Diamond Light Source II– Upgrade will add gains in brightness and coherence

Gianluigi Botton

Enabling world-class science in universities and industry for researchers both nationally and internationally the UK's synchrotron, Diamond Light Source, is on course for a transformative upgrade that will provide capabilities to underpin future innovation in almost all fields of research. Supported with funding from the UK Government and the Wellcome Trust, Diamond currently offers access to 31 beamlines *(Figure 1)* and an impressive suite of complementary facilities – the Electron Bio-Imaging Centre (eBIC), the Electron Physical Science Imaging Centre (ePSIC), the MPL (Membrane Protein Lab), the XChem Fragment Screening service and the XFEL Hub, which develops technology for sample delivery and data analysis for Free Electron Lasers for life sciences.

The proposed upgrade will necessitate downtime for the facility – a darktime period of around two years. So what does this mean for research groups and what can they expect when operations restart?

Gianluigi Botton, CEO of Diamond Light Source and Senior Responsible Officer for the Diamond-II upgrade provided some short facts and insights for readers of International Labmate.

After the Diamond-II upgrade, how will Diamond Light Source differ to the original Diamond investment and what are the reasons behind the upgrade?

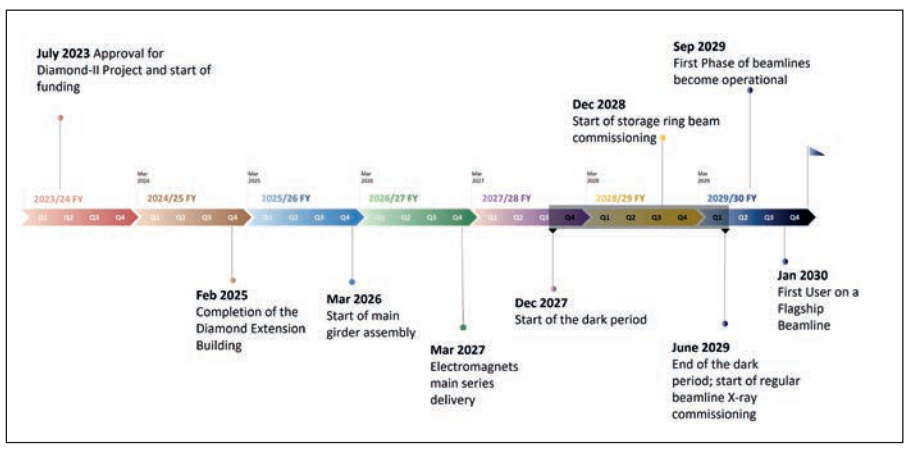
Diamond has been a leader in the field of synchrotron research – when we were inaugurated in 2007, our machine was the brightest synchrotron of its class in the world. Our beamlines have provided the UK research community with direct access to the most incisive measurements of the electronic, chemical and structural properties of a huge range of materials, from viruses to critical components of next-generation batteries. The knowledge derived from such measurements has proved invaluable over the past decade in establishing or boosting the UK's world-leading position in many important areas of research that use it. Diamond-II will transform Diamond into a 4th generation synchrotron source, enabling it to retain its prominent position in the top-tier of international synchrotron facilities. This will be achieved by exploiting new technology that is being used or in the planning stages at synchrotrons in other leading scientific nations. In addition to this, there will be extensive upgrades to beamlines, and a boost in computing and software capability to better translate measurements into usable data.

Without this investment, the UK would fall behind its competitors, inevitably leading to Diamond becoming uncompetitive in regards to the science it delivers through its 14,000 strong user community, and the people it can attract, recruit and retain.

What is the expected timeline of the machine's downtime and predicted re-opening? What will Diamond be doing to mitigate the impact of this dark period for research?

Diamond is scheduled to be off-line (referred to as the dark period) between December 2027 and June 2029, after which the different beamlines and capabilities will ramp back up over time. As of April 2024, there are six calls for proposals remaining for Diamond users. Typically, these calls are twice a year with deadlines in April and October.

Below is an estimated timeline for the Diamond-II upgrade programme. This will be regularly revised and updated with key achievement as the project progresses.



Proposed Timeline for the Diamond II upgrade programme

What will Diamond-II offer in terms of increased research capability, new beamlines and their areas of focus?

The unique design of the Diamond-II machine will enable the current beamlines to be retained but in addition, the new storage ring will allow for up to three new flagship beamlines to be developed and ready to fully exploit the improved characteristics of the new beams after the dark period. In addition, four of our existing beamlines (B07, B16, B18, B21) will be upgraded to work with more powerful insertion device sources compared to the existing bending magnet sources.

Beamline for Coherent Soft X-Ray Imaging and Diffraction – CSXID/I17

PBS – David Burns

The CSXID beamline will be key to the future research direction for a range of functional materials. It will provide high-resolution 3D imaging to explore and understand these materials along with the opportunities for 3D electrochemical reaction tracking and chemical speciation location. Sample environments including electrochemical flow cells with electrical biasing, gas mixing and time-resolved infrastructure and sample heating will be provided to enable research under a range of operando conditions. This beamline will allow a range of high-resolution coherent imaging techniques including ptychography, holography and Bragg coherent diffraction imaging which will be supported by scanning transmission X-ray microscopy and with a probe into the third dimension through tomography and laminography. The CSXID beamline requires a source capable of producing arbitrary linear and circular polarised light in the range 250 – 3500 eV with a high degree of partial coherence. This will be achieved through the low emittance electron beam source offered by the Diamond-II upgrade and by being positioned on a long straight within the storage ring.

Beamline for Fast Operando Spectroscopy – SWIFT (spectroscopy within fast timescales)

PBS – Giannantonio Cibin

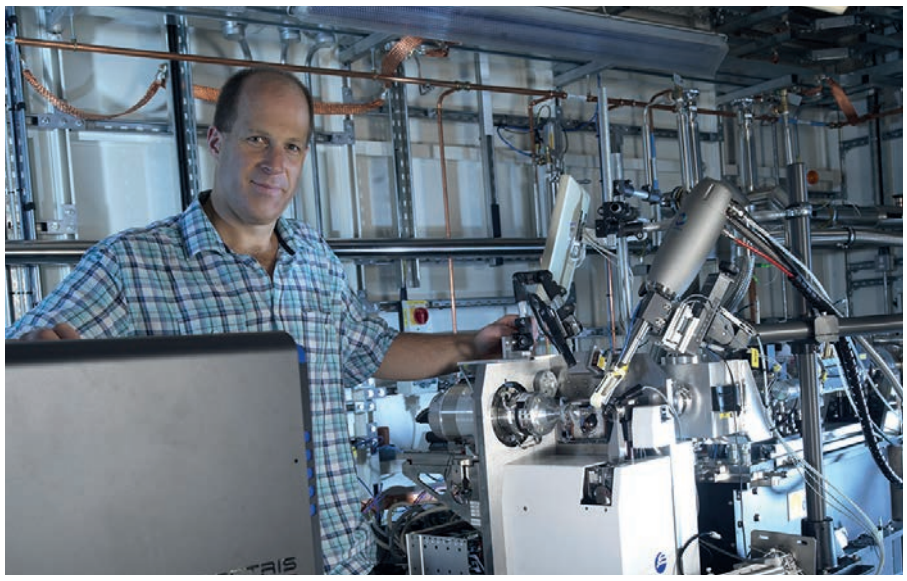
SWIFT is a high flux spectroscopy beamline to be built on a mid-straight section as part as the Diamond-II programme. The beamline is optimised for the study of samples under operando conditions, with the added potential to investigate sample heterogeneities at the 20 µm scale.

SWIFT's combination of high flux, time and spatial resolution will offer new opportunities in a very broad spectrum of scientific areas, spanning from chemistry, energy, catalysis and earth sciences to the study of metals in tissues. SWIFT's enhanced technical capabilities will represent a step change to Diamond's capability to support the spectroscopy community from both academia and industry.

Ultra-high throughput beamline for MX and XChem - K04

Project Lead – Frank von Delft

K04 is an ultra-high throughput beamline for MX and XChem. The K04 XChem flagship builds on the success and oversubscription of the XChem fragment screening facility, developed in tandem with the evolution of beamline I04-1. The current facility provides a world-unique offering for structure-based drug design (SBDD), which is in heavy demand by academia and industry. The beamline played a key role during the COVID-19 pandemic, enabling fragment-based drug discovery campaigns for nine key non-structural proteins of SARS-CoV-2 to accelerate the discovery of antivirals. The proposed new flagship beamline K04 will provide further acceleration of the science at a factor of 3-5 increase in throughput to support future work in pandemic preparedness and drug discovery.



Frank von Delft by the Ultra-high throughput beamline for MX and XCem -K04

Will Diamond-II offer more access to an increased number of user groups through advanced capacity and beamline technology?

The investment will be beneficial to a diverse range of sciences. Diamond has seen its community of researchers grow two-fold over the past 20 years so Diamond-II will be key in consolidating Diamond's leading position and synchrotron of choice by the user community.

How will the dark period impact on other local and national facilities, universities, and connected industries?

The implementation of Diamond-II will require a significant shutdown. Other synchrotrons around Europe will be upgrading on a similar timescale to Diamond and timings will inevitably be dictated by national priorities. We are investigating strategic collaborations with other facilities, and we expect that mitigation measures will be tailored to the characteristics of the different science communities.

How will the new facility fit into the international networks of light and accelerator sources and will Diamond-II's international/European participation be significantly increased?

Diamond is already a member of several organisations such as lightsources and LEAPS. In the LEAPS association, members are already in close relationship to follow the development of upgrades for European synchrotrons. With the development of new flagship beamlines, Diamond will attract more researchers worldwide. The new K04 beamline, aims to have 10 times increasing throughput, making it one of the pillars in drug discovery worldwide.

The CSXID beamline team, in front of the future flagship beamline location. Copyright Diamond Light Source

Gianluigi Botton, CEO of Diamond Light Source. Copyright Diamond Light Source

Will there be an increase in staff, in user support programmes and in apprenticeships/young researcher intake following the opening?

The construction and operation of Diamond during the Diamond-II upgrade and after the completion will provide new career opportunities in many areas: scientists, engineers (electrical, mechanical, software and technicians), including apprentices and young researchers.

Further details relating to the Diamond II upgrade can be found on the website.

More information: diamond.communications@diamond.ac.uk

The SWIFT beamline and supporting Spectroscopy group, in front of the future flagship beamline location. Copyright Diamond Light Source

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