THE MEASUREMENT AND MONITORING OF SPECTRUM AND WAVELENGTH OF COHERENT RADIATION AT NOVOSIBIRSK FREE ELECTRON LASER

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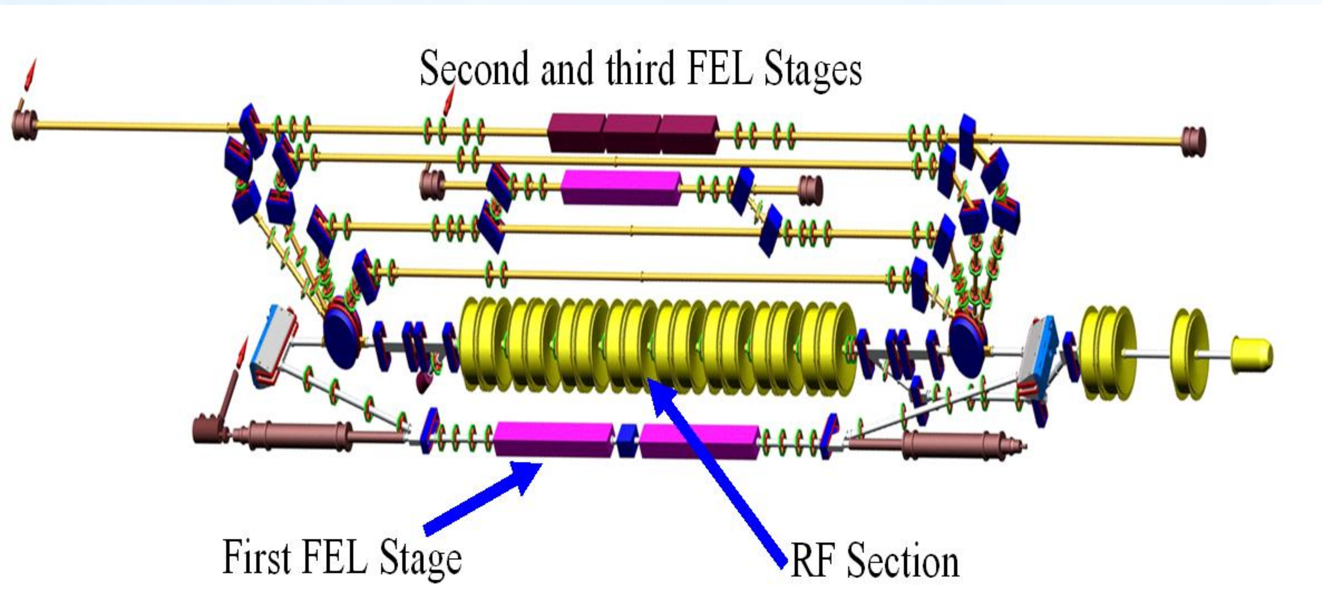
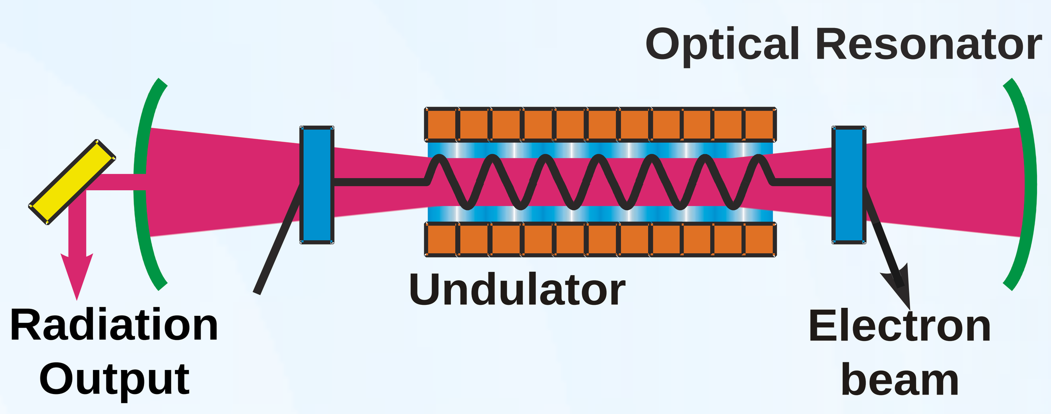
Abstract.
This paper describes in detail the architecture and capabilities of the system for measurement of the free electron laser (FEL) radiation spectrum. The measurements are performed with a monochromator and a step-motor with a radiation power sensor. The measurements result in the transmission of the curve of the radiation spectrum to the control computer. As this subsystem is fully integrated into the common FEL control system, the results of the Novosibirsk FEL measurements – the spectrum graph, average wavelength, and radiation power calculated – can be transmitted to any other computer in the FEL control local area network, as well as to computers of the user stations.



FEL radiation generation layout and wavelength formula



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

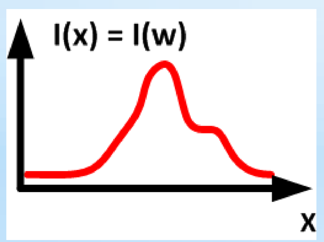
Where:
λ - is the radiation wavelength;
d - is the undulator period;
γ - is the relativistic factor of electrons;
K - is the undulator parameter :
, where I is the current in the coils of the electromagnetic undulator,
and is the constant of proportionality.

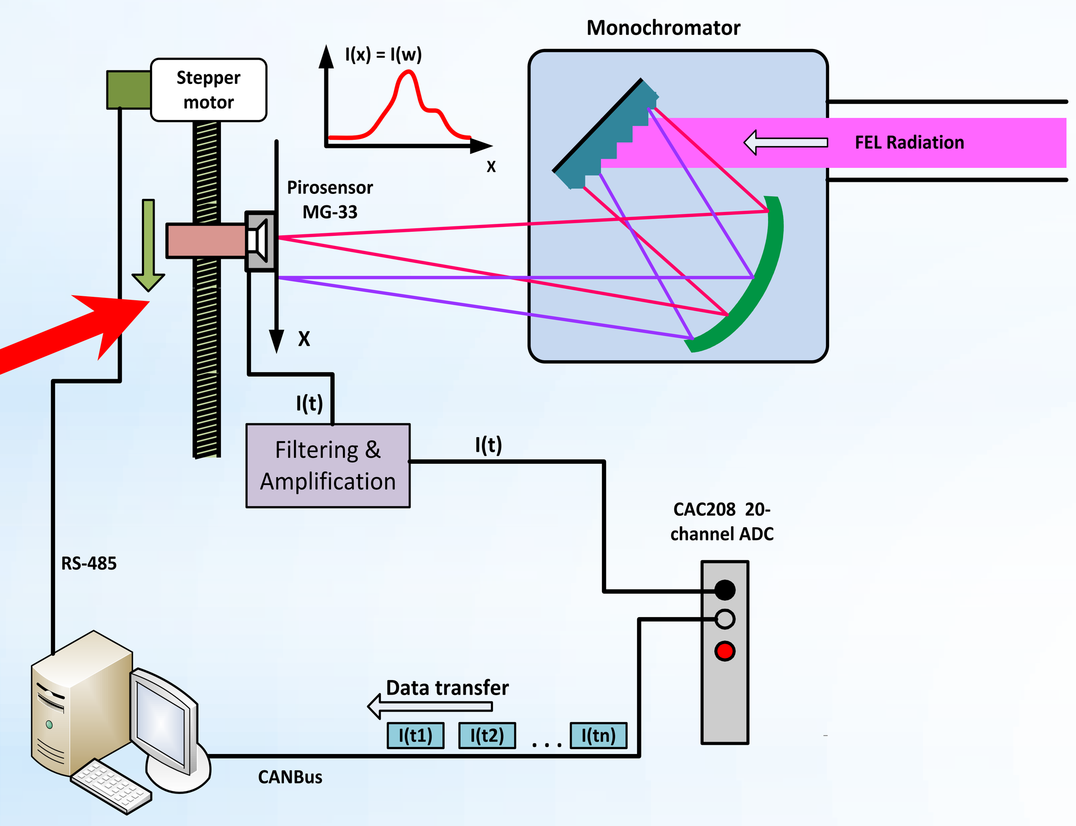
As seen from formula, wavelength of FEL radiation depends on several physical parameters of FEL, some of which(energy of electron beam) are difficult to measure in real-time mode during facility operation. Therefore, experimental measurements of FEL radiation spectrum, and following calculation of wavelength, power, and width of spectral line in real-time mode is necessary task for successful experiments with FEL radiation.

Spectrum measurement installation layout

For measuring spectrum of radiation, monochromator and radiation pirosensor MG-33, moved along monochromator output window is used

The radiation, outgoing monochromator, has the transversal distribution of intensity, corresponding to spectrum of input radiation :





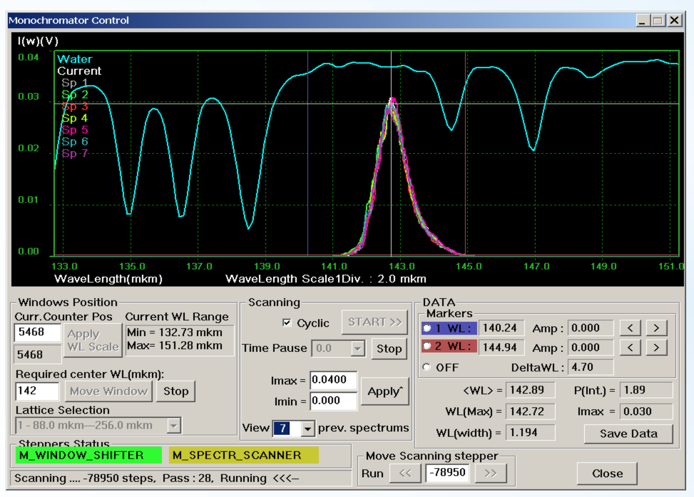
During measurement process pirosensor is moved across output window (**x** coordinate) by means of stepper motor, driven by controller, which in controller from IBM PC through RS-485 interface.

Spectrum measurement process

The process of measurement of FEL radiation spectrum is completely controlled from application, running on IBM PC.

The process of measurement is running continuously, during all FEL operation, and includes the following steps :

1. Moving support with pirosensor to leftmost position.
2. Sending command to ADC for continuous measurements of voltage, measured from pirosensor and send these measurements to control application.
3. Sending command to step-motor controller to move support from leftmost to rightmost position.
4. Acquiring measured data during step motor move the support, outputs it on plot of control application main window:



5. After support reaching the rightmost position, steps 2-4 are repeat, with only difference, that support changes the direction of movement (from rightmost to leftmost)

Wavelength scale calibration and processing of obtained spectrum

The wavelength step between neighboring ADC measurements is calculated by formula :

Where:
- wavelength step value between two ADC measurements ;
- wavelength step value per one millimeter across monochromantor output window;
- Time of one ADC measurement;
- speed of step motor movement(steps per second) :
- speed of stepper movement (steps of step-motor per required for shift on 1 mm of support)

The initial wavelength value is obtained from monochromator counter

After obtaining new spectrum waveform, application executes the following calculations:

1. Calculation of the total power of the FEL radiation from the spectrum curve with application of calibration coefficients.
2. Calculation of the “average” wavelength of the radiation using the following formula:

where is the wavelength corresponding to the *i*th element in the measured waveform, is the value of the *i*th element in the measured waveform, - minimum value of the radiation intensity in the waveform of the obtained spectrum.

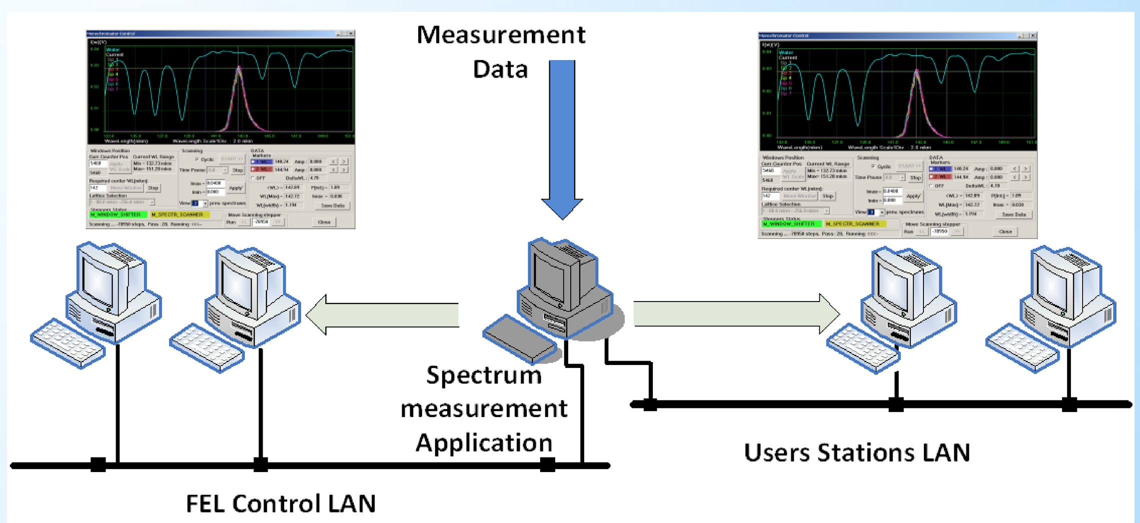
3. Calculation of the width of the spectral line of the radiation using the following formula:

Where is , the maximum value of the radiation intensity in the waveform of the obtained spectrum.

Transmission of FEL radiation spectrum and other parameters

Default communication protocol for whole FEL control system – EPICS Channel Access

Relative to Channel Access protocol, control application can run both in server and client modes.
Application instance, running on computer, directly controls monochromator, and measurement process, is running in server mode. Channel Access server is create and update PVs, representing all measured data values.
Application instances, running on other computers are running in client mode, and displaying data, obtained from corresponding PVs.
The user interface and graphical display of data are identical for both modes.



Values transmitted :
1. Spectrum waveform (vector PV)
2. Calculated total radiation power (scalar PV)
3. Average and maximum wavelength (scalar PV)
4. Spectral Line width (scalar PV)