Diamond Light Source

Mark Heron

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Diamond Accelerator Complex



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 μ s) 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



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Booster

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







Storage Ring



nominal, non-zero dispersion lattice

Energy 3 GeV Circumference 561.6 m No. cells 24 6 **Symmetry** 6 x 8m, 18 x 5m Straight sections 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 35, 3 µrad Beam divergence (h, v) (at centre of 5 m ID)

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Storage Ring





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SR RF Cavity and Amplifier



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



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June 2004







Celebrating First turns in the SR May 2006



Commissioning Schedule and Reality



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

Tech System	Contract Techs	Tech Group Staff	Controls Staff
Linac	(turnkey ?)	1	0.5
PSUs	3	3	1
Vacuum	3	2	0.5 PLCs 0.5 CS
MPS	3		2 PLCs 0.5 CS
RF SR	(turnkey ?)	4	0.5
Diagnostics & FOFB	1	4	2.5
PSS	4	3	.5
Timing			0.5 HW 0.5 SW
IDs Turnkey	1	1	0.5
FEs	2	1 Elec	1 PLCs 0.5 CS
Girder Align	(turnkey ?)	0.5 Elec Eng	

Linac Commissioning





Installation complete:Aug. 3rd 20051st beam from gun:Aug. 31st 20051st 100 MeV beam:Sep. 7th 2005Acceptance test
complete:mid-Oct. 2005

Complete: Temporary Cu Network Local Timing Generator Booting IOC of development servers Temporary Control Room

diamond

Booster Commissioning

- Booster installation completed
- First injection into booster from LTB
- Capture of beam by booster RF
- Acceleration to 700 MeV
- First extraction from booster at 700 MeV
- First 700 MeV injection into storage ring
- 3 GeV extracted



December 2005 December 22nd 2005 February 2006 March 3rd 2006 April 4th 2006 May 2006 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

Diamond Installation and Commissioning



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Booster Commissioning





First beam in the Booster (100 MeV, no RF)

Dec. 21st 2005



llation and Commissioning



Booster Commissioning 3 GeV June 2006



2 mA typical, with ~ 70 % transfer efficiency from before injection to after extraction.

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Diamond Inst



Tunes corrected through the ramp



- planned for current week	4 1		2		3	4		5	6		7		8		9		10	1	
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Attach G3 Sector Valve to stand	1 3	3	3	3	3 3	3	3 3	3 3	3 3	3 3	3	3	3 3	3	3 :	3 3	1		Prodressing final tasks to meet
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Functional testing of vacuum racks;	3	3	3	3	3 3	3	3 3	3 3	3 3	3 3	3	3	3 3	3	3	3 3	1		Concentrated on ensuring
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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

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Diamond Control Room



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- 1St beam,1 Turn on 5th May 2006
- Limited by a Quad with incorrect polarity



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May 6th/7th: 600 turns (sextupoles off, RF off)



May 19th/20th: 2000 turns (sextupoles on, RF off)



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May 20th/21st: 106,764 turns !

May 21st/22nd: 0.4 mA, 70% injection efficiency



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First stored beam ! ... 0.5 hour lifetime at 0.5 mA





•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





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> 2 mA accumulated



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



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- 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





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- 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 Mark Heron Diamond Light Source
 Diamond Installation and Commissioning





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

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

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Previous slides are a typical sanitised view of accelerator commissioning.

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- 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

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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.

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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

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- 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

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- 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

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03:00 - Repea	t above.								
04:33 - I06B in	n fault (tilt). Called bean	line and recovered I	D.						
04:43 - Beam 06:08 - Poor L	TB-BTS injection off Ad	usted V Str 7 but put	t hack as made it worse						
06:30 - LTB-B	TS OK.	usted v Sti 7 but put	t back as made it worse						
07.00 cl/b r	- 1								
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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

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- 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

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- 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

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- 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.

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- 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

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- 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

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- 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

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• 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

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- 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

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Routine Operations

- Schedule 2007/2008
- 11 Runs of ~ 2 weeks
- •3000Hrs of Beamline Mode
- Ongoing commissioning (Red Blocks)
- Shutdowns 1½ 4 weeks, for maintenance and installation:
 - 2nd RF cavity
 - ID6 module 2, ID11, ID24
 - FEs 11, 16, 19, 23, 24

n and Commissioning



Draft Operations Schedule for 2007 (17/8/06)

I am very grateful to Vince Kempson, Diamond Operations Manager, for discussion and input to commissioning lessons.

Mark Heron Diamond Light Source



Thank You For Your Attention.

Mark Heron Diamond Light Source

