DESIGN STUDY OF PAL-STRETCHER RING*

I. S. Ko, G. N. Kim, J. Choi, M. H. Cho, and W. Namkung
Pohang Accelerator Laboratory, POSTECH
Pohang 790-784, Korea

We completed the commissioning of the PLS 2-GeV electron linac, which is a full energy injector for the storage ring of the Pohang Light Source, in June 1994. The prime mission for providing beams to the storage ring requires a few minutes for each injection, and a few times per day when the PLS is under the normal operation. Hence, we can utilize high energy electron beams to the electron scattering experiments. In order to produce high current and high duty factor beams, the design of a pulse stretcher ring is underway. This paper presents the result of the design study as well as the experimental plan.

I. INTRODUCTION

During the last few decades, the electron has been a preferable probe for the study on a short distance structure of nucleons. Since the electron does not have internal structures, the interactions with the nucleons is considered as a single-step character. It also gives a quantitative analysis on the electron-nucleon interaction since the electromagnetic interaction of the electron is explicitly calculable in terms of quantum electro-dynamics. Thus, the electron-nucleon scattering experiments can be unambiguously interpreted in terms of the structure of the nucleon to be proved. Such experiments performed in the 1960's showed that the nucleon form factors fell rapidly with increasing momentum transfer. These suggest a composite picture of the nucleon. It is now well known that nucleons are made of quarks, and that the force between quarks is generated by the exchange of a particle called the gluon. This fundamental force is described by the theory of color interaction known as quantum chromodynamics (QCD). However, it is far from easy to calculate hadronic and nuclear properties in terms of this theory. In order to have a better understanding on such matters, one continues experiments on the structure of nuclei and nucleons over decades. Such experiments demand higher energy and intensity of electron beams along with more sophisticated detectors.

The electron linac, which is generally used for electron scattering and photonuclear reaction experiments, provides a beam of a relatively high average current ranging up to several hundreds of μA. However, the linac usually gives a poor duty factor ranging up to at most a few percent. Such characteristics provide no difficulties for experiments such as inclusive electron-nucleon scattering experiments, in which only a scattered electron is detected. But, coincident experiments, in which emitted particles are detected in coincident with the scattered electron, are difficult to be performed because of bad accidental coincident rate (which is inversely proportional to the duty factor). Electron beams with high-current and nearly 100%-duty-factor are essential for such experiments. A linac-stretcher combination of a conventional electron linac and a pulse stretcher ring is one of the most promising solutions.

The Pohang Accelerator Laboratory (PAL) has recently completed the 2-GeV synchrotron radiation source named the Pohang Light Source (PLS). The PLS will serve as a low-emittance light source for various research such as basic science, applied science, and industrial and medical applications [1]. There is a 2-GeV linear accelerator as a full energy injector to the PLS. The prime mission for providing electron beams to the storage ring requires a few minutes for each injection and a few times per day when the PLS is under the normal operation. Hence, we can utilize the high energy electron beams of various energies for nuclear physics and other branches of basic and applied sciences. There are also increasing demands on the nuclear physics experiments using the PLS linac by many nuclear physicists in Korea [2]. The low duty-factor of present electron linac makes electron scattering experiments difficult. Such motivations encourage us strongly to design a pulse stretcher at the Pohang Accelerator Laboratory.

The future expansion of the PLS 2-GeV linac has been fully exploited during the site planning period in 1990. So the site of the stretcher ring and the extension of the beam transport line to the stretcher have been well considered as shown in Fig. 1 with other expansion plans. There is even a branch tunnel of about 5-m long at the end of the linac tunnel in order to minimize the PLS operation from the construction of the stretcher ring if such a plan approved.

II. STRETCHER DESIGN

There are several pulse stretcher rings under operations, and also several proposals to build them [3]. In the PAL stretcher ring, we fix the energy to 2-GeV since our injector linac provides 2-GeV beams. We also fix the repetition rate to 120 Hz because all modulators are designed to operate at maximum 120 Hz. Otherwise, increasing the repetition rate will require significant modifications to the modulators and high-power RF loads.

Usually, the stretcher ring requires a fast radiation-damping time to have a smaller energy spread for extracted beams. To have fast damping time, we need a higher magnetic field in the bending magnets. This gives a smaller circumference ring which is less costly. If the repetition rate is high, there is not enough time for the radiation damping. This restriction demands a smaller energy spread for the injection beam from the linac, which is also difficult to achieve. Instead, if we reduce the repetition rate low enough, then we have to keep a larger stored beam current in the stretcher before the beam is fully extracted. Otherwise, the extraction current will be reduced. Maintaining a large current in the stretcher ring may raise various beam instabilities or simply impossible due to the RF bucket limit. For 100% duty factor, it may give a poor energy spread for the first part of the extracted beam unless the injected beam has an excellent energy spread.

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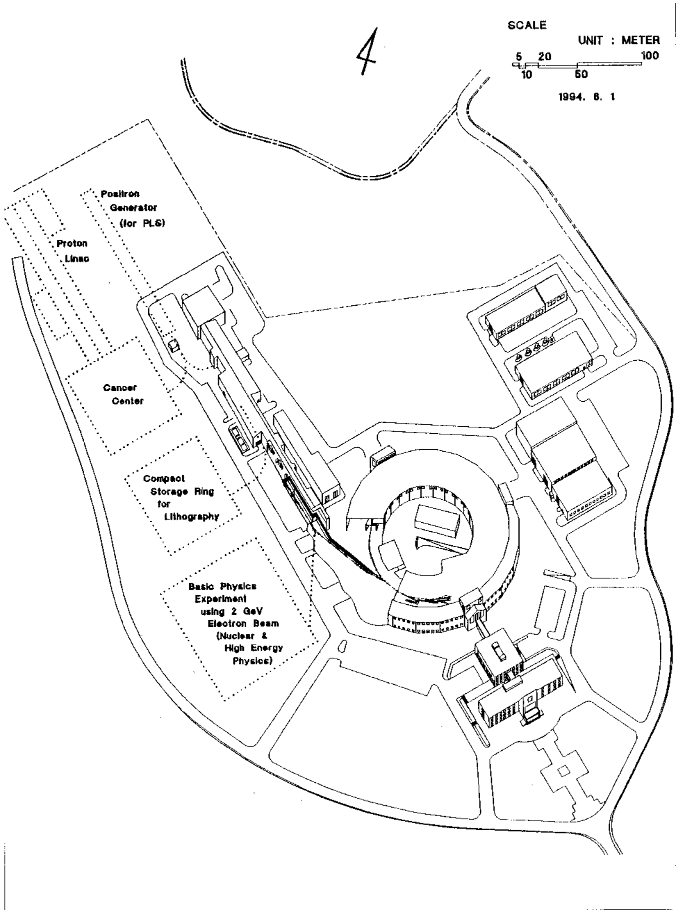

Fig. 1: Site Layout of Pohang Accelerator Laboratory

Such demands are sometimes self-conflicted, so we have chosen important parameters of the PAL stretcher ring listed in Table 1. The lattice of the PAL stretcher ring is shown in Fig. 2, and its beta functions are shown in Fig. 3.

There will be two beam exits; one for coincident experiments and the other for photon tagging experiments. The beam extraction will be made by slow excitations using sextupoles.

III. LINAC UPGRADE

In order to provide such electron beams, we need to improve the present PLS 2-GeV linac quite significantly. First of all, we have to deliver the number of electrons at least 100 (even 1,000) times more. We have to face significant beam loading effects and/or beam breakups. There must be several ways to compensate the energy spread such as a chicane or frequency-shifted energy spread compressions [4]. Furthermore, it may require to install wigglers in the stretcher ring for faster radiation damping. At present, we use 10 pulse compressors to accelerate the electron more effectively to 2-GeV. Such pulse compressors can not provide 4 μs flat-top pulses to accelerate the electron beam uniformly. There is a 15-m long space at the end of the linac to extend the 2-GeV linac if a higher energy beam is required. At present, this space is a part of the beam transport line to the storage ring. When we install one more klystron and 4 accelerating columns in this space, we can get the 2-GeV beams without using pulse compressors. Regardless of the PAL stretcher project, this upgrade plan will be carried out in 1996-1997 period to provide the 2-GeV beams for more secure operation of the Pohang Light Source.

It is also required to reduce the beam loss during the acceleration in order to improve injection/extraction efficiency in the stretcher ring and also to avoid extremely high radiation level.

Table 1: Major parameters for PAL stretcher ring.

Beam Energy	2-GeV
Circumference	241.5 m
Lattice Type	FODO
Symmetry	2 (racetrack type)
Bending Magnet	
Number	64 sets
Bending Angle	5.625°
Magnetic Field	0.7 T
Length	1.0 m
Curvature	10.19 m
RF Frequency	2,856 MHz
Harmonic Number	2,300
Repetition Rate	60/120 Hz
Revolution Time	0.81 μs
Extraction Current	100 μA
Injection Current	3.25 μs x 400 mA
Duty Factor	0.78
Injection	multi-turn
Energy Spread (injection)	< 0.1 %
Energy Spread (extraction)	+/- 0.02 %

IV. ACKNOWLEDGMENTS

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V. REFERENCES

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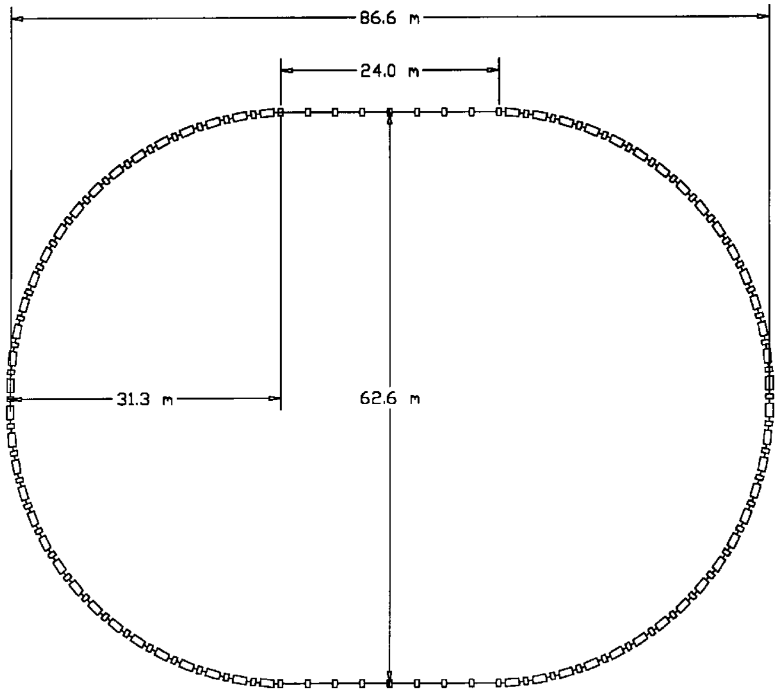

Fig. 2: Lattice of PAL stretcher.

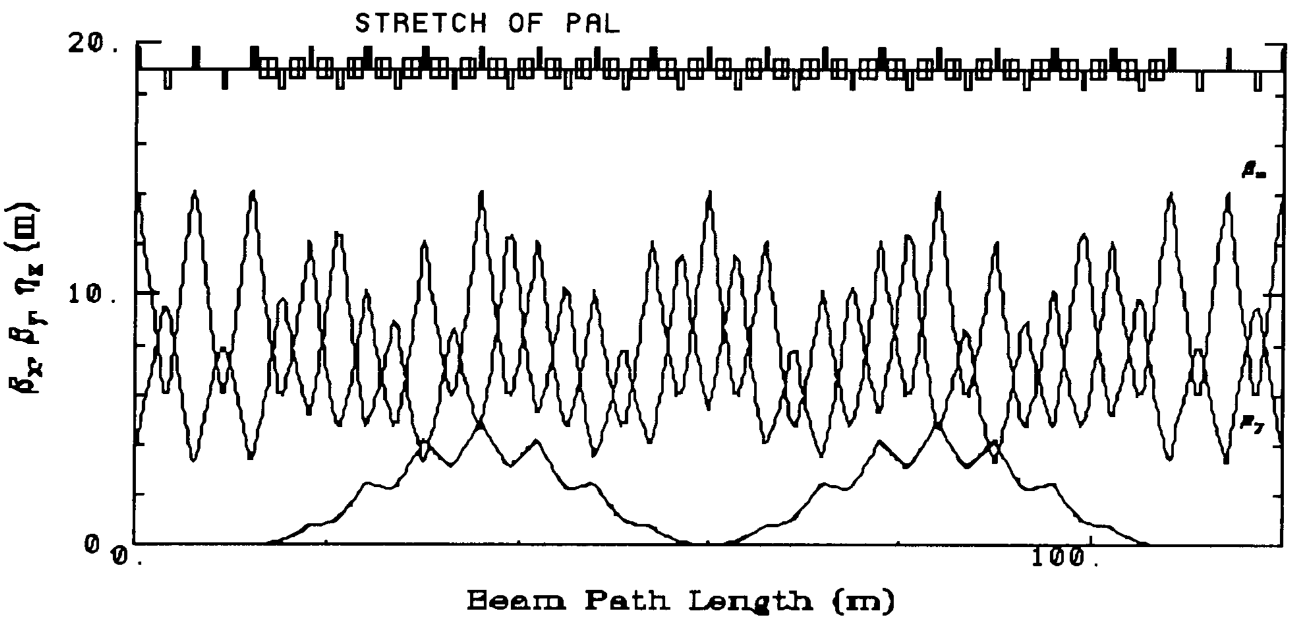

Fig. 3: Beta functions of the PAL stretcher ring.