Light Sources Update

I. Martin

JAI Advisory Board Meeting

7th April 2022

John Adams Institute for Accelerator Science

diamond

Talk Outline

Update on Diamond-II:

- Project goals
- Recent developments
- Ongoing and future AP studies

Updates from JAI members:

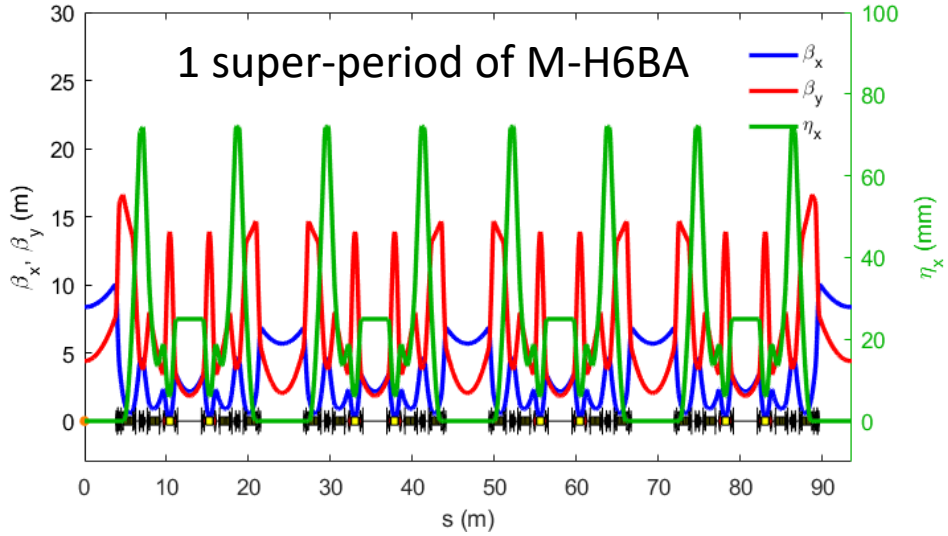
- Feasibility Studies of Cherenkov Diffraction Radiation BPMs (D. Harryman, A. Clapp)
- Provision for Timing Mode Users at Multi-bend Achromat Synchrotron Light Sources (S. Wilkes)
- Joint-Appointment PDRA between Oxford / Diamond

Conclusions

Diamond-II: Design Goals

Objective #1: Optimise the science enabled at Diamond

Objective #2: Maximise the impact it has for researchers both in universities and in industry



- New Modified Hybrid 6-Bend Achromat (M-H6BA) storage ring
  - Lower emittance (x~20) to increase brightness and coherence
  - Double number of straight sections to increase capacity
- Raise energy from 3 GeV to 3.5 GeV to increase flux and brightness above 10 keV
- Upgrade insertion devices, new flagship beamlines
- Improved data handling/computation, automation, ...

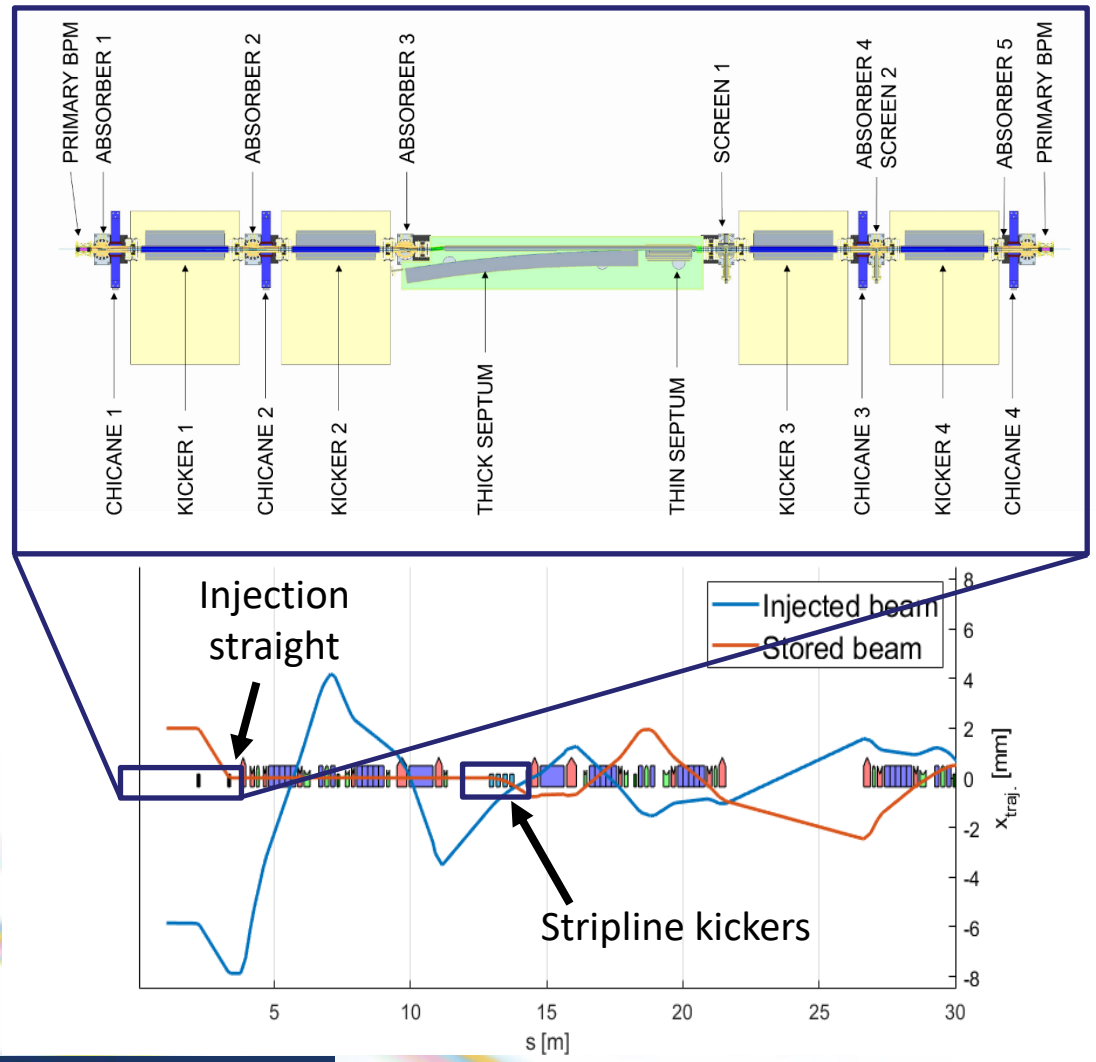
Science case and Conceptual Design Report published in 2019:
https://www.diamond.ac.uk/Home/About/Vision/Diamond-II.html

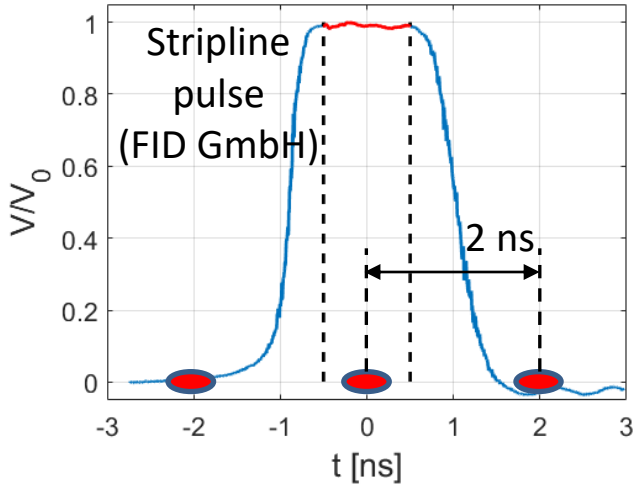
	Bare lattice	With IDs
Average ε_x*	163 pm.rad	120 pm.rad
Average σ_E*	0.095 %	0.109 %
Average σ_L* (RMS)	49.1 ps	48.1ps
Total Lifetime*	7.0 ± 0.2	7.0 ± 0.3

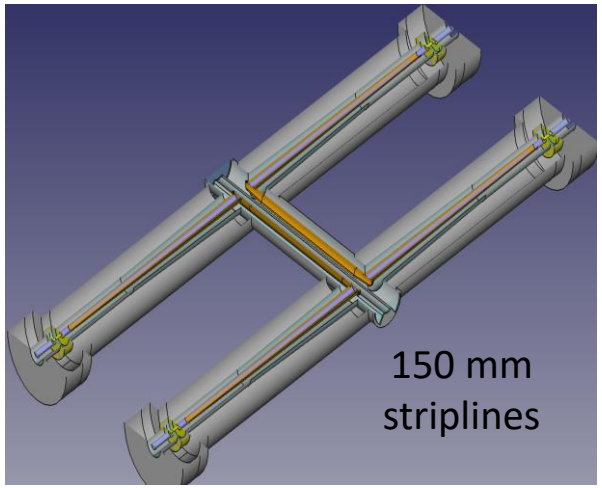
**final parameters including effects of intra-beam scattering, wake-fields and harmonic cavity*

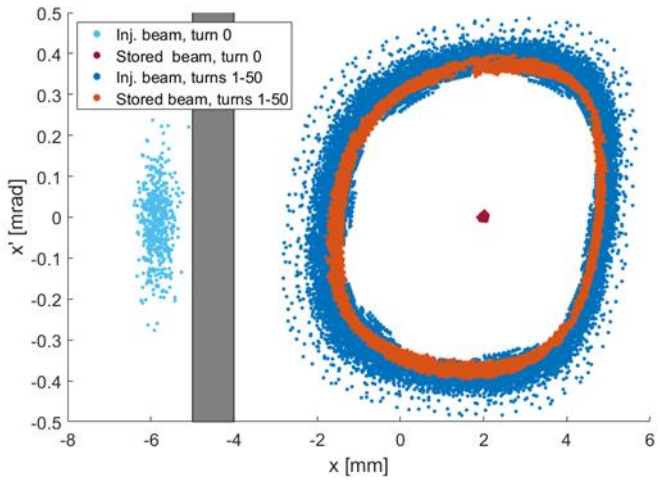
Diamond-II: Injection Scheme

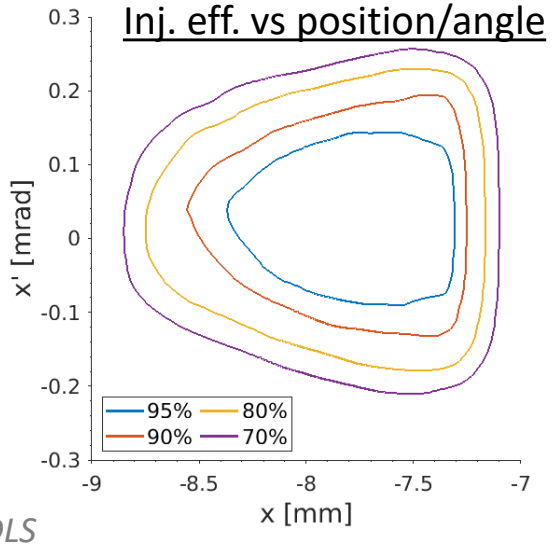
Diamond-II injection will use a single-bunch ‘aperture-sharing’ scheme utilising a combination of thick/thin septum magnets and fast stripline kickers to improve transparency of injection process







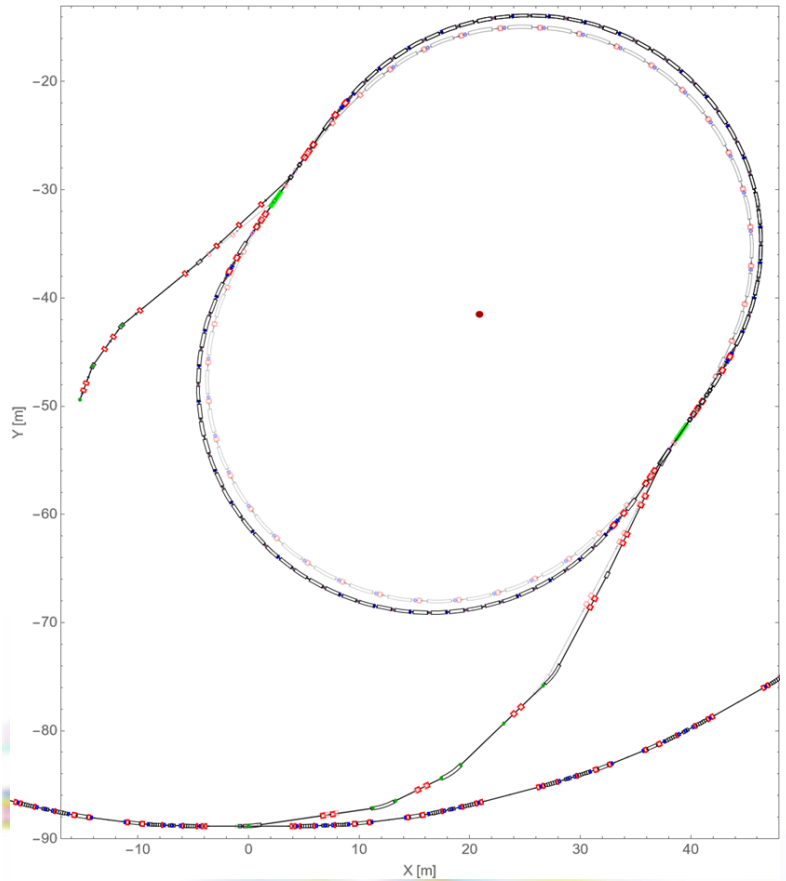


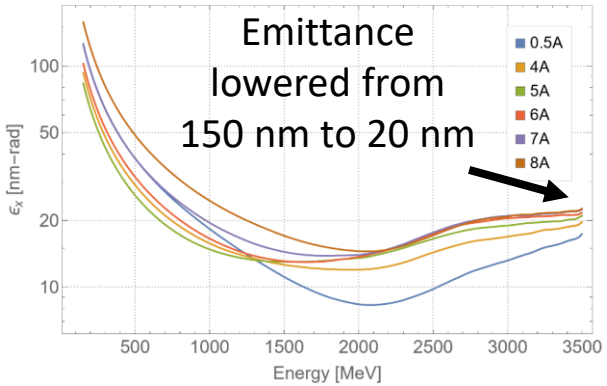


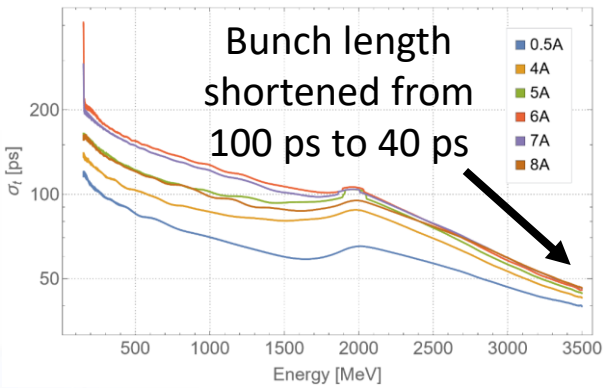
J. Kallestrup, DLS

Diamond-II: Injector

1) Efficient injection into Diamond-II storage ring at higher energy requires a new linac, a new booster and reconfigured transfer lines
2) Aim to maximise charge/shot to reduce fill times and enable a variety injection schemes

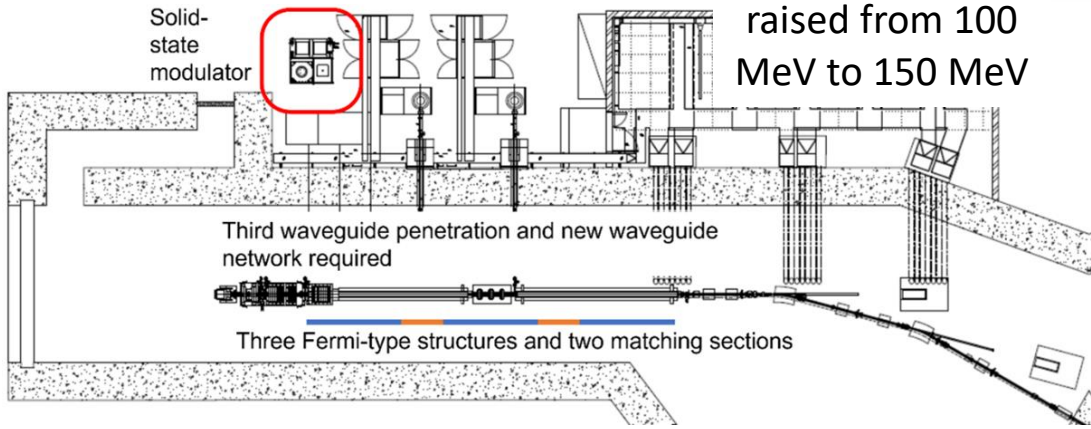


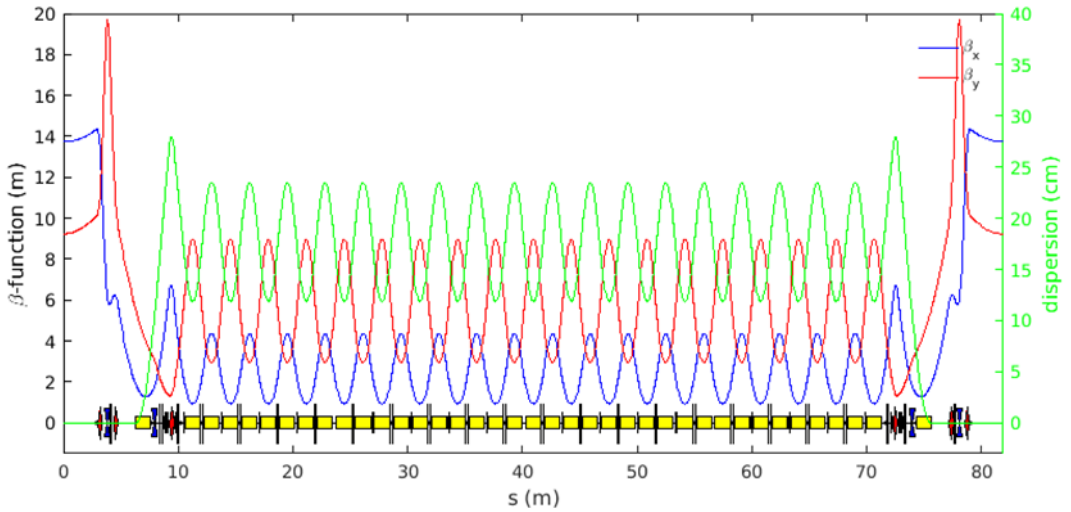




J. Jones, ASTeC

Linac energy raised from 100 MeV to 150 MeV





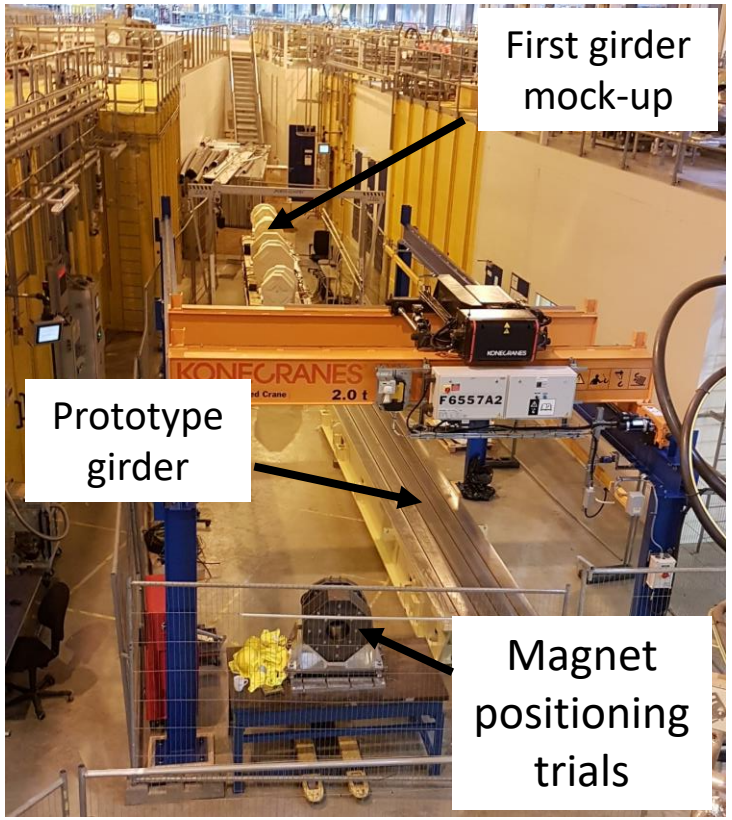
Diamond-II: Prototyping

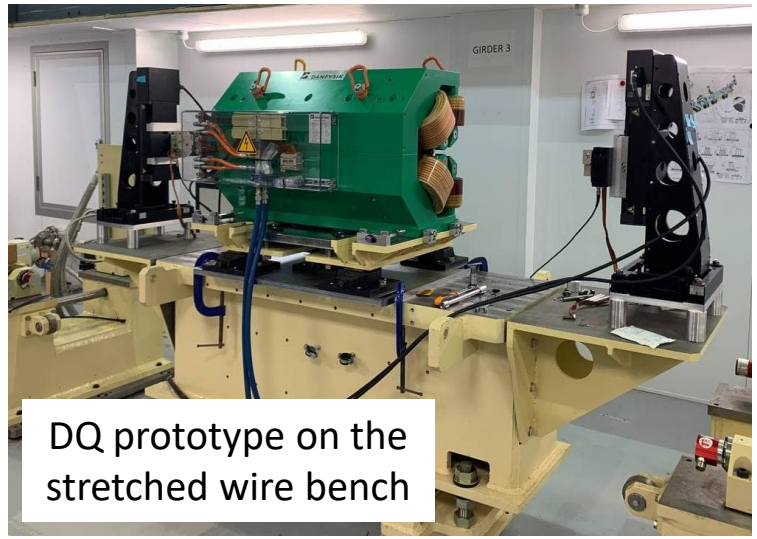
Many developments are either underway …

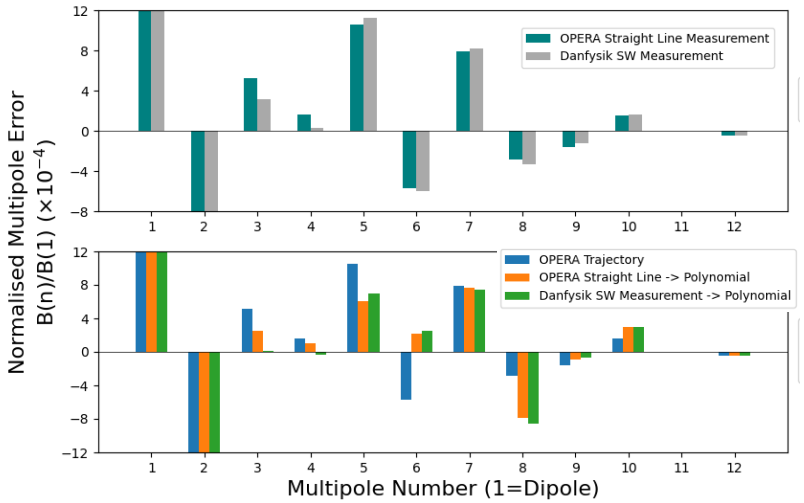
- Magnet alignment trials
- Girder electrical wiring
- Power supply controller
- Front-end/ID control rack upgrades
- New BPM electronics
- New fast-feedback architecture
- Girder motion system

… or planned:

- Permanent magnet dipoles
- Injection stripline(s) and pulser
- Multi-bunch feedback
- Ceramic kicker vessel
- Fast corrector & power supply
- Collimators





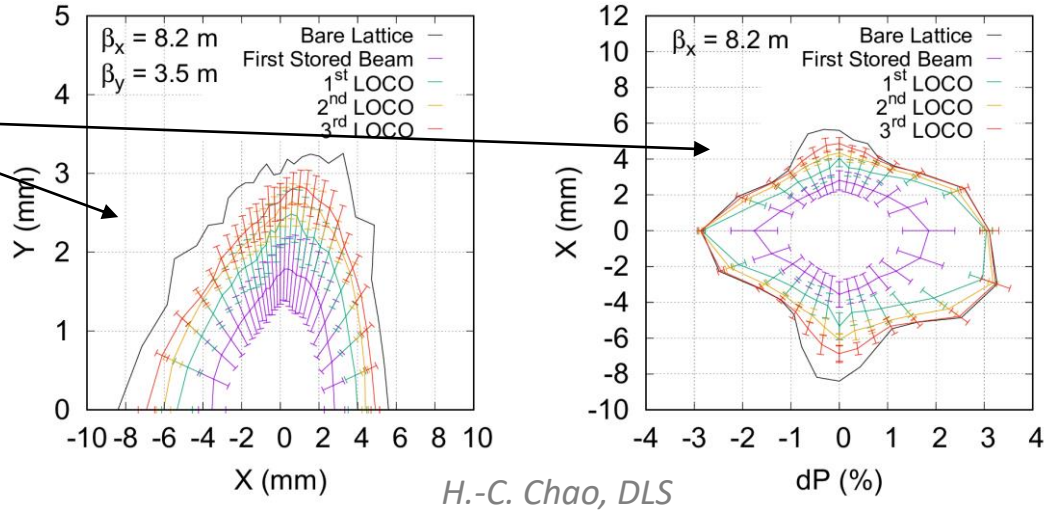


A. Shahveh, DLS

Diamond-II: Ongoing and Future AP Activities

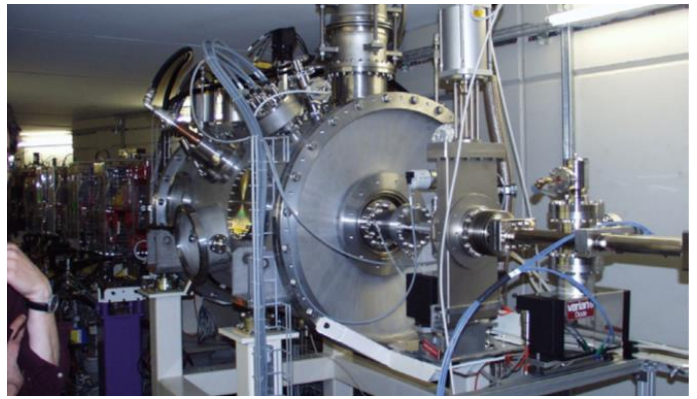
Currently finalising the Technical Design Report. Draft reviewed by Machine Advisory Committee March 2022.

Simulated commissioning process from first turns through to ID commissioning

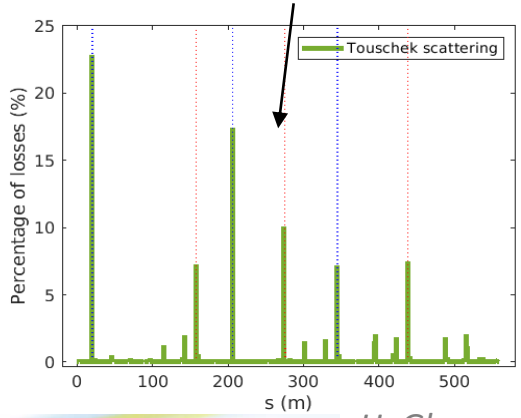


H.-C. Chao, DLS

SC harmonic cavity at SLS

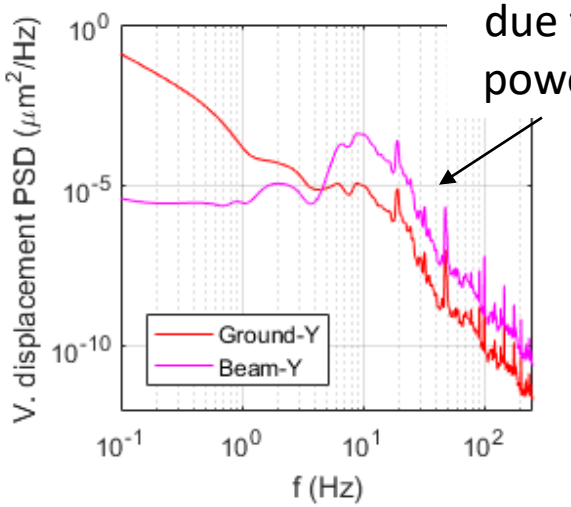


Loss distributions studied for different scattering mechanisms

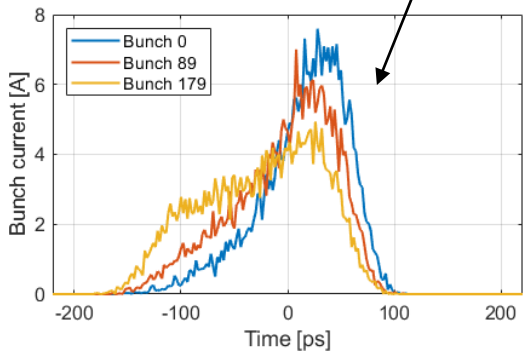


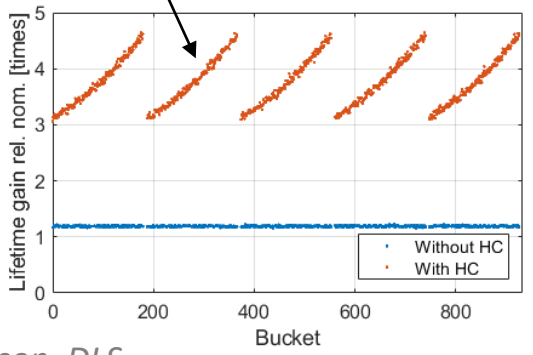
H. Ghasem, DLS

Electron beam stability due to ground motion, power supply ripple, …



Equilibrium bunch profile and lifetime gain due to harmonic cavity

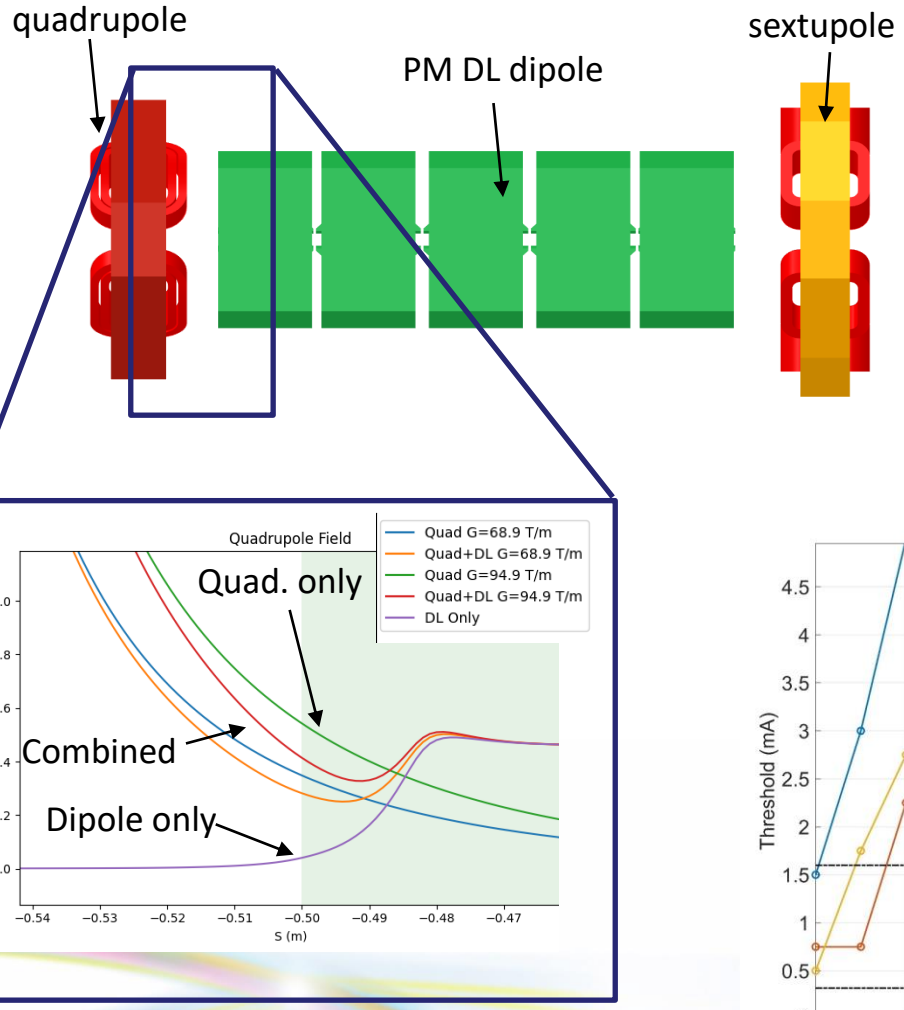




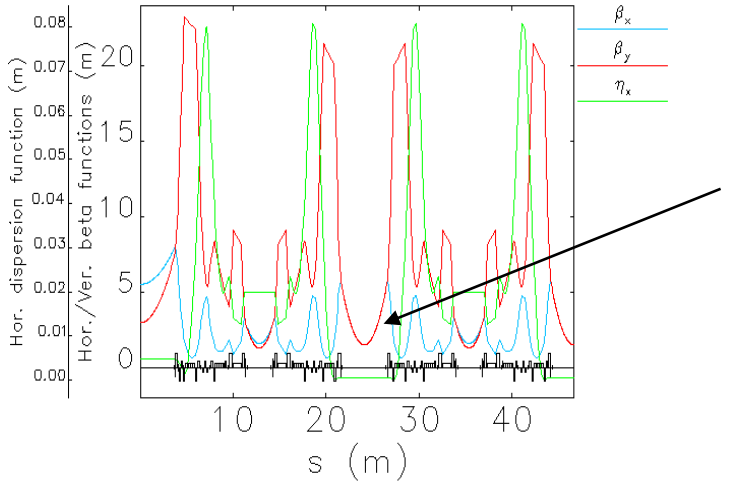
T. Olsson, DLS

Diamond-II: Ongoing and Future AP Studies

Impact of magnet cross-talk due to high-fields and close proximity

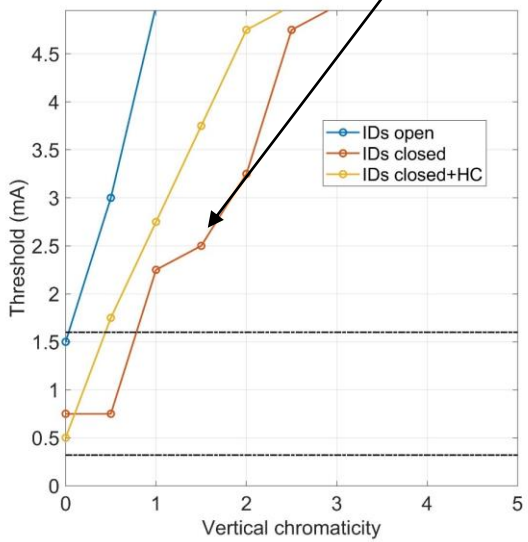


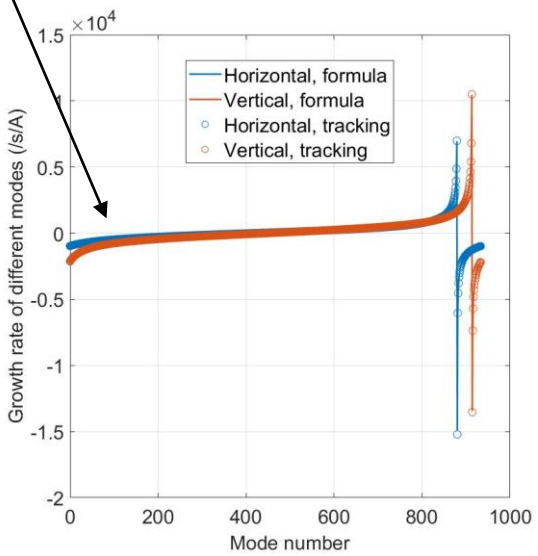
B. Nicolson, DLS



Alternative lattice solutions to increase photon beam brightness (reduce emittance, improved optics at IDs)

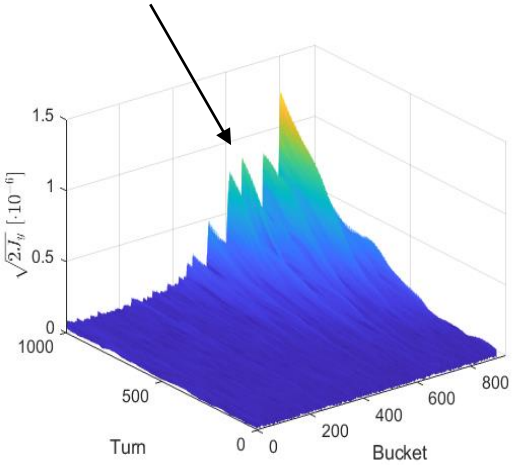
Single and coupled-bunch instability thresholds





S. Wang, DLS

Vertical instability due to ion-trapping



T. Olsson, DLS

Diamond-II: Timeline

Diamond funded as a Joint Venture between two sources (UK Govn./STFC 86% and Wellcome Trust 14%):

- Same funding structure planned for Diamond-II
- Full Business Case (FBC) to be reviewed by UKRI's Infrastructure Advisory Working Group (IAWG), Executive Committee (Exco) and BEIS Project and Investment Committee (PIC), June-August 2022
- Wellcome Trust have approved funding for D-II, subject to final approval from UK Government
- Funding decision expected November 2022

Nominal Timeline:

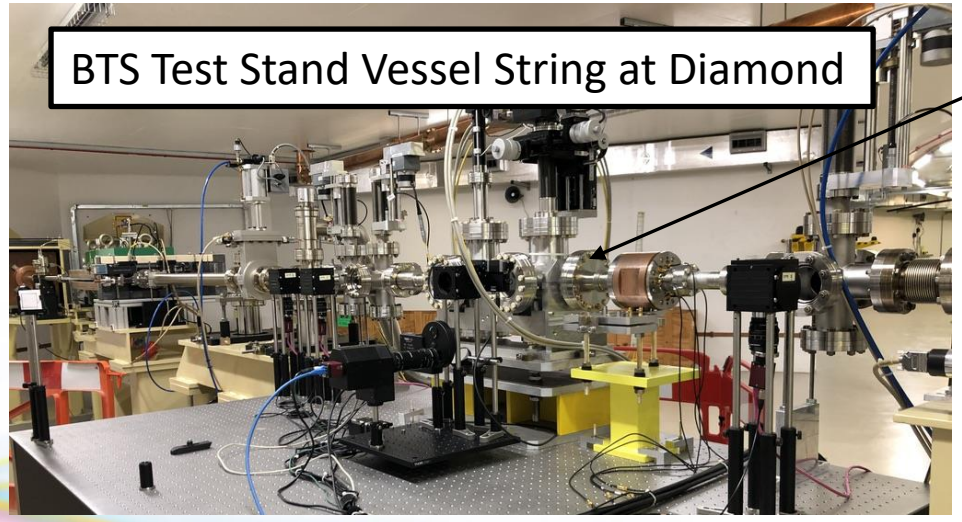
TDR published	May 2022
Start of shutdown	September 2026
End of booster commissioning	July 2027
End of storage ring commissioning	December 2027
User beam resumes	March 2028

PhD Students: Dan Harryman, Alec Clapp (started 2021)

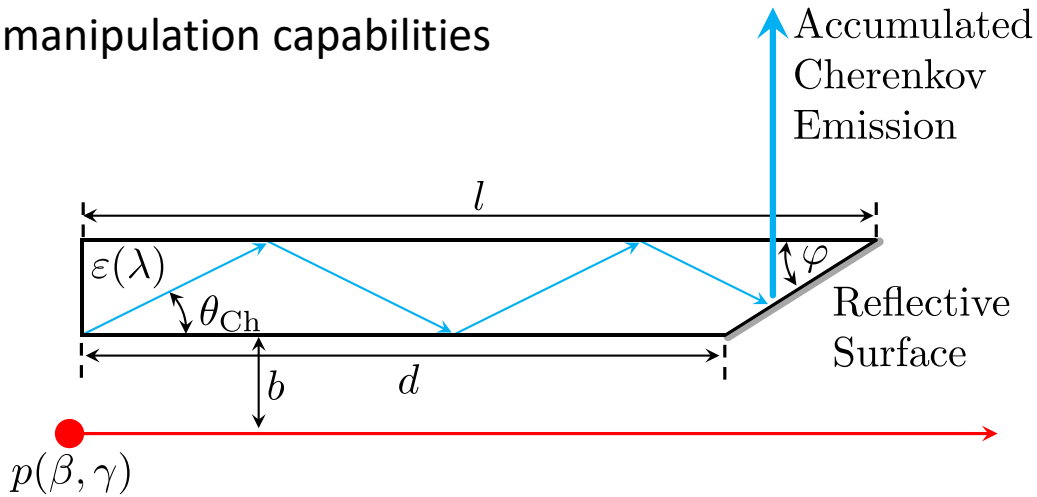
“Feasibility study on the use of incoherent Cherenkov Diffraction Radiation to develop a non-invasive BPM”

This work is part of a wider research group* exploring the applications of ChDR for beam diagnostics in collaboration with CERN, Tomsk and Royal Holloway, Uni of London, with experimental setups at CERN, KEK and Diamond Light Source.

- Cherenkov Diffraction Radiation (ChDR) occurs when a charged particle moves in the vicinity a medium.
- The photon yield of ChDR is dependent upon the distance between the charged particle and the dielectric medium.
- Thus ChDR can be exploited for novel beam position monitors (BPM), where traditional rf pick-ups are challenging, (e.g. inside a bending magnet)



Experimental station with multi-axis manipulation capabilities



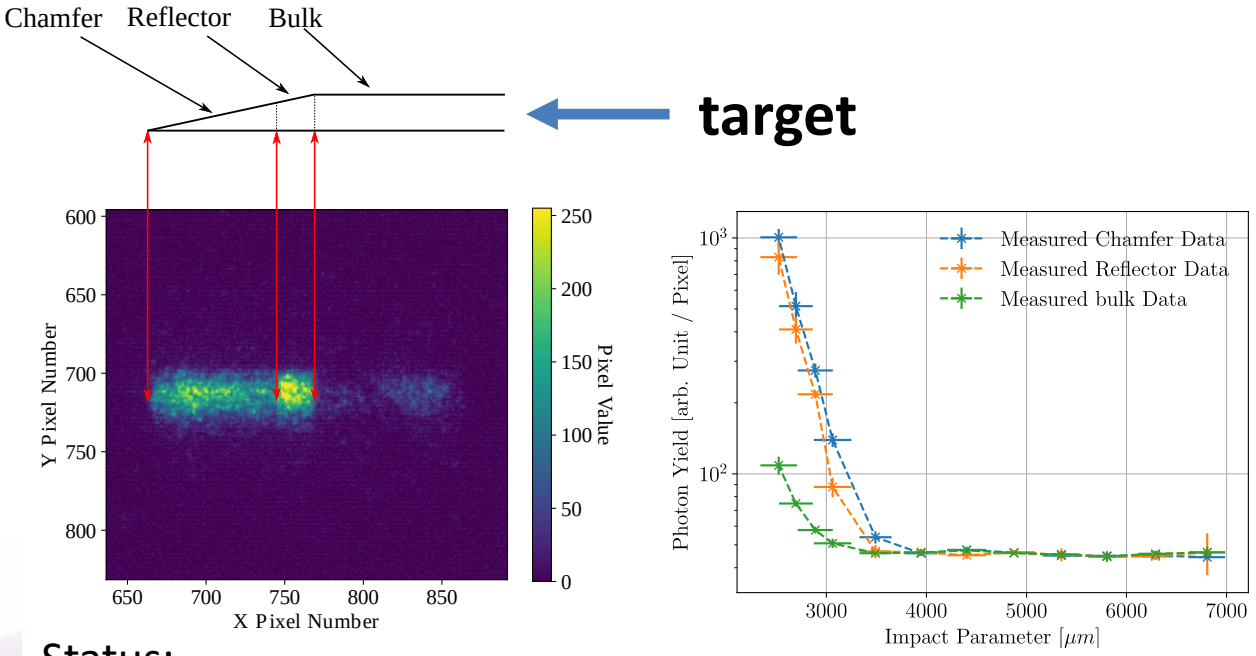
*R. Kieffer et al., Phys. Rev. Lett. 121, 054802 (2018)

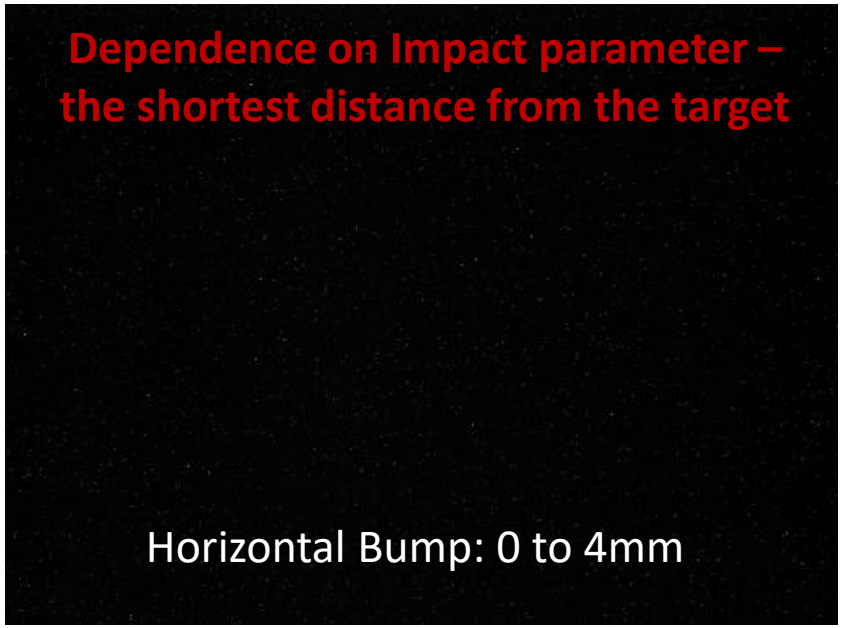
Supervisors: P. Karataev and L. Bobb

PhD Students: Dan Harryman, Alec Clapp (started 2021)

Experimental Observations (imaging of ChDR target):

- When imaging the ChDR radiator three distinct areas can be seen.
- Incoherent unfiltered emission can't be seen until impact parameters of 3.5mm or less are reached.
- Given the beam size at these areas there will be noise and contamination from direct Cherenkov radiation caused by direct beam and radiator collision





Status:

- New radiator is being developed taking into account experimental experience from CERN and Daresbury Laboratory
- Experimental work is planned every shutdown

Supervisors: P. Karataev and L. Bobb

D.Phil. Student: Seb Wilkes (Started 2021)

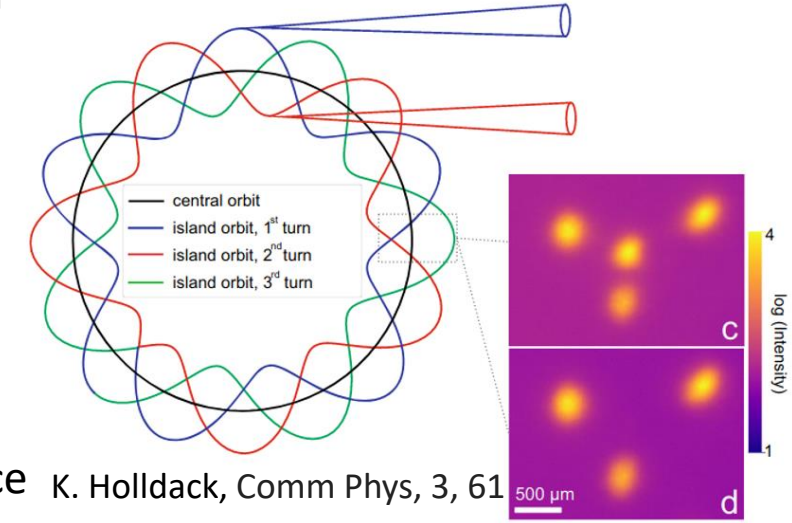
“Provision for Timing Mode Users at Multi-bend Achromat Synchrotron Light Sources”

An open question for Diamond-II is how best to **provide short, isolated x-ray pulses** for time-resolved studies

Many options to study:

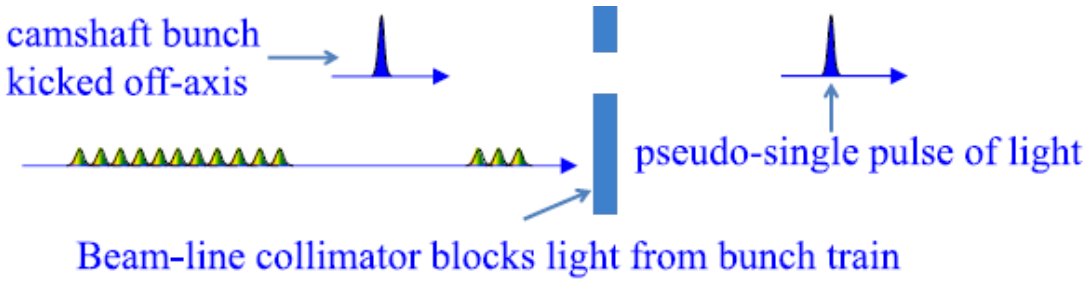
1) ‘**hybrid-mode**’ filling pattern with an isolated single bunch in a long gap
2) ‘**Pulse-Picking by Resonant Excitation**’ by increasing the vertical beam size of a single bunch by driving at the synchrotron sideband
3) ‘**Pseudo single bunch**’ by kicking a single bunch onto a different trajectory
4) ‘**Transverse Resonant Island Buckets**’ by shifting the tune point close to a resonance
5) Use of a **higher-harmonic RF cavity** to manipulate the longitudinal potential well

Transverse Resonance Island Buckets



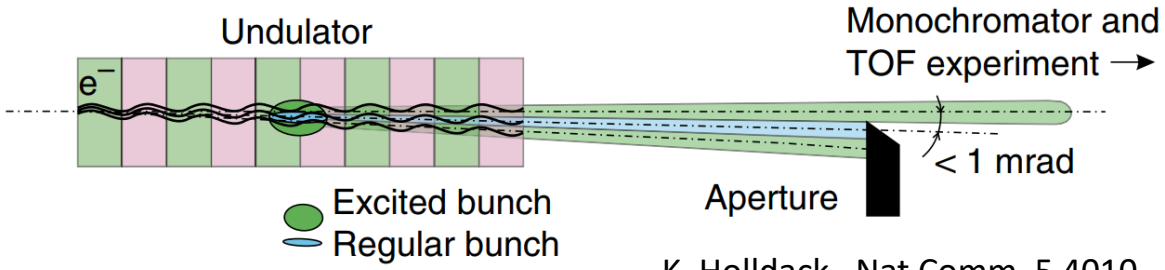
K. Holldack, Comm Phys, 3, 61

Pseudo-Single Bunch



C. Sun, PRL, 109, 264801

Pulse-Picking by Resonant Excitation

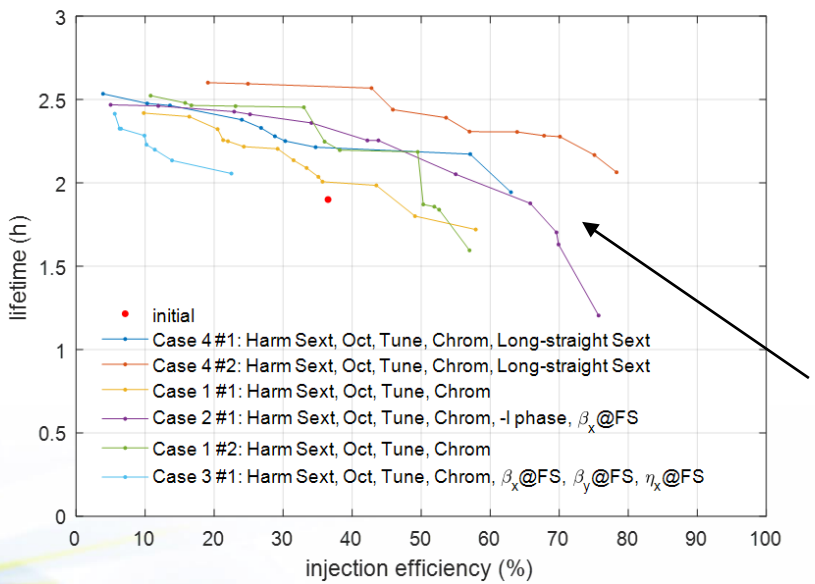


K. Holldack , Nat Comm, 5 4010

Supervisors: P. Burrows and I. Martin

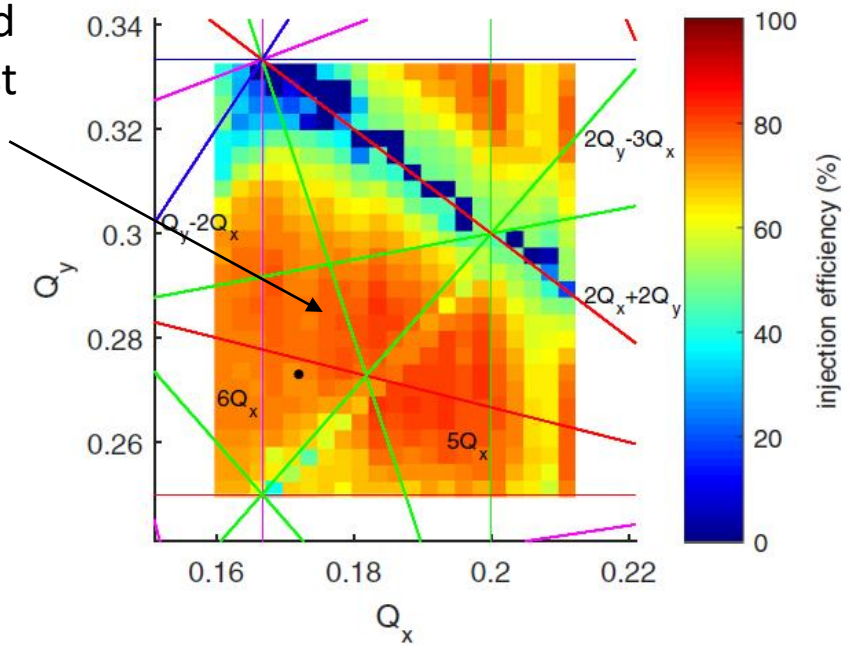
Oxford / Diamond PDRA Joint Appointment

- Joint appointment for a PDRA created between Oxford University and Diamond Light Source (up to March 2025)
- Aim to conduct numerical optimisation of the Diamond-II lattice
  - apply multi-objective optimisation algorithms to maximise lifetime and dynamic aperture for injection
  - systematic scans of tune-point and chromaticity
  - re-configure magnet families to investigate if better solutions exist
  - study baseline and high-brightness optics



Early MOGA optimisation of the D-II lattice

Scans of the Diamond lattice to identify best tune point for injection efficiency



- An offer has been accepted, start data beginning July 2022 (TBC)

Conclusions

JAI continues to be active in a number of areas of light source design and operation:

- Facility design
- Enhanced performance
- Special operating modes
- Photon / electron beam diagnostics

Providing training and expertise for next generation of accelerator physicists:

- Two new PhD Studentships started September 2021 (RHUL and Oxford)
- Joint Diamond / JAI PDRA to work on Diamond-II

Updates from previous students:

- Niki Vitoratou: PDRA at CI on AWAKE (2020-2021)
  Permanent position at Diamond working on visible light diagnostics (May 2021)
- Ji Li: Fellowship at institute in Chinese Academy of Science