ULTRA-LOW EMITTANCE LIGHT SOURCE WITH A TORUS-KNOT TYPE ACCUMULATOR RING

A. Miyamoto and S. Sasaki
HSRC; Hiroshima Synchrotron Radiation Center, Hiroshima University
2-313 Kagamiyama, Higashi-Hiroshima, Japan

Abstract

We proposed a torus knot type synchrotron radiation ring in that the beam orbit does not close in one turn but closes after multiple turns around the ring. This ring is capable to have many straight sections and it is advantageous to installation of many insertion devices. Currently, we are designing a new ring based on the shape of a (11, 3) torus knot for our future plan 'HiSOR-II.' This ring is mid-low energy light source ring with a beam energy of 700 MeV. It has eleven 3.6-m-long straight sections though the ring diameter is as compact as 15 m.

In late years, some compact light source rings achieved very low emittance of several tens of nmrad. However for the ring we propose, the emittance can be reached less than 10 nmrad when the multi-bend scheme is adopted to the arc section. With this ultra-low emittance, the size and divergence of electron beam is smaller than the diffraction limited light in lower energy part of VUV region, and it will be very useful for many synchrotron radiation users' experiments. Therefore we are designing this ultra-low emittance light source ring having innovatively odd shape.

INTRODUCTION

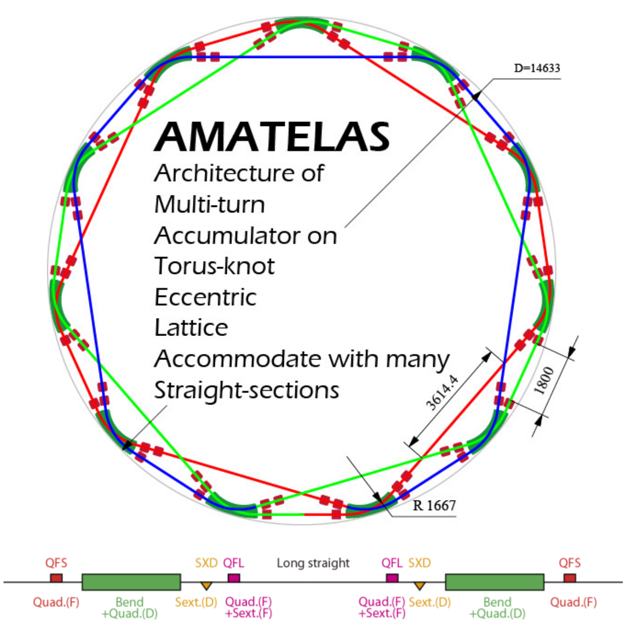

Figure 1: Schematic drawings of (11, 3) AMATELAS designed for HiSOR-II and the lattice of unit cell.

For small light source rings, it is very important to obtain a lot of straight sections in which we can install insertion devices, but it is difficult in reality because they are occupied by various magnets, RF systems or beam monitors. In this context 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.

We are planning a new light source ring for our facility [3], therefore we are designing a new ring based on the shape of a (11, 3) torus knot for our future plan 'HiSOR-II' [4]. This ring has 11 long straight sections and we can place insertion devices efficiently by placing the elements such as quadrupole magnets near bending magnet, outside of the orbit crossing section. Furthermore, this ring has about 3 times longer closed orbit in comparison with the conventional ring, the diameter of this ring is as compact as 15 m, but its total orbit length is as long as 130 m. The AMATELAS ring designed for HiSOR-II and the lattice of unit cell are shown in Figure 1, and the main parameters of (11, 3) AMATELAS designed for HiSOR-II storage ring [5] is shown in Table 1, and beta or dispersion function of a unit cell is shown in Figure 2.

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

Perimeter	45.97 m
Orbit shape	(11,3) Torus knot
Perimeter	45.97 m
Orbit length	130.187 m
Beam energy	700 MeV
Straight sections	3.614 m ×11 1.728 m ×11
Betatron tune	(10.362, 7.807)
Natural emittance	17.9 nmrad
Chromaticity	(+1.0, +1.0)

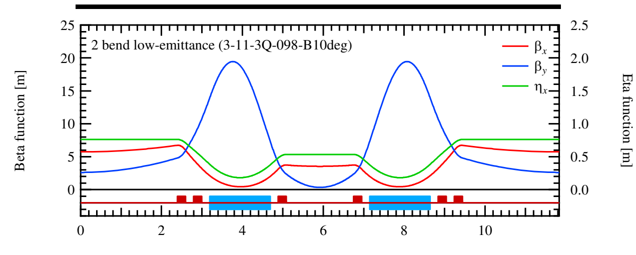

Figure 2: Optical function of (11, 3) AMATELAS for HiSOR-II storage ring.

ULTRA-LOW EMITTANCE WITH MULTI-BEND LATTICE

In late years, some compact light source ring achieved ultra-low emittance of several tens of nmrad. For VUV light sources, it means that it obtains the diffraction limited light to achieve such a low emittance beam. Generally, the beam emittance to obtain the diffraction limited light is given as the following.

$$\varepsilon \leq \frac{\lambda}{4\pi}$$

If energy of the light from undulator is 10 eV, this equation shows that emittance should be less than about 10 nmrad. We judged emittance of this size to be possible by adopting the multi-bend lattice, and we started the design ultra-low emittance light source ring for HiSOR-II.

Multi-bend lattice

In the original lattice shown in Figure 1, it has two bending magnets in one unit cell. It is advantageous to lower emittance that the bend is divided into more bends, however, we decided to adopt the multi-bend lattice having 4 bending magnets for reasons of the geometric size of this ring. There are many variations to length of magnets or drift spaces between the magnets in lattices having 4 bends in one cell, but we notice that placement is not so much easy from necessity to place on a torus-knot shape.

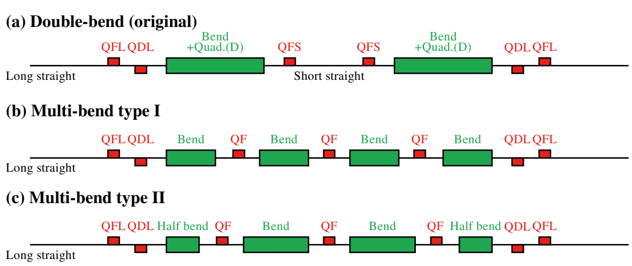

Figure 3: Multi-bend type cells compared with double-bend lattice. (a) is original double-bend lattice. (b) shows multi-bend lattice that all bends has equal length, and (c) is the other type that 2 bends at the end of arc have a half length.

The schematic draws of two types of the multi-bend lattices are shown in Figure 3. In this figure, (a) shows the original double-bend lattice, (b) and (c) are the multi-bend lattices. (b) shows the lattice that all bends has equal length. In another type (c), the length of two bends at the end of arc section is half of the ones in the central section.

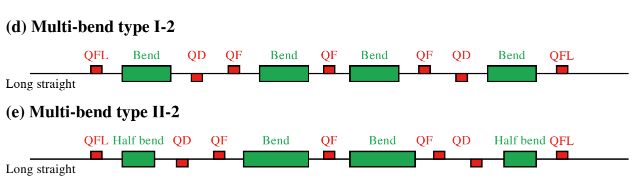

Figure 4: The modified lattices that the doublets are placed in the inside arc section.

In all lattices shown in Figure 3, quadrupole doublets are placed in the outside of arc section, but those doublets should be placed in the inside of arc to control the three parameters, β_x, β_y and η_x in a achromatic lattice better. These modified lattices from (b) and (c) in Figure 3 are shown in Figure 4.

Geometry

In original double-bend type lattice, beam orbit crosses in the bending magnets, but it is necessary to consider where it should cross in these multi-bend lattices. As for the simplest geometry, all magnets of arc section are placed in the outside of the crossing section, however actually it is impossible to have enough length. Therefore we consider some cases that the crossing section of the orbit is in the bending magnet of the edge of arc, in the specific quadrupole magnet and in the drift space.

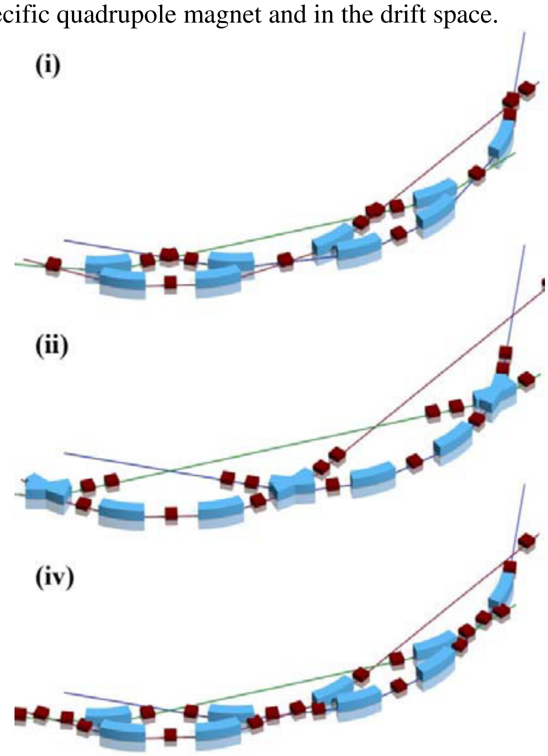

Figure 5: Geometries of multi-bend lattice type-I.

Figure 5 and Figure 6 show geometries in case of multi-bend lattice type-I and type-II. The crossing points of orbit are different in each geometries, it is placed in the singlet quadrupole in arc section in (i), in the bend of edge of arc in (ii), in the one of doublet quadrupole in (iii), in the drift space between the doublet in (iv). Because the crossing angle of the orbit is too small in Type-I (iii) and the magnets are not able to placed, it is not described in Figure 5

ISBN 978-3-95450-138-0

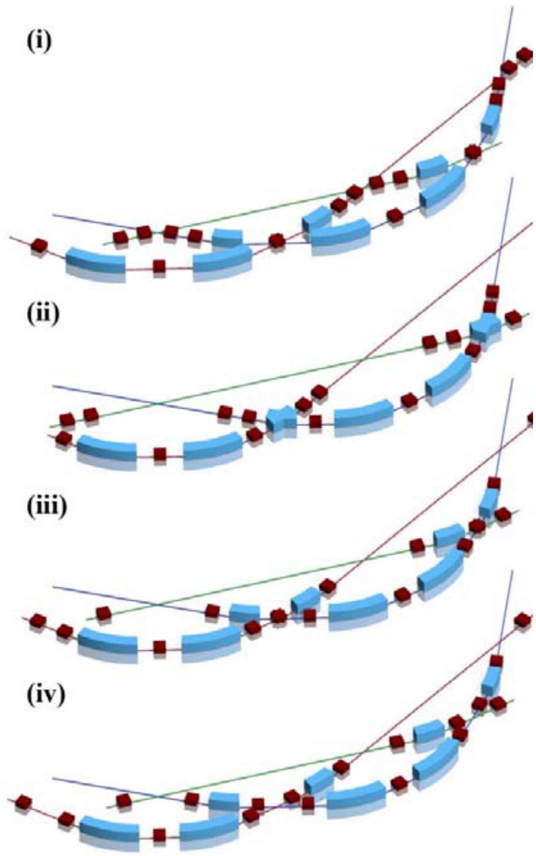

Figure 6: Geometries of multi-bend lattice type-II.

In these lattices, all bend has equal quadrupole force K=-1.8 [m^{-2}] except (iii) type that orbit crosses in bending magnet. Finally, the optical functions in the unit cell and natural emittance of each lattice are shown in Figure 7 and Figure 8.

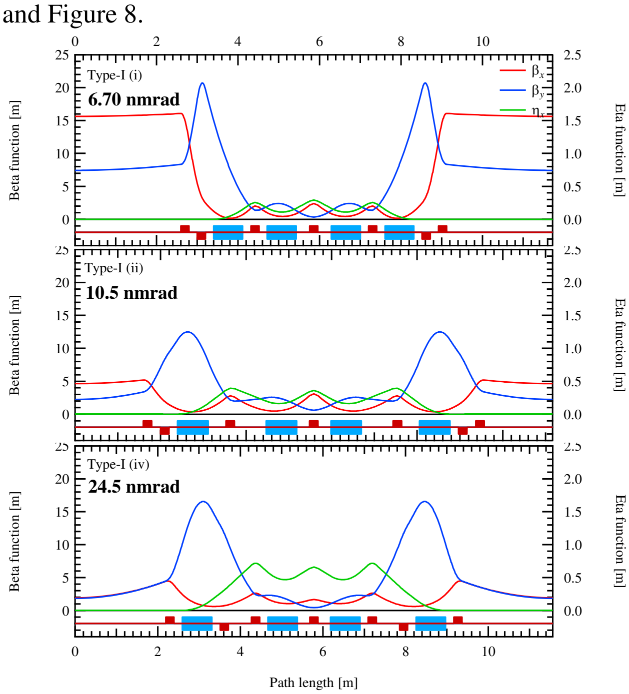

Figure 7: Optical functions of multi-bend lattice type-I.

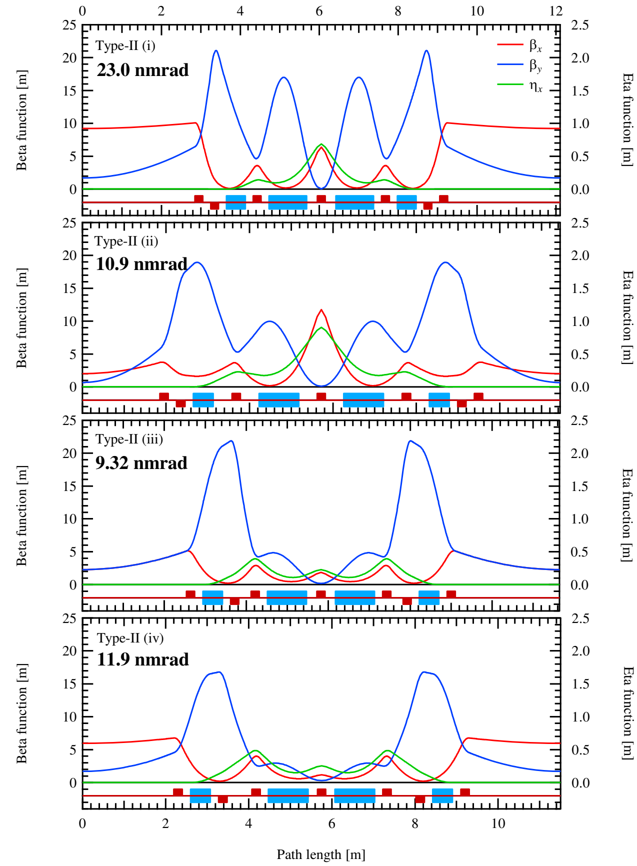

Figure 8: Optical functions of multi-bend lattice type-II.

SUMMERY

We are designing the light source ring based on the torus-knot shape as our future plan HiSOR-II. We can get smaller emittanc6e and may get diffraction limited light in the VUV region adopting a multi-bend lattice to this ring.

As a result of considering in various lattices in the linear dynamics, we were able to make the lattice that reached emittance less than 10 nmrad as our target. However, the geometric conditions by the torus-knot are severe, and it is necessary to consider about the effective chromaticity correction that does not reduce the dynamic aperture.

REFERENCES

[1] http://en.wikipedia.org/wiki/Torus_knot
[2] S. Sasaki and A. Miyamoto, Proc. of IPAC2011, San Sebastian, Spain, TUPO010, pp.1467-1469 (2011).
[3] A. Miyamoto, et. al., Proc. of IPAC'10, Kyoto, Japan, WEPEA029,.pp.2546-2548 (2010).
[4] A. Miyamoto and S. Sasaki, Proc. of IPAC2011, San Sebastian, Spain, TUPO009, pp.1464-1466 (2011).
[5] A. Miyamoto and S. Sasaki, Proc. of IPAC2012, New Orleans, Louisiana, USA TUPPP014, pp.1635-1637 (2012).