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The Laser-hybrid Accelerator for Radiobiological Applications (LhARA)

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Introduction

While most radiotherapy (RT) treatments are delivered using photons, recent years have seen an increase in the use of particle-beam therapy (PBT) with proton and ion beams. In PBT, dose may be conformed precisely to the tumour, sparing healthy tissue and organs at risk. The importance of PBT is widely recognised in the UK and overseas.

PBT today is delivered at low dose rates (< 10 Gy/min) within restricted beam characteristics by employing a small number of temporal schemes and spatial distributions. The damage to the healthy tissue limits the dose delivered and, thus, constraints the clinical efficacy. Exciting evidence of enhanced therapeutic benefit has been recently found with the use of novel beams with strikingly different characteristics, e.g. very high dose per fraction, very high dose rate (> 40 Gy/s, "FLASH"), and spatially fractionated dose from "mini-beams" (MBRT). The exploration of new regimens of PBT together with developments in our understanding of personalised medicine based on the biology of individual tumours, now provides the impetus for a radical transformation of PBT.

The 'Laser-hybrid Accelerator for Radiobiological Applications', LhARA [1], is conceived as a novel, uniquely flexible facility dedicated to the study of the biological response to ionising radiation. With the potential to deliver multiple ion species in beams with a wide range of temporal and spatial profiles, and at ultra-high dose rates, LhARA will enable the exploration of a completely new regime of particle-beam therapy. The high flux, short bunch duration, and high repetition rate are well-suited to study the radiobiological mechanisms by which the therapeutic benefit is generated. The new approach is based on a high-power laser which creates a large flux of protons or light ions from a foil target. The particles are captured and focused using electron plasma lenses, thus evading the current limits on the maximum instantaneous dose rate.

Methods

The LhARA facility has been simulated using a variety of codes. I will outline the state of the art in laser-driven ion acceleration, describe the motivation for LhARA, present the status of its development, and summarise the programme upon which the LhARA collaboration has embarked to drive a step-change in clinical capability.

Results & Discussion

LhARA will be developed in two stages. In the first stage, a programme of *in-vitro* experiments (e.g. focusing on 2D cell survival and 3D spheroid/organoid growth in tumour-specific models, kinetics of DNA damage and repair) will be served with proton beams with energies up to 15 MeV. In stage two, a high-energy *in-vitro* end station and an *in-vivo* end station will be served by proton beams with energy up to 127 MeV. In addition, ion beams, with energies up to 30 MeV per nucleon for carbon, will be available for *in-vitro* and *in-vivo* experiments. The results of the simulation of the LhARA facility will be presented. The spatial distribution of the beam at the end stations has been estimated and the instantaneous and average dose rates have been calculated.

Conclusion

The LhARA initiative has the potential to deliver the required automated proton and ion-beam therapy at FLASH rates in a variety of spatial and spectral configurations. The programme is structured to maximise the breadth of the impact it will generate in the R&D and proof-of-principle phases in areas such as compact high-repetition proton sources driven by lasers, real-time *in-vivo* dose monitoring, and novel automated biological end stations.

References

1. Aymar G. *et al.* LhARA: The Laser-hybrid Accelerator for Radiobiological Applications. *Front Phys*. 2020;0:432.