Aladdin II[+]

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Abstract

Aladdin II is a lattice variation of the Aladdin 1 GeV electron storage ring located at the Synchrotron Radiation Center. The new lattice is realized without any physical repositioning of dipoles or quadrupoles by uncoupling and separately powering four sets of quadrupoles. The Aladdin II lattice is characterized by long straight sections having zero dispersion and symmetric beta functions that can be varied from 0.5 m to 5 m. The Aladdin and Aladdin II lattice functions are compared and dynamic aperture calculations for each lattice are presented. Even though the dynamic aperture for Aladdin II is reduced slightly, it is still dominated by the physical aperture. Changes in injection and in the characteristics of the dipole synchrotron radiation sources are also discussed.

I. Introduction

During the early design stages of the Aladdin 1 GeV electron storage ring at the Synchrotron Radiation Center, the beam optic design of the long straight sections was driven by the requirement of betatron and dispersion matching. Figure 1 shows the lattice functions for one quadrant of Aladdin.

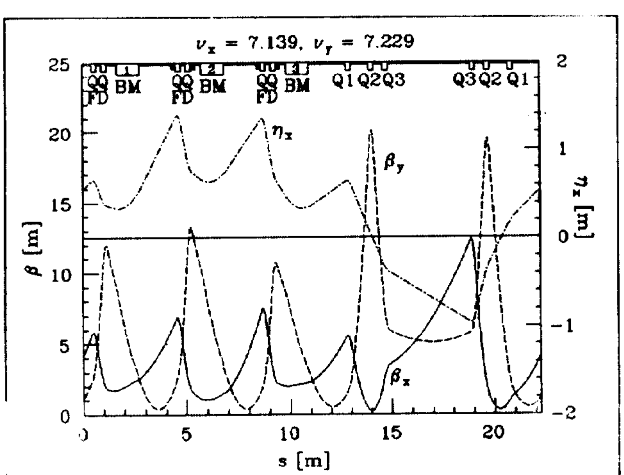

Figure 1. Aladdin Lattice Functions.

Several features should be noted: 1) there is a rather large negative dispersion in the middle of the long straight sections, 2) the radial betatron function is very asymmetric with respect to the center of the straight between the quadrupole triplets, and 3) the betatron function and dispersion is about the same in each dipole, implying that each radiation source point has about the same size. Aladdin was originally designed to be a bending magnet synchrotron radiation source machine with long straight sections to be utilized at some future date. This original design was accomplished with five independent quadrupole power supply strings, labeled QF, QD, Q1, Q2, and Q3.

During the latter part of Aladdin commissioning, it was suggested that the Aladdin lattice could be reconfigured to have long straight sections with zero dispersion [1]. This could be accomplished **without repositioning or moving any of the major components.** Moreover, the betatron functions could be made symmetric with respect to the center of the straight sections. This could be accomplished by breaking up four of the quadrupole strings and making four new quadrupole sets, making nine in all. The new sets are called QFX, QDX, Q1X, and Q2X. The next section will discuss the linear dynamics and the following section will look into the changes in dynamic aperture. Section V will discuss some of the operational and user aspects of the new machine, Aladdin II.

II. Linear Dynamics

A. Procedure

In order to zero the dispersion and its slope in the long straight sections, the only easily adjustable elements are the quadrupole doublets, QF and QD. Using the codes LATTICE [2] and SYNCH [3] the values of QF and QD were set to give the zero dispersion condition. At the same time, with zero dispersion in the entire long straight section, the quadrupole doublet at the end of the straight and just before the first dipole of the three that make up a quadrant can be connected to different power supplies, QFX and QDX. These separate quads can now be used to adjust tunes.

For the purpose of adjusting the lattice functions and tunes, five sets of quadrupoles are now available: the original Q1, Q2, and Q3 sets; and the new QFX and QDX sets. This leaves no flexibility with respect to changing of the betatron function values or symmetry with respect to the center of the long straight. Control of the long straight lattice functions is accomplished by freeing the Q1 and Q2 quadrupoles closest to QFX and QDX from their strings and

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putting them on their own power supplies. This gives a final complement of nine quadrupole sets.

With the flexability afforded by the extra quadrupole sets, several betatron function distributions for the long straight sections have been studied. Aladdin has 4 m available for undulators or wigglers at the middle of the long straight sections. Theses devices perform best when centered at a point where the betatron function is symmetric. To this end the only Aladdin II lattices studied had the slope of both β_x and β_y equal to zero at the middle of the central 4 m section. The quadrupole and sextupole excitations for several of the lattices studied are given in Table 1. The only constraints used in determining the acceptability of a particular configuration were the maximum gradient of the quadrupoles and sextupoles and the maximum current of their power supplies. The units of the quadrupoles (Q's) are T/m and of the sextupoles (S's) are T/m². Figure 2 shows the lattice functions for the Aladdin II, Mark VI design. This variation has $\beta_x = \beta_y = 5$ m at the middle of a long straight section. While many zero dispersion lattices have been studied, the Mark VI version was chosen for initial implementation beacause of 1) a conservative form factor for the betatron functions and 2) very conservative values for the chromaticity sextupoles. These conditions were chosen over trying to maintain the dispersion at identically zero. In fact the dispersion for the Mark VI lattice has a maximum value of 5.5 cm in the long straight, still a very small value.

Table 1
Lattice parameters for several designs

	Aladdin	Aladdin II Mark III	Aladdin II Mark VI	Aladdin Plus
QF	14.17	15.31	15.45	15.31
QFX		4.84	11.08	15.31
QD	-14.89	-14.98	-14.67	-14.98
QDX		-7.14	-11.46	-14.98
Q1	12.50	10.62	8.94	9.06
Q1X		4.58	4.53	9.06
Q2	-14.94	-13.79	-12.65	-14.16
Q2X		-10.44	-10.04	-14.16
Q3	12.42	8.79	7.21	10.8
SF	80.20	43.58	43.44	46.60
SD	-158.00	-186.92	-128.59	-176.20

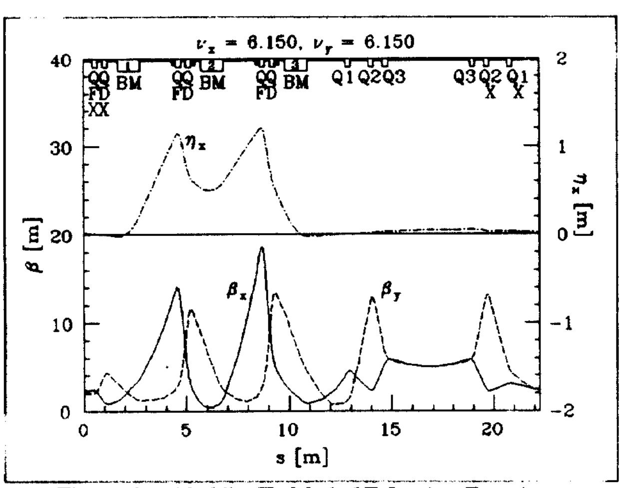

Figure 2. Aladdin II, Mark VI Lattice Functions.

B. Aladdin Plus

Table 1 also shows a set of parameters for an interim experimental lattice which is simply made by retuning all five of the present Aladdin quadrupole sets. The resulting machine has the same tunes as Aladdin but zero dispersion in the long straight sections. Under these conditions there is no capability for betatron function control. The free sets of quadrupoles are used only to keep the tunes constant. This configuration has been successfully run and shows little difference in lifetime or photon source sizes when compared to Aladdin.

III. Nonlinear Dynamics

In order to estimate the performance of Aladdin II, calculations of dynamic aperture for Aladdin and Aladdin II were compared. The calculations were done using the code MARYLIE [4]. The calculations up to now do not include alignment errors or synchrotron oscillations. The particles were tracked for 10,000 turns. The resulting dynamic aperture for Aladdin is shown if Figure 3. The limiting

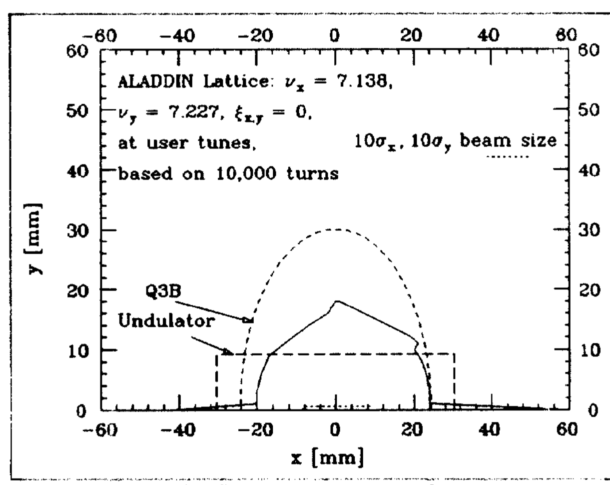

Figure 3. Dynamic Aperture of Aladdin.

vertical aperture is the vacuum chamber at the undulator, 19 mm full height. The limiting horizontal aperture appears to be at the second Q3 quadrupole in the long straight section. Figure 4 shows the same computation performed on the Aladdin II, Mark VI lattice. The dynamic aperture still

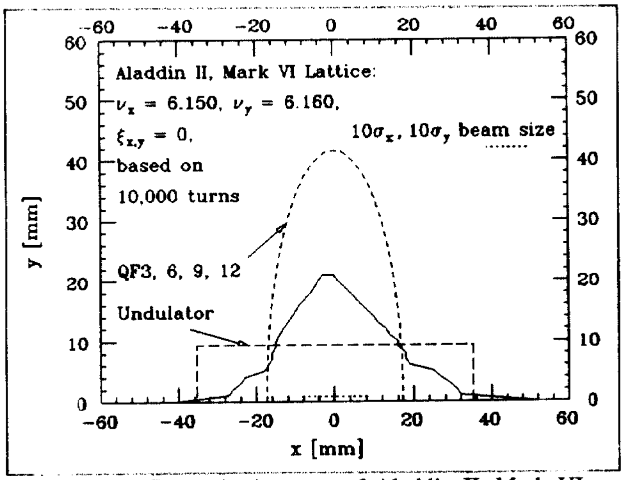

Figure 4. Dynamic Aperture of Aladdin II, Mark VI.

has the same gross features, i. e. the vertical limit dominated by the undulator vacuum chamber and the horizontal limit at quadrupoles QF3. From the point of view of the simplest dynamic model, the performance of the two lattices is expected to be the same. Also shown on each of the two Figures 3 and 4 are 10 σ values as determined by emittance calculations from the code SYNCH. These calculations use a 10% size coupling for obtaining the vertical emittance.

With the addition of the four quadrupole strings, the lattice is very flexible with respect to tuning the betatron functions at the middle of the straight section. As an example, Table 1 includes the necessary quadrupole strengths for Aladdin II, Mark III. This variation has $\beta_x = \beta_y = 1$ m at the middle of a long straight. One can see that the SD sextupole strength is much greater than that of Aladdin. In fact, to utilize this lattice different sextupoles would have to be constructed, with different power supplies. These alternative lattices will be studied in detail once Aladdin II, Mark VI, is operational.

V. Other Considerations

A. Injection

In order to inject into the Aladdin II lattice, an extra kicker had to be added. Aladdin uses two kicker magnets, separated by 180° in betatron phase. The addition of a third kicker between the two already there will allow direct injection into any of the Aladdin II variations, and may even help improve injection efficiency for Aladdin.

B. Source Sizes

The original Aladdin concept was to provide the same source size from each of the bending magnet ports. The machine design was basically 12-fold symmetric with matching long straight sections. Under this format each dipole presented similar source cross sections. In the Aladdin II configurations, the vertical source sizes at the three dipoles in each quadrant, are significantly different. Table 2 compares calculated beam sizes for Aladdin and Aladdin II, Mark VI, and includes the values at the position of an undulator in the middle of a long straight section. As an example, σ_y for dipole type 3 is almost a factor of two larger than that of dipole type 1 (Dipole types are indicated in Figures 1 and 2 as BM 1, etc.) in the Mark VI lattice. These differences may have an impact on the future location of photon beamlines.

Table 2
Source Size Comparison

	Aladdin		Aladdin II Mark VI	
Dipole	σ_x	σ_y	σ_x	σ_y
1	469.2	74.8	508.1	55.3
2	440.7	82.3	322.7	90.3
3	476.3	75.3	518.8	106.6
Und'r	848.5	63.0	821.0	82.5

(all values are in μm)

VI. Next Steps

The implementation of Aladdin II is well underway. The four extra power supplies are on site and their plumbing and power busses are being installed. The third kicker driver is under construction. Commissioning of Aladdin II is expected to start in the fall of 1991.

VII. Acknowledgement

The authors are indebted to the entire staff at SRC for their aid and cooperation. A special thanks goes to the machine operators for their patience in allowing us to experiment with a user oriented facility.

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