THE NEW OPTICAL DEVICE FOR TURN-TO TURN BEAM PROFILE MEASUREMENT

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Abstract

The electron beam quality determines the main synchrotron radiation characteristics therefore beam diagnostics is of great importance for synchrotron radiation source performance. The real-time processing of the electron beam parameters is a necessary procedure to optimize the key characteristics of the source using feedback loops.

The frequency of electron beam cycling in the synchrotron storage ring is about 1 MHz. In multi-bunch mode electrons are grouped into a series of bunches. The bunch repetition frequency depends on the total number of bunches and usually reaches hundreds of MHz. The actual problem is to study multi-bunch beam instabilities.

To solve this problem a turn-to-turn electron beam profile monitor is developed for Siberia-2 synchrotron light source. The linear avalanche photodiodes array is applied to imaging. The apparatus is able to record a transversal profile of selected bunches and analyze the dynamics of beam during 10^6 turns.

INTRODUCTION

The project of a new station which was launched in 2012 is now under way at the synchrotron radiation storage ring SIBERIA-2 at Kurchatov Institute [1], [2], Fig.1. The station with its measurement part uses SR from bending magnet and for the purpose of easy operation, control and alignment, is located outside the shielding wall of the storage ring.

The new station will meet modern requirements of beam parameters precise measurement, automatic monitoring and control of electron bunches parameters. Parameters of 2.5 GeV electron beam of SIBERIA-2 storage ring at the azimuth of station disposition are given in Table 1.

OPTICAL OBSERVATION STATION

Measurement Part

In Fig. 1 the layout of the optical measurement at SIBERIA-2 storage ring is presented. SR emitted from source point in bending magnet of the storage ring propagates further along the vacuum beam line and fallls on first cooled metallic mirror.

Table 1: Electron Beam Parameters at SIBERIA-2

Revolution frequency, MHz	2.4152
Bunch repetition rate, MHz	2.415 – 181.14
Bunch sizes, mm: σy, σx, σs	0.059, 0.45, 20
Bunch duration (FWHM), ns	0.16

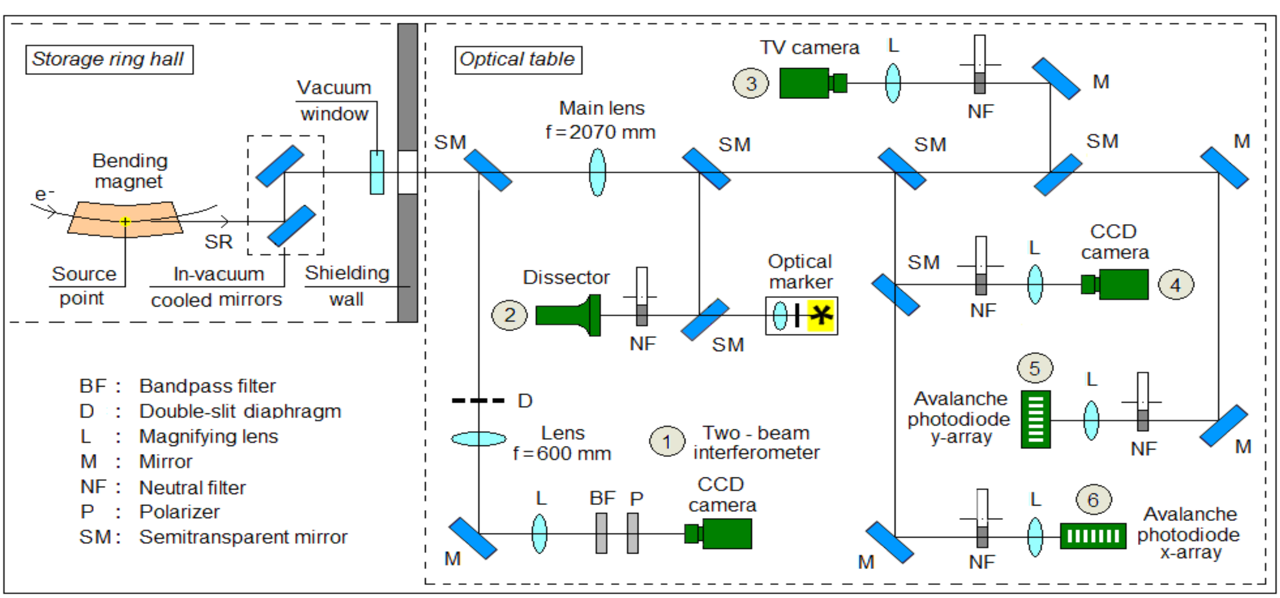

Figure 1: Layout of the optical observation station measurement part at SIBERIA-2 storage ring.

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The optical component of SR reflected from the cooled mirrors goes through the quartz vacuum window out of the vacuum chamber and further along the non-vacuum beam line which is 120 mm above the vacuum beam line to the optical measurement part. This measurement part consists of six diagnostic systems with different functions located on the optical table outside the storage ring shielding wall. By means of mirrors and semitransparent mirrors the light beam is distributed between the remaining diagnostic systems. The main lens and magnifying lenses form a beam image simultaneously on all the optical detectors of the systems. Remotely controlled neutral filters expand the dynamic range of the system. The detailed description of the systems is provided in [1].

Turn-by-turn beam transverse cross-section measurement systems (5, 6) serves the purpose of measuring y- and x- distribution of electron density within a chosen bunch, betatron and synchrotron oscillation frequency (defined by way of Fourier analysis of bunch dipole oscillations triggered by kick) as well as investigating y- or x- dynamics of beam shape in a chosen separatrix.

The diagnostics should provide a one-turn distribution during tens of thousands turns of beam. The systems comprise a measuring linear photo-detector based on 16 element avalanche photodiode array.

The previous version of similar diagnostics has been successfully developed at VEPP-4M electron-positron collider [3-5]. This installation operates at 2×2 bunches mode. We have an aim to design a diagnostics responding to the modern demands of the physics of accelerators, i.e. capable to operate at multi-bunch mode.

THE DEVICE DESCRIPTION

The device includes a AA16-0.13-9 SOJ22GL photodetector unit and signal recorder (Figure 2, 3). The photodetector unit is built on a photodiode strip consisting of 16 integrated avalanche photodiodes (PD1…PD16).

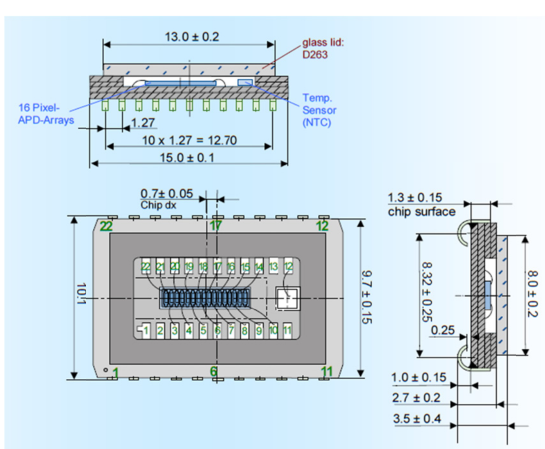

Figure 2: Package of AA16-0.13-9 APD linear array.

Dimensions of the single sensitive element are 648×208 μm and a pitch between two elements is 320 μm

It takes the radiation intensity distribution on the electron beam profile. Electric pulses from the photodiodes are fed to inputs of analog integrators. The integrator operates continuously without reset between two adjacent pulses. Varying continuously the integrator output level consistently takes the value of the every input pulse integral (Figure 4).

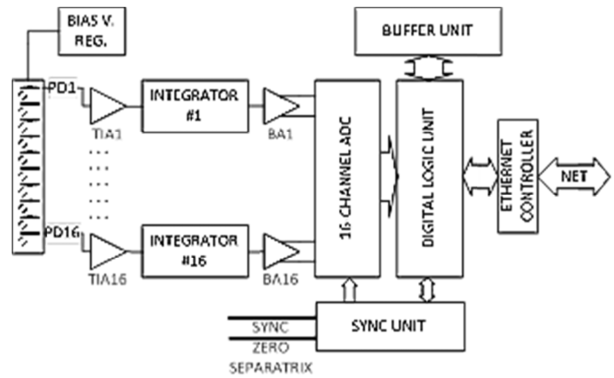

Figure 3: Functional diagram of the device.

This technique improves the integrator performance. The integrator is designed for input pulse repetition rate of 200 MHz. The 16-channel signal recorder fixes the integrals values, performs their 12-bit analog-to-digital conversion and buffering in the internal 3 Gb memory. The accumulated data is transferred via Ethernet 100BASE-T. The recorder also contains a synchronization unit consisting of a clock synthesizer with a phase-locked loop (PLL) and digital delay elements to adjust the clock phase of analog-to-digital converter (ADC). This unit synchronizes the recorder with a frequency of bunches and provides timing of the registration process to the zero separatrix. The device parameters are listed in the Table 2.

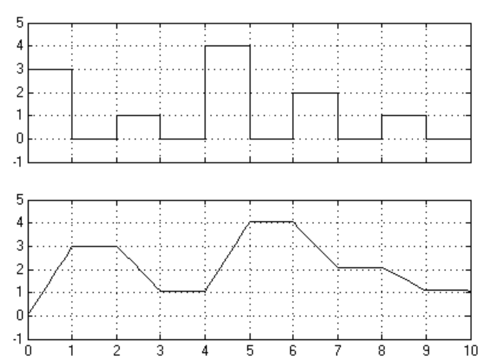

Figure 4: The integrator model in Simulink. Input signal (the 1st diagram) and output signal (the 2nd diagram).

Table 2: Device Parameters

Frame resolution, pixels	1x16
Frame rate, Mfps	50
Time resolution, ns	5
Dynamic range, bit	12
Memory, frames	15625000
Data transfer speed, Mbps	100

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Spectral range, nm	450…1050
Pixel size, um	320
Max quantum efficient, %	85
Max avalan. multiplication	100
Max power consumption, W	25
Supply voltage, V	220
Module size, mm	100x100x400

Multi-channel registration of each bunch is possible but requires expensive and technically complex solution (16-channel ADC with 200 MHz sampling rate). The compromise solution is to record every 5th bunch with the ability to select a specific sequence of bunches (16-channel 50 MHz ADC with serial outputs is used). Any sequence can be chosen by configuring the synchronization unit via device GUI (Fig. 4). Some pictures of hardware are presented in Fig. 5.

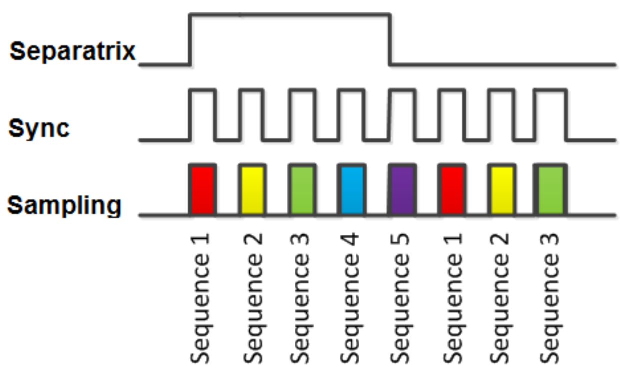

Figure 4: Different sequences.

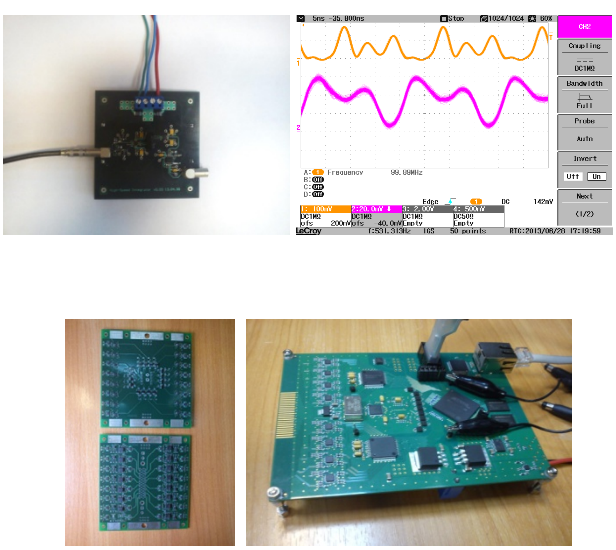

Figure 5: Photos of the electronics hardware and test of analog integrator.

CONCLUSION

The device design has been completed. The program shell developing is in progress. The prototype of the analog integrator has been tested. The next stage is the whole device prototyping and testing at Siberia-2. The device described must continuously implement 15625000 measurements of the vertical or horizontal electron beam profile at 16 points with a time resolution of 5 ns at 50 MHz rate. It will make possible to monitor single bunches and study multi-bunch beam instabilities.

We hope that at future the new optical observation station will meet the requirements of accelerator physics experiments and experiments with the use of SR related to the knowledge of exact parameters of separate electron bunches.

ASKNOWLEDGMENTS

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