OMA Express
March 2023
Issue 19

Highlights

- Research News
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Updates from our Fellows, events, and more

It is hard to believe that it has now been more than 3 years that the OMA project officially ended. It really seems like yesterday that we had our end-of-project-meeting in beautiful Seville, Spain.

A lot has obviously happened since that time and it is great to see that a number of R&D projects have emerged as a result of our network. I would like to encourage all project partners, past Fellows and collaborators to continue contributing to our newsletter and website more generally. This really is a very efficient way of making others aware of the latest research outcomes – it benefits hugely from input that cuts across particle beam therapy, instrumentation and associated simulation studies. A simple email to Dr Ricardo Torres or myself is sufficient *(contact details on the last page)*.

This *OMA Express* gives several updates from our past Fellows – either in the form of an interview or through research articles that they have recently (co)authored. It is such a vibrant field and really nice to see that they keep pushing the limits of technology and help improve ion beam based therapy.

One project that has just started and which I thought I should highlight here is the EuPRAXIA Doctoral Network. Funded by Horizon Europe and the UKRI Guarantee Funds, EuPRAXIA-DN is an MSCA network that directly follows the spirit of OMA. The project will train 12 Fellows at institutions across Europe who will start their projects later this year. Their training will be directly based on the OMA program, enhanced by the feedback from our past Fellows and supervisors. You will find more details about this network in this OMA Express. There will be many opportunities to get involved and I hope to see you at one of our many EuPRAXIA-DN events!

With my very best wishes

Prof Dr Carsten P Welsch
OMA Coordinator

Research News

Experimental Validation of a Real-Time Adaptive 4D-Optimized Particle Radiotherapy Approach to Treat Irregularly Moving Tumors

Treatment of locally advanced lung cancer is limited by toxicity and insufficient local control. Particle therapy could enable more conformal treatment than intensity modulated photon therapy but is challenged by irregular tumor motion, associated range changes, and tumor deformations.

Former OMA Fellow Michelle Lis and collaborators have proposed a new strategy for robust, online adaptive particle therapy, synergizing 4-dimensional optimization with real-time adaptive beam tracking. The strategy was tested and the required motion monitoring precision was determined.

The results were published in the International Journal of Radiation Oncology, Biology, Physics.

In multiphase 4-dimensional dose delivery (MP4D), a dedicated quasistatic treatment plan is delivered to each motion phase of periodic 4-dimensional computed tomography (4DCT). In the new extension, "MP4D with residual tracking" (MP4DRT), lateral beam tracking compensates for the displacement of the tumor center-of-mass relative to the current phase in the planning 4DCT.

The authors implemented this method in the dose delivery system of a clinical carbon facility and tested it experimentally for a lung cancer plan based on a periodic subset of a virtual lung 4DCT (planned motion amplitude 20mm). Treatments were delivered in a quality assurance-like setting to a moving ionization chamber array. They considered variable motion amplitudes and baseline drifts. The required motion monitoring precision was evaluated by adding noise to the motion signal. Log-file-based dose reconstructions were performed in silico on the entire 4DCT phantom data set capable of simulating nonperiodic motion. MP4DRT was compared with MP4D, rescanned beam tracking, and internal target volume plans. Treatment quality was assessed in terms of target coverage (D95), dose homogeneity (D5-D95), conformity number, and dose to heart and lung.

For all considered motion scenarios and metrics, MP4DRT produced the most favorable metrics among the tested motion mitigation strategies and delivered high-quality treatments. The conformity was similar to static treatments. The motion monitoring precision required for D95 >95% was 1.9mm.

With clinically feasible motion monitoring, MP4DRT can deliver highly conformal dose distributions to irregularly moving targets.

Full article:

Steinsberger, Timo; Donetti, Marco; Lis, Michelle; Volz, Lennart; Wolf, Moritz; Durante, Marco; Graeff, Christian, "Experimental Validation of a Real-Time Adaptive 4D-Optimized Particle Radiotherapy Approach to Treat Irregularly Moving Tumors", INTERNATIONAL JOURNAL OF RADIATION ONCOLOGY, BIOLOGY, PHYSICS (2022)
https://doi.org/10.1016/j.ijrobp.2022.11.034

First application of the BIANCA biophysical model to carbon-ion patient cases

Former OMA Fellow Giulia Arico and colleagues have published an article in [Physics in Medicine And Biology] reporting the first application of the BIANCA (BIophysical ANalysis of Cell death and chromosome Aberrations) biophysical model to carbon-ion patients.

The main objective of the work consisted of applying, for the first time, the BIANCA biophysical model to the relative biological effectiveness (RBE) calculation for C-ion cancer patients, and comparing the outcomes with those obtained by the LEM I model, which is applied in clinics.

Indeed, the continuous development of heavy-ion cancer therapy requires modelling of biological effects of ion beams on tumours and normal tissues. The RBE of heavy ions is higher than that of protons, with a significant variation along the beam path. Therefore, it requires a precise modelling, especially for the pencil-beam scanning technique.

Currently, two radiobiological models, LEM I and MKM, are in use for heavy ions in scanned pencil-beam facilities. Utilizing an interface with the FLUKA Particle Therapy Tool, BIANCA was applied to re-calculate the RBE-weighted dose distribution for carbon-ion treatment of three patients (chordoma, head-and-neck and prostate) previously irradiated at CNAO, where radiobiological optimization was based on LEM I.

The predictions obtained by BIANCA were based either on chordoma cell survival (RBEsurv), or on dicentric aberrations in peripheral blood lymphocytes (RBEab), which are indicators of late normal tissue damage, including secondary tumours. The simulation outcomes were then compared with those provided by LEM I.

While in the target and in the entrance channel BIANCA predictions were lower than those obtained by LEM I, the two models provided very similar results in the considered OAR. The observed differences between RBEsurv and RBEab (which were also dependent on fractional dose and linear energy transfer (LET) suggest that in normal tissues the information on cell survival should be integrated by information more closely related to the induction of late damage, such as chromosome aberrations.

This work showed that BIANCA is suitable for treatment plan optimization in ion-beam therapy, especially considering that it can predict both cell survival and chromosome aberrations and has previously shown good agreement with carbon-ion experimental data.

Full article:

Kozlowska, Wioletta S.; Carante, Mario P.; Arico, Giulia; Embriaco, Alessia; Ferrari, Alfredo; Magro, Giuseppe; Mairani, Andrea; Ramos, Ricardo; Sala, Paola; Georg, Dietmar; Ballarini, Francesca, "First application of the BIANCA biophysical model to carbon-ion patient cases", PHYSICS IN MEDICINE AND BIOLOGY **67**(11), 115013 (2022)
https://doi.org/10.1088/1361-6560/ac702b

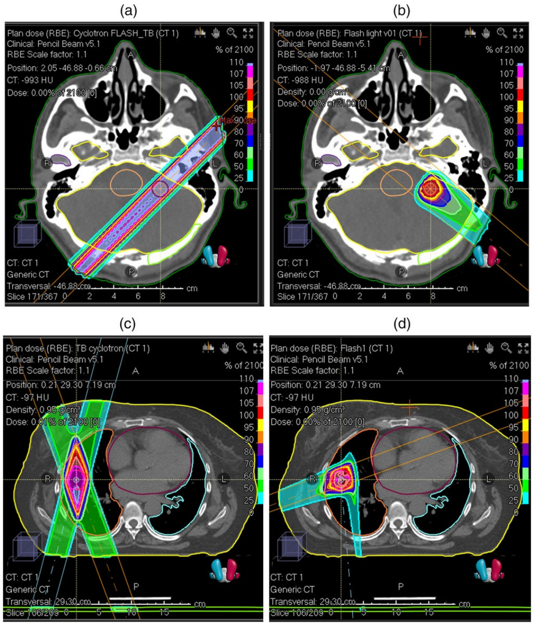
Ultra-high dose rate radiation production and delivery systems intended for FLASH

Higher dose rates, a trend for radiotherapy machines, can be beneficial in shortening treatment times for radiosurgery and mitigating the effects of motion. Recently, even higher doses (e.g., 100 times greater) have become targeted because of their potential to generate the FLASH effect (FE).

In a recent article published in Medical Physics, former OMA Fellow Sud Srinivasan and colleagues explore the production and delivery systems of ultra-high dose rate radiation (UHDR) for FLASH.

The complete relationship between UHDR and the FE is unknown, but UHDR systems are needed to explore the relationship further and to deliver clinical UHDR treatments where indicated. Despite the challenging set of unknowns, the authors seek to make reasonable assumptions to probe how existing and developing technology can address the UHDR conditions needed to provide beam generation capable of producing the FE in preclinical and clinical applications.

As a preface, the paper discusses the known and unknown relationships between UHDR and the FE. Based on these, different accelerator and ionizing radiation types are then discussed regarding the relevant UHDR needs. The details of UHDR beam production are discussed for existing and potential future systems such as linacs, cyclotrons, synchrotrons, synchrocyclotrons, and laser accelerators. In addition, various UHDR delivery mechanisms are discussed, along with required developments in beam diagnostics and dose control systems.



Comparison of PBS transmission (proton cyclotron) vs conformal (proton linac) 21 Gy single fraction UHDR plans for a 2 cm diameter brain and lung target (produced with RayStation, RaySearch AB, Stockholm).

Full article:

Farr, Jonathan; Grilj, Veljko; Malka, Victor; Sudharsan, Srinivasan; Schippers, Marco, “Ultra-high dose rate radiation production and delivery systems intended for FLASH”, MEDICAL PHYSICS **49**(7), 4875 – 4911 (2022)
https://doi.org/10.1002/mp.15659

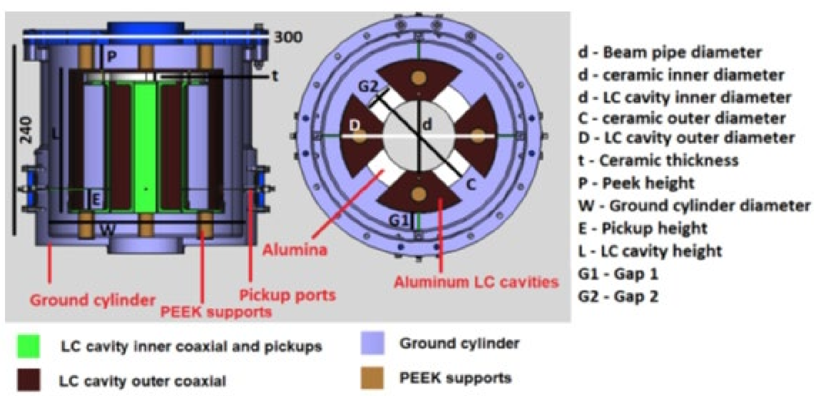
Development of a novel beam position monitor for proton therapy facilities

Former OMA Fellow Sud Srinivasan and colleagues from the Paul Scherrer Institute (Switzerland) and the University of Groningen (Netherlands) have presented a novel type of non-intercepting beam position monitor (BPM) for the Paul Scherrer Institute's superconducting cyclotron "COMET", which delivers 250 MeV proton beams for radiation therapy in pulses of 1ns at the cyclotron frequency of 72.85 MHz.

The report, published in the latest issue of the Journal of Instrumentation, discusses the fundamental characteristics of the BPM, is based on the detection of the transverse magnetic dipole mode of the EM field generated by the beam in a cavity resonator tuned to the second harmonic of the cyclotron's RF. This mode is only excited for off-center beam positions and can be measured with the help of four floating cavities within a common grounded cylinder.
The authors estimated the expected signals from the prototype BPM for position offsets from simulations and compared them with test-bench measurements and beam measurements with the prototype and an improvised BPM design.

This new system can achieve a position precision (1σ) better than 0.5 mm at proton beam currents of 0.1–10 nA in the beam transport line downstream of the degrader, which is essential for efficient operation of the cyclotron and a safe beam delivery for treatment.

This is the first non-interceptive beam position monitor to have demonstrated position measurements in a cyclotron-based proton therapy facility. Such a cavity BPM could also have advantages compared to the typically used ionization chambers for the purpose of daily quality checks in irradiations using higher beam intensities.



Cut plane of the cavity BPM prototype. Dimensions are in mm.
Credit: S. Srinivasan et al 2022 JINST 17 P09013 CC BY 4.0

Full article:

S. Srinivasan, S. Brandenburg, J.M. Schippers and P.A. Duperrex, "Development of a fourfold dielectric-filled reentrant cavity as a beam position monitor (BPM) in a proton therapy facility", JOURNAL OF INSTRUMENTATION, **17**, P09013 (2022)
https://doi.org/10.1088/1748-0221/17/09/P09013

An ion-independent phenomenological relative biological effectiveness (RBE) model for proton therapy

A relative biological effectiveness (RBE) of 1.1 is used for proton therapy though clinical evidence of varying RBE was raised. Clinical studies on RBE variability have been conducted for decades for carbon radiation, which could advance the understanding of the clinical proton RBE given an ion - independent RBE model.

In a recent article published in [Radiotherapy and Oncology](), former OMA Fellow Liheng Tian and collaborators, have tested a linear and simple, ion-independent RBE model using the beam quantity $Q = Z^2/E$, where Z is the ion charge and E is kinetic energy per nucleon. The model was compared to the commonly used Wedenberg RBE model, proton-specific and based on the linear energy transfer (LET).

The Wedenberg and Q models, both predicting RBEmax and RBEmin (i.e., RBE at vanishing and very high dose, respectively), were compared in terms of ion-dependence and prediction power. An experimental in-vitro data ensemble covering 115 publications for various ions was used as dataset.

The model parameter of the Q model was observed to be similar for different ions (in contrast to LET). The Q model was trained without any prior knowledge of proton data. For proton RBE, the differences between experimental data and corresponding predictions of the Wedenberg or the Q model were highly comparable.

Therefore, adding (pre)clinical knowledge from carbon ion therapy may reduce the dominating biological uncertainty in proton RBE modelling. This would translate in reduced RBE related uncertainty in proton therapy treatment planning.

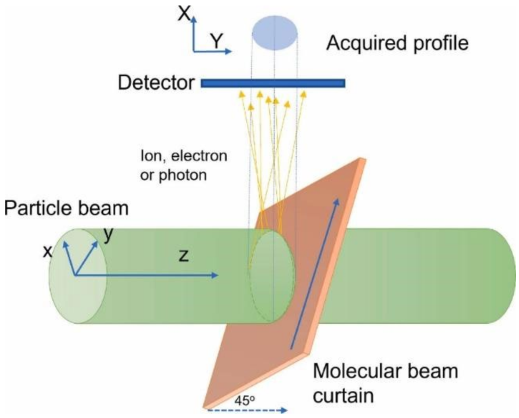
Full article:

Tian, Liheng; Hahn, Christian; Luehr, Armin, "An ion-independent phenomenological relative biological effectiveness (RBE) model for proton therapy", RADIOTHERAPY AND ONCOLOGY **174**, 69 – 76 (2022)
https://doi.org/10.1016/j.radonc.2022.06.023

Characterizing a molecular beam curtain for non-invasive beam profile monitor

Non-invasive beam profile monitors are highly desirable for modern accelerators. They can provide comprehensive information about the particle beam, such as beam sizes and emittances, without stopping the operation. This would be ideal for many applications, including high intensity and high energy applications, such as the Large Hardon Collider (LHC) and the European Spallation Source (ESS), and proton therapy accelerators, where a beam profile monitor based on a supersonic molecular curtain would guarantee a safe and smooth operation.

The advantages of such a method include minimum disturbance, two-dimensional measurement and versatility. The principle of such a monitor can be seen in the image.

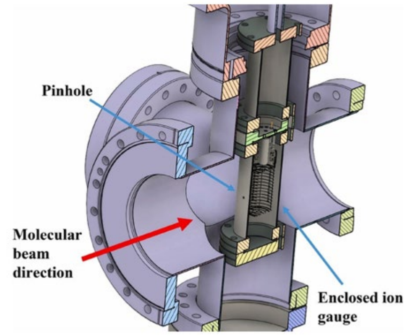


Concept of using a gas jet as a Beam profile monitor. (Image credit: Zhang, H et al. Vacuum 208, 111701, 2023, CC BY 4.0)

To fulfil the versatility of such methods, different sets of nozzle and skimmers will be used to generate molecular curtains with different sizes and number densities to tailor the need of particular accelerators with the requirement of the vacuum condition preservation and measurement time. Such modifications need to be characterized before their application. Recently in an open-access paper just published in Vacuum, researchers from the University of Liverpool's QUASAR Group developed a compression gauge method to quantify the molecular curtain. This method uses a hot ion gauge enclosed in a small chamber but with a pinhole opening for accepting the molecular beam for absolute number density measurement as seen in schematic drawing of the movable gauge. By mechanically scanning the pinhole, the distribution can also be measured.

Previously, laser interferometry techniques, Rayleigh scattering, a common microphone or pressure transducer, multi-photon ionization, and nuclear scattering were used to determine the molecular flow in the number density range of 1020 – 1022 m-3 or higher but suffer from the signal-to-noise ratio for our application where the number density is much lower. This research fills the gap in measuring molecular beams in the ranges from 1014 – 1017 m-3.

This method does not only pave the way for further improvement of beam profile monitor development but can also be applied in other fields such as nuclear physics, nuclear astrophysics and atomic physics where similar supersonic gas jets or molecular beam sources are widely used.



Schematic drawing of the movable gauge (Image credit: Zhang, H et al. Vacuum 208, 111701, 2023, CC BY 4.0)

Full article:

*H.D. Zhang, A. Salehilashkajani, O. Sedlacek, C.P. Welsch, "*Characterization of a supersonic molecular beam for charged particle beam profile monitor"*, VACUUM,* Volume **208 (**2023) https://doi.org/10.1016/j.vacuum.2022.111701

Fellows Activity

Catching up with the Fellows – Navrit Bal

Now that the formal period of the OMA project has come to an end we were very keen to find out which routes our Fellows have taken, their plans for the future and how they reflect on their time as OMA Fellow.

What have you been working on since the end of OMA?

"Following the end of the OMA project, I was half way through my PhD at Nikhef. That has now come to an end as of January 2022, the intention is to defend my thesis in the summer. The working title is: "Medipix3: Spectral X-ray micro-CT and hadron therapy". Almost by accident, I have found myself with a postdoc position at Aarhus, Denmark at the University Hospital / DPCT (Danish Centre for Particle Therapy). This came about as part of a grant I co-applied for with my collaborator during the OMA project.

Alongside this, I co-founded a company with my old supervisor on IIoT (Industrial Internet of Things). We are currently getting our first customers after a series of pilot projects."."

Did the networking opportunities within OMA help you to get your present job?

"While they did not contribute directly, opportunities have come my way via contacts made with the OMA network."

What are the skills that you learned in OMA that are most valued in your current job?

""I found the multinational and interdisciplinary networking and socialising aspects to be the most useful. I would say the most important were technical knowledge (hadron therapy), high performance programming and the realities of startups."

Are you still in contact with the OMA Fellows?

"Of course! Jacinta and I talk very frequently, many cat memes are exchanged. However, since there are no other OMA fellows in the Netherlands, there haven't been any in person meetings... We do our best to have group calls with as many OMA fellows as possible every now and then, which are always very interesting.

I'm really looking forward to the promised last OMA meeting!"

What will be your most cherished memory from OMA?

"There are so many! I would highlight IPAC (10th International Particle Accelerator Conference) 2019 in Melbourne. Sud and I were the last attendees to hold a python. I took the opportunity to go on a solo road-trip around the state of Victoria. Then, I continued around Japan on the way back with my girlfriend and the Shinkansen!"

And the one you'd rather forget?

"Missing the last day of the conference in Seville that I was meant to chair."

Partner News

Adaptix receives 510(k) clearance from the U.S. Food and Drug Administration for its first medical imaging product

Adaptix's new imaging system is portable and provides 3D X-ray imaging of hands, elbows and feet. Photo courtesy of Adaptix.

Adaptix, based at Oxford University Science Park, is driven by a mission to transform radiology by offering affordable low-dose 3D ('Digital Tomosynthesis' or 'DT') imaging at the point-of-care.

The first Adaptix medical product is a Digital Tomosynthesis Orthopedic imaging system. It is a portable, low-dose imaging system capable of delivering fast, lower-cost, X-ray imaging at the point of patient care. Developed specifically to offer 3D X-ray imaging of hands, elbows and feet at a fraction of the radiation dose and per-study price of traditional CT systems, the system provides clinicians with clearer images than 2D X-ray systems, offering advantages in terms of fewer acquisitions, accelerated patient workflow and enhanced diagnostic accuracy.

Adaptix is already serving veterinary and industrial (Non-Destructive Evaluation) markets using its novel and patent-protected technologies. Receiving the 510(k) clearance is important as it is the first step in Adaptix delivering its mission to transform radiology through provision of innovative truly-portable 3D imaging technologies into healthcare providers.

Mark Evans, Adaptix's CEO, stated, *"We are delighted to receive the 510(k) clearance which allows this innovative technology, and our first medical product, to be marketed in the world's largest healthcare market. The team are energized by achieving this milestone, and we look forward to delivering enhanced orthopedic DT imaging systems; a dental DT imaging system; and a chest DT imaging system for Intensive Care and Emergency Department use. We see a future where 3D travels to the patient at the point-of-care throughout hospitals, clinics and primary care transforming patient pathways, improving patient experience, and reducing the cost of care delivery."*

About Adaptix Limited

2D X-ray is currently the world's dominant diagnostic modality due to speed and cost, however, this frequently results in inconclusive reads due to areas of clinical interest being obscured by overlying and underlying tissues. This can lead to diagnostic "misses" and delays, additional referrals for an "over-read", and excessive and expensive escalation to Computer Tomography (CT) or MRI, as well as potentially unnecessary immobilisation of a limb for a patient awaiting diagnosis.

Adaptix Limited is transforming radiology through the development of innovative 3D imaging technologies. At the core of their patent portfolio and commercialization strategy is a distributed Flat Panel X-ray Source (FPS) system which has applications across a multitude of global markets that are currently limited to 2D X-ray imaging systems where cost, speed to diagnostic result, location or dose concerns mean CT is not optimal. Adaptix's central mission is to transform radiology by offering affordable low-dose 3D imaging at the point-of-care and allowing "3D-first" as the standard of care.

This project has been supported by the European Space Agency, as part of an ESA Business Applications project, and by Innovate UK.

Article adapted from: https://adaptix.com/u-s-fda-510k-clearance-received/

GSI in one of the 10 breakthroughs of 2022: Investigating new weapons in the fight against cancer

World's leading oncology journal dedicates its cover story to the FLASH method in which GSI has a leading role.

It could become a powerful weapon in the fight against cancer and open up completely new possibilities for tumor therapy with charged particles. FLASH irradiation – the application of an ultra-high radiation dose in a very short time – is in strong focus worldwide and is being advanced with high expertise at GSI and FAIR. FLASH clinical implementation is one of the top 10 Breakthroughs of the Year 2022 according to "Physics World". In its December issue, the world's leading high-impact journal for oncology "Nature Reviews Clinical Oncology" presents the FLASH method as its current cover story. The head of GSI biophysics department, Prof. Marco Durante, is one of the three authors.

At GSI/FAIR, the scientists are working on constantly improving particle therapy through new technologies and treatment procedures for the benefit of society. The new FLASH method is a highly promising approach. During the FAIR Phase 0 experimental period the scientists succeeded in performing a carbon ion FLASH experiment on the GSI/FAIR campus for the first time. In addition, GSI/FAIR joins forces in an international cooperation with participants from industry and science to advance medical-technical developments in the field of FLASH therapy. The goal is to pave the way to clinical application.

The cover story in "Nature Reviews Clinical Oncology" refers to a recent research paper by Professor Marco Durante, Head of GSI's Biophysics, and Dr. Marie-Catherine Vozenin and Professor Jean Bourhis, Lausanne University Hospital and University of Lausanne, which is entitled "Towards clinical translation of FLASH radiotherapy". The authors describe the worldwide status of this highly innovative treatment method and evaluate possible perspectives for FLASH radiotherapy.

The cover of "Nature Reviews Clinical Oncology". © Cover design: Simon Bradbrook

In their conclusion, they summarize: "At present, FLASH radiotherapy has largely sparked the imagination and interest of radiation scientists and oncologists. The advantages of ultra-short treatments at high doses of radiation go beyond the potential widening of the therapeutic window, because short treatment times could also improve the comfort of the patient and the workflow of clinical centers, even if imaging time will remain a limiting factor for accelerating such workflows". They also provide an overview: "In translational and clinical research, studies on the dose and fraction dependence, tissue specificity, combined treatments and, of course, phase I trials are the highest priority. The future of FLASH radiotherapy will strongly depend on the results of these experiments and the answers to some key questions, including those we have discussed herein".

The Scientific Managing Director of GSI and FAIR, Professor Paolo Giubellino, said: "*GSI and FAIR are leading research centers in the research and development of FLASH therapy. I am very glad to see the current research placed so prominently in one of the most impactful scientific media for oncology showing the overall importance of this topic. This demonstrates once again how strongly our basic research boosts the development of new technologies and methods of high societal impact. Together with strong partners, we are working hard to ensure that our scientific breakthroughs will serve society.*"

Reproduced from: https://www.gsi.de/…/erforschung-neuer-waffen-im-kampf-gegen-krebs

IBA wins ten proton therapy system contract in Spain

IBA (Ion Beam Applications S.A.), a key member of OMA and one of the leaders in medical accelerators, has confirmed the signing of a contract with the Spanish Ministry of Health to install ten proton therapy systems across Spain as part of a significant public tender. This follows the announcement in August that IBA had qualified as the only supplier of the tender.

The total value of the contract to IBA is currently EUR 217 million, all taxes excluded, for the ten systems to be installed at nine different sites in Spain. The contract does not include the typical multi-year maintenance component which will be negotiated at a later stage. Revenue recognition will start in 2022.

The project is being funded by the Amancio Ortega Foundation, which signed an agreement with the Spanish Ministry of Health in 2021 under which the Foundation agreed to donate funds for the purchase of ten proton therapy systems to be installed across Spain.

Olivier Legrain, Chief Executive Officer of IBA commented: “*This significant contract win for IBA is testament to the world-class quality of our offering and validates our established status as the proton therapy market leader with the unique ability to respond to a contract of such scale. We look forward to working closely with the nine centers across Spain to deliver this life-saving treatment to their patients*.”

Luk Herremans, Executive Vice President of IBA Proton Therapy added “*Securing such a major public tender underlines the growing importance of proton therapy in the treatment of cancer, in a market that continues to see strong momentum globally with more clinical evidence being generated on the treatment modality than ever before. We welcome these new Spanish centers to our IBA Campus community, which is the largest in the world and where they will be able to both learn from and share with other members in order to provide cutting-edge cancer care to their patients.”*

The OMA network congratulates its partner IBA for this remarkable success.

Based on an article published on the IBA news page: https://www.iba-worldwide.com/content/iba-wins-10-proton-therapy-system-contract-spain

EuPRAXIA Doctoral Network to research on laser-driven proton beam therapy

The EuPRAXIA Doctoral Network (EuPRAXIA-DN) is a new Horizon Europe Marie Skłodowska-Curie Actions Doctoral Network (MSCA-DN), offering 12 high level fellowships between universities, research centres and industry to will carry out an interdisciplinary and cross-sector plasma accelerator research and training program for the new EuPRAXIA research infrastructure.

Included in the European Strategy Forum on Research Infrastructures (ESFRI) Roadmap in 2021, EuPRAXIA will develop an innovative electron accelerator using laser- and electron-beam-driven plasma wakefield acceleration.

EuPRAXIA-DN will focus on the formation of early stage researchers by their completion of a dedicated research project and an intense programme of training and secondments across a number of European institutions. One of the projects on offer, led by the University of Liverpool, will be devoted to laser-driven proton beam therapy.

EuPRAXIA provides an exciting platform to explore new, highly flexible radiation sources which can allow proton and ion beams to be captured at energies significantly above the proton- and ion-capture energies that pertain in conventional facilities, thereby evading the current space-charge limit on the instantaneous dose rate that can be delivered.

This project will investigate Laser-driven Proton Beam Therapy as a potential application with important health, economic and social impact. It will study concepts for using a laser to drive the creation of a large flux of protons or light ions which are captured and formed into a beam by strong-focusing plasma lenses.

A laser-driven source allows protons and ions to be captured at energies significantly above those that pertain in conventional facilities, thus evading the current space-charge limit on the instantaneous dose rate that can be delivered.

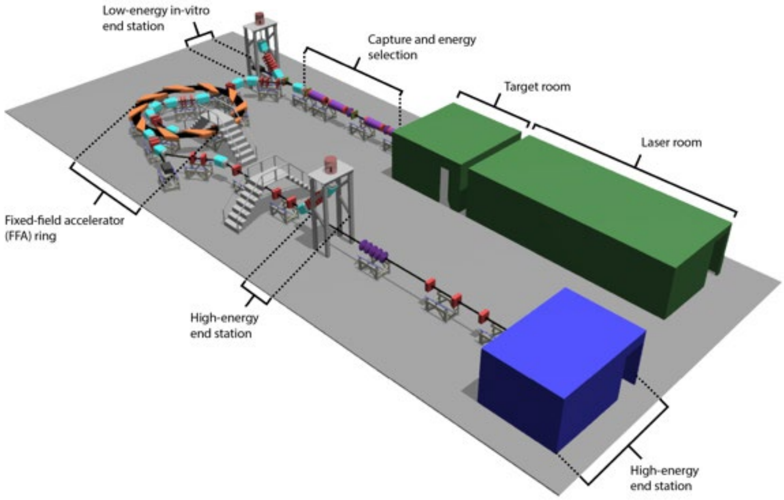
The project will also explore the use of gas jet technology for characterizing charged particle beams. The University of Liverpool's QUASAR Group has pushed this technology for more than a decade and already optimized it for use with low energy electrons and antiprotons, as well as for the high luminosity upgrade of the Large Hadron Collider (LHC) at CERN.

In EuPRAXIA-DN this will be adapted for the challenges found in laser-driven ion beam cancer therapy and connected with the R&D carried out in other initiatives such as the LhARA project. This requires online, shot-by-shot measurement of beam position, profile and intensity which shall all be achieved by a single monitor.

The Fellow will have access to the wide-ranging EuPRAXIA-DN training program which will include several international schools and workshops on plasma accelerator science and technology, as well as complementary skills. They will be registered for their PhD at the University of Liverpool and have access to the postgraduate lecture program at the Cockcroft Institute.

More information at: www.eupraxia-dn.org

Supporting next generation radiotherapy for cancer treatment



The Ion Therapy Research Facility. The laser and the laser-target vessel are housed in a shielded bunker (green structures). The capture line, composed of three Gabor lenses emerges, from the bunker and guides the beam to the acceleration system and biological research laboratories. (Credit: ITRF)

University of Liverpool physicists are providing their expertise to a new UKRI research project that will underpin the next generation of ion radiotherapy treatments for cancer.

The £2million project will support the establishment of the Ion Therapy Research Facility (ITRF), which will bring together leading UK and international clinicians, scientists, engineers and industry to exploit the UK's advanced expertise in developing new laser technologies for medical applications.

The Laser hybrid Accelerator for Radiobiology Applications (LhARA) forms part of ITRF and University of Liverpool physicists are developing technology for LhARA.

LhARA will use laser sources to create intense proton and ion beams which it will steer to their target with the help of plasma lenses, guided by beam monitoring systems that are being developed by the University's Physics Department.

Developing these new technologies will mean that LhARA can provide more types of ions with greater control over how they are used for treatment than is possible with current radiotherapy facilities, and do this at a lower cost.

Proton therapy targets cancers very precisely, increasing success rates and reducing side-effects. This makes it the ideal treatment for children whose organs are still growing, or solid tumours close to sensitive tissues.

For this reason, the NHS has recently opened two proton therapy centres, one at the Christie in Manchester and another at UCLH in London. These are in addition to the proton facilities at the Clatterbridge Cancer Centre in Bebington which are dedicated for tumours of the eye.

LhARA will allow investigations into the use of carbon and other ions which are even more effective at killing cancer cells than protons.

Professor Ken Long from Imperial College, who is leading the LhARA project, said: *"It is great news that we have got funding to start up LhARA. In the next two years we will start tests of the laser source concept and investigate plasma lenses for steering particle beams, two key technologies we must develop for the project."*

Another major part of the LhARA programme is the development of new treatment monitoring techniques. The LhARA team has shown that the ion beams will produce ultrasound signals. Measuring these while radiotherapy treatment is occurring will give an instantaneous picture of the effect of the radiation and of the treated and surrounding tissues, which will take treatment optimisation for the individual patient to new levels. This cutting-edge R&D will be carried out within the University's QUASAR Group, led by Professor Carsten P Welsch.

As LhARA is developed, intermediate stages of the facilities will be used to study the effects of the beams it produces on cancer cells as well as on normal tissue.

Professor Jason Parsons, a radiobiologist from the University of Liverpool who is engaged with the LhARA programme, said: "This will greatly accelerate our understanding of how protons and ions interact and are effective in killing cancer cells, while simultaneously giving us experience of running the novel beam provided through the LhARA machine. Together, the technology and the science will help us make a big step forward in optimising radiotherapy treatments for cancer patients."

Organised through the Science and Technology Facilities Council's (STFC) Daresbury Laboratory, at Sci-Tech Daresbury, UKRI is investing £2 million in researching the next generation of radiotherapy treatments for cancer, through the development of the Ion Therapy Research Facility (ITRF).

For further information visit: Researching a new generation of technology to treat cancer – UKRI

Selected Publications

Steinsberger, Timo; Donetti, Marco; Lis, Michelle; Volz, Lennart; Wolf, Moritz; Durante, Marco; Graeff, Christian, **“Experimental Validation of a Real-Time Adaptive 4D-Optimized Particle Radiotherapy Approach to Treat Irregularly Moving Tumors”**, INTERNATIONAL JOURNAL OF RADIATION ONCOLOGY, BIOLOGY, PHYSICS (2022) https://doi.org/10.1016/j.ijrobp.2022.11.034

Kozlowska, Wioletta S.; Carante, Mario P.; Arico, Giulia; Embriaco, Alessia; Ferrari, Alfredo; Magro, Giuseppe; Mairani, Andrea; Ramos, Ricardo; Sala, Paola; Georg, Dietmar; Ballarini, Francesca, **“First application of the BIANCA biophysical model to carbon-ion patient cases”**, PHYSICS IN MEDICINE AND BIOLOGY 67(11), 115013 (2022) https://doi.org/10.1088/1361-6560/ac702b

Farr, Jonathan; Grilj, Veljko; Malka, Victor; Sudharsan, Srinivasan; Schippers, Marco, **“Ultra-high dose rate radiation production and delivery systems intended for FLASH”**, MEDICAL PHYSICS 49(7), 4875 – 4911 (2022) https://doi.org/10.1002/mp.15659

S. Srinivasan, S. Brandenburg, J.M. Schippers and P.A. Duperrex, **“Development of a fourfold dielectric-filled reentrant cavity as a beam position monitor (BPM) in a proton therapy facility”**, Journal of Instrumentation 17, P09013 (2022) https://doi.org/10.1088/1748-0221/17/09/P09013

Tian, Liheng; Hahn, Christian; Luehr, Armin, **“An ion-independent phenomenological relative biological effectiveness (RBE) model for proton therapy”**, RADIOTHERAPY AND ONCOLOGY 174, 69 – 76 (2022) https://doi.org/10.1016/j.radonc.2022.06.023

H.D. Zhang, A. Salehilashkajani, O. Sedlacek, C. P. Welsch, **“Characterization of a supersonic molecular beam for charged particle beam profile monitor”**, VACUUM 208, 111701 (2023) https://doi.org/10.1016/j.vacuum.2022.111701

Other Events

May 7th – 12th 2023	14th International Particle Accelerator Conference (IPAC'23), Venice, Italy
Sept 10th – 14th 2023	12th International Beam Instrumentation Conference, Saskatoon, Canada
Dec 5th - 7th 2023	Flash Radiotherapy and Particle Therapy (FRPT 2023), Toronto, Canada
May 18th – 24th 2023	15th International Particle Accelerator Conference (IPAC'24), Nashville, USA

www.oma-project.eu

Project Coordinator
Prof Carsten P. Welsch
c.p.welsch@liverpool.ac.uk

Project Manager
Dr Ricardo Torres
r.torres@liverpool.ac.uk

Newsletter Editor
Alexandra Welsch
a.welsch@liverpool.ac.uk

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 675265.