Science in School
The European journal for science teachers

ISSUE 57 – April 2022

Topics Engineering | Physics | News from the EIROs
Science and society | Sustainability

JET sets new fusion energy record

Chris Warrick

Recent results from EUROfusion's JET experiment have demonstrated sustained high fusion power for the first time. These ground-breaking results could pave the way for fusion energy to play a key role in tackling climate change.

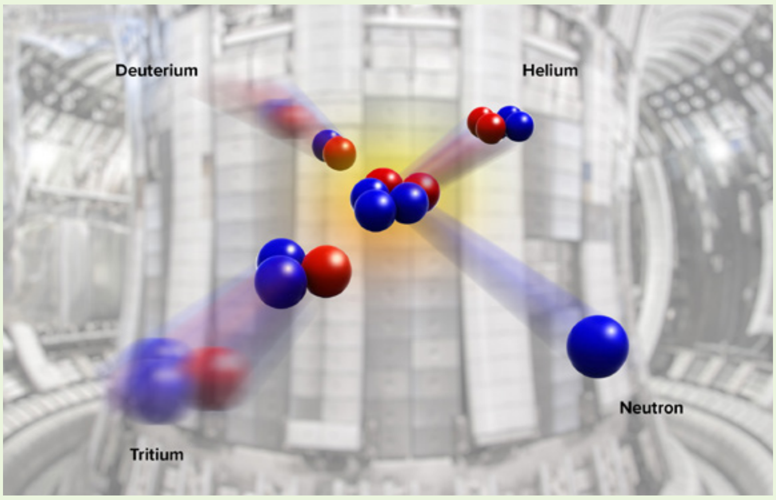
Introduction

Imagine a source of electricity that is low carbon, with fuel reserves that last millions of years, and which is inherently safe and produces shorter-lived radioactivated structures than nuclear fission. As the world strives for a low-carbon future this sounds just too good to be true, but a worldwide research programme developing fusion for electricity generation is aiming to make this dream a reality.

The fusion of hydrogen nuclei is what makes the Sun and stars shine, and it has long been an aim of researchers to replicate that process here on Earth, specifically by using the fusion of two hydrogen isotopes, deuterium and tritium. However, bringing fusion down to Earth is very hard to do – the fuel gases must be heated to extreme temperatures (150 million ºC) and effectively confined inside a suitable chamber.

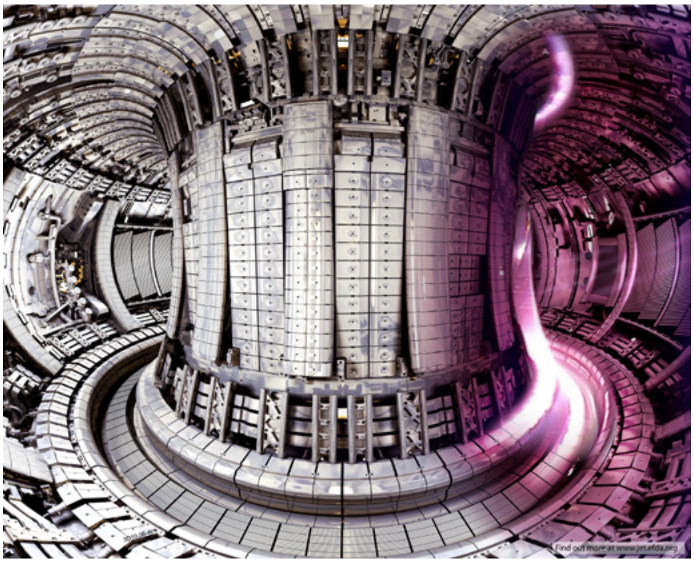
Fusion

The fusion of light nuclei produces heavier nuclei and an excess of energy because the energy required to bind the heavier nucleus is reduced. The Sun fuses hydrogen nuclei together to make helium and energy, but the reaction is inefficient and slow. The optimum fusion reaction for future electricity on Earth would be between two heavy forms (or isotopes) of hydrogen: deuterium and tritium. The reaction produces a helium nucleus and a neutron – and lots of excess energy. Deuterium is available from water and tritium can be produced from lithium, meaning that future fusion fuel reserves are abundant.



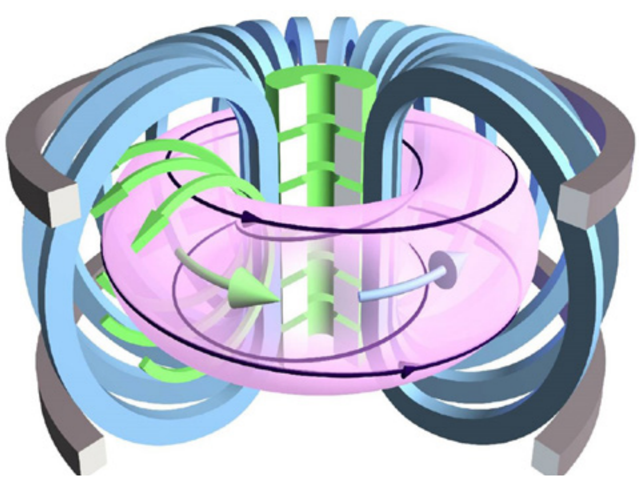
The fusion reaction D + T → He + n + Energy
© UKAEA

Fusion research



The interior of the JET with hot plasma on the right
© EUROfusion

The most advanced fusion research programme uses powerful magnetic fields to confine and control a ring of hot gas (or plasma) in devices called tokamaks. Many tokamak experiments operate around the world but the largest and most powerful is the iconic Joint European Torus (JET) experiment, which is operated by the UK Atomic Energy Authority (UKAEA) at its Culham site in the UK for the wider European fusion community coordinated by the EUROfusion consortium. JET is the only fusion device that can use (radioactive) tritium as well as the commonly used deuterium, and is the closest in design to next-step machines like the massive international thermonuclear experimental reactor (ITER) device (an international power-plant-scale fusion tokamak, currently under construction in the south of France) and several future fusion power plant designs.

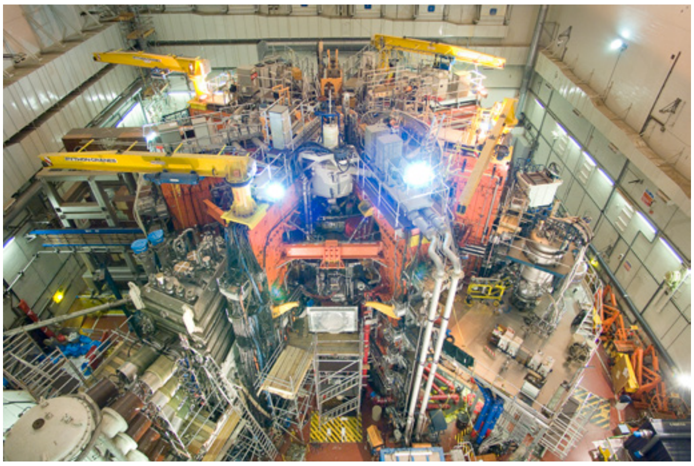


Schematic of a tokamak – the magnetic coils (shown in blue and grey) are used to control the fusion plasma (in pink)
© UKAEA

JET sets a new world record

JET really hit the headlines in early February as it announced genuinely landmark results: for the first time ever, it sustained significant fusion power (11 MW for 5-6s) with a deuterium-tritium mix and set a new fusion energy record of 59 MJ. Over many years of operation, JET has achieved high fusion powers before, but only transiently (for much less than a second). The real challenge has always been to sustain these power levels in a plasma ten times hotter than the sun that is naturally unstable and difficult to confine; this has now been accomplished.

Sustaining high fusion performance for five or six seconds does not seem a long time to most of us – it has probably taken you almost that long to just read this sentence! But for a fast-changing fusion plasma, it is a really long time; quite simply, it is a steady state.



The JET machine from above
© EUROfusion

Indeed, JET is limited to short pulse lengths, typically of only a few ten of seconds, due to heating of its copper magnetic coils (ITER will have superconducting coils that will not heat up and will consequently run for much longer). As Tony Donné, EUROfusion's programme manager stated in the media, "If we can maintain fusion for five seconds, we can do it for five minutes and then five hours as we scale up our operations in future machines. This is a big moment for every one of us and the entire fusion community."

The people who make fusion happen

This is a success story not just for the science, but also for the scientists and engineers who worked so hard to make this happen; the 400 or so UKAEA engineers who ensured that JET was working properly and the hundreds of scientists in 30 research institutes across 25 countries who worked tirelessly to produce these results – all during a global pandemic that necessitated remote working.

A fusion future

So what does this all mean? There is now real confidence that ITER will achieve its goal of demonstrating 300-500 MW of fusion power for an hour or more and, furthermore, that future fusion power plants will produce economically viable base-load fusion electricity for long durations or continuously.

There are still challenges to face before we can realise the dream of putting fusion electricity on the grid, but without a doubt these results from JET are a major step forward. Make no mistake, the world needs fusion as it plots a route to sustain a future low-carbon society.

So when will fusion be on the grid? With ITER starting up in the next few years, and several major power plant design activities around the world progressing well, it is hoped that the first fusion power will be generated in about 2050, with widespread commercial deployment in the latter half of this century.

Fusion won't be the 'silver bullet' that solves the energy crisis, but it will a valuable addition to renewables and nuclear fission to give us a chance. UKAEA's CEO Ian Chapman is clear on the objective, "We're building the knowledge and developing the new technology required to deliver a low-carbon, sustainable source of baseload energy that helps protect the planet for future generations. Our world needs fusion energy."

These recent results from JET take us another major step closer to a fusion future. «

References

[1] EUROfusion's press release: https://www.euro-fusion.org/news/2022/european-researchers-achieve-fusion-energy-record/

Resources

- For more information on JET and fusion, see www.euro-fusion.org and www.ccfe.ukaea.uk .
- Further EUROfusion resources for educators.
- Organize a visit – in person or virtual – at JET
- Find out more about the difference between fusion and fission: EUROfusion (2021) Fusion vs fission. *Science in School* **51**.
- Read an article on fusion reaction in the Universe and where we come from: Boffin H, Pierce-Price D (2007) Fusion in the Universe: we are all stardust. *Science in School* **4**: 61–63.
- Discover how drones are used to repair fusion devices: Kidambi M (2017) Fusion drones: robot technicians for nuclear devices. *Science in School* **40**: 8–11.

AUTHOR BIOGRAPHY

Chris Warrick is Outreach and Student Placement manager at UKAEA. Chris joined UKAEA in 1990 as an experimental physicist. He subsequently joined the Communications team, with particular responsibility for education and public outreach, before leading the group in April 2010 and becoming head of stakeholder engagement in 2020.

EIROforum EUROfusion