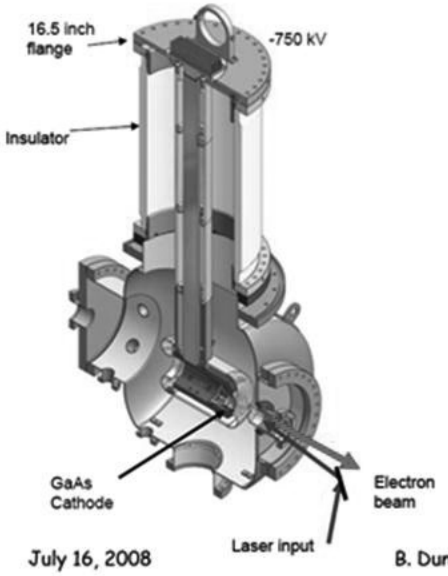
Photogun options for ERLs

DC
Cornell University

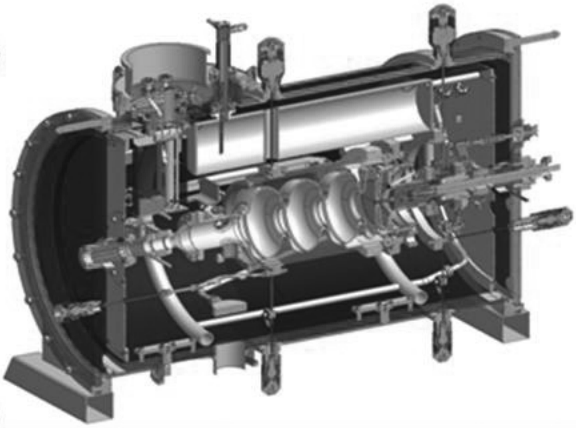


July 16, 2008 B. Dunham,

NRF

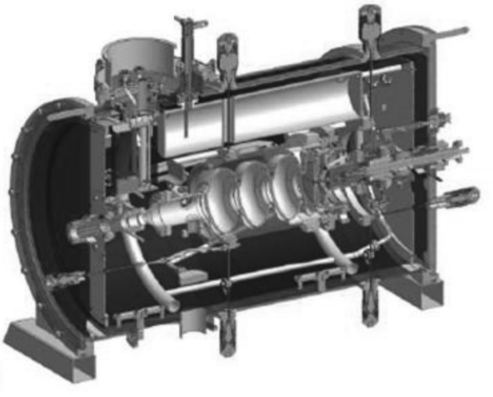
Boeing
25% DF

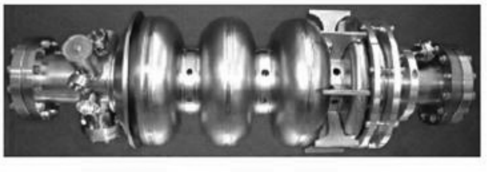
SRF



FZ-Dresden, BESSY, MBI, DESY

The Rossendorf SRF gun





1.3 GHz, 9.5 MeV, CW operation
3 modes of operation:
- 77 pC at 13 MHz
- 1 nC up to 1 MHz (1 mA)
- 2.5nC at 1 kHz

	ELBE mode	high charge mode	BESSY-FEL
RF frequency	1.3 GHz		
beam energy	9.5 MeV		
operation	CW		
drive laser	262 nm		
photocathode	Cs_2Te		
quantum efficiency	]1 %		]2.5 %
average current	1 mA		2.5 µA
pulse length	5 ps	20 ps	50 ps
repetition rate	13 MHz	[1MHz	1 kHz
bunch charge	77 pC	1 nC	2.5 nC
transverse emittance	1.5 µm	2.5 µm	3.0 µm

The maximum value of electron current

- The version suggested for some single-turn ERL projects - using current up to 100 mA for keeping the photon flux - seems to be far from optimum, since with such an increase in current the brightness does not increase and even decreases sometimes.

- In order to achieve full spatial coherence of the source we suggest that the charge in one bunch be no more than

$$Q= 7.7 \cdot 10^{-12} \text{ Coul}$$

For F_{RF}=1.3 GHz that corresponds to a current value of 10 mA for a single-turn accelerator and 2.5 mA for a four-turn accelerator.

- To compensate the decrease in the current value compared with that of the 3rd generation SR sources, we shall use radiation only from three types of undulators with N_{u1}=100, N_{u2}=1000, N_{u3}=10 000, not from bending magnets. In this case, we solve the problem of full spatial coherence and at the same time keep the photon flux at the level of the 3rd generation sources.

Due to the small bunch charge (Q=8 pC) and relatively long bunch length (2 ps) in MARS we hope to suppress current-dependent effects of growth of transverse and longitudinal emittance and beam loss due to:

- **beam break-up;**
- **coherent synchrotron radiation;**
- **intrabeam scattering (Touschek);**
- **disturbance from ions.**

Superconducting RF ("ERL 2005" Conference)

Superconducting RF technology was developed by Cornell University, KEK, CERN, Jefferson Lab, and DESY.

Parameters of the TESLA cryomodule:

- ❑ Cryostat length — L= 12 m
- ❑ Gradient — 15 MV/m
- ❑ Energy gain — ΔE = 110 MeV
- ❑ AC power 0.6-0.9 MW per cryomodule

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European XFEL Overview

European XFEL

Superconducting "TESLA" Technology

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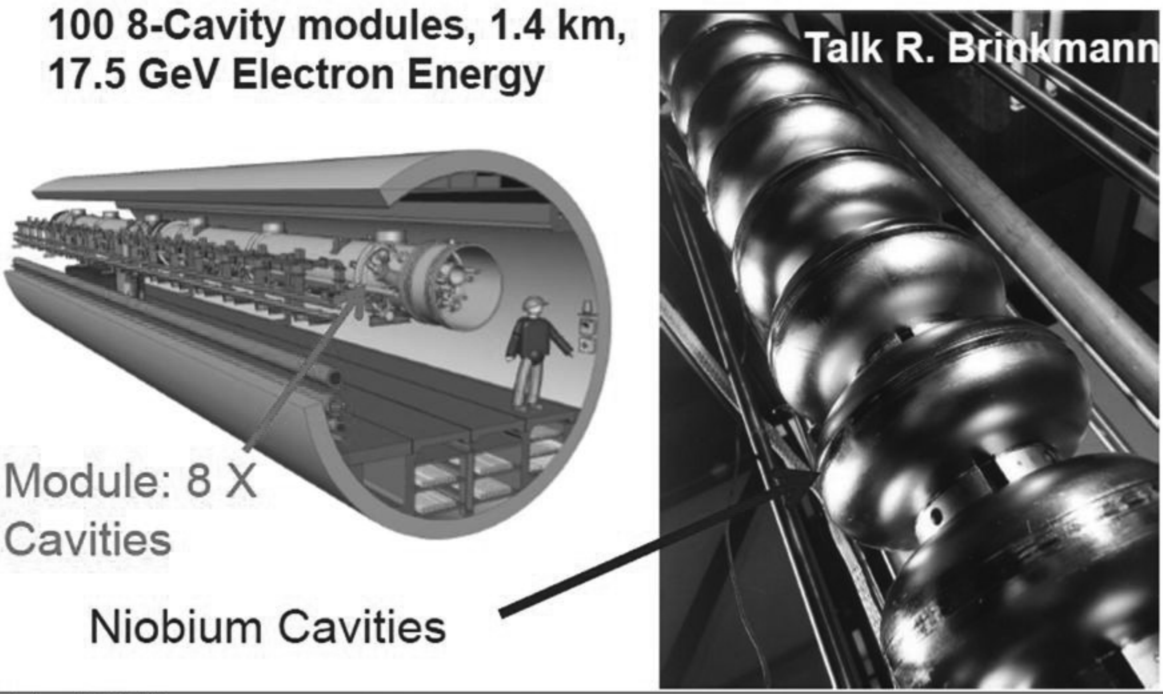
100 8-Cavity modules, 1.4 km, 17.5 GeV Electron Energy

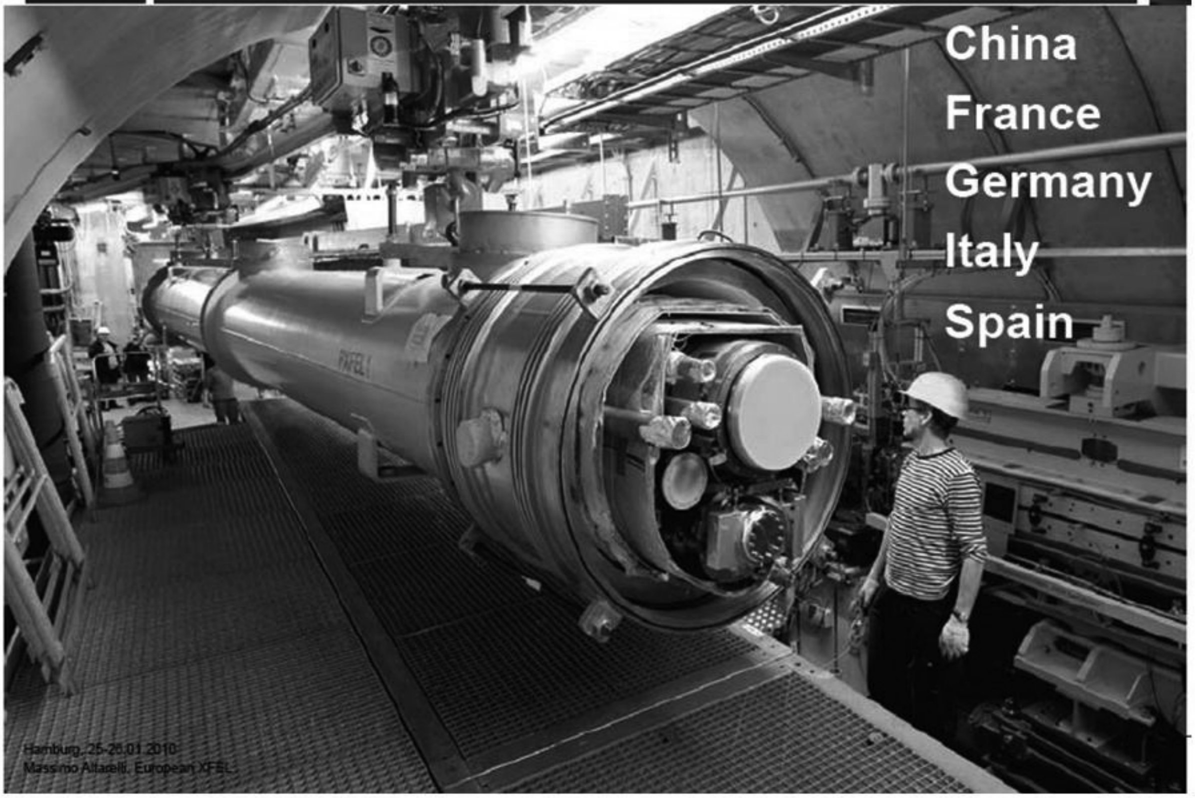


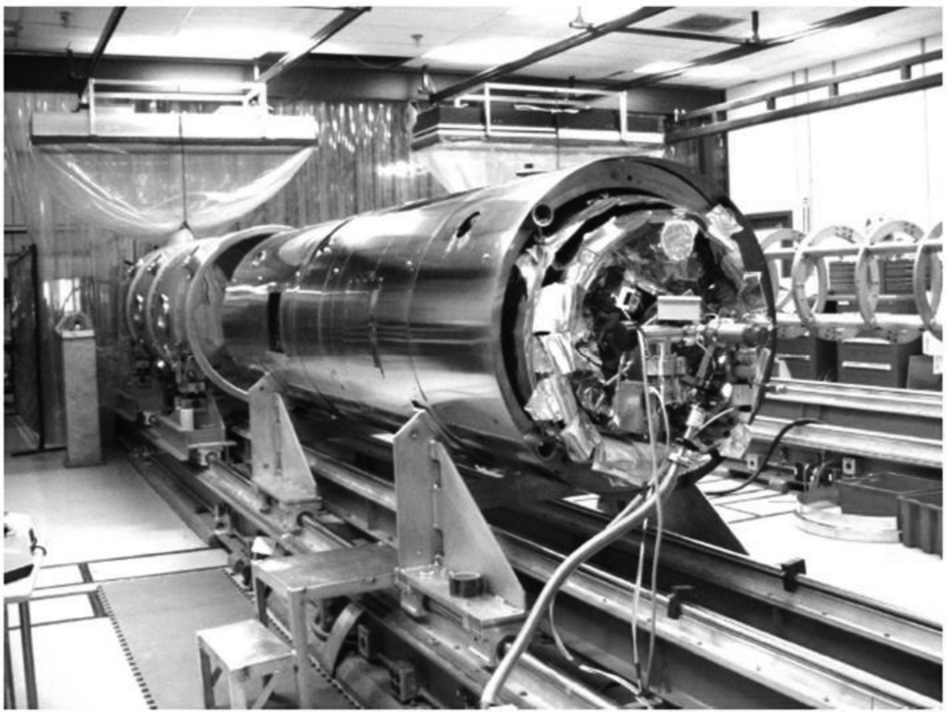
Hamburg, 25-26.01.2010
Massimo Altarelli, European XFEL

European XFEL

European XFEL Overview

Accelerator Module Prototype PXFEL1





The undulator

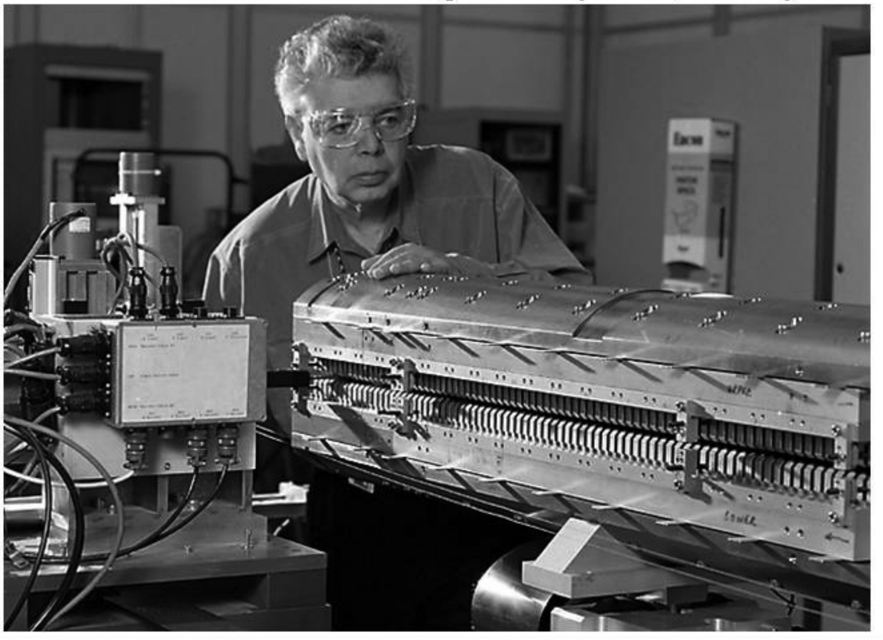
- The undulator gap will be limited mainly by radiation losses in the walls of the vacuum chamber; *g* = 0.5 cm seems to be reasonable.
- Choosing the undulator parameter K ~ 1 for *g* = 0.5 cm, one can obtain from the Hallbach equation λ_u = 1.5 cm .
- Maximum length of the undulator is determined by the increase in energy spread in the undulator due to quantum fluctuation of undulator radiation.

$$For \quad E = 6\,GeV: \left(\frac{\sigma_E}{E}\right)_{max} = 3\cdot 10^{-5}$$

$$\lambda_u = 1.5\,cm; K = 1 \quad L_u < 180m$$

- The undulator must be segmented into sections of L ~ 5 m with a 1 m straight section in between. Each straight section contains a 3-pole phase adjuster, focusing the quadrupoles, steering magnets and beam position monitor.
- The quadrupoles between the undulator sections are necessary to provide equal and almost constant (inside undulators) beta functions $\beta_x \sim \beta_z$
- For a very long undulator, the superconduction technology or a combination of the electromagnet and permanent magnet technology (equipotential-bus electromagnetic undulator) can be more appropriate for tuning the photon energy.
- Photon beam monitors and a monochromator for spectral measurements have to be installed on the beamline for feedback to the steering coils and phase adjusters.

Undulator for X-ray FEL (ANL, USA)



• Gap		6.8 mm
• Period Length	30.0±0.05	mm
• Effective On-Axis Field	1.249	T
• Segment Length	3.40	m
• Number of Segments	33	
• Undulator Magnetic Length	112.2	m

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European XFEL

Status of WP71 (Undulator Systems)

Overview over Undulator Systems

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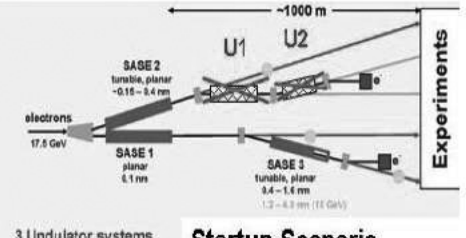
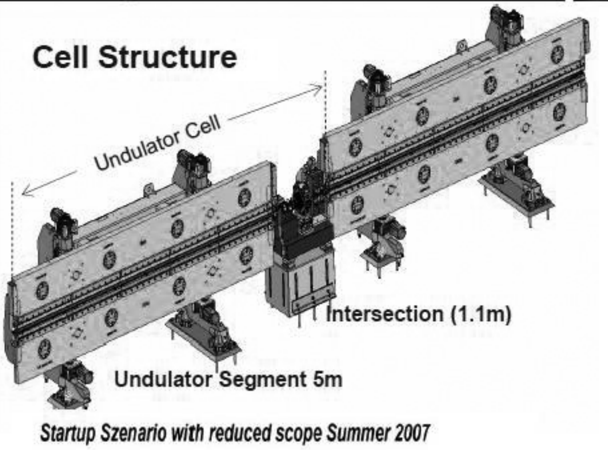


3 Undulator systems
3 Photon diagnostics
3 Photon beamline
6 Instruments

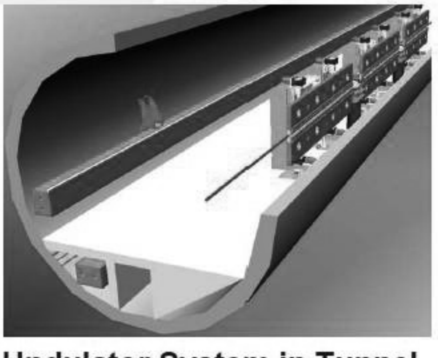
Startup Scenario
SASE1: Full
SASE2: Shortened by 5 Seg
SASE3: Linear



Startup Szenario with reduced scope Summer 2007

	λ_R [Å]	λ_0 [mm]	Gap [mm]	B_0 [T]	K	β_0 [m]	L_{Sat} + [m]	N_{Tot} ++	L_{Tot} +++ [m]
SASE 1 *	1	35.6	10	1.0	3.3	32	133	33	201.3
SASE 2 *	1-4	48	19-10	0.63-1.37	2.8-6.1	46-15	174 - 72	37	225.7
SASE3P *	4-16	65	23-10	0.66-1.76	4.0-10.7	15	≈100	21	128.1
							Total	91	555.1

* Planar Hybrid Undulator
** 1st Harmonic of Spontaneous Emitters
\+ Net saturation length with no contingency for field errors
++ Number of 5m undulator segments including 20% contingency
+++ Total system length includes 1.1m long intersection after each undulator segment



Undulator System in Tunnel

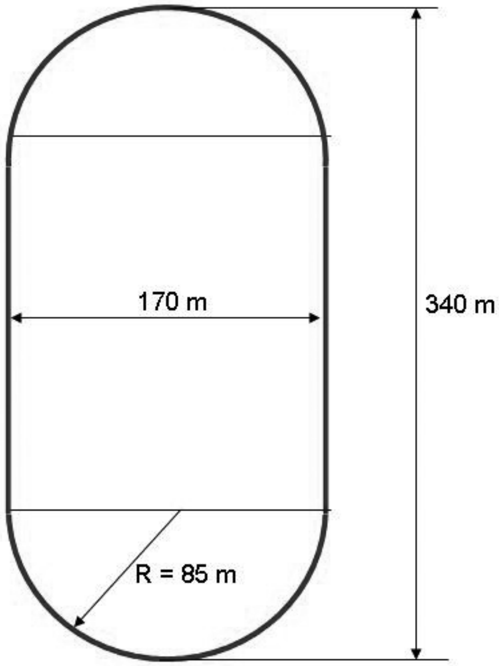
- At present, projects of the 4th generation SR sources on the basis of accelerators-recuperators are considered at Budker INP, Daresbury Laboratory, Jefferson Laboratory, Cornell University, LBL, KEK, Erlangen University, and Brookhaven National Laboratory.

- The accelerating schemes and most systems making the basis of the projects have already been tested at many laboratories (Jefferson Laboratory, DESY, MAMI, LEP, Budker INP, KEK, and MAX).

MARS at the RRC "Kurchatov Institute"

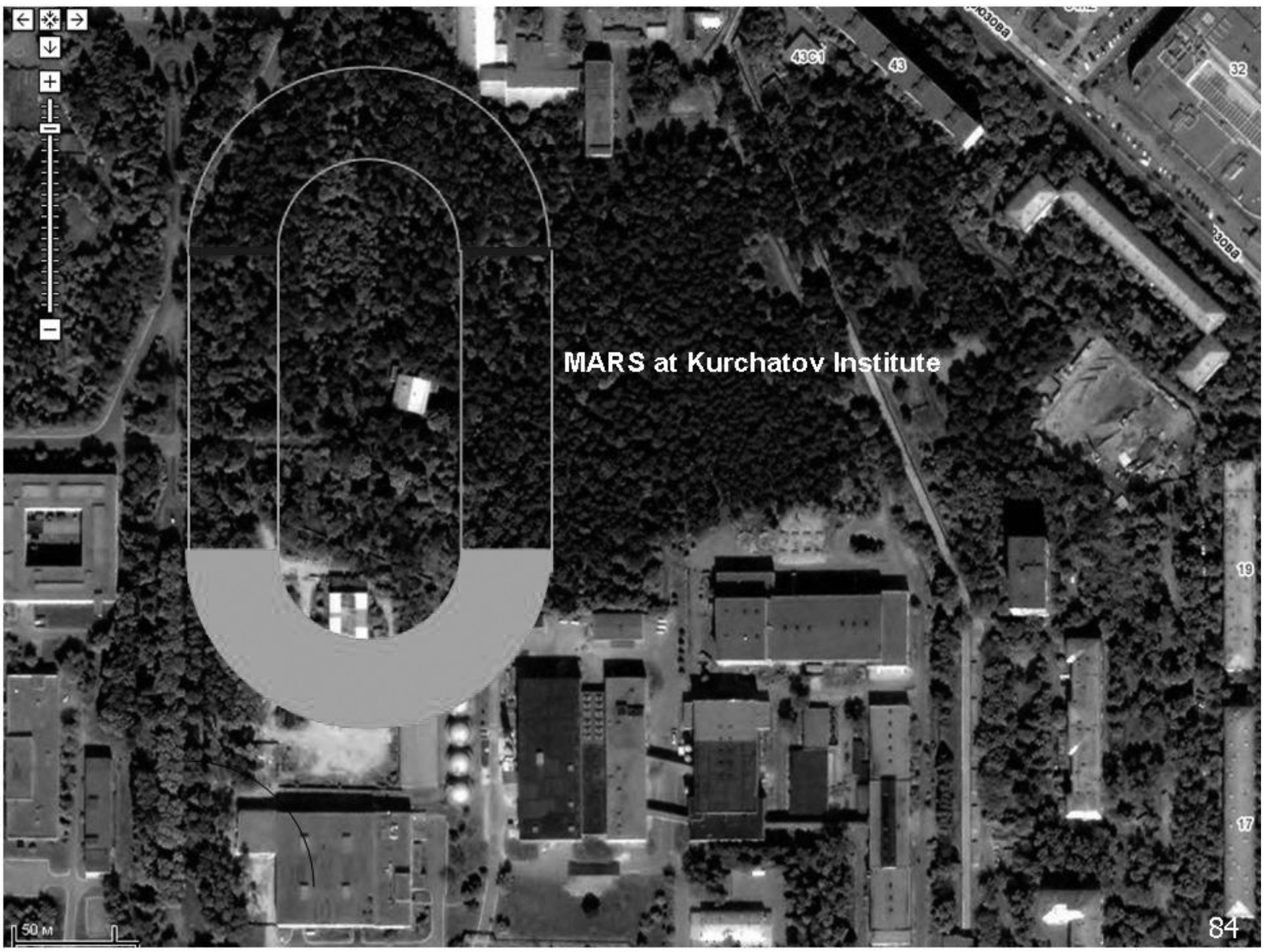
- Realization of the "MARS" project at the RRC "Kurchatov Institute" was discussed in detail within the framework of the Russia-Germany meeting "Kurchatov Centre of Synchrotron Radiation and Nanotechnology" (18-19 February 2008, the RRC "Kurchatov Institute", Moscow).
- A technical proposal and draft project of the SR source MARS under the contract with the RRC "Kurchatov Institute" will be completed till the end of 2011.

The basic dimensions of the MARS main rings



Perimeter = 874 m

Summary length of 4 rings ~ 3.5 km



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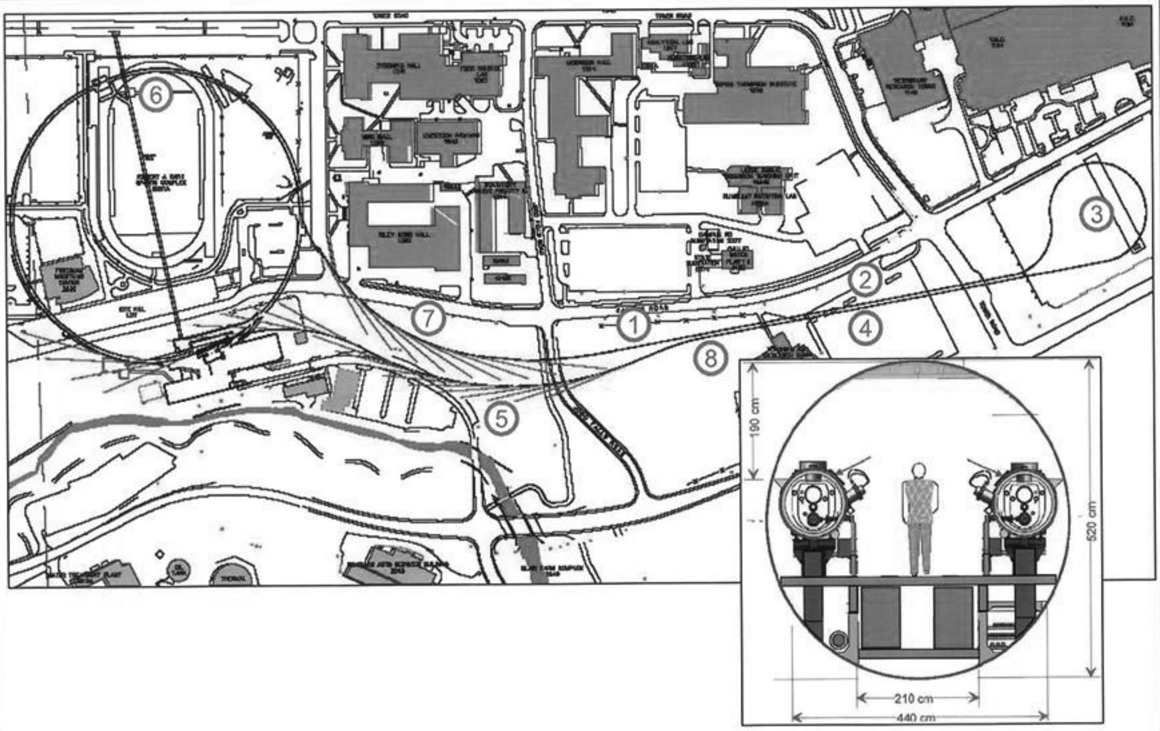
ERL@CESR design version 1.3

CHESS & LEPP



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APS Upgrade Review

CHESS & LEPP

An "Outfield" ERL Option (G. Decker[1])

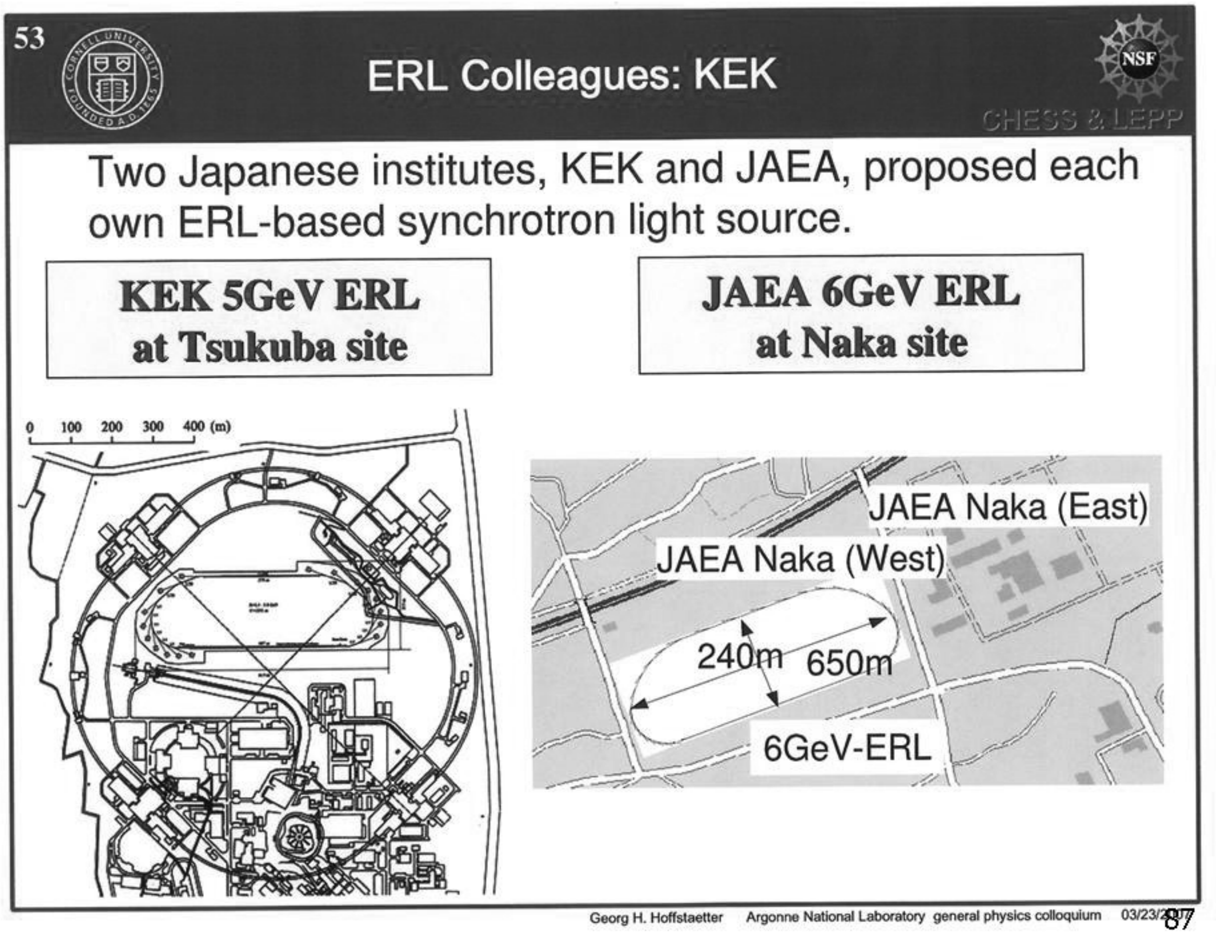
- **Advantages**
  - Linac points away from APS[2] to give straight-ahead FEL hall[3]
  - Beam goes first into new, emittance-preserving turn-around arc[4]
  - Avoids wetlands etc. by using narrow corridor for linac and return line
- **Issues**
  - Big and expensive
  - Turn-around should be *bigger* than shown
  - Beam goes wrong way around the APS in this sketch (readily fixed)
  - No space for really long undulators.

[1]G. Decker, "APS Upgrade External ERL Option," 9/27/06.

[2]M. Borland, "ERL Upgrade Options and Possible Performance," 9/18/06.

[3]M. Borland, "Can APS Compete with the Next Generation?", May 2002.

[4]M. Borland, OAG-TN-2006-031, 8/16/06.



Summary

All the requirements to X-ray radiation sources of the 4th generation cannot be satisfied with the use of only one kind of a source. The high peak brightness and femtosecond duration of radiation pulses can be attained at the linac based X-ray SASE FEL with a high pulse current (I_p >1 kA). All the remaining requirements are easier and cheaper realized with the use of radiation from the long undulators installed at the accelerator-recuperator.

Acknowledgement

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Thank you for your attention