THE FEEDBACK SYSTEM FOR DAMPING COHERENT BETATRON AND SYNCHROTRON OSCILLATIONS OF ELECTRON BEAM AT DEDICATED SYNCHROTRON RADIATION SOURCE SIBERIA-2

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Abstract

In the article the bunch-by-bunch feedback system for damping coherent betatron and synchrotron oscillations of the electron beam which is realized at the present time at the synchrotron radiation source of the Kurchatov Institute is presented.

An installation of the new feedback system into the storage ring will allows to improve a quality of synchrotron radiation beams. In particular, with the help of the feedback system it's possible to increase a maximum stored beam current at the beam injection energy (450 MeV) and at the operation beam energy (2.5 GeV) the system will provides an additional electron beam spatial stabilization.

In the article a description of the new feedback system, principals of the operation and its technical characteristics are presented. Also, kickers used in the system, which design is of a special interest, are described.

INTRODUCTION

At the present time works on modernization of the synchrotron radiation source and improvement of the quality of synchrotron radiation beams are carried out at the storage ring Siberia-2. In particular, new radiation sources (superconducting and warm wigglers), new output channels of synchrotron radiation and experimental stations are established. In this connection requirements to the quality of photon and, therefore, electron beams will become tougher only.

Some of electron beam parameters at the storage ring SIBERIA-2 are presented in Table 1.

Table 1: Electron Beam Parameters at SIBERIA-2

Beam current, mA	1 - 200
Injection / operation beam energy, MeV	450 / 2500
Revolution frequency, MHz	2.4152
Beam emittance, nm·rad	18 - 98
Lifetime at 160 mA current, h	~ 20
Number of bunches	1 - 75
Bunch sizes, mm: σ_x, σ_z, σ_s	0.34, 0.059, 20.0

One of steps to improve qualities of the facility is to increase the stored beam current at the synchrotron radiation source. One of reasons limiting the current is the development of coupled-bunch instabilities of the electron beam, due to an interaction of the beam with high order modes of cavities, the environment (elements of the vacuum chamber, elements of the diagnostic system and etc.) or ions of the residual gas. An influence of collective instabilities on dynamic of the electron beam is particularly strong at the beam injection energy. Herewith, as a rule, there is a partial or complete loss of the beam current. At the operation beam energy the influence of collective instabilities on the beam is greatly weakened. But, nevertheless, instabilities are possible to cause the increasing of the effective beam emittance, and in some cases lead to the beam loss. For our facility it's most optimum to cure beam instabilities will be the development of the fast feedback system for damping of coherent electron beam oscillations.

BUNCH-BY-BUNCH FEEDBACK SYSTEM

The feedback system for damping of coherent betatron and synchrotron electron beam oscillations at the storage ring SIBERIA-2 is created on the basis of Libera Bunch-by-Bunch and Libera Bunch-by-Bunch Front End units, developed by the company Instrumentation Technologies, Slovenia.

The system architecture is standard. The schematic layout of the feedback system is shown in Fig. 1. The system consist of a pickup, hybrid junctions, three Libera Bunch-by-Bunch processing units (X-, Z- and S-plane), Libera Bunch-by-Bunch Front End unit, different splitters, 25 W (X- and Z-plane) and 100 W (S-plane) power amplifiers and three different kickers (X-, Z- and S-plane).

The Hybrid junctions and Libera Bunch-by-Bunch Front End pre-processing module are used for an amplitude and phase conversion of broadband signals received from pickup electrodes into two signals for the transverse feedback system and one for the longitudinal feedback system.

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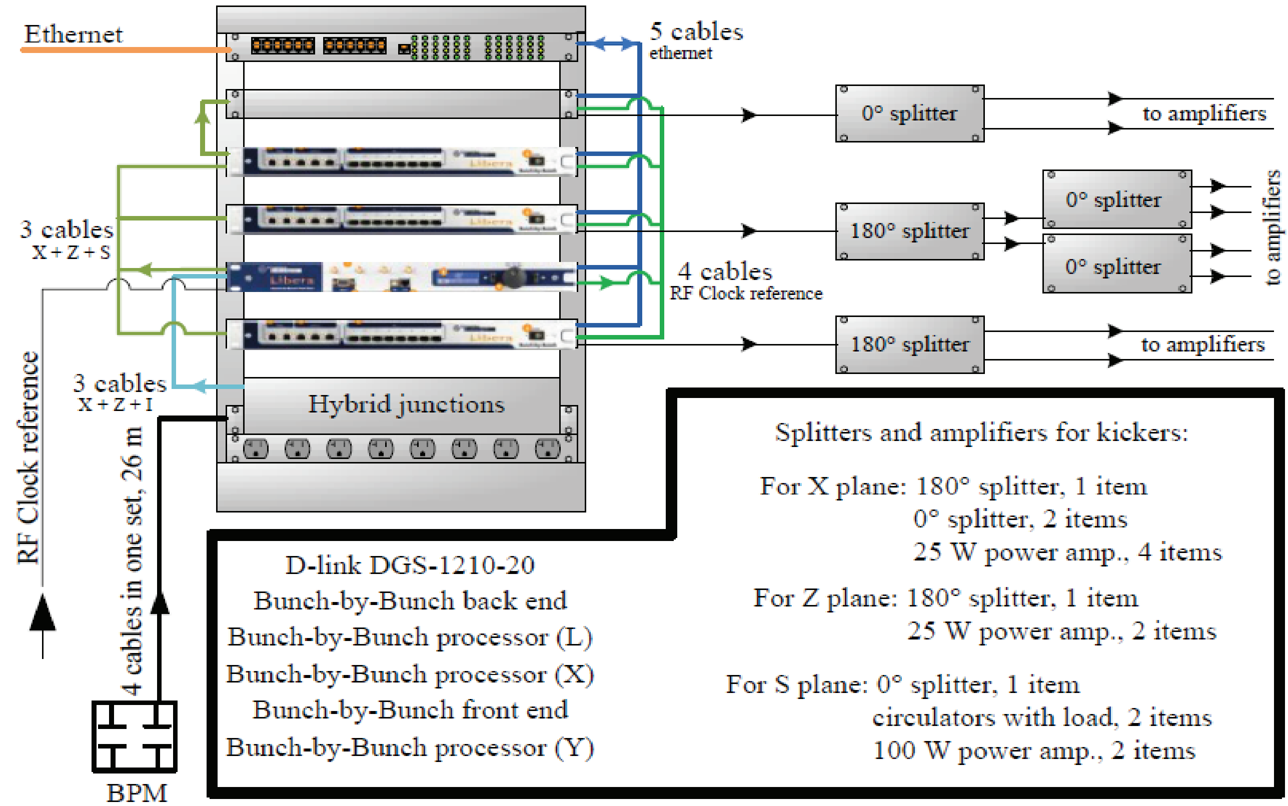

Figure 1: The schematic layout of the feedback system.

Libera Bunch-by-Bunch is a digital processing unit for damping coupled bunch instabilities. It samples data at sampling rate equal to RF frequency (181 MHz) of Siberia-2 by using fast 12 bit ADC. Samples are divided per bunch. Each bunch is filtered with 16 tap FIR filter. Additional processing, like gain, delay or phase shifting, can be applied. Due to restrictions on the speed of FPGA devices, processing is divided in 4 chains, where each chain processes one quarter of all bunches. Processed samples are converted to analog domain by usage of 14 bit 500 MHz DAC.

KICKERS

Kickers designed to the transverse feedback system, initially were used in another systems. Consequently, it was necessary to adapt kickers and the output part of the damping system. So, for both kickers the special RF-adapters from the custom-type jack to the standard N-type jack were developed. Thanks to this it became possible to connect amplifiers and loads to kickers by a simple standard method.

As the X-kicker the four electrode stripline-pickup, turned on 45°, is used. Such position of kicker electrodes was chosen to provide the unconstrained passing of the synchrotron radiation in a median plane of the kicker. Due to this we have to use two 0° splitters and two amplifiers.

Initially the Z-kicker was used in the pulse deflection system, thus to connect it to the feedback system two special RF-adapters were designed and fabricated (Fig. 2). The design feature of these adaptors is a presence of two teflon washers, which hold the heavy center conductor. This allowed to obtain necessary VSWR (losses of the power don't exceed 5% at the frequency range to 6 GHz).

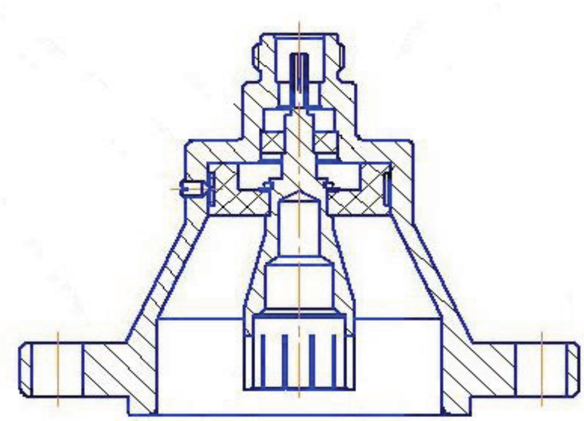

Figure 2: The RF-adapter for the Z-kicker.

The kicker with RF-adapters, used for the longitudinal feedback system, has the calculated parameters as the center frequency of 951.2 MHz, the bandwidth of 89 MHz, the quality factor of 10.7 and the shunt impedance of 1529 Ω. The design of the kicker is shown in Fig. 3. When developing our kicker we took the model used in the Duke storage ring as a basis [1]. Our kicker is fabricated from an aluminum alloy, to connect with the vacuum chamber bimetallic details are used in the design of flanges. Special for the longitudinal kicker the high-

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vacuum RF-adapter with the standard N-type jack was developed.

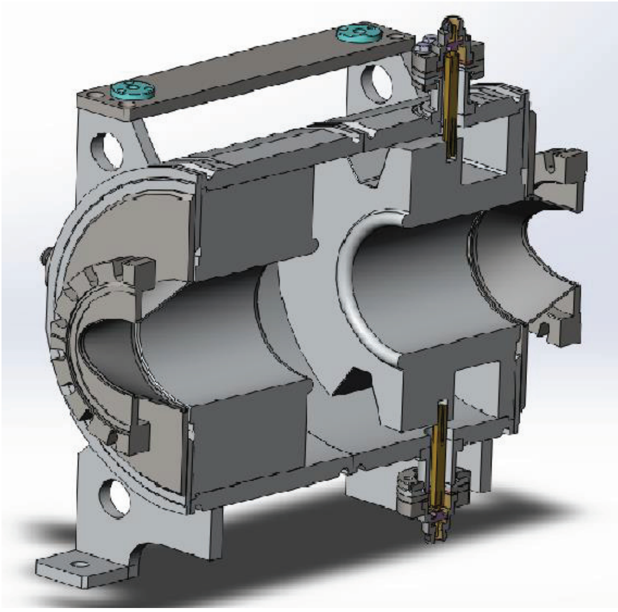

Figure 3: The kicker of the longitudinal feedback system.

Measurements of frequency parameters of the kicker were made after an installation on the storage ring. The kicker was connected according to the scheme, shown in Fig. 4. A broadband (to 6 GHz) spectrum analyzer was used to measurements, which signal was given on two entrances of the kicker through a resistive splitter and cables of the equal length.

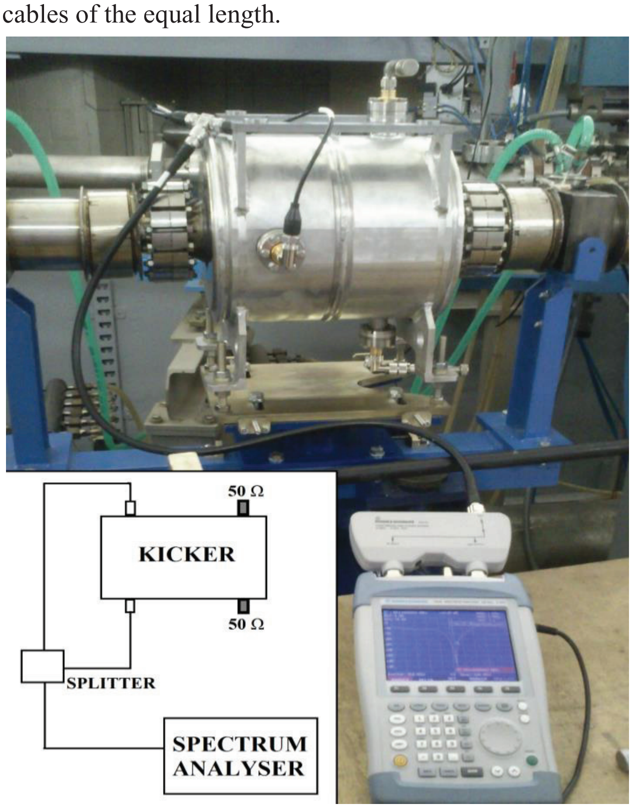

Figure 4: The scheme of the connection of the kicker to the spectrum analyzer.

The measured reflectivity is shown in Fig. 5. The operation frequency of the kicker is 954.67 MHz, the operation bandwidth is 104. 67 MHz.

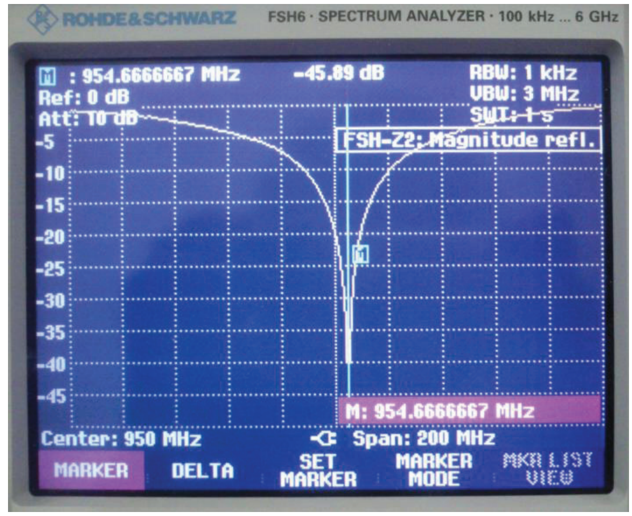

Figure 5: The measured reflectivity of the longitudinal kicker.

The received frequency parameters well correspond to calculation dates. Deviations of measured values are bound with errors brought by measuring inventory (the splitter and cables), a spectrum analyzer scanning and admissions on a kicker manufacture.

CONCLUSION

The pickup and kickers were established on the storage ring in June 2013. The connection of electronics to installed devices is planned in the near future. The introduction in the operation of the feedback system will allows to increase the maximum stored beam current at the storage ring Siberia-2, and also it will provides the additional electron beam stabilization during the work on users.

REFERENCES

[1] W.Z. Wu et al., "Development of a bunch-by-bunch longitudinal feedback system with a wide dynamic range for the HIGS facility", Nucl. Instr. and Meth. A, Vol 632, p. 32-42 (2011); www.elsevier.com

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