Review of Third Generation Light Sources

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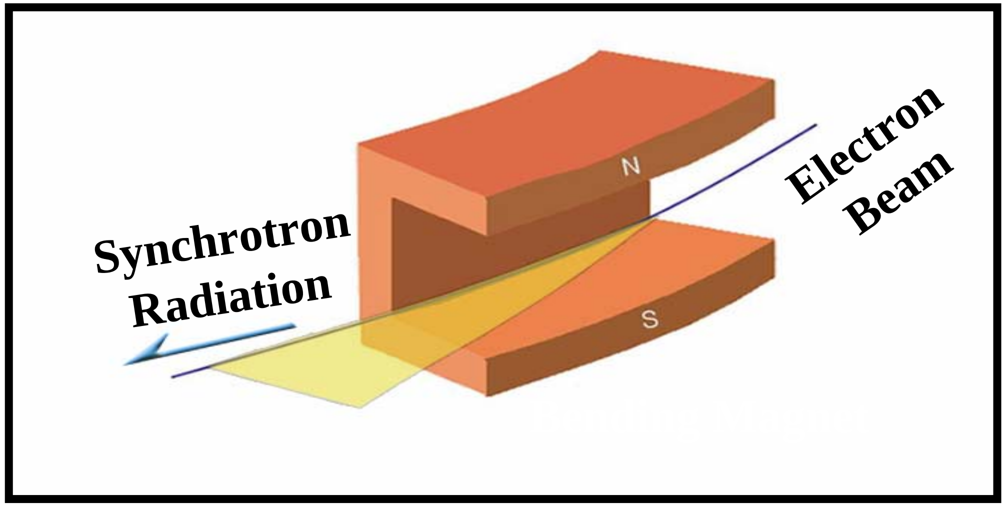
Outlines

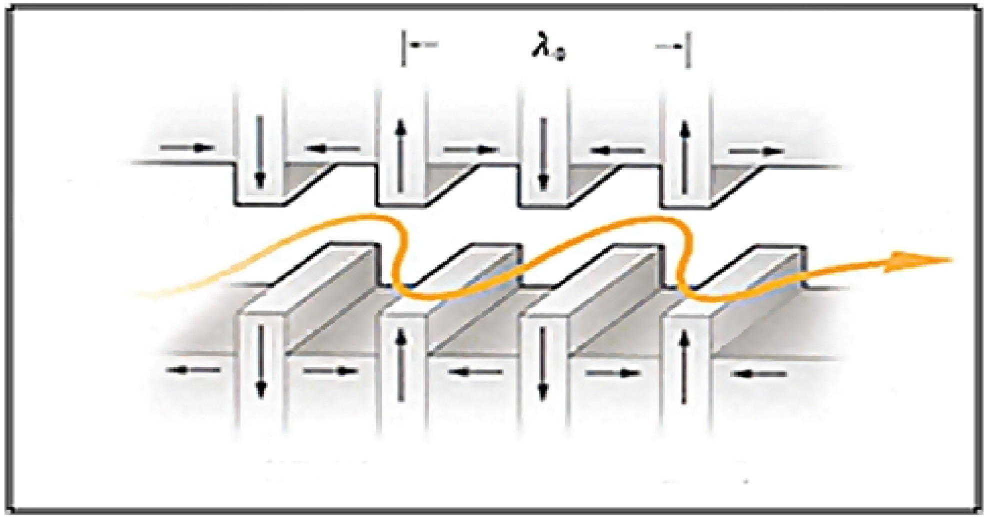
- Brief History
- US Policy in 1984 and 2003
- 3^{rd} Generation Light Sources in Operations
- Examples: SLS, SSRF, ALBA, NSLS-II, TPS,
  SESAME, PLS-II
- On Users and Technologies
- Summary

Brief History



Bending Magnet

- First observed in 1947 in GE Synchrotron by Edler et al.
- 1st Generation: Used High-energy physics accelerators
- 2nd Generation: Dedicated users' facilities (1980s)
  (SRS, PF, NSLS, BESSY, Doris, SPEAR-II, Aladdin, …)



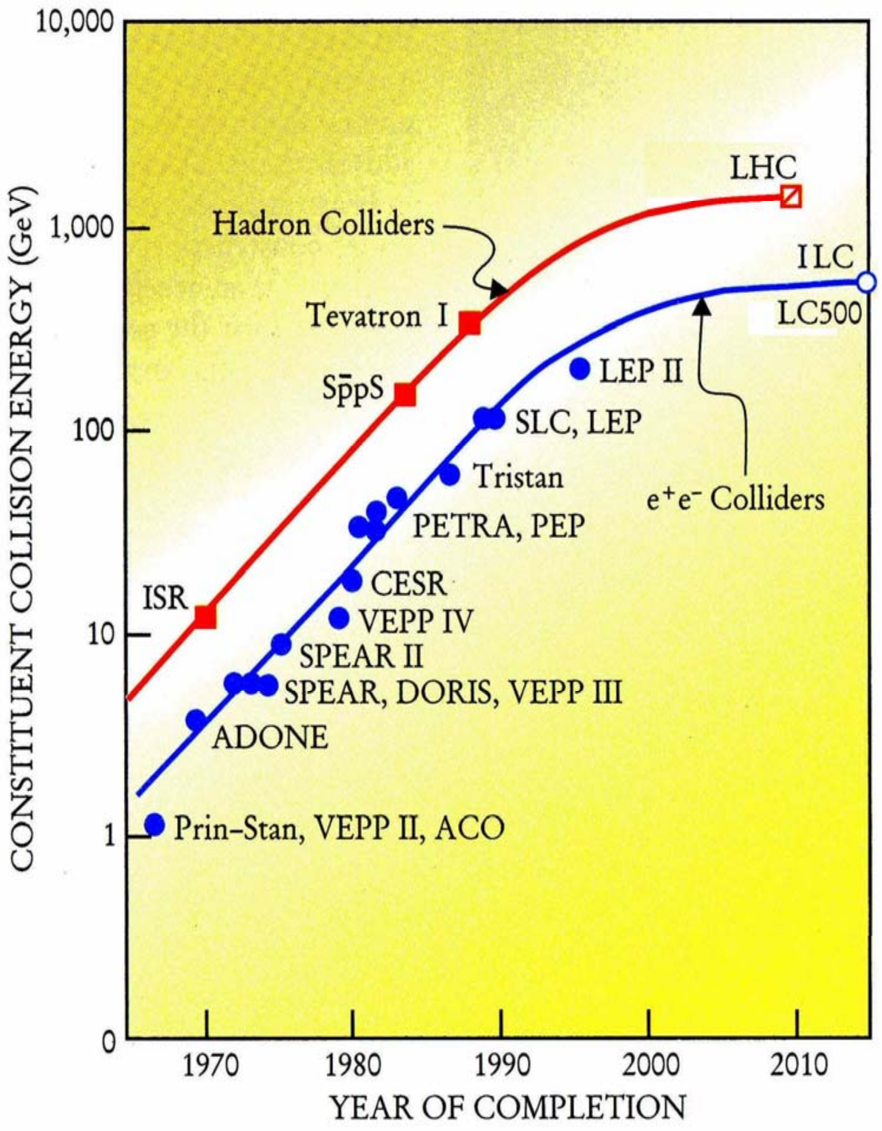
Undulator

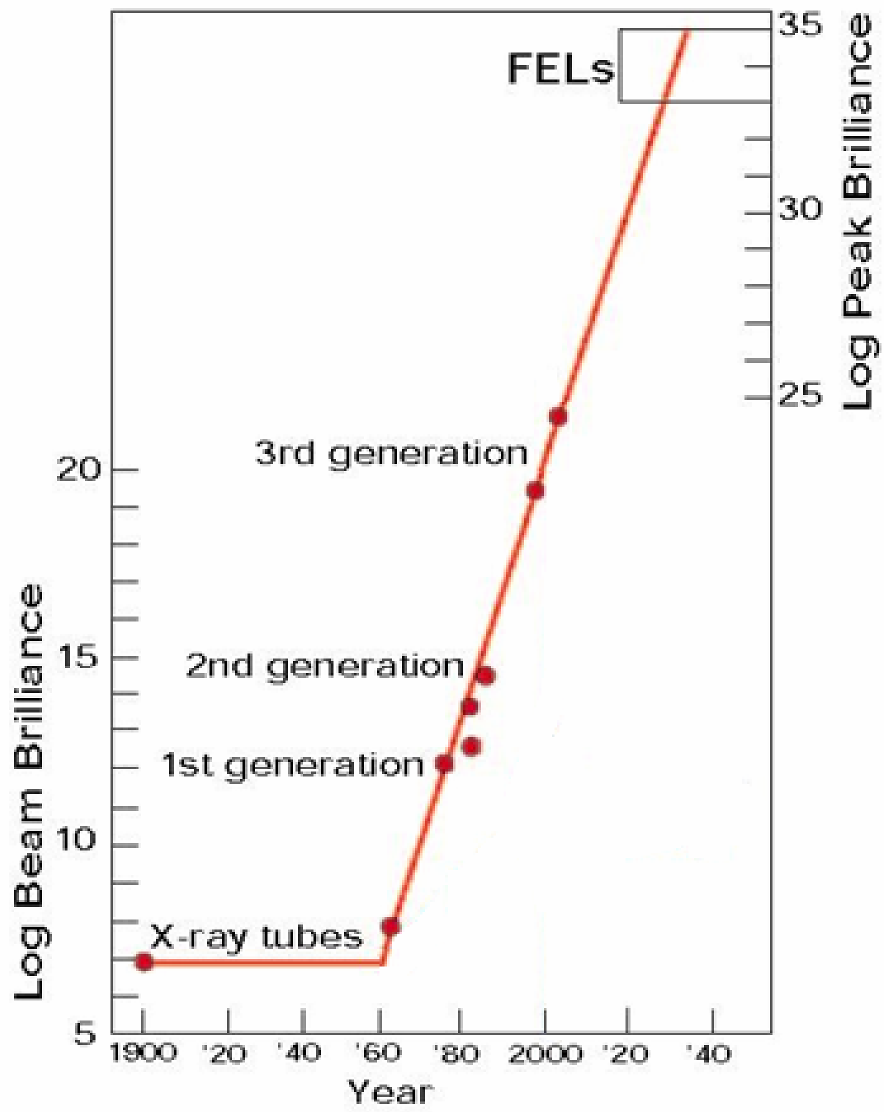
$$\lambda \approx \frac{\lambda_u}{2\gamma^2}\left(1+\frac{K^2}{2}\right)$$

- 3rd Generation: Maximum use of insertion devices
  1990s: Big three-rings (ESRF, APS, Spring-8) and
  Medium four-rings (ALS, TLS, Elettra, PLS), ….
  2000s: (SLS, CLS, SPEAR-III, Soleil, Diamond, ASP, SSRF,….)
  2010s: (SSRF, ALBA, PLS-II, NSLS-II, TPS, MAX IV, SESAME,..)

- 4th Generation: Using SASE XFEL with Linacs (LCLS, SCSS, Euro-XFEL), and alternative advanced concepts (ERL and XFELO)

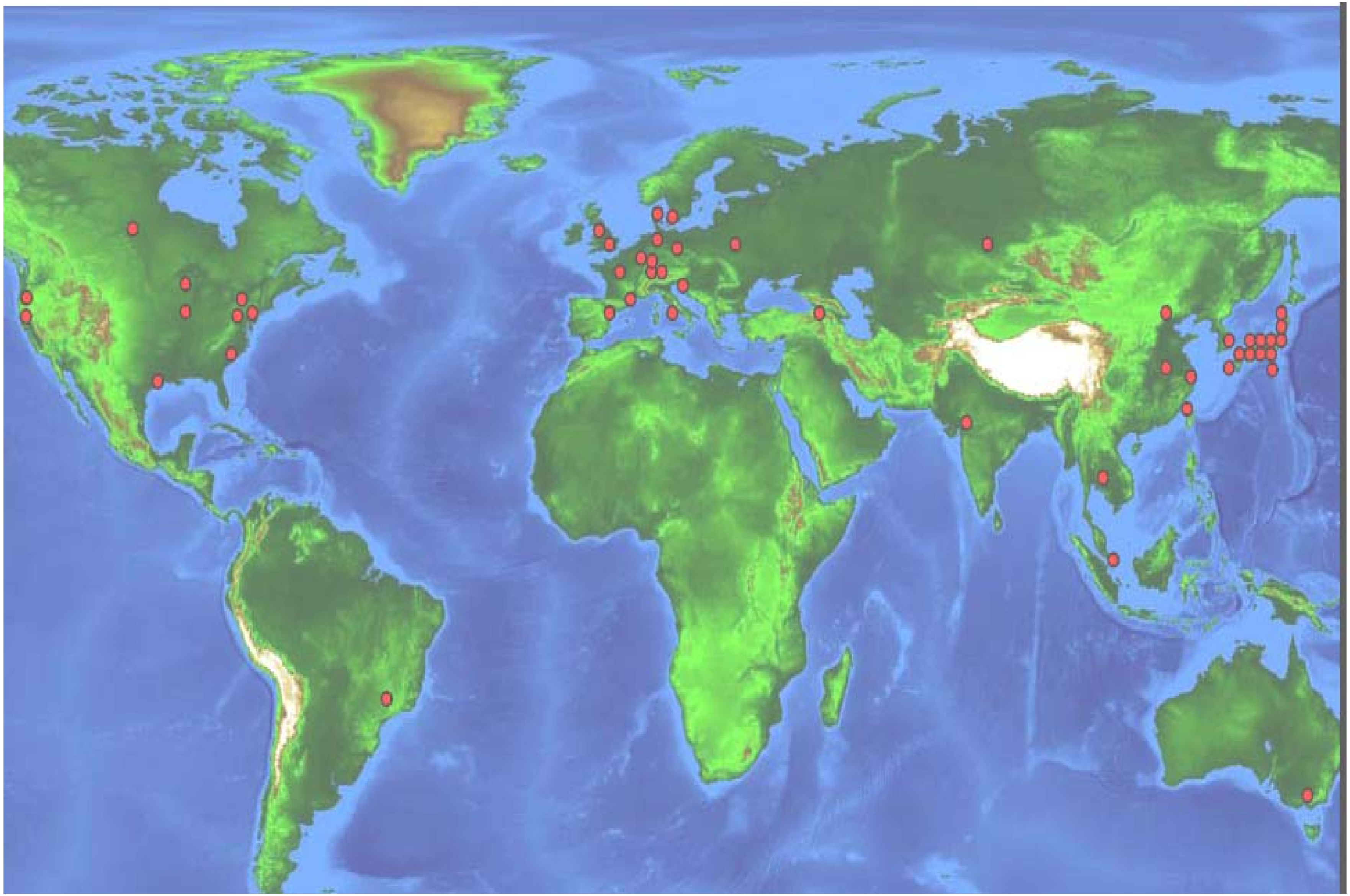
Livingston Chart: Colliders and Light Sources





www.lightsources.org

America => 18, Europe => 25, Asia and Oceania => 26



US-DOE Policy Established in 1984

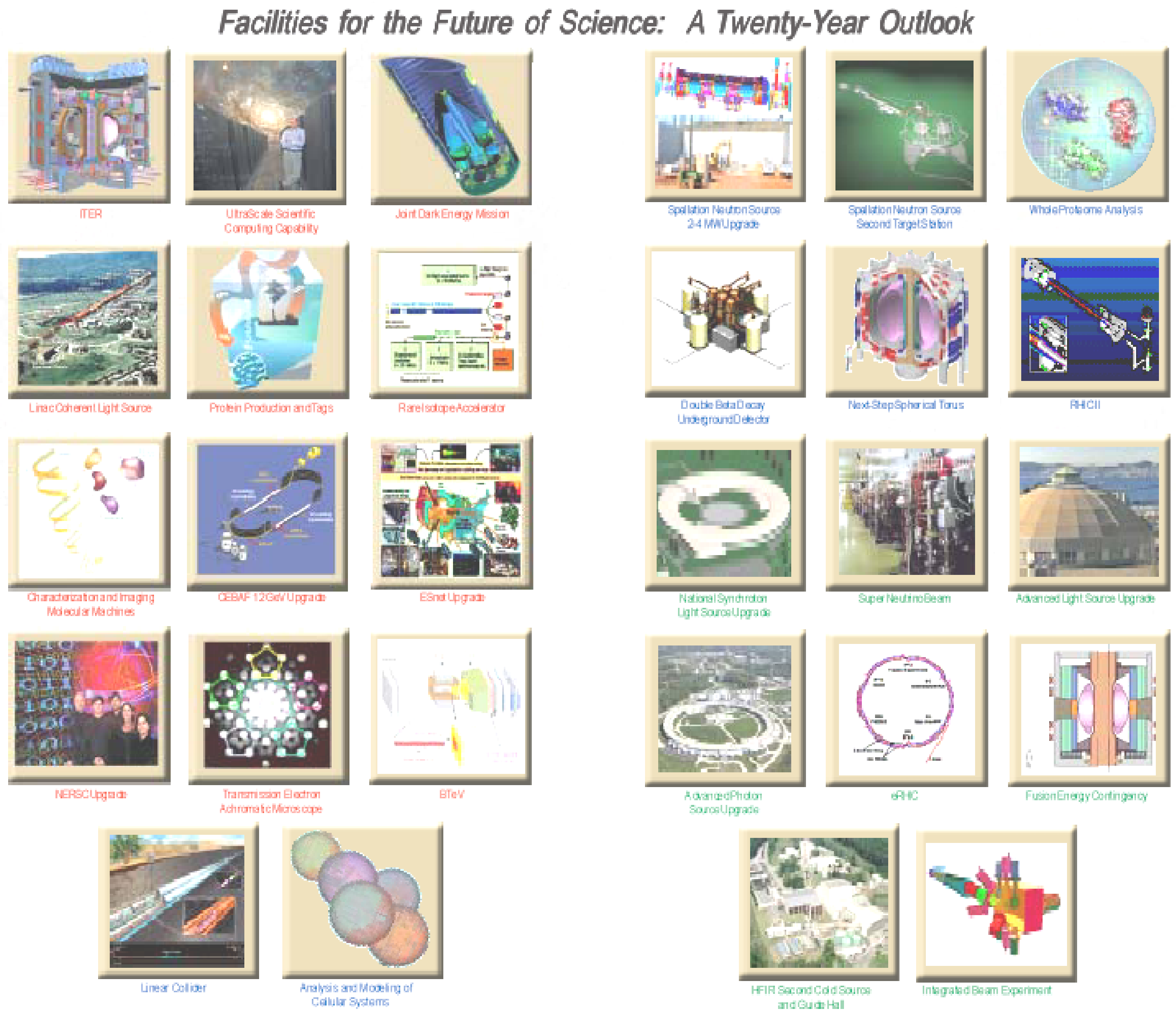
US-DOE Major Materials Facilities Committee
(Eastman-Seitz Committee) recommended:

- 6 GeV Synchrotron Radiation Facility => APS (Argonne)
- Advanced Steady State Neutron Facility => ANS (cancelled)
- 1-2 GeV Synchrotron Radiation Facility => ALS (Berkeley)
- High-intensity Pulsed Neutron Facility => SNS (Oak Ridge)

Ref.: "*Major Facilities for Materials Research and Related Disciplines,*"
(National Academy Press, Washington, DC, 1984)

Note that it triggered the 3rd Generation construction race.

US DOE Plan for 20-years (2003)



Third Generation Light Sources in Operation (1993 – 1999)

Light Source	Energy (GeV)	Circumference (m)	Emittance (nm-Rad)	Current (mA)	Straight Section	Status
ESRF	6.0	844.4	4.0	200	32 × 6.3 m	Operational (1993)
APS	7.0	1104	3.0	100	40 × 6.7 m	Operational (1996)
SPring-8	8.0	1436	3.4	100	44 × 7 m, 4 × 30 m	Operational (1997)
ALS	1.9	196.8	6.3	400	12 × 6.7 m	Operational (1993)
TLS	1.5	120	25	240	6 × 6 m	Operational (1993)
ELETTRA	2.4	259	7.0	300	12 × 6.1 m	Operational (1994)
PLS	2.5	280.56	12.0	200	12 × 6.8 m	Operational (1995)
LNLS	1.37	93.2	100	250	6 × 3 m	Operational (1997)
MAX-II	1.5	90	9.0	280	10 × 3.2 m	Operational (1997)
BESSY-II	1.7	240	6.1	200	8 × 4.9 m, 8 × 5.7 m	Operational (1999)
Siberia-II	2.5	124	98	200	12 × 3 m	Operational (1999)

Third Generation Light Sources in Operation (1993 – 1999)











Third Generation Light Sources in Operation (2000-2010)

Light Source	Energy (GeV)	Circumference (m)	Emittance (nm-Rad)	Current (mA)	Straight Section	Status
New SUBARU	1.5	118.7	38	500	4 x 2.6 m, 2 x 14 m	Operational (2000)
SLS	2.4	288	5	400	3 × 11.7 m, 3 × 7 m, 6 × 4 m	Operational (2001)
ANKA	2.5	110.4	50	200	4 × 5.6 m, 4 × 2.2 m	Operational (2002)
CLS	2.9	170.88	22.7	300	12 × 5.2 m	Operational (2003)
SPEAR-3	3.0	234	18	500	12 × 3 m, 4 × 4.5 m, 2 × 7.5 m	Operational (2004)
SAGA-LS	1.4	75.6	7.5	300	8 × 2.5 m	Operational (2006)
SOLEIL	2.75	354.1	3.74	500	4 × 12 m, 12 × 7 m, 8 × 3.8 m	Operational (2007)
Diamond	3.0	561.6	2.7	300	6 × 11.3 m, 18 × 8.3 m	Operational (2007)
ASP	3.0	216	10	200	14 × 5.4 m	Operational (2008)
Indus II	2.5	172.5	58.1	300	8 × 4.5 m	Operational (2008)
SSRF	3.5	432	3.9	300	4 × 12 m, 16 × 6.5 m	Operational (2009)
ALBA	3.0	268.8	4.3	400	4 × 8 m, 12 × 4.2 m, 8 × 2.6 m	Operational (2010)
PETRA III	6.0	2304	1	100	20 × 4 m	Operational (2010)

Third Generation Light Sources in Operation (2000-2010)



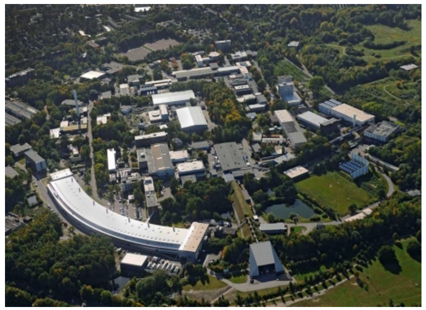












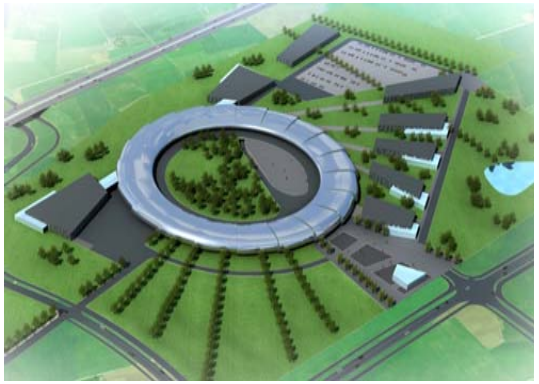
New Third Generation Light Sources (After 2011)

Light Source	Energy (GeV)	Circumference (m)	Emittance (nm-Rad)	Current (mA)	Straight Section	Status
CANDLE	3.0	216	8.4	350	16 x 4.8 m	Planned
MAX IV (two rings)	1.5/3.0	96 / 528	5.6 / 0.24	500	12 / 20 - straight sections	Ground breaking in 2010
PLS-II	3.0	280	5.8	400	12 X 6.8 m, 12 x 3.1 m	Construction (2011)
TPS	3.0	518	1.7	400	18 x 7 m, 6 x 12 m	Construction (2013)
NSLS-II	3.0	792	1.5	500	15 x 6 m, 15 x 9.3 m	Construction (2014)
SESAME	2.5	133	26	400	4 x 5 m, 8 x 3.5 m, 4 x 1.9 m	Construction (2014)

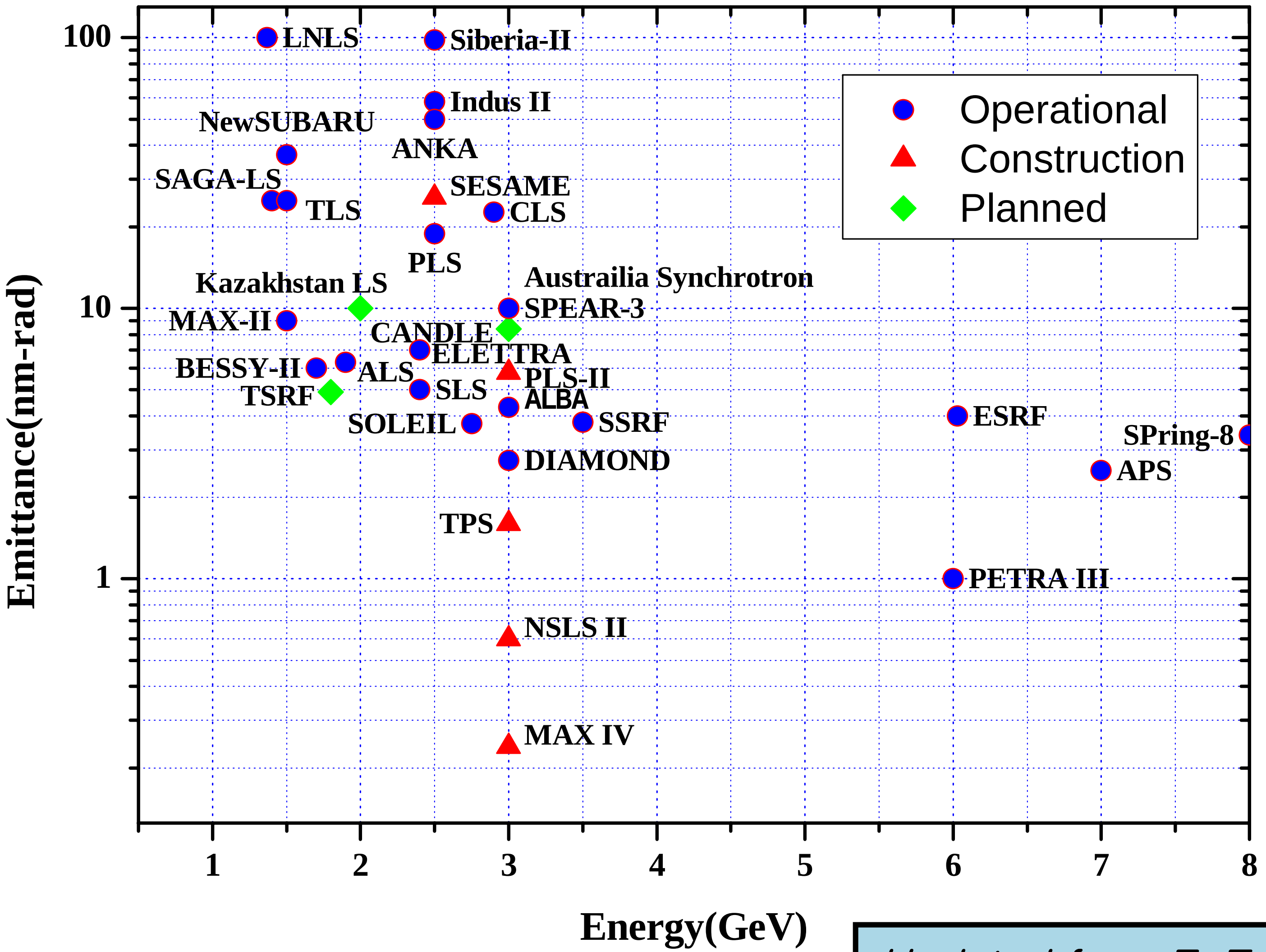
Talks at this conference:

TPS MOOCMH01 C.-C. Kuo
PETRA-III TUXRA01 K. Balewski
SSRF WEOARA01 Z. T. Zhao
SESAME WEOARA02 A. Nadji,

New Third Generation Light Sources (2011 and after)

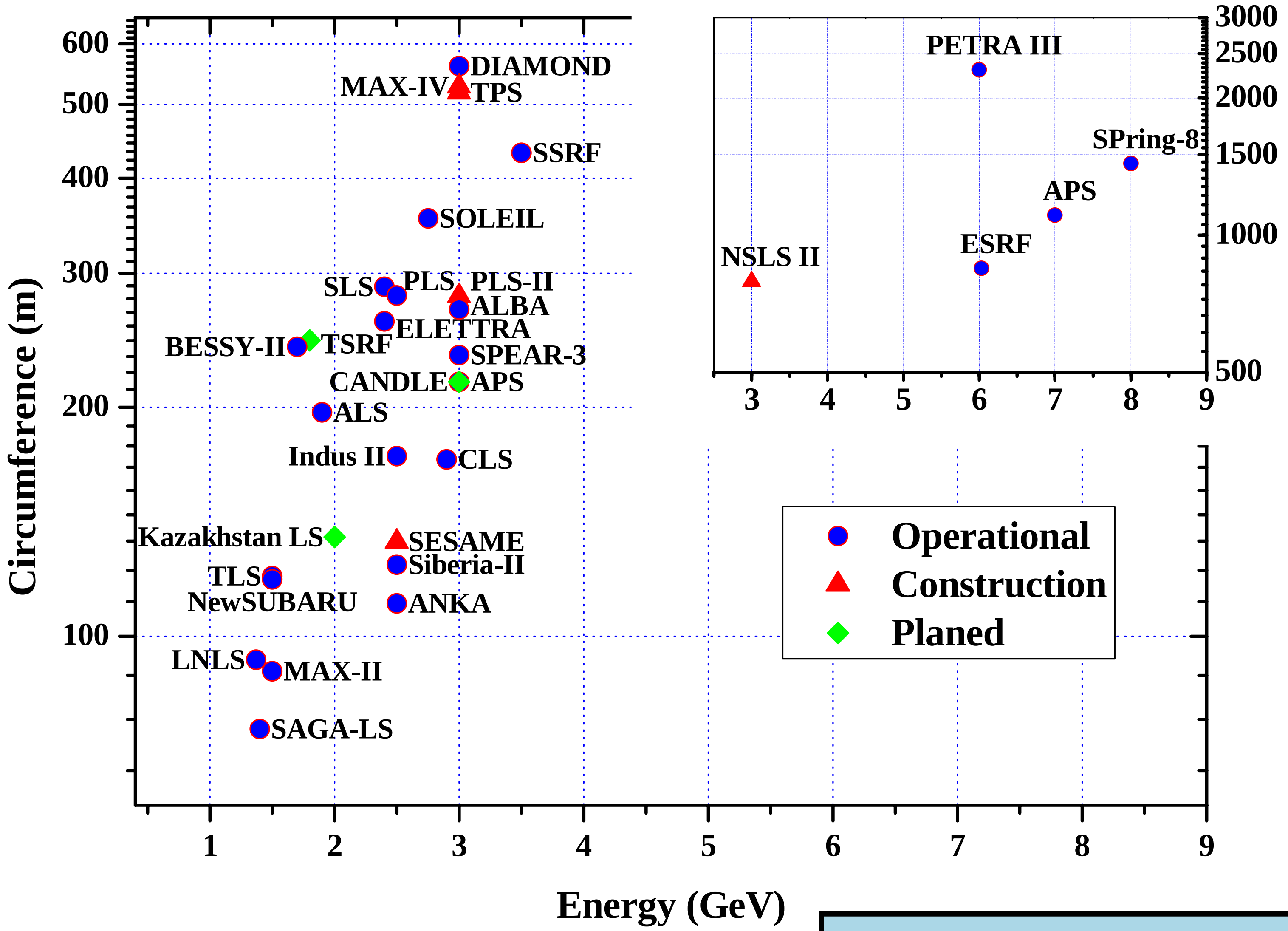


Emittance vs. Energy



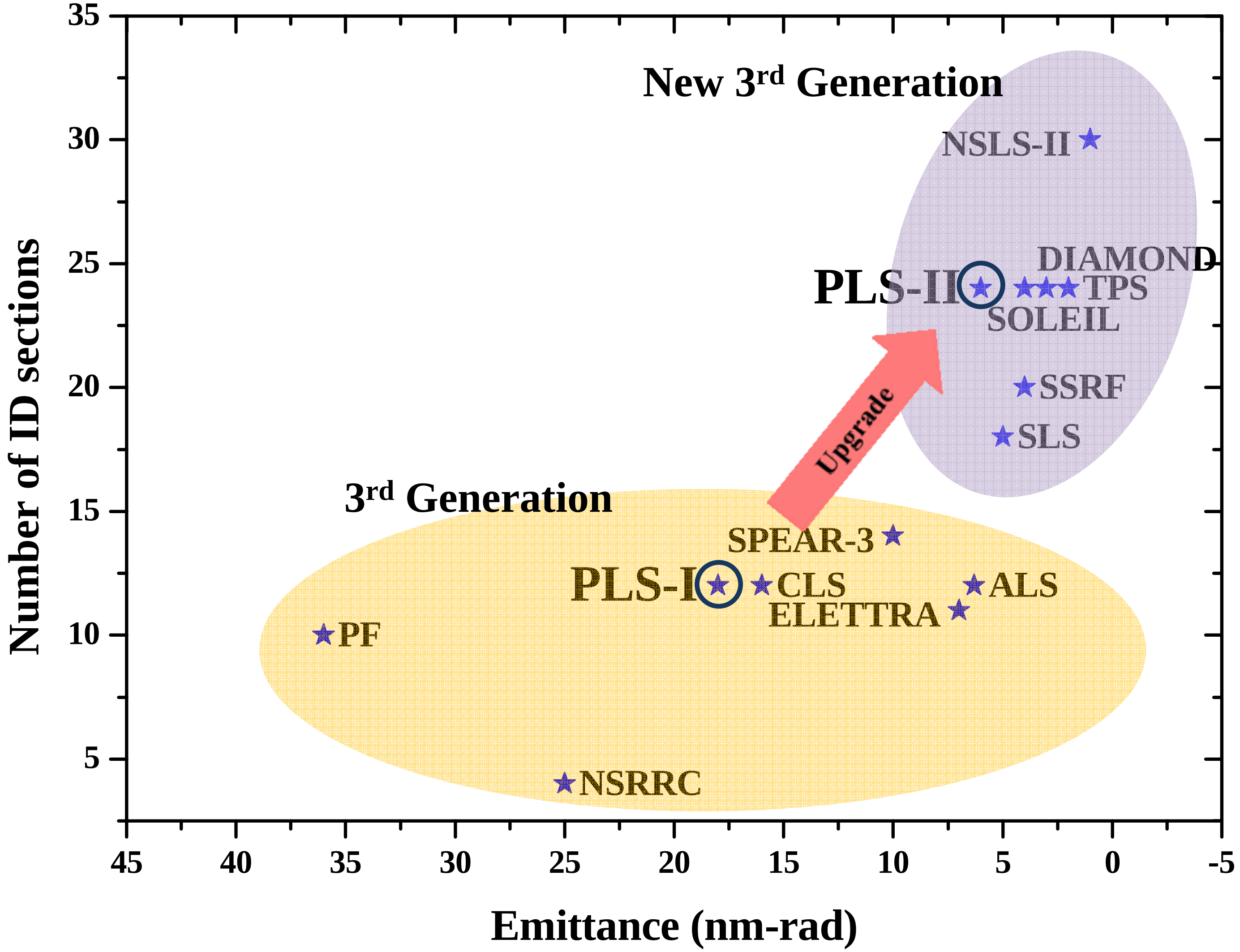
Updated from Z. T. Zhao, SSRF

Circumference vs. Energy



Updated from Z. T. Zhao, SSRF

Number of ID Section vs. Emittance



SLS (1998-2001)

Energy:	2.4 - 2.7 GeV
Circumf.	288 m
Lattice:	TBA
Emittance:	5.0 nm-rad
Current:	400 mA
Straight	
Sections:	3 x11.7 m,
	3 x 7.0 m
	6 x 4 m
Injection:	Top-up only
Beam lines:	18

Courtesy: L. Rivkin

SSRF (2004-2009)

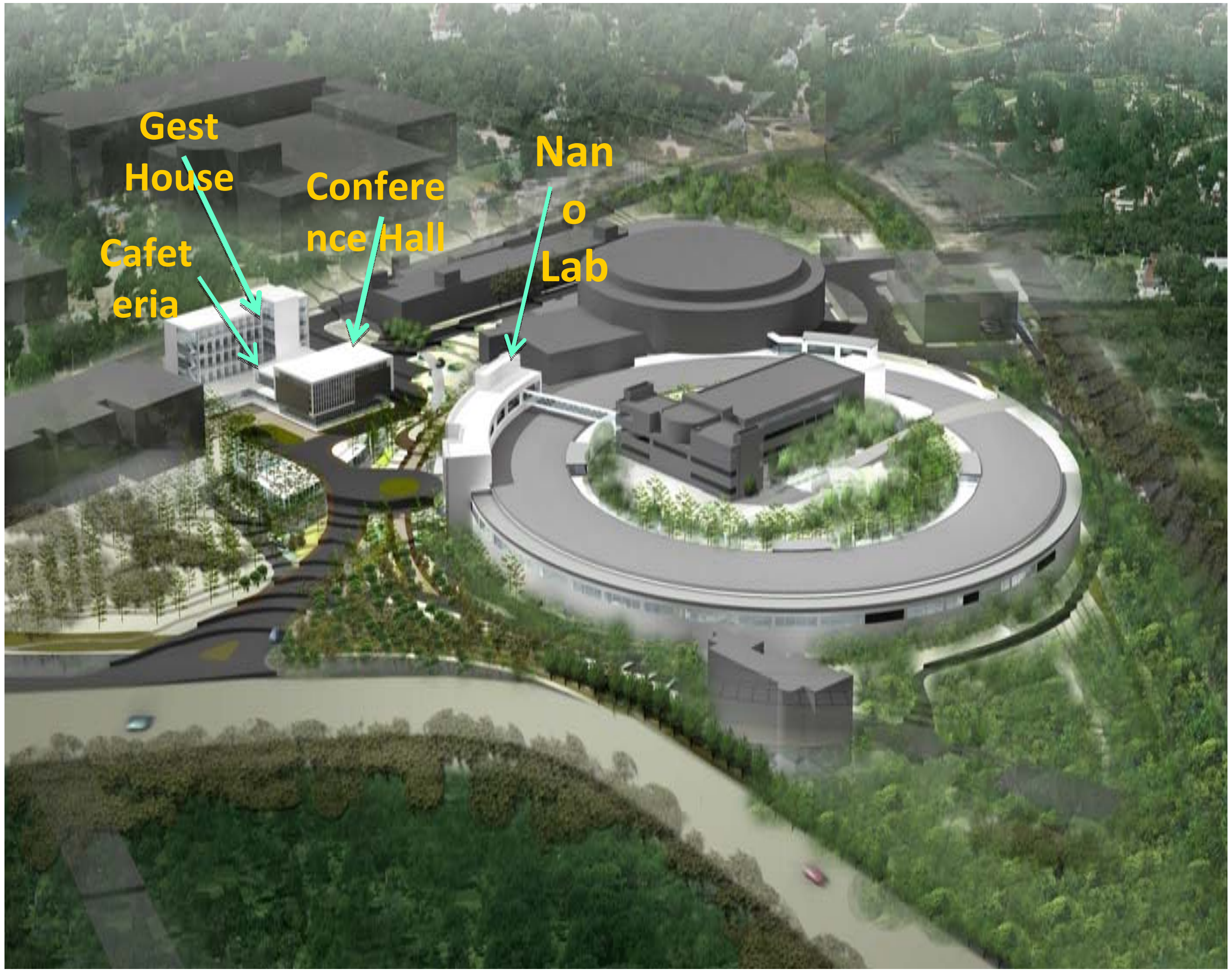
Energy:	3.5 GeV
Circumf.	432 m
Lattice:	DBA
Emittance:	3.9 nm-rad
Current:	300 mA
RF Cavity:	SC (3)
Straight Sections:	4 x 12 m
	16 x 6.5 m
Injection:	Top-up
Beam lines:	7 (Phase-I)

Courtesy: Z.T. Zhao

ALBA (2003-2010)

Energy:	3.0 GeV
Circumf.	268.8 m
Lattice:	DBA
Emittance:	4.3 nm-rad
Current:	400 mA
RF Cavity:	NC (6)
Straight Sections:	8 x 2.5 m
	12 x 4.2 m
	4 x 8 m
Injection:	Top-up
Beamlines:	7 (Phase-I)

Courtesy: D. Einfeld



TSP (2007-2013)

Energy:	3.0 GeV
Circumf.	518.4 m
Lattice:	DBA
Emittance:	1.6 nm-rad
Current:	400 mA
RF Cavity:	SC (2)
Straight Sections:	18 x 7.0 m 6 x 12.0 m
Injection:	Top-up

NSLS-II *(*2005-2014)

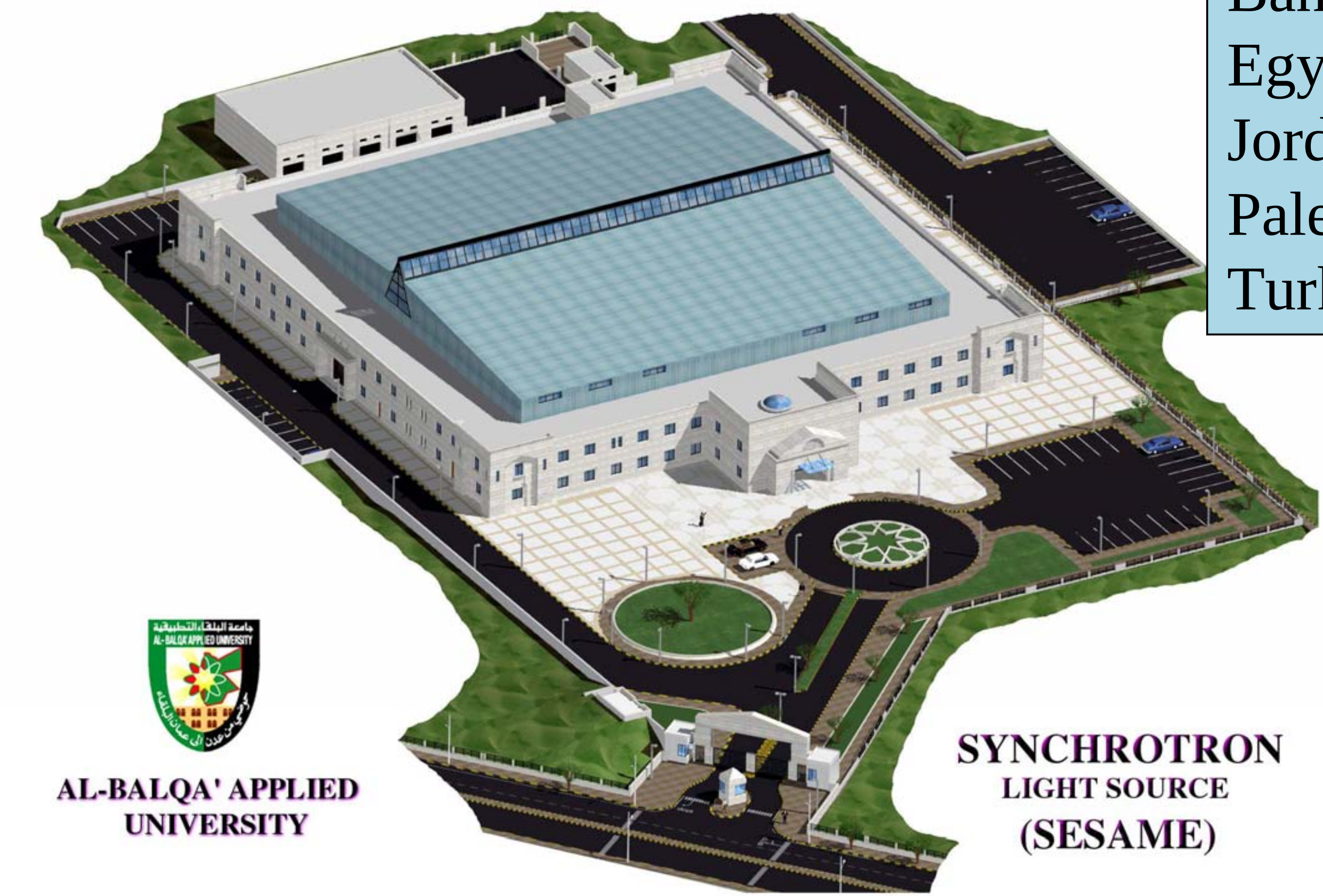
Energy:	3.0 GeV
Circumf.	792 m
Lattice:	DBA
Emittance:	1.5 nm-rad
Current:	500 mA
RF Cavity:	SC (2)
Straight Sections:	15 x 6.6 m, 15 x 9.3 m
Injection:	Top-up
Beamlines:	10 (Phase-I)

Courtesy: F. Willeke

SESAME

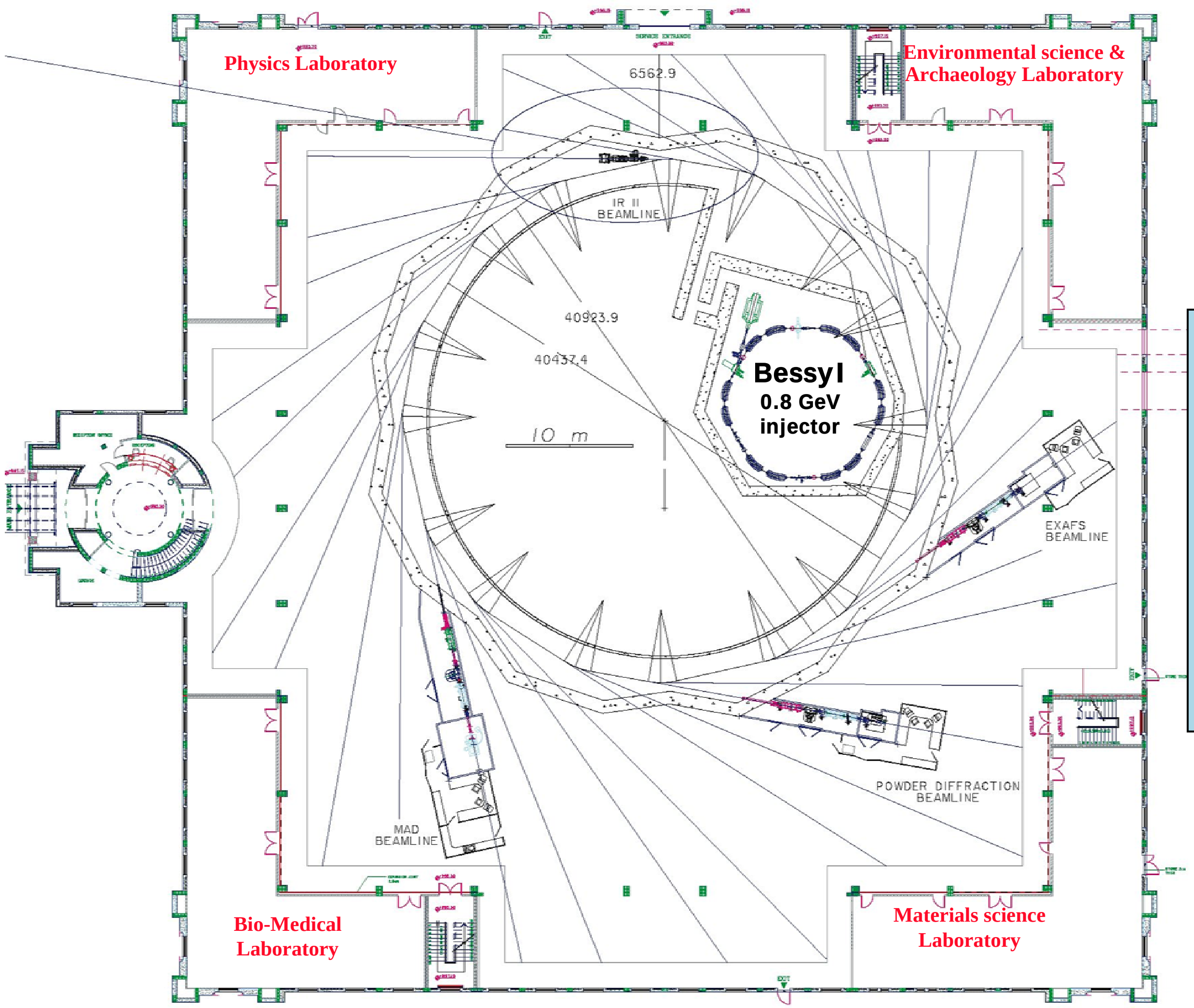
Synchrotron-Light for Experimental Science
and
Applications in the Middle East

Bahrain, Cyprus, Egypt, Iran, Israel, Jordan, Pakistan, Palestinian Authority, Turkey



Courtesy: H. Winick

www.sesame.org.jo



Energy; 2.5 GeV

Circumference; 133m

Emittance; 26 nm-rad

Space for 12 Insertion Devices

SESAME; *in construction in Jordan*

www.sesame.org.jo

Courtesy: H. Winick

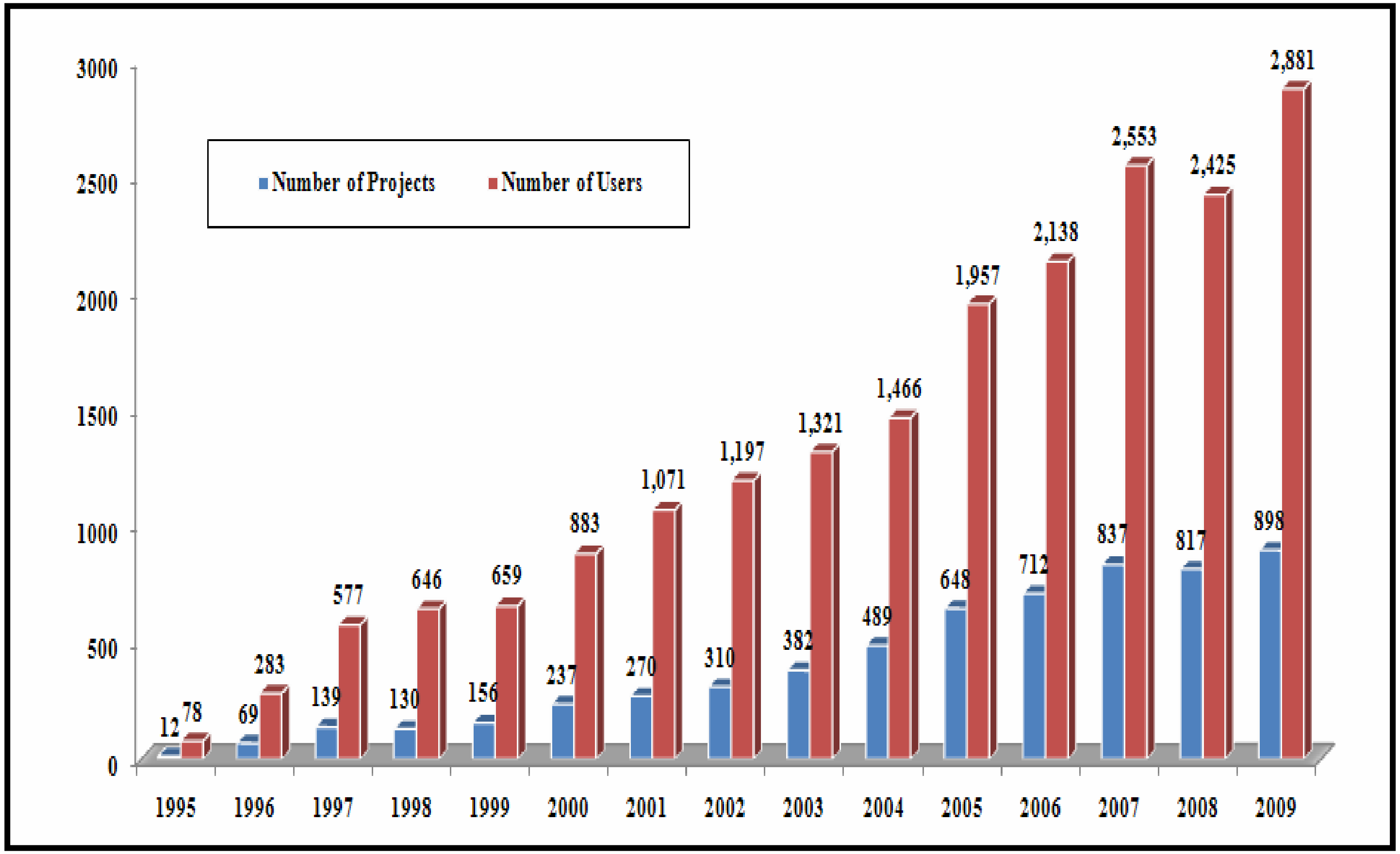

Pohang Light Source
(2.5 GeV: 3rd Generation Facility)
Utilities
E-Gun
LINAC
Storage Ring
Administration
Beam Lines
(Experimental Station)

PLS –II (2009 - 2011)

Parameter	PLS	PLS-II
Beam Energy (GeV)	2.5	3.0
Beam emittance (nm)	18	5.8
Beam Current (mA)	200	400
IDs	10	20
Tune (H/V)	14.28 / 8.18	15.24 / 9.17
Natural Chromaticity (H/ V)	-23.36 / -18.19	-32.95 / -14.88
Harmonic Number	468	470
Circumference	280	281
RF voltage (MV)	NC/2.0	SC (3)/3.3
Lattice	TBA	DBA
Operation	Decay	Top-Up
Brightness	$\sim 2 \times 10^{18}$	$\sim 10^{20}$

Statistics for users and proposals at PLS

Number of Users are increasing dramatically in the world.
There were less than 10 users in Korea, when the PLS project started in 1988.



Nobel Prizes in Light Source Users

1997 Chemistry

John E. Walker, “Structure of F1-ATPase”

2003 Chemistry

Roderick McKinnon, “Structure of Cellular Ion Channels”

2006 Chemistry

Roger D. Kronberg, “Structure of RNA polimerase”

2009 Chemistry

Ada E. Yonath,

“Structure and function of the ribosome”

On Technology and Experience

There are many dramatic technological changes during the 3rd Generation construction and operational experiences. For examples:

- Alignment technology (laser tracker)
- In-vacuum undulators (requires shorter straight sections)
- Computing capacity:
  - Simulation and CAD
- Networks and controls (no hard wires to control rooms)
- Advanced diagnostics
- SC cavities (higher RF voltage, and stability)
- Top-up operations (users’ strong demands)

- Experiences (no need for positron and more than 96% availability)

Summary

- When 3rd generation was conceived in 20-years ago, there was no demand from life science, but there was mainly for materials science.

- There are more new facilities under construction and planning, especially intermediate-size machines.

- Users are very much diversified and expanding rapidly to other research areas.

- The superconducting technology will share benefits in other large-scale scientific facilities.

- Starting with LCLS in 2009, more 4th generation facilities (SCSS, Euro-XFEL, and others) will be followed. One may expect unforeseen results.

  - ERL and XFELO are other new approaches in competing with the 4th generation machines.

Acknowledgements

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