Simulation of An Octupole Scanning Magnet for Spot Scanning in Proton Therapy

BOlei Jia, Lianhua Ouyang, and Zhentang Zhao

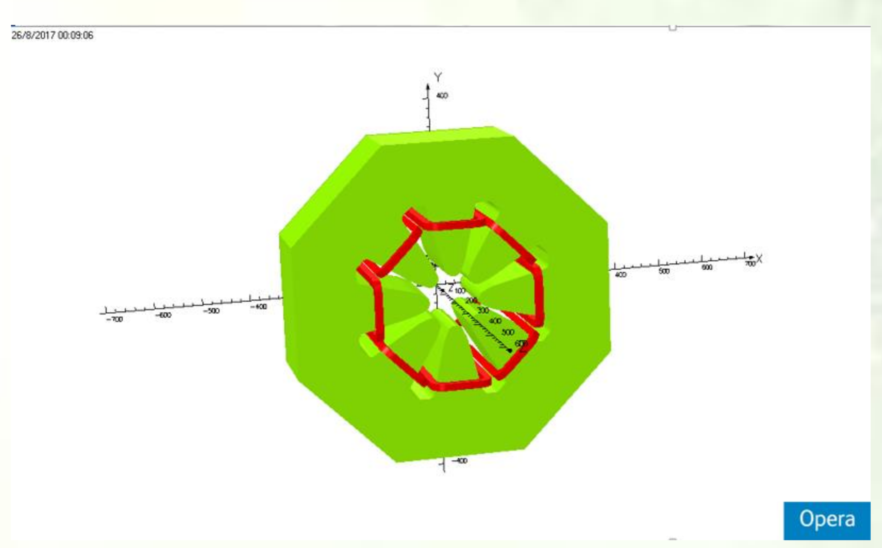
Shanghai Institute of Applied Physics, C. A. S., Shanghai 201800, P. R. China

Abstract

Current proton therapy scanning systems always use two independent dipole magnets for spot scanning in proton therapy. However, the space occupied by these two dipole magnets located after the final gantry bending magnets is very large and increases the overall size of the gantry. In order to construct a compact nozzle and decrease the size of the gantry, we decide to design an octupole scanning magnet to replace these two separate dipole magnets. The octupole scanning magnet, which is completely different from traditional octupole magnet, can generate rotating dipole magnetic field with the change of the loaded sinusoidal current phases. In the paper, we have finished the static optimization of an octupole scanning magnet model, including the length and shape of the poles, the diameter of the gap and the shims on the pole edges, both in Opera 2D and 3D. The corresponding relationship between the size of the gap and the good field region was also studied. The effect of eddy currents on magnetic field stability was also simulated in Opera 3D.

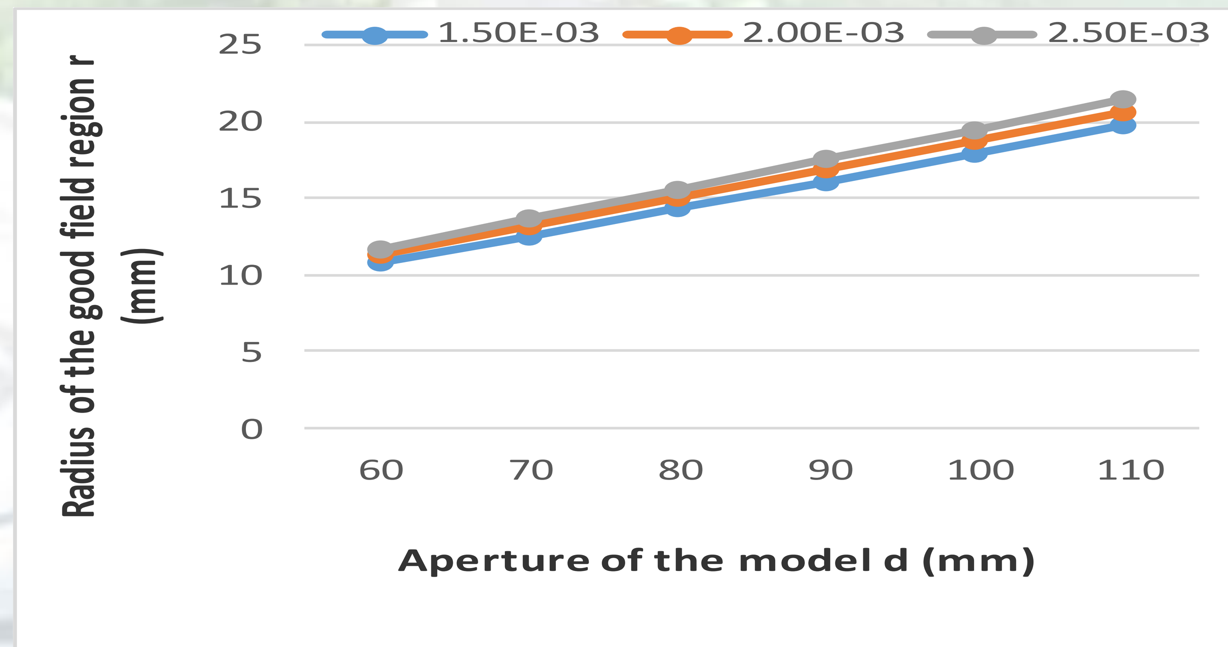
Design parameters

The main parameters of the simulated magnet model	
Distance away from the iso-center	2.1 m
Integrated field	0.1679 Tm
Mechanical length	35 cm
Good field region	20 mm(radius)
Aperture	104 mm
Field homogeneity	$\pm 2.5\times10^{-3}$
Pole tip width	26 mm

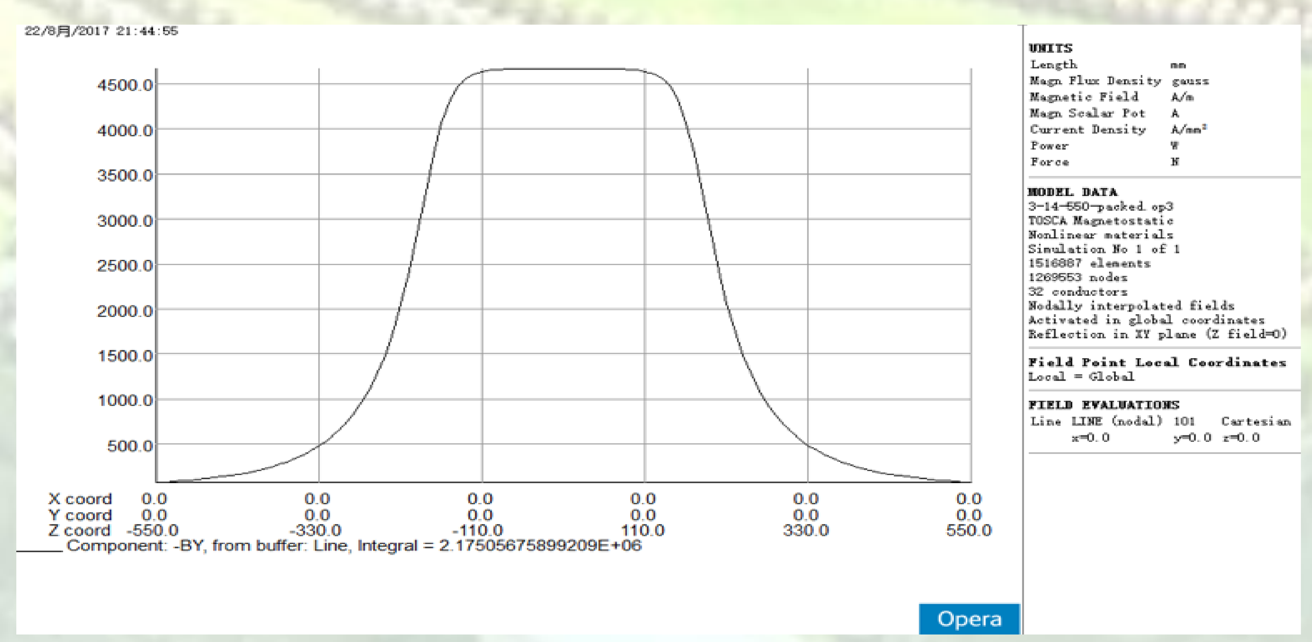


3D simulation model with coils

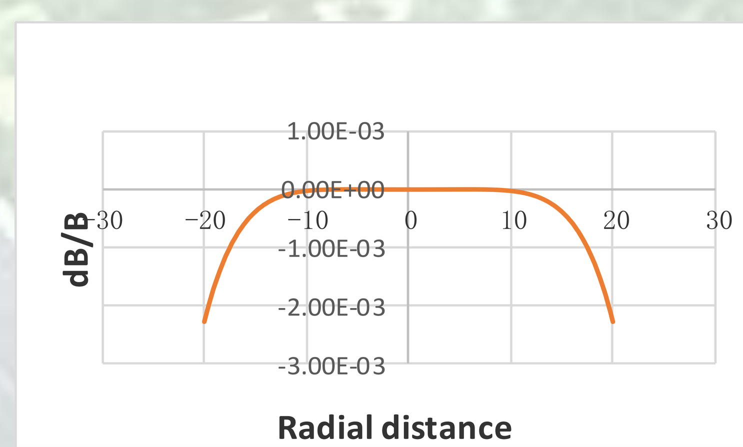
Static simulation



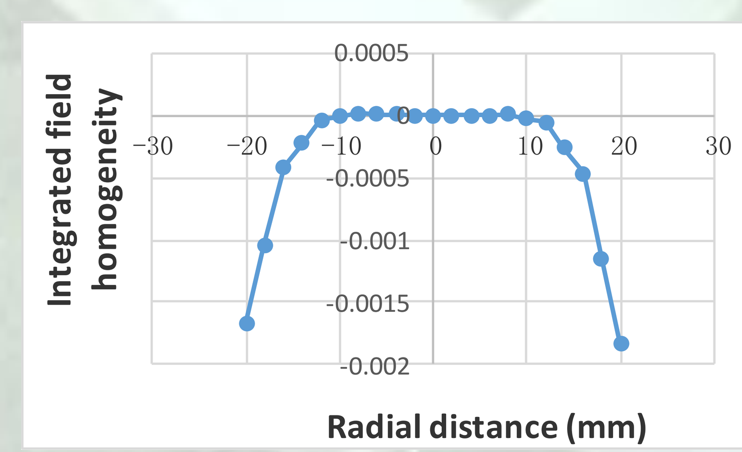
The relationship between the aperture and the radius of the good field region in different field homogeneity. It indicates that the radius of different good field region is approximately proportional to the aperture of the model and the scale factor dependents on the required field homogeneity.



The distribution of the magnetic field along z axis.



Field error at B= 4673 Gs



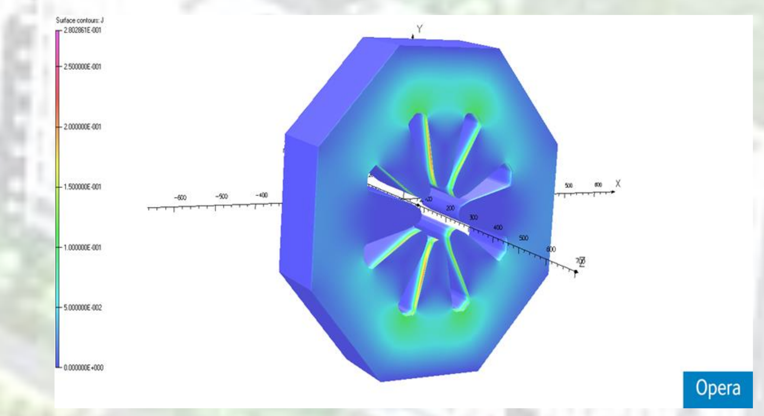
Integrated field error in the good field region

Dynamic simulation

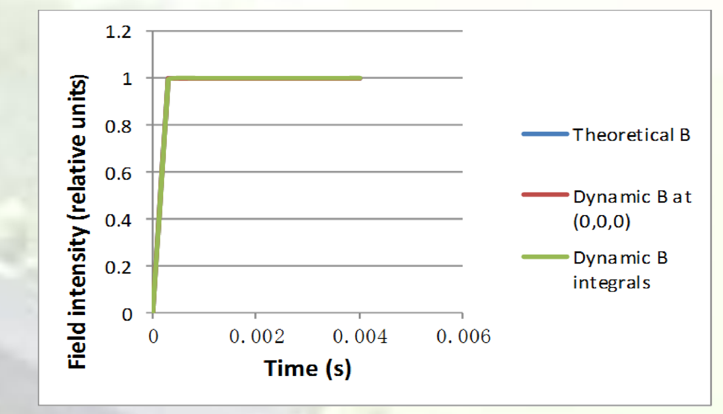
（1）Principle

The octupole scanning magnet can generate a rotating dipole field when each pair of opposing poles is given a regular sinusoid independently. All the currents are with a same amplitude. The current amplitude determines the field strength. The phases of the currents determines the deflection angle of the dipole field. The field can rotate with the change of the current phases and the deflection angle of the field is equal to the magnitude of the phase change.

（2）Simulation of the field strength increasing

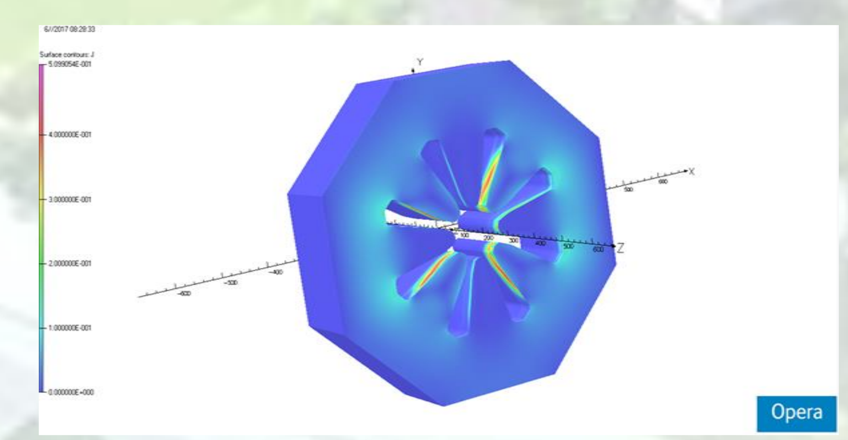


The distribution of the eddy currents at t = 1 ms.

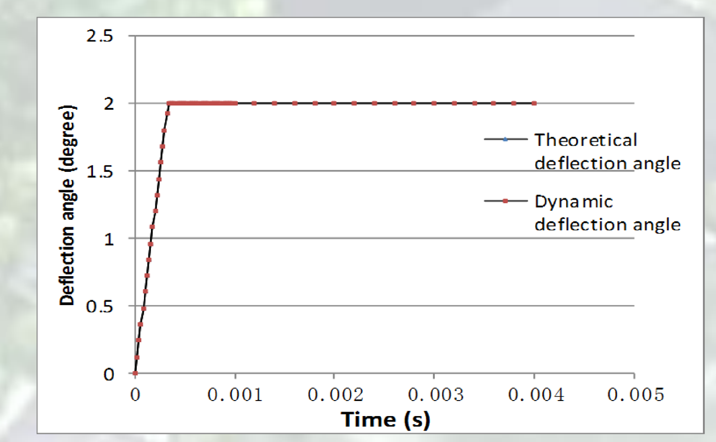


The field strength varying with time

（3）Simulation of the field rotation



The distribution of the eddy currents at t = 1 ms.



The deflection angle of the field varying with time.

Conclusions

- The integrated field reached 0.2175 Tm which is larger than the required.
- The radius of the good field region is approximately proportional to the aperture of the model.
- The uniformity of the field integral was controlled below 2.5×10^{-3} within the good field region using the tangent shims.
- The effect of the eddy currents on the stability of field can be negligible and the stability time is very short.