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THE TOHOKU UNIVERSITY STRETCHER-STORAGE RING PROJECT

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ABSTRACT

A new electron ring facility is proposed at the laboratory of nuclear science, Tohoku University. In the proposal, the present linac will be used as the injector to the ring by increasing its energy up to 1.0 GeV with adding two more Klystrons and a recirculation system.

The new ring of 160 m circumference operated in the stretcher mode supplies continuous electron beams of energy up to 1 GeV (30 μA average current) for nuclear physics. In the storage mode operation, injected electrons are re-accelerated up to 1.5 GeV to obtain synchro-tron radiation mainly from devises installed in the straight sections.

INTRODUCTION

The principal emphasis on the future nuclear physics will be on the coincidence experiments which requires high duty electron beams. The physics accesible with these experiments is expected very important for an understanding of nuclear structure and dynamics.

Our laboratory proposed 1.5 GeV linac-stretcher combination in 1979 and began construction of a prototype stretcher ring to study technical probrems inherent to the stretcher. The prototype ring came to operation at the end of 1981 and proved that extension to higher energy is within existing technology. At the moment the ring is being used for coincidence experiments in nuclear physics. The beam of about 1 μA is constantly obtained at 130 MeV with 80% duty factor and energy spread less than 0.2%.

The stretcher ring has, as well known, structures quite similar to the storage ring dedicated for synchrotron radiations, thus some precautions make the ring enable to be used as a synchrotron radiation source.

The modern storage ring dedicated to the synchrotron radiation has long straight sections in order to install various types of radiation source depending on the range of wave length. This makes eventually the circumference of the ring large, which is satisfactory to store large number of electrons in the ring to extract intense electron beam in the stretcher mode operation.

OUTLINE OF THE PROPOSAL

The present linac and the hausing will be fully used in the proposal after adding two more klystrons and replacing the accelerator tubes by new ones. Fig. 1 shows the general layout of the accelerator hausing and the experimental halls. The tunnel for recirculation system are built parallel to the present linac by about 30 m apart. The total length of the system including accelerator sections is 300 m, exactly the same length as the beam pulse length (1 μsec) so as to realize the head-to-tail recirculation.

The beam pulses extracted from the recirculation system are sent toward the ring by a 90° deflecting system. On the up-streem of the deflecting system, every third beam pulse (50 pps) is deflected by a pulsed magnet (PM) toward the neutron diffraction hall (ND).

The 90° deflecting system is able to debunch elec-

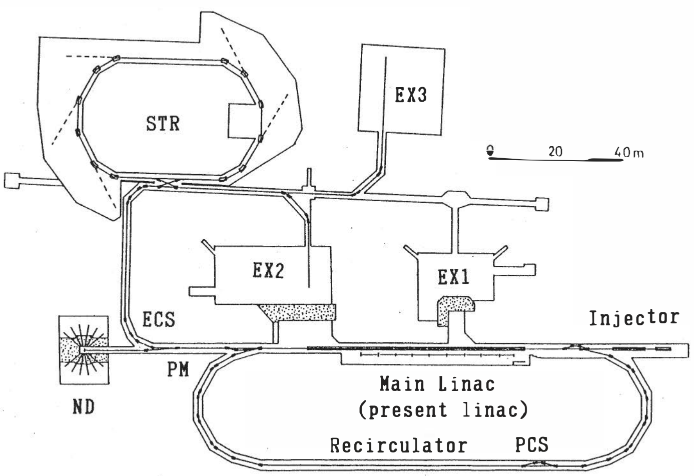

Fig. 1 Layout of Strecher-Storage Ring Facility
STR:Stretcher-Storage ring. PM:pulse magnet
ECS:energy compression system. EX:experimental room. ND:neutron diffration hall.

tron beams and to comprise an energy compressing system (ECS) with an accelerating tube for energy compensation. This system adjusts the energy spread of the beam suitably for stretcher operation of the ring.

The electrons injected into the ring is accelerated up to 1.5 MeV in the operation of storage mode. On the other hand, in the stretcher mode operation, beam extraction begins just after injection and keep the extracted current and energy are constant. Thus the extacted beam has the same energy with the injection energy. The extracted high duty beam or pulsed beam skipped the ring are transported to experimental rooms along the present TOF tunnel.

ELECTRON LINAC AND RECIRCULATION

Two more klystrons will be added and all of the present accelerating tubes are replaced by the ones newly desiged. Thus the maximum energy increases up to 0.53 GeV at 100 mA peak, 60 μA average current and 2 μsec beam pulse.

The recirculation system is installed to accelerate electrons twice by the main accelerating section composed of 6 klystrons. The final energy will be 1.01GeV at 100mA in return for reducing the beam pulse to 1 μsec and average current of 30 μA.

The leading edge of the recirculated beam is connected to its own tail (head-to-tail). This avoids the fluctuation of energy gain when the second acceleration begins, because the beam loading does not change. However the transient effect of beam loading still remains in the first acceleration. Therefore the firing time of each Klystron is carefully adjusted to compensate this effect.

In the injector section, this method can not be applied, because only one klystron belongs to the section. So we should use the other method or reject simply the leading edge of the beam by a magnet system before entering into the main accelerator.

To achieve the second acceleration succesfully, the bunches of the recirculated beam must arrive in the correct RF-phase at the entrance of the main accelerator. Therefore a phase controle system(PCS) consisting of four magnet detour is installed on the return path. Moreover the recirculation path should be achromatic and isochronous as a whole in order to avoid excess energy spreading due to debunching during recirculation.

STRETCHER-STORAGE RING

The ring has a racetrack shape composed of two long straight sections (22.5m×2) and 10 straight sections of moderate length separated by 12 bending magnets with 4 m radius, as shown in Fig. 2. One of the long straight section is reserved for beam injection and extraction. Each of the ten straight sections provides 4.8 m free space so that devices for synchrotron radiation may be inserted and/or nuclear experiments such as internal targets are available.

(Stretcher mode operation)

The circumference of the ring is chosen to be 165 m in order to store the 1 μsec (300 m) beam from the linac by two-turn injection in the stretcher mode operation. To obtain continuous and uniform beams which are essential for coincidence experiments, it is necessary to store electrons in uniform density along the circumference. Therefore the method of beam injection is tightly relevant to the beam extraction and uniformity of the extracted beam.

In the case of the stretcher ring, high average current should be handled. Whole electrons must be

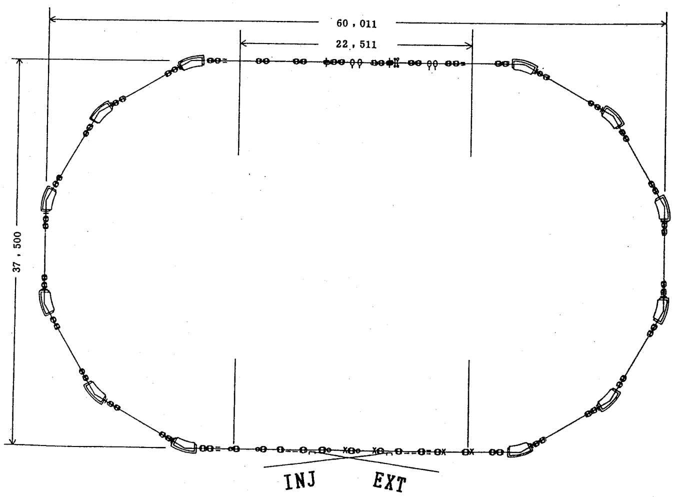

Fig. 2 Stretcher-Storage Ring.

extracted from the ring before next injection occurs. Otherwise, they would not only lose beam intensity, but also cause serious damage to the ring. Thus the half integer resonant extraction is chosen rather than the third integer extraction, expecting high extraction efficiency and better matching with the two-turn injection. The horizontal betatron oscilation with the tune of 6.48 near to the half integer is utilized to the beam injection. The long straight section is so designed as to be non-dipersive for injection and extraction.

At the operation energy higher than 600 MeV, RF-acceleration with the linac frequency (2856 MHz) is

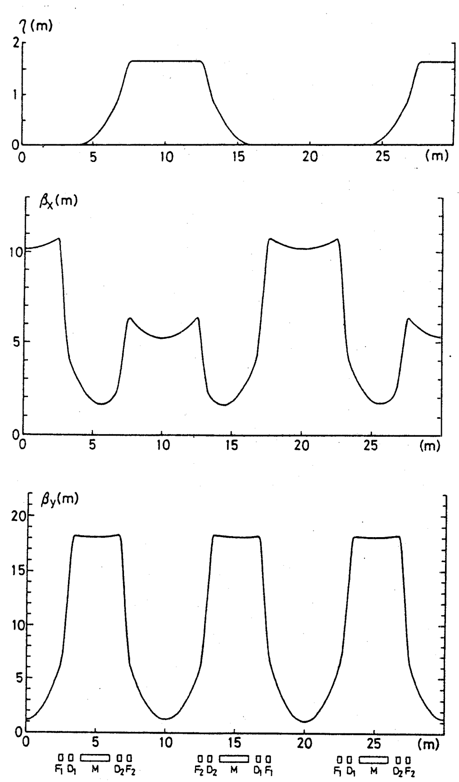

Fig. 3 Dispersion and betatron functions in a quadrant of curved sections.

used to compensate energy loss due to synchrotron radiation. The energy loss during successive beam injection increases rapidly with increasing electron energy and exeeds the limit of 3% acceptance due to energy dipersion (Fig.3).

(Storage mode operation)

As mentioned before, the modern storage ring dedicated to the shychrotron radiation consitutes of the straight sections which has length suitable for various kind of insertion devices. The undulator and wiggler will be commonly utilized in the storage rings of the coming generation. These devices require circulating beams of high quality, such as low emittance and non-dispersion.

In the standered operation listed in Table 2, the half number of the ten straight sections, as well as two long straight sections, are so designed as to be non-dipersive. The parameters of the quadrupole magnets and their positions are optimized to realize low emittance. The betatron functions and the dispersion functions are shown in Fig.3.

The maximum energy of the ring is chosen to be 1.5 GeV by taking into account the fact that there are important research fields around wave length of the order of 1 Å. The 1.5GeV electrons are able to produce this wave length using the superconducting wiggler.

To attain to this energy stored electrons are accelerated after 1.0 GeV injection.

Table 1

Electron Linac Parameters

Accelerating tubes (travelling wave)	
RF frequency	2856 MHz
Quasiconstant gradient,	$2\pi/3$ mode
Shunt impedance	73 MΩ/m
Effective length	2.0 m
No. of tubes	28
(main acceleration	24)
(injector	4)
(energy compression system	1)
No of Klystrons	7
(Typical operation)	
Pulse repetition rate	300 pps
Energy gain (at 100 mA peak)	20 MeV/tube
RF input	4.5 MW/tube
Klystron	
Peak power	25 MW
average power	22 kW
RF pulse length	3.0 μsec
Electron Beam with recirculation. [( ) single acc.]	
Energy	1.0 (0.53) GeV
Peak current	100 mA
Pulse length	1.0 (2.0) μsec
Average	30 (60) μA
Energy spread (with ECS)	0.1 %

Table 2

Stretcher-Storage Ring

Circumference	165.010 m
Curved section	59.994m×2
(Free space for insertion devises	4.8m×10)
Long straight section	22.511m×2
Mean Radius	26.262 m
No. of Bending Magnets	12
Bending radius	4 m
bending angle	30°
(Typical operation. Stretcher Mode)	
Betatron Frequency	
Horizontal (at injection)	6.48
Vertical (at injection)	6.70
Dilatation factor	0.0068
Electron energy	1.0,(0.6)GeV
Injection	two-turn
Pulse length	1 μsec
Repetition rate	300 pps
Peak current	100 mA
Energy spread	0.1,(3.0)%
Average current	30 μA
Stored Beam	
Circulating current	0.2A max.
Extraction	third integer
Mode	achromatic(monochromatic)
Average Current	30 μA
Duty factor	90 %
Energy spread	0.1%
RF system	
RF frequency	2856 MHz
Beam loading	4.4 kW
klystron	1kW×6
(Typical operation, storage mode)	
Electron Energy	1.5 GeV
Betatron Frequency	
Horizontal	6.39
Vertical	6.70
Dispersion Function(free space center)	1.6 m
Betatron Function (free space center)	
Horizontal(dispersive space)	5.3 m
(non-dispersive s.)	10.2 m
Vertical	1.2 m
RF-acceleration	
Frequency	476 MHz
Harmonic number	262
Beam loading (at 0.2 A)	23 kW
Klystron	100kW×1
Stored Beam	
Damping of energy oscillation	7.1 msec
Emittance	0.16 π mm·mr
Energy spread	0.064%