Upgraded Bunch length monitoring system for CEBAF

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Abstract

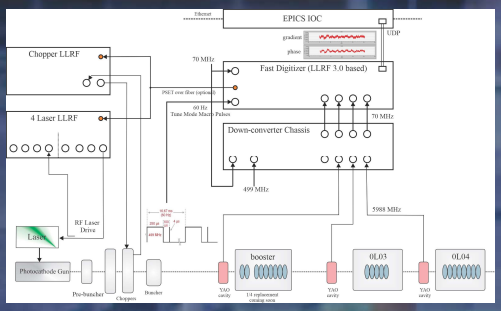
The CEBAF accelerator is a 12 GeV recirculating electron machine. The existing bunch length monitoring system in the injector section was designed and installed more than thirty years ago. This system measures the beam induced signals from three 5.988 GHz cavities (Yao cavity) in the injector. Phase signal from the measurement is compared to a reference signal using a double balanced mixer/phase detector. The data are acquired using a Computer Automated Measurement and Control (CAMAC) system for bunch length analysis and optimization. The existing system can only measure one of these signals at a time. Upgraded system has three RF receivers to measure signals from all three cavities simultaneously. This system also has FPGA based DAQ which acquires and displays the phase information synchronous with the pulsed beam

ARCHITECTURE

1. RF receiver chassis
2. FPGA based Data acquisition
3. UDP over Ethernet and EPICS
4. Bunch length measurement and Analysis

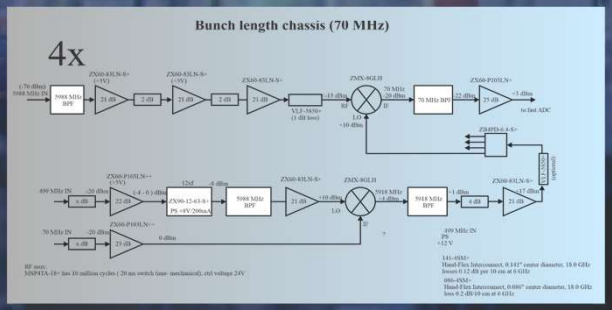
CEBAF Injector RF

The injector RF systems that interface with the bunch length system are a four laser chassis which provides the RF signal (250/500 MHz) to different lasers and chopper LLRF controlling chopper cavities. The bunch-length measurement method used at CEBAF was first successfully tested by C.G.Yao[1][2]. The method Yao developed measures the charge distribution along the phase within the bunch by detecting a phase shift of fields induced by the series sub-bunches in a cavity while sweeping the phase of the chopper system with respect to the rest of the injector[1].



RF receiver chassis

RF receiver chassis uses 499 MHz and 70 MHz reference from CEBAF to generate the LO (5918 MHz) for down conversion of the 5988 MHz signal from the Yao cavity. This chassis can have up to 4 such channels. This chassis produces IF signal at 70 MHz for digitization and signal processing

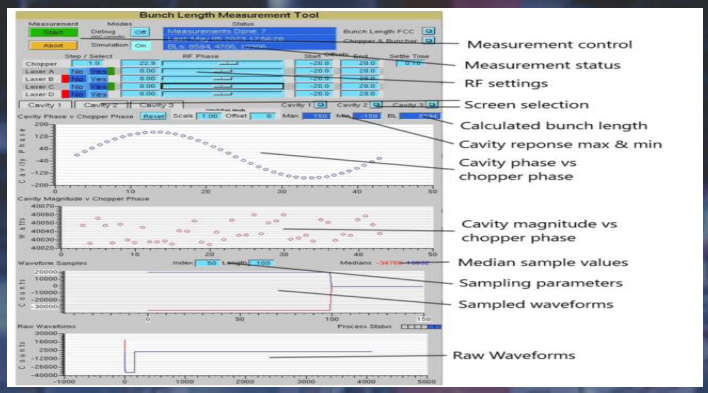


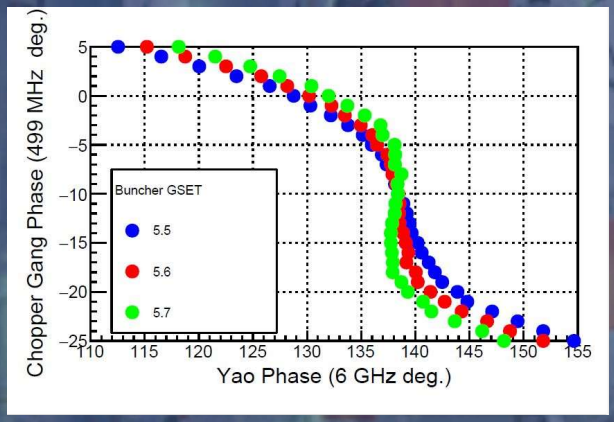
FPGA based Data Acquisition

FPGA based DAQ consists of two modules. A digitizer which receives the 70 MHz IF signals from the RF receiver chassis and an FPGA board which processes these signals to generate Amplitude and Phase. This system can simultaneously acquire data from four receivers. This data are synchronous with a beam sync signal. This system used UDP to communicate with EPICS.

MEASUREMENTS

Data is transferred from the FPGA into EPICS waveforms via UDP. Waveforms are critical for this application as the pulse beam is only 250 us, and the data are sampled at 1 us rate. An EPICS IOC application extracts the phase information from the plateau section of the measurement. It achieves this by varying the chopper gang phase while acquiring Yao cavity phase data for the measurement. Measurements can be taken from three Yao cavities simultaneously. The data are displayed in real time and also stored for further analysis and optimization.





Here are results for three measurements from the new bunch length system using the first Yao cavity located in front of the booster (see system overview diagram). The bunch length plot of chopper gang phase vs. Yao cavity phase approximates the longitudinal energy vs. time phase space with chopper gang phase representing beam energy and the detected arrival phase at the Yao cavity representing time [3]. The goal of this set of measurements is to find the buncher GSET to longitudinally focus (upright orientation in phase space) the beam at the Yao cavity. The buncher cavity, operated at zero-crossing (midpoint between minimum and maximum energy gain), is located between the chopper system and the Yao cavity (see system overview diagram). From these measurements one can see that the tilt of the phase space changes with buncher GSET, and the GSET to produce a longitudinally focused beam is between 5.6 and 5.7.

CONCLUSION

Existing bunch length measurement system which installed 30 years ago system has been upgraded with new RF downconverter and FPGA based data acquisition systems. It has been installed and successfully tested with the pulsed beam for bunch length measurements. This new system serves the purpose of acquiring multiple signals simultaneously and also makes it easier to maintain the system for many years to come. The new system has faster measurement times and reproducible measurement results. More testing and analysis is needed for optimizing the bunch length and this process is in progress.

References

1. THE CEBAF INJECTOR RF DISTRIBUTION AND BUNCH-LENGTH MEASUREMENT SYSTEM. R.Abbott et al, LINAC 1992, Ottawa ON CANADA
2. C. G. Yao, A New Scheme For Measuring The Length Of Very Short Bunches At CEBAF, Accelerator Instrumentation Conference (Conference Proceedings),September 1990
3. G.A. Krafft, Status of the Continuous Electron Beam Accelerator Facility, LINAC 1994, Tsukuba, Japan.

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