NEW PROJECT OF 1.5 GeV ELECTRON LINAC AND PULSE STRETCHER

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High duty cycle beams are inevitable for new electron accelerators due to the rapid developement of nuclear physics. After considering several types of accelerators to deliver continuous beams, a conventional linac together with a pulse stretcher has been chosen because of its existing technology and adaptabilities for various research. Stretchers have been studied at several laboratories and noticed that no serious difficulty exists for construction. Layout of the new linac is shown in Fig. 1. The 210 m long linac is followed by an energy compressing system(ECS) in order to improve an energy spectrum of the beam from 2% to 0.2%. When a continuous beam is required, the pulse stretcher ring(STR) is excited to convert a pulsed beam into continuous one with a duty factor of better than 90%. The ring is also used for a storage ring creating synchrotron radiation and monochromatic gamma rays.

A high resolution electron spectrometer(SP-E) and a proton spectrometer(SP-P) are set up in the electron scattering hall. These spectrometers are to be used for coincident experiments such as (e,e' p) in addition to single arm experiments. The photonuclear experimental hall is equipped with a broad range spectrometer and an apparatus for a tagged photon experiment which is a very promissing field with use of continuous electron

BS;Broad Range Spectrometer
TP;Tagged Photon
ME;Meson Experimental Hall
SP-E;Electron Spectrometer
SP-P;Proton Spectrometer
SR;Synchrotron Radiation
MG;Monochromatic Gamma Ray
ECS;Energy Compressing System
STR;Pulse Stretcher
KM;Kicker Magnet
ND;Neutron Diffraction

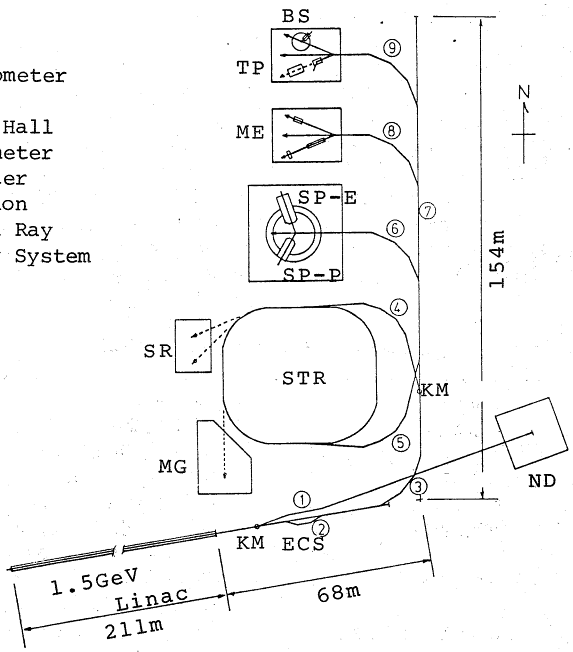

FIG. 1. Layout of the Next Tohoku Electron Linac

beams. The meson experimental hall is devoted to the studies concerning pion, kaon and muon physics. Experiments of neutron diffraction are to be made in the ND hall.

1.5 GeV Linac

An accelerator system consists of an injection system, 32 accelerator waveguides and ECS. Each of them is connected to one of the 34 klystrons. Electron beams are accelerated after being bunched at 2856 MHz by a prebuncher and a buncher. Since rf cavity in STR operates at 476 MHz, the beam can be bunched at 476 MHz by a subharmonic buncher before injected into a prebuncher. A waveguide, which is 4.85 m long, consists of 131 cavities with a variation of disk hole diameters to make a quasi-constant gradient type. In order to prevent beam blowup (BBU), all 32 waveguides have slightly different variations of disk hole diameters and waveguides with closest dimensions are arranged as not being neighbors. The repetition rate of the beam can be varied from 50 pps to 600 pps. The beams with several kinds of parameters, such as pulse width and electron energy, can be accelerated pulse to pulse so that two or three experiments are made simultaneously. The beams are separated at the end of the linac by a pulsed kicker magnet, for example, some portions of the beam is delivered to the ND experiment, and the rest of the beam is used for other experiments. Fig. 2 shows energy-current characteristics of the linac and main parameters of the electron beam are summerized in Table 1.

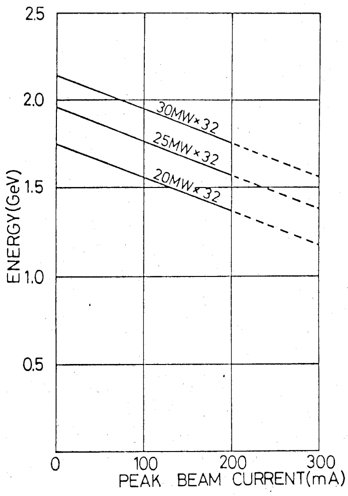

FIG. 2. Current-energy relation of 1.5 GeV linac. The numbers beside the lines indicate the peak values of rf input power to an accelerator waveguide.

Table 1 Parameters of Electron Beam

Energy (unloaded)	≃2 GeV
Energy (loaded)	300 MeV - 1.5 GeV
Current (peak);Ip	10 - 1000 mA
Current (average)	200 μA (max.)
Power (average)	300 kW (max.)
Pulse width;Tp	0.1 - 0.5 μsec
	0.5 - 3.0 μsec (Ip <250 mA)
Energy spread	≃2 % (without ECS†)
	≃0.2 % (with ECS)
Pulse repetition rate	50 - 300 pps
	50 - 600 pps (Tp ≲1 μsec)
Acceleration frequency	2856 MHz
Emittance;ε	≲1 mm mrad.

† Energy Compression System

Pulse Stretcher

The pulse stretcher ring is 160 m in circumference and consists of 4 straight sections and 4 quadrats. Each of the quadrats is composed by 8 bending magnets of 8 m radius of curvature and 8 quadrupole magnets. Each quadrat forms an achromatic system so that the value of the off-energy function vanishes in all straight sections. The third integer resonance of 19/3 in the horizontal direction is used to extract a continuous beam from the ring. The betatron frequencies are 6.3 and 6.2 in the horizontal and vertical planes respectively. At the time of injection, the equilibrium orbit is brought near the septum magnet by bumper magnets and the betatron frequency is changed to ν_x=6.25 by pulsed quadrupole magnets. After a three turn injection is over, the bumper magnets and quadrupole magnets are turned off during the fourth turn and the trajectory is returned to the central orbit. Circulating electrons lose their energy through synchrotron radiation. STR is operated withour rf acceleration as much as possible, because it breaks uniformity of the beam bunched. The beam extraction is made by different modes for different ranges of electron energy. The beam extraction modes are shown in Fig. 3 When electrons lose over 3% of their energy through synchrotron radiation in the ring, rf acceleration has to conpensate the energy. The achromatic extraction is adopted in this energy range, changing the betatron frequency in the horizontal direction asymptotically close to 19/3 by means of the quadrupole magnets. When the energy loss is under 0.1% of the injected electron energy, no rf acceleration is needed. The achromatic extraction is also used in this

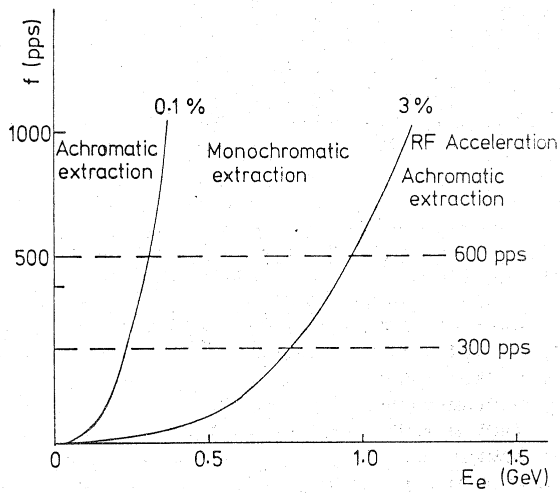

FIG. 3. Beam extraction modes of STR. Different modes are adopted according to the electron energy and the repetition rate.

Table 2 Parameters of Pulse Stretcher

Circumference	160 m
Radius of curvature	8.0 m
Betatron frequency	6.30 (horizontal) 6.20 (vertical)
Injection mode	3 turn horizontal oscillation
Extraction mode	third integer resonance
Extracted beam emittance	0.8 mm mrad (horizontal) 1.0 mm mrad (vertical)
Dilatation factor	0.045
RF frequency	476 MHz
RF peak voltage	200 kV

range. Electrons losing their energy between 0.1% and 3% in the ring can be extracted by the monochromatic extraction. the beam is injected with energy spread equal to the maximum energy loss. The lowest energy of the injected electrons corresponds to the third integer resonance. Electrons, losing their energy through synchrotron radiation down to the energy of the resonance, are extracted consecutively. An average current of 96 μA will be obtained, which is equal to the average current from the linac when the linac is operated with the repetition rate of 300 pps, 1.6 μsec in pulse width, and a peak current of 200 mA. The main parameters of STR are listed in Table 2.

Test Stretcher Ring

A small stretcher ring is under construction, which is used for studying technical problems and supplies continuous beams to the present electron spectrometer. A two turn injection puts a electron beam of 100 nsec in pulse width into the ring of around 15 m circumference. The maximum energy of stored electrons is 150 MeV. The betatron frequencies are 1.3 and 1.2 in the horizontal and vertical planes respectively. The monochromatic extraction by the third integer resonance of 4/3 in the horizontal plane is introduced, which has been stated before. A 3 μA electron beam is expected to be obtained with a duty factor of 90%, when a pulsed electron beam of 100 mA peak is injected with the repetition rate of 300 pps. Fig. 4 shows the layout of the test ring.

M ; Bending magnet
Q ; Quadrupole magnet
FQ ; Quadrupole magnet for fine tuning
PQ ; Pulsed quadrupole magnet
HM ; Hexapole magnet for high order corrections
PHM ; Pulsed hexapole magnet
KM ; Kicker magnet
SMI ; Septum magnet for injection
SME ; Septum magnet for extraction
SM ; Septum magnet
SE ; Septum electrode
LDM ; Electron spectrometer

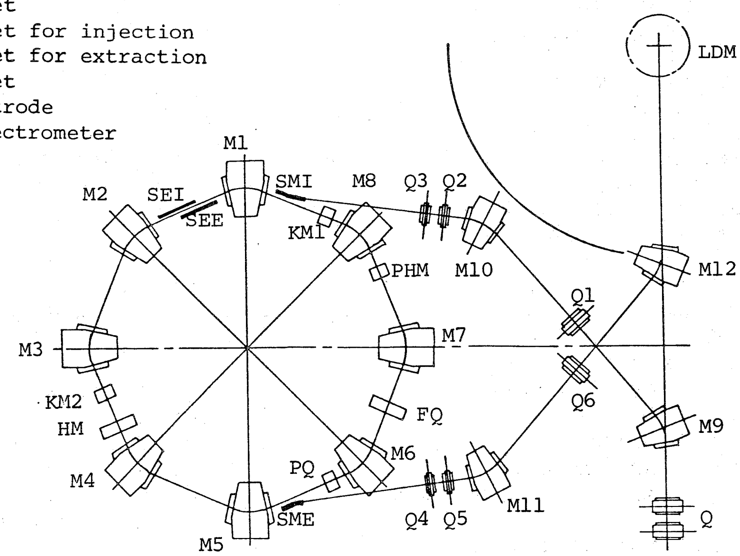

FIG. 4. Layout of the test pulse stretcher.