# Developing the institute

## BioPhysicsX

BiophysicsX is a unique multidisciplinary institute spanning the physics, radiobiology and clinical disciplines that will ultimately be based at Imperial College’s White City Campus. It is based on a partnership between Imperial College London and Oxford University with national and international collaborators. The innovative setting at the institute will enhance skills and knowledge development at all levels, from student to expert, developing a coherent multidisciplinary community that will include academics, clinicians and industry. The entrepreneurial environment is key to this unique multidisciplinary international collaboration which is a medium risk very high return project.

### Purpose

The institute creates an environment for ground-breaking physics, engineering, laser, biological, and clinical research that aims to deliver novel cancer care and to transform clinical practice. Through the realisation of novel techniques, systems and facilities, the institute will investigate how the DNA in cells reacts to different types of beams and treatment regimens and use this knowledge in the development of new cancer treatments. The step change in understanding at the gene level that is developed will lead to improved treatments with lower levels of toxicity and better clinical systems to deliver them rapidly resulting in improved outcomes for patients.

The co-location of experts from different disciplines, coupled with an interdisciplinary leadership team and governance structure focused on the clinical delivery end point, will generate highly productive conditions for novel research. The momentum and synergy will drive forward progress, for example, in physics, capturing and using a laser-driven beam would be significant for the field as would the study of the cellular and molecular effects of spatially and temporally fractionated beams at very high doses be for radiobiology. Collectively these step changes in understanding will facilitate the development of new types of treatment with enhanced patient experiences and outcomes.

A co-creation of a flexible system for beam delivery lies at the heart of the institute. Innovative physics techniques are being developed firstly to build a research tool for *in-vitro* and *in-vivo* experiments using lasers to create the beams that are rapidly accelerated, opening up new research areas in radiation biology. These advances will pave the way for a radical redesign of therapy machines, for example removing the need for a large gantry. The interdisciplinary activities of the institute will enable further development into a patient treatment machine.

### Research

Guided by the clinical imperatives, research will initially be focused on two strands: the development and construction of the Laser-hybrid Accelerator for Radiobiological Applications (LhARA); and radiobiological research that will later use LhARA as its research base.

LhARA is an ion beam accelerator that can deliver a variety of ion species at ultra-high dose rate in different spatial-, temporal-, and spectral-fractionation schemes. It brings together components used in other physics research fields to create a compact system with numerous advantages to the benefit of the life science and medical fields, for example:

* The laser system creates a large flux of protons or light ions in nano-second long pulses that can be triggered and which allows accurate targeting of the beam that can be coupled to an interactive feedback system to reposition the beam;
* The Gabor lens is a strong focusing electron-plasma device that can capture protons and ions at higher energies than conventional systems, removing limitations on the instantaneous dose rate and at a fraction of the cost of conventional systems;
* The fixed field alternating gradient accelerator (FFA) provides an energy-efficient system that maintains the structure of the beam. This advanced technique of capturing and accelerating the beam would mark an engineering breakthrough making LhARA a unique research tool for physicists, including medical physicists, as well as adding value to a variety of physics disciplines; and
* Ion-acoustic dose profile measurement will allow the dose and its distribution to be measured in real time. This will be fully automated so that it can be tailored to meet individual needs and pulse-to-pulse adaptations as the beam is delivered.

Combining these elements creates a highly flexible tool and a stable and easily-accessible beam that offers researchers a wealth of R&D opportunities in all of the associated fields. From the outset, and regardless of eventual outcomes, the development possibilities in instrumentation and computing will be of benefit to the medical-physics field and have the potential to be spun out into treatment planning. Some of the more fundamental laser research will have implications for the semiconductor industry.

Initial extensive use is being made of computer simulation techniques and machine learning to optimise the design and to enhance the prototyping of components and systems. Construction will follow the present pre-construction R&D phase bringing in state-of-the-art instrumentation prior to development of a therapy machine.

The current funding for the 2-year preliminary phase is enabling R&D and initial prototyping for the conceptual design report.

The radiobiological research which will run in parallel will examine the relative biological effectiveness of different ions and the effectiveness of different beam-delivery systems, leading to an understanding of the interaction of different charged beams at high repetition rates on living cells and the biological mechanisms involved in breaking DNA strands. These insights will pave the way to improve radiation therapy and clinical practice. Current research aims to provide the basis for comparison between conventional and novel beams, developing the techniques that will maximise the scientific benefits of LhARA when access becomes available.

### Industry

The institute environment and White City location embeds constructive interaction and collaboration to enhance the benefits of industrial partnership. Activities will range from research projects at PhD or shorter collaboration level, to more extensive, focused partnerships, through to incubation of spin-out companies. Research projects likely to interest medical equipment suppliers and give sponsoring organisations insight into emerging technology and new or emerging data, as well as offering training in cutting edge technologies, instrumentation, and a wealth of opportunities to employ novel computing techniques, including Artificial Intelligence.

An existing example of collaboration is the links made through a UKRI funded Future Leadership Fellow at LEO Cancer Care, a company that is developing upright radiation therapy solutions.

### Skills and training

The institute will bring currently fragmented research strands together to forge a coherent and holistic vision, quickly creating synergies that are likely to produce a step change in capability. It will offer substantial research opportunities and under- and post-graduate level education and training in research areas, including those not currently accommodated. Integration, and close location, of the clinicians at the Hammersmith Hospital will ensure the ultimate clinical focus and overall direction will be maintained.

### Structure

At present the development of the research strategies is through institutional collaboration. A step change in focus will come through the creation and funding of the institute’s senior leadership team (CEO, director of physics, director of radiobiology), which will enhance the interdisciplinary aspects of skills and training and help drive forward engagement with potential industry and international partners.