Developments and Upgrades of Linac

Accelerator Stabilization

A new method was invented to realize complete synchronization of the beam trigger and the linac RF, as described in the SPring-8 Research Frontiers 2000/2001. This system started to operate in 2001 and successfully reduced shot-by-shot fluctuation of the beam-energy center (Fig. 6).

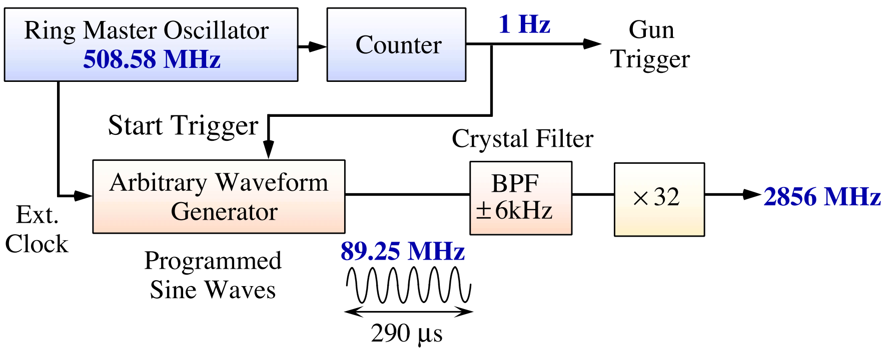

Fig. 6. Block diagram of synchronous RF reference generator.

Stability of a charged quantity of a beam bunch was examined as follows: An electron gun of the SPring-8 linac can generate a 250-ps beam. A buncher compresses almost all or a part of the 250-ps beam according to an RF phase where the beam is injected, then forms a single bunch. That is, beam timing defined in terms of the RF phase determines the beam charge. Figure 7 shows an example of beam current measurement in single-bunch acceleration. The current fluctuation observed when using the previous asynchronous system does not appear in the new synchronous system. Thus, this measurement clearly proves that the new 2856-MHz reference signal synchronizes with the beam trigger.

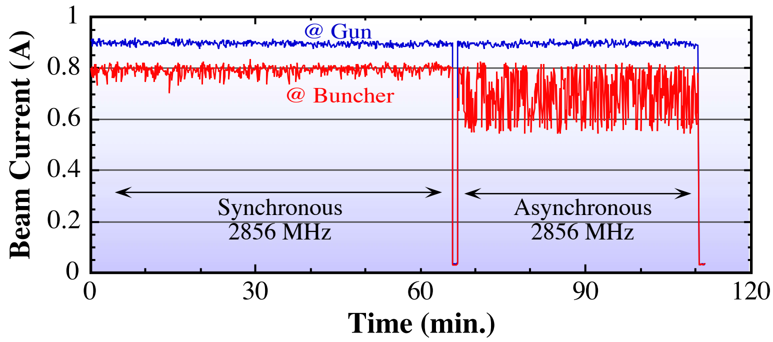

Fig. 7. Stability of single-bunched beam.

Reinforcement of Beam Monitor

A BPM system employing a strip-line type pickup and a logarithmic detection method has been developed and was installed in 2001. The system has a dynamic range wider than 45 dB and a maximum position resolution of a few tens of microns (2σ). A data acquisition system was required to process data of all the channels synchronizing with 60-Hz beam pulses to represent a one-pass beam orbit of the linac. Therefore, a shared-memory method was introduced for synchronized data acquisition by several VMEs, as shown in Fig. 8. The data acquisition system is almost completed and an automatic beam steering program has been made and is currently undergoing testing. The shared memory network will function soon.

To monitor the beam energy and energy distribution, a beam-penetration type thin foil screen monitor was introduced in the center of the ECS' chicane section where the energy dispersion is 1 m. The thin foil is a 12.5-μm thick Kapton film coated with 0.4-μm thick aluminum, and is strained on a frame. A CCD camera captures OTR (Optical Transition Radiation) emitted by beam irradiations on the screen. The captured beam images are analyzed to determine the beam energy and its spread. The 1-GeV beam has an absolute 90% emittance of 4×10^{-2} π mm•mrad and the screen increases it to 1.2×10^{-1} π mm•mrad. This emittance growth is negligible for injection into the booster synchrotron. Therefore, the screen is always inserted to monitor the beam energy during the beam injection.

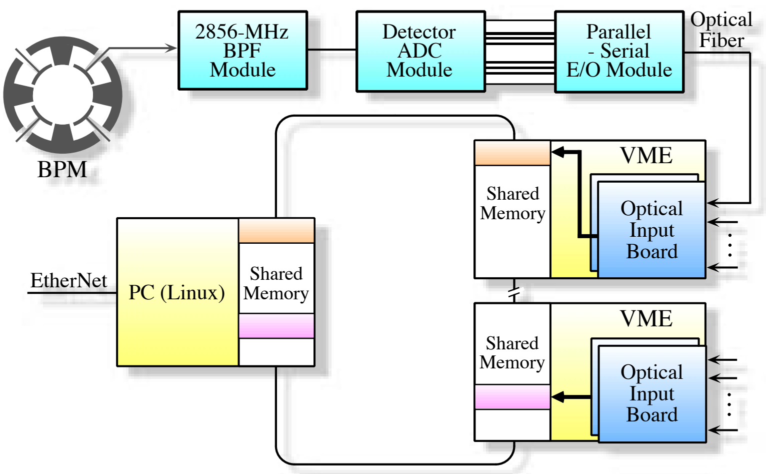

Fig. 8. Block diagram of BPM data acquisition system.

RF Gun Development

Since 1996 we have been developing a photocathode RF gun as a highly qualified electron beam source in a test facility at SPring-8. The quality of the laser beam irradiated on a cathode surface is essential for stabilizing the total system and generating a low-emittance electron beam. In particular, it needs higher pulse energy stability and improvements in the homogeneous spatial and temporal profiles of the UV-laser light source.

We shaped the laser spatial profiles with a microlens array. This microlens array is a collection of small hexagonal convex lenses with a pitch of 250 μm. The transmission of this optical array is about 80% in the ultraviolet region. It makes any shape of laser spatial profile possible, such as a Silk-hat (cylindrical flattop) with convex lens combinations, as shown in Fig. 9. The outskirts of quasi-flattop-shaped laser beam were cut through a pinhole with a diameter of 100 or 200 μm, stabilizing the energy and pointing stability of the UV-laser. This optical set-up made the experimental results reproducible. Consequently, it was possible to position the laser spot on the cathode surface accurately on an optimum beam axis, where the center axis of an RF gun cavity and the magnetic center axis of a beam focussing Helmholtz coils were aligned. As a result, we could obtain the minimum emittance value of 2π mm•mrad with a beam energy of 3.1 MeV, holding its charge to 0.1 nC/bunch.

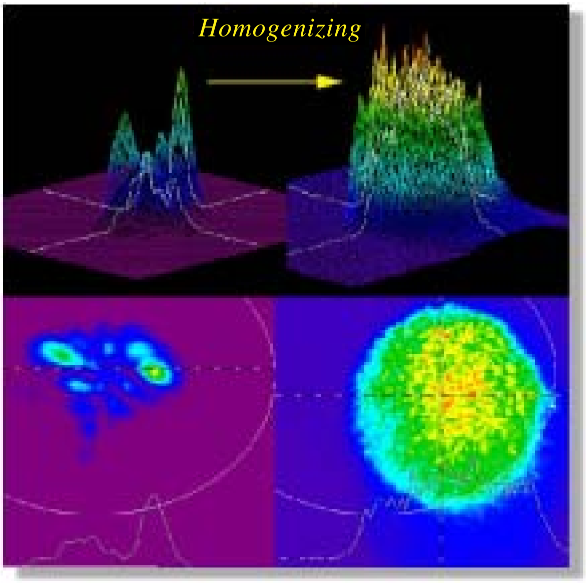

Fig. 9. Improvement of the laser spatial profile by a microlens array.

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