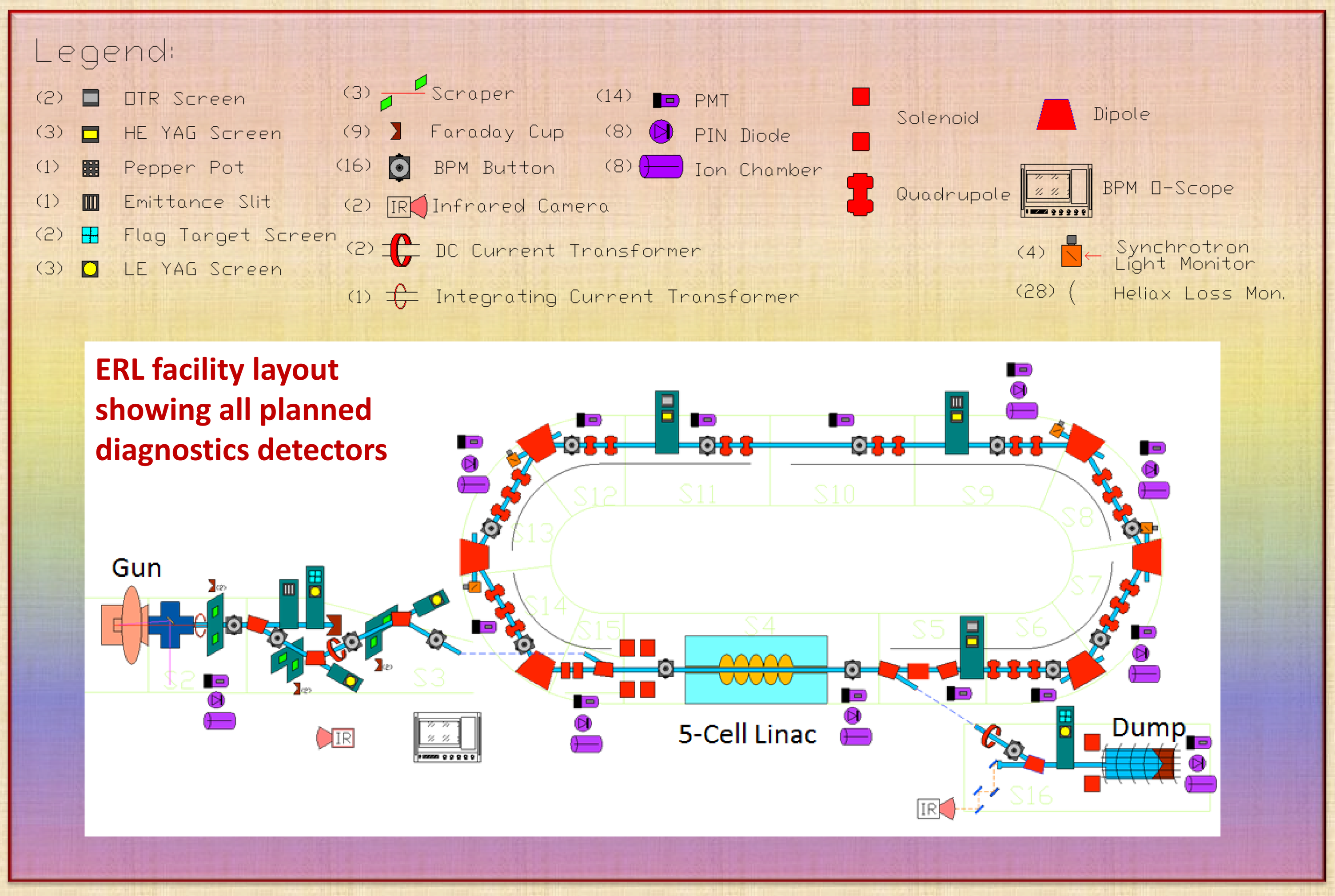


Above image is a 3D rendering of the ERL facility showing the SCRF Gun, zig-zag injection transport, 5-cell SCRF Linac, recovery loop, high power dump, and location details of some of the instrumentation systems.

Beam Position Monitors

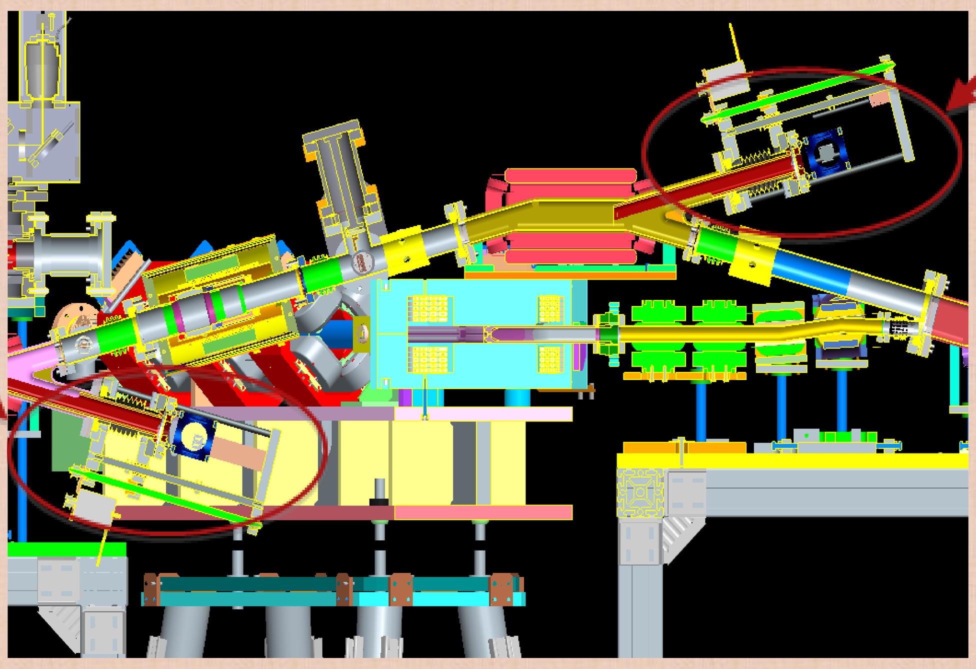
There are 16 dual plane 10mm diameter button style Beam Position Monitors (BPMs), 4 in the injection transport, 11 in the recirculation loop, and 1 in the dump line. The buttons are Times Microwave Systems model SK-59044; they are mounted on stainless cubes that are welded to the adjacent 6 cm diameter beam pipes. The orientations of the installed cubes are either at 45° or 90° depending on their location. A 45° orientation is used if there are space limitations, and to avoid beam related energy deposition on a button downstream of bending magnets. The BPMs will be baked to 150C.

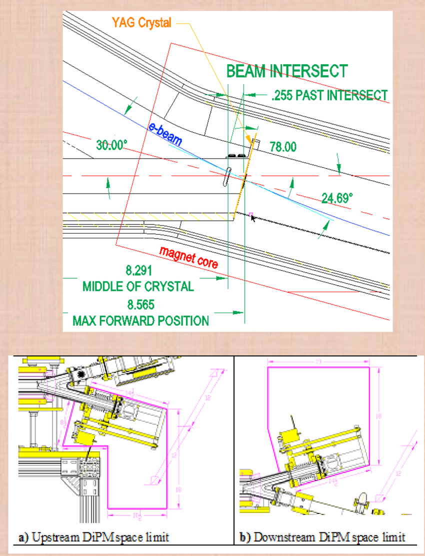
Libera Brilliance Single Pass electronics from Instrumentation Technologies will process signals from the BPMs. These modules have been customized with a 700MHz SAW band pass filter that matches the fundamental frequency of the SCRF gun and Linac accelerating cavities. The Libera BPM electronic units have been integrated into the standard RHIC control system. ADO (accelerator device object) software has been written and executes directly on the Linux kernel that is resident in the Libera hardware. The ADO provides on-board communication to the Libera hardware through the CSPI (control system programming interface) library provided by I-Tech, and communicates to higher level workstations via Ethernet using standard RHIC control system utilities.



Dipole Profile Monitor

A pair of specially designed YAG Dipole Profile Monitors will be provided, they will plunge into the beam path inside of the two injection 30° vertical dipole chambers as shown in the figures below. Precise positioning will be provided by a stepper motor actuated plunging mechanism with a 4-inch stroke, containing a long YAG screen holder that extends into the dipole magnet chamber through an auxiliary port to intercept the electron beam. The beam can be imaged at different places on the crystal including the edge depending on the plunge depth. This can be useful for semi-destructive beam halo monitoring. A specification and statement of work has been prepared, we hope to receive these devices from the vendor next year.

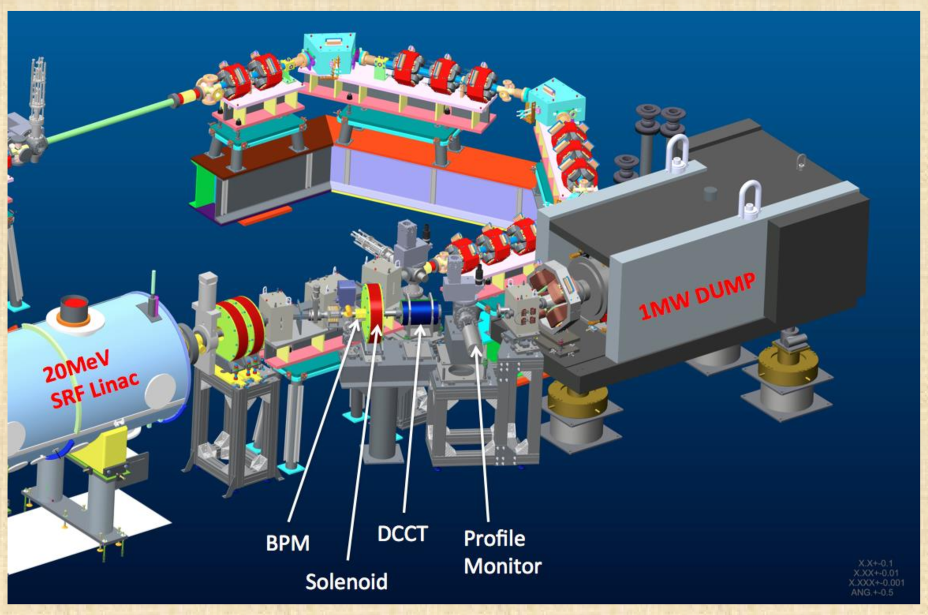




Dipole Profile Monitor mechanical details

GigE Imaging Cameras

Images from the YAG and OTR screens are transported through a mirror labyrinth to a 3-motor lens and CCD camera in a local enclosed optics box. Communication cable length requirements and poor support for FireWire 1394 cameras in the WS5 and WS6 RedHat Linux kernels we currently use has prompted a migration to GigE camera technology for digital imaging tasks within our controls subsystems. The Manta G-201B from Allied Vision Technologies is the camera we plan to use for early operations. A software middleware layer is implemented using Aravis, an open-source glib/gobject based library which enables video acquisition from genicam based cameras, which makes the images available to various viewing and image processing applications. Users can control parameters such as image size, bit depth, resolution, exposure, gain, gamma, binning, triggering, etc. The images are used to characterize the beam and can be stored for later examination and calculation of projections, centroids, etc.



ERL Extraction Beam line – 2MeV

The design of the 2 MeV beam line transport from the 5-cell Linac to the dump was detailed as shown in the Figure above. This instrumentation includes a BPM, DCCT and a plunging YAG profile monitor.

REFERENCES

[1] Gassner, David., et. al., "BNL Energy Recovery Linac Instrumentation", ERL 2011, WG4003.
[2] Cameron, Peter, et. al., "A First Look at Beam Diagnostics for the RHIC Electron Cooling Project", DIPAC 2005.
[3] Cameron, Peter, et. al., "Beam Diagnostics for the BNL Energy Recovery Linac Test Facility", BIW 2004, page 232.
[4] Pozdeyev, Eduard, et. al., "Diagnostics of the BNL ERL", PAC07, page 4387, FRPMS116.
[5] Kayran, Dmitry. et. al., "A Method of Emittance Preservation in ERL Merging System", THPP071, FEL 2005, Stanford CA.
[6] Jamilkowski, James, et. al., "Controls System Developments for the ERL Facility", ICALEPCS 2011, MOPMU027.
[7] Cameron, Peter, et. al., "Differential Current Measurement in the BNL ERL Facility", ERL2005 Workshop.
[8] Altinbas, Z., et. al., "The Machine Protection System for the R&D Energy Recovery Linac", MOP277, PAC2011.
[9] Perry, J., et. al., "The CEBAF Beam Loss Sensors", PAC 1993, page 2184-2186.
[10] Yan, J., Mahoney, K.., "New Beam Loss Monitor for 12 GeV Upgrade, WEP092, ICALEPCS2009.
[11] Miller, T. et al "Instrumentation Designs for Beam Distribution Measurements in the ERL Beam Dump at BNL" these proceedings.