# AUTOMATION OF THE LEBEDEV PHYSICAL INSTITUTE SYNCHROTRON TO THE ENERGY 1.3 GEV AS THE FIRST STAGE OF THE ACCELERATOR UPGRADE

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*Abstract*

Lebedev Physical Institute electron synchrotron to the maximum energy up to 1.3 GeV is under operation since the mid of seventieth. It is weak focusing machine consisting of four 90-degree sectors with the radii 4 m and four straight sections between them. The microtron with the energy 7 MeV and pulse current 50 mA is used for injection into the main accelerator. The average intensity of the synchrotron is 0.1 μA, repetition rate being equal to 50 Hz. Extracted electron beam and bremsstrahlung photons are used for the experiments in the field of nuclear and elementary particles physics. The most remarkable achievement at this machine is the discovery of creation and decay of η-mesic nuclei arising from reaction of photon of energy 1 GeV with carbon nuclei, having been made at the end of 90th. Up to now computer was not used for synchrotron parameters monitoring and control. We expect that automation might improve significantly the main parameters of the accelerator as well as much better time dependent stability of the electron energy and intensity. The paper is the extraction from conception design of accelerator automation project. We plan to use the concept and experience acquired during development of the Lebedev Physical Institute Radiation Complex. The basis of this concept is the flexible computer interface at the level of executable that allows build any desirable representation of acquired data as well as controls to affect the accelerator systems. Necessary upgrade of the existing computer code will be undertaken to meet additional requirements of distributed control and measurements.

## 1 INTRODUCTION

Lebedev Physical Institute synchrotron to the energy 1.3 GeV had been put into operation in the mid of seventies. This is weak focusing machine that had been build in Troitsk – nice town in the Moscow region. There were plans to use multi stage accelerator schema [1] with additional synchrotron but only the first stage of the whole project with ordinary injection has been realized. The first experiments after the synchrotron commissioning were carried out on the bremsstrahlung beams. Since the mid of 90$^{th}$ these were supplemented by the experiments with tagged photons on the electron beam extracted from the accelerator and transported to the experimental hall. The most remarkable achievement at the machine in the field of nuclear physics is the discovery of creation and decay of η-mesic nuclei in the reaction $\gamma + {}^{12}C \rightarrow p(n) +_{\eta} (A-1) \rightarrow \pi^{+} + n + X$ [2]. Although the work of the accelerator parameter computer monitoring and control was carried out it was not completed. The idea of automation of the accelerator had arisen again as the result of successful performance of computer controlled data acquisition at Lebedev Physical Institute Radiation Complex [3,4]. It appeared that the concept suggested and based on the idea of flexible computer interface is very fruitful for use computer technology in any activity connected with measurements and control. In this paper short description of Lebedev Physical Institute electron synchrotron to the energy 1.3 GeV is presented followed by accelerator computer control and monitoring conception discussion.

## 2 THE ELECTRON SYNCHROTRON

The schematic drawing of the electron synchrotron is given on fig. 1.

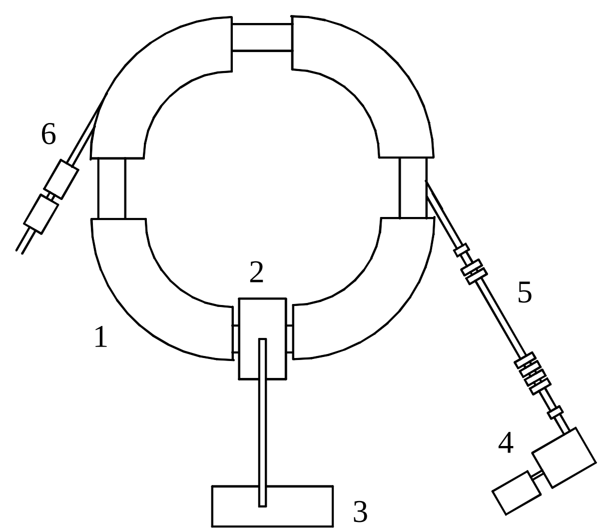


Fig. 1: Lebedev Physical Institute synchrotron layout. 1 - bending magnet, 2- rf cavity, 3- rf amplifier, 4 -microtron, 5 – injection beam line, 6 - extraction beam line.

The accelerator lattice is composed of four bending magnets and four straight sections. Profiled poles of bending magnets form non uniform magnetic field with

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field index n=0.55 in the region 15 cm in horizontal plane and 7 cm in vertical direction, the radius of orbit being equal to 4 m. The total length of straight sections is 7.6 m, and these serve for installation of rf cavity as well as septum magnets for the electron beam injection and slow extraction of the beam being accelerated up to the final energy. Special pole winding are used for field index correction at the injection energy and for excitation of non-linear resonance during beam slow extraction. Extracted beam is directed by beam line to experimental hall #1, where it is used for tagged photons experiments. Bremsstrahlung photons are produced on the target installed in synchrotron vacuum chamber. The position of the target provides necessary geometry to ensure bremsstrahlung beam propagation to experimental installation in the hall #2.

Repetition rate of synchrotron is equal to the 50 Hz and this is synchronized with the commercial frequency. The windings of bending magnets are power supplied with dc (rectifier) and ac (inverter), the total power assumption being about 2 MW at mode operation with the maximum electron energy (1.3 GeV). Dc magnetic bias is used to lower plug power and intertwin voltage. This approach makes it possible to adjust rate of guiding magnetic field rise at the injection as well.

RF cavity of cylinder type with the isolated cylinder electrode between flat planes forms two accelerating gaps and operates at the frequency of 55 MHz. Such geometry had been chosen to avoid multipactor effect – the last one can be suppressed by dc voltage between the inner cylinder electrode and outer cavity walls. Eigen resonator frequency adjustment is achieved by appropriate position of tuning loop driven by motor. Cavity is excited by rf power delivered by the feeder from rf amplifier, the cavity coupler design allows to change coupling strength, while double-stub transformer makes it possible full matching providing feeder operation in travelling wave regime. Ceramic window separates cavity vacuum from the atmosphere air of the feeder. Special stainless steel container surrounding resonator provides necessary vacuum conditions inside cavity.

RF amplifier consists of several cascades and provides the output power up to 50 kW. The input signal is delivered from rf synthesizer installed in control room. First cascade is modulated by the signal of the special form providing fast raise of accelerating voltage after injection as well as slow voltage raise from approximately 10 kV at the injection to the final value up to more than hundred kV during acceleration to compensate the effects of synchrotron radiation. Modulating voltage drops to zero value during 3 ms at the end of accelerating cycle when internal target is used. The modulation low inside this interval is adjusted in a manner that provides uniform bremsstrahlung stretching.

Classical microtron is used for the electron beam injection into the main accelerator. Electrons are extracted by rf field from the $LaB_6$ cathode installed in the cylindrical cavity near drift hole and heated to the temperature 1700. Due to simultaneous action of crossed magnetic and rf fields emitted electrons leave the cavity and move on circular trajectory around the cavity. If resonance conditions take place electron bunches traverse cavity approximately in the same phase of rf field and thus increase the energy and the radius of trajectory. Magnetic channel is installed at definite radius thus allowing the bunches to leave the microtron. Beam line with quadruple lenses and correcting coils directs electron bunches to the septum magnet being installed in straight section of the synchrotron. Beam transformers and luminescent screens with TV system are used for beam monitoring at beam line.

Microtron resonator is excited by rf power from pulse magnetron with the maximum rf power 2 MW. Together with others this ensures electron beam current up to 50 mA in the pulse duration 4 μs at the entrance of beam line. Tetrode modulator with partial capacitance battery discharge is used to form high voltage pulse for magnetron excitation.

The main synchrotron parameters are listed in table 1.

Table 1. The main parameters of Lebedev Physical Institute synchrotron

| | |
|---|---|
| The electron maximum energy (GeV) | 1.3 |
| Repetition rate (Hz) | 50 |
| Synchrotron lattice | FO |
| Number of periods | 4 |
| Field index | 0.55 |
| The radius of orbit in bending magnet (m) | 4 |
| The straight section length (m) | 1.9 |
| Injector type | microtron |
| Injection energy (MeV) | 7 |
| Injector pulse duration (μs) | 5 |
| Injector pulse current (mA) | 50 |
| Rf frequency (MHz) | 55 |
| Harmonic number | 6 |
| Max. output power of rf amplifier (kW) | 60 |
| Cavity rf voltage range (kV) | 5 - 150 |

## 3 PRINCIPLES OF SYNCHROTRON AUTOMATION

So far operator controlled the accelerator physical parameters from the main and auxiliary consoles at control room, observing the results of accelerator systems tuning with the oscilloscopes. What we plan to do at first stage is to replace manual control with computer control as well as usual electronic and electrical monitoring with computer monitoring and data collection at least for the main synchrotron systems. It appeared that computer based monitoring system that had been developed for the Lebedev Physical Institute Radiation Complex could be good basis for this purpose.

The main feature of system mentioned is the flexible user interface. This means that the user (operator) can build up any desired arrangement of virtual devices available from program menu on monitor screen and assign necessary properties to these devices. All this is carried out in so called design mode. Of course real primary sensors as well as necessary electronic interface have to be available. After that the built computer interface may be turned to measurement mode and real measurement can be start immediately without compiling and linking. This is a powerful feature of developed code that differs it from the known programs for computer based measurements. The software is based on Borland C++ Builder technology and programming interface used is very similar to system mentioned. The essential feature of the code developed at Lebedev Physical Institute is that building procedure is moved to executable level.

Several data representation can be used for visualization of measured value. These are numerical indicator, time dependent representation (oscilloscope), spectrum and histogram. All data can be processed in real time scale before their visualization and this function is available from computation component. The transformation low can be edited in special editor (or loaded from the file) by user and compiled by built in compiler. Network data acquisition is foreseen as well. This is done to provide data collection from “hot” zone in order to reduce inducing from operating physical equipment. To visualize time dependent multi channel processes (spectrum) animation component is included. The acquired data can be stored on hard drive and played back off line. This process can be accomplished data processing before visualization. We consider this possibility as very important feature of our software. The whole accelerator run can be stored and played back later to look for not evident correlation between different accelerator parameters.

Control of accelerator systems is realized through the low-level voltage control mainly. We are going to use this low level voltage control as the basis for digital computer control making necessary upgrade of electronics used. Although control for some accelerator systems can not be reduced to time independent voltage control the last one is never the less the most frequently used and for this reason is the most attractive for computer control.

For digital computer control and data acquisition and processing in real time scale digit-to-analog converters (ADC) as well analog-to-digit converters (DAC) with the appropriate attributes are the main devices of hardware interface that stands between primary physical sensor and computer. CAMAC is used for a long time at our department for two reasons – a lot amount of devices in this standard are available and temporal properties (1 MHz controller clock) were quite sufficient for our applications. This standard we be used for the synchrotron automation. The other interface – ISA bus will be taken into account too. It is worth wise to underline that the most slow process in computer base measurements is data visualization.

Two kinds of digital devices are under development. The first one is waveform digitizer that will be accomplished in two modifications for fast (frequency of digitizing up to 20 MHz) and slow (20 kHz) processes. Fast ADC is planed to be used for injection system while slow digitizers for relatively slow synchrotron cycle (10 ms) and beam extraction and stretching. These digitizers are based on 10 bit ADC and fast memory units, up to 6-8 such devices will be installed in one CAMAC unit. Each channel will be equipped with digitally controlled amplifier or attenuator in order to use maximum ADC bits for precise measurements. As it was already mentioned DACs will be used as time independent voltage controls. 8-channels 10 bits devices will be used with additional 3 bits precise trimming. In addition to DAC or ADCs each CAMAC or ISA unit has the 14 bits ADC with multiplexer and memory in interface part for precise measurement at any fixed moment.

Synchrotron automation will be made in three steps. First step is the moving the existing manual control and measurements status to computer based level with hard and software just described, existing sensors being used. At the second step we plan to improve the beam diagnostic by installing additional sensors as well to move to computer based measurements level the rest accelerator systems. This step will be used for accelerator studding aiming its following upgrade. At last third step will be used to automate the acceleration process.

## 4 CONCLUSION

We consider the synchrotron automation as the first stage of accelerator upgrade. For the reason of very limited resources we can not realize our plans to build up new accelerator for the research in the physics of intermediate energies. That is why we study the possibility for moderate upgrade to improve the accelerator performance. New injection system as well as improved considerably slow electron extraction may be among possible solutions for moving the existing facility to the level that is required for modern experiments.

## 5 REFERENCES


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