DEVELOPMENT OF NEW COMPACT SR RING “AURORA-2”

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Abstract

A new racetrack type compact SR ring for soft X-ray source, “AURORA-2” (A2), was designed using normal-conducting high-field bending magnets which achieved 2.7 Tesla to keep the ring small without superconducting technology. There exists two versions, AURORA-2S (A2S) and AURORA-2D (A2D). The former is designed as a dedicated ring for X-ray lithography, and the latter for various scientific researches. The latter A2D has therefore two long straight sections for insertion devices such as undulators and/or wigglers. A prototype of A2D had been constructed and successfully tested with a 7 Tesla superconducting wiggler. The ring was then disassembled after its performance test clarifying the stored current of 300 mA, and reassembled as A2S which has now been under commissioning. One more A2D type had also been constructed and installed with two undulators in Hiroshima University as HiSOR.

1 INTRODUCTION

We have been developing compact SR rings, the AURORA series, since 1986. The target of most small rings is for industrial use, especially for X-ray lithography. The first AURORA which is unique because of its half-integer resonant injection method is the only circular ring in the world, the ultimate shape of compactness. AURORA is one of the typical superconducting SR rings, which was transferred from our Lab. to Ritsumeikan Univ. in 1995 [1].

We started designing an advanced compact ring A2 in 1994 with a new concept of normal conducting magnet which enabled us to use 2.7 T bending field without superconducting technology [2]. A version having Single quadurupole in its straight section , thus called A2S, is the one optimized for X-ray lithography

Fig. 1-a) Overall view of AURORA-2S (A2S).

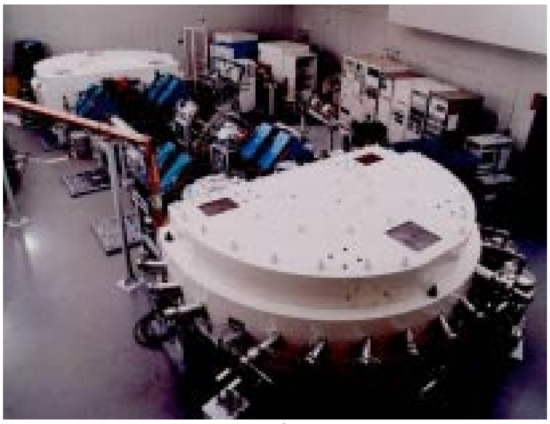

Fig. 1-b) Overall view of AURORA-2D (A2D).

achieving the ring as compact as possible. The other having quadrupole Doublet, thus called A2D, was designed to accomodate insertion devices in its straight sections. Figs. 1-a), 1-b) show the whole view of the both rings.

Prior to the commissioning of A2S, we carried out the performance check of A2D after the completion of construction and assembling in March 1997. Following the satisfactory performance test of A2D, we immediately installed a 7 T superconducting wiggler and proved the possibility of A2D to inject and accelerate a 150 MeV beam under the existence of the wiggler field within the very limited period from August to September in 1997.

On the other hand, the commissioning of HiSOR (= the second A2D) in Hiroshima University also started shortly after the A2D’s initial performance test. In July 1997, the machine accomplished the delivery condition, and the operation of HiSOR has been being done by the university staff since then [3].

2 BRIEF DESIGN FEATURES

The most outstanding feature of A2 lies in the design of 2.7 T normal conducting bending magnet. A2 takes over many advantages of the original AURORA, however, the injector racetrack microtron of 150 MeV [4], cryopanels of high vacuum in the chamber of the bending magnets and self-shielding function for A2S, for instance. Another unique feature of A2 is in the control system. On the contrary to other control systems, we built simple but flexible, and economical system. It consists of one server and four PC’s connected together by LAN. Signals are transmitted maimly on GPIB to all equipments. Under this system, obsolete hardwares would be easily replaced.

More precise features of both A2S and A2D are presented in the reference [2]. The parameters related to A2 are listed in Tabel 1. Beam simulation results of A2D in the presence of wiggler, single and double, are described in the references [5], [6]. Figs. 2-a), 2-b) show the layout of A2S and A2D, where the distance between two 180° bending magnets of A2D is 7m and a part of this length, actually 3m, is reserved for insertion devices. Fig. 3 shows the SR spectra from bending magnet and 7 T wiggler, where both critical wavelengths are 1.4 nm and 0.54 nm, respectively.

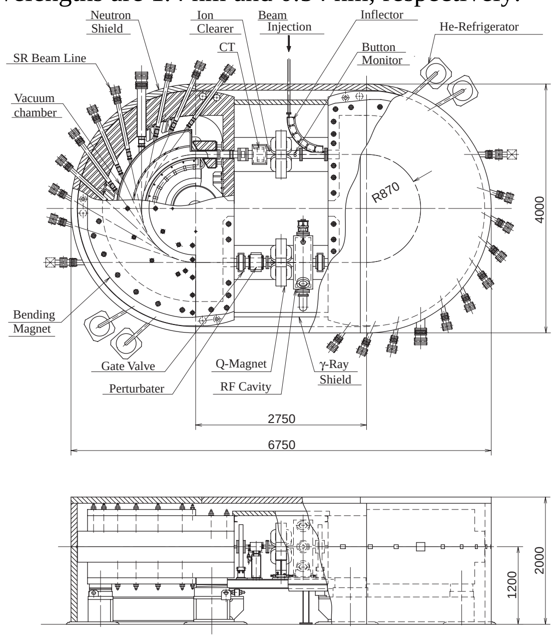

Fig. 2-a) Schematic of A2S.

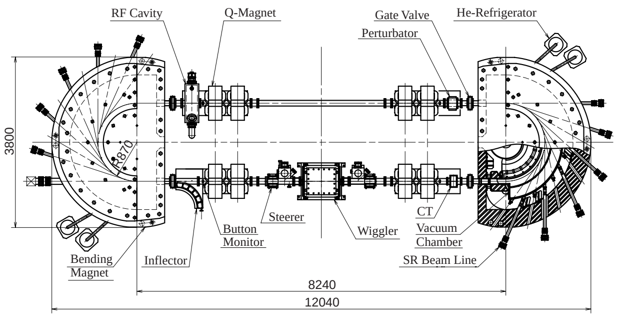

Fig. 2-b) Plan of A2D with 7 Tesla wiggler.

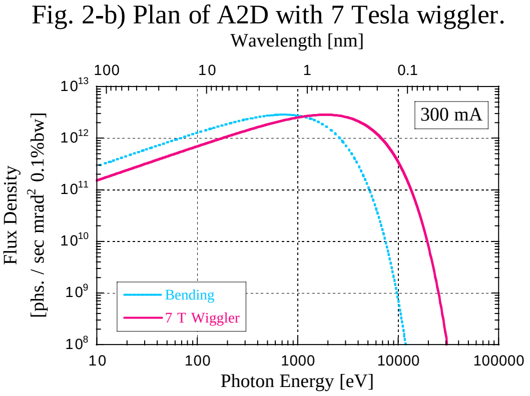

Fig. 3 Energy spectra of SR from 7 Tesla wiggler.

3 TEST RESULTS OF A2D

The test started in early April. It took just one week to find the proper ramping pattern keeping the synchronization between both the bending and quadrupole fields. What necessary while acceleration is to take into account the eddy current effect induced in the massive solid-iron poles of bending magnets, which causes some delay in the rising of bending field. To compensate this effect which increases in proportion to the exciting speed di/dt, 6 A/sec is the rate finally adopted, we introduced time difference in between the ramping pattern of those bending and two quadrupoles [7]. It takes two minutes to ramp up the bending field by the current from 103 A to 833 A, which is equivalent to the beam energy from 150 MeV to 700 MeV.

We succeeded in accumulating 700 MeV beam in both A2D and HiSOR within a month. In principle the behaviors of two rings were about the same and we did not find any inconvenience derived from individuality of two systems.

3.1 Beam Test of A2D without wiggler

The test of A2D started in April and stopped in July in order to add the 7 T superconducting wiggler. As the operation was interrupted once in a while, vacuum improvement work etc., the net operation was limited to forty days in total. Within this term, we recorded 318 mA stored current at 700 MeV, starting from 384 mA of injected beam with 83% of acceleration efficiency as shown in Fig. 4-a). The maximum injected current at 150 MeV recorded 424 mA. The lifetime at 100 mA was limited around 30 min because of poor vacuum 5×10^{-8} Torr.

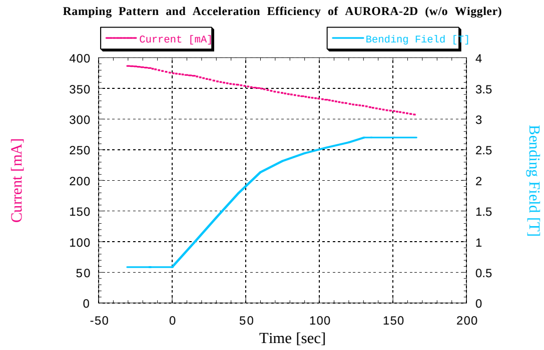

Fig. 4-a) Typical acceleration pattern of A2D.

On the contrary, HiSOR was kept in operation and an aging effect seemed to be coming out towards 3 hrs lifetime at 100 mA after 12A･Hr of integrated current. The ring was entering 10^{-9} Torr at 100 mA.

3.2 Beam Test with 7 Tesla Wiggler

The main pole of the wiggler is kept at 1.5T while injection and 7T while accumulation. It takes 5.5 min. to accelerate the beam up to 700 MeV. The ramping pattern of the wiggler was made with constant di/dt of the exciting current, which is equivalent to excite the bending field as constant dB/dt [7]. It means that if we apply this ramping pattern to the ring without wiggler, we can shorten the acceleration period about 25%, from 2 min. to 1.5 min.

The test was carried out under the poor vacuum condition, $1x10^{-8}$ Torr base pressure in the straight section, because of tight schedule. The obtained results were as follows; maximum injected current =116 mA, maximum accumulated current =19 mA, and typical acceleration efficiency =32% starting from 56 mA and 18 mA remained. This low efficiency is mainly due to poor vacuum, $5x10^{-7}$ Torr while acceleration. When the starting current was reduced to 18.6 mA, then we obtained 61% efficiency with 11.4 mA remaining. Fig. 4-b) shows those acceleration conditions.

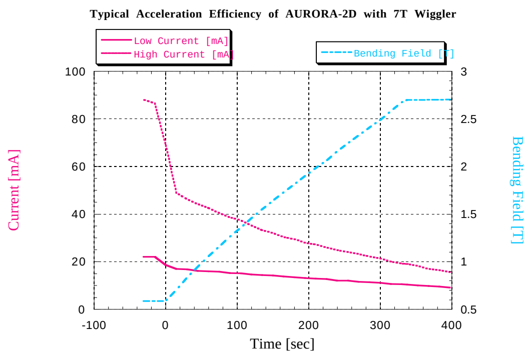

Fig. 4-b) Acceleration efficiency of A2D with wiggler.

4 STATUS OF A2S BEAM TEST

The disassembling from A2D and reassembling to A2S was made in between September 1997 to January 1998. The commissioning of A2S which started in late January has been continued. At present it recorded about 200 mA injected current and 100 mA of stored current, about one-fifth of the goal 500 mA. The aging of the ring is not in mature, therefore, we cannot expect sufficient lifetime to the stored current for a while. We found no difficulties in the acceleration pattern while ramping the 150 MeV injected current up to 700 MeV in two minutes.

Our intensive effort has been directed to analyse the phenomena of unexpected instability observed in the injected beam, which can be seen from very low current, even less than 1mA for instance. It seems some longitudinal coupled bunch instablity caused by higher order modes of the RF cavity. The damping time of transverse oscillation was measured by a real time spectrum analyser (type 3066 of Sony Techtronix) and found too short, ~2 msec in typical, to enhance transverse instabilities. The study to remodel the installed cavity has been in progress.

5 CONCLUSION

It is proved that even a compact SR ring like A2D is able to co-operate with a superconducting wiggler. SR users may get a useful tool even from the small machine with insertion devices such as undulators and wigglers. On the other hand, a small ring like A2S also has a chance to meet some instabilities. This time, the most doubtful is a coupled bunch instability originated in the RF cavity. Some measures are in preparation to suppress the instability.

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6 REFERENCES

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	A2S	*A2D*	*1W7T*
Energy (GeV)	0.7	0.7	0.7
Circumference (m)	10.97	21.95	21.95
RF voltage (kV)	220	220	220
Harmonic number	7	14	14
RF frequency (MHz)	191.36	191.24	191.24
Energy aperture (MeV)	7.72	5.94	5.50
Energy loss (keV/turn)	24.42	24.42	29.07
Synchrotron freq (MHz)	1.42	0.147	0.156
Momentum compaction	0.196	0.165	0.185
Tune : horizontal	1.46	1.59	1.59
vertical	0.73	1.55	2.10
Natural chromaticity :			
horizontal	-1.68	-1.4	-2.3
vertical	-0.82	-2.8	-3.8
Natural ε (π nm·rad)	527.6	474.0	934.6
Energy spread (MeV)	0.449	0.421	0.444
Radiation damping :			
horizontal (msec)	2.13	5.87	5.60
vertical (msec)	2.10	4.20	3.53
longitudinal (msec)	1.04	1.84	1.49
Bunch length (mm)	26.5	32.4	36.2
Touschek life (hour)	6.6	5.7	9.9
Quantum life (hour)	$>10^{32}$	$>10^{32}$	$7x10^{24}$
Field strength : B (T)	2.7	2.7	2.7
QF (T/m)	12.5	9.4	10.9
QD (T/m)	—	-8.6	-12.3

Table 1 Parameters of A2 with and without a wiggler.