HISOR-II, COMPACT LIGHT SOURCE WITH AN INNOVATIVE LATTICE DESIGN

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Abstract

We proposed a ring that a beam orbit is not closed with one turn and return to starting point after multiple turns around the ring. The idea of this new accumulation ring was inspired based on the torus knot theory. This ring has a long length of the total closed orbit in comparison with a conventional ring which has the orbit of one turn. Therefore this ring can have many straight sections and is advantageous to installation of insertion devices.

On the other hand, this ring must achieve low emittance to operate as the 3rd generation light source ring. Therefore we designed lattice of this ring in reference to MAX-III and achieved low emittance by using bending magnets with combined function.

INTRODUCTION

For small light source rings, it is very important problem to obtain a lot of straight sections that we can install the insertion devices, but it is difficult in reality, because they are occupied by various magnets, RF systems or beam monitors. Therefore we got a hint from the shape of the torus knot [1], and contrived the ring which had the orbit closed after multiple turns around the ring [2] and named it AMATELAS.

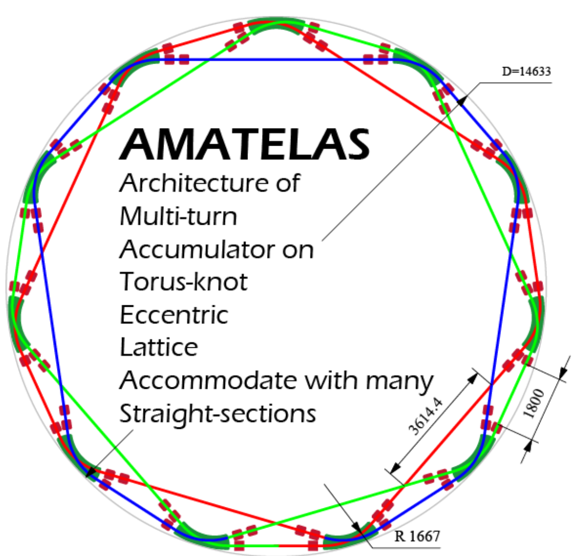

Figure 1: Schematic draw of (11, 3) AMATELAS designed for HiSOR-II.

We are designing a new ring based on the shape of a (11, 3) torus knot for our future plan 'HiSOR-II' [3]. This ring has 11 long straight sections and can place undulators effectively by placing elements such as quadrupole magnets at the place near bending magnet, outside of the orbit crossing section. Furthermore, this ring has about 3 times longer circumference in comparison with the conventional ring, the diameter of the ring is as compact as 15 m, but its circumference is as long as 130 m. The AMATELAS ring designed for HiSOR-II is shown in Figure 1.

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DESIGN FOR SR RING

Low Emittance Lattices

Double Bend Achromat (DBA) is generally well known as a low emittance lattice, and it is often used for synchrotron light source rings. In late years, the lattice which introduced dispersion into the straight sections is applied to achieve low emittance than that of DBA.

The natural emittance is written with radiation integrals as follows [4].

$$\varepsilon_x = C_q \gamma^2 \frac{I_5}{I_2 - I_4}$$

Where C_q is the classical radius of the electrons, and I_2, I_4 and I_5 are

$$I_2 = \oint \frac{1}{\rho^2} ds,\ I_4 = \oint \frac{D}{\rho}\left(\frac{1}{\rho^2} + 2K\right) ds,\ I_5 = \oint \frac{\mathcal{H}}{|\rho|^3} ds.$$

In MAX-III of MAX-lab., they adopt the combined function type bending magnet with QD field and use the lattice that K in I_4 is negative value and achieve ultra low emittance. Therefore we considered in possibility of the adoption of the MAX-III type lattice to the AMATELAS ring.

Crossed Orbit in Bending with Gradient Field

The combined type bending magnet with QD fields are necessary to MAX-III type lattice. On the other hand, beam orbit crosses in the bending magnet of AMATELAS, but it is impossible to superimpose two crossing bending sections having field gradient. (Shown in Figure 2(a)).

Therefore we consider one big magnet that have field gradient along imaginary centre orbit which pass through the cross point of 2 orbits. (Figure 2(b)) When we ignore bending fields, this orbit is similar to orbit passing a quadrupole magnet diagonally. (Figure 2(c)) However, it is necessary to consider that the bending radius and the focusing force change by the differences of the bending forces and changing the angles for the imaginary centre orbit.

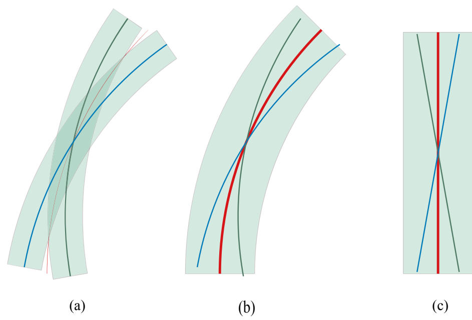

Figure 2: Crossed orbit in the bending magnet with gradient field.

We calculated one of two orbits crossing in a bending magnet with concrete parameters and show the result in Figure 3. The blue dotted line in the figure shows the orbit of the arc of radius 1667 mm when there is no field gradient, and the imaginary central orbit becomes the arc of a radius of 1838 mm of the red solid line from a geometric condition. When -1.0 T/m magnetic field gradient was given along its centre axis, the beam of 700 MeV goes along the orbit of the green solid line.

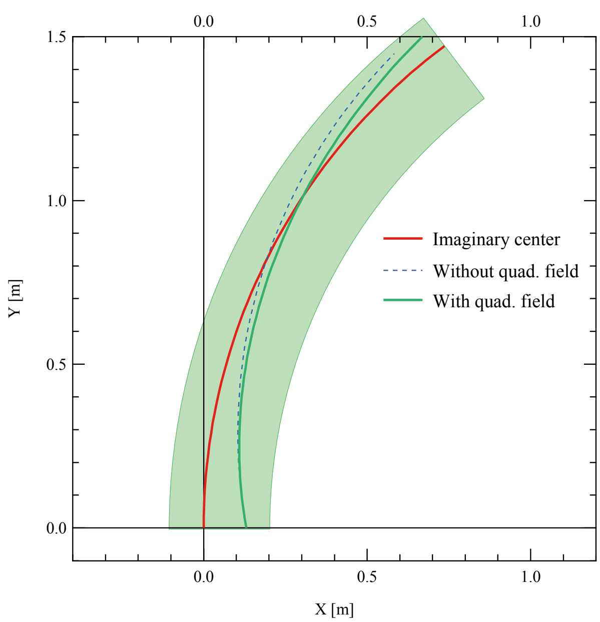

Figure 3: The difference of orbit by field gradient of the bending magnet.

Figure 4 shows the calculated result of the deviation of focusing force that the beam receives along this real orbit. The magnetic field gradient along the imaginary central orbit is supposed with -1.0 T/m, but the focusing force that the beam feels becomes weak because the beam orbit inclines 9.44 degrees at an entrance of the magnet. Furthermore, the gradient along the beam orbit changes so that an angle with the imaginary central orbit changes as the beam goes ahead through in the magnet. However its change is about 1% and we expect that it does not have a so much serious influence on the linear lattice calculation.

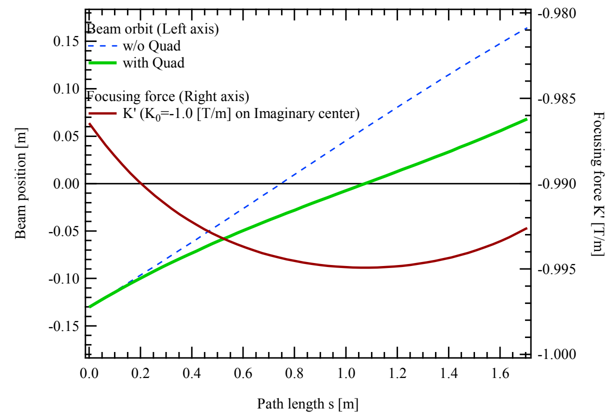

Figure 4: The deviation of focusing force along the orbit in the combined bending magnet.

Operating Point and Optical Functions

The AMATELAS has straight sections of two kinds of length, and they are placed including two bending magnets alternately. Therefore this ring can apply Double Bend system. We adopt the combined function type that we mentioned previously to the bending magnets, furthermore, using the quadrupole magnet of three families, we adopt the placement of magnets that it is possible to switch two kinds of lattice, MAX-III type and DBA.

Figure 5 shows the optical functions of 1/3 of the ring when the operating point of the ring is set at the Low emittance mode and DBA mode each, and the natural emittance in each mode achieved 17.4 nmrad and about 35 nmrad. The main parameters of (11, 3) AMATELAS designed for HiSOR-II storage ring is shown in Table 1.

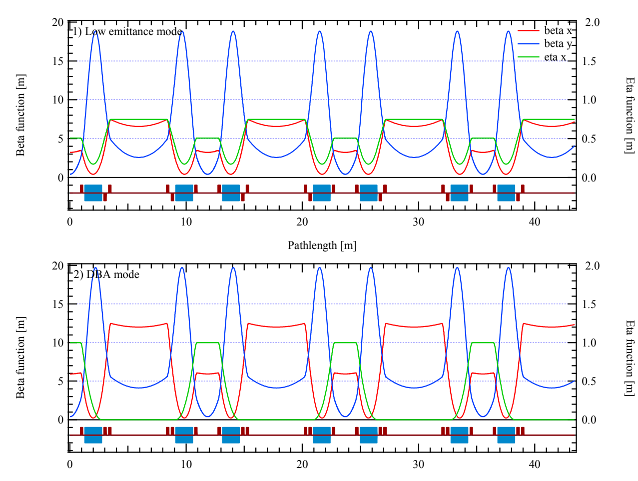

Figure 5: The optical functions on each operating point. 1):Low emittance mode, 2):DBA mode.

Table 1: The main parameters of (11, 3) AMATELAS designed for HiSOR-II storage ring.

Perimeter	45.97 m
Orbit shape	(11,3) Torus knot
Orbit length	130.297 m
Beam energy	700 MeV
Straight sections	3.614 m ×11 1.800 m ×11
Harmonic number	88
RF frequency	202.474 MHz
Low emittance mode	
Betatron tune	(10.54, 6.67)
Natural emittance	17.4 nmrad
DBA mode	
Betatron tune	(10.78, 6.93)
Natural emittance	34.6 nmrad

Beam Collision at the Crossing Section

One beam orbit intersects the other at the straight sections and the bending sections of AMATELAS. If we do not make the charge density of the bunch high so much, it is thought that there is no serious influence which the beam is lost, for example. However, we considered that we made the electron bunch and the light from undulator or the other bunch interact intentionally, studied about the condition to collide the beam.

The length of each part of AMATELAS is almost unchangeable because of the geometric condition. When we fixed the bending radius to ρ=1667mm and changed length of the long straight sections and RF frequency, we calculated the distance d from the crossing point to the bunch which was at nearest position. The result of calculation is shown in Figure 6.

The numbers in the figure are harmonic number h, because this ring has 3 turns orbit, the periodicity of three is seen. The real bunches have finite longitudinal length, therefore the collision of the beams occurs in the condition that d is shorter than the bunch length. In the parameters that we considered, there is the condition that the collision is caused in the case of about f_{RF}=320 MHz and the beams do not collide at frequency except this condition.

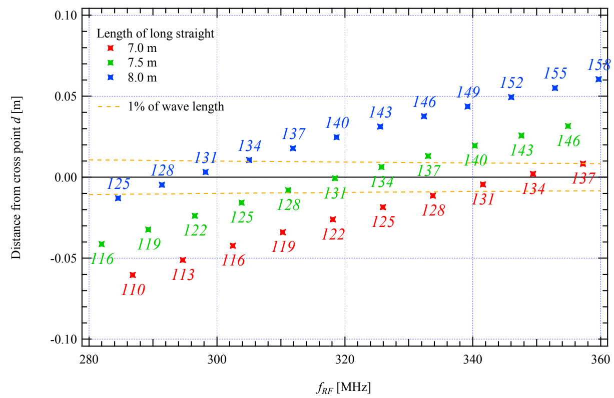

Figure 6: RF frequency and the harmonic number of conditions that the beams collide with each other.

SUMMARY

We proposed a new ring based on the torus knot which was effective for a small accumulation ring. The accumulation ring which has the orbit with several turns returning to the starting point has many straight sections and it is advantageous in that we can install a lot of insertion devices when we assume it SR light source ring. Further we adopted the MAX-III type lattice in this ring and found the possibility that could realize low emittance. Furthermore, we showed the condition that the beams collided with in the crossing point of the orbits.

REFERENCES

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