Diamond Light Source

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Diamond Accelerator Complex

**Linac**
- Pulsed, 5Hz
- 0 MeV to 100 MeV
- 3 nC 15 nA

**Storage Ring**
- Continuous
- 3 GeV
- 1.5 nC to 0.5 µC
- 0.8 mA to 300 mA

**Booster**
- Pulsed 5 Hz
- 100 MeV to 3 GeV
- 1.5 nC 3 mA
Linac

- 100 MeV Linac of the DESY S-band Linear Collider Type II design, supplied "turn-key" by Accel Instruments. (DLS supplied diagnostics, vacuum and control system components, and beam analysis software)
- Thermionic gun; short (< 1 ns) and long pulse (0.1-1 µs) modes
- 500 MHz sub-harmonic pre-buncher, 3 GHz primary buncher, 3 GHz final buncher
- Two 5.2 m constant gradient accelerating sections fed by independent klystrons
Booster

Energy 3 GeV
Circumference 158.4 m
Emittance 141 nm rad
Repetition rate 5 Hz
Lattice FODO, missing dipole
Storage Ring

Energy

3 GeV

Circumference

561.6 m

No. cells

24

Symmetry

6

Straight sections

6 x 8m, 18 x 5m

Insertion devices

4 x 8m, 18 x 5m

Beam current

300 mA (500 mA)

Emittance (h, v)

2.7, 0.03 nm rad

Lifetime

> 10 h

Min. ID gap

7 mm (5 mm)

Beam size (h, v)

80, 8 µm

Beam divergence (h, v)

35, 3 µrad

(at centre of 5 m ID)

nominal, non-zero dispersion lattice
SR RF: design os for 3 superconducting cavities in an 8m straight, 2 currently installed.

SR RF: Amplifier use 4x 80kW IOTs as the RF power source
Celebrating First turns in the SR May 2006
Commissioning Schedule and Reality

- LINAC commissioning
  - Mar 2005
  - LINAC comm.
- Boosted commissioning
  - Jun 2005
  - Booster commissioning
- Storage ring commissioning
  - Dec 2005
  - Storage ring comm.
- Beamline commissioning
  - Jun 2006
  - Beamlines comm.

First users:
- Jan 07

Timeline:
- 31/08/05
- 21/12/05
- 03/05/06
- 04/09/06
- 23/10/2006
System Commissioning Effort

- Contract for commissioning staff in place for Nov 2004
- Commission of system used a mix of contract and in-house for Acc commissioning May 2005, Oct 2006

<table>
<thead>
<tr>
<th>Tech System</th>
<th>Contract Techs</th>
<th>Tech Group Staff</th>
<th>Controls Staff</th>
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<tbody>
<tr>
<td>Linac</td>
<td>(turnkey ?)</td>
<td>1</td>
<td>0.5</td>
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<td>PSUs</td>
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<td>3</td>
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<td>2</td>
<td>0.5 PLCs 0.5 CS</td>
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<tr>
<td>Diagnostics &amp; FOFB</td>
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<td>4</td>
<td>2.5</td>
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<tr>
<td>PSS</td>
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<td>3</td>
<td>.5</td>
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<td>Timing</td>
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<td>0.5 HW 0.5 SW</td>
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<td>1</td>
<td>0.5</td>
</tr>
<tr>
<td>FEs</td>
<td>2</td>
<td>1 Elec</td>
<td>1 PLCs 0.5 CS</td>
</tr>
<tr>
<td>Girder Align</td>
<td>(turnkey ?)</td>
<td>0.5 Elec Eng</td>
<td></td>
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</table>
Linac Commissioning

Installation complete: Aug. 3rd 2005
1st beam from gun: Aug. 31st 2005
1st 100 MeV beam: Sep. 7th 2005
Acceptance test complete: mid-Oct. 2005

Temporary Cu Network
Local Timing Generator
Booting IOC of development servers
Temporary Control Room
Booster Commissioning

- Booster installation completed: December 2005
- First injection into booster from LTB: December 22nd 2005
- Capture of beam by booster RF: February 2006
- Acceleration to 700 MeV: March 3rd 2006
- First extraction from booster at 700 MeV: April 4th 2006
- First 700 MeV injection into storage ring: May 2006
- 3 GeV extracted: June 2006

- Operational network and servers were installed because of building
- Timing EVG installed and timing distributed signal distributed over computer network
- 2nd temporary Control Room a Booster CIA
Booster Commissioning

First beam in the Booster (100 MeV, no RF)
Dec. 21\textsuperscript{st} 2005
2 mA typical, with ~ 70 % transfer efficiency from before injection to after extraction.

Booster Commissioning 3 GeV
June 2006

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Tunes corrected through the ramp
Storage Ring Technical Systems Commissioning

- Jan to April 2006
- Progressing final tasks to meet first beam, out of programme of 12k tasks
- Concentrated on ensuring commissioning
  - Coordinating multiple activities in the tunnel
- Progress Matrix
  - Tasks completed past weeks (Green)
  - Tasks not completed (Red)
  - Tasks for planned the current week (Blue)
- Progressed weekly

Diamond Installation and Commissioning

• Progressed weekly
• Progress Matrix
  - Coordinating multiple activities in the tunnel
• Concentrated on ensuring commissioning
  - Tasks completed past weeks (Green)
  - Tasks not completed (Red)
  - Tasks for planned the current week (Blue)
• Progressed weekly
Status in April 2006

• All Storage Ring technical systems required for beam system commissioned
  ▪ Building not finished and no cooling
  ▪ Only Night and weekend commissioning with beam
  ▪ Ongoing day time installation of Building, Cooling, Frontends

• Booster and Storage Ring Commission in 2 phases
  ▪ 1st Phase 700MeV
    ▪ Booster Dec 100MeV SR
    ▪ Booster Jan–Feb 700MeV
    ▪ SR April-May 2006
  ▪ 2nd Phase 3GeV
    ▪ June 2006 Booster 3GeV (on temporary cooling)
    ▪ SR Sept onwards 3GeV
Diamond Control Room
SR Commissioning at 700 MeV

- 1st beam, 1 Turn on 5th May 2006
- Limited by a Quad with incorrect polarity
May 6th/7th:  600 turns  
(sextupoles off, RF off)

May 19th/20th:  2000 turns  
(sextupoles on, RF off)
May 20\(^{\text{th}}/21\(^{\text{st}}\): 106,764 turns!

May 21\(^{\text{st}}/22\(^{\text{nd}}\): 0.4 mA, 70% injection efficiency
SR Commissioning at 700 MeV

First stored beam! ...

0.5 hour lifetime at 0.5 mA

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Diamond Installation and Commissioning
SR Commissioning at 700 MeV

But initially the beam did not accumulate

Believed to be due to differences between the kicker pulse shapes (which were not tuned for operation at 700 MeV)

After an optimisation procedure
SR Commissioning at 700 MeV

> 2 mA accumulated

SR visible on SLM
SR Commissioning at 3GeV:
1st Beam on 4th September 2006
SR 3 GeV Commissioning

- Sep. 4th/5th – 5 turns, no correctors!
- Sep. 5th/6th – 120 turns, no RF on
- Sep. 6th/7th – RF On .. 2 mA stored;
- 2mA limit since absorber water flow interlocks not commissioned
- Sep. 9th – 10 mA
- 10mA limited since orbit interlock not commissioned
- Sep. 25th – 25 mA
- Oct. 2nd – 60 mA
- Oct. 10th – 90 mA
SR 3 GeV Commissioning

- Poor correction of closed orbit,
- Initial BBA measurement very noisy but offsets applied and subsequent measurement much cleaner
- Three BBA runs to establish BPM centres carried out, which improved orbit

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Diamond Installation and Commissioning
SR 3 GeV Commissioning

- LOCO Measurement and correction applied to optics
- Initial Beta Beat 40%, was reduced in iterations to about 2%
SR 3 GeV Commissioning

- SR orbit corrected to < 1um
- Slow orbit FB run in AT application

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Diamond Installation and Commissioning
SR 3 GeV Commissioning

Pinhole camera #1  nominal:
sigma-x = 56 $\mu$m  52 $\mu$m
sigma-y = 14.5 $\mu$m  25 $\mu$m

Pinhole camera #2  nominal:
sigma-x = 47 $\mu$m  45 $\mu$m
sigma-y = 19 $\mu$m  25 $\mu$m

Best fit:  emittance 3.2 nm, energy spread 0.014%, coupling 0.4%
Previous slides are a typical sanitised view of accelerator commissioning.
Commissioning Lessons : No 1

• Safety

• Electricity is one of the biggest hazards and hence a risk on the project

• Need robust process for a sub system to go from un-powered and safe to powered and potentially un-safe ie operational
  ▪ It will not be clear cut and may need temporary power for vac pumps

• Need to know what systems are operational

• When a system is deemed operational, you need a system of work to make safe
  ▪ Permit to Work
  ▪ Lock Off Tag Off

• These Safety Processes are different from facility to facility
  ▪ Staff and contractors need educating in them
Commissioning Lessons: No 2

• **Be prepared for the unexpected**
  - Late deliveries from key suppliers (magnet suppliers in particular!!)
  - Buildings not finished, cables not installed (!) a major issue for us…
  - Football World Cup influenced commissioning of the Diamond SR

• **Be flexible**
  - Value from running equipment into dummy loads and powering up as soon as possible just to check things out and check they can be controlled by the control system
  - Cable check out is vital – we had many poorly fitted connectors in the storage ring
  - If services are not ready it might mean: hiring external pumping systems and water supplies (we did this for the booster); hiring generators if local power not available and running in temporary cables.
Commissioning Lessons : No 3

• **Establish an Operations Group**
  • Who champions the value of the beam in design reviews!

• **Start Operators on 24 hour Shift cover from when you switch on the first system**
  • Who responds to a fire alarm out of hours?

• **Have Operations coordinate commissioning**
  • Process for Technical groups to request subsystem commissioning time

• **For beam commissioning Operators carry and record status of systems at handover**
  • Ideal have some cross over from one shift to next

• **Managing**
  • Permits, Tools, Safety, On Call

• **Review objectives and progress daily/weekly with Technical groups**
Commissioning Lessons: No 4

• **Start tests as soon as the kit is ready for test**
  - Not to some arbitrary schedule.

• **Information gathered early is vital**
  • Document as you go along

• **Establish an operating mode for sub systems**
  - Avoid needing expert to switch On or Tune up system
  - Establish operating procedure

• **Establish routine running**
  - Bring out faults
Commissioning Lessons : No 5

• Have an Electronic Log Book system up and running from day one

• Insist everyone uses
  ▪ No private logs

• Open access is available across all groups

• Capture
  ▪ Shift Aims
  ▪ Shift Summary
  ▪ System commissioning
  ▪ Beam commissioning
  ▪ Faults
  ▪ Call-Ins
  ▪ Status of the accelerator ie Backup and Restore
Operations Shift Summary 15 10 2018 07:22


Operator: V Winter
Run 04-2018 - User Beam

Summary of Events:

19:00 - Shift Start.

23:02 - Booster zone 1 leak alarm. Gas shows as contamination at 32m but then cleared. Reset locally by Linac entrance.
01:25 - Reset Medium level trip latch on FE20. Required EHC to re-seach EH.
03:00 - Repeat above.
04:33 - 106B in fault (illt). Called beamline and recovered ID.
04:43 - Beam to 106.
05:08 - Poor LTB-BTS Injection off. Adjusted V Str 7 but put back as made it worse.
06:30 - LTB-BTS OK.

07:00 - Shift End.

• BURT Restore performed

Posted by EPICS on Mon, 15/10/2018 09:38:32 in Operations logbook.

• BURT Restore performed

Posted by EPICS on Mon, 15/10/2018 09:46:09 in Operations logbook.

Process Variables restored from following files:

Restore Group: home/beamline/scans/Files/110901c5c0-180830-139635.png

Snapshot Files:

/home/beamline/scans/Files/110901c5c0-180830-120030.png
/home/beamline/scans/Files/110901c5c0-180830-110030.png
/home/beamline/scans/Files/110901c5c0-180830-100030.png
/home/beamline/scans/Files/110901c5c0-180830-139635.png
/home/beamline/scans/Files/110901c5c0-180830-190635.png
/home/beamline/scans/Files/110901c5c0-180830-200635.png
/home/beamline/scans/Files/110901c5c0-180830-210635.png
/home/beamline/scans/Files/110901c5c0-180830-220635.png
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/home/beamline/scans/Files/110901c5c0-180830-210635.png
/home/beamline/scans/Files/110901c5c0-180830-220635.png
/home/beamline/scans/Files/110901c5c0-180830-230635.png
/home/beamline/scans/Files/110901c5c0-180830-000635.png

All process variables successfully restored.

• Top Up x3 missed due to a Linac issue : Fault ID 7705

Posted by Wayne Peruma on Mon, 15/10/2018 16:20:42 in Operations logbook.

This fault occurred at 09:30:00 on the 15/10/2018.

08:10 ATropp noted an intermittent issue with the Linac Amp-02 RF Power-In.

09:21 CC/AT investigate 'Pulse Power Amp.Unit' and sensed a smell of burning within the unit.
Commissioning Lessons : No 6

• You need two spares as a minimum
  ▪ Not always possible – especially with high value items

• Why
  ▪ 1/ The in service component dies. Install the spare; it dies. More to point it was killed. Only then do you look to understand what the fault was
  ▪ 2/ The first spare is dead
  ▪ 3/ Having installed one of two spares, you now have one spare while you order/repair the failed component

• Track all hardware through its life
  ▪ Purchased, onsite, in stock, installed, removed, **faulty**, repaired, loaned
  ▪ Know where spares are
  ▪ Test spares

• Remember spares are not development components
  ▪ Recipe for a dead spare
Commissioning Lessons : No 7

• Checklists

• Drive things by pre agreed checklists for each technical area until some or all are ready for beam testing
  ▪ Gives clear visibility

• Focus on the areas needed from day 1 of commissioning but never forget the individual subsystem testing without beam has to be cleared for ‘with beam testing ready’ to start
Commissioning Lessons : No 8

• Prepare for overnight working

• Likely you will need a system of working where technical systems are
  ▪ Worked on during the day
  ▪ Powered and beam tested at night / weekends

• Power up systems at the end of day in preparation for the night running
  ▪ You only see a system does not work when you switch it On
  ▪ Greater probability of technical experts around during the day

• Have experts On Call over night
  ▪ Available to come on and to address problem remotely ie access the control system hardware remotely
Commissioning Lessons : No 9

• Contract management

• To keep a programme on track it might be necessary to take control of contracts
  ▪ Be prepared do the work yourselves
  ▪ Address the contractual implication later

• Diamond Linac commissioning was initially delayed due to only two Accel engineers were able to come to Diamond once every two weeks
  ▪ We took over and did the beam tests ourselves.
Commissioning Lessons : No 10

- Lateral thinking
- Diamond had a possible 6-month delay in cooling services for the storage ring
- Decided to run the completed storage ring at a low enough energy - 700MeV - to not need water-cooling and beam test that way
- The beam tests were difficult but all subsystems were checked with beam.
  - Bugs were spotted and corrected
- Ready for the full energy beam tests when the building cooling systems were available
Commissioning Lessons : No 11

• **Diamond planned for a year’s commissioning time**
  - First 9 months will be making components work together under the control systems
  - Last 3 months on beam testing

• **75% of time the subsystem commissioning and 25% to beam test**
Commissioning Lessons : No 12

• Be aware of hidden late systems
  • “Everyone knows the building will be late so I am OK ….”

• It is clear what group or system is on or near to the critical path and running late
  ▪ You focus you effort on these systems

• The concern is the group(s) or system(s) which are hiding behind the known late system or group
  ▪ Be concerned about optimistic reporting of progress
  ▪ A water circuit only works when its 100% complete end-to-end.

• Without focus these will hurt the programme
Commissioning Lessons : No 13

• Call a friend

• Beam commissioning team makeup
  ▪ Acc Physics
  ▪ Controls/software
  ▪ System expert
  ▪ Lead
  ▪ Technician

• You need all these skills
  ▪ Invite friends from other projects with relevant experience to join in beam commissioning

• Back seat drivers/ spectators are valuable
Commissioning Lessons: No 14

- Restore machine settings
- Produce snapshot files during commissioning as way to go back to an operating point
  - You need a naming convention to understand them
- You need to know what operating point mode is loaded
  - Operating/working point is often applicable to a campaign
- Need a process to promote “an” operating/working point to “the” operating/working point
- Related to hand over from Acc Physics studies to Operations
- Key to establish repeatable operations
Draft Operations Schedule for 2007 (17/8/06)

Routine Operations

- Schedule 2007/2008
- 11 Runs of ~ 2 weeks
- 3000Hrs of Beamline Mode
- Ongoing commissioning (Red Blocks)

Shutdows 1½ - 4 weeks, for maintenance and installation:
- 2nd RF cavity
- ID6 module 2, ID11, ID24
- FEs 11, 16, 19, 23, 24
I am very grateful to Vince Kempson, Diamond Operations Manager, for discussion and input to commissioning lessons.
Thank You For Your Attention.