CONTROL AND DIAGNOSTIC SYSTEM FOR NOVOSIBIRSK FEL RADIATION

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Abstract

The architecture and main capabilities of the control and diagnostic system for the Novosibirsk FEL coherent radiation are described. The software managing this system employs a client-server model. The software developed is able to work both in client and server modes. It can also control various equipment – from the FEL optical cavity mirrors to the local equipment of user stations. The mode of control program operation and controlled equipment are determined by external configuration files. Some results of the system operation are also presented.

INTRODUCTION

The first stage of the free electron laser (FEL) based on energy recovery linac is now working at Budker Institute of Nuclear Physics [1]. Generation of coherent radiation in the wavelength range of 120 to 200 microns has been achieved. This radiation is applied in a number of user and diagnostic experiments. To apply the radiation successfully, it is necessary both to know its main parameters and to transmit them to the user stations and FEL control panel. In addition, it is necessary to control some radiation parameters (wavelength) and to set up the system.

To solve these and some other tasks, a control system has been developed. It performs the following:

1. Measurement and diagnostics of the main radiation parameters, i.e. wavelength, power and transversal shape of radiation beam.
2. Control over some FEL components (optical cavity) as well as over the radiation wavelength.
3. Real-time transmission of the main radiation parameters to the computers of user stations.

Operation of this system is considered in more details below.

SYSTEM ARCHITECTURE

This system consists of a certain set of equipment (ADCs and controllers of step motors) and a program to manage this equipment. Besides, the program uses a remote control interface for a set of parameters of the energy recovery linac as well as reading some parameters necessary for users. Figure 1 presents a scheme of the entire system. The program can work in client and server modes. The program mode and configuration of equipment to control (step motor controllers, numbers of ADC channels, etc.) are set in external configuration files. Thus, applying various configuration files, the program can work in various modes and control different equipment.

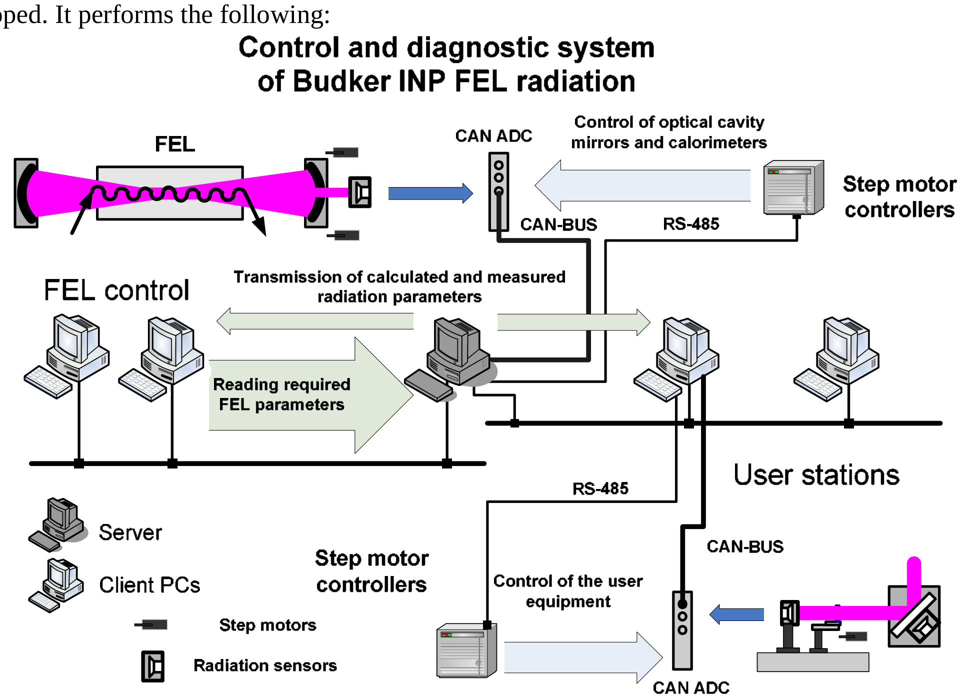

Figure 1: Scheme of the system

The server program runs only on one computer, which is linked with two local networks – a FEL control network and a network of user computers (see Fig.1). The server captures required parameters of FEL operation, transforms them, calculates needed values and yields them to both networks. The server also has means to control the radiation wavelength and the FEL optical cavity. These means are inaccessible for the client part of the program.

The client programs work both the computers controlling the FEL and those at the user stations. The client programs have a number of sub-programs to measure radiation characteristics that are inaccessible in the server part of the program.

CONTROL OVER THE PARAMETERS OF THE OPTICAL SYSTEM AND FEL RADIATION

FEL operation is frequently linked with the necessity of setting up separate components of the optical system. For instance, it is necessary to periodically adjust the position of the mirrors of the optical cavity as to the maximum of extracted radiation with the help of step motors. Sometimes it is also necessary to measure radiation power in a cavity with the help of calorimeters. Since these parameters are linked with the FEL as a whole, the system has been developed in such way that they could be controlled only from one computer, the server program is running on, and they would be inaccessible for other client programs. The configuration files of the server program contain information about the step motors connected to the mirrors of cavity and scrappers as well as information about the ADC channels intended for radiation measurement in several places – immediately at the cavity output (see Fig.1) and at the accelerator hall output. Control over all these parameters makes it possible to set up different operational modes of the FEL optical system and work with them.

As is known, the main merit of FEL is the possibility of rapid re-tuning of radiation wavelength. That is why scanning over the radiation wavelength is another radiation control function of the server. The FEL radiation wavelength dependence is expressed by the following formula:

$$\lambda = \frac{d}{2\gamma^2}\left(1+\frac{k^2}{2}\right),$$

where

λ is the radiation wavelength;

d is the period of undulator;

γ is the electrons' relativistic factor;

k is the undulator parameter, $k = k_0 \cdot I$,

where I is the current in the windings of the undulator and k_0 is the coefficient of proportionality.

The best way to rapidly re-tune radiation wavelength is through varying undulator current. Undulator current is managed from the control program for the magnetic system, so current value variation has to be realized via the option of magnetic system remote control with the Epics Channel Access protocol [2]. A scheme of scanning cycle is presented in Fig.2. The server organizes a cycle of sequential variation of undulator current within set limits and with a given step. The program sends client requests for undulator current adjustment to the server of the control program for the magnetic system, waits for 3 seconds (for the field to reach the steady state) and then reads the indications of radiation sensors. In addition, in order to compensate the possible influence of undulator field variation on the beam path, requests for adjustment of some other elements of the magnetic system are sent (see Fig.2). The total (incident) power of radiation and power of radiation absorbed in a sample or transmitted radiation are measured in the course of retuning cycle. The desired spectrum is obtained after normalization of the obtained dependence of the second value on the undulator current as to the first value (the total power), since the total power can vary a little during the measurement cycle. By now, the maximal range of continuous scanning is 120 to 150 microns, while the total range of radiation wavelength is 120 to 230 microns.

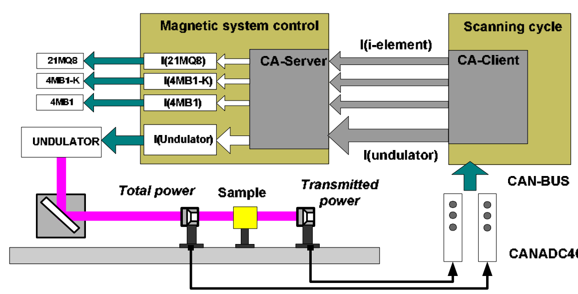

Figure 2: Cycle of scanning over the radiation wavelength.

MEASUREMENT OF MAIN PARAMETERS OF RADIATION

For experiments with FEL radiation it is necessary to know its main parameters, i.e. the radiation wavelength, radiation beam shape and its power. Since these parameters can vary with time, it is necessary to measure them periodically. Most of these measurements are done at a specially-created diagnostic station. In the system being described, these functions are realized as a set of sub-programs, which are only accessible in the client part of program. The following have been done by now:

1. Radiation wavelength measurement with the help of Fabri-Perot interferometer.
2. Radiation power measurement with the help of sapphire calorimeter.
3. Measurement of the transversal distribution of radiation beam power via two-coordinate scanning.

Radiation wavelength has been measured via a cycle of scanning over the angles of rotation of Fabri-Perot etalon [3] relative to the incident radiation beam. In the course of this cycle, the program displays a graph of radiation intensity vs. this angle. A typical plot is shown in fig.3

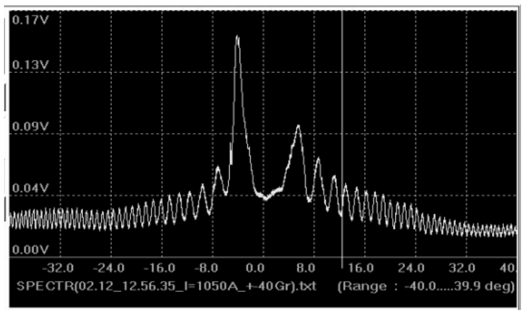

Figure 3: Radiation wavelength measurement with the help of Fabri-Perot interferometer

The radiation wavelength is calculated from the positions of maximums in the graph, by the following formula:

$$\lambda = \frac{2d}{n}\left(\cos\theta_1 - \cos\theta_n\right)$$

where:
λ is the radiation wavelength to measure;
d is the distance between the lattices;
θ_1 and θ_n are the rotation angles corresponding to the 1st and nth maximums.

It can be seen from the formula that the accuracy of radiation wavelength determination is in proportion to the ***n***, the number of the last maximum, or to the maximal rotation angle. That is why the cycle is organized over a maximal possible range of angles.

Transversal beam distribution was measured with the help of a two-row array of piroelectric radiation detectors, installed in the path of the incident FEL radiation. The array is connected with a shifter, which moves in a direction normal to the line of detectors. In the course of measurement the program organizes a cycle over the coordinate of line shift. All detectors in the line are inquired between the steps of this cycle. As a result, radiation power on a rectangular area of scanning gets measured. This area covers the entire radiation beam and amounts to about 15x20 cm. The spatial measurement resolution equals the distance between adjacent detectors and is less than 1 cm in one coordinate and about 4 mm in the other. Fig. 4 presents a graph of the picked-up distribution of radiation power.

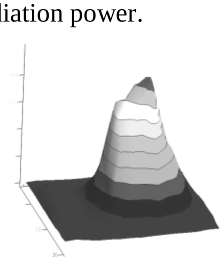

Figure 4: Transversal distirbution of power in the radaition beam.

TRANSMISSION OF MAIN PARAMETERS OF RADIATION TO THE USERS

For experimental work with radiation, a user station needs real-time information on radiation parameters – wavelength and power – as well as on the main parameters of the accelerator – frequency and energy of the beam and current of the undulator. In this system, this information is transmitted from the program working in the server configuration to programs running in the client mode. The Epics Channel Access protocol is used as the communications protocol. A scheme of this interaction is shown in Fig.1. The server program gets main parameters of FEL operation from other control systems of the FEL. Then the program computes a theoretical wavelength of radiation from these parameters. Then the Channel Access Server specifies this wavelength and some other of main FEL parameters under other names, making them accessible for reading by clients. Besides, the computer the server is running on is connected to an ADC on which measurements of radiation are terminated. These values are also specified by the server and are accessible for all client programs.

As it is shown in the fig. 1, the computer the server is running on is connected to two local networks – a control network for the FEL and a network of user computers. As a result, all information yielded by the server program is accessible both on control computers and on the user stations. In any of its configurations (server or client), the program has means for displaying these values in real time. Besides, it is able to write the history of all parameter values for the last working session on a hard disc, which can be useful at long-term experiments since radiation power can vary during FEL operation.

CONCLUSION

This system is now used in FEL operation. Capabilities of the system allow one both to control FEL radiation and carry out experiments on measurement of its characteristics. Different configurations of program work make it possible both to transmit and receive main parameters of system operation as well as to control different devices, e.g. the mirrors of the optical cavity and equipment at the user stations.

REFERENCES

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