STATUS OF THE 1GEV SYNCHROTRON RADIATION SOURCE AT SORTEC

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ABSTRACT

The construction of the 1GeV synchrotron radiation source facility[1] optimized for the production of soft x rays has been completed in the end of March this year at Tsukuba Research Laboratory of SORTEC Corporation.

Initial beam operation has been started in the end of July after four months of tests without beam.

The first beam was successfully stored in the storage ring at the design energy on September 28. The stored beam current of 200mA which is our design goal has been achieved with the beam lifetime of over 4 hours only one month after the first beam storage.

This paper gives a summary of the characteristics of the facility and describes the remarkable progress during the initial beam operation.

INTRODUCTION

Synchrotron radiation is expected to offer remarkable possibilities for many fields of science and technology. In recent years, there are worldwide interests in the field of industrial applications including x-ray lithography[2]-[4].

The major purpose of SORTEC Corporation is to study the application technologies making use of synchrotron radiation. Therefore, the facility is optimized for the production of soft x-rays around 1 nm which meet the lithography requirements.

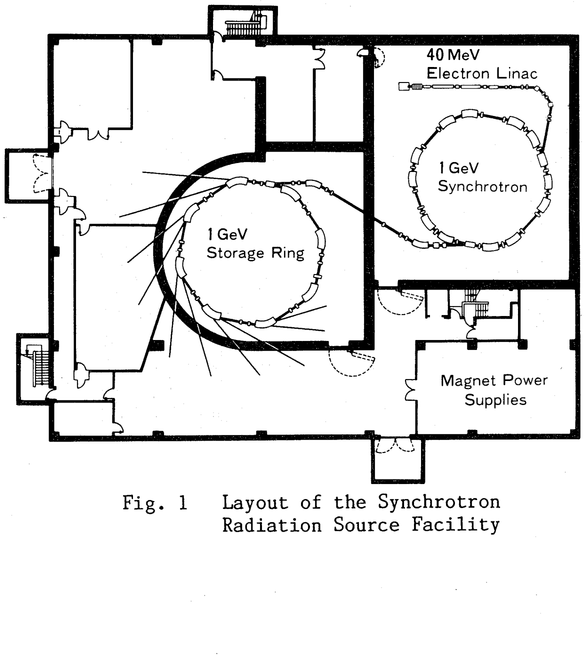


Fig. 1 Layout of the Synchrotron Radiation Source Facility

Table 1
Major parameters of the 1GeV
Synchrotron Radiation Source Facility

	Designed	Achieved
Storage Ring		
Energy	1 GeV	1 GeV
Dipole Field	1.2 T	-
Bending Radius	2.78 m	-
Critical Wavelength	15.5 Å	-
Beam Current	200 mA	200 mA
Beam Lifetime	4 hr	4 hr
Circumference	45.7 m	-
Synchrotron(injector)		
Injection Energy	40 MeV	-
Maximum Energy	1 GeV	1 GeV
Dipole Field(max.)	1.1 T	-
Beam Current	30 mA	50 mA
Circumference	43.2 m	-
Linac(pre-injector)		
Energy	40 MeV	40 MeV
Beam Current*	>30 mA	60-80 mA
$\Delta E/E$	<±1.5 %	±0.67 %
Emittance	<3.8π mm mrad	0.7π mm mrad

* Useful beam current which satisfies the values of $\Delta E/E$ and beam emittance

1 GEV SYNCHROTRON RADIATION SOURCE FACILITY

As shown in Fig.1, the facility consists of a 40MeV electron linac(pre-injector), a 40MeV to 1GeV booster synchrotron(injector) and a 1GeV storage ring(SOR ring).

Though, in general, industries would prefer that synchrotron radiation source be as compact as possible in the future lithography system, we have determined to adopt a steady accelerator system for our facility making use of proven technologies such as full energy injection scheme and normal conducting magnet system in order to attain a stable light source and to provide sufficient intensity of synchrotron radiation as soon as possible.

Table 1 shows major design parameters of our facility together with the achieved values as of October 31.

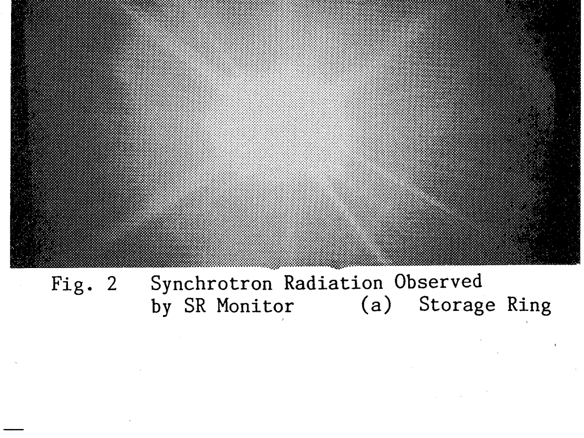


Fig. 2 Synchrotron Radiation Observed by SR Monitor (a) Storage Ring

The fact that the beam energy, current and lifetime all reached design goals successfully only a month after the first beam storage, indicates the validity of our choice described above.

Fig.2 shows the pictures of synchrotron radiation observed by SR monitors through the viewing-ports.

As to the spectral characteristics and the intensity of radiation, the electron energy and the dipole field of the storage ring have been selected to generate synchrotron radiation of nearly 1.5 nm critical wavelength and the stored beam current of 200 mA has been chosen. Spectrum and spatial distribution of synchrotron radiation are shown in Fig.3.

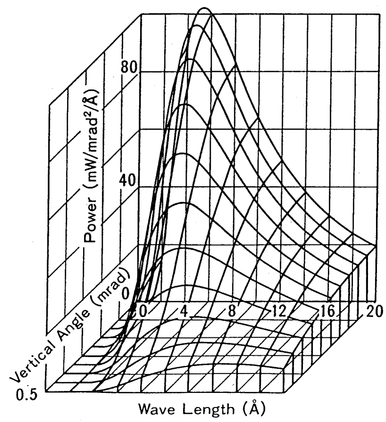


Fig. 3 Spectrum and Spatial Distribution of Synchrotron Radiation

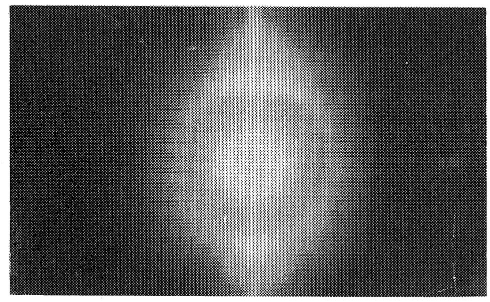


Fig. 2 Synchrotron Radiation Observed by SR Monitor
(b) Injector Synchrotron

The pictures of accelerators are shown in Fig.4. The linac and the booster synchrotron are placed in the injector room adjacent to the storage ring room. The power supplies for dipole and quadrupole magnets for the synchrotron and beam transport system are placed in another room as shown in Fig.1. In case of the storage ring, the whole power supplies are placed inside the ring as shown in Fig.4. The accelerators are placed in the basement except for the computer control system.

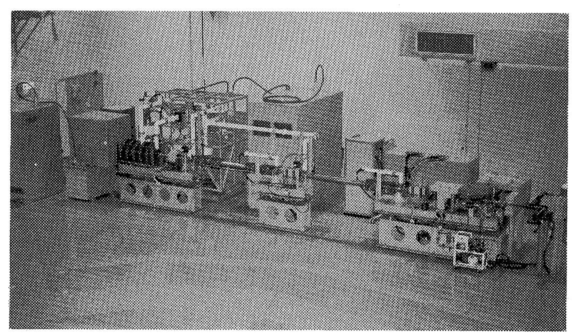
INITIAL BEAM OPERATION AND IT'S RESULTS

The initial beam operation of our facility has been started on July 26 1989. At first, the optics of the beam ejected from the electron linac was surveyed and adjusted so that the beam can be guided along design orbit of low energy beam transport line. Also in this beam transport line, the beam current, the energy spectrum and the beam emittance were measured.

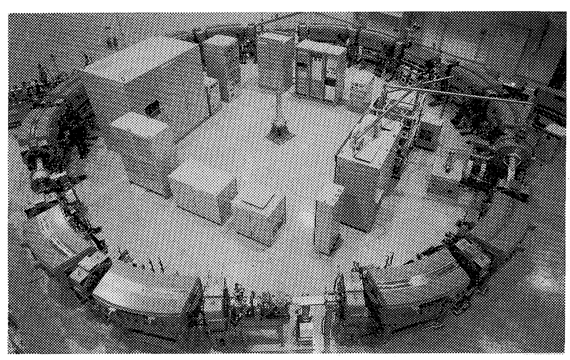
The output beam quality from the linac satisfied the requirement as a pre-injector as shown in table 1. The beam characteristic from the linac and configuration of the beam transport line are reported in detail in ref.(5).

At the beginning of August, beam test of the synchrotron has been started. The beam from the transport line is injected into the septum magnet and is stacked by multi-turn-injection process during 1 μs and energy is ramped from 40MeV to 1GeV in 400ms. Though the injection cycle is designed to be repeated every 800ms, the cycle was repeated every 3.2s during the initial beam operation.

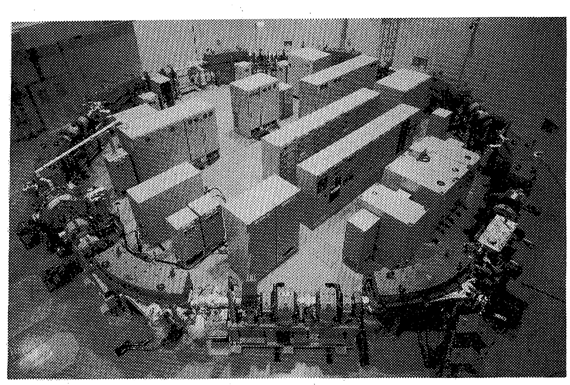
At the middle of september,the beam acceleration to the top energy was succeeded after several beam tests concerned with the multi-turn-injection process, the adjustment of betatron tunes and tracking of magnetic fields between dipoles and quadrupoles during the acceleration of energy.



(a) Electron Linac



(b) Injector Synchrotron



(c) Storage Ring

Fig. 4 The Pictures of Accelerators in the Synchrotron Radiation Source Facility

Synchrotron radiation was also observed through a SR beam monitor of the synchrotron during the acceleration as shown in Fig.2 (b).

Maximum accelerated beam current of 50mA, which is 70% larger than the design current, has been obtained up to now. The more details about the synchrotron are reported in references (6) and (7).

The beam injection into the storage ring and single turn test began on September 27 making use of screen monitors. The beam current of 3.5mA has been stored at the design energy the day after the first injection. Synchrotron radiation was also observed through SR beam monitors.

The first stored beam lasted 2 hours until the beam was stopped by intention. The substantial time required for the beam tuning for the attainment of the first beam storage was 9 hours.

After 2 weeks of beam cleaning by the maximum beam current of around 60mA, the beam lifetime reached 3 hours at 50mA and 2 hours at 80mA . Corresponding pressure in the vacuum chamber is 1.4×10^{-9} Torr. with beam and 6.4×10^{-11} Torr. without beam.

The stored beam current of 200mA which is our design goal has been achieved on October 23. Also the beam lifetime of 4hours at 200mA has been achieved at the end of October. In Fig.5, the beam current, the lifetime and corresponding vacuum pressure at the end of October are shown. In this figure, measured lifetime, i.e. the two fold lifetime(200mA to 100mA) and the e-fold lifetime(200mA to 200/e mA) are also shown.

The improvement of the beam lifetime day by day is also shown in Fig.6 which represents the decay rate of the beam current[8] .

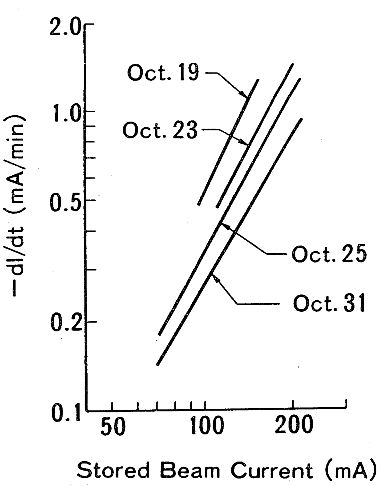


Fig. 6 The Improvement of the Beam Lifetime (The Decay Rate Plot)

In parallel with the beam cleaning, the tuning of the beam was carried out such as adjustment of betatron tunes, COD corrections, detuning of the RF cavity and ion clearing,etc.. The more details about the storage ring are reported in ref.(9).

The picture of the synchrotron radiation shown in Fig.2(a) was taken at the beam current of 175mA with optical filters for the protection of CCD camera.

The maximum injected current per shot into the storage ring is about 5mA which is 12% of the synchrotron beam. The minimum time required for the storage of 200mA beam in the storage ring is 3 minutes up to now, which is faster than our estimation in the design stage.

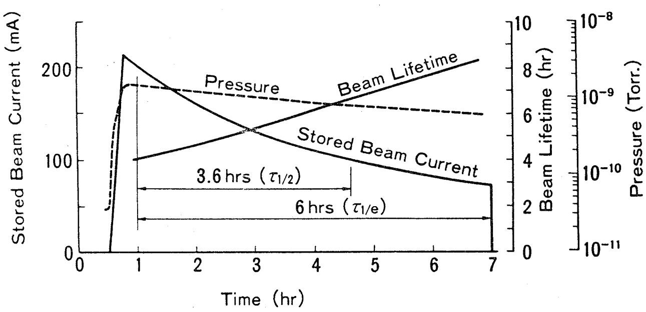


Fig. 5 Stored Beam Current, Beam Lifetime and Vacuum Pressure Obtained at the End of October 1989

Since the beam tuning and machine conditioning are in progress, the improvement of the performance can be expected hereafter with more precise measurements of the beam behavior.

The user operation is planned to start at the end of this fiscal year for the study of the application technologies of synchrotron radiation. In parallel with the regular operation, the machine studies will be continued to achieve the beam current of over 500mA.

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