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Development of novel beam instrumentation for in vivo and in vitro end stations for Laser-hybrid Accelerator for Radiobiological Applications (LhARA)

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Radiotherapy is a cornerstone of modern cancer treatment, utilising x-ray photons, electrons and ion beams to non-invasively target cancerous tumours, effectively. The Laser-hybrid Accelerator for Radiobiological Applications (LhARA) is a novel laser-driven accelerator system currently under development that aims to transform Particle Beam Therapy (PBT) by enabling flexible, high-flux multi-ion irradiations for radiobiological studies. Unlike conventional PBT systems, LhARA seeks to harness laser-driven proton and ion beams, offering a platform for investigating the radiobiological effects of ultra-high dose rate (FLASH) and spatially fractionated radiation therapy.

A critical challenge in this endeavour is the precise focusing and shaping of proton and light ion beams at the in vivo and in vitro end stations, without the limitations imposed by mechanical collimation. This study presents the development of a novel, magnetically focussed beam delivery system designed to produce minibeams (beams with a diameter of less than 1 mm). The proposed method consists of a double quadrupole triplet configuration to focus the beam. The first quadrupole triplet focuses an initially broad 1 cm beam distribution into a high-intensity focal spot, while the second triplet ensures controlled divergence to produce the required 1 mm spot distribution with an energy of 15 MeV, for the low energy in vitro end station's experimental requirements.

This approach offers several advantages over traditional collimation techniques, including enhanced beam transmission efficiency, reduced scatter-induced dose perturbations and the potential for precise spatial dose modulation. The experimental validation of this method will mark a significant step towards the realisation of a next-generation radiobiological research facility. Future work will focus on optimising beam transport dynamics, characterising dose delivery precision and expanding the technique for multi-ion beam applications.

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