SINGLE-BUNCH INJECTION SYSTEM FOR THE LNLS BOOSTER INJECTOR

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Abstract

A system was developed at LNLS to perform bunch cleaning in the booster synchrotron injector to satisfy the requests for single-bunch runs either for time-resolved experiments or machine studies. This system eliminates all but one electron bunch through the excitation of a horizontal betatron resonance. In this process it is necessary to switch off the RF excitation signal for less than 2.10 ns ($1 / f_{RF}$) to obtain a single-bunch. This fast switching is achieved through the utilization of a double balanced mixer. The switched excitation signal is amplified and applied to a stripline kicker. A PECL timing card supplies the gating signal, synchronized to the f_{RF}, which (negatively) modulates the excitation carrier. A local processor card and an FPGA interfacing board provide the bunch cleaner with seamless integration to the storage ring control system, which controls the parameters of the process, namely: the carrier power and the fine gating time. The system performance and operational results are presented.

INTRODUCTION

The LNLS synchrotron light source [1] is composed of a 120-MeV linear accelerator, a 500-MeV booster synchrotron injector and a 1.37-GeV storage ring.

The RF frequency of both storage ring and booster is 476.066 MHz and the booster harmonic number is 54.

The electron gun produces 200 ns current pulses that fill the entire booster during the injection process at a 0.17 Hz rate. In each booster cycle, about 5 mA are injected in the storage ring, therefore, in the multi-bunch mode, a 250 mA accumulation usually takes five minutes.

We realized that producing the single-bunch mode by eliminating undesired bunches at the booster [2] would be easier and less costly than modifying the LINAC electron gun pulser.

SYSTEM DESCRIPTION

A DSP C6711' evaluation board is used to manage the system internal circuits and integrate it with the LNLS control system. A card based on a XILINX FPGA (Spartan family model XC2S50E) provides digital integration between the internal modules and DSP board.

In fact, the booster "bunch cleaner" or the "bunch killer" is one of the RF front-ends that the DSP-FPGA back-end controls in this instrument. There is another front-end that measures the storage ring filling-pattern (also reported in these proceedings).

An external RF generator (Fluke 6061A) provides the RF carrier signal that is applied directly to the double balanced mixer (DBM). The DBM employed was the Minicircuits rms-30.

A homemade PECL programmable divider was developed to produce a signal with 8.816 MHz, which is the booster revolution frequency. This card has also a programmable delay generator with 20 ps resolution and rms jitter inferior to 5 ps. This last feature is very useful to align the blanking on the carrier with the RF bucket, which contains the bunch to be preserved.

The fast DBM aperture pulse (800 ps FWHM) is obtained with a simple PECL digital circuit through the delay introduced by a transmission line. Figure 1 shows the block diagram of this circuit and the Figure 2 shows the block diagram of the instrument.

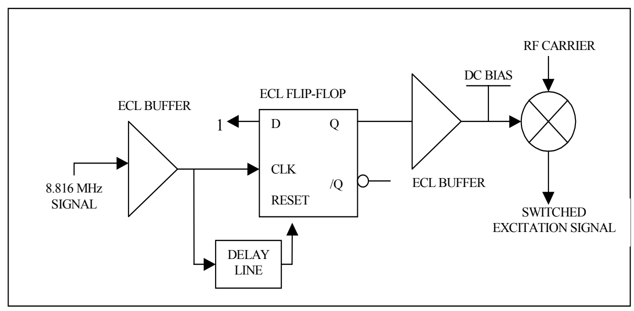

Figure 1 – Block diagram of the DBM aperture circuit

A programmable attenuator placed after the DBM is used to adjust the output power level and turns the excitation off when multi-bunch injection is desired.

PRACTICAL DETAILS

We had some previous knowledge about DBMs operated with fast pulses when we started to work on the single-bunch mode. It was a natural choice to use the DBM as a fast switch in order to save some development time.

After some empirical work to match the IF input of the DBM, the initial tests showed that it was possible to switch the DBM fast enough to preserve only one bunch.

Once the instrument was installed in the booster, we noticed that about 3 seconds of betatron excitation were necessary to kill the undesired bunches, so the duration of the injection cycles increased from 6 to 9 seconds.

In an attempt to obtain a shorter duration for the single-bunch injection cycles, the excitation power was increased from 1 W to 5 W. The result showed that the isolation of this DBM becomes the limiting factor at this power level. By increasing the excitation power, instead of decreasing the single-bunch purification time, we could

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observe that the main bunch preservation was negatively affected, therefore we decided to maintain the system operating with 1 W RF power amplifiers at the expense of the cycle time.

The bunches are spaced by 2.1 ns intervals, however, in order to preserve a single-bunch, fast pulses (800 ps) are necessary to switch the DBM. This is due the filter effect produced by the cables and devices, which are placed after the mixer. Figure 3 shows the signal after crossing the programmable attenuator and some meters of coaxial cable.

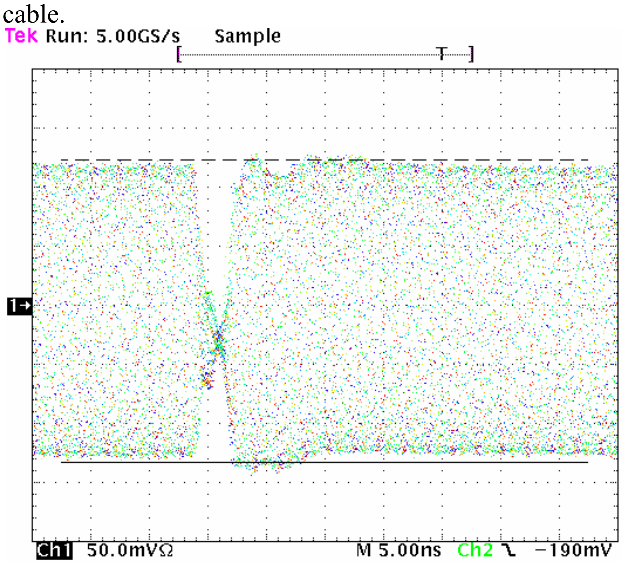

Figure 3 – Excitation signal after crossing the programmable attenuator and some meters of coaxial cable. The valley at this point is larger than 800 ps. (50 mV / division, 5 ns / division).

The undesired electron bunches are knocked out from the booster though excitation of a horizontal betatron resonance line. The lower sidebands measured in f_{RF} (476.066 MHz) are at 2.056 MHz (f_H) and 1.410 MHz (f_V), and are related to the horizontal and vertical tunes, respectively. The chosen excitation frequency (f_{EX}) is 474.010 MHz; $f_{EX} = f_{RF} - f_H$.

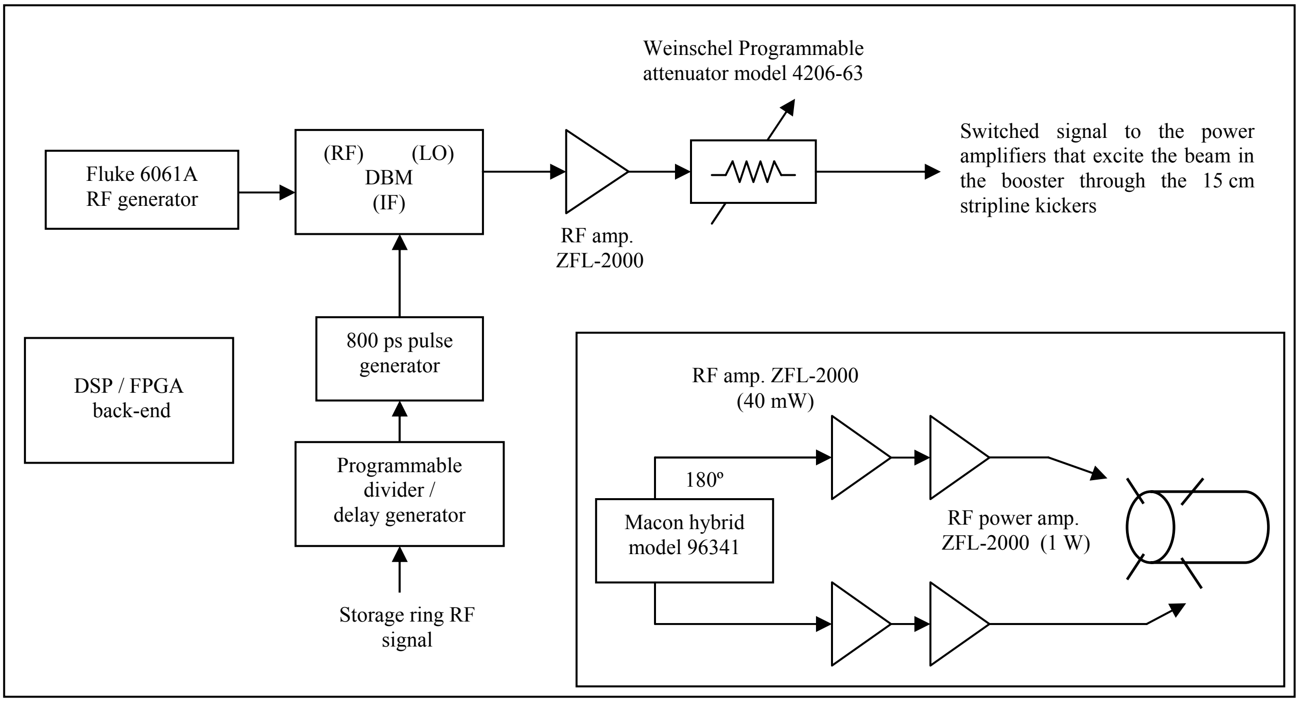

Figure 2: Block diagram of the bunch cleaner.

RESULTS

Figure 4 shows the signal from a stripline pick-up in the booster after about 3 seconds of resonant excitation. The revolution period of the booster is 113 ns.

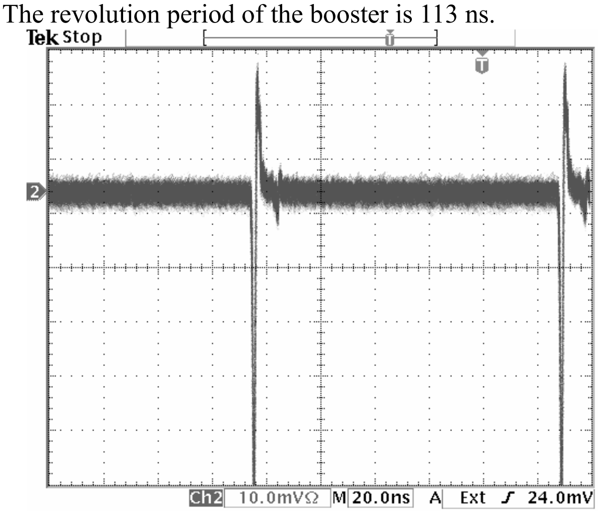

Figure 4 – Signal from a stripline pick-up in the booster 3 seconds after the beam had been injected. We determined that the small signal after the pulse is due to a reflection. (10 mV / division, 20 ns / division).

The duration of the single-bunch injection depends on the LINAC conditions. Typically it takes about one hour to reach 15 mA. We have not observed instabilities which showed us the upper limit of the single-bunch storage current. The limitation seems to be the lifetime, which is about 6 hours @ 10 mA / 1.37-GeV.

Figure 5 shows a typical signal from a stripline pick-up in the storage ring with a single-bunch beam stored.

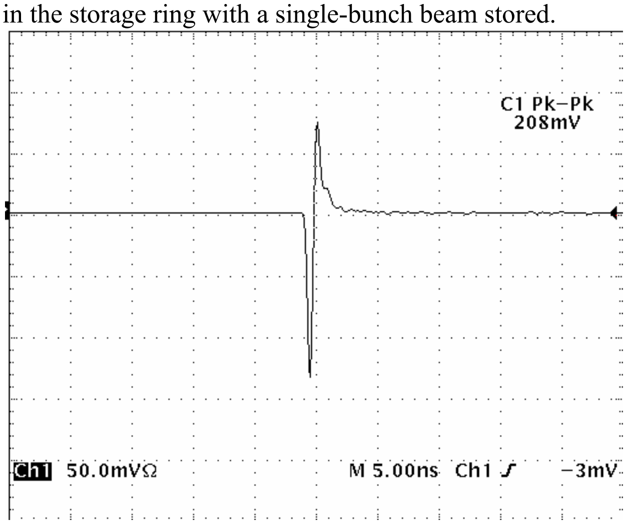

Figure 5 – Typical signal from a stripline pick-up in the storage ring. The accumulated current was about 4 mA. (50 mV / division, 5 ns / division).

The use of a DBM as a fast switch proved to be a good method to provide coarse cleaning in the booster injector, and electrical measurements such as the one shown above indicate a purity factor better than $2x10^3$ [3]. In order to improve the purity factor to the 10^5 – 10^6 range, a bunch fine cleaning system can be designed and installed in the storage ring. Probably this system will be based on the same principle: betatron resonant excitation, switched or not. The shift in the betatron frequency for bunches with different charges [4], enables either a fine cleaning in the storage ring at 500-MeV before the energy ramp or the maintenance of excitation on at 1.37-GeV during users' runs.

The single-bunch beam was provided for users for 2 weeks last March. Three different beam lines utilized synchrotron light [5] [6] [7], among them, we can mention a very innovative experiment using synchrotron excitation in a sample of ultra-cold atoms. In this experiment, neutral cesium atoms were spatially confined into a magneto-optical trap. The purity achieved was enough for all the users to perform their TOF (time of flight) spectrum based experiments.

CONCLUSIONS

The LNLS purification system was developed and installed in the booster synchrotron injector in a relatively short period of time (about 4 months). The results showed us that the purity factor achieved ($2x10^3$) could be improved by either using a fast switch with better isolation or with a single-bunch fine cleaning system in the storage ring. The objective of providing the users with single-bunch beams for TOF experiments was achieved successfully.

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