DIAGNOSTICS OF ELECTRON BEAM FOR NOVOSIBIRSK HIGH-POWER FEL

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Abstract The diagnostics of 2-MeV electron injector for the Novosibirsk high average power FEL based on microtron-recuperator are described. The beam diagnostic system includes beam position monitors, peak and average beam current monitors, and optical diagnostics with the use of optical transition radiation screen. The parameters of this devices and the results of the measurements are presented. The scheme and possibilities of the future optical diagnostic station for microtron-recuperator are proposed and discussed.
Keywords FEL, electron injector, beam diagnostics.

I. Introduction

A 2-MeV electron injector for the Novosibirsk high-power FEL [1),2)] was built and commissioned in 1998. Its basic parameters and schematic drawing see in [3)]. The injector contains a set of beam diagnostics devices that provides stable operation and permits thorough adjustment of the machine.

II. Existing Beam Diagnostics Devices

a) Beam Position Monitor

A beam position monitor (BPM) contains four pickup-electrodes inside the vacuum chamber. Signals inducted on the electrodes by bunches passing through the BPM come to amplifiers with low-pass filters and then to sampling ADC. Digital signals are compared in the control computer and coordinates of beam is calculated. Accumulation is used to reduce random errors.

The BPM is able to detect small beam loss in the vacuum chamber before it. In this case scattered electrons strike pickup-electrodes and induce signal that differs in shape from one caused by electrons passing through (א). Taking samples in two appropriate moments of time one can detect beam loss.

b) Beam Direct Current Monitor

A beam direct current monitor (BDCM) is a combination of a Rogovsky coil and a DCCT in one module. First probe has small enough response time (~1 μs) while the latter provides necessary accuracy (long term drift ~5 μA, random error <1 μA). BDCM is used for three purposes: (i) as a precise monitor of beam average current; (ii) for interlocking - the difference of beam currents at the beginning and at the end of the machine ΔI is measured, and if $\int \Delta I \exp(-t/\tau)dt > tol$ the machine is locked; and (iii) for fine adjustment of the beamline to avoid any beam loss. The value *tol* in the locking condition is chosen 50τ μA·s, while τ is ~ 10 s. This assures no overheating caused by electron beam.

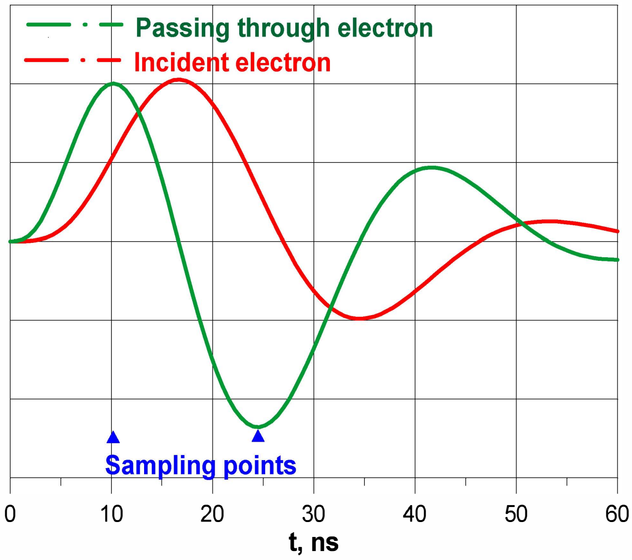

Fig. 1. Signals induced in pickup-electrodes by electrons passing through and ones incident upon electrodes. Sampling moments are marked.

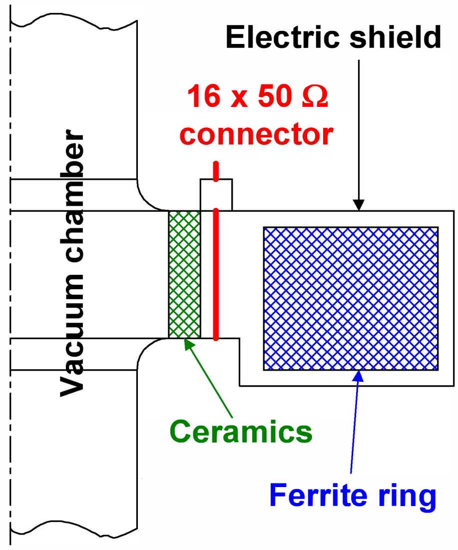

Fig. 2. Beam wide-band current monitor.

c) Beam Wide-Band Current Monitor

A beam wide-band current monitor (BWBM) is a loaded, magnetically insulated, and electrically shielded gap in the stainless steel vacuum chamber (ב). It measures current induced by electron bunches on the walls of conducting vacuum chamber. Note that its time resolution can't be better than $\sim R/c\beta\gamma$, where R is the radius of the vacuum chamber, c is the light velocity, $\beta = v/c$ is the normalized longitudinal velocity of electrons, and $\gamma = 1/\sqrt{1-\beta^2}$ is the relativistic factor. In our case this value is ~100 ps and ~35 ps for electron energies 300 keV and 1.5 MeV (kinetic) respectively. Real BWBM has time resolution ≈300 ps (half-amplitude).

d) Beam Measurement Module

A beam measurement module (BMM) is a part of vacuum chamber with an optical transition radiation (OTR) screen, a set of optical mirrors, and an optical vacuum window (ג). A steering magnet is used to bend electron beam to the OTR-screen. Light generated by electron beam on the OTR-screen is directed to a CCD-camera to analyze transverse structure of the beam or to an image dissector tube (IDT) [4] to measure its longitudinal structure. The shortest signal obtained from the IDT was of 150 ps duration (half-amplitude), so probably it means the IDT has time resolution comparable, but less than this value. Some details on measurement of transverse parameters of electron beam see in [3]. The OTR-screen can absorb up to 500 W average beam power. Sensitivity of the CCD-camera is quiet enough in this case, but multiple accumulation is necessary to improve signal-to-noise ratio while using the IDT. Typical results of longitudinal measurements and typical beam image are placed in Fig. 4 and Fig. 5 respectively.

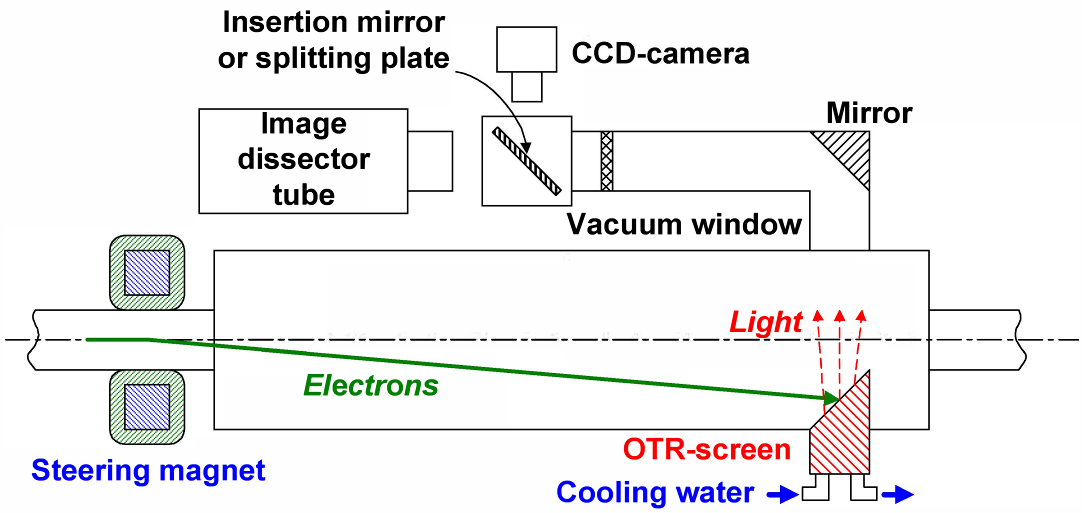

Fig. 3. Beam measurement module.

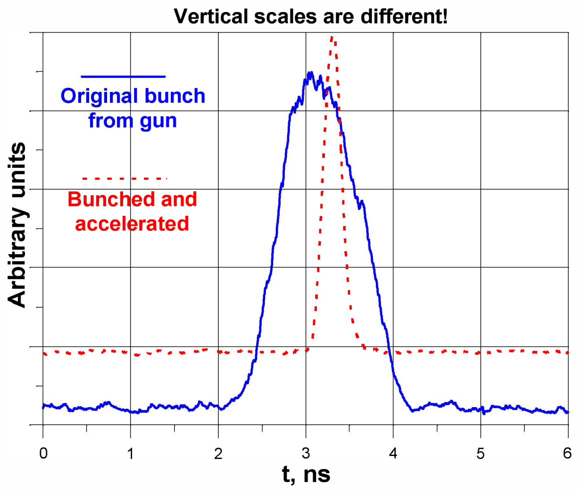

Fig. 4. Typical longitudinal structures of original and bunched beam.

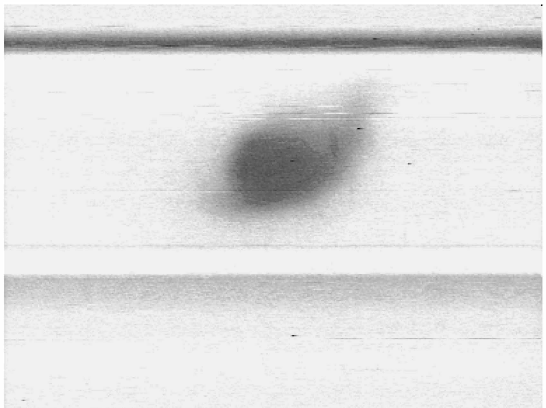

Fig. 5. Typical beam image (inverted) from the OTR-screen and the CCD-camera.

III. Devices to Be Installed in the First-Stage Machine

Some additional diagnostics is necessary to monitor electron beam in the first-stage accelerator-recuperator (AR) [2)] due to higher energy and shorter bunches in this machine.

a) Micro-Strip Line

A 50 Ω micro-strip line is to be installed in the backward track of AR inside a homogeneous vacuum chamber. It is a kind of pickup-electrode, but certainly with much less response time due to good matching at the terminals. Probably the only appropriate monitor for these short signals (down to 10 ps) is a sampling oscilloscope connected directly to the line with a cable as short as possible.

b) OTR and Luminescent Water Cooled Screens.

It is planned to install a set of OTR and luminescent water cooled screens behind each bending magnet so that beam strikes the screen when the magnet is off. It is much more convenient and simple than BMM. Only a screen itself at the edge of the vacuum chamber is needed to monitor electron beam. All the screens will have the same design.

c) Modified Beam Position Monitors

A set of BPM will be installed in the first-stage machine. The problem is that two different sets of bunches, accelerating and decelerating, with different positions come through the common track of the AR. It is necessary to monitor their positions independently. It seems to be possible as the gap between two consequent bunches is never less than ≈20 ns. As a sampling ADC is used it is possible to distinguish consequent bunches if the duration of the impulse response of the amplifier will be less than mentioned value. Now it is ~50 ns.

d) Streak-Camera

A streak-camera is another monitor of longitudinal structure of electron beam. Now the device having better then 0.1 ps resolution is being designed. It is planned to connect it to any OTR-screen.

VI. Summary

- The existing beam measurement system contains all the necessary devices to monitor longitudinal and transverse beam parameters and to provide successful operation of the injector.
- Some improvements are necessary to shorten impulse responses of longitudinal structure monitors.
- A set of new devices are being designed to install in the first-stage AR. This set covers all known requirements in beam monitoring for the first-stage machine.

References

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