# ELECTRON BEAM DIAGNOSTICS FOR COMPACT 1.2 GEV BOOSTER SYNCHROTRON*

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*Abstract*

First operational experience has been gained with the linac and booster diagnostic system during the commissioning of the booster synchrotron at Duke University. The booster was designed and developed as an injector for the storage ring as a part of the High Intensity Gamma-ray Source (HIGS) upgrade of Duke FEL storage ring. Booster beam instrumentation includes: beam charge measurements (Faraday cups, Integrated Current Transformers (ICT), Modular Parametric Current Transformer (MPCT)), beam position monitoring (BPM), betatron tune measurements using synchrotron radiation (SR), transverse profile and temporal beam structure monitoring (insertable screens, striplines, dissector). The diagnostics provided good understanding of electron beam behavior and allowed us to adjust important beam parameters within design specifications. An overview of the diagnostic instrumentation of the Duke Booster synchrotron is given along with measurement examples and discussion of operational experience.

## INTRODUCTION

Beam diagnostics for the booster and injection beam lines have been selected with a premium on ease of use and operation. Nine sets of BPM button modules from Bergoz, five insertable screens of DFELL design, one ceramic break hosts a MPCT, also from Bergoz. One ceramic break in the LTB and one in the BTR vacuum system provide a space for the Bergoz ICT at the entrance and exit of the booster.

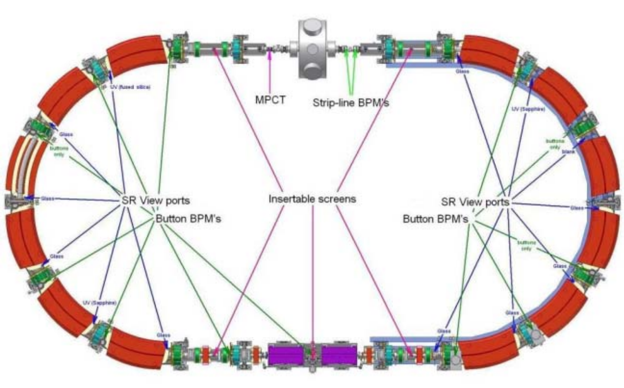


Figure 1. Layout of the main booster diagnostic components.

## BEAM CHARGE MONITORING

### *Faraday cups*

Linac as a part of the booster injection system has a number of instruments for a beam charge measurements. A few pulse transformers do not provide any reliable information because of very short length of beam pulse. Wall current monitor has clean and reliable output signal but still very short duration for direct measurements. Moreover, absolute calibration of this device depends on the beam position. DFELL linac equipped with two Faraday cups as well. They are not look like a traditional Faraday cup. These are two chunks of aluminum mounted on the isolated platforms. Electrical potential of this "cup" is proportional to the beam charge absorbed by aluminum. DFELL has designed and developed pretty simple device based on sample and hold technique which is triggered by front edge of the voltage pulse. Hold time is big enough to enable measurement by conventional ADC. Both linac Faraday cups are combined with energy spectrometers. Low energy spectrometer (LES) installed after first section of the linac there e-beam has 35 Mev. High energy spectrometer (HES) installed on the output of the 270 Mev linac. Both LES and HES faraday cups have been calibrated by using Bergoz Integrating Current Transformer (ICT, [4]), model "ICT-082-070-10:1". Two of these ICT have been installed later on the Linac-to-Booster (LTB) and Booster-to-Ring (BTR) beam lines. An accuracy of faraday cup measurements determines by signal-noise ratio and for charge above 0.1 nC is about 5%. Fig. 2 shows shape of signals from HES faraday cup, ICT and digitally derived integral of the ICT voltage.

### *ICT*

According to Bergoz Certificates of Calibration both our ICT's have absolute accuracy better than 0.5%. But typical charge per pulse coming from DFEL linac is about 0.2 nC, that corresponds to voltage level of ICT which is less than 15 mV on a 50 Ohm load. Broad-band amplifier with gain 10 based on OPA567 operational amplifier has been designed and developed to improve signal-noise ratio.

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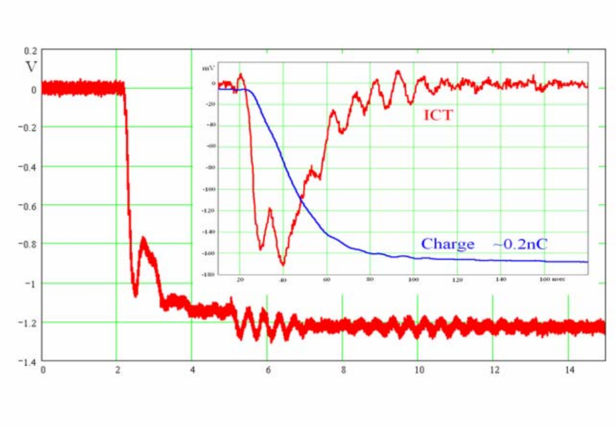


Figure 2. Faraday cup and ICT signals.

## BOOSTER RING DIAGNOSTICS

### *MPCT*

Another product from Bergoz has been employed in the booster for monitoring of circulating current. It is Modular Parametric Current Transformer (MPCT). The ceramic gap on the vacuum tube prepared for MPCT installation has been bypassed with surface-mount capacitors evenly distributed over the slit. The MPCT also was equipped with magnetic shield. The range of measured beam current is switchable. Minimal available range is 10 mA. This device has very good absolute accuracy and linearity but can not be useful below 100 μA of beam current because of noise.

Faraday cups, ICT's, and MPCT are sufficiently sensitive to monitor efficiency of injection and extraction with the typical amount of beam charge of 0.15-0.3 nC per pulse.

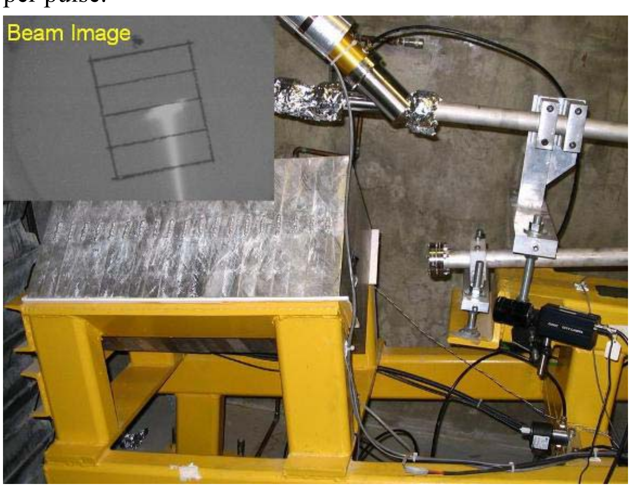


Figure 3. HES and beam image.

### *BPM*

Booster has 9 sets of BPM button modules. BPM's were found out to be reasonably sensitive at ~50 μA of beam current, which allowed the required orbit correction.

The BPM were calibrated based upon the measured machine dispersion function. Fig.2 shows the result of this calibration for x-direction.

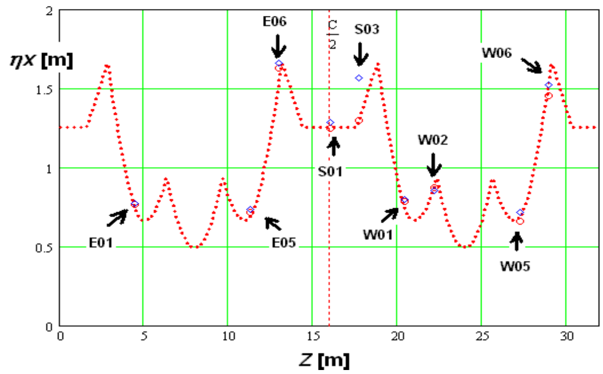


Figure 4. X-dispersion function and BPM measurements.

We also have two sets of stripline-style BPM's. Four stripline electrodes electrically grounded at one end of BPM are located at 45°with respect to the median plane. One of this BPM we are using to monitor beam pattern and second one to excite beam oscillations during betatron measurements.

### *SR monitors*

For standardization of design, synchrotron radiation view ports (SRP) have been incorporated into 14 locations (see Fig.1) at the booster arcs, 12 of which receive synchrotron radiation from the adjacent upstream dipole magnets.

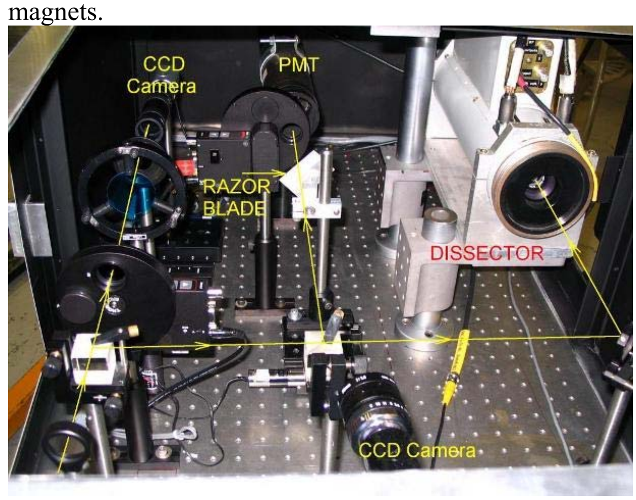


Figure 5. NW optical table.

### *Tune measurements*

We developed a PMT based system capable of measurement of betatron tunes with a beam current as low as 5-10 μA [2, 6]. That allowed us to continue commissioning of the booster even after the failure of driving Minilite-II laser, using a multi bunch mode with very low currents (~10-15 μA per bunch).


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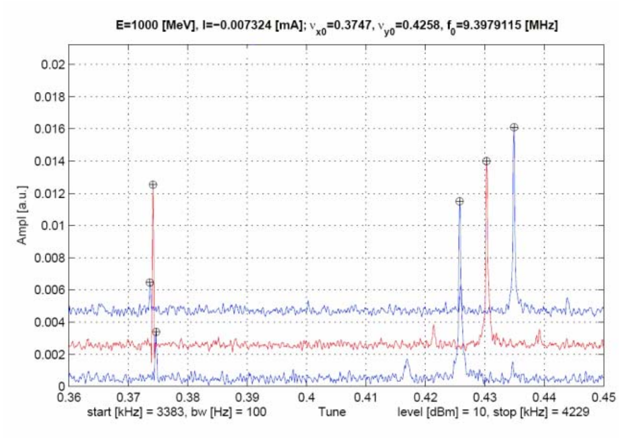


Figure 6. Example of the betatron tune measurements.

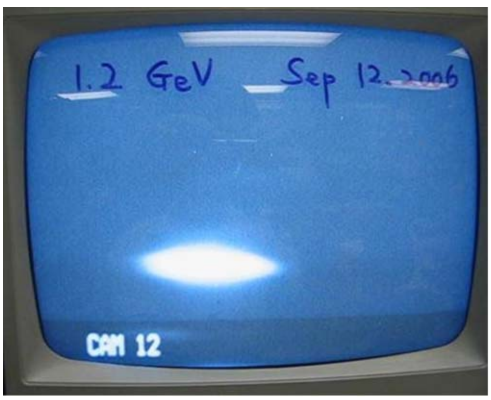


Figure 7. Beam image from SR view port.

### *Screens and CCD's*

Twelve insertable screens designed at DFELL (two in the Linac to Booster line (LTB), five in the booster ring, and five in the Booster to Ring (BTR) line) have fluorescent coating and in combination with CCD cameras provide us with reliable information about beam transverse profile and position.

### *Dissector*

To monitor a temporal structure of bunch a dissector with 20 psec resolution has been installed. This device utilizes an image dissector tube (LI-602M) Most detailed experience with dissector one can find at [7].

Control electronics and high voltage supply system were designed and developed in collaboration with Budker Institute of Nuclear Physics (BINP), Russia. Similar system employed for DFEEL storage ring few years ago.

## CONCLUSION

The accelerator instrumentation proved to be sufficient for troubleshooting of any kind. It allowed us to successfully commission injection and energy ramping in the booster and further extraction into the storage ring. We plan further implementation of the available diagnostic data into the EPICS control system. We are also going to realize temporal measurements of electron bunch using our dissector.

## REFERENCES

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