RADIATE News

August 2019

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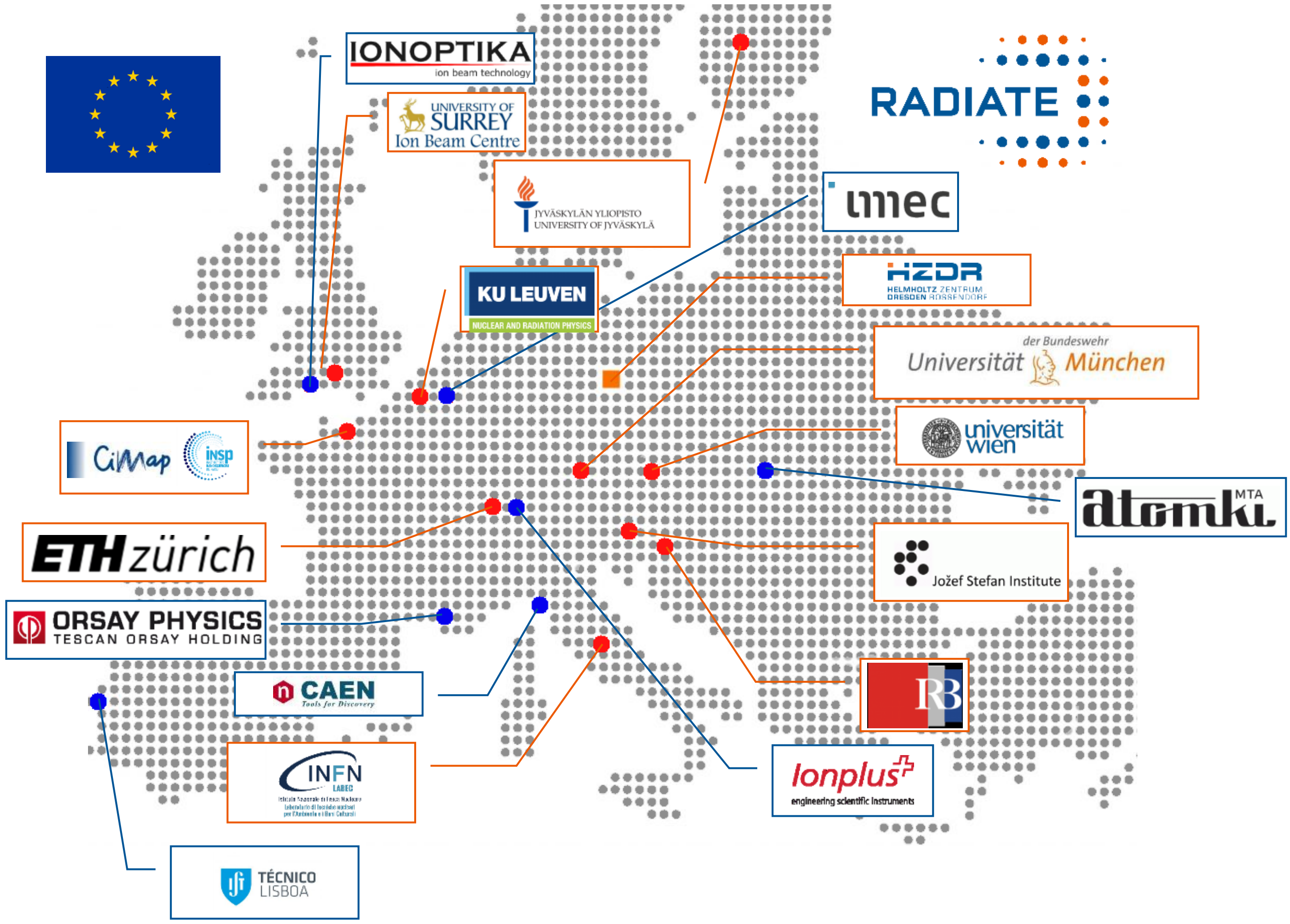

What is RADIATE?

Research And Development with Ion Beams – Advancing Technology in Europe (RADIATE) is a consortium of 14 partners from public research and 4 SMEs, joining forces to exchange experience and best practice examples in order to structure the European Research Area of ion technology application. RADIATE is funded by the EU Research and Innovation programme Horizon 2020.

Besides further developing ion beam technology and strengthening the cooperation between European ion beam infrastructures, RADIATE is committed to providing easy, flexible and efficient access for researchers from academia and industry to the participating ion beam facilities. About 15.800 hours of transnational access in total is going to be offered free of charge to users at 11 of RADIATE's project partners (shown as red dots).

Joint research activities and workshops aim to strengthen Europe's leading role in ion beam science and technology. The collaboration with industrial partners will tackle specific challenges for major advances across multiple subfields of ion beam science and technology.

RADIATE aims to attract new users from a variety of research fields, who are not yet acquainted with ion beam techniques in their research and introduce them to ion beam technology and its applicability to their field of research. New users will be given extensive support and training.

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RADIATE is building on the achievements of SPIRIT (Support of Public and Industrial Research using Ion Beam Technology), a previous EU funded project coordinated by the Helmholtz-Zentrum Dresden-Rossendorf (HZDR). SPIRIT ran from 2009 to 2013 and united 7 European ion beam centres and 4 research providers.

The RADIATE project in numbers

- *18 project partners*
- *11 facilities offering transnational access*
- *4 SMEs*
- *4 years run time (01/2019 – 12/2022)*
- *€ 9.9M budget*
- *15,800 hours of transnational access*
- *Continuous acceptance of proposals without any deadlines*

RADIATE kick-off meeting at HZDR, Rossendorf

Who is eligible?

RADIATE's main target group are users working in EU member states and associated states. A user is only eligible for beam time in a different country than the country of employment, i.e. a French group or company cannot be granted access to a French facility under RADIATE.

It is possible to provide a limited amount of access to users not working in an EU or associated country, i.e. third countries outside of the EU.

Grants are not solely given to scientists working at research institutes, but also welcomes applications from industry. However, to be granted beam time, the RADIATE user selection panel must assess the proposal. Your proposal will, of course, be handled confidentially.

How to get access?

To be granted transnational access, you will have to submit a proposal to RADIATE's submission system, RADIATE GATE. Access is granted free of charge to positively evaluated proposals as long as the allocated hours are not used up. Travel costs are reimbursed to a certain extent. The process is summarised as follows (more detail available on the website):

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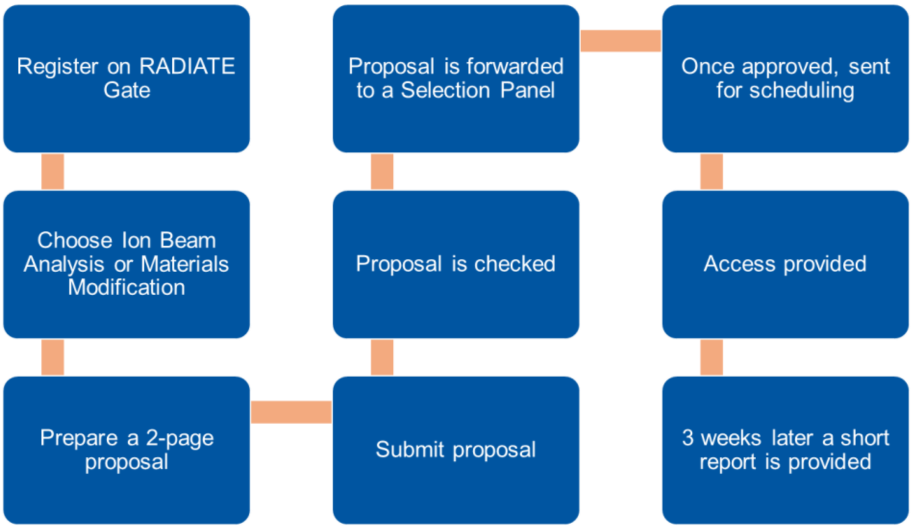
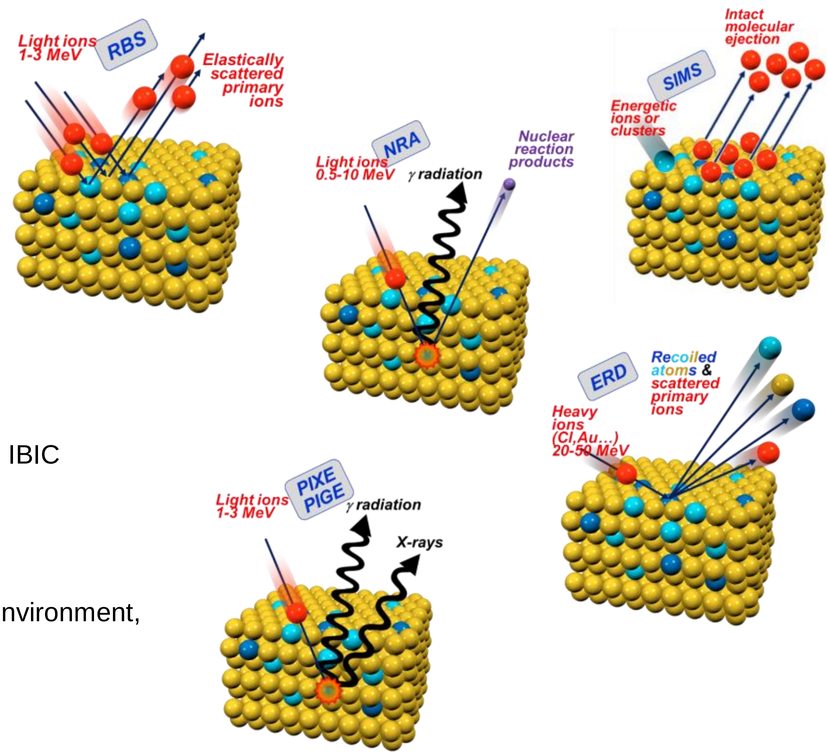


Facilities Available

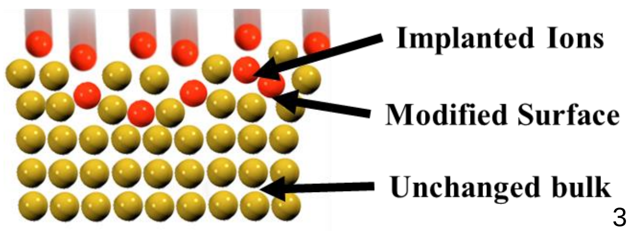


Analysis:

- *Elemental, Thin Film & Depth Profiling*
  RBS, ERD, PIXE, PIGE/NRA, MEIS
- *Chemical and Molecular*
  MeV-SIMS, in-situ MS, High Res PIXE
- *Ultrahigh Sensitivity*
  AMS (Note: does not include ^{14}C)
- *Ambient (and Vacuum) Imaging*
  PIXE, MeV-SIMS, H, He-Ne microscopy, IBIC

Modification:

- *Broad beam*
  Implantation/doping, Multi-beam, clean environment,
  Deep - MeV, swift heavy ions
  Shallow - keV or highly charged ions
- *Focussed beam*
  Non-Ga FIB lithography
- *Single Ion*
  Deterministic implantation for Quantum applications
- *Biological cell irradiation*



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August 2019

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Training of New Users – Open Calls

To extend the use of ion beam technologies across Europe, RADIATE offers three Training Actions with **travelling funds being provided** for potential new users:

• Within a series of four **Summer Schools**, the first **RADIATE Summer School will be organized at Paris (France) on October 10-12, 2019** in connection with the Ion Beam Analysis Conference (IBA 2019 - https://www.iba2019.com/) and the associated Tutorials. Participants of the School will have to **register via the IBA webpages** (https://www.iba2019.com/Radiate-summer-school) and **may apply for travel grants by RADIATE** (see https://www.ionbeamcenters.eu/radiate/training/radiate-summer-school/ also for further details).

• In particular addressing younger scientists from European of Associated Countries in which the use of ion beam technologies is less established and/or which do not host large ion beam facilities, **RADIATE infrastructures will host Guest Researchers** for stays of typically between six weeks and three months duration, **with full funding of the travelling and local costs**. The action is open for applications via https://www.ionbeamcenters.eu/radiate/training/radiate-guest-researcher-program/.

• Via the so-called **Twinning Program,** new or less experienced users of ion technologies may participate as a mentee in the beam time of an experienced user group at one of the RADIATE infrastructures. For stays of typically 2-3 days, **travelling and local costs will be covered** by RADIATE. The action is open for applications via https://www.ionbeamcenters.eu/radiate/training/radiate-twinning-program/.

Joint Research Activities

Visit to Leuven & IMEC

J. England, J. Meersschaut

In March three members of Surrey Ion Beam Centre (SIBC) travelled to Leuven to visit the Katholieke Universiteit and IMEC. Jonathan England (Technical Director), Pierre Couture (Liaison Fellow) and Aneirin Ellis (M.Phys student) first met with André Vantomme (Prof of Physics) at KU Leuven for some in depth discussions about channelling. The SIBC group has recently been using RBS-c to investigate crystal quality in MBE grown InGaAsBi and implant damaged Si and wanted to ask an expert [1] some detailed questions about experimental alignment techniques and data interpretation. The results of these discussions should be of general interest and so it is intended to publish these as a RADIATE Report. Both KU Leuven and SIBC offer ion beam analysis (IBA) and implantation services through RADIATE's Transnational Access.

In the afternoon the group visited Johan Meersschaut (Researcher) and Grazia Laricchiuta (PhD student) at IMEC to discuss future activities on the measurement of 3D nanostructures. IMEC [2] and SIBC [3] have both recently published papers on this topic and IMEC will be leading a 3D Nanometrology project within RADIATE's Joint Research Activity on Software and Data Handling. Tours of IMEC's IBA facilities and 300mm wafer FAB also stimulated some very fruitful discussions.

From left to right Aneirin, Johan, Pierre, André and Jonathan after exchanging ideas over an excellent lunch at IMEC.

[1] André Vantomme, "50 years of ion channeling in materials science", Nuclear Instruments and Methods in Physics Research B 371 (2016) 12–26; doi: 10.1016/j.nimb.2015.11.035
[2] Grazia Laricchiuta, Wilfried Vandervorst, Ian Vickridge, Matej Mayer, and Johan Meersschaut, "Rutherford backscattering spectrometry analysis of InGaAs nanostructures", Journal of Vacuum Science & Technology A 37, 020601 (2019); doi: 10.1116/1.5079520
[3] Jonathan England, Lucio Dos Santos Rosa, Won Ja Min, Jwasoon Kim (2018) "TRI3DYN Modelling and MEIS Measurements of Arsenic Dopant Profiles in FinFETS" Proceedings of IIT 2018 IEEE

TNA Reports

Global distribution of the long-lived anthropogenic radionuclide Technetium-99 (19001694-ST)

J. Pitters, K. Hain

Universität der Bundeswehr München
Institute for Applied Physics and Measurement Technology

In our project we study the global distribution of the long-lived anthropogenic radionuclide Technetium-99, which is released into the environment as global fallout from nuclear weapons tests, by reprocessing plants and nowadays also by nuclear medicine. The detection of ^{99}Tc by Accelerator Mass Spectrometry (AMS) requires high particle energies, which are available at our partner facility Uni BWM, at the Maier-Leibnitz-Laboratory in Munich. A terminal voltage as high as 12 MV together with a sophisticated detection setup allows us to measure ^{99}Tc concentrations at environmental levels. During our first RADIATE beamtime, we could reach an excellent separation from interfering masses, using a time-of-flight path and the unique Gas-filled Analysing Magnet System (GAMS). The optimisation of the detection setup allowed us to reach an unprecedented sensitivity of few 10^6 ^{99}Tc atoms per sample. We have studied pore water samples that were collected from two different peat bogs in Austria, the Pürgschachener Moor and Rotmoos. These first measurements confirm the effectiveness of our chemical sample preparation procedure and give an indication on the behaviour of the radioisotope in this physio-chemical environment. Preliminary results show a signal from ^{99}Tc in the peat bog samples significantly above the blank level which is in the order of $5 \cdot 10^7$ ^{99}Tc atoms per sample which corresponds to an environmental concentration of 10^5 ^{99}Tc atoms/g. This is about one order of magnitude lower than a previous result obtained in surface water from the Wildseemoor (Germany) which shows the need for further investigations. In future beamtimes these results will be compared to ^{99}Tc levels in other environmental reservoirs such as ocean water to establish a baseline for ^{99}Tc concentrations globally.

Highlights

Quantum Technologies and How We Will Build Them

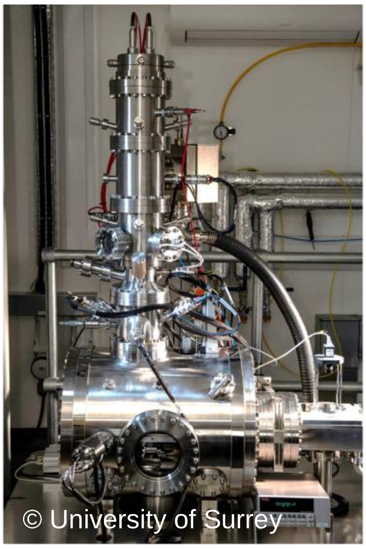
Nathan Cassidy

Moore’s Law has held remarkable true for the past 50 years, resulting in transistors as small as 10nm, with node dimensions approaching the limit where quantum mechanical effects cannot be ignored. To continue this advancement in computational power, these quantum mechanical effects are to be embraced to open vast new heights of computational power. Through exploitation of the unique properties of confined single atoms there is exciting new developments being made in the fields of quantum technologies and quantum computing.

Group V donors in silicon are an extremely promising (but not the lone) candidate for applications within quantum technologies due to an existing compatibility with a silicon-based microelectronics industry. The design for a quantum computer by Bruce Kane in 1998 is widely regarded as the foremost architecture for the application of donors in silicon. The design utilises arrays of confined phosphorus atoms precisely positioned 20 nm apart: far enough for the donors to be confined within a potential well, but also close enough for their ground-state wavefunctions to strongly interact. In this design the donor nuclear spin used to store a quantum bit of information: a qubit.

Quantum computers will allow for the utilisation of various quantum algorithms to accomplish tasks that are not currently feasible, such as large factorisations and the modelling of molecular interactions.

The manufacture of these quantum technologies requires the realisation of ultrapure materials into which single atoms can be placed with exceptional accuracy in position and be deterministic in number. Ion implantation provides many advantages as a manufacturing method for such devices, such as speed, scalability, and flexibility in the choice of ions species and substrate. With current focused ion beam (FIB) technology there is currently no way to completely control the number of implanted ions. Therefore, much effort is being put into developing deterministic ion implantation methods. One such example is the SIMPLE (Single Ion Multispecies Positioning at Low Energy) tool, a new FIB tool in operation designed specifically for the manufacture of quantum technologies. Deterministic ion implantation is achieved through extraction of single ions through fast beam blanking with low currents, ion implant detection through collection of secondary electron (SE) signal from the target, and high spatial precision in ion placement. Currently the tool has achieved a 90% probability of implanting a single 25 keV Bi^{+} ion into bulk silicon without error, with a 20 nm beam spot size determining dopant placement precision. The Surrey Ion Beam Centre and the ADDRFSS research group at the University of Surrey is currently using the SIMPLE tool to manufacture the first devices demonstrating the effects of ordered arrays of bismuth dopants in silicon.



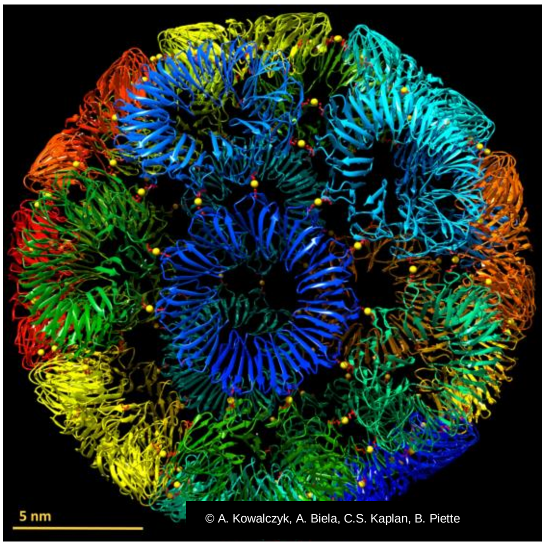
SIMPLE (Single Ion Multispecies Positioning at Low Energy) tool at the Surrey Ion Beam Centre

Researchers Make "Impossible" Nano-sized Protein Cages Sewn Together by Gold Atoms

An international group of researchers from Poland, Japan, United Kingdom, Slovenia and Canada reports on a super-stable artificial protein ball that apparently defies the rules of geometry and which may have applications in materials science and medicine [1].

Every role-playing gamer knows that there are restrictions governing the shape of dice; try to make a six-sided die by replacing the square faces with triangles and you will be left with something horribly distorted and certainly not fair. The reason for this is that there are geometrical rules describing what kind of shapes are allowed to be the faces of die-like shapes, so-called regular convex polyhedral [2]. In nature too such shapes are common at the microscopic level. Usually made from many proteins and having a hollow interior, these nanoscale objects are known as protein cages and they carry out a variety of important tasks. The most famous example are viruses where the cage carries viral genetic material into host cells.

Researchers are interested in making artificial protein cages in the hope that they may be able to design them to have useful properties not found in nature. There are two challenges to achieving this goal. The first is the geometry problem: some proteins may have great potential utility but seem to be ruled out because they have the wrong shape to assemble into cages. The second problem is complexity: in nature the many proteins that form a protein cage are held together by a complex network of chemical bonds and these are very difficult to predict and simulate.



In the new work, headed by Professor Jonathan Heddle from the Jagiellonian University in Krakow, researchers found a way to solve both of these problems. They were able to replace the complex interactions between proteins with a simple 'staple' consisting of a single gold atom. This simplifies the design problem and allowed them to imbue the cages with new properties such as assembly and disassembly on demand. The research has also found a way to get around the geometrical problem: the building block of a protein cage is an 11-sided shape. Theoretically this should not be able to form the faces of a regular convex polyhedron. However, the research has found that “impossible shapes” can assemble into cages which are so close to being regular that the errors are not noticeable. This means that now we may go and form the proteins which previously were not considered because they are theoretically unable to form cages.

The stoichiometry of proteins containing metal atoms is a field, where micro-PIXE method shows extreme potential. Combining lateral resolution, high elemental sensitivity and inherent concentration quantification capabilities, micro-PIXE provides the stoichiometric ratio between the number of metallic atoms and sulphur atoms, an information extremely precious for proteomic research. The pioneering work has been done by Garman and Grime [2] on the natural proteins. In the work of Malay et al [1], micro-PIXE was applied at Jožef Stefan Institute (JSI) to determine the number of gold atoms binding together 24 eleven-sided rings of TRAP protein in a large synthetic protein molecule, resembling a soccer ball with a diameter of 22 nanometres. The micro-PIXE methodology at JSI was largely improved over the last decade within the JRA work of the “SPIRIT” and “RADIATE”, providing the capacities to tackle demanding research problems at the field of biology, medicine and proteomics.

Authors share an optimistic view that the work can be expanded further to produce cages with new intriguing cage-like structures, and investigated for potential applications in drug delivery. In particular, colleagues from JSI are enthusiastic to contribute further with micro-PIXE method to the extremely dynamic research on synthetic proteins. See full paper here: https://doi.org/10.1038/s41586-019-1185-4

[1] Malay A.D. et al, “An ultra-stable gold-coordinated protein cage displaying reversible assembly”, Nature 569, 439–443 (2019).
[2] Yeates T.O. “Protein assembles into Archimedean geometry”, Nature 569 (2019), 340.
[3] Garman E.F and Grime G.W., “Elemental analysis of proteins by microPIXE”, Progress in Biophysics and Molecular Biology 89 (2005) 173–205.

Conference Reports

Workshop: Ion beams for future technologies 2019

This workshop, organised by the Ruđer Bošković Institute (RBI) and co-funded by the Centre of excellence for advanced materials and sensing devices (CEMS), took place in Dubrovnik, Croatia between the 1st and 3rd of April 2019. The programme included 26 talks on topics related to applications of focussed ion beams or single ion irradiation, with special focus on emerging technologies revolving around quantum computing and sensing. Key topics included:

- Quantum sensing and computing
- Deterministic ion implantation and single ion hit detection
- Nanostructuring using single ions
- Functionalization using ion beams
- Ion beams for changing optical properties
- Biosensing and dosimetry
- Development of ion beam irradiation techniques

Ion Beams for Future Technologies, Croatia

Of the 26 talks presented at the conference 12 came from labs participating in RADIATE. Participation came from 7 European countries as well as China, Japan, USA, South Africa and Singapore.

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16th International Conference on Particle Induced X-ray Emission (PIXE2019)

PIXE2019, Portugal

The 16th International Conference on Particle Induced X-ray Emission (PIXE2019) took place between 24-29 March in the Cultural and Congress Centre of Caldas da Rainha, Portugal. The PIXE2019 theme was "*Unravelling secrets from atoms to planets*", highlighting the far-ranging application areas of the technique at all length scales. The 46 oral contributions, of which 11 included contribution from RADIATE partners, and 42 posters touched on themes ranging from biology (e.g. multimodal imaging, single cell and protein analysis) to forensic science, with an update on the IAEA co-ordinated research programme on forensic science. The conference social included a talk by Prof. John L. Campbell's talk on "α-particles PIXE", which gave an exciting overview of PIXE on the Mars Rover, followed by lunch in São Martinho to Porto, a visit to the Alcobaça Monastery and Nazaré. A highlight of the conference was a detector workshop, which gave opportunities to discuss strategic improvements to PIXE detector systems, and in particular the possibility to carry out high resolution PIXE measurements. The next PIXE conference is to be held in conjunction with the Ion Beam Analysis Conference (to be announced), to give researchers from both communities the opportunity to share ideas and information.

13th European Conference on Accelerators in Applied Research and Technology (ECAART13)

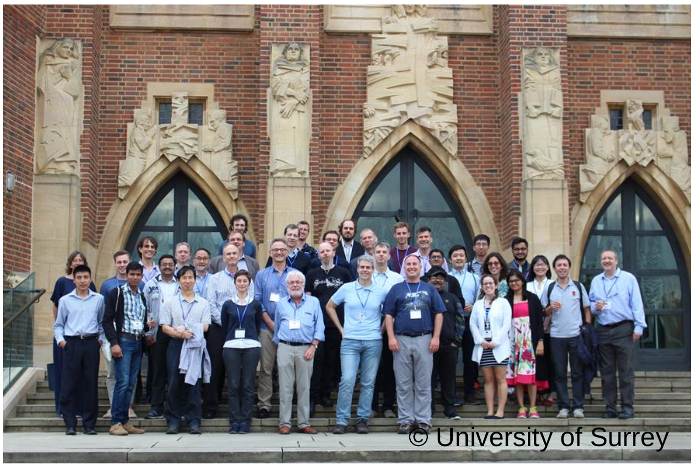
ECAART13, Croatia

In the week of 5-10 May 2019, the Ion Beam community convened in the beautiful city of Split in Croatia for the 13th European Conference on Accelerators in Applied Research and Technology (ECAART13), hosted by the Ruđer Bošković Institute (RBI). The 53 invited and oral contributions, 13 of those from RADIATE partners, focussed on areas such as ion beam analysis and applications, simulation and fundamentals, accelerator mass spectrometry, material modifications using ion beams and quantum and nanotechnology applications. Accelerator application areas discussed at the conference ranged from therapeutic scenarios (e.g. prosthesis rejection cases and proton beam therapy) to art and archaeological analysis.

Conference outing included a trip to the KRKA Waterfalls National park.

10th International Workshop on Nanoscale Pattern Formation at Surfaces

The 2019 Nanopatterning workshop, sponsored by RADIATE and hosted by the Surrey Ion Beam Centre, took place at the University of Surrey in Guildford (UK) between the 7th and 10th of July. RADIATE partners contributed to 8 out of the 25 talks given at the workshop, touching on subjects such as ion beam processes, biological applications, non-ion beam patterning and quantum applications. Delegates were taken for a guided tour of the city of Guildford and a conference dinner by Guildford Cathedral. Conference culminated with a guided tour of the Surrey Ion Beam Centre facilities.



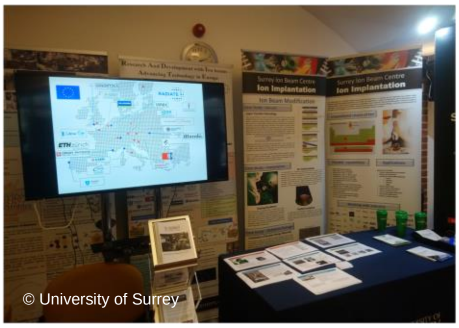
Nanopatterning 2019, UK

Exhibitions

As part of RADIATE's Dissemination, Training, Outreach & Public Engagement work package, RADIATE has been promoted at conference and exhibitions all around Europe, for example:

E-MRS Spring meeting - Nice, France

Thermo Scientific LC-MS Symposium - London, UK



Connecting industry in the South to Metamaterials and Emerging Materials Research and Investors, KTN event - University of Sussex, UK

The Advanced Materials Show - Telford, UK

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Upcoming Events

RADIATE Summer School
- C2RMF in Paris, France, from 10-11 October 2019

24th International Conference on Ion Beam Analysis
- Antibes, France, from 13-18 October 2019

22nd International Conference on Secondary Ion Mass Spectrometry
- Kyoto, Japan, from 20-25 October 2019

Personnel

© S.G. Chauhan

Samirsinh Ganpatsinh Chauhan has been appointed as a Joint Research Activities Fellow at KUL (100% appointment) and is developing ultra-low energy ion implantation, exploring in particular the use of ion cooling to improve the technique's reliability. Samir obtained his B.Sc. and M.Sc. in Physics from Sardar Patel University, India. He then obtained a Ph.D. from HBNI, Institute for Plasma Research, Ahmedabad, India. During his Ph.D. he worked on transition of electron sheath into an ionizing double layer in anodic glow discharge plasma. He further continued his research as postdoctoral fellow at the same institute and developed a prototype ion beam irradiation technique using a commercial sputter magnetron. Samir came to Leuven and the end of 2018 as a postdoctoral researcher before joining RADIATE, and his research has since focused on the development of ultra-low energy ion implantation for applications in 2D materials.

© S. Rudigkeit

Sarah Rudigkeit is appointed as a PhD student and investigates the effects of irradiation with temporal (FLASH irradiation) and spatial (microbeam irradiation) focused ions for preclinical studies with cells and mice. For this project she also improves the setup and the evaluation with methods based on deep learning. She obtained her Bachelors and Masters degree in physics with the focus on biophysics at the Technical University of Munich.

© C. Costa

Catia Costa joined the Surrey Ion Beam Centre in 2017 as a Liaison Fellow and has been appointed as the centre's transnational access manager for RADIATE. Catia obtained her MChem in Chemistry from the University of Surrey and stayed on to do a PhD on the detection of cocaine and respective metabolites from latent fingerprints. Catia's interests include finding new applications for new mass spectrometry methods and the combination of molecular (mass spectrometry imaging) and elemental (PIXE) mapping. Catia's most recent work revolved around the development of ambient megaelectron volt secondary ion mass spectrometry (AP-MeV-SIMS) at Surrey.