Accelerator Physics Exercises No. 1

- Work to be handed in on 24 January 2024

The aim of Hilary Term's work is to prepare a Student Design Project on the study of the dedicated radiobiology research facility LhARA – the Laser-hybrid Accelerator for Radiobiological Applications.

The Student Design Project relates to LhARA, conceived as a novel and flexible facility dedicated to the study of radiobiology. The technologies demonstrated in LhARA, which have wide application, will be developed to allow particle-beam therapy to be delivered in a new regimen, combining a variety of ion species in a single treatment fraction and exploiting ultra-high dose rates.

The Student Design Project will concentrate on the LhARA Stage 1, focusing on laser-target proton and light ion production and acceleration, the capture and focusing by a plasma (Gabor) lens, and the beam transport & delivery to an end station for *in-vitro* radiobiology studies with a flexible spot size.

A detailed description of LhARA is available in the publication (and references therein) at

https://www.frontiersin.org/articles/10.3389/fphy.2020.567738/full

Question 1.1 (Introduction)

Imagine you are writing the introductory section of the LhARA Design Report. Describe clearly and in detail the following:

(a) The motivation of LhARA, including the need for the systematic study of the radiobiology of proton and light-ion beams; the need for novel beams for radiobiology; and the need of laser-hybrid beams for radiobiology and clinical applications. Compare with other types of facilities that have the same aims.

(b) Describe the LhARA Stage 1 facility, including the laser-driven proton and ion sources; the capture and focusing of proton and ion beams; and the beam transport and delivery to the low-energy *in-vitro* end station. Provide an overview of the post-acceleration and beam delivery to the *in-vitro* and *in-vivo* end stations of Stage 2.

(c) Describe the LhARA Stage 1 and Stage 2 design parameters and elaborate on the particle beam and performance requirements.

Question 1.2 (The Lattice)

Using the MAD-X input file attached, perform the following studies.

a) Reproduce the lay-out of the full LhARA Stage 1 lattice and describe in detail the configuration of the full beamline.

b) Calculate and plot the beam envelopes and optical functions of the LhARA Stage 1 beamline.

c) Calculate the spot size at the location of the low-energy *in-vitro* end station. The definition of spot size is 2 sigma diameter (with the beam envelope being 1 sigma radius)?

For any clarification, please contact Dr. William Shields (William.Shields@rhul.ac.uk).

Question 1.3 (The RF Cavities)

Referring to the publication above in *Frontiers in Physics* and Lectures 16-19 from last term at the course INDICO site, elaborate on the following points for the LhARA RF system for Stage 1.

a) Examine and present the main requirements of the RF system including frequency and gap voltage.

b) Evaluate which of the technology options discussed in your RF lectures would be most suitable for these requirements.

c) Propose and design in SuperFish a normal-conducting single cell cavity as an option for LhARA. Present your cavity design, the main parameters and the field on axis. Discuss the advantages and disadvantages of adopting such a design.

For any clarification, please contact Dr. Ciprian Plostinar (ciprian.plostinar@ess.eu).

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19 December 2023