

# Design of LhARA- Laser hybrid Accelerator for Radiobiological Applications

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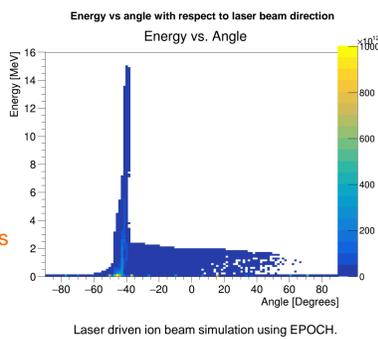
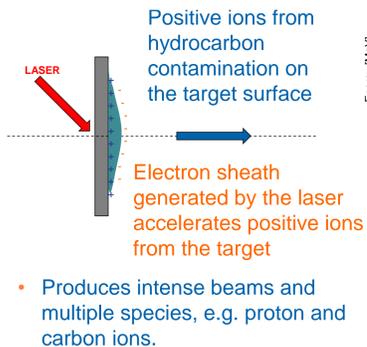
## ABSTRACT

Recent developments of using lasers interacting with targets for the creation of ion beams offer a possibility to provide beams for radiobiology research. This research aims to precisely study the radiobiological effectiveness of charged particles on various cultures of cells, which is essential to inform next generation hadron therapy treatment plans. The Laser hybrid Accelerator for Radiobiological Applications (LhARA) has been proposed to use a laser driven beam, which will be captured and focused using Gabor Lenses. The beam will be then energy and momentum selected to create a beam for in-vitro cells studies or sent to a post-accelerator ring to create beam for in-vivo studies. The optical design of LhARA is presented in this paper.

## Motivation

- A detailed systematic study of the relative biological effectiveness (RBE) for protons and heavier ions, under different physical conditions, with different tissue types could enable to improve treatment planning protocols in hadrontherapy.
- Novel laser driven sources provide multi-ion beams with flexible dose capabilities.

## LASER SOURCE



## GABOR LENS

- The Gabor lens uses an electron plasma to generate a strong electrostatic focusing field.
- Assembled lens prototype is being tested at Imperial.

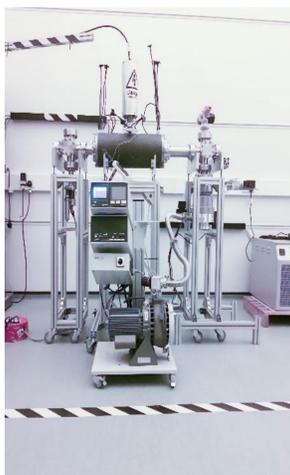


Table 1: Parameters of Gabor lenses assumed in LhARA

Parameter	Value	Units
Total length	1.157	m
Effective focusing length	0.857	m
Max. Cathode voltage	65	kV
Cathode radius	0.0365	m

## Layout of LhARA Stage-1

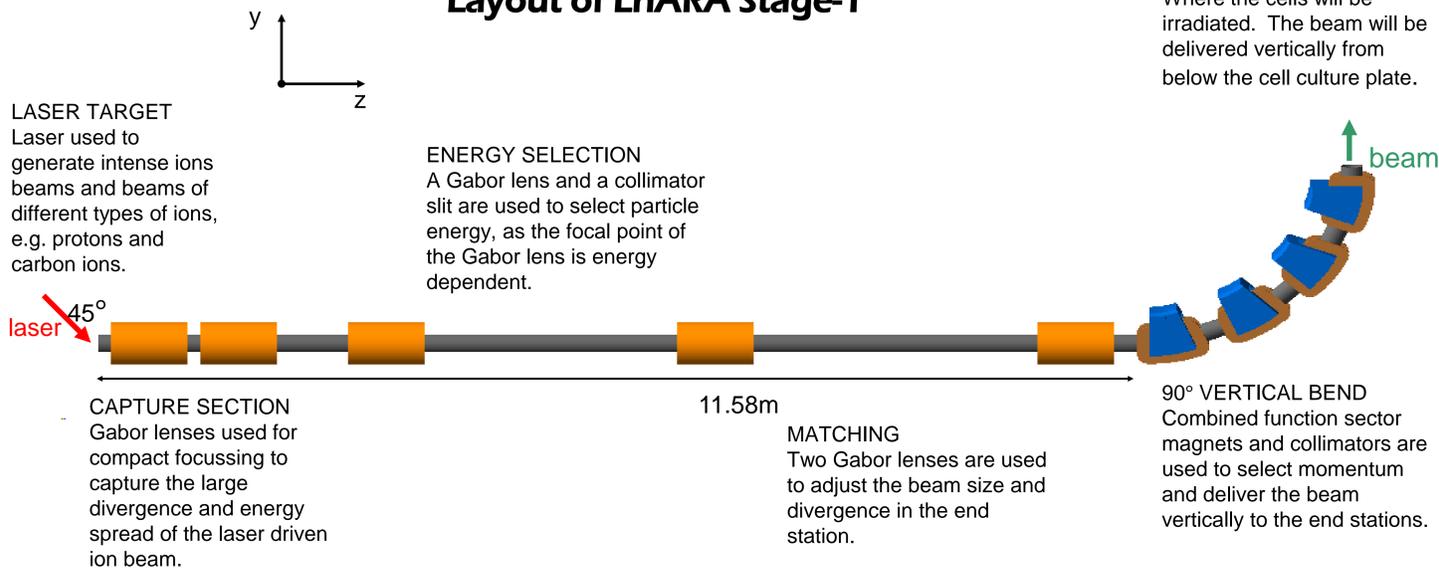
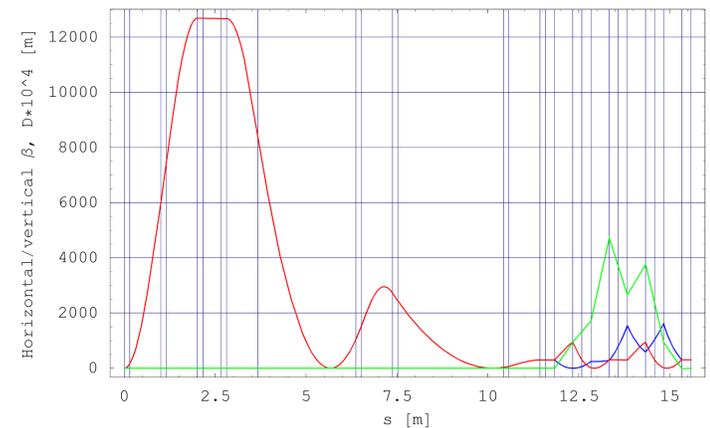


Table 2: Parameters of LhARA, Stage 1.

Parameter	Value	Units
Total length	15.58	m
Length w/o arc	11.58	m
Rep. rate	10	Hz
Initial pulse duration (FWHM)	35	fs
Beam spot size at the target (FWHM)	4	um
Physical emittance (rms)	0.021	$\pi$ .mm.mrad
Proton energy range	12-15	MeV
Final energy spread	$\pm 2\%$	-
Mean dose rate	2	Gy/min
Final spot size (total diameter)	1-15	mm
Final bunch intensity	$10^6$ - $10^9$	-

## LhARA lattice design

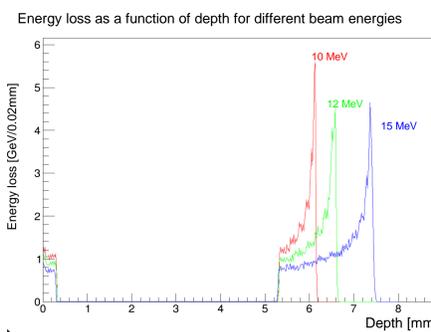
- Input beam will come from laser irradiating a thin plastic foil
- Highly divergent beam will be captured using a very strongly focusing Gabor lenses,
- Beam will be focused strongly back on the collimator, which will reduce the energy spread.
- Downstream the collimator Gabor lenses will provide a beam matching
- A vertical achromatic 90° bend will enable to transport the beam to the radiobiological experiment, while selecting particle momentum.



Vertical (red) and horizontal (blue) betatron functions, and dispersion (green, scaled by  $10^4$  in order to be visible on the plot) in LhARA Stage 1.

## END STATION

- Material budget determines required beam energy.
  - More material increases cost of laser.
  - Consider cell sample containers.
- Energy deposition and dose calculation very important for the design of the end station.
  - Want the Bragg peak in the cell layer.
  - Ensure efficient delivery of dose to the cells (i.e. minimize the time needed to irradiate a sample).
- BDSIM provides energy loss along beam direction.



## CONCLUSION AND FUTURE PLANS

The LhARA facility aims to explore novel accelerator technologies to deliver intense beams of protons and ions from helium to carbon. The optics design of the beam-line for the first stage of LhARA has been created. This stage of the facility aims to explore beam energies in the range 12–15MeV allowing cells to be irradiated before and within the region of the Bragg peak. It may also commission the ion beams needed for Stage 2 of the facility. The optics design will be followed by dedicated beam dynamics studies including tracking studies with and without space charge effects, which will help to verify the performance of the facility. In parallel, Stage 2 of the facility will be designed including an FFA based post-accelerator.



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