Current Status and Future Scope on the RIKEN Accelerator Research Facility

Yasushige Yano
The Institute of Physical and Chemical Research (RIKEN)
Wako-shi, Saitama 351-01, Japan

Abstract

The RIKEN Accelerator Research Facility (RARF) has been further upgraded since 1991, according to the short- and middle-term improvement programs. Beam currents of 135 MeV/nucleon light ions routinely exceed 200 pnA; the maximum record has reached 500 pnA. A polarized deuteron beam of 270 MeV has been successfully obtained. Beam currents of RILAC-injected heavy ions have been improved by a factor of 2-3, by newly installing a second-harmonic buncher on the injection beam line of the RILAC.

The current status of the improvement programs including these achievements are given. A future plan of the facility presently under discussion is also briefly presented.

I. INTRODUCTION

The fifteen-year construction project of the RIKEN Accelerator Research Facility (RARF) [1] was completed in 1990. The milestones are outlined as follows. The heavy-ion linac (RILAC) was commissioned in 1981, and subsequently construction of the RIKEN ring cyclotron (RRC) was started. In late 1986, the RRC was commissioned, coupled with the RILAC. The routine operation of this accelerator complex began in April 1987. In 1987 - 1989, construction of the injector AVF cyclotron (AVF) and its ECR ion source, fabrication of major experimental apparatus, and extension of beam distribution lines were conducted. The commissioning of the AVF in 1989 allowed us to achieve the design goal of light-ion acceleration. Since September 1989, experimental programs have been carried out by using both RILAC and AVF injected beams. In late 1990 an ECR ion source, NEOMAFIOS [2], was newly installed on a high voltage terminal of the RILAC, being substituted for an old PIG ion source. This ECR source greatly improved the RILAC performance, and consequently the RRC performance for heavy-ion acceleration.

Since 1991, we have projected short- and middle-term programs to further upgrade the facility: extensive improvements are currently underway for the accelerators, beam lines and experimental apparatus. The programs are summarized in Fig. 1, some of which are described below.

II. UPGRADE PROGRAMS

A. 10 GHz ECR ion source for the AVF

The plasma cathode method has been applied to the first-stage structure of the 10 GHz ECR ion source, in an attempt to efficiently supply electrons into the second-stage plasma. As a result of this simple modification, beam currents of highly charged gaseous ions has been greatly improved, e.g. 80 eμA of $^{40}Ar^{11+}$. The method is also very effective to produce highly-charged metallic ions from their oxide, because electron temperature in the plasma becomes sufficiently high to evaporate them. In addition, distinct characteristics of very long lifetime, quite small gas consumption and comfortable stability have been realized.[3]

By means of this method, the AVF-RRC complex has been able to routinely provide, e.g., over 200 pnA (the maximum 500 pnA) of 135MeV/nucleon light ions and over 60 pnA of 95 MeV/nucleon ^{40}Ar ions.

B. Polarized p/d ion source for the AVF

The polarized proton/deuteron ion source was commissioned in June 1992. Through the modifications mainly of the dissociator, the ECR ionizer and the extraction device, the present level of performance for deuterons has reached to 140 μA with 50-60% polarization of the ideal value. Although this performance is less than perfect in the polarization, the source is ready for experimental use. Polarized deuteron beam of 100 nA has been obtained at 270 MeV. The current will be increased to the order of μA.[4]

C. Single turn extraction for the AVF and the RRC

The single turn extraction, caused by the first harmonic field perturbation, enables us to routinely obtain over 75% extraction efficiency for the AVF.[5] On the other hand, the off-centered acceleration technique to facilitate single turn extraction has been established for the RRC. Owing to this technique, beam transmission efficiency through the RRC is routinely over 70 %.[6]

Taking advantage of these single-turn extraction techniques, a spin of polarized deuteron accelerated by the AVF-RRC can be easily pointed in a wanted direction by an E×B spin rotator placed immediately downstream of the ion source.[4]

D. Second-harmonic buncher for the RILAC

An additional beam buncher, operating in a second-harmonic mode to an existing one, has been installed on the injection beam line of the RILAC. This two-buncher system has enhanced a phase compression power so that the beam transmission efficiency through the RILAC has increased by a factor of 1.6.[7] Moreover, the qualities of accelerated beams have been improved, and as a result the transmission through both the transfer line and the RRC has been improved. These improvements have produced the net upgrade of the beam currents of RILAC-injected heavy ions by a factor of 2-3.

The increase of the heavy-ion current has, for the first time, enabled us to create high-spin isomer beams, incorporated with a newly modified experimental apparatus in E1.

E. Stand-alone utilization of the AVF

Two experimental devices have been installed on the AVF extraction beam lines: one is an radioisotope production port placed at the end of the extraction straight line; another is a scattering chamber for slow-positron experiments placed at the end of the extraction vertical line in E7. At the end of the horizontal line in E7 a versatile scattering chamber will be installed. The AVF experimental programs, which are carried out during RILAC-RRC machine times, begun in June 1993.[5]

F. MCP beam phase detector

A new beam detector with a micro-channel plate (MCP) has been developed for time-structure measurement of the AVF and the RRC beams. It works not only as a phase monitor to stabilize the magnetic fields of the cyclotrons, but also as a monitor for single-turn extraction or a measuring instrument of turn number inside cyclotrons.[8]

G. New injector for the RILAC

Although the NEOMAFIOS, energy-saving ion source, suits the use inside the 500 kV high voltage terminal, its performance is much low, e.g. as compared with the 10 GHz AVF ECR ion source. Accordingly, for further upgrading RILAC beam currents, it is crucial to introduce a high-performance ECR ion source placed at a low voltage. The output beam from the source can be efficiently accelerated by an RFQ linac up to a necessary injection energy to the RILAC. A new injector of such configuration is being studied as the substitution of the existing injector.

For the ion source, a single-stage high-field 18 GHz ECR ion source has been preliminarily designed.[9] The reason for adopting the single-stage type is that very high charge states are not necessary for the RILAC, and that this type has high performance for low charge states in contrast to the two-stage type. For the RFQ, development is indispensable of a variable frequency RFQ producing the acceleration voltage equivalent to the terminal voltage. By computer simulations, we have designed a new variable frequency RFQ of a folded coaxial (FC) structure with a movable shorting plate.[10] This FCRFQ has the advantage of compactness even for a low frequency.

The new injector is scheduled for completion in late 1995, and is anticipated to upgrade beam currents of heavy ions by one or two order of magnitude.

H. RI beam generator

Low-energy and high-energy radioisotope (RI) beam generators are being designed. The former is to be installed as a new RILAC beam line, producing RI beams near the stability line by utilizing transfer reactions. On the other hand, the latter, utilizing projectile fragmentation reactions, is to be substituted for the analyzing magnets of the RRC beam, to distribute high-energy RI beams not so far from the stability line to the experimental rooms E2-E5.

III. FUTURE SCOPE

The concept of the RARF future plan is to construct "RI Beam Factory," where high-current RI beams of a wide mass range are available at a wide energy range up to several hundred MeV/nucleon. In oder to efficiently produce such RI beams via projectile-fragmentation reactions, energies of primary light-ion and very-heavy-ion beams are desired to exceed at least 500 MeV/nucleon and 100 MeV/nucleon, respectively.

One of the feasible machines to meet the requirements is a superconducting ring cyclotron boosting output energies of the RRC beams, keeping their currents. Feasibilities of a FFAG machine and a synchrotron-storage ring are also to be investigated.

IV REFERENCES

[1] H. Kamitsubo, "IPCR separated sector cyclotron with K=540," *in Proceedings of the 9th International Conference on Cyclotrons and their Applications.* Caen, France, September 1981, pp. 13-22.

[2] G. Melin, et al., *in Proceedings of Int. Conf. on Physics of Multiply Charged Ions and Int. Workshop on ECR Ion Sources*, Grenoble, France 1988, p.673.

[3] T. Nakagawa, et al.,"Status on the RIKEN ECRIS"s," *in this proceedings.*

[4] K. Ikegami, et al.,"Development of the RIKEN polarized ion source," *in this proceedings.*

[5] A. Goto, et al.,"Status of the RIKEN AVF cyclotron," *in this proceedings.*

[6] Y. Yano, "Recent achievements at the RIKEN ring cyclotron," *in Proceedings of the 13th International Conference on Cyclotrons and their Applications*, Vancouver, Canada, July 1992, pp. 102-105.

[7] S. Kohara, et al.,"Development of a second-harmonic buncher for the RILAC," *in this proceedings.*

[8] M. Kase, et al.,"Development of a beam phase monitor with a micro-channel plate for the RIKEN ring cyclotron," *in this proceedings.*

[9] T. Nakagawa, et al.,"Design of the 18 GHz ECRIS for the RILAC," *in this proceedings.*

[10] O. Kamigaito, et al.,"Design of a variable frequency RFQ linac for the RILAC," *in this proceedings.*

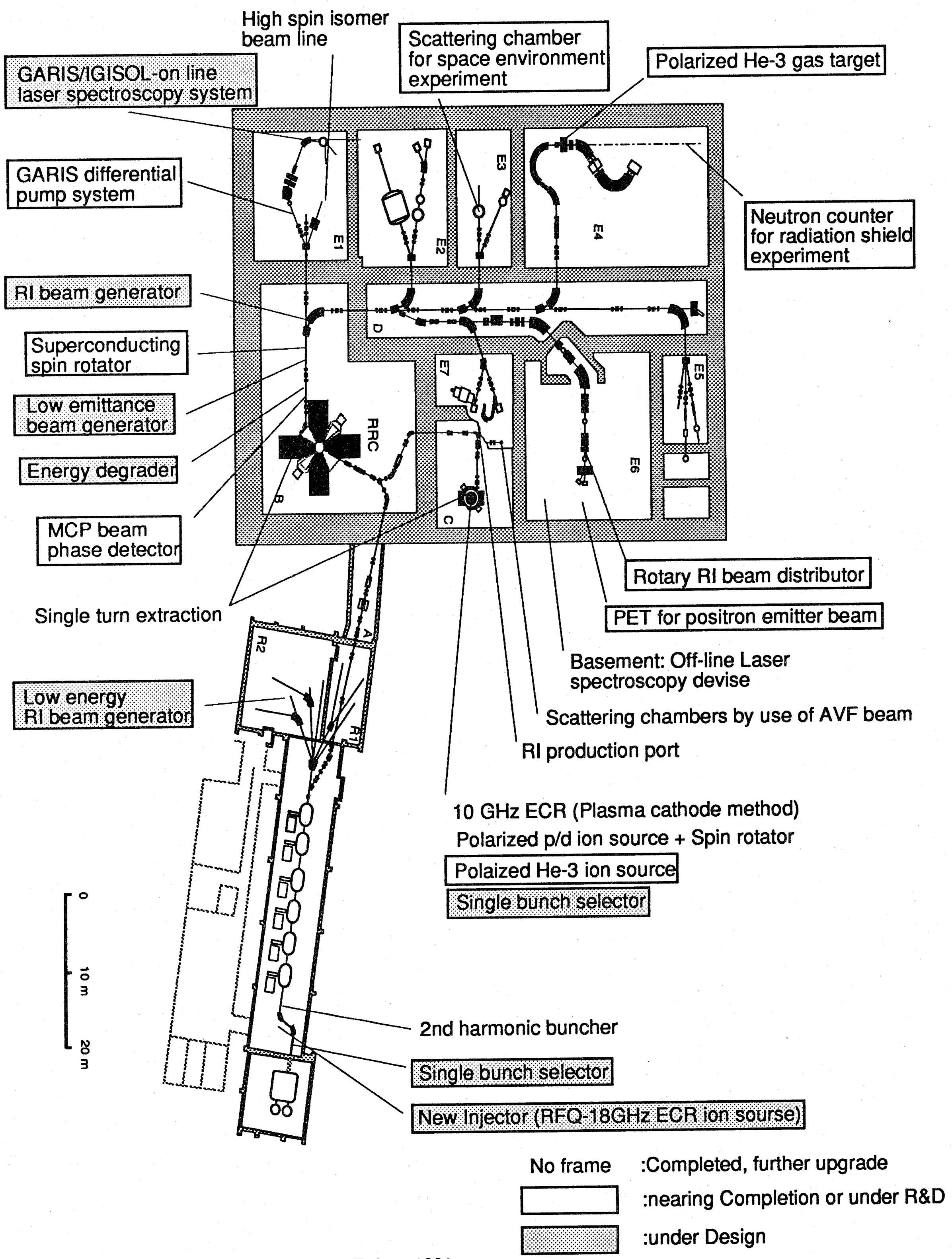

Fig. 1. Upgrade programs of the RARF since 1991.