

Optimization Study on Stacking Parameters of Metal Mesh Ripple Filters for Carbon Ion Radiotherapy

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Abstract

Spot-scanning carbon ion radiotherapy relies on ripple filters (RiFi) to enhance treatment efficiency. Existing multi-layer metallic mesh ripple filters (mRiFi) employ random stacking configurations, resulting in poor dose distribution consistency. This study designed three-dimensional mRiFi matrices with a wire diameter of 0.1 mm, wire spacing of 0.5 mm, and layer numbers of 10, 20, 30, and 40 using Python, and optimized the stacking parameters using a genetic algorithm. The Bragg peak broadening capability and dose distribution consistency before and after optimization were evaluated through Monte Carlo dose simulations using the TOPAS program for carbon ion beams traversing the mRiFi. The results demonstrate that stainless steel mRiFi exhibits superior broadening capability compared to aluminum mRiFi. For 100.5 MeV/u carbon ions passing through a 40-layer stainless steel mRiFi, the Bragg peak width was broadened from 0.23 mm to 4.08 mm, whereas aluminum mRiFi broadened it to 1.73 mm. Following genetic algorithm optimization of stacking parameters, the consistency of pencil beam dose distribution improved. For both aluminum and stainless steel mRiFi with 10, 20, 30, and 40 layers, the average gamma pass rates improved when comparing dose distributions at various irradiation positions with those at the central position before and after optimization, with statistically significant differences observed in most scenarios. This study indicates that genetically optimized mRiFi can significantly enhance Bragg peak dose distribution consistency, offering an improved solution for mRiFi construction in carbon ion radiotherapy.

Full Text

Figures

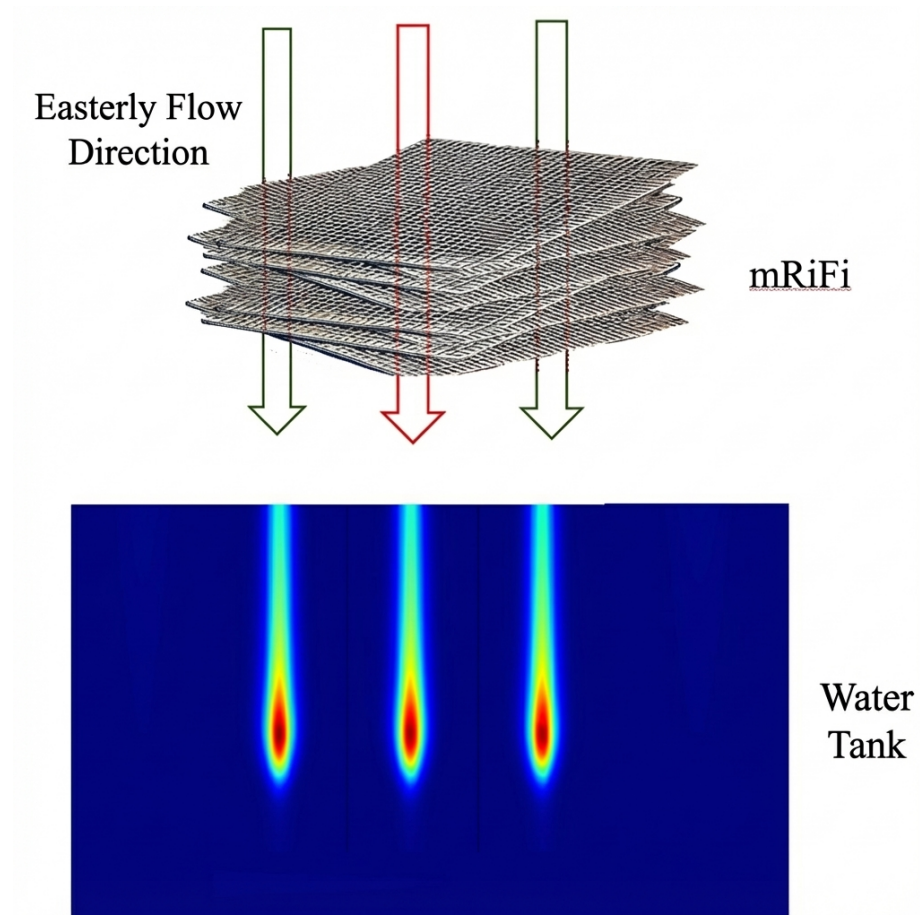


Figure 1: Figure 4

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