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Expanding and improving the LEADS code for dynamics design and multiparticle simulation

LI Jin-Hai(李金海)[1)] REN Xiu-Yan(任秀艳) MA Yan-Yun(马雁云)

Department of Nuclear Technology Application, Chinese Institute of Atomic Energy, Beijing 102413, China

Abstract: In order to calculate the effect on the beam caused by an irregular accelerator element, we have expanded and improved the Linear and Electrostatic Accelerator Dynamics Simulation (LEADS) code. To achieve better calculation precision, the element was divided into lots of equal intervals. In order to simplify the calculation process, a one-dimensional field is simulated and the Lorenz equation is used directly. A one-dimensional field can be imported into the LEADS code. The heteromorphic quadrupole is invented and its field is simulated and optimized using the POISSON code. As examples, the effect on the beam caused by the heteromorphic quadrupole and octupole is simulated.

Key words: LEADS, multiparticle simulation, beam redistribution, heteromorphic quadrupole, octupole

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1 Introduction

The Linear and Electrostatic Accelerator Dynamics Simulation (LEADS) code was written by Professor Lü Jianqin in 1995 [1]. The code can be applied to dynamics design and multiparticle simulation. The beam optics system, which is composed of common elements such as a magnetic quadrupole, electrostatic quadrupole, drift space, dipole magnet, three tube Einzel lens, two tube gap lens, three aperture Einzel lens, DC accelerating columns, as well as a quarter wave resonator and split loop resonator RF structure, can be calculated by LEADS. Since 2003, Some improvements have been made by Li Chaolong, Li Jinhai and Zhao Xiaosong. In 2003, Li Chaolong expanded the code for an intense pulse beam transported in an axial-symmetrical electrostatic field [2]. In 2006, Li Jinhai expanded the code for nonlinear calculation up to the third order and inserted three kinds of accelerator elements, which include the electrostatic quadrupole, electrostatic analyzer and Wein filter [3][2)]. In 2009, Zhao Xiaosong expanded the code for intense DC beam transport [4, 5]. The LEADS code can only be used to calculate the regular accelerator element, as mentioned above, because fields of those kinds of accelerator elements can be written as one formula. However, there are some kinds of elements whose field formula can not be represented as one function, or it should be represented as combined functions. As for irregular accelerator elements, the field can be represented using an approximation method [6]. However, the calculation precision of the moving particle should be improved.

2 Expanding the LEADS code for the new calculation function

In many cases, especially for the redistribution of the beam [6], we need to calculate the effect on the beam caused by an irregular accelerator element. For this kind of field, is very difficult to obtain a map of the particle phase space coordinate, so it is necessary to trace every particle by the field and the Newton function directly. For simplicity, we use the Lorenz equation to calculate the particle trace. First, the element was divided into lots of equal intervals. In each interval, the field can be seen as unchanged when the particle is transported. Therefore, the map of the

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1) E-mail: lijh@ihep.ac.cn

2) Li Jinhai, The Lie Algebraic Analysis and the Program Design of the Nonlinear Beam Transport in the Accelerators, dissertation for the PHD of Peking University, 2005

phase space coordinate can be written as:

$$x' = \arcsin((r\times\sin x'_0+l)/r),$$
$$x = x_0+r\times(\cos x'_0-\cos x'), \qquad (1)$$

where r is the rotation radius, and it is a constant because of the unchanged field; l is the length of the interval.

In order to decrease the coupling between X and Y caused by the element, the beam is always focused on a spot with a large aspect ratio[1)]. Then, the field of the element that particle experiences can be treated as one dimension. As a consequence, the LEADS code reads the one dimensional field given by POISSON for simplicity. Simulation of the two dimensional and three dimensional field will be improved in future. The LEADS code has been also improved to read the phase space coordinate of the particle using the PAMILA code, which is very convenient for multiparticle simulation. The beam density curve can be shown in the X-Y plane.

3 Calculation example

A new Compact Pulsed Hadron Source project will be built by the Department of Engineering Physics of Tsinghua University[1)]. The project includes a neutron target station, which needs a uniform beam distribution on the neutron target. However, the natural beam distribution is always Gaussian-like. So we designed a new special element called a heteromorphic quadrupole (HQ) for the beam redistribution and calculated its field using the POISSON code, as shown in Fig. 1 (only a quarter of the element is shown). The HQ is similar to the common quadrupole except that a couple of poles are inserted for shielding the magnet field and obtaining the field on the X axis, as shown in Fig. 2, for beam redistribution.

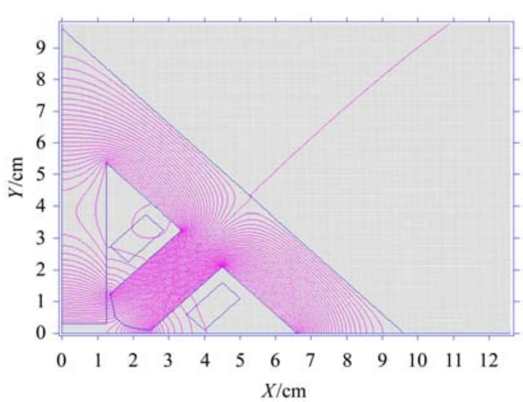

Fig. 1. The scheme of the heteromorphic quadrupole.

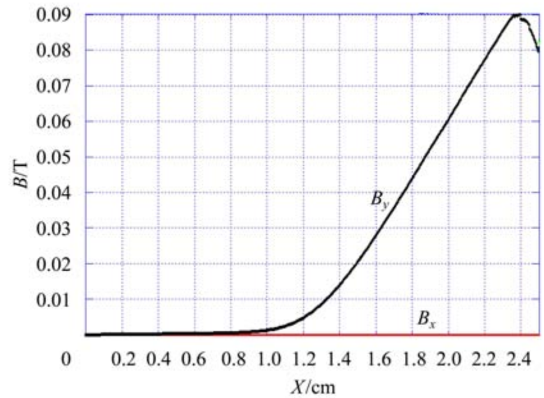

Fig. 2. The field on the X axis.

The particle distribution in X-X' phase space before the element is shown in Fig. 3. The phase space change after the element is shown in Fig. 4. After a quadrupole and a drift space, the phase space is shown in Fig. 5. Then, the beam density in the transverse plane is shown in Fig. 6. The result is not good because there are two ears.

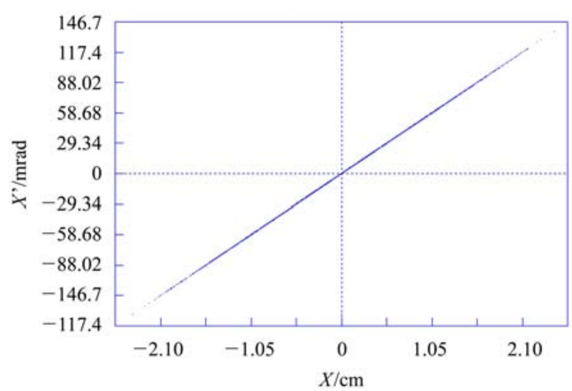

Fig. 3. The phase space before the element.

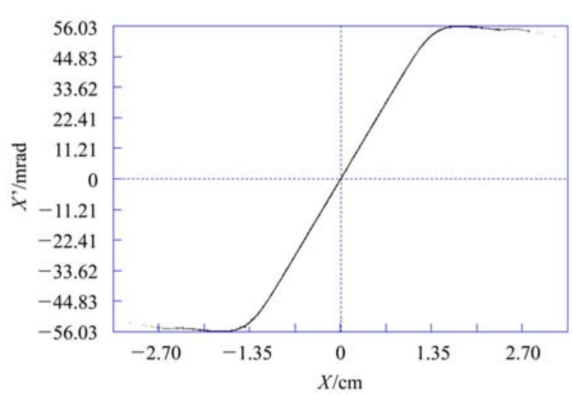

Fig. 4. The phase space after the element.

1) The first international mini-workshop on Compact Pulsed Hadron Sources, Tsinghua University, Beijing, China, 2009

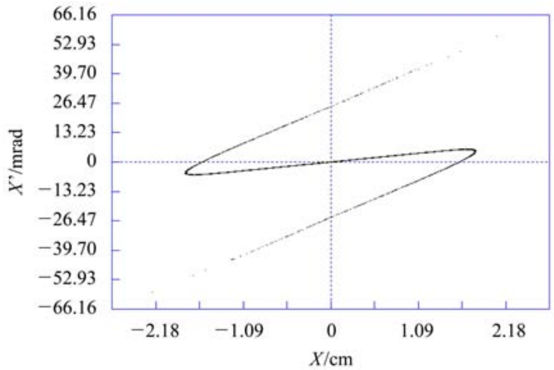

Fig. 5. The phase space after quadrupole and drift space.

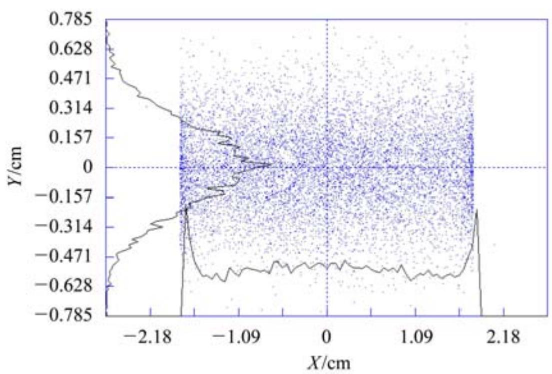

Fig. 6. The beam density in the transverse plane.

For comparison, the octupole is calculated, as shown in Fig. 7 and Fig. 8, and the effect on the beam caused by the octupole is shown in Fig. 9. The beam distribution is shown in Fig. 10, which is similar to that of Ref. [7].

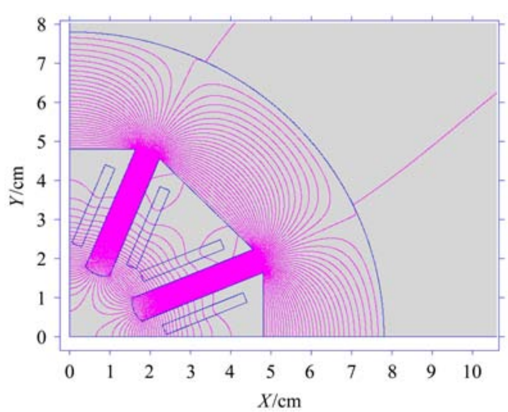

Fig. 7. The schematic of the octupole.

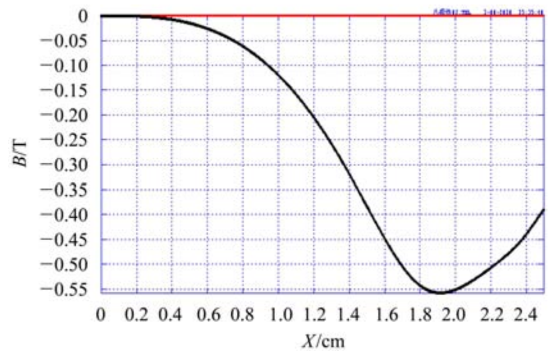

Fig. 8. The field on the X axis.

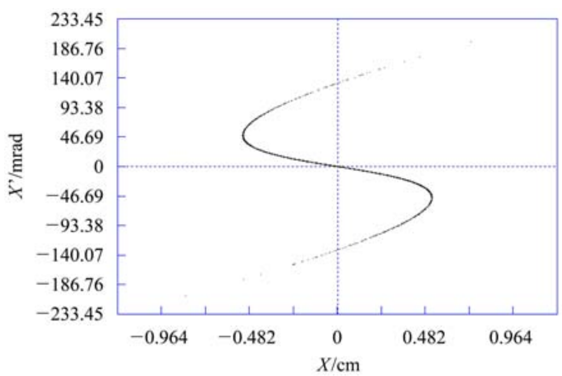

Fig. 9. The phase space after octupole and drift space.

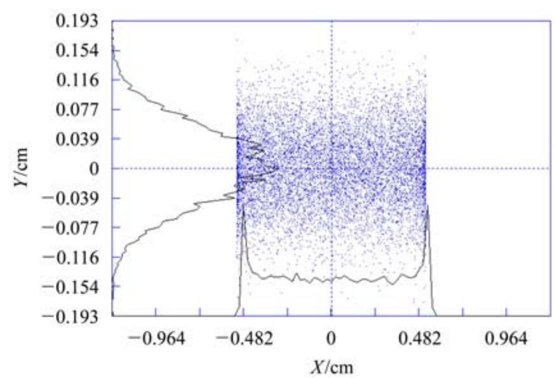

Fig. 10. The beam density in the transverse plane.

4 Conclusion

After expansion and improvement, the LEADS code can perform a multiparticle simulation of the irregular accelerator element. Therefore, it can be used in the beam redistribution field. The calculation result is similar to other references.

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