What will Diamond II do for you?

Y. Duan, C. Y. Leong, J. Liu, R. Mahammod, L. Shanahan, M. Shuai, D. Trieu, A. Westerby

Supervisor: Dr. Roger Johnson

UCL, Physics and Astronomy Department

UCL

Aims & Objectives

To investigate the quantitative and qualitative benefits of the Diamond II upgrade and understand the impact on the scientific community.

Background

Diamond Light Source is the UK's national synchrotron facility, which produces intense X-ray beams used to investigate many areas of research.
Diamond is made of 4 main components:

- Electron source
- Booster ring
- Storage ring
- Beamlines

How Are X-rays Produced?

Electrons are generated via thermionic emission. A booster ring accelerates them to ~3 GeV, which are injected into a storage ring. This ring contains dipole (bending), quadrupole, and sextupole magnets.
X-ray frequencies: 3 x 1016 – 3 x 1019 Hz. An electron emits EM radiation when changing direction. X-rays are generated in bending magnets, undulators, and wigglers.

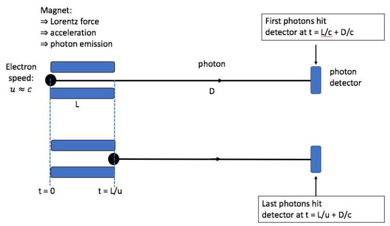

Figure 1: Diagram X-ray production.

How can we increase the resolution of experimental data?

Diamond II will replace the old DBA storage ring and utilise a lattice consisting of Double Triple Bend Achromats (DTBAs). This will achieve a reduction in the beam emittance.

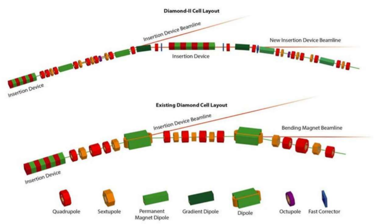

Figure 2: Comparison between the existing DBA lattice and the new DTBAs lattice.

Method

Our investigation primarily focused on the Coherent diffraction imaging (CDI) experiment in Diamonds I-13 branchline. CDI is a lensless tomographic technique that measures the diffraction pattern of x-rays that have scattered off of a nanoscaled sample (e.g.nanotube). From this diffraction pattern it is possible to reconstruct a highly resolved image of the sample and thus is a widely used technique in both material and biomedical sciences.

In CDI the resolution of the image is dependent solely on the coherence of the incoming x-ray beam. However, a major drawback with CDI is that by measuring the scattered intensity distribution all phase information of the x-ray beam is lost. Thus information of the sample is also lost and must be iterated over to retrieve an image of the sample.

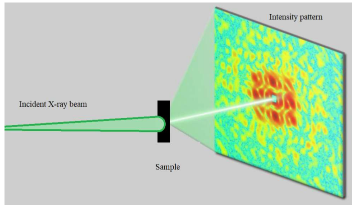

Figure 3: Illustration of X-ray beam diffraction.

A computational model was created to examine the effect that the proposed upgrade will have on the CDI experiment.

- A Comparison was made between both Diamond 1, Diamond 2 and an ideal coherent beam.
- The chi-square between the generated images and the original sample image was measured to determine the similarities per iteration.
- The model used an iterative feedback algorithm known as the oversampling algorithm to reconstruct the image off a generated intensity distribution

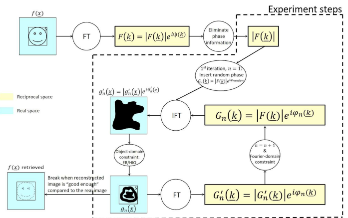

Figure 4: Flow chart of the oversampling algorithm.

Acknowledgments & References

Prof. Angelos Michaelides – course coordinator and Dr Roger Johnson-board member

Results

The results show an increase in the resolution with each iteration. From our computational model, Diamond II does not improve the quality of the diffraction pattern. It was also found that the ideal case had no effect in the resolution of the diffraction pattern.
There are three potential causes for such a phenomenon to occur :

- The chi-square limit
- Computational precision of the results reaching a value that is indistinguishable
- Our simplified model does not account for how the upgrade affects the efficiency of the upgrade.

X-ray	χ^2	σx (m)	σy (m)	Iterations
Coherent	1e-8	1/∞	1/∞	49
Diamond I	1e-8	2.509e-6	1.329e-7	49
Diamond II	1e-8	5.611e-7	1.329e-7	49

Table 1: Computational results.

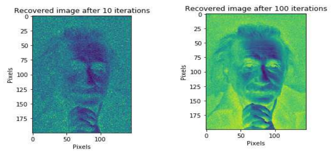

Figure 5: Recovered image using GS algorithm.

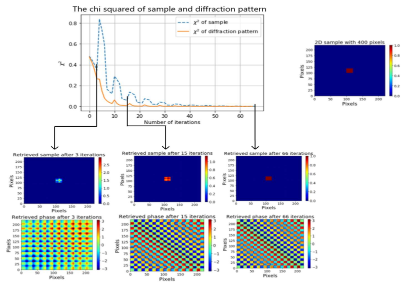

Figure 6: Recovered images using HIO and ER algorithms.

Conclusion

Diamond II helps to improve experimental research by enhancing the parameters as shown in table 2.

This upgrade also results in :

- higher flux - more photons per area per second
- smaller beam - less overall radiation damage
- shorter pulses - improved time resolution

Diamond II opens up the following research areas:

- Battery research
- G protein-coupled receptors
- Target-drug kinetics
- Study of Coronaviruses in a more efficient way

From our findings we believe that, in an age of exponential technological development, it is evident that institutions, such as the Diamond Light Source, be upgraded to ensure that the UK's scientific community remains competitive by contributing to cutting-edge global research.

	Brilliance (photon $sec^{-1} mm^{-2} mrad^{-2} 0.1\% bw^{-1}$)	Emittance (nm mrad)	Current (mA)	Beam Energy (GeV)
Diamond I	3.0×10^{20}	3.1	300	3.00
Diamond II	$>3.0 \times 10^{20}$	0.125	300	3.50

Table 2: Comparison between Diamond I and Diamond II parameters