CSPT: A GPU-ACCELERATED LATTICE DESIGN TOOLKIT ESPECIALLY FOR CCT

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Abstract

Canted-Cosine-Thera (CCT) coil is a promising alternative for normal-conducting magnets in compact accelerator systems such as large hadron colliders or particle therapy facilities. For the convenience of lattice design with CCT, we develop the CCT Simulation and Particle Tracking (CSPT) toolkit. It's a program that can perform both simulations of the beam dynamic process within particle accelerators and basic electromagnetic harmonic analysis. The charged particle tracking and electromagnetic calculation process can be accelerated by either CPU multicore or GPU parallel, with a maximum speed-up ratio of 457. The simulation result of the program is well consistent with Opera and COSY Infinity.

Software Structure

- **The toolkit is compatible with both beam dynamic simulation and electromagnetic field analysis.**
- **The toolkit provides interfaces with Geant4 and Opera to input particles and electromagnetic tables.**
- **The structure of the toolkit is shown in Fig.1. Generally, it can be divided into 4 parts: Fundamental Classes, Magnetic Elements, High-level Classes and Extra functions.**

- **The toolkit only supports magnetic elements, at present. The CCT magnet can be defined by the path function of coils. Magnetic fields of CCT are calculated with Biot-Savart Law.**
- **The Particle Classes allow users to define a particle with its position and velocity, or define a beam with Twiss or Sigma parameters.**
- **The Beamline class is the highest-level class in the toolkit. Users can use the Beamline class to achieve most of the tasks, including building lattices, magnetic field analysis and particle tracking.**
- **To accelerate the calculation speed, CUDA and openMP are adopted. Besides, the toolkit is embedded with GA algorithm, so that it can perform lattice optimization.**

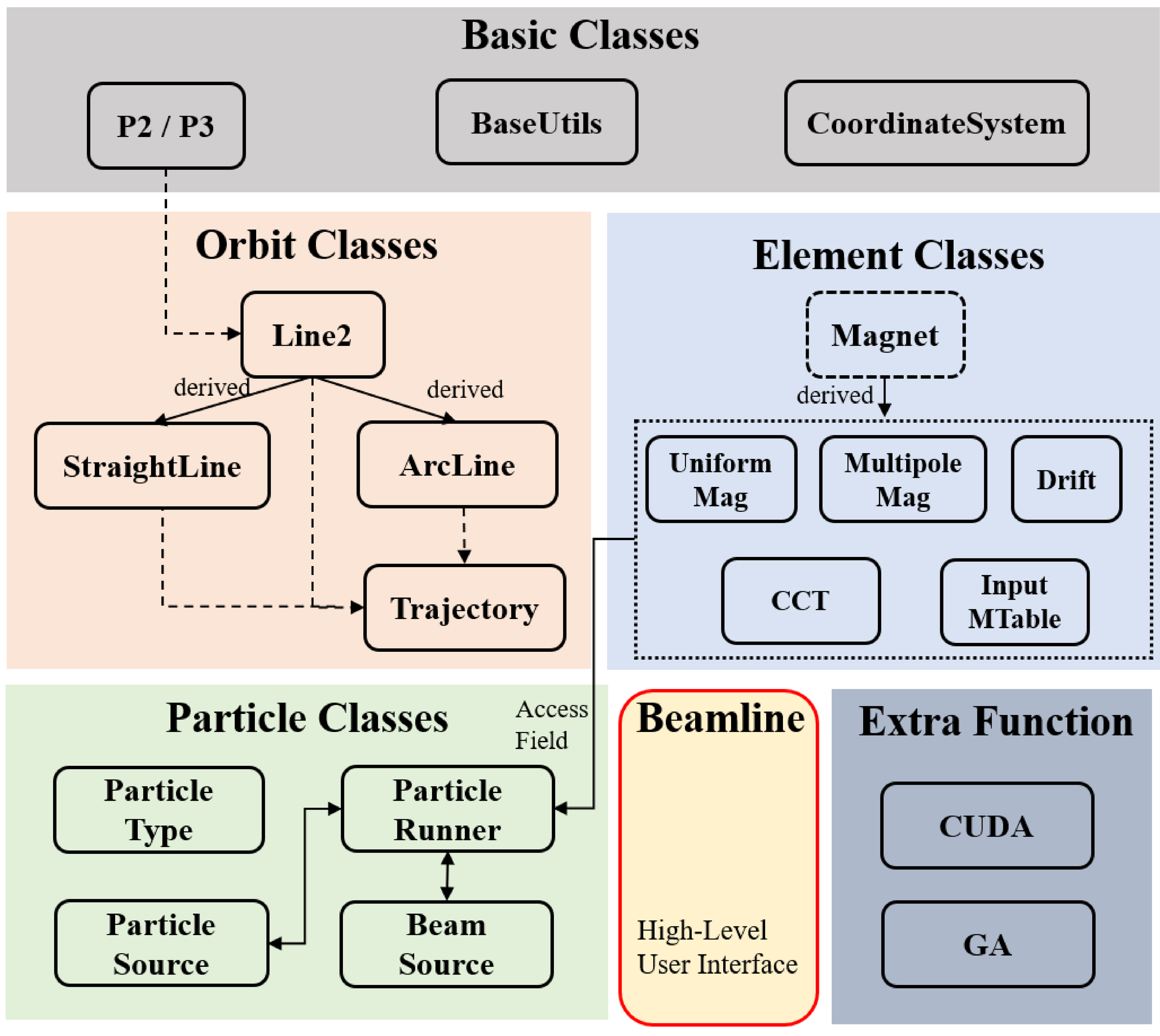

Fig. 1 The structure of the CSPT toolkit.

Results

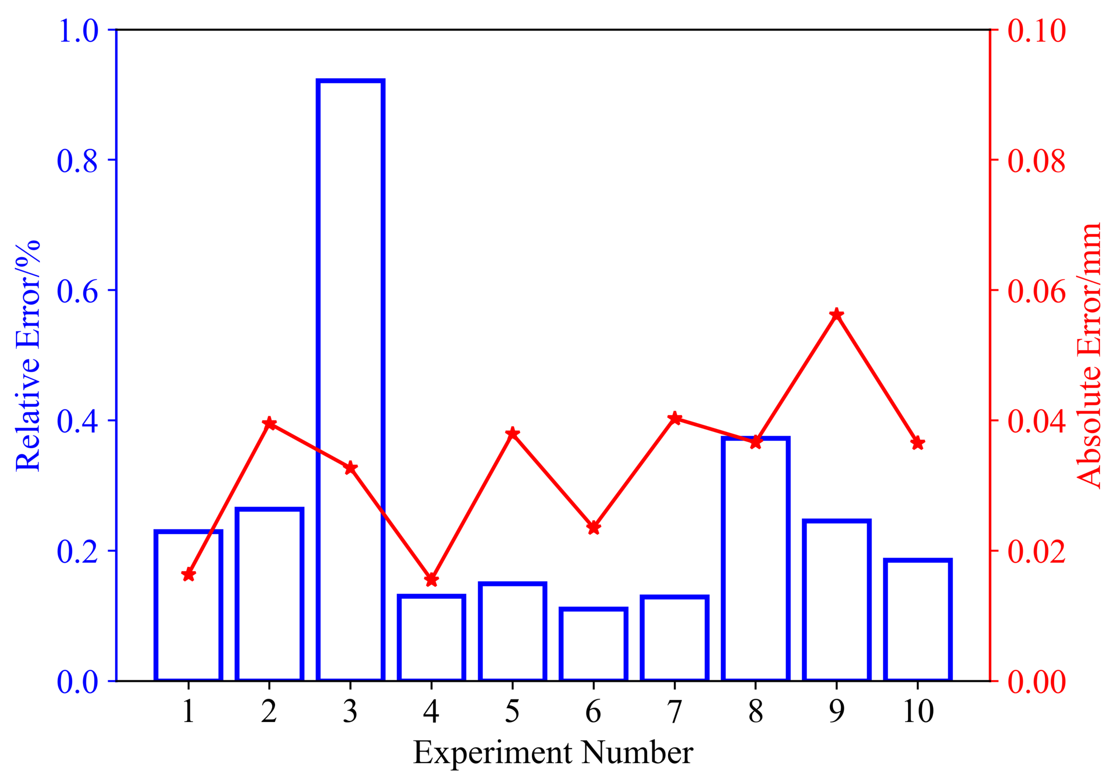

Fig. 2 The error of the CSPT tracking results with respect to COSY.

- **A beamline lattice of HUST-PTF gantry is generated in CSPT and COSY Infinity, respectively;**
- **10 experiments are conducted by changing the parameter of the lattice and initial particle;**
- **Fig. 2 shows the error of the phase space results in the experiments, with a maximum relative error of 0.92% and a maximum absolute error of 0.056 mm.**

- **Fig. 3 denotes the field components of a 4 layers CCT magnet in CSPT and Opera;**
- **The difference of sextupole and octupole between the two programs at both ends of the magnet is mainly due to the numerical error of the FFT process.**

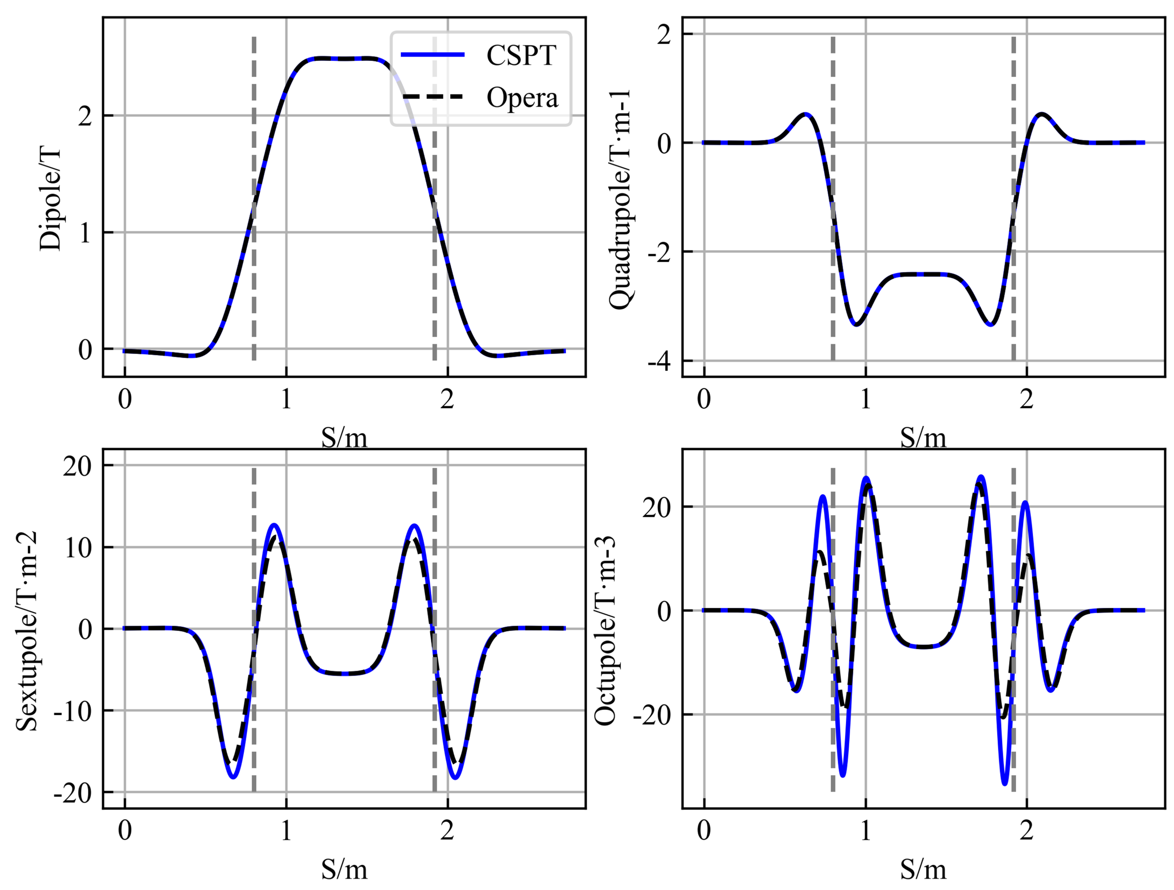

Fig. 3 The field components of a 4 layers CCT on the orbit.

- **The field calculation of CCT is a very time-consuming process, because there are an enormous number of current units.**
- **The CPU multicore and GPU parallel technology are applied. In Table.1, the GPU parallel enables the toolkit to calculate a maximum of 457 times faster, exchanged with merely a 0.32% relative error increase.**

Table 1 Calculation time of 250 particles in a beamline under different settings

Method	Total time	Speed-up ratio
CPU (1 core)	77 298 sec	-
CPU (12 cores)	13 318 sec	5.8
CUDA (double)	531 sec	145.6
CUDA (float)	169 sec	457.0

Conclusions

- **The CSPT toolkit is capable of dealing with particle tracking and field analysis tasks of lattices with CCT magnet.**
- **The experiment shows that the toolkit can produce accurate results with a relative error below 1.0% in a considerably short time.**
- **Due to limited time, the Graphic User Interface(GUI) and lattice error analysis module are still ongoing.**

References

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