BEAM INSTRUMENTATION FOR KEK ERL TEST FACILITY

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Abstract

A test facility to establish the functions of ERL have been planned in the KEK. Designs and developments of beam instrumentation for the ERL test facility has started under the collaboration of several laboratories in Japan. To examine the beam response from the beam monitor devices using a short-bunch length beam, we have constructed a test beam line near the injection point of KEK-PF. Present status of the design and the development of beam instrumentation are descried.

INTRODUCTION

Synchrotron light from the Energy Recovery Linac (ERL) has so many outstanding features compared to ordinary light source, especially with its extremely low emittance and the possibility of ultra short bunch length. The KEK is planning to construct a hard X-ray ERL facility with arc energy of around 5 GeV under Japanese ERL collaboration, for the fourth generation light source[1,2]. However, there exist many key components such as DC photocathode gun, 1.3 GHz drive laser, super-conducting accelerating cavities including cryomodules and cryosystems, to be established before the staring the construction of full-scale facility. The beam instrumentation is also very important.

A construction of test facility with arc energy of around 60MeV to 200MeV is planned to perform R&D works and beam studies [3]. With this test facility, we will identify the critical components under beam operations, generation and acceleration of the ultra-low emittance beam, and/or short bunch length beam. Commissioning of the test facility will also help to understand the accelerator physics issues. The design parameters of the test ERL accelerator are listed in Table.1

Table 1 Main parameter of KEK ERL test accelerator

Parameters	
Injection Energy	5 MeV (10-15MeV)
Injector beam power	500kW (1MW)
Beam energy in arcs	~60MeV(160-200MeV)
SC cavities	9 cells x 4: single module
Normalized emittance	1 mm mrad (0.1mm mrad)
Beam Current	10mA – 100mA
RMS bunch length	1~2ps (0.1ps)

Figure 1 Arrangement plan of KEK ERL test facility in PS-East experimental hall.

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To design the necessary beam instrumentation for ERL accelerator, we have recently formed ERL beam instrumentation team under several laboratories in Japan. Our missions are 1) to develop the beam monitors for ERL and 2) to develop the control systems including femto-second timing technology. Figure 1 shows the arrangement plan of KEK-ERL test facility. In the early stage of commissioning, we will keep the long straight section just opposite site of the cavity section for the test port of beam instrumentation.

PRESENT STATUS OF DEVELOPMENT OF BEAM INSTRUMENTATAIONS

Test beam line for short beam at PF-BT

We have constructed a test beam line near the injection point of the KEK PF ring for the developments of beam instrumentation using a short pulsed beam from the linac of beam energy 2.5 GeV. By tuning R56 and T566 of the beam transport line, we will be able to obtain a very short beam with the bunch length of 0.17 mm (0.57 ps). Figure 2 shows a photograph of the constructed test beam line.

Figure 2 Test beam line (to the right) near PF injection point.

From autumn 2007 runs, we will start the simultaneous injection scheme between the KEKB HER ring and the KEK PF ring using a fast switching bending magnet[4]. We will be able to use the beam freely with the maximum repetition rate of around 25Hz for the test line.

SR related monitors

We have been developing the SR related monitors such as optical phase space monitor, bunch length monitor using intensity interferometry, input optics system with all reflective-optics for femto-second streak camera, and beam halo monitor by means of coronagraph [5]. An example of result of beam halo images obtained by coronagraph during single bunch operation of PF ring is shown in Fig. 3. We can see clearly beam halo of order of about $10^{-7}$of main beam.

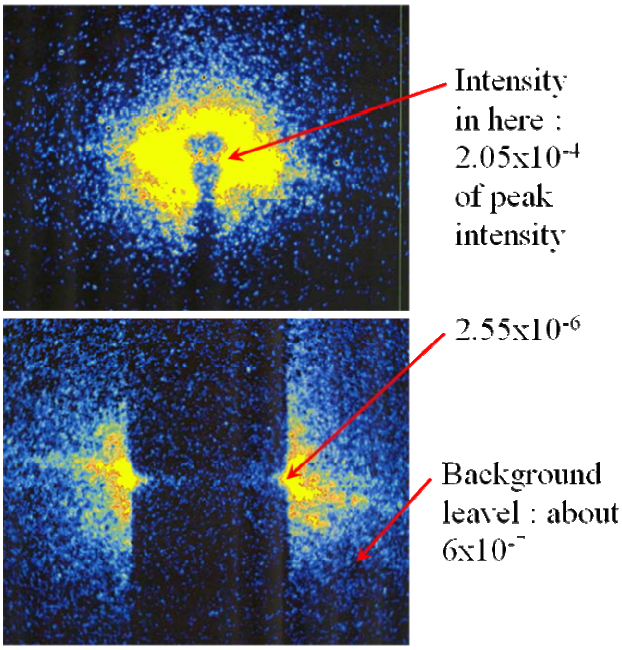

Figure 3 Observation of beam halo. Upper: near center (CCD exposure time of 3ms). Lower: far tail (exposure time 100ms).

Beam position monitors

In the acceleration section, two beams (beam in the acceleration and in the deceleration) may pass within very short time interval (~0.38ns). Since the two beam can naturally take different orbit, it is necessary to measure the two orbit simultaneously and independently. One idea is to develop a BPM electrode with very good time response, and gate the output with good signal isolation. To achieve very good time response, we have developed the glass-type sealed feedthrough with smaller relative permittivity (ε_r~4) than normal alumina-ceramic type (ε_r~10). Also we can reduce the beam response within 0.4ns by improving the button structure. A result of simulation using GdfidL is shown in Fig. 4. To investigate the performances of the feedthroughs, we fabricated several kinds of BPM electrodes with changing the seal materials (different permittivity) and seal structures. They will be installed in the test beam line at PF-BT to measure the beam responses.

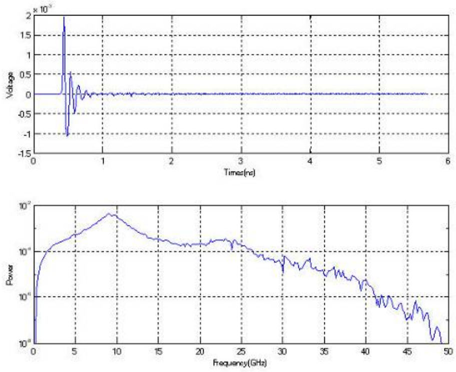

Figure 4 Simulated beam response using GdfidL of a glass-sealed BPM with its frequency response. The bunch length was 3mm in this case.

iGp for full-speed bunch-by-bunch position detection

We have been collaborating with SLAC and INFN-LNF to develop next generation feedback signal processor system under the support of US-Japan collaboration in High Energy Physics. As a first stage, we have developed a simple signal processor (iGp system)[6]. It consists of a fast ADC (MAX108), a fast and dense FPGA (Vertex2 XC2V6000) and a fast DAC (MAX5889) as shown in the block diagram of Fig. 5. A photograph is shown in Fig. 6.

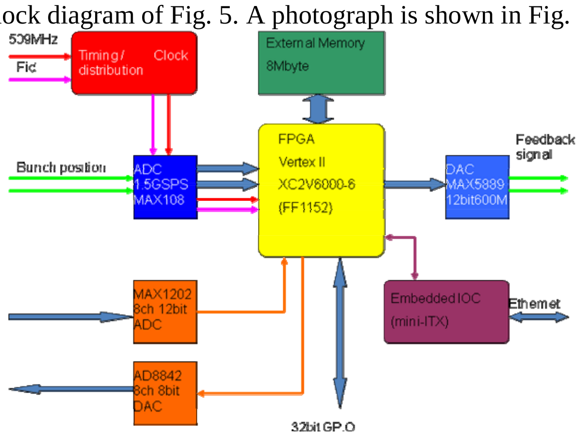

Figure 5 Block diagram of iGp feedback processor.

The KEKB iGp systems have been confirmed to work up to 560 MHz with simple FPGA firmware. This limitation comes from the scattering in delays of output timings of the FPGA to the high speed DAC. The ADC and input of FPGA (and memory) seems working with higher frequency. In fact, it is already confirmed that the test set of MAX104 (1GSPS) and Spartan-3 FPGA works up to 1GHz of master clock. We expect the present iGp system might be usable to record the bunch position with clock rate of 1.3GHz. Detailed study will be made soon.

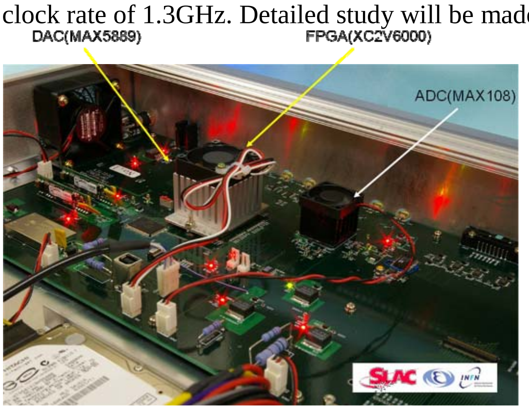

Figure 6 Photo of iGp feedback processor.

SUMMARY

We have started the design and the development of the beam instrumentation of KEK-ERL test facility under collaboration of several laboratories and institutes. Using the existing accelerators such as KEK-PF and KEKB, several instruments such as beam position monitors, SR related monitors, have already been studied. To examine the beam response of the instruments, we have constructed a test beam line for short pulse beam at the end of PF-BT. We plan to install BPMs, SR related monitors soon.

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