PRESENT STATUS OF SUPER-ALIS

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Abstract

The progress and present status of Super-ALIS are described. Fundamental ring parameters are measured. Stored beam current exceeds 100 mA. Beam life is short due to poor vacuum pressure caused by photon stimulated desorption.

Introduction

NTT has developed an SOR facility at NTT Atsugi R & D Center to study SOR applications to LSI technologies. [1, 2] This facility consists mainly of an injector linac, NAR, Super-ALIS, and a beam transport system. Electron beams of 15 MeV are transported from the linac to either the NAR or the Super-ALIS. NAR is a multipurpose low-energy-injection storage ring that uses normal conducting bending magnets. It also functions as a booster and backup machine for the Super-ALIS. Super-ALIS is a superconducting compact electron storage ring that is fully dedicated to X-ray lithography. At present, three beam lines are installed to the NAR. X-ray lithography research has been performed using one of these beam lines since June, 1988.

Super-ALIS

Super-ALIS is a race track type storage ring that uses a low-energy-one-pulse-injection scheme in which 15 MeV electrons are injected, then accelerated up to 600 MeV in a ring with a 125 MHz cavity. Figure 1 shows the Super-ALIS diagram. Table I shows main ring parameters. The maximum bending field is 3 T. The bending magnets, excited by one power supply, have iron yokes with magnetic poles. This configuration has the following advantages: a wide uniform magnetic field region at the injection level, smaller magnetomotive force and a smaller mechanical force acting on the superconducting coils, which reduces manufacturing risks for the superconducting magnets. Six quadrupole, two sextupole, and one octupole magnets are installed in the two straight sections. Low energy electrons from the linac are injected through an electro-static inflector. High energy electrons from the NAR are injected through a magnetic inflector. A perturbator is used for 15 to 600 MeV electrons. Each quadrupole magnet has a trim coil for betatron function measurement. The ring has a button type RF pick-up, RFKO electrodes, a DCCT, a fast CT, and beam profile monitors with fluorescent screens. Button electrodes for position measurements are located on each quadrupole magnet. At BL2 and BL8, SOR monitors are installed to observe the beam profiles during acceleration and the storage state. Each magnet has five SOR extraction ports. In X-ray lithography, the horizontal size of the port duct is large, enabling SOR with a horizontal angle of 10 degrees to pass. Another feature for lithography purposes is an orbit wobbling system, that moves the electron orbit while maintaining the same displacement at all SOR source points, as is shown in Fig. 2, thus expanding the vertical irradiation area by up to ±15 mm.

Injection Linac

Efficient large current injection is a key technology to achieve low-energy-one-pulse-injection. For this injection, low transverse emittance, large current, and narrow energy spread are demanded of the injection accelerator. We have developed an injection linac that can satisfy the above demands. [3] Figure 3 shows the block diagram of this linac system. The 90 keV electrons from the gun are longitudinally modulated by two pre-bunchers, and then accelerated to 15 MeV in the

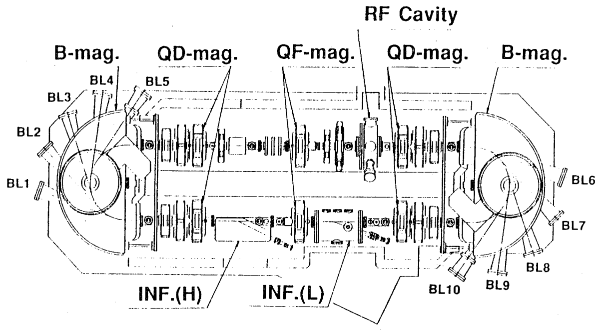

Fig. 1. Super-ALIS diagram.

Table I. Super-ALIS ring parameters

		Designed	Achieved
Final Energy		600 MeV	600 MeV
Injection Energy		15 MeV	15 MeV
Maximum Bending Field		3 T	3 T
Betatron Number	νx	1.55~1.70	1.565
	νy	0.2 ~0.7	0.530
Beam Size	σx	< 1 mm	1.26 mm
	σy	-	0.19 mm
RF Frequency		125 MHz	124.855 MHz
Critical Wavelength		17.3 Å	-
Vacuum Pressure *		5×10^{-10} Torr	2×10^{-10} Torr
SOR Port Number		10	-
Circumference		16.8 m	-
Footprint		2.5 × 8.8 m²	-

* without beams

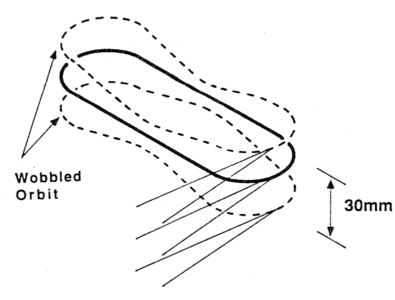

Fig. 2. Wobbled orbit illustration.

standing-wave type cavities. Beam energy spread is reduced, by a factor of ten, by an energy compression system (ECS). Beam energy and spread are measured by a succeeding energy analyzer. Several beam monitors are located after each of the subsystems; electron gun, accelerating cavities, and ECS, thus making tuning of the linac system easy and precise. Table II summerizes linac specifications and performances.

Progress and Present Status

The linac, the beam transport system and the NAR were installed in November 1987. Super-ALIS installation, parts

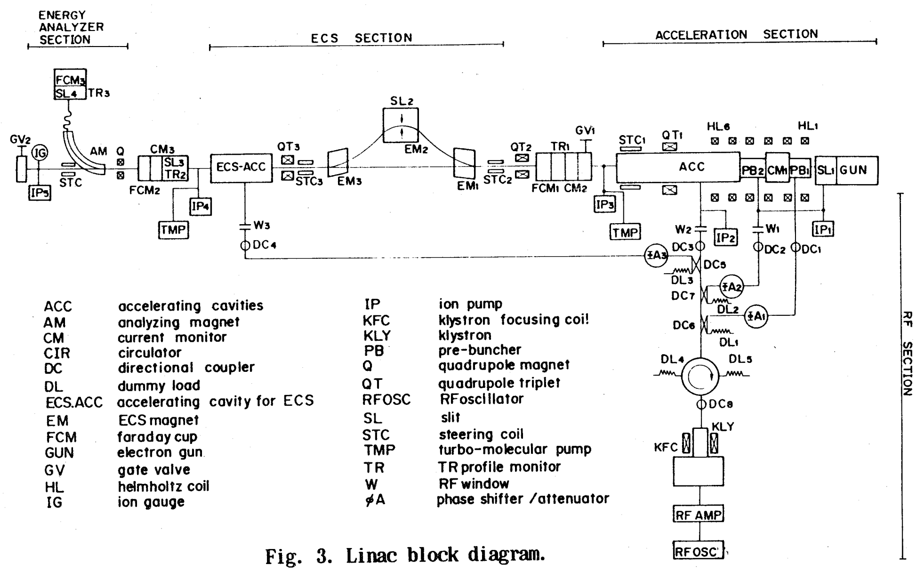

Fig. 3. Linac block diagram.

Table II. Linac parameters

	Designed	Achieved
Beam Energy	> 13 MeV	15 MeV
Beam Pulse Width	> 2.0 μs	2.0 μs
Beam Current	> 250 mA	270 mA
Energy Spread	< 1 %	1 % (FW)
Beam Size	< 4.0 mmϕ	3.0 mmϕ
Beam Divergence	< 0.5 mrad	1.4 mrad
Transverse Emittance	< 1 $\times 10^{-6}$ π mrad	2.1 $\times 10^{-6}$ π mrad
Repetition Frequency	3 Hz max.	3 Hz max.

inspection, and magnet field measurements at the installation site have been completed in April 1988. Machine tuning, including the beam transport system, started in May 1988. Beam acceleration and storage at 600 MeV was accomplished on February 3rd, 1989. The first stored beam current was 1.6 mA. Major effort has been devoted to increasing the current ever since. A beam current of 13 mA was achieved in March of this year, 45 mA in June, and currently it is over 100 mA. [3,4] Figure 4 shows stored beam current progress. These beam currents have been obtained using the low-energy-one-pulse injection scheme. Higher energy injection has not been used.

Beam current, at the beginning of acceleration, is around 150 mA. Short life and tracking errors are the main causes for beam loss in the early stages of acceleration. This short life is due to the large beam size caused by injection, and the large scattering cross section of residual gas molecules for low energy electrons. Ion trapping effect becomes serious when beam energy nears 100 MeV. For successful acceleration to be performed this effect must be supressed. Stored beam current is limited due to the following reasons;

(a) Linac beam current degradation. This degradation is believed to result from extended electron gun operating time in excess of 4000 hours.
(b) insufficient tuning of the beam transport system.
(c) Unoptimized tracking patterns of the Super-ALIS.

Beam life is somewhat short. It is around 3000 sec at 80 mA. The average vacuum pressure is 2×10^{-8} Torr with 80 mA beams and 2×10^{-10} Torr without them. Figure 5 shows the relationship between beam life and vacuum pressure. Beam life is roughly inversely proportional to the pressure independent of the beam current. This indicates that this short life is mainly due to the poor vacuum pressure

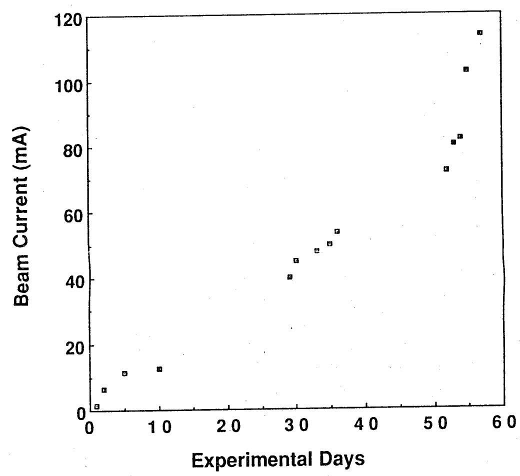

Fig. 4. Stored beam current progress.

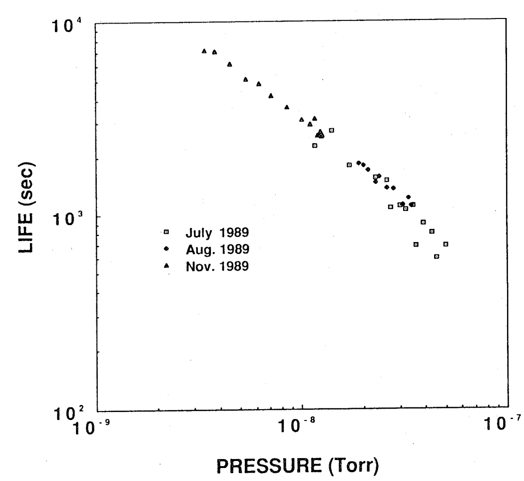

Fig. 5. Vacuum pressure vs beam life.

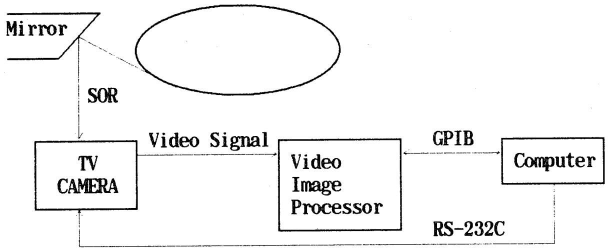

Fig. 6. SOR profile monitoring system.

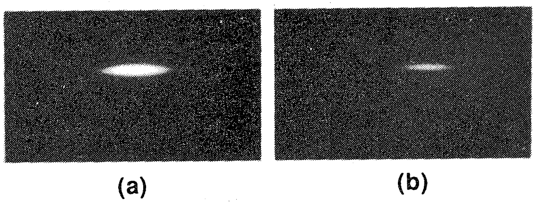

Fig. 7. SOR profiles at beam currents of (a)80mA, (b)10mA. TV camera sensitivity is the same. Beam energy is 600 MeV.

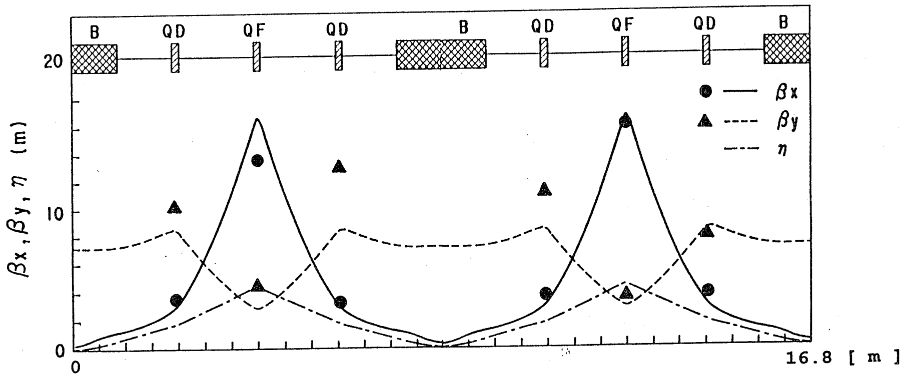

Fig. 8. Measured betatron functions. Solid and dotted lines indicate calculated results.

caused by photon stimulated desorption. Therefore, life is expected to increase by using successive machine operaion. The long time required to lower vacuum pressure is, however, a serious problem in regards to industrial machines. A new material with a lower photodesorption yield for absorbers may solve this problem. (5)

Figure 6 shows the SOR profile measurement system. The SOR is reflected by a water-cooled oxygen-free-copper mirror, coated with platinum, and focused by an optical lens on a CCD in a television camera through a sapphire window coated with titanium. Video signals from the camera are transmitted to an image processor. The camera and the image processor are controlled by computer through the RS-232C and GPIB, respectively. The processor averages the TV images and then measures the distance between the points where image instensity reaches 1/e of the peak value, thus obtaining beam size. Resolution of the system is 0.044 mm. Figure 7 shows SOR profiles for 80 mA and 10 mA beams at 600 MeV. Though beam size looks different, depending on beam current, in Fig. 7 measured beam sizes are nearly the same; σx=1.26 mm, σy=0.19 mm. Measured horizontal beam size is slightly larger than the calculated one.

Betatron frequencies were measured by the RFKO method. The modulated beam signal is detected, not by an optical sensor, but by 4 button electrodes because the SOR intensity is too weak to detect in a low energy range. Signals from the electrodes are combined to produce horizontal and vertical positional signals. The Measured frequencies are νx= 1.565 and νy=0.530 at 600 MeV. Betaron functions are estimated from the tune shift that occurs when the trim coils are excited. The results are shown in Fig. 8. Discrepancies between calculated and measured βy may be due to closed orbit distortion (COD), since the CODs have not been corrected. The measurement results are summerized in Table Ⅰ.

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