Diamond and the UK new light source

Chris Christou, X-band workshop,
Cockcroft Institute, 1st December 2008

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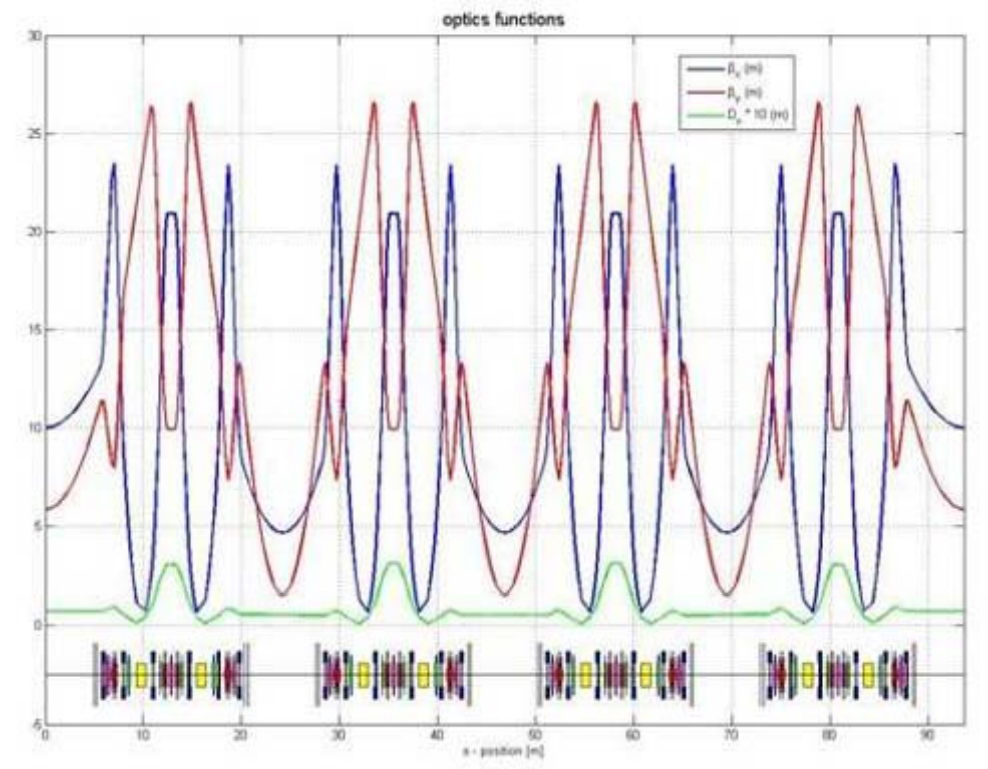
Diamond Light Source



nominal, non-zero dispersion lattice

Energy	3 GeV
Circumference	561.6 m
No. cells	24 DBA
Symmetry	6
Straight sections	6 x 8m, 18 x 5m
Insertion devices	4 x 8m, 18 x 5m
Beam current	300 mA
Emittance (h, v)	2.7, 0.03 nm rad
Lifetime	> 10 h
Min. ID gap	7 mm
Beam size (h, v)	123, 6 μm
Beam divergence (h, v) *(at centre of 5 m ID)*	24, 4 μrad

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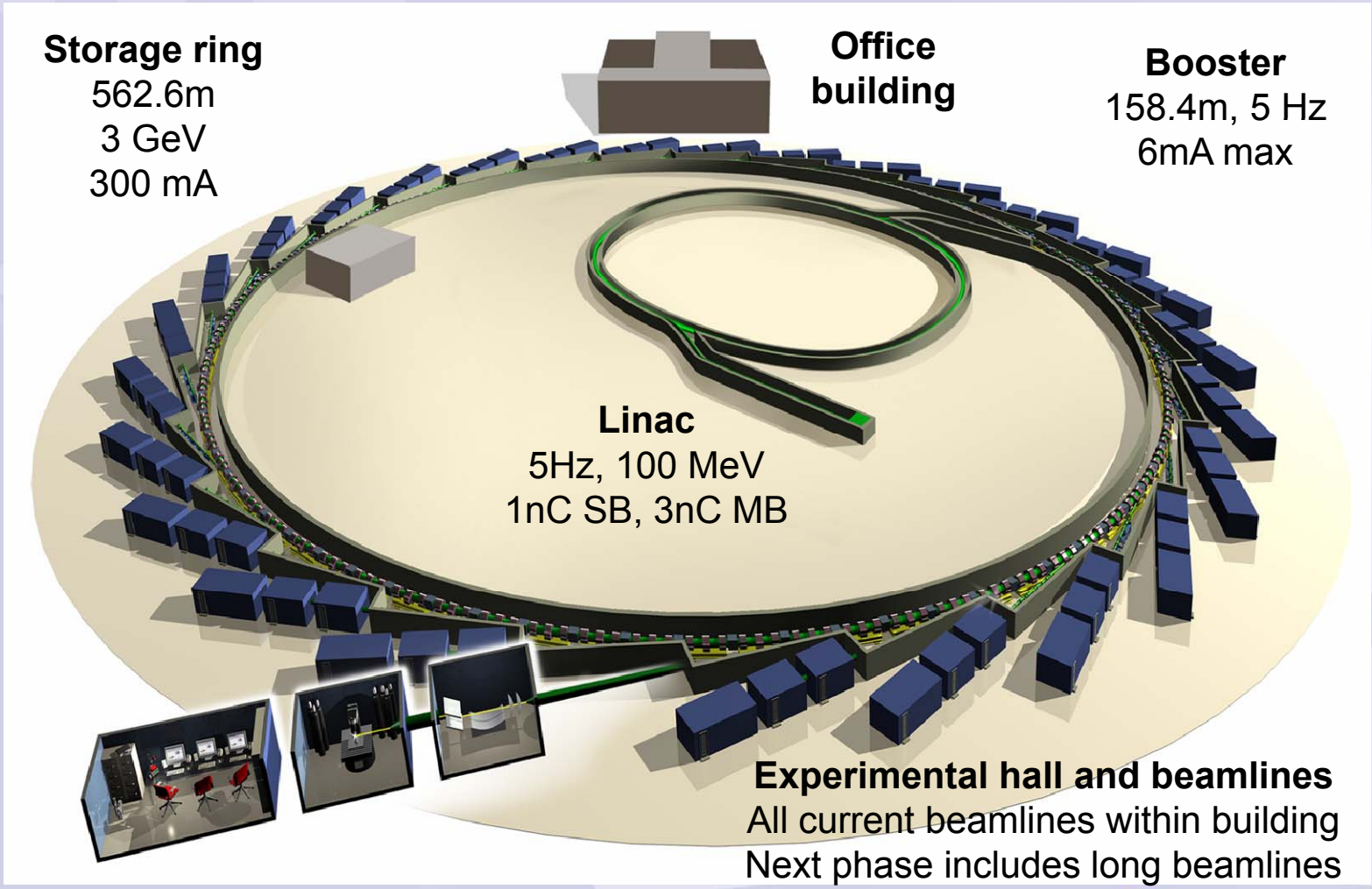
Layout of Diamond Light Source



Linac, booster and storage ring are in separate vaults

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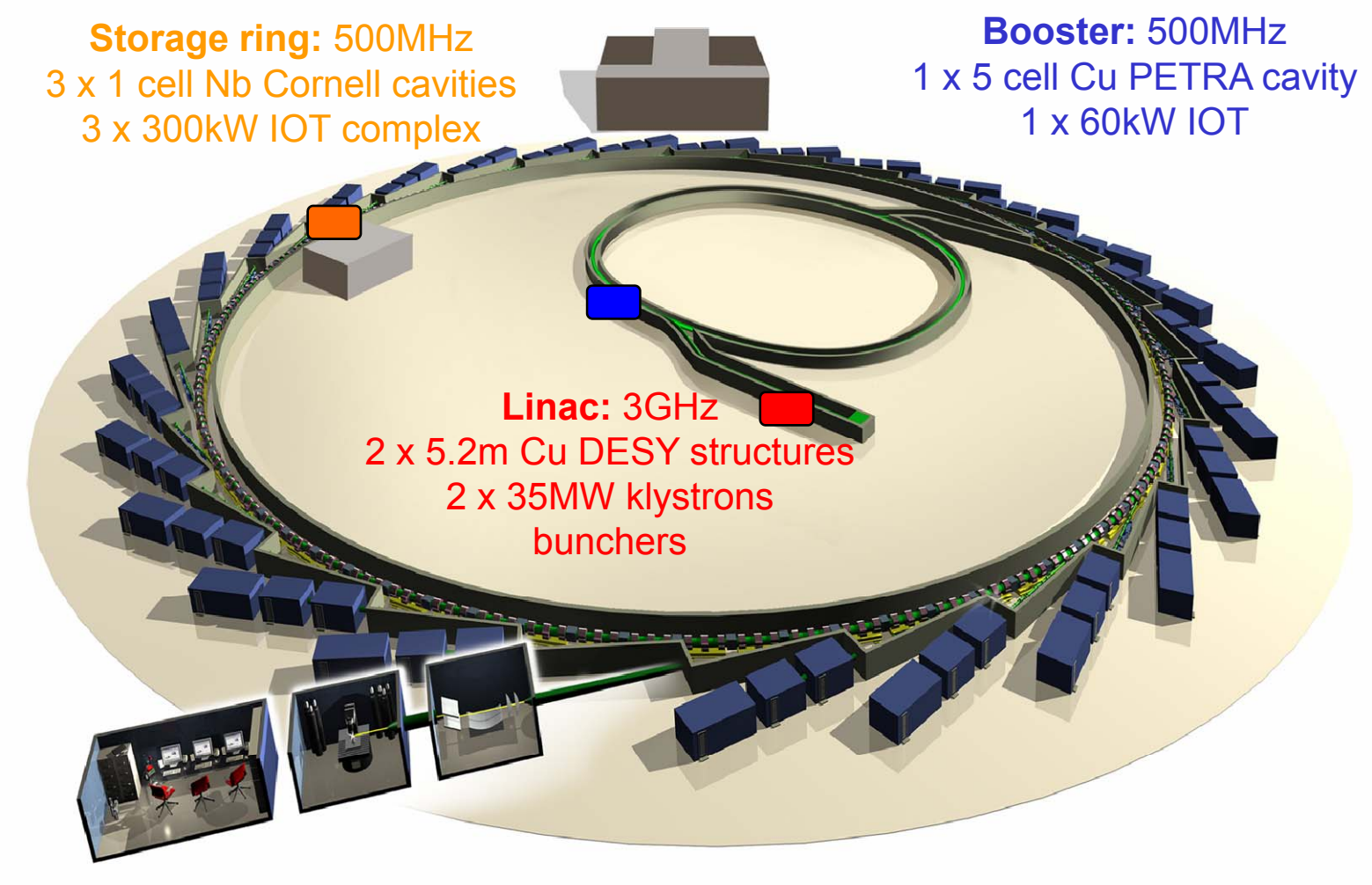
RF Systems



Cavities from Accel. Amplifiers from Thales

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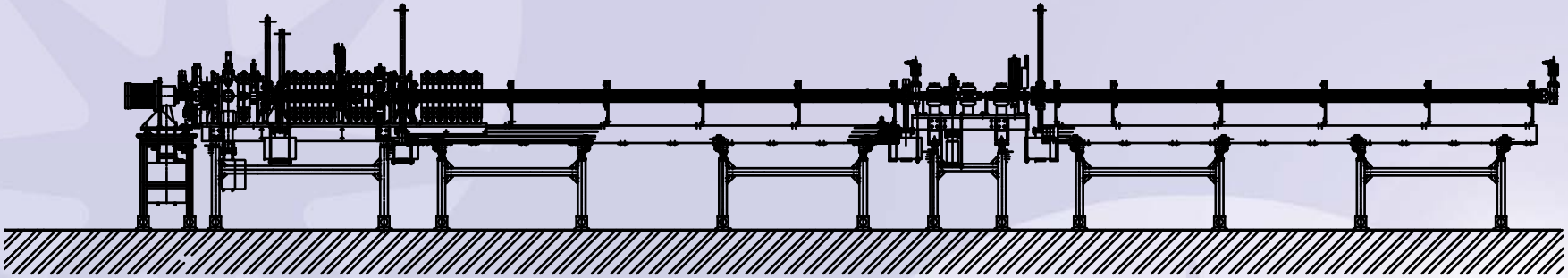
S-band linac



- 100 MeV 5 Hz repetition rate
- 2 DESY Type II 5.2 m structures
- Thales TH2100 klystrons
- thermionic gun
- short pulse 1 nC, 1 ns
- long pulse 3 nC < 1 ms
- x and y emittance < 50 π.mm.mrad
- 0.2 ns pulse width
- 100 ps jitter
- 0.1% energy variation
- 0.2% energy spread

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12 Insertion Devices Installed

Beamline	ID	Type
I02	U23	In-vacuum
I03	U21	In-vacuum
I04	U23	In-vacuum
I06	HU64	APPLE-II
I07	U23	In-vacuum (not yet operational)
I11	U22	In-vacuum
I15	SCW	3.5 T Superconducting Multipole Wiggler
I16	U27	In-vacuum
I18	U27	In-vacuum
I19	U22	In-vacuum
I22	U25	In-vacuum
I24	U21	In-vacuum

- 10 x in-vacuum undulators
- 1 x variable polarization APPLEII device
- 1 x 3.5T superconducting wiggler

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Insertion Devices for Future Beamlines

- **I04.1 (Beamline operation date October 2009)**
  Short, ex-vacuum, permanent magnet device.
- **I07 (Oct. ’09)**
  Cryogenic Permanent Magnet Undulator.
- **I12 (Oct. ’09)**
  Superconducting multipole wiggler, 4.2 T.
- **I20 (Dec. ’09)**
  2 x hybrid wigglers, W83.
- **I10 (Dec. ’10)**
  2 x APPLE II devices with fast polarization switching proposed.
- **I13 (Apr. ’11)**
  2 x in-vac. undulators with “double mini-beta” optics proposed.
- **I09 (Apr. ’11)**
  Helical undulator with “double mini-beta” optics proposed.

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Current Machine Status

	Target	Achieved	
Energy	3 GeV	3 GeV	
Beam current	300 mA	300 mA	*Machine Development*
		250 mA	*User Mode*
Emittance			
- horizontal	2.7 nm rad	2.7 nm rad	
- vertical	27 pm rad	4-50 pm rad	*~ 27 pm in User Mode*
Lifetime at 300 mA	> 10 h	~ 18 h	
Min. ID gap	7 mm	5-7 mm	*User Mode, depending on ID*
Stability	< 10%	2.5% (H), 7.5% (V)	*No feedback*
	of beam size	0.5% (H), 1.7% (V)	*Feedback, 1-100 Hz*
	& divergence	0.7% (H), 7.3% (V)	*Feedback, 1-1000Hz*

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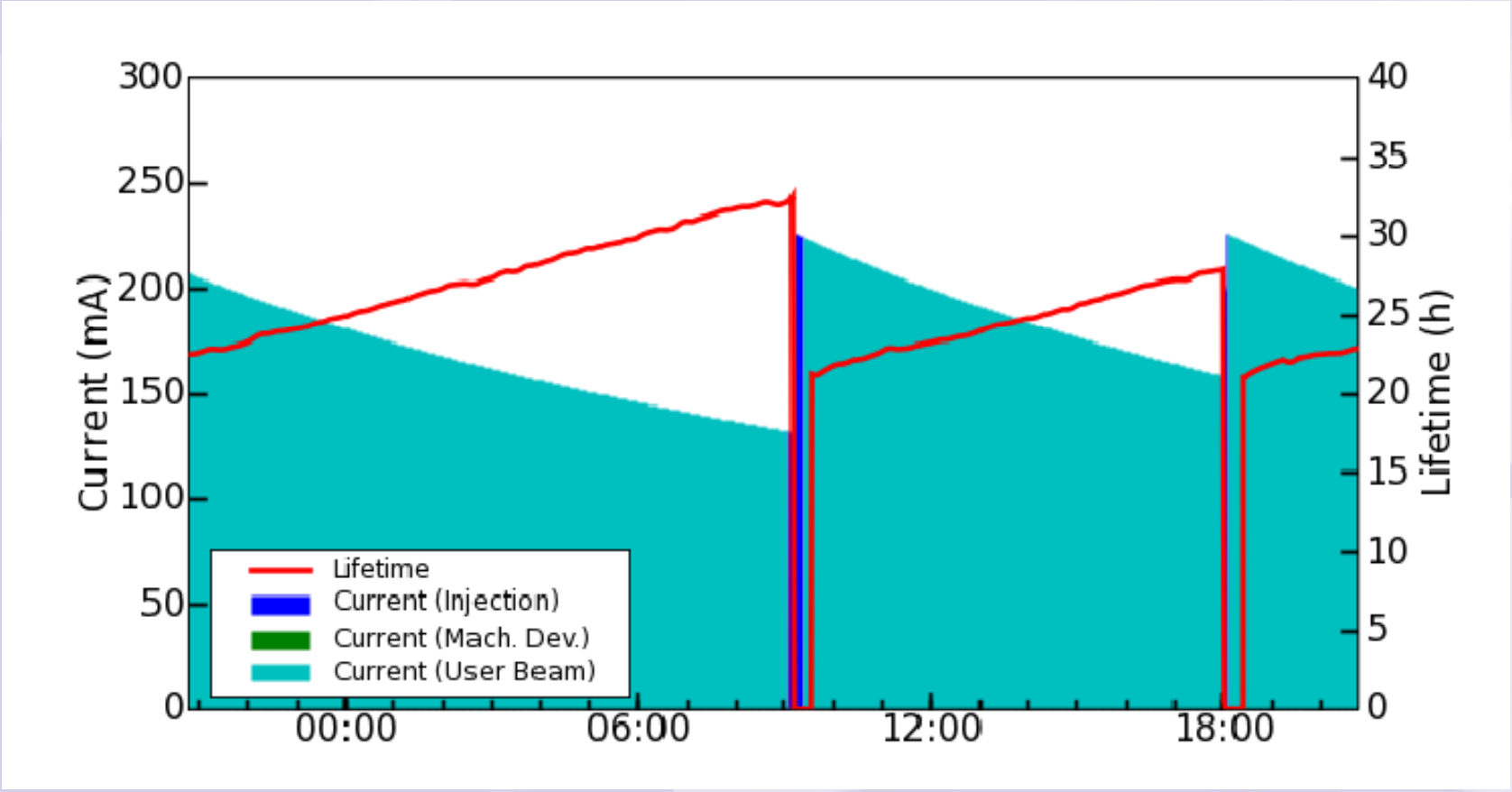
User-Mode Operations

User operations since January 2007
Most recent run: 250 mA maximum, 2 injections/day



300 mA from Jan. 2009

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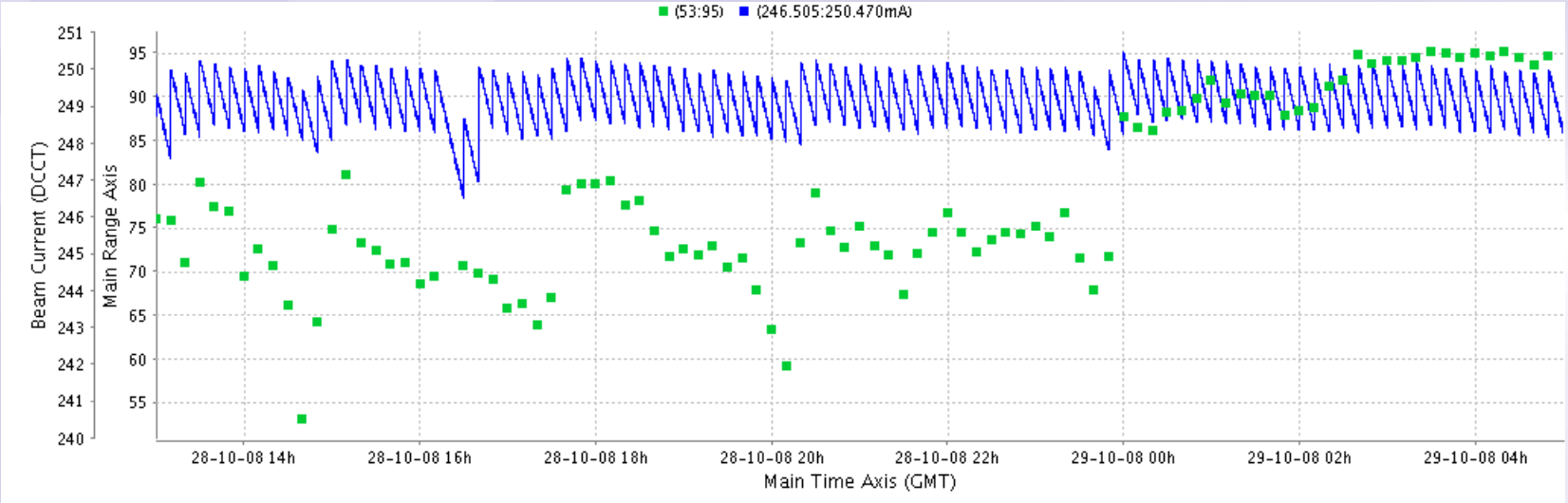
Top-up for users

Operated in top-up mode for users from 28th to 30th October 2008



- Operation in top-up mode does not increase the frequency of beam trips
- BS-SR injection efficiency very high
- Some work required on understanding injection efficiency changes
- Current user period (from 27th November) is conducted in top-up mode

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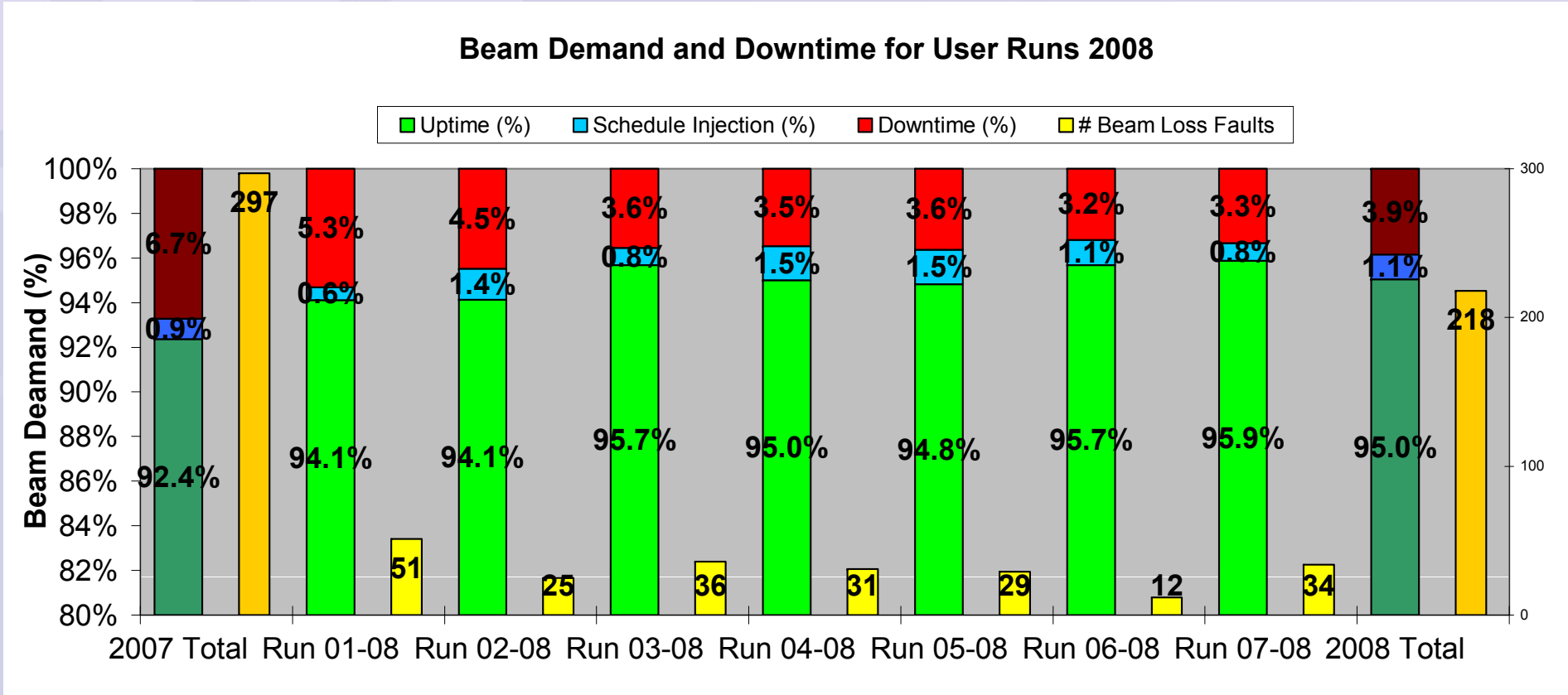
Beamtime Statistics (to end Sep.)



2008: 3177h delivered with 95.0% uptime, MTBF = 14.6 h

2007: 3120h delivered with 92.4% uptime, MTBF = 10.0 h

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The UK's New Light Source Project

Project to consider the scientific case and develop a conceptual design for a possible next generation light source based on a combination of advanced conventional laser and free-electron laser sources.

- **STFC Daresbury and Rutherford Laboratories**
- **Accelerator Science and Technology Centre (ASTeC)**
- **Central Laser Facility (CLF)**
- **Diamond Light Source**
- **John Adams and Cockcroft accelerator institutes**
- **Various Universities**

NLS Progress

- **Official Launch, April 11th 2008**
- **Science Workshops, May 13th – June 19th**
- **Draft Science Case published, Sep. 11th**
- **Science Case approved by the Physical And Life Science committee of the STFC, Oct. 17th**

→ approval to proceed to the design stage

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www.newlightsource.org

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NLS Desired Baseline Specification

- High brightness (up to 1012 photons/pulse)
- Coverage from THz to ~ 1 keV in the fundamental
- ~ 1 kHz repetition rate with even pulse spacing
- Capable of smooth tuning across most of the spectral range
- Pulse durations down to ~ 20 fs
- Two-colour capability for pump-probe experiments
- High degree of transverse coherence
- High degree of longitudinal coherence, at least up to 400 eV
- Synchronised to short pulse lasers

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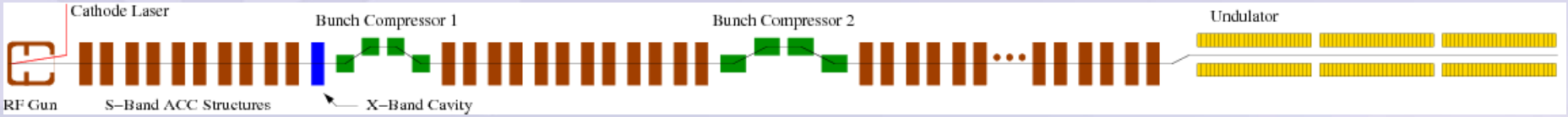
NLS: normal conducting option



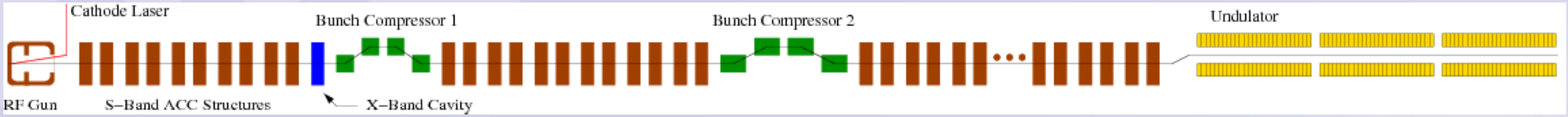
S-band for acceleration

Design	DESY structure	SLAC structure
Length	5.2 m	3.0 m
Shunt impedance	51.5 MΩ/m	52 MΩ/m
Mode	2π/3	2π/3
Q	14000	12500
Filling time	740 ns	690 ns
Number of cells	156	89

X-band for phase space linearisation at input to BC1

Design	NLC/LCLS structure
Length	0.6 m
Shunt impedance	30 MΩ
Mode	5π/6

Power supplies for normal conducting option



Klystrons	Thales	Toshiba	SLAC
Model	TH2155	E3730A	XL4
Waveband	S-band	S-band	X-band
Frequency	2998 MHz	2856 MHz	11.42 GHz
Peak power	45 MW	50 MW	50 MW
Efficiency	44%	45%	40%
Gain	54 dB	51 dB	50 dB
Pulse length	3.5 μs	4 μs	1.5 μs

- Solid state inductive adder-style modulator for S-band
  - offers 1 kHz repetition rate (but limited elsewhere)
- LCLS X-band modulator

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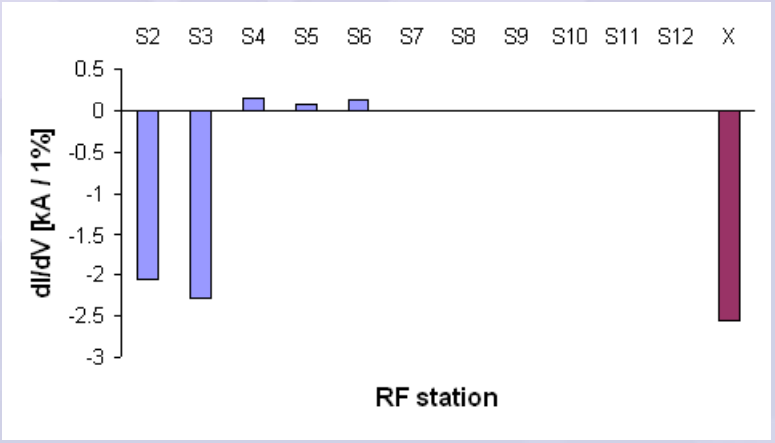
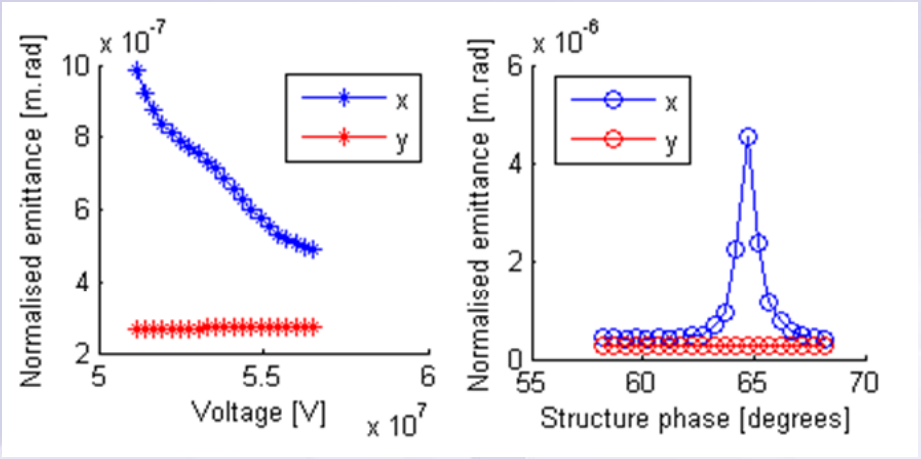
Jitter budget for normal conducting option

3 GeV, 0.2nC, 7kA peak current, 0.7mm.mrad normalised emittance, 0.2% ΔE



Beam current and structure voltage



Accelerating structure before BC1

	Before BC1	BC1-BC2	After BC2	X-band	Units
dE/dV	1.64	2.44	3.03	-0.30	MeV/1%
dE/dφ	-0.43	1.81	0.038	1.245	MeV/1°
$d\varepsilon_{nx}/dV$	-0.076	0.01	4e-4	-0.04	mm.mrad/1%
$d\varepsilon_{nx}/d\varphi$	0.87	0.08	2e-4	-0.61	mm.mrad/1°
dI/dV	-2.18	0.11	-7e-3	-2.56	kA/1%
dI/dφ	19.7	1.77	0.055	-12.3	kA/1°

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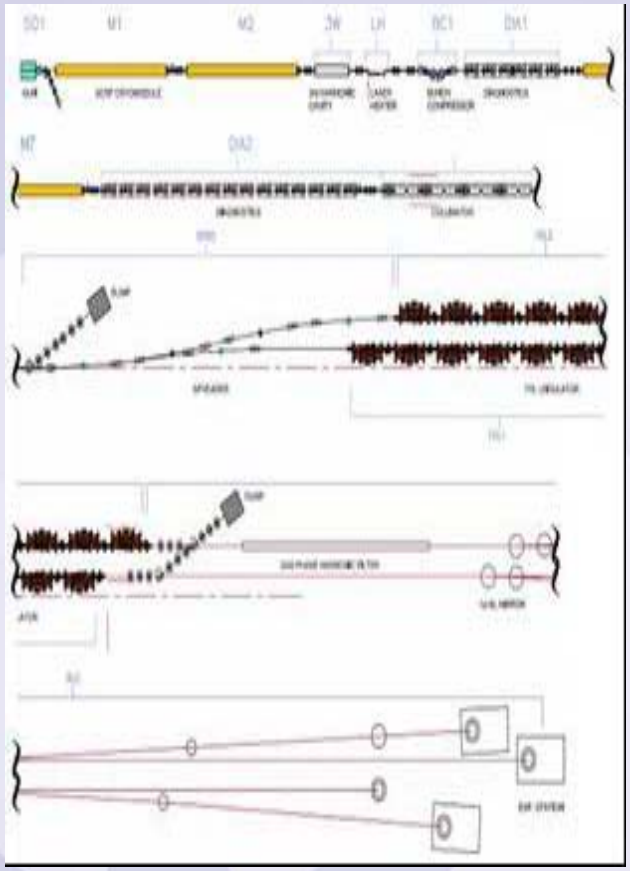
NLS: superconducting option

	1GeV		2GeV		3GeV		Units
RF Frequency	1.3	1.3	1.3	1.3	1.3	1.3	GHz
Bunch Charge (max)	200	200	200	200	200	200	pC
Repetition Rate (max)	1	1000	1	1000	1	1000	kHz
Average Current (max)	0.0002	0.2	0.0002	0.2	0.0002	0.2	mA
Number of cells/cavity	9	9	9	9	9	9	
Number of Cavities	56	56	112	112	168	168	
Number of Modules	7	7	14	14	21	21	
Cavity R/Q	1036	1036	1036	1036	1036	1036	Ω
Qo	2.0E+10	2.0E+10	2.0E+10	2.0E+10	2.0E+10	2.0E+10	
Energy Gain	1	1	2	2	3	3	GeV
Eacc	17.2	17.2	17.2	17.2	17.2	17.2	MV/m
Qe	5.0E+07	5.0E+07	5.0E+07	5.0E+07	5.0E+07	5.0E+07	
Cavity Filling Time	6.121	6.121	6.121	6.121	6.121	6.121	ms
RF Power per Cavity	6	6	6	6	6	6	kW
Total RF Power per Linac	0.345	0.345	0.689	0.689	1.034	1.034	MW
Dynamic load per Cavity	14.3	14.3	14.3	14.3	14.3	14.3	W
Dynamic load per Linac	803.0	803.0	1606.0	1606.0	2408.9	2408.9	W
Static load per Linac	70	70	140	140	210	210	W
Total CW load at 1.8K	873.0	873.0	1746.0	1746.0	2618.9	2618.9	W
Total Linac Active Length	84	84	168	168	252	252	m
Total Machine Length	370	370	510	510	640	640	m



Possible SRF Linac Parameters for NLS

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NLS: superconducting option

Accelerator	CEBAF Upg.	XFEL	BESSY FEL	ALICE	DICC
Average Cavity Gradient (MV/m)	19.2	23.6	15.4	13	20
Frequency (GHz)	1.5	1.3	1.3	1.3	1.3
Qo	8.0E+09	1.0E+10	2.0E+10	5.0E+09	1.0E+10
Input coupler Qe	2E+07 (fixed)	4.6E+06	3.0E+07	5E+06 (fixed)	1E+07 – 1E+08
Max Input Coupler Power (kW)	13	169 (pulsed)	5	10	25
Cavities per cryomodule	8	8	8	2	2
Module Energy Gain (MeV)	108	196	128	27	32
Cryomodule Length (m)	10	12	12	3	3
	Application on NLS				
Number of Cryomodules (1GeV)	10	PULSED	8	48	32
Active Length of Linac (m)	100		96	144	96
Dynamic RF load per cryomodule (W)	199.8		98.6	70.3	64.7
Total Linac Dynamic load (W)	1997.6		788.9	3372.9	2069.2
Cryomodule dynamic load/energy gain (W/MeV)	1.8		0.8	2.6	2.0

SRF Module Comparison and NLS Application for 1 GeV option

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Upgrade Paths

- Higher photon energies, ≥ 1.5 keV – additional linac
- Increased rep. rate, ≥ 10 kHz – VHF/SC gun
- Longitudinal coherence to ≥ 1 keV – improved seeding sources
- Shorter pulses, ≤ 1 fs – slicing/single-spike
- Additional FELs/experimental stations

Latest News

- NLS Project Governing Body agreed on Nov. 19th to proceed with the cw superconducting option.
- Studies will now concentrate on both the straight and recirculating SC linac options, with 1 keV baseline photon energy.

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Thank you – any questions?

Thanks to Richard Walker, Peter McIntosh and many others for contributions

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