LhARA: the Laser-hybrid Accelerator for Radiobiological Applications

Vision:

LhARA will revolutionise cancer treatment. LhARA is a multidisciplinary consortium that will create within the UK the capability to deliver the particle-beam therapy systems of the future.

Concept:

Beams of protons or ions delivered at ultra-high dose rate and/or with spatial fractionation are believed to offer significant clinical advantages over conventional beams. LhARA will provide a capability to generate the radiobiological evidence base such beams and therefore guide the future of radiotherapy Internationally.

LhARA will create the capability to deliver particle- and ion-beam therapy in completely new regimes by combining a variety of ion species in a single treatment fraction, exploiting ultra-high dose rates in novel spatial, temporal and spectral fractionation schemes which will deliver new cancer treatments

LhARA will make “best in class” treatments available to the many by demonstrating in operation a system that incorporates dose-deposition imaging in a fast feedback and-control system thereby removing the requirement for a large gantry reducing the footprint of the system compared to existing facilities.

The laser-driven source provides enormous flexibility in the beams that can be delivered and can therefore serve a world-leading radiobiology programme using novel technologies that could be developed to deliver a paradigm shift in the way particle beams are used to treat cancer.

Members of the consortium internationally span academia, the NHS and industry. This initial investment is for a five-year R&D programme in technology transfer, radiobiology, patient and public involvement, and outreach.

Key Features:

- Flexibility
- Dedicated facility
- Multiple ion sources

Technology:

LhARA will exploit a laser to create a large flux of protons or light ions which will be captured and formed into a beam by strong-focusing plasma lenses and accelerated using a fixed-field alternating-gradient accelerator. The hybrid-accelerator technique will allow the time, energy, and spatial structure of the beam to be varied.

Proton beams with energies between 12 MeV and 125 MeV and ion beams with energies up to 34 MeV-per-nucleon will be provided in bunches containing 10^8–10^9 particles. Bunches, which can be as short as 10 ns–40 ns, will be provided at programmable intervals that can be as small as 100 ms. The beam's spatial distribution may be varied to deliver a uniform dose over a circular area with a diameter of 1 cm–3 cm or focused to a spot with diameter of ≤1 mm.

The key features that will make LhARA the ideal facility for radiobiology are:

• Flexibility to provide a wide variety of temporal, spectral, and spatial beam structures to enable exhaustive investigation of the micro-biophysical processes that determine the response of living tissue to ionising radiation;

• Multiple ion species provided over a variety of temporal, spectral, and spatial distributions in a single facility to allow direct comparison of the radiobiological impact of different species and to assess their relative benefits for therapy;

• Low beam divergence on entry to the in vitro and the in vivo end-stations to allow the detailed study of spatially fractionated radiotherapy; and

• A facility dedicated to radiobiology to allow the assessment of temporal and spatial fractionation schemes in combination with immunotherapy and chemotherapy.

• Deliverable on a relatively short timescale

Outcomes

The execution of the LhARA programme will:

• Prove the feasibility of the laser-hybrid technique, evading the instantaneous flux limit imposed by the space-charge effect in current proton and ion sources;

• Demonstrate that electron-plasma lenses are a viable alternative to high-field solenoids for the capture and transport of proton and ion beams;

• Demonstrate through operation that a fixed field alternating gradient accelerator with variable extraction energy is capable of the routine acceleration of proton and ion beams in a production facility; and

• Integrate real-time dose-deposition imaging in a fast feedback-and-control system to demonstrate the reproducible delivery of dose using a laser-hybrid accelerator system.