Increasing the dynaic and momentum apertures of the Thomx ring by means of octupoles correctors

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Abstract

The electron ring of the compact Compton-backscattering X-ray source ThomX which is being built at LAL featured with a small circumference of 18 meters and a low beam energy 50-70 MeV, and its long term single particle dynamics is dominated by the non linear effects in the transverse and longitudinal planes. **In this paper, we study the feasibilities to reduce the sextupole resonances and then increase the dynamic aperture and momentum aperture of the ThomX ring, using octupoles correctors**

Introduction

The compact Compton-backscattering X-ray source ThomX is under construction by a collaboration of seven institutes and an industry partner at LAL-Orsay, France. The accelerator part of this X-ray source is composed of an **electron photon-gun, a linac, and a ring**; and is featured with the compact size of 10 m long and 7 m wide, and the high average flux of 10^{11} to 10^{13} photons/second. However, the **small size of the ring of 18 circumference and the low electron beam energy 50-70 MeV determine that the beam dynamics in the ThomX ring is dominated by the non-linear effect**, which is a common issue for the future generation circular accelerators, like the low emittance light sources and the high luminosity colliders. **For such type of accelerators, the dynamic aperture (DA) is normally smaller than the vacuum chamber size, and the momentum aperture (MA) is limited by the non linear motions of the off momentum particles [1]**

DA and MA of the ThomX ring

In the final version of the ThomX ring lattice, there are **12 sextupoles** which are composed of one family focusing sextupoles and two families defocusing sextupoles.

- The **DA** is **reduced to around 15 mm in the horizontal plane and 20 mm in the vertical plane**, which are respectively 30 times of the horizontal beam size σ_x and 57 times of the vertical beam size σ_z at the injection point of the ring
- The **MA** is around **+/-3%, which is much larger than the final beam energy spread 0.6% after 20 ms storage time**

Relative systematic multipole field errors in the ThomX ring, with the unit 10^{-4} at 18 mm radial position. From the OPERA-3D simulations[2]

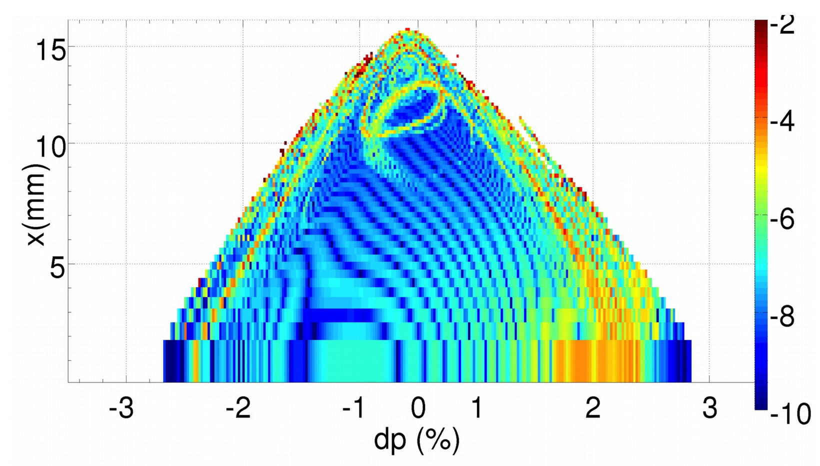
Pole N	Inner dip.	Outer dip.	Quad.	Sext.
6	+8.5	-16	-	
8	+0.1	-0.7	-	
10	+3	-6	-	
12	-	-	+2	-
18	-	-	-	-4
20	-	-	-6	-
28	-	-	-9	-
30	-	-	-	-0.9

Table 1

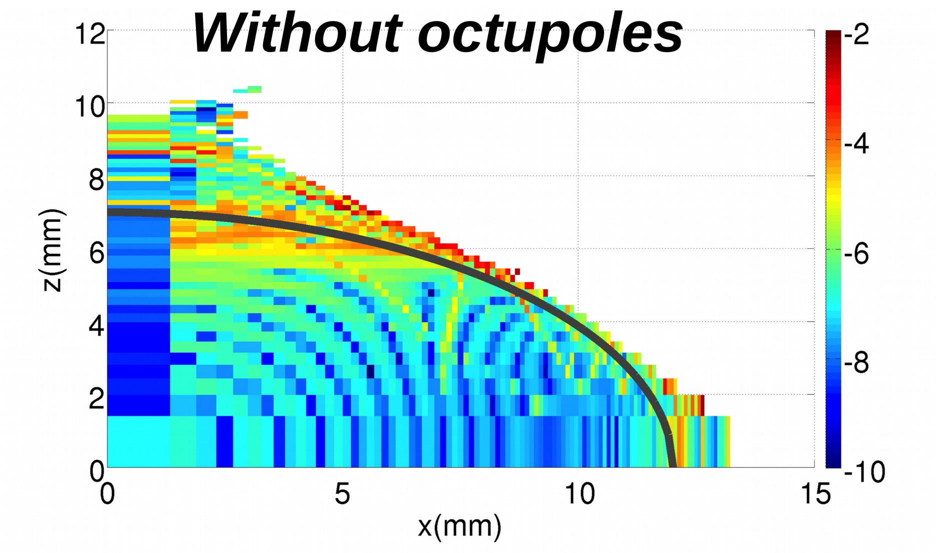
Engineering construction of the magnets introduces high order magnetic field errors. With the systematic multipole field errors shown in the Table 1:

- The **DA** is reduced to around 13 mm (25 times of σ_x) in x and to 10 mm (29 times of σ_z) in z, which is smaller than the physical vacuum chamber size of 20 mm in and 14 mm in z, while larger than the scaled chamber size of 12 mm in x and 7 mm in z;
- The **MA** is reduced to -1.8% and 2% which is comparable to the energy momentum acceptance +/-2% limited by the vacuum chamber size

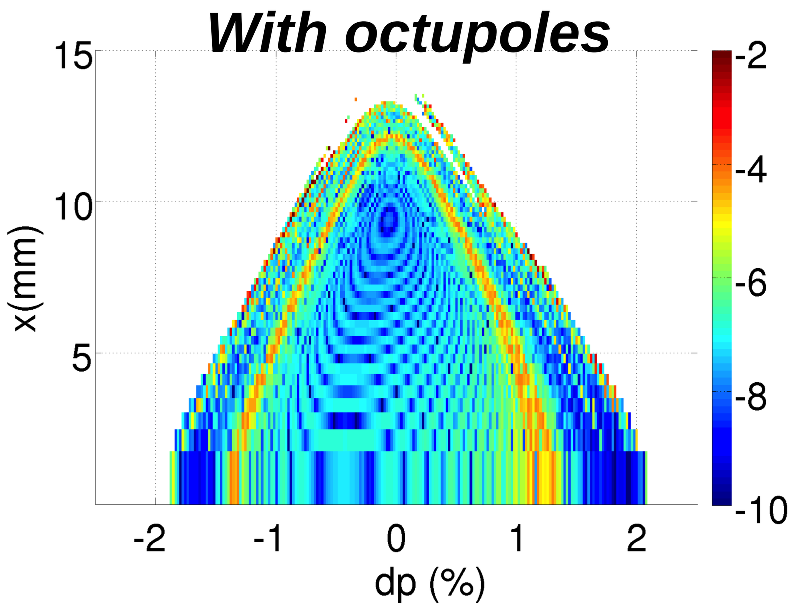
Without octupoles



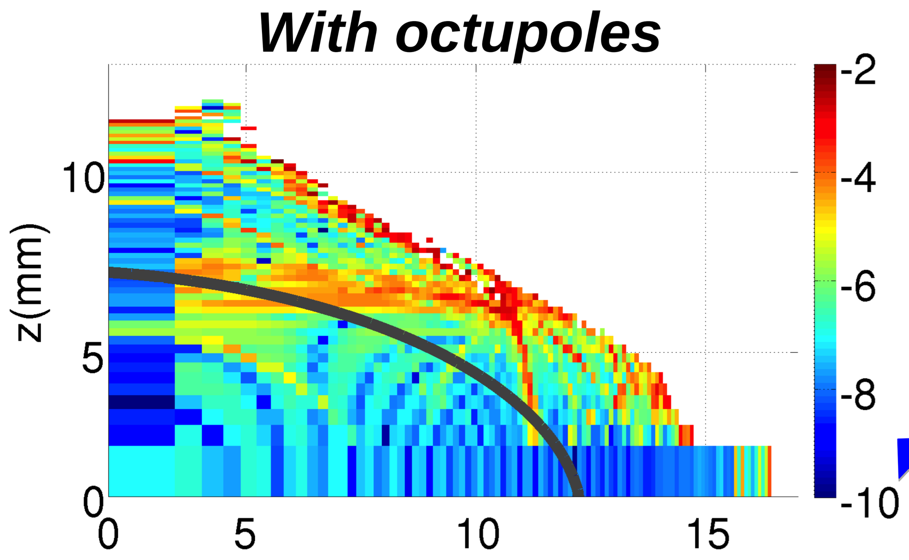
Without octupoles



With octupoles

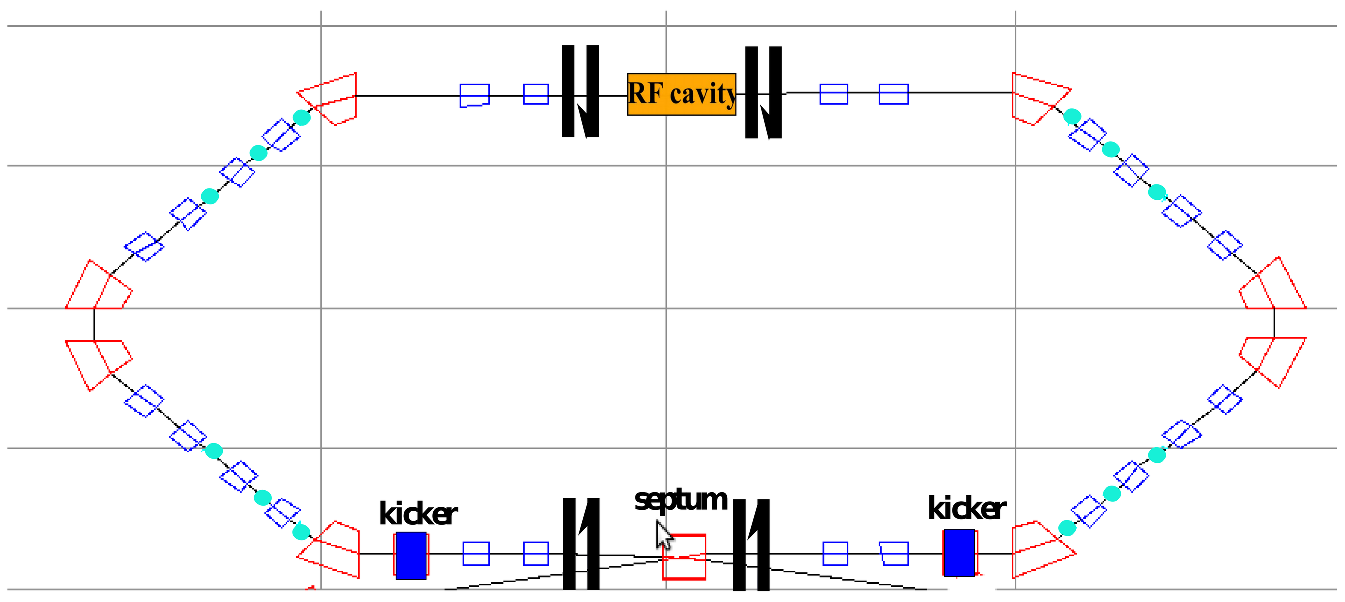


With octupoles



The DA is increased by 8 times of σ_x and 5 times of σ_z, and the MA is increased by 0.5% and, compared to the case without octupole correctors

Layout of the ThomX ring



DA and MA of the ThomX ring with octupoles

To optimize the **DA** and **MA** of the ThomX ring, one powerful method is the analysis of the Hamiltonian resonance components. Normally the resonances from the sextupoles are the main sources to introduce non linear beam motions and then limit the DA and MA. Consequently, one can use the octupoles to compensate the non linear resonances from the sextupoles and then increase the DA and MA[3]. To compensate the non linear resonances introduced by the sextupoles using octupole correctors, one can use the normal form [4], Lie algebra [5]and TPSA [6,7] to get the sextupole resonances components from

$$H(x, p_x; z, p_z; -ct, \delta; s) \approx \frac{p_x^2 + p_z^2}{2} + A_s(x, z, s)$$

x: is the horizontal coordinate
z: is the vertical coordinate,
$p_{x,z}$: are the canonical momentums;
-ct: is the longitudinal coordinate of the particle relative to the reference particle
δ: is the momentum offset
$A_{s(x,z,s)}$: is the longitudinal magnetic vector potential component

$$A_s(x, z, s) = \frac{b_3}{3}(x^3 - 3xy^2) \quad \text{(sextupole)}$$

$$A_s(x, z, s) = \frac{b_4}{4}(x^4 - 6x^2y^2 + y^4) \quad \text{(octupole)}$$

- **Two identical defocusing octupoles are placed symmetrically beside the RF cavityand Two identical focusing octupoles are placed symmetrically beside the septum**
- The strengths and the positions of the octupoles are optimized using the code OPA [9,10]

Conclusions & Future Plans

Due to the compact size and the low beam energy, the beam dynamics in the ThomX ring is dominated by the non linear effects. As a result, the DA and MA of the ring are limited by the sexutupoles, multipole field errors and other perturbation sources. In order to increase the DA and MA, two pairs of focusing and defocusing octupoles are placed in the two long straight sections of the ThomX ring. Without breaking the symmetry of the ring lattice, the octupole positions and strengths are optimized to reduce the second order sextupole resonances. **The results show that the DA and MA of the ThomX ring can be increased by the octupole correctors. In the future, the feasibility to increase the DA and MA using octupoles will be investigated with the ThomX lattice of non-zero dispersions in the straight sections**

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