Operation

1. Linac

1.1 Operation Status of SPring-8 Linac

The 1 GeV linac is able to produce the two kinds of beam pulse widths that are required for the SPring-8 storage ring operation mode: 1 nsec for single/several-bunch operation and 40 nsec for multi-bunch operation. For user service mode, the beam is injected into the storage ring once or twice a day.

Since the beam commissioning of the 1.5 GeV synchrotron radiation facility (“New SUBARU”) in September 1998, the linac has been an injector not only for the SPring-8 synchrotron but also for the New SUBARU. The beam parameters for the injection into the synchrotron and New SUBARU are summarized in Table 1.

Table 1. Beam Parameter of the SPring-8 Linac

	Storage Ring		New SUBARU
Pulse width	40 nsec	1 nsec	1 nsec
Beam current @ 1GeV BT	80 mA	0.1-1.0 A	50-200 mA
Transmission	77 %	45 % @ 1.0 A	84 % @ 67 mA
Energy spread	0.8 %	0.5 %	0.3 %

1.2 Stability of Linac

In order to realize uniformity of the bunch train in the storage ring, it has to satisfy the requirements of both reproducibility and stability of beam energy at the linac, which has a lot of high power RF equipment. During March, the intensive measurement of phase and power for many types of RF equipment that depends on outside factors have been carried out. As a result of suppressing the temperature fluctuation and other causes, the stability of beam current and beam energy at LSBT have been maintained within 0.7 % (1σ) and 0.1 % (1σ) variations, respectively [1-2].

1.3 Beam Energy Analyzing System

A beam energy analyzing system was completed at the end of the linac in January 1999. This system, which has a chicane shape, consists of four rectangular bending magnets, a bending angle of 24 °, a beam profile monitor and a non-destructive beam center energy monitor. These monitors are installed between the 2nd and 3rd magnets where the function η is 1 m. In order to confirm the performance of this system, a beam test was done by using the beam profile monitor of this system. As a result, the dispersion-free condition could not be satisfied downstream at the chicaine because the magnetic field has a quadrupole component. Two correction quadrupole magnets were installed at the monitor section in order to cancel the dispersion at the chicane. During normal beam injection, the 1 GeV beam is always analyzed by this system.

1.4 Beam Transport Line

The beam dispersion at the synchrotron is determined by the lattice at the Beam Transport line from the Linac to the Synchrotron (LSBT), which consists of a matching section and an achromatic section. In order to reduce the dispersion at the synchrotron, readjustment was carried out for five quadrupole magnets and septum magnets of the achromatic section.

During the summer shutdown period in 1998, two beam transport lines were constructed at the end of the Linac in addition to LSBT. One is for the injection into the New SUBARU and the other is the beamline to an experimental hall of the accelerator and beamline R&D facility. The basic transport of the beamline to the New SUBARU adopted a double-bend-achromatic lattice, while the beamline to the experimental hall has a triple-bend-isochronous-achromatic lattice. It was confirmed that the beam transport achieved the design lattice when the commissioning of the New SUBARU began in September 1998 [3].

2. Synchrotron

2.1 Activities for Synchrotron Operation

Single-bunch and several-bunch beams were formed by an rf knockout system (RF-KO) in the Synchrotron at the flat-bottom section of the beam energy of 1GeV. In order to decrease impurity, which is defined as the ratio of other-bunch beam current to main-bunch beam current, we increased the flat-bottom section from 150 msec to 250 msec to increase the time interval of single-bunch formation. Since the operation pattern of the synchrotron was changed, the optimum excitation pattern for the main magnets had to be redetermined.

The control system of the synchrotron was integrated with the standard control system of the SPring-8 [4]. Consequently, the parameters of the synchrotron could be changed quickly. Furthermore, operation of all of the equipment for the synchrotron has become simpler.

2.2 Major Problems in Synchrotron

Stored power in the rf cavities was lost twice a day on average because of the power reflection. It was recovered within 30 minutes. Since this mainly occurred due to the phase pattern operation of the rf system, the phase operation now begins one hour before the time of beam injection into the storage ring to avoid the influence of such trouble. Both the klystron and the thyratron in the power supply of the kicker magnet for beam extraction are replaced once a year due to breakdown. In order to recover from this problem quickly, we always keep maintenance parts.

Besides the above mentioned hardware problems, the parameters of the LSBT had to be adjusted twice during 1998 for user time operation.

2.3 1999 Plans for Synchrotron

Shot-by-shot fluctuation of beam current increases as the power of the RF-KO system increases because the timing system of the synchrotron was not synchronized to that of the linac. With stable beam current, we will investigate whether the bunch purity is improved by a high power RF-KO system. For the LSBT and the Beam Transport line from the Synchrotron to the Storage Ring (SSBT), a method will be established to adjust parameters simply and quickly. For the synchrotron, the drift of tune, change of COD and other major beam parameters will be observed for a long time.

3. Storage Ring

3.1 Operation of Storage Ring

The storage ring is usually operated on a three-week basis (1 cycle), with 38 × 8 hour shifts for user service mode, another 6 × 8 hour shifts for machine studies, and about 48 hours for machine tuning and beamline tuning.

In 1998, total operation time of the storage ring was 4,190 hours, and of this 2,624 hours (62.6 %) was delivered to the users during the year 1998. The down time was 110 hours, 2.6 % of the total operation time. The most significant incident in 1998 was a user time interruption of 15 hours due to a breakdown of the power supply of the sextupole magnets. During the last stage of 1998, user time was often interrupted when an action of the interlock system of the magnet and photon-absorber occurred due to a drop in flow rate of the cooling water.

3.2 Filling Modes

62.3 % of the total user time was delivered in the multi-bunch mode as shown in Fig. 1. In the first half of 1998, a full filling mode was used for the user time operation. After the summer shutdown period of 1998, a 2/3-filling mode was adopted for the user time operation, where two third of the 2,436 available RF buckets were filled continuously with electrons. In the storage ring, the beam lifetime in the uniform filling mode is significantly longer than that in the partial

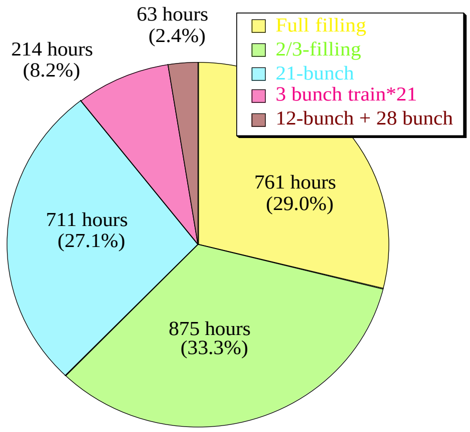

Fig. 1. Filling modes for user time during 1998.

filling mode. The cause may be that the electron beam size grows as a result of the instability due to an ion-trapping effect.

Nevertheless, usage of the several-bunch modes is increasing. For example, there was much time (724 hours) in 21-bunch mode (21 equally spaced bunches) between May and early July 1998. Other several-bunch modes are the 21-bunch train mode (21 equally spaced 3- or 7-bunch trains), 10-bunch + partially filled multi-bunch, and so on. Since we can select an arbitrary RF bucket among the 2,436 at each injection, the filling pattern in the storage ring can be easily controlled. 1 or 0.5 mA/bunch are stored, and purities in the low 10^{-6} range are routinely achieved in user time operation. The maximum current per bunch is about 12 mA in machine studies.

3.3 Performance of Storage Ring

The overall performance characteristics are listed in Table 2.

3.3.1 Optics

The lattice structure of the storage ring is a double-bend achromat type, and there are 48 straight sections where the dispersion vanishes. These straight sections are used to install not only insertion devices but also septum magnets for injection or RF cavities.

During normal operation of the storage ring, the “hybrid” optics was used. In the “hybrid” optics, the horizontal betatron function β_x takes a large value (about 20 m) and a small value (about 1 m) alternately in the straight sections.

The storage ring was routinely operated near the coupling resonance (ν_x=51.25, ν_y=16.32) with a coupling ratio of about 0.4 % before September 1998. Since the summer shutdown period of 1998, the procedure for decreasing the coupling, *i.e.* adjusting the operation point, has been successfully performed. The new operation point is (ν_x =51.15, ν_y=16.31). At this operation point, the coupling ratio is estimated to be around 0.06 %. When compared with the previous 0.4 %, this reduction gives an equivalent gain of a factor of 0.4 in the vertical beam size.

Table 2. Performance of SPring-8 Storage Ring

	Designed	Achieved
Unit cell type	Chasman-Green	-
Energy	8 GeV	8 GeV
Circumference	1435.948 m	-
Number of cell		
(normal / straight)	44 / 4	-
Current		
single bunch	5 mA	12 mA
multi bunch	100 mA	100 mA
Number of bucket	2436	-
Revolution time	4.79 µs	-
Tunes (ν_x / ν_y)	51.22 / 16.16	51.16 / 16.31
Chromaticities	-115.86 / -40.03 (natural)	3.21 / 3.93 (operation)
Energy Spread (ΔE/E)	0.0011	0.0012
Emittance	6.99 nm.rad	6.8±0.5 nm.rad
Coupling	10 %	≤0.06 %
Lifetime		
100 mA (full-filling)	24 hr	~60 hr
1 mA (single-bunch)		6 hr
Bunch length (FWHM)	35 ps[$1]	36 ps[$1]
Residual dispersion at non-dispersive section		
horizontal (rms)	0	1.4 cm
vertical (rms)	0	0.4 cm
COD		
horizontal (rms)	-	≤ 0.1 mm
vertical (rms)	-	≤ 0.1 mm

[$1] These values are estimated and measured at V_{rf}=11.6 MV.

3.3.2 Beam Reproducibility and Stability

The fill-to-fill and cycle-to-cycle reproducibility of the storage ring parameters are assured by strictly following a prescribed start-up sequence that includes conditioning of all magnets at start-up or after a failure that shuts down a power supply. The power supplies of magnets are kept turned on between cycles of 4 or 5 days. The reproducibility is checked by measuring the betatron tunes, COD and dispersion, which are sensitive to both magnet settings.

In order to stabilize the orbit of the storage ring, a periodic and global orbit correction is now routinely used in user time operation [5].

3.3.3 Beam Lifetime

The averaged pressure readings of the storage ring are 1×10^{-8} Pa without electron beam, 1×10^{-7} Pa at the straight section chamber and 9×10^{-7} Pa at the crotch and absorber location with a beam current of 70 mA. After a continuous cleaning by the synchrotron radiation, the pressure rise due to the photon induced desorption (PID) effect was significantly reduced. An integrated beam dose of 190 A•h and a beam lifetime of 60 hours at 100 mA of the beam current were achieved in the multi-bunch mode after two year operation. The lifetime in the several-bunch mode is limited by the Touschek effect. Touschek lifetime is about 6 hours in the single-bunch operation (1 mA/bunch) of the nominal machine parameter of the storage ring. Since the total lifetime (τ) in the 2/3-filling mode is 65 hours at a beam current of 70 mA, gas scattering lifetime is estimated to be $\tau_g \approx 140$ hours [6].

References

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