THE YEREVAN ELECTRON ACCELERATOR: STATUS AND DEVELOPMENT

A.Ts.Amatuni, R.O.Avakyan, A.Z.Babaian, A.I.Baryshev,
H.A.Vartapetyan, N.A.Zapolsky, I.P.Karabekov, E.M.Lasyev,
R.O.Manoukyan, H.A.Martirosyan, V,Ts.Nikogosyan, G.G.Oksuzyan
K.A.Sadoian, Kh.A.Simonyan, V,M.Tsakanov, A.R.Toumanyan
Yerevan Physics Institute, Yerevan, USSR
V.P.Belov, V.P.Goncharenko, A.A.Makarov
D.S.Efremov SRIEPA, Leningrad, USSR
W.Bothe, J.Rossbach, J.Rummler, K.Steffen
DESY, Hamburg, FRG

The program of the physical researches at Yerevan Physics Institute and rising from it the program of 6 GeV synchrotron development were presented at the latter conference [1]. In this paper the results of the completed work and some ways of their elaboration in future are given.

1. Modernization of the operating synchrotron

According to the program of synchrotron modernization, the injection energy of the operating linac has been attained 75 MeV due to the 25 MeV additional section. Average injection current was managed 2 μA at E/E = +-0.5 % . This allowed, even with the existent RF accelerating system, to get a considerable improvement of the particles capture into the accelerating mode. In addition the conditions of the beam extraction were improved at the flat top for duration of 4ms. At present time a new 120 Mev high current linac is under construction one of the aims of which is the use of the synchrotron as the injector. The major part of the building work is completed and some of equipment is being received.

To decrease the energy spread of the new injector to 0.001 is supposed to set up a system of beam monochromatization in the injection tract of the synchrotron. After starting a new injector and with the use of a more powerful RF system the average current of the synchrotron will be 0.8 - 10 μA.

The construction of a new injector prototype (30 MeV high current accelerator) will be accomplished in the near future. Besides of adjustment and test of the main units of linac, there will be carried out researches of the new methods of the charged particles acceleration in the wake fields, excited in periodic structures and plasma.

At present Yerevan synchrotron operates on extracted beam of 3 ms duration at 50 Hz repetition rate, on 4.5 GeV extracted beam energy and 1 μA average current. Works are carried out for construction of a new accelerating system with 466.1 MHz frequency, to increase duty factor, bunch structure of the extracted beam, rise its energy up to 6 GeV and current to 10 μA (the main parameters of the system are given in [1]). Choice of the frequency was determined by the possibilities of the electrovacuum devices.

Two cylindrical resonators with the length of $\pi/2$ each , which are strongly connected by the hole for the beam passing (the coupling factor k= 0.5) are used as accelerating structure. Hence the beam passing factor, which equals $\pi/2$, reduces shunt impedance efficiency, makes the resonator construction simpler and increases its strength. Two prototypes of such structures, which differ by their manufacturing technique, are being tested at the present time.

Works continue to increase the flat top duration to 2 ms. Physical starting of the first stage of the system for flat top formation of 4 ms at 4.5 GeV was made in december 1987. The aim of this intermediate stage was to analyze the work of the accelerator facility during slow extraction. the experiment showed that at the moment of the flat top formation there occurred high frequency oscillations (15 Hz), which were caused by the discharge of the spurious capacitances of the resonance circuit through the electromagnet, which significantly complicated the electron beam extraction. Therefore a new scheme of the flat top formation is being developed.

For ensuring the possibility to increase the duration of the beam extraction to 20 ms at the 6 GeV there is considered a version of replacement of synchrotron magnet system with combined functions by a new magnet ring with separate ones to realize the dumping of all three oscillation modes.

A new ring is suggested to be installed instead of the operating one with the same average radius (R = 34.5 m), but with the reduced bending one (19 m) in the bending magnets. Then the maximum field in the bending magnets will increase to 1.1 T at 6 GeV energy [2].

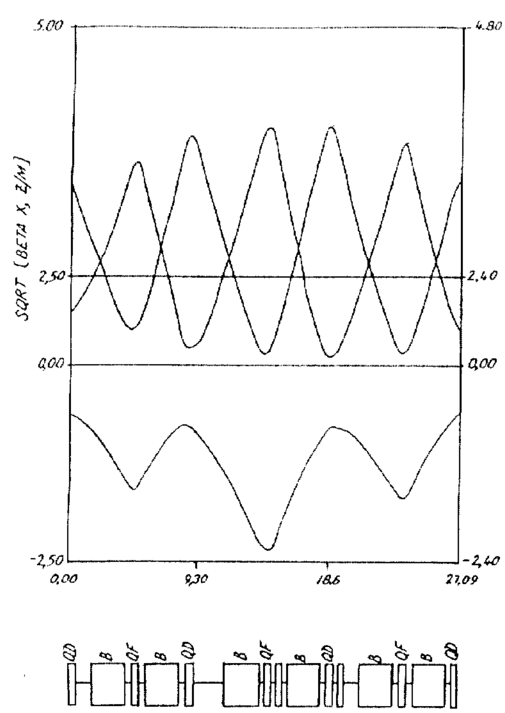

Fig.1

The magnet lattice consists of 8 superperiods which allow to have the same number of free gaps of 2.11 m each. It is necessary for injection and slow extraction on the third-order resonance. The rest of the gaps may be used for resonators and sextupoles installation. The main parameters of the new ring are given in Table 1.

Table 1.

Energy	6 GeV
Bending radius	19 m
Max. field in bending magnet	1.1 T
Max. gradient in quadrupoles	9.8 T/m
Horizontal tune	5.26
Vertical tune	5.17
Damping time of H oscillations	1.4 ms
Damping time of V oscillations	1.4 ms
Damping time of synchrotron. oscill	0.7 ms
Space compaction factor	0.043

Fig. 1 shows the graphic display of betatron function along horizontal β_x and vertical β_z.

Since the new ring will work almost as an electron storage ring in flat top mode of big duration (20 ms); then it will be necessary to compensate for the chromaticity: horizontal $\xi_x = -6.78$ and vertical $\xi_z = -6.1$. It is suggested for this to install 8 sextupoles on the orbit which can be used for the third-order resonance building up during slow extraction. In this design of magnet system replacement there are considered also the possibilities of super cycle synchrotron stretcher creation, i.e. the possibility of reducing the acceleration periods duration and magnet field fall for increasing the extracted beam duty factor [3].

2. The Prospects of Development

Two versions of 6 GeV stretcher construction are discussed for getting electron beam continuous extraction with 100 % duty factor and 10 μA average current. One of them is supposed to be located in the existent synchrotron tunnel, and the second one is thought to be made in the form of the separate ring with the orbit length exceeding 5 - 7 times the synchrotron orbit length.

The first version of the stretcher is developed in details. .Its basis is a storage ring, located along the outer tunnel wall of the synchrotron. At the end of each acceleration cycle, 6 GeV electron beam accelerated in the synchrotron is injected into the stretcher, followed by a continuous uniform extraction during 20 ms.

The stretcher magnet lattice is being designed with separate functions to ensure the radiation damping of the horizontal oscillations.

The use of the conventional FODO lattice is unfit in our case since a long free gap of 3.2 m is required for injection of 6 GeV electron beam from the synchrotron. A big free gap will ensure suitable conditions for uniform extraction from the stretcher. So, the chosen magnet lattice of the stretcher consists of 8 super periods with 3 simple FODO cells in each. It leads to the bending radius increase up to 20 m.

The main parameters of the stretcher are given in Table 2.

Table 2.

Bending radius	20 m
Horizontal tune	6.33
Vertical tune	6.25
Bending magnet field	1 T
F quadrupoles gradient	12 T/m
D quadrupoles gradient	12.5 T/m
Rms energy spread	0.114 %
Horizontal emittance	0.66 mm/rad
Momentum compaction	0.0238

In figure 2 are shown the graphs of betatron functions β_x and β_z and the dispersion function η for one super period. Injecting and extracting septums will be installed in the big free gap behind the bending magnets.

Phase advance between the two free gaps L1 and L5 of 1.5 m length is near π. They can be used for kicker magnets installation while building the compensated bump in the point of particles injection from the synchrotron. Sextupoles can be located in the rest free gaps for compensating the quadratic chromaticity and creation a resonance harmonic on orbit for continuous extraction from the stretcher.

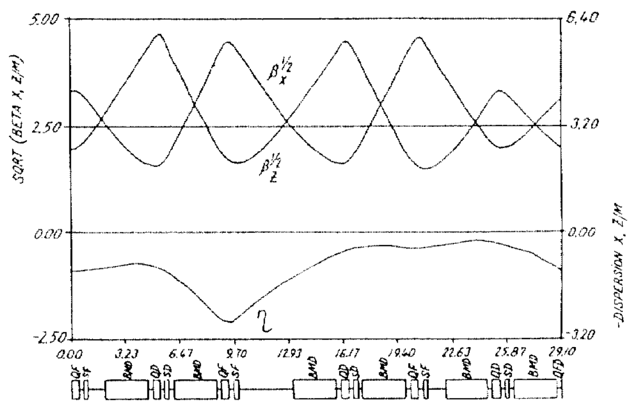

Fig.2.

The total length of the 6 GeV electron beam transport line from synchrotron into stretcher is 27.5 m. That's why the extracted beam is necessary to turn by 34^{o} angle.

To get high efficiency (more than 90 %) of particles extraction from the synchrotron it is supposed to use one-turn extraction. Such particles extraction from synchrotron into the stretcher is done by 2 kicker and 2 septum magnets. The vertical beam size of 20 mm at 6 GeV defines the use of 2 kickers with the power source voltage of each kicker about 40 kV. The bump preliminary shifts the accelerated electron beam by 35 mm from the axes of the chamber.The electron beam is thrown behind the first septum edge (by 34 mm) by 2 kickers constructed identically.

Kickers and the first septum will be aligned in the near three focusing gaps. The second septum will be installed in the defocusing gap following the first septum.

The main parameters of kickers and septums are given in Tab.3 and 4 correspondently [4].

Transport line starts after particles extraction from the second septum. It includes 5 bending magnets and 6 quadrupoles

Table 3.

Kicker type	LC parts
Ejection energy	6 GeV
Delection of each kicker	1.39 mrad
Ferrite length	0.6 m
Ferrite aperture (h * w)	40 * 80
Magnetic field	46.4 mT
Pulse	rectangular
Pulse length	1.2 μs
Kicker impendance	12.5 Ohm
Load impendance	12.5 Ohm
Pulse current	1.475 kA
Voltage at kicker	18.5 kV
Voltage at cable	38.0 kV
Voltage at PS	20.0 kV

Table 4.

Septum type	frontshield		
Pulse	half sine		
Septums	S1	S2	
Ejection energy	6	6	MeV
Deflection	28	64	mrad
Iron length	0.56	0.8	m
Gap aperture	10 * 30	10 *40	mm
Magnet field	1	1.6	T
Pulse length	220	220	μs
Impendance	0.0374	0.052	Ohm
Pulse current	7.995	12.733	kA
Voltage	300	662	V

for matching synchrotron and stretcher ellipses which is realized by matching the amplitude functions β_x β_z and η at the injection and extraction point. Each bending magnet of 1.5 m length and 1.6 T field provides bending of 6 GeV electron beam by the 6.8^{o} angle. The envelope of the electron beam along the whole transport line is shown in Fig. 3. It corresponds to the normalized 1 mm/mrad emittance.

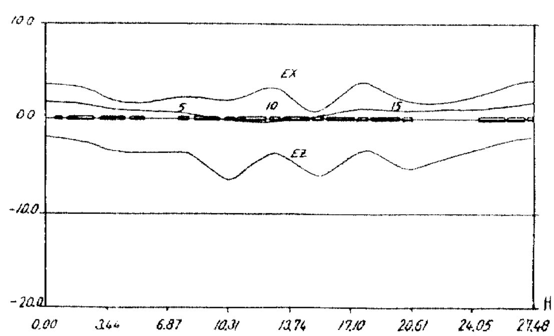

Fig.3.

Particles injection into the stretcher is realized from inside of the ring. For landing the particles on the orbit it is necessary to turn the electron beam by 10^{o}. To do this two septums of 1.6 T and 1 T will be installed in the free gap of the stretcher. The amplitude of the bumped orbit in the stretcher injected point is 60 mm.

Energy loss of the 6 GeV particle per turn for the synchrotron radiation in the stretcher is 5.7 MeV. To get continuous extracted beam of 10 μA current one ought to have 250 μA circulating current in the stretcher. Then the total RF power needed by the beam will be 1.43 MW.

It should be noted that stretcher can be used also in the storing mode for producing synchrotron radiation. The wavelength in the synchrotron radiation specter will be 0.516Å.

The design of the second version of the stretcher, which is a new big ring with the circumference 5-7 times longer than that of the synchrotron one, is under development now.

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