FUSION IN EUROPE
NEWS & VIEWS ON THE PROGRESS OF FUSION RESEARCH

Fusion spin-offs: seeing cancer clearly

FUSION: QUENCHING YOUR THIRST FOR ENERGY

CRACKING OPEN OPEN SCIENCE
STUDENTS GO ON A HERO’S JOURNEY

SPRING 2019
LETTER FROM THE EDITOR

Dear Reader,

Temperatures in excess of 100 million degrees are required for hydrogen molecules to fuse. How unbelievable is that?

Oh, and by the way we have made that happen here on Earth. In fact it happens multiple times each day. Say what?! How is that even possible??

While EUROfusion researchers and staff strive to make fusion electricity a reality, it is easy to lose sight of the marvel and the wonder of what it is they are trying to achieve. The incredible soon becomes just another number. The astonishing … just another day in the lab or at the office.

As your regular Editor Anne Purschwitz steps back to raise her newborn, I have the chance to take you along with me as I look at fusion energy with fresh, newbie eyes. Over four issues I’ll be sharing my experience with you, and hope some of my enthusiasm rubs off.

Ask yourself, “What do I find exciting about fusion energy?” Or if you are new to fusion like me, try the question “What would I like to better understand about fusion?” Then email me your answers. Sharing your passion and curiosity will make this adventure all the more interesting!

Welcome to the Spring 2019 edition of Fusion in Europe magazine.

Karl Tischler
Editor of Fusion in Europe
magazine@euro-fusion.org
A GLASS OF SEAWATER

Join us behind the mics for an inside look at a podcast dedicated entirely to fusion energy.
*Picture: Image by cocoparisienne from Pixabay*

OPEN SCIENCE – PART 1

It’s an ambitious project for the good of humanity – so what’s the hold-up?

FUSION SPIN-OFF: CHROMODYNAMICS

Wouter Vijvers developed a better way to photograph plasma. In the future it could be saving lives.

POSTER: MAGNUM PSI

Our first-ever pull-out wall poster – decorate your walls with this photo of the Magnum PSI device!
*Picture: Christophe Roux, CEA, France*
The European Commission and the UK signed a contract extension that guarantees the Joint European Torus’ (JET) operations until the end of 2020 regardless of the Brexit outcome. As the only experimental fusion device currently capable of using Deuterium-Tritium fuel, JET will provide invaluable fusion experiments leading up to the 2025 opening of the world’s largest magnetic confinement fusion device called ITER.

Extending this contract means cutting-edge and world-leading fusion research can continue in this country, which I know will be a welcome reassurance to the hundreds of workers at Culham. Science has no borders and as we leave the EU, this kind of international collaboration remains at the heart of our modern Industrial Strategy to maintain the UK’s position as a world leader in research and innovation.

Chris Skidmore, UK Science Minister

The extension to the contract is excellent news for both EU and UK science. JET has been a shining example of scientific cooperation between EU members, and this news means that these mutually beneficial collaborations will continue, allowing us to do essential experiments on the path to delivering fusion power.

Prof. Ian Chapman, CEO of the UK Atomic Energy Authority

A heavy weight has been lifted off our shoulders. This is extraordinarily good news for EUROfusion and the European fusion community as a whole. We can now continue to work on the realisation of fusion energy together with the indispensable experience of our British partner.

Prof. Tony Donné, EUROfusion Programme Manager
March 8, International Women’s Day: Think equal, build smart, innovate for change. To mark is Day, EUROfusion asked women fusion researchers to share what interests them about fusion energy. Here are some excerpts:

“Developing a new source of energy is something super-interesting for both women and men. In research we need to be creative, innovative and the mix of gender and ethnicities is an asset.”

Marie-Line Mayoral, Deputy Head of ITER Physics Department

“I look into the behaviour of the material when they are facing plasmas under extreme heat flux and develop advanced diagnostics like incoherent and coherent Thomson scattering. I want to make an impact in the area of research that I am doing.”

Mozhgan Laki, currently pursuing her PhD at DIFFER

“I would use a nice quote from a former JET task-force leader: The boundary of plasma in Tokamaks is where the stellar world of hot plasmas meets the very earthly world of solid materials. Understanding and controlling the interaction between these two worlds is key for future fusion reactors.”

Emmanuelle Tsitrone, Task Force Leader at CEA Cadarache

“Tritium is one of the hydrogen isotopes you can use for fusion experiments. And JET is the only machine that can use tritium. Tritium is like adding nitro to the standard fuel for your car … it will boost the fuel performance by a factor of 100.”

Eva Belonohy, CCFE Researcher
You may have noticed that the fusion community often compares its most mature fusion confinement device, the tokamak, to a doughnut. Or rapid bursts in magnetic fields to fishbones. Such analogies play an integral role when attempting to explain fusion and all of its complexities to people outside of the fusion community. By relating what is happening to something we already know, we are able to more easily imagine and then understand what is being explained.
Just ask the team of PhD students behind the podcast *A Glass of Seawater*, winners of this year’s Rutherford Plasma Physics Communication Prize. Since March of 2018 they have been sharing their points of view each month through “A light, informative, inspiring podcast all about the field of fusion energy research as seen through the eyes of PhD students ...” Using analogies has been the key to successfully convey concepts and technologies related to fusion energy and plasma physics to their audience.

FOOD FOR THOUGHT

“We do cheat a bit by using ‘show notes’ which are links to pictures and other information that we put on our website for each episode,” says PhD student and podcaster William Trickey. “But in general we have to rely on analogies in our podcasts.”

Fellow podcaster Andrew Malcolm-Neale agrees. “Learning to cope without visuals or hand gestures is an important part of learning to communicate through podcasts.”

And if the recollections of the team are anything to go by, successful analogies can paint vivid mental images of even the most complex technical concepts. “I remember when we were trying to explain the geometry of a tokamak in the introduction to magnetic confinement fusion episode,” says Andrew. “First we tried using ringed-doughnuts but then changed to bagels because we could compare the direction of spreading a topping like cream cheese on a bagel to toroidal directions.”

BEHIND THE NAME

When it comes to creating memorable and vivid mental images, it is hard to beat the phrase ‘a glass of seawater’. Podcaster and PhD Student Bhavin Patel, who originally came up with the name for the podcast, speaks about the episode that focussed on how much fusion fuel can be obtained from a glass of seawater. “You talk about this salty glass of water which contains as much potential energy as many kilograms of coal or a ton of TNT,” he explains. “It gave perspective on how energy dense fusion fuel really is. That was a really nice analogy.”

Reflecting back on the decision to name the podcast after this fusion energy example, William recalls, “We had a brainstorm session and had a lot of suggested names! The original idea was ‘Can I have a glass of seawater?’ which was rather long.” Among the suggested names was Talk-a-mak. While it didn’t make the final cut, it did get used as the title for an episode delving into the world of magnetic confinement fusion.

INTO THE MIXING GLASS

The young fusion researchers all hail from the Fusion Centre for Doctoral Training (CDT) which is a collaboration between five of the UK’s top universities: Durham, Liverpool, Manchester, Oxford and York. There they learn about fusion-relevant disciplines such as plasma physics, nuclear physics, materials science, technology, laser physics, instrumentation & more.
A Glass of Seawater is unique in that it takes both a broad and in-depth look at fusion. Their niche, says the team, is covering the nitty-gritties of fusion research. "Fusion covers a breadth of different topics from lasers, to plasmas, to neutrons, to a whole bunch of different things. General science podcasts only have time to give the big picture about fusion as an energy source. In comparison we talk about the nuances of fusion research," says Bhavin. "A Glass of Seawater gives listeners a better picture of just how complicated fusion really is because there are so many different things that we are researching at the same time."

Andrew, who also maintains the podcast's twitter handle @glassofseawater with fusion news, agrees: "In our initial episodes we deliberately started by talking very broadly about what fusion is. In comparison, our later episodes focus on recent developments in fusion research. We want to give the idea that fusion research is an ongoing research project where there are lots of exciting little things happening all the time. And this is where the strength of the podcast medium lies. With a podcast you get a chance to tell a longer and more detailed story. It allows us to take time with each topic and it allows people to choose how in-depth they want to go."

"You do get to see how it all fits together," William adds. "For example, we can spend some time talking about lasers in fusion and then about lasers in space technology. And we also get a chance to talk about other drivers in fusion such as superconductors and their applications."

From high school students to fusion enthusiasts and the fusion community, the team says they craft episodes to match different audiences. There is something for anyone who’s curious about the world of fusion research. Having crossed the learning curve and fine-tuned workflows, the team has now stepped into Season 3 of the podcast. So go ahead, whet your fusion appetite and check out what's already been served!
FILLED TO THE BRIM

Things are looking good for A Glass of Seawater. “We still have plenty of topics to cover”, says Andrew. “And the amount of support and interest we’ve received has exceeded our expectations,” shares Bhavin.

But the team isn’t resting on their laurels. They want to take the podcast on the road to fusion centres like CCFE (The Culham Centre for Fusion Energy), RAL (The Rutherford Appleton Laboratory) and MRF (Materials Research Facility) in the UK. They’ve just released an episode on plasma thrusters for space and have plans to record episodes in collaboration with researchers at ITER as well as on the use of superconductors, machine learning and modelling in fusion... so lots to look forward to!

Leaving nothing to chance, they’ve formed a committee to address their biggest challenge. “We’re getting new people involved and hopefully ready to take over A Glass of Seawater after we finish our studies,” explains William. “There is always something new happening in the world of fusion. We hope this podcast continues to cover these developments for years to come – analogies and all!”

Who’s Who at A Glass of Seawater (from left)

Andrew Malcolm-Neale: PhD candidate, University of York, a diagnostician studying the interaction of turbulence and flows. As Podcast Producer, he gets everything together to keep the podcast running smoothly; Bhavin Patel: PhD candidate, University of York, working on his thesis titled: ‘In Search of Compact Routes to Fusion’. As Head Editor, he makes all the sound bites pristine and clear; William Trickey: PhD candidate, University of York, working on extreme shockwave studies for inertial fusion. In charge of public engagement & outreach, he has his finger on how many listeners tune in.
It’s a story told and re-told countless times across cultures and generations: the hero’s journey. Our heroes are 16 apprentices from the UKAEA (United Kingdom Atomic Energy Authority) called upon to help realise EUROfusion’s upcoming travelling exhibition on fusion energy.
CALL TO ADVENTURE
Right from the start the plan was to include an educational component in this outreach project. As EUROfusion’s Responsible Officer for the Fusion Expo, Mohamed Belhorma sought a team of students to develop the 2nd of three parts for his state-of-the-art, novel approach. “The Apprenticeship Scheme is a unique programme with fusion resources actually in-house. And the students would clearly benefit from this communications exercise,” shares Mohamed.

It was a good fit for the Apprenticeship Scheme too. “Working with other people is a big part of what science is about,” explains John Hill, Manager of the UKAEA’s Apprenticeship Scheme. “The opportunity for our young people to collaborate on such a big, international project was ideal for their personal and professional development into fusion technicians and engineers.”

DIVERSE ON PURPOSE
The UKAEA’s Apprenticeship Scheme brings together younger people who share an interest in engineering and fusion energy. The scheme fits to each individual – for some more hands on, for others more theoretical.

“Fusion is not limited to just mechanical and electrical areas,” tells Katriya Sabin, third year apprentice and one of two elected team leads for the Fusion Expo project. “It encompasses robotics, air control, radioactive gases, cryogenics, and many more areas.”

2ND (IS) BEST
Designing the 2nd part of the Fusion Expo project was initially daunting. “It was a surprise,” shares Katriya. “All we knew was that we had to design an exhibition! We just saw ourselves as apprentices … How could we do all that?! ”

But do it they did. Mohamed had judiciously given them the most conventional part of the Fusion Expo to design. Tasked with communicating what is happening in fusion right now, the apprentices could explore many similar exhibits, models and references such as the
Science Museum in London. Most helpful was the workshop and guided tour they were given by professional curators, museum accessibility technicians, gender-equity hands-on designers and others at the Cité des Sciences et de l’Industrie in Paris. “For everything engineering-related, all the info they needed was accessible to them on-site. This was important given that the students could only dedicate 1 to 3 hours per week to this project,” imparts Mohamed.

CROSSING THE THRESHOLD
With help from their mentors, the apprentices quickly incorporated new information and began learning about the challenges of scientific communication.

“We were quite disappointed to learn how little people know about fusion,” confesses Katriya. “Our interest is an anomaly!” As the fusion enthusiasts learned about fusion communication challenges such as lack of immediacy, past mistakes and exaggerated claims, the solutions became ever clearer.

Katriya continues, “Honesty and integrity are the best paths forward. ‘Bringing the Sun to Earth’ or ‘a star in a jar’ sounds like science fiction. People imagine Star Trek. We should keep it factual: we are re-using old equipment and control rooms built in the 70’s and 80’s but conducting cutting-edge science with it. To gain public trust and make fusion relatable we have to be vulnerable. Science is not omniscient. It is trial and error until we get a conclusion. We fail, we create fantastic initiatives, we are not perfect. If we were, we wouldn’t be here now.”

REVELATION
Science is difficult to communicate. Scientists struggle to communicate internally amongst themselves, let alone externally with the general public.

I wouldn’t trade this experience for anything. It is the best decision I have ever made. The EUROfusion project has made me more social, more confident.

Katriya Sabin

The Fusion Expo Project will be a participatory and educational endeavour seeking to create awareness about energy issues and develop individuals’ opinions about the future role of fusion energy in our energy mix. Currently it is wrapping up the prototype development stage. Check future issues of Fusion in Europe to see how this project develops!

RETURN

The apprentices are presently turning their designs into prototypes for the official presentation to EUROfusion this summer. Once accepted, they will begin to build them. “Fusion is about challenges,” explains John. “These 16 apprentices are becoming very skilled and experienced people who will be prepared for any challenge that comes their way and invaluable members of the fusion community as a result.”

To learn more about the UKAEA Apprenticeship Scheme, visit its website:

www.culhamapprenticeshipscheme.com
What does this image make you think of? Sometimes science can be unexpectedly beautiful. A good example is this photo of the 18 meter long EUROfusion Magnum-PSI linear plasma generator at DIFFER PS-H Lab in the Netherlands. Researchers use it to study plasma-wall interactions in a similar environment to a fusion reactor.
Science is better shared. Scientists have long understood this. They travelled the “known world” to exchange ideas between different fields of knowledge. They wrote papers to make sense of their observations – the data they gathered – and have conducted peer reviews of their findings through academic journals since the 17th century. Standards and transparency strengthened credibility and improved knowledge sharing.
Three and a half centuries later, the Open Science movement seeks to broaden and deepen the sharing of scientific research and thereby accelerate it and make it more innovative, accountable, and collaborative. This sounds simple. But the devil is in the details.

NEW FRAMEWORK
Sharing public-funded research is a sure-win in many cases. With proper infrastructure and resources in place, findings are relatively easy to share. Combining them with research and data from other fields of study can lead to new insights and discoveries. This scientific cross-pollination shows great potential.

Sometimes research is easy to share but hard to use due to its complexity. Misinterpretation by non-experts could cause confusion instead of furthering understanding. The research may even be so specialized that cross-pollination isn’t possible. Opening this research up to the general public creates little benefit.

Finally there are cases of highly complex, niche-like research that is difficult to share and use. A good example is fusion energy research. While the first photograph of a black hole recently released by the European Southern Observatory (ESO) captured headlines and the public’s imagination, a EUROfusion study into deuterium-tritium plasma instabilities due to infinitesimally small changes in magnetic field conditions is largely ignored outside of the fusion community for rather obvious reasons. Sharing this research publicly outside the fusion community makes little sense – especially because it is so difficult and costly to share!

But why is that?

HOW TO GET PUBLISHED
Publishing papers in science journals is surprisingly complex, restrictive and sometimes costly. In 2018, EUROfusion Consortium researchers submitted 1.100 papers for review.

Researchers want their paper published in the most prestigious journal possible for the distinction and exposure it brings. Journals are selective about which papers they publish and send them to experts for peer-review before publishing. “Some journals’ acceptance rate is only 30%,” informs Kinga Gal, Scientific Secretary in the EUROfusion Programme Management Unit. “Thanks to our own internal review process to ensure the quality of each paper, around 70% of our submitted papers get published.”

EMBARGO
In return for their efforts, journals collect a publishing fee from the researcher(s). The more prestigious the journal, the higher the price. Fusion journals charge on average €2,000 per paper, but it costs up to €5,000 in other scientific fields.

Journals also charge for access to published papers. During the “embargo period” lasting from six months to two years, the paper is only accessible via paid subscriptions or a one-time purchase. While subscriptions are more or less affordable, one-time purchases can be costly: a recent scientific conference paid €130,000 in licensing fees for its 150 attendees – even after a 50% discount!
After the embargo period, papers can be shared following Green Open Access practices. However only the submitted, non-typeset version of the paper can be freely shared. And only via an institutional or personal repository, each with additional different rules. The journal continues to charge a nominal fee for access to the published version which remains its property.

There is also a Gold Open Access option. In exchange for a higher page rate plus a substantial fee, a journal gives free access to the paper via its website. But the researcher incurs all the costs, leaving less money for research.

As you can see, the existing publishing process is complex and expensive. Changing this traditional process is being actively discussed. We’ll have to see what develops.

**VERSIONS OF A SCIENTIFIC PAPER**
- “Draft” peer-reviewed internally by EUROfusion
- “Submitted” to journal
- “Accepted” journal peer-reviewed
- “Embargo” journal formatted & published
- “Preprint” submitted version made public
- “Post-print” published version publicly available after embargo period

**VERSIONS OF OPEN ACCESS (OA)**
- “Gold OA” researcher pays a hefty sum for immediate open access of the published version via the journal’s website
- “Green OA” after the embargo period the preprint version can be shared via the institute’s online repository

**MORE THAN DATA**
Adding the paper’s related supporting data, software and methods compounds sharing complexity. Data can be terabytes in size, might only be understandable by experienced professionals, and even require supercomputer processing capabilities to use. To keep it usable, the data’s format must be kept current. And when software has to be provided, it creates software licensing issues.

“The methods used to create the data and the research notes and codes which convey data in real physical terms are also essential,” elaborates Tony Donné, EUROfusion Programme Manager.
(REALLY) BIG DATA
The sheer amount of data to be shared also complicated things. At the Joint European Torus (JET) fusion research facility, 10 to 100 gigabytes of data are captured with each experiment, commonly referred to as a “shot”. To date they have made nearly 100 thousand shots. At the ASDEX Upgrade fusion device they have made around 37 thousand shots. That’s a lot of data!

Modelling is an even bigger source of data. A big plasma turbulence code easily generates terabytes of data. And then there will be ITER, the international fusion megaproject being built in southern France. It may capture as much as one petabyte of data per shot.

Storing, managing and maintaining this amount of data is costly. Gathering and sharing it as well.

I SCRATCH YOUR BACK…
Once data is openly shared it is available to everyone in the world. But is it right for expensive publicly-funded research to benefit non-reciprocal citizens and countries?

“We keep our data to ourselves for a certain period, in the order of a year,” explains Tony Donné. “This gives the EUROfusion community enough time to use it first. For multiple experiments, or when we plan to use data in other ways, we’ll hold onto it even longer.” This ensures that research helps the countries who funded it first.

SECURITY & INTELLECTUAL PROPERTY
Security must also be considered. Because fusion is a nuclear science, some research could be misused. Any new Open Science methodology must highlight and protect such information from being released publicly.

There is also the question of intellectual property rights (IPR). How best to protect and profit from IPR when the rules and laws are so different even between EU member states? It will be no small undertaking to develop the system necessary to manage IPR.

SO MANY CONSIDERATIONS
What seemed like an easy task now involves financial, commercial, IPR, maintenance and accessibility considerations. The people working towards the realisation of Open Science have to create a system flexible enough to handle all this plus work across and within different areas of scientific research. It must also be sufficiently adaptable to remain affordable and usable in an ever-changing world.

In this way, it will be possible to work towards, attain and maintain the delicate balance required for Open Science to work – both as an accelerator of innovation and a magnifier of returns on public investment in scientific research.

In an upcoming issue of Fusion in Europe we will look at the people working behind the scenes towards the realisation of Open Science in Europe, and the benefits these efforts have already created. Stay tuned!
When it comes to diagnosing cancer, you can never be too early. Early cancer diagnosis saves lives – few facts in medicine are as undisputable. So what if there could be a way to speed up the multiple steps of endoscopy, biopsy, lab tests and diagnosis before beginning treatment? What if endoscopy, diagnosis and tumour removal could be completed in a single procedure? Sounds like a pipedream? Not if you lend your ears to former fusion researcher Wouter Vijvers, founder and CEO of fusion spin-off Chromodynamics.
Wouter, who worked at the Dutch Institute for Fundamental Energy Research (DIFFER) and the Swiss Plasma Center (SPC), developed a novel imaging diagnostic known as MANTIS (Multispectral Advanced Narrowband Tokamak Imaging System) to study the plasma edge. Now, he wants to cross over this imaging diagnostic to provide a real-time single step solution for diagnosing and removing cancerous tumours. This is one of the main long-term goals of Chromodynamics, a start-up, which Wouter says, “has a vision of what matter’s”.

LOOKING INTO THE SOUL OF THE PLASMA EDGE

Wouter developed MANTIS at DIFFER with the support of a grant from the Netherlands Organisation for Scientific Research to carry out work at SPC’s TCV (Tokamak à Configuration Variable, literally “variable configuration tokamak”) tokamak in Lausanne, Switzerland. Earlier, when Wouter was working at TCV, he had used a refurbished imaging system called the MultiCam to obtain plasma images. He realised that the old imaging system, despite its limitations, was becoming a very useful control room tool. “A single image can already provide so much information, let alone what you can glean from multiple videos of the fusion plasma,” explains Wouter. While at TCV he crystallised the idea of taking imaging a step further into quantitative real-time imaging which “allows one to determine the shape of the plasma as well as its local plasma parameters. If you can do that you have so much information at your disposal,” he says.

But there were no multispectral cameras that met the rigorous requirements of fusion research available on the market. This is when the idea to develop MANTIS was sowed.

The MANTIS system collects light through a single window in the tokamak and feeds it to ten cameras that each look at a very narrow wavelength band. When the information from these cameras is combined, researchers can pinpoint the exact position of the plasma edge and reconstruct temperatures along the exhaust stream. They can also analyse where impurities are present and how they influence the plasma conditions. All this happens in real time as the fusion experiment runs, enabling fusion researchers to not only collect and analyse data but to also adjust the experimental parameters as required. “I knew as soon as it worked that we had something unique,” says Wouter. “We were able to have real-time information on plasma parameters like temperature and density, and also the physical and chemical processes that take place in a dedicated area of the experiment.”

FOR FUSION EXPERIMENTS…

At TCV, MANTIS is one of the systems that monitors the plasma discharges during fusion experiments. It looks at the lower part of the plasma discharge where magnetic fields guide the hot, charged gas to the reactor exhaust wall. And these multispectral and real-time capabilities make MANTIS an interesting tool for fusion researchers everywhere. But could the applications of this technology extend beyond fusion? Wouter was convinced that it could, so he founded the spin-off company Chromodynamics, whose tagline is “Real-time chemical imaging.”
While Chromodynamics aims to put its real-time imaging at the heart of future healthcare and other areas such as industrial quality and process control, it began its start-up journey in familiar territory: fusion. On February 19th, 2019, the Netherlands Organisation for Applied Scientific Research (TNO), DIFFER, the European company Active Space Technologies, and Chromodynamics signed a cooperation agreement with the world’s largest magnetic confinement fusion device project, ITER, to design a visible spectroscopy reference system. At ITER, the system will be set up to monitor if plasma conditions remain conducive to absorbing the enormous power from the neutral beam injection systems. For Wouter, this cooperation agreement means not only contributing to the world’s biggest fusion experiment, but also establishing a stable basis from which to expand the application of multispectral imaging systems.

...AND SO MUCH MORE

“Let’s take semiconductor devices for example,” says Wouter. “These devices are made by depositing and etching multiple layers of thin semiconductor films on wafers. These thin films need to be very homogeneous and clean. With multispectral imaging techniques you can determine how homogeneous and pure each film is. If you can do this in real time for the whole wafer at once, you could tweak the parameters of the machine to produce the highest-quality layers possible during the manufacturing process itself, rather than having to wait for a whole batch to be produced, analysed and then trying it again,” he explains.

This is just one example. Wouter envisions many areas where real-time multispectral imaging could find applications. But, as mentioned, the long-term goal is to change the approach to cancer diagnosis and tumour removal. Imagine if a surgeon removing a malignant tumour could precisely see the tumour margins while operating on the patient. This is something that could potentially be done using real-time multispectral imaging. “Healthy tissues and malignant tissues have different chemical profiles, and this difference is what multispectral imaging will be able to capture and show,” Wouter explains. “Combine that with real-time capabilities, and a surgeon could see the image of the malignant tissue while operating to ensure complete tumour removal.”
Like any novel medical technology, Wouter knows his idea has to be thoroughly vetted and it will be several years before it enters the market. But with two awards that recognise promising start-ups (Golden Lightbulb and the Beyond Tech Pitch Competition), a cooperation agreement with ITER and a grant from the European Union, it seems that Chromodynamics is on track to make innovative imaging systems as relevant to medical diagnosis, industrial quality and process control in the future as it is to fusion energy today.

**UPDATE:**

On April 19, 2019, Chromodynamics along with partners DIFFER and Vrije Universiteit Amsterdam were awarded a European ATTRACT grant of €100,000 to “develop a camera system that can see the chemical composition of materials and biological tissues” according to the press release. Congratulations!

This edition’s Impressions features a selection of photographs selected by photographer Christophe Roux, CEA, France. These pictures are part of the EUROfusion Devices Photo Project, on which EUROfusion Communications Officer Misha Kidambi and Christophe worked together. The pictures highlight the research work carried out at European fusion devices involved in EUROfusion experiments. It’s not just the fascinating devices that caught the photographer’s eye but the people in the labs and the little details that one comes across. This gallery will let you see the pictures through the photographer’s eye as Christophe explains why he selected the pictures for the Impressions gallery.

1. Marcin Jakubowski: This composite picture and the speaker both tell the same story – that of Wendelstein7-X. The hand gestures of the speaker blend in beautifully with the picture of the machine as he talks about his work at Wendelstein7-X.

2. Inside MAST: This picture is an ‘unfaithful reality’ of the interior of MAST (Mega Ampere Spherical Tokamak) because the fisheye lens used distorts geometry; one cannot guess what lines are parallel and which ones are perpendicular. But at the same time it gives a clear view of the inside of the machine. Another feature that I like is the kind of science fiction aspect this picture lends itself to.

3. Cold Valve Box in JET (Joint European Torus). The complexity of the pipes/cables and the strength of the arrows on the floor are striking.

4. Eva Belonohy. It’s almost as if the researcher is talking from the inside of the JET vacuum vessel and her excitement as she talks about the machine is evident in her expressions and gestures.

5. Francesco Carpanese speaks about his work at TCV (Tokamak à Configuration Variable). I’ll call it the Game of Hands: the hands express the strong involvement of the narrator as he talks about his work at TCV and composure of the interviewer as she receives the narration.
6. TCV control room: I like the multi-layer composition in this picture; the different lines of sight of each character in the control room steering different aspects of the machine and all finally work together when the machine runs.

7. Contrasts. There is sort of ‘animality’ to this machine, perhaps because of the contrasts. The contrast between the colours of the cables and the coldness of stainless steel makes the colours look warm.

8. At the Magnum-PSI hall, a Graphite galaxy! One of the numerous little surprises found in the fusion laboratories that are but a small part of the everyday work but make for great pictures.

9. Inside PSI-2. The devil inside the machine because the devil is in the details! And details can be beautiful! The picture, captured when the device was being conditioned before starting experiments, shows the target manipulator head in the target exchange chamber.
Coming from EUROfusion’s 30 research organisations and 150+ universities, these exceptional young people are the ITER Generation – the ones who will realise the vast yet evasive potential of nuclear fusion electricity.

**Florian M. Laggner**  
The former handball champion tackling the complexity of plasma physics is Austria-born Dr. Florian Laggner. With his PhD in Technical Sciences from Vienna University of Technology (TU Wien), Florian is now Staff Research Physicist at the Princeton Plasma Physics Laboratory (PPPL) in the US. His main research focuses on edge and pedestal physics in the DIII-D National fusion facility.  

Florian’s PhD research contributed to EUROfusion’s Mission 1 – plasma regimes of operation.  

*On EUROfusion:*  
EUROfusion provides the framework for smaller university research groups (like at TU Wien) to get access and support for onsite research at large scale experiments (in my case this was ASDEX Upgrade). EUROfusion also encourages and supports intercultural exchange among graduate students, which to me is indispensable for forming a strong, collaborative team and workforce to tackle the challenge of developing fusion energy.

**Dr. Chem. Artūrs Zariņš**  
A self-declared fan of the Bela Lugosi classic film Dracula (1931), Latvia-born Artūrs Zariņš completed his PhD in Physical Chemistry (subfield: Radiation Chemistry) last year at the University of Latvia where he now works as Leading Researcher at the Institute of Chemical Physics in the Department of Radiation Processes. There he is currently analysing high energy radiation-induced processes in lithium containing tritium breeding ceramics for nuclear fusion reactors.  

Artūrs’ work directly contributes to EUROfusion’s Mission 4 – tritium self-sufficiency.  

*On fusion research:*  
This has been my passion since high school. Fusion reactors offer clean and safe energy with minimal amount of short-lived radioactive waste and therefore could solve the global energy supply problem. Fusion offers the prospect of an almost inexhaustible source of energy for future generations.

**Andrius Tidikas**  
The literature-loving Lithuanian Andrius Tidikas recently finished the Energetics and Power Engineering Ph.D. study programme at the Lithuanian Energy Institute. He is currently pursuing a doctoral thesis on the safety of nuclear installations with a primary focus on neutron interaction with matter and material activation. He is involved in activation calculations for the Joint European Torus (JET) and in preliminary activation calculations for European DEMO breeder blanket modules and the DEMO divertor.  

Andrius’ research directly contributes to EUROfusion’s Mission 5 – implementation of the intrinsic safety features of fusion.  

*On fusion research:*  
Being involved in nuclear fusion places you at the forefront of progress. There are always new ideas to explore and challenges to face. Another aspect I thoroughly enjoy is the research community. It is always a pleasure to meet fellow researchers and share the experiences, knowledge and problems surging from the wonderful world of fusion.
# EUROPEAN CONSORTIUM FOR THE DEVELOPMENT OF FUSION ENERGY

## REALISING FUSION ELECTRICITY

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**Our partners:**

- FRANCE
- SPAIN
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