THE PROSPECTS OF IMPROVEMENT AND DEVELOPMENT OF ACCELERATOR INSTALLATIONS AT YEREVAN PHYSICS INSTITUTE

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1. Basic Trends of Researches up to 2000 and Requirements to Yerevan Synchrotron Beams

Our present-day knowledge of properties of the microworld allows us to assert that along with the study of elementary particle structure and nuclear properties at superhigh energies, there exist extremely urgent problems also in the region of intermediate energies (1÷6 GeV). The experience of the recent years as well as the analysis of the status of these problems point out that one of the fundamental problems of the modern nuclear physics is not as yet solved, namely the determination of the validity region of the quantum chromodynamics and its relation to really existent hadrons. The phenomenon of quark confinement in hadrons remained unexplained; elementary particle structure as well as nuclear structure at small distances (less than or equal to nucleon sizes) also remained unestablished. A particular role in the solution of these problems belongs to the study of interaction of electrons and photons with hadrons and nuclei in the investigation of phenomena at distances of 0.1÷1 Fermi, for which intense, nearly continuous multi-GeV electron beams are required. This is stipulated by advantages of electromagnetic probes: their interaction is well-known being weak enough not to distort the structure of the studied object, and at use of nuclear structure makes it possible to study total volume of nuclear matter. Precisely due to this circumstance, recently, in many large national centres there are elaborated long-term programs of such researches (CEBAF, ELSA, Kharkov, etc.).

Analysis of accomplished and planned experiments and theoretical aspects of intermediate energy physics /1/ permits us to outline the following principal research trends:

- the study of baryon and meson systematics (mass spectrum, quantum numbers, decay modes, coupling constants, etc.) and their comparison with predictions of symmetry schemes and dynamical models of multiquark and gluon systems including orbital and radial excitations of such systems;
- the detection of elementary particle exotic states (multiquark states, hermaphrodites, bound-state gluons) and dibaryons whose existence is predicted by quantum chromodynamics;
- the study of the role of quark-gluon structure of interacting particles in processes of hadron photo- and electroproduction in the energy region of 1÷6 GeV;
- the study of nuclear structure at small distances and variation of nucleon structure in nuclear medium. The establishment under what conditions and in what region of transfer momenta and energies the nuclear structure description on the basis of the quark picture will be adequate; the detection of transition from the region where quark currents are dominant.

Thus, electron accelerators in multi-GeV energy range with a sufficiently intense and (quasi-)continuous current of accelerated particles have an extended range of application. Experimental findings obtainable with their help will be of paramount importance for our understanding of matter structure. A more detailed estimation of operation conditions of concrete experiments has shown that sufficiently optimal in the solution of cited problems are the following electron beam parameters: energy - up to 6 GeV, average current - from unities of microamperes up to a few tens of microamperes, duty cycle close to 100%. These parameters must be ensured by the current program of technical re-equipment and long-term development of the Yerevan synchrotron.

2. Stages of Program Realization

The principal items of this program are as follows: construction of a new injection system, construction of a new accelerating RF system of synchrotron, realization of accelerating-stretching conditions of synchrotron, construction of a stretcher.

All these items are based on considerable reserves which allow us to outline the following stages of the program realization.

The first stage meant to be accomplished in 1989 will allow to ensure the following parameters of the ejected electron beam: energy - up to 4.7 GeV, average extracted electron current - 0.3 μA, flat top duration of synchrotron magnetic field - 4 msec (duty cycle 20%).

By the end of the program second stage in 1991(92), the following parameters will be attained: energy - up to 6 GeV, average extracted current - 0.3 μA, flat stretching duration of magnetic field - up to 50 msec.

The third stage expected to be completed in 1994(95) will ensure the parameters: energy - 6 GeV, average extracted current - 2.5 μA, flat stretching duration of magnetic field - 50 msec.

Finally, the fourth stage which is planned to accomplish in 2000 will allow to ensure average current of 10 ÷ 20 μA and 100% duty cycle at 6 GeV energy.

3. Technical Parameters and Status of Separate Systems of Synchrotron

Works on realization of the I stage are practically completed. At present the system of formation of the synchrotron magnetic field flat top is being adjusted, and works on increase of injected beam energy from 50 to 75 MeV are under way.

A circuit of magnetic field flat top formation is shown in Fig.1 /2/. Additional inductors L_q are connected in-series with capacitor bank C . The magnitude of this inductance is nearly 15% of inductance of resonance group. In this circuit a flat top is formed as follows: after reaching a required value of magnetic intensity the thyristor keys TK are turned on, these latters shorting out the circuit of in-series connected capacitor bank and additional inductor. The electromagnet winding voltage abruptly falls off to zero and is maintained zero. In this case in the magnetic intensity curve a flat top subcircuit is formed.

At the moment of short-circuit the capacitor bank voltage is applied to additional inductor, energy exchange occurs between them, and due to capacitor bank recharge the thyristor keys are automatically locked. The process of flat top formation is explained by the current and voltage diagrams given in Fig.2.

The flat top subcircuit duration is determined by the magnitude of additional inductance and voltage on a capacitor bank.

The main advantages of the chosen method for flat top formation are as follows:

a) the absence of circuit of forced lock of thyristor keys, this increasing substantially the reliability of the system operation;

b) the presence of additional inductors leads to limitation of extracurrents in emergency operation (for example, at false operation of thyristor keys at the maximal value of voltage on capacitors);

c) the reduction approximately by 20% in the required value of average radio-frequency supply power;

d) a relatively higher precision of magnetic field maintenance during flat top, this enabling to exclude additional sources of active loss compensation.

The main feature of the elaborated method is its flexibility which allows to form a flat top of different duration by means of simple circuit variations and intensification of thyristor keys.

The limiting values of acceleration rate and the accelerator operation off-duty factor are determined mainly by constructive and electric strength of the ring-shaped electromagnet units and the accelerating system equipment.

The increase of the injected beam energy is attained by installing one more additional accelerating section and klystron station.

To realize the II stage, there must be constructed a new accelerating radio-frequency system and a system of formation of durative (up to 50 msec) stretching of magnetic field. The main parameters of the new accelerating RF system are as follows /3/:

the number of cavities - 40 (20 accelerating modules);

RF frequency - 466 MHz;
orbiting frequency multiplicity factor -337
total RF peak power ~1 Mw;
total RF average power ~ 0.3 Mw.

At present one specimen of accelerating module is made, which is under investigation. The construction of RF accelerating system is planned to accomplish in 1991. By the same time a durative stretching system must be constructed.

To realize the III stage, the construction of a new injection system must be accomplished. The linac this system is based on is realized as a multifunctional installation one of aims of which is to inject electrons into synchrotron. The main parameters of the linac /4,5/ are as follows:

Rating energy	120 MeV
Rating injection energy	200 MeV
Energy limits	80-240 MeV
Injection energy limits	120-200 MeV
Current pulse duration	2.5÷8 sec
Electron bunch repetition rate:	
at chopper switched-off	2800 MHz
at chopper switched-on	466 MHz
Pulsed current limits	0.015÷1.5 A
Energy spread for 75% of electrons on linac output:	
at beam current 0.015 A	±(1÷1.5)%
at beam current 1.5 A	±(1.5÷2)%
Energy spread for 75% of electrons at active monochromatization system-on	±(0.2÷0.3)%
Current stability with energy spread ±(0.2÷0.3)%	±2%
Emittance	3 mm.mrad
Basic accelerating section length	2 m
RF power on accelerating section input	18 Mw
Total number of accelerating sections	12

At present the facilities of the head part of electron linac (three sections) are constructed which are under test. The construction of the new injection system is planned to accomplish in 1994.

4. Accelerating-Stretching Complex for 6 GeV

The presented program of technical reequipment of separate synchrotron systems enables us to improve some of its parameters for solving some problems of intermediate-energy physics and thus prolong the term of scientific urgency of the accelerator till the construction of a specialized facility. Such specialized facility is a new accelerating-stretching complex permitting to produce electron and gamma-quanta continuous beams of energy up to 6 GeV /6/ at relatively low currents ~10-20 μA.

The stretcher is set up in the ring tunnel of the operating accelerator along the larger-radius wall. The mean radius of the ring-shaped electromagnet is 37.5 m, and the radius of curvature ~15 m, this at magnetic field intensity ~1.33 T ensuring confinement of particles with 6 GeV. For the injection of particles with this limiting energy, a free gap with a length no less than 4 m is provided for in the stretcher. At optimization of the cell structure it proved to be reasonable to include such gap in all cells of the magnet system. The number of gradient periods is chosen to be 24.

Thus, on the stretcher ring there will be 24 four-meter long gaps. Part of these gaps will be occupied by injection systems and intended for mounting RF cavities. Others, free of technological equipment, may be occupied by undulators and wigglers which will produce intense synchrotron radiation beams at the installation storage operational mode as a source of synchrotron radiation and during operation on internal targets.

At the first stage, as a stretcher injector there will be used the existent synchro-

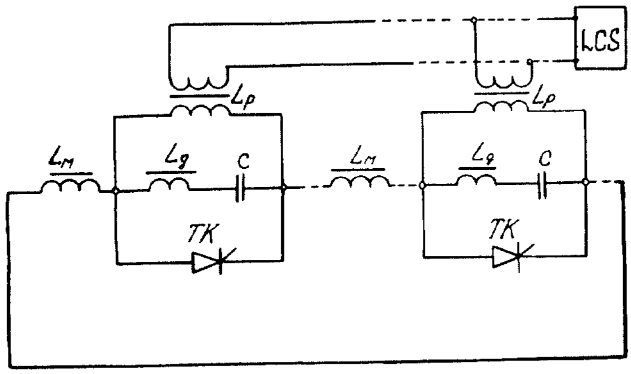

Fig.1. Flat top circuit.

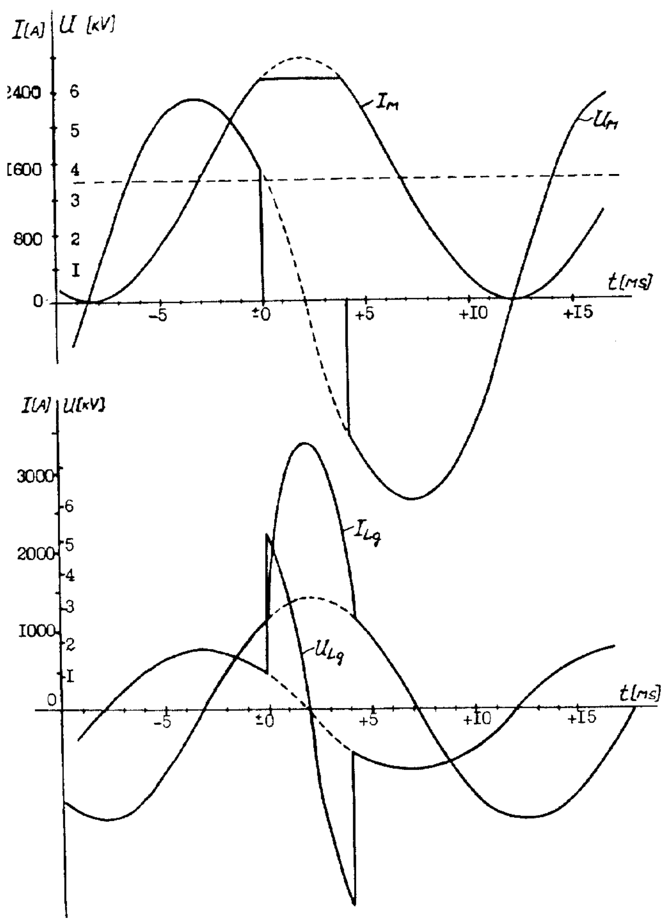

Fig.2. Parameters of the circuit shown in Fig.1 as functions of time at 6 GeV and flat top duration 4 ms.
I_M, U_M - current and voltage of electromagnet;
I_{Lq}, U_{Lq} - current and voltage of additional inductance.

tron, which after the above-mentioned modernization will allow to attain average current of the beam extracted from the stretcher $\sim 4 \div 6\ \mu A$.

Further increase of the stretcher average current will be feasible on a new specialized synchrotron which will allow to obtain average currents $\sim 10 \div 20\ \mu A$. Such intensity may be attained due to the increase of separatrix area at the instant of particle capture, increase of injection energy, increase of repetition rate of acceleration cycles, construction of a more powerful RF system, and so on.

To solve these problems, investigations and technical developments have already started at Yerevan Physics Institute.

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