The BESSY Soft X-Ray SASE FEL (Free Electron Laser)

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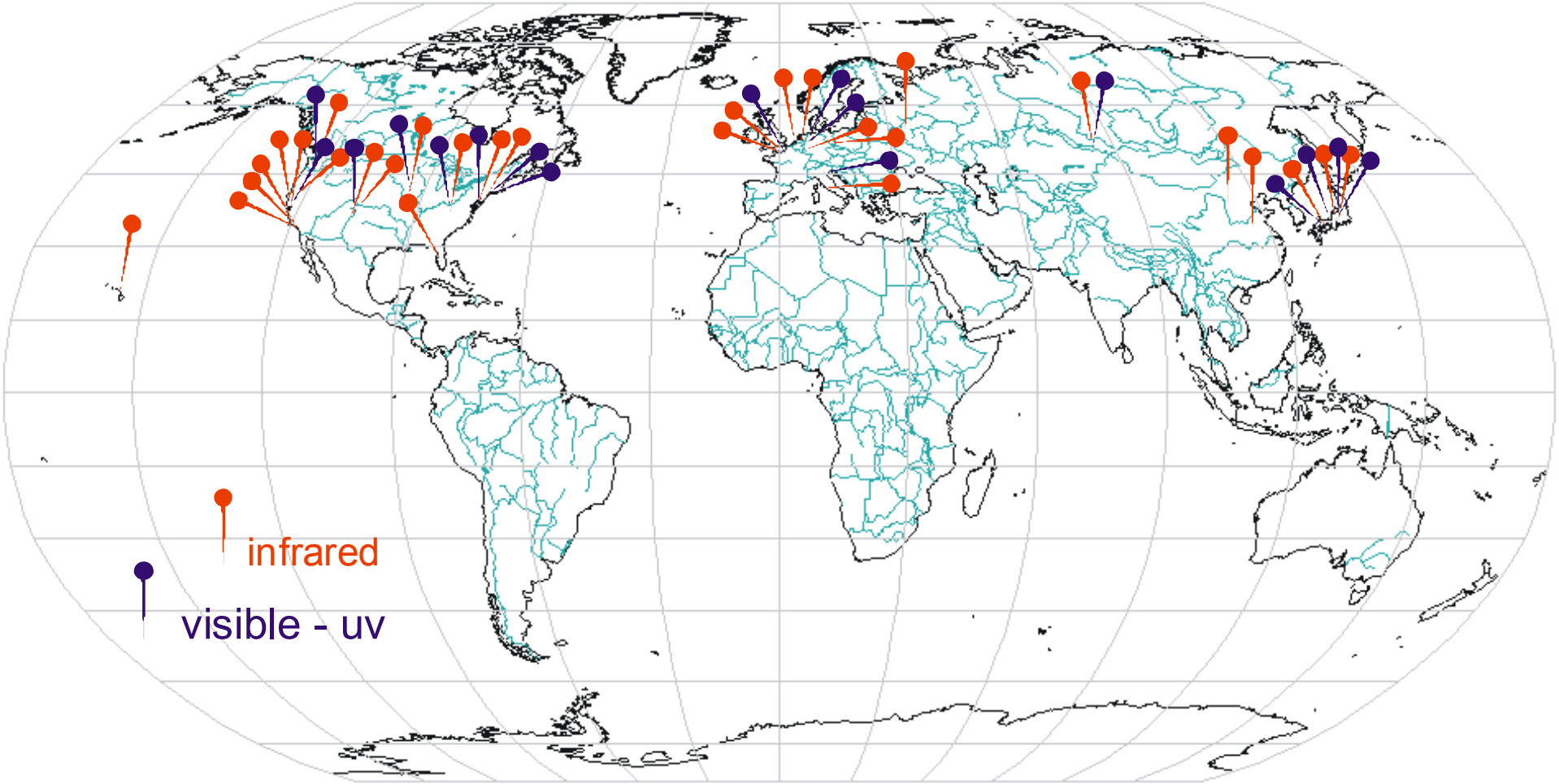
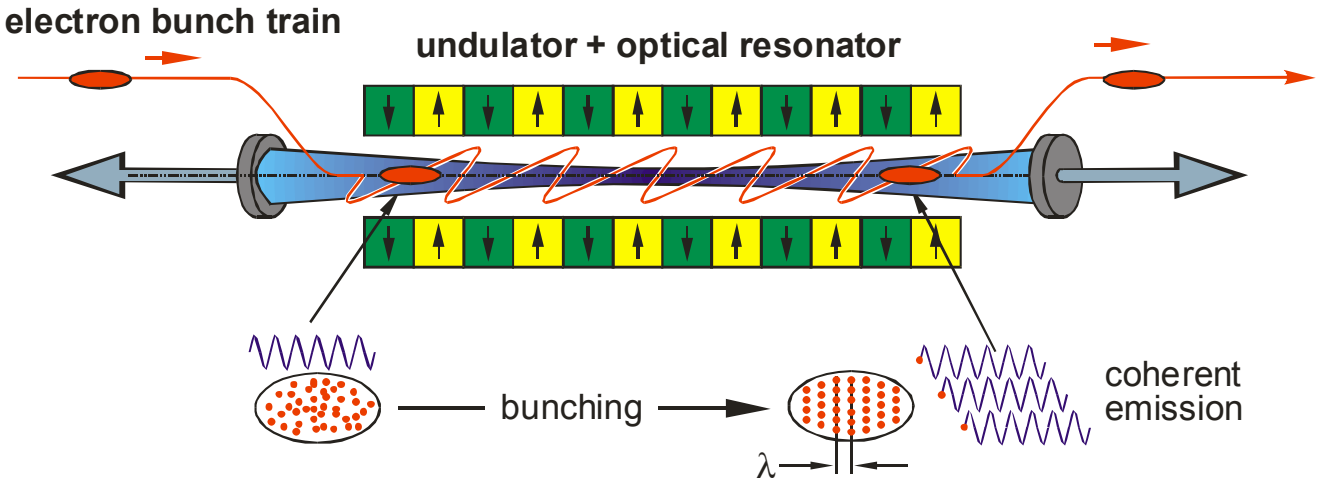
EPICS Meeting Spring `02, BESSY, Berlin

FEL facilities

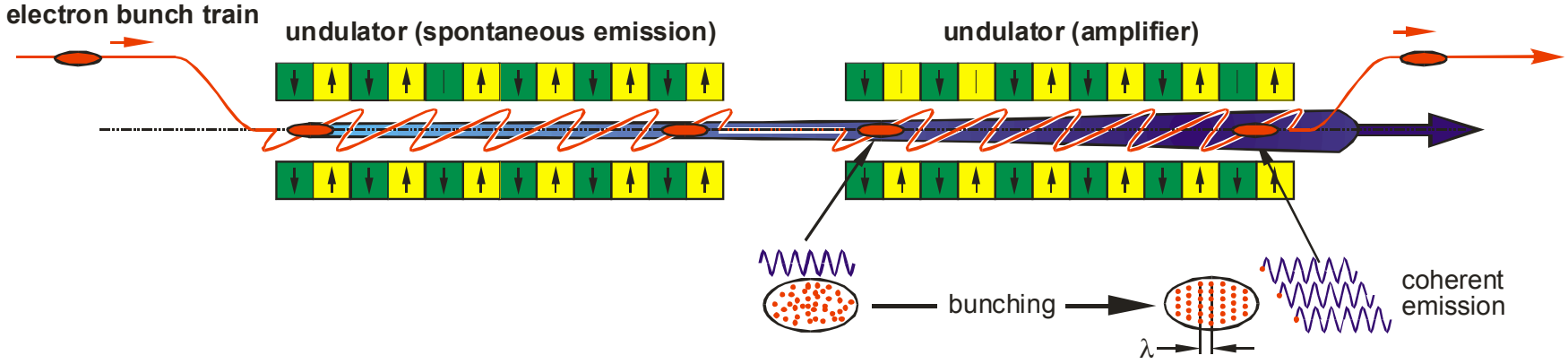


Classical FEL Scheme



SASE FEL Scheme

(Self Amplified Spontaneous Emission)

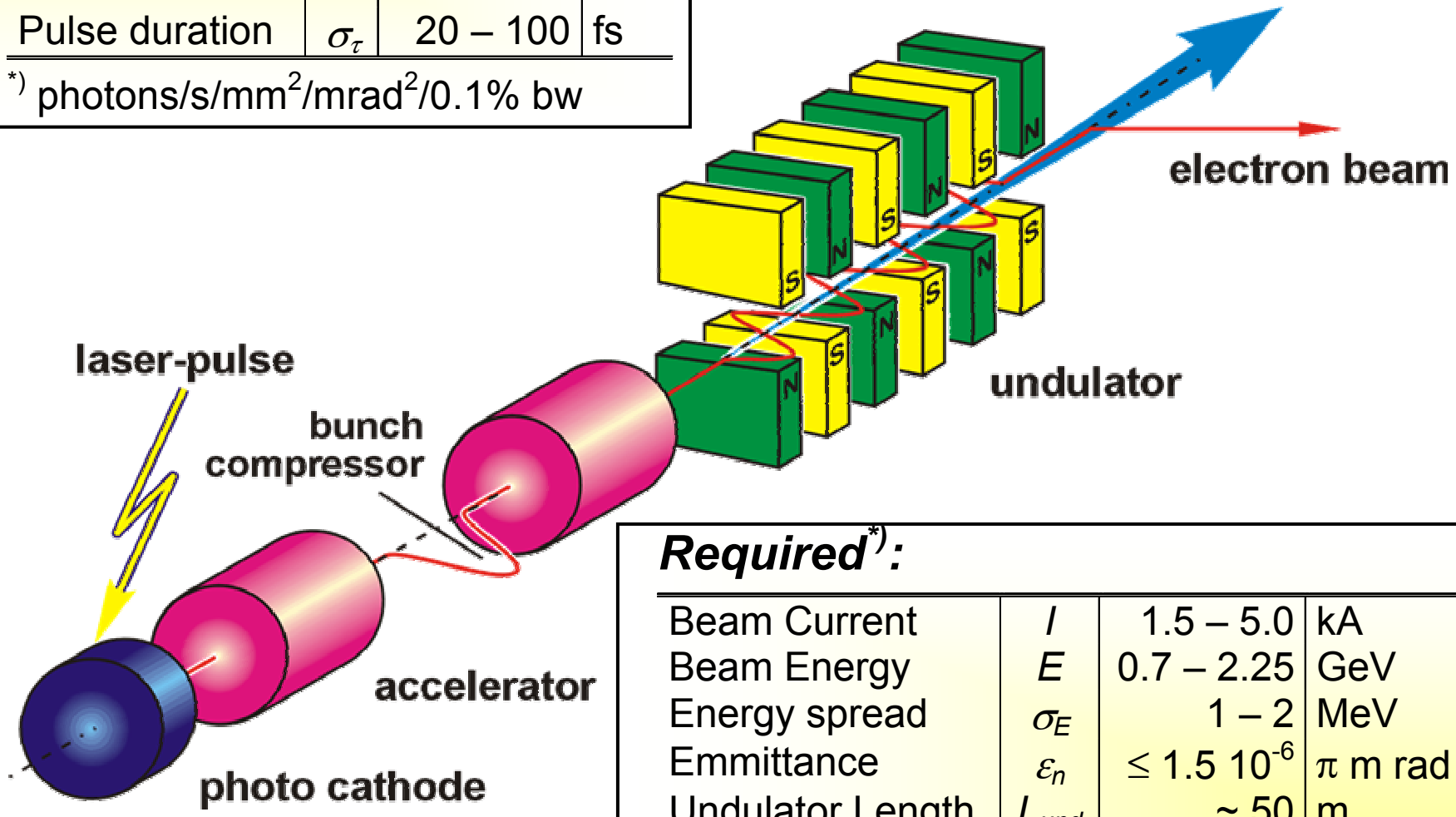


SASE-FEL Setup

Goal:

Photon Energy	E_ϕ	0.02 – 1	keV
Wavelength	λ	60 – 1.2	nm
Peak Brilliance	B	~10^{29}	*)
Pulse duration	σ_τ	20 – 100	fs

*) photons/s/mm^2/mrad^2/0.1% bw



Required*):

Beam Current	I	1.5 – 5.0	kA
Beam Energy	E	0.7 – 2.25	GeV
Energy spread	σ_E	1 – 2	MeV
Emmittance	ε_n	$\leq 1.5\ 10^{-6}$	π m rad
Undulator Length	L_{und}	~ 50	m

*) Parameters are coupled

History of SASE

1980	First proposal
1996	First experimental observation
	UCLA: λ = 16 μm
Dec. 1999	APS: lasing at λ = 523 nm
Feb. 2000	DESY: lasing at λ = 80 nm
Sep. 2000	APS: saturation at λ = 523 nm
Feb. 2001	VISA/BNL: saturation at λ = 800 nm
Apr. 2001	APS: saturation at λ = 385 and λ = 265 nm
Sep. 2001	DESY: saturation at λ = 100 nm
Oct. 2001	First user experiments @ DESY-TTF

Development steps towards VUV and X-ray FELs

SASE FEL User Facilities

Under construction and/or operational

- TTF / DESY* $\lambda > 6$ nm (80 nm)
- LEUTL / APS* $\lambda > 120$ nm (265 nm)

Proposed

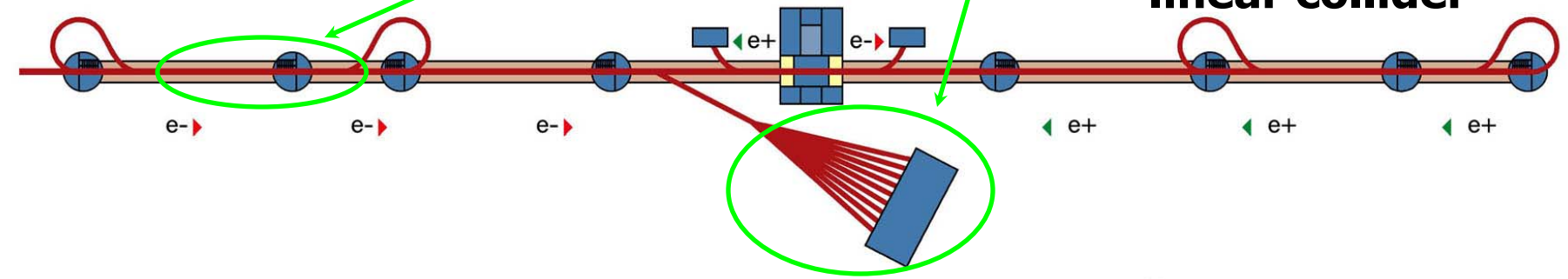
- BESSY $\lambda \geq 1.2$ nm (1 keV)
- SLAC $\lambda \geq 1.5$ Å (8 keV)
- SPring8 $\lambda \geq 15$ nm $\rightarrow$ 3.6 nm $\rightarrow$ 0.1 nm
- TESLA $\lambda \geq 0.85$ Å (14 keV)
- ELETTRA, ENEA, Daresbury ……

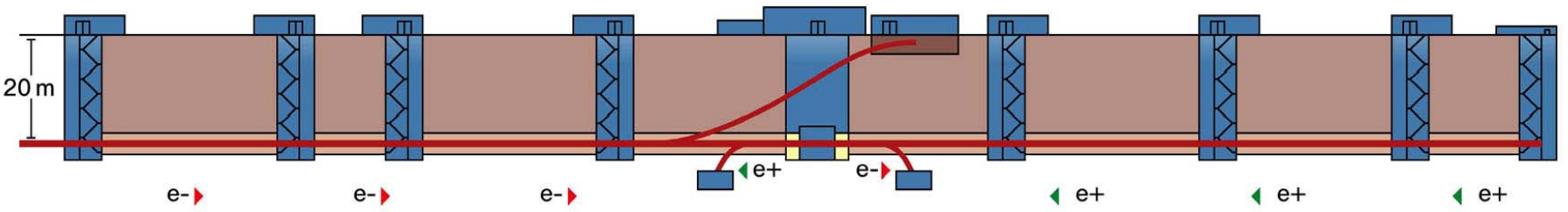
* Hybrid between FEL development & user facility

TESLA X-ray FEL

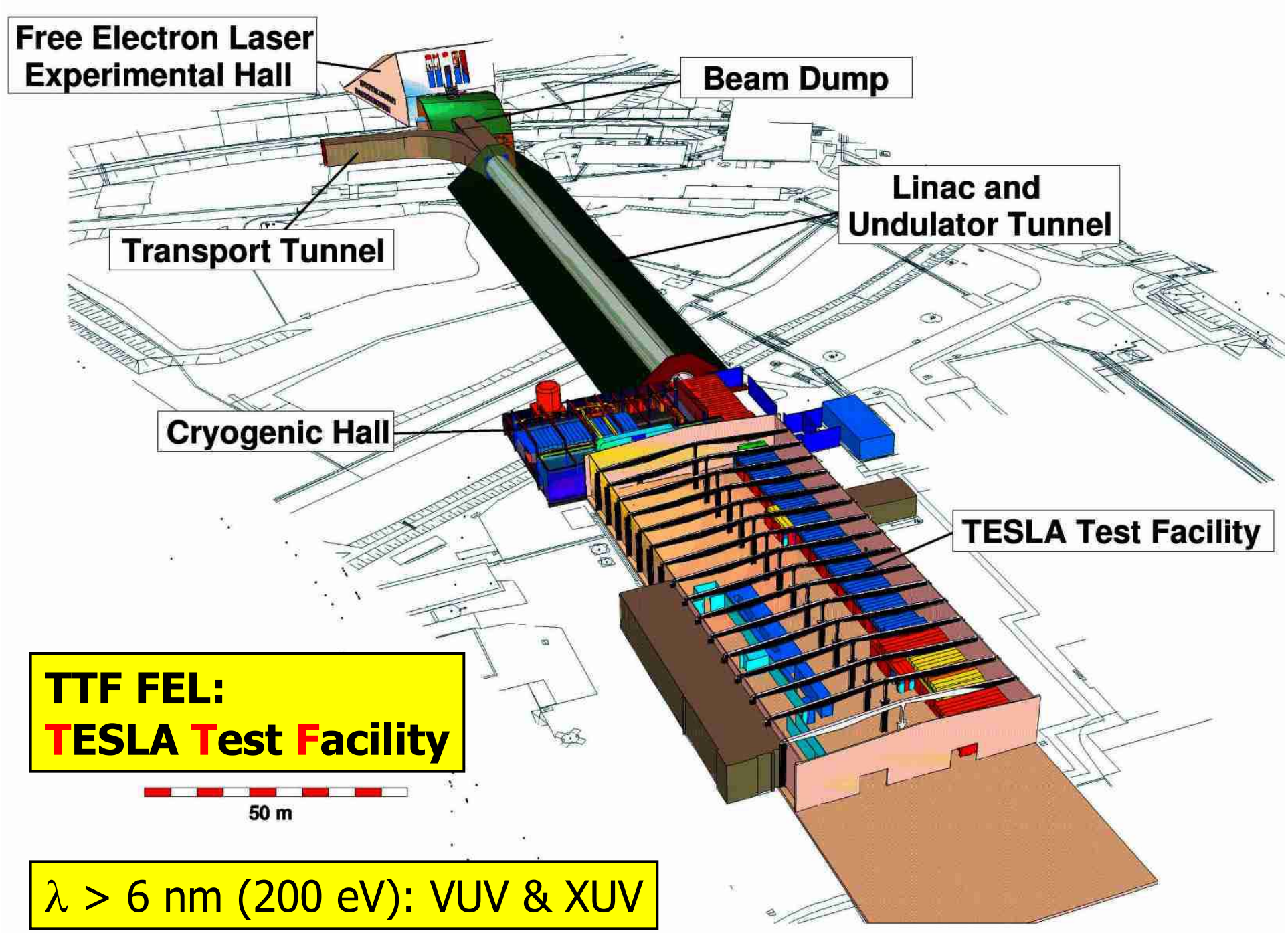
$\lambda > 0.85$ Å (14 keV): X-rays

Top view





Side view


Free Electron Laser
Experimental Hall
Beam Dump
Linac and
Undulator Tunnel
Transport Tunnel
Cryogenic Hall
TESLA Test Facility
TTF FEL:
TESLA Test Facility
50 m
λ > 6 nm (200 eV): VUV & XUV

User Feedback

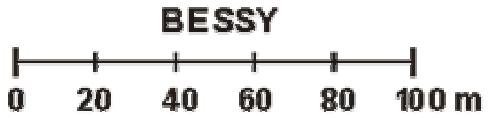
Important issues:

- Photon energy:..... 20 eV - 1.0 keV ($60 \leq \lambda \leq 1.2$ nm)
- Micro-pulse duration:..... $\tau \leq 20$ fs
- Narrow spectral width:..... $\Delta\lambda/\lambda \leq 10^{-4}$
- Synchronization with fs lasers
- As many as possible photons per pulse
- High average brilliance

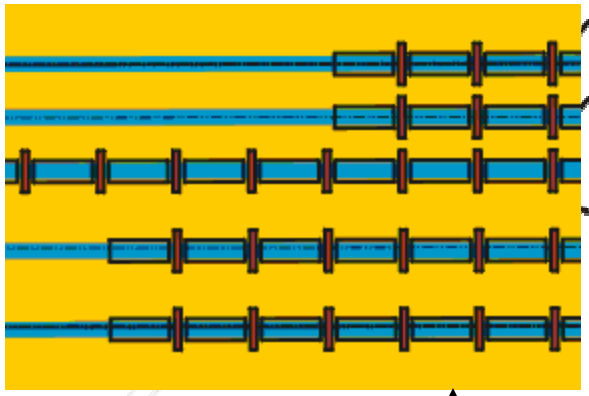
Proposal: FEL user-facility that becomes operational after 2007

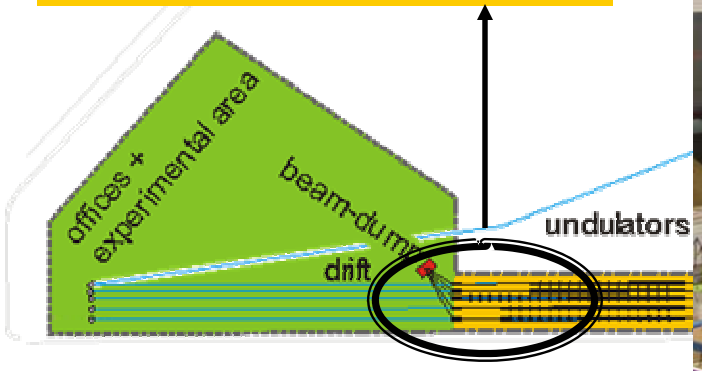
The BESSY FEL

1.5 - 2.25 GeV linac

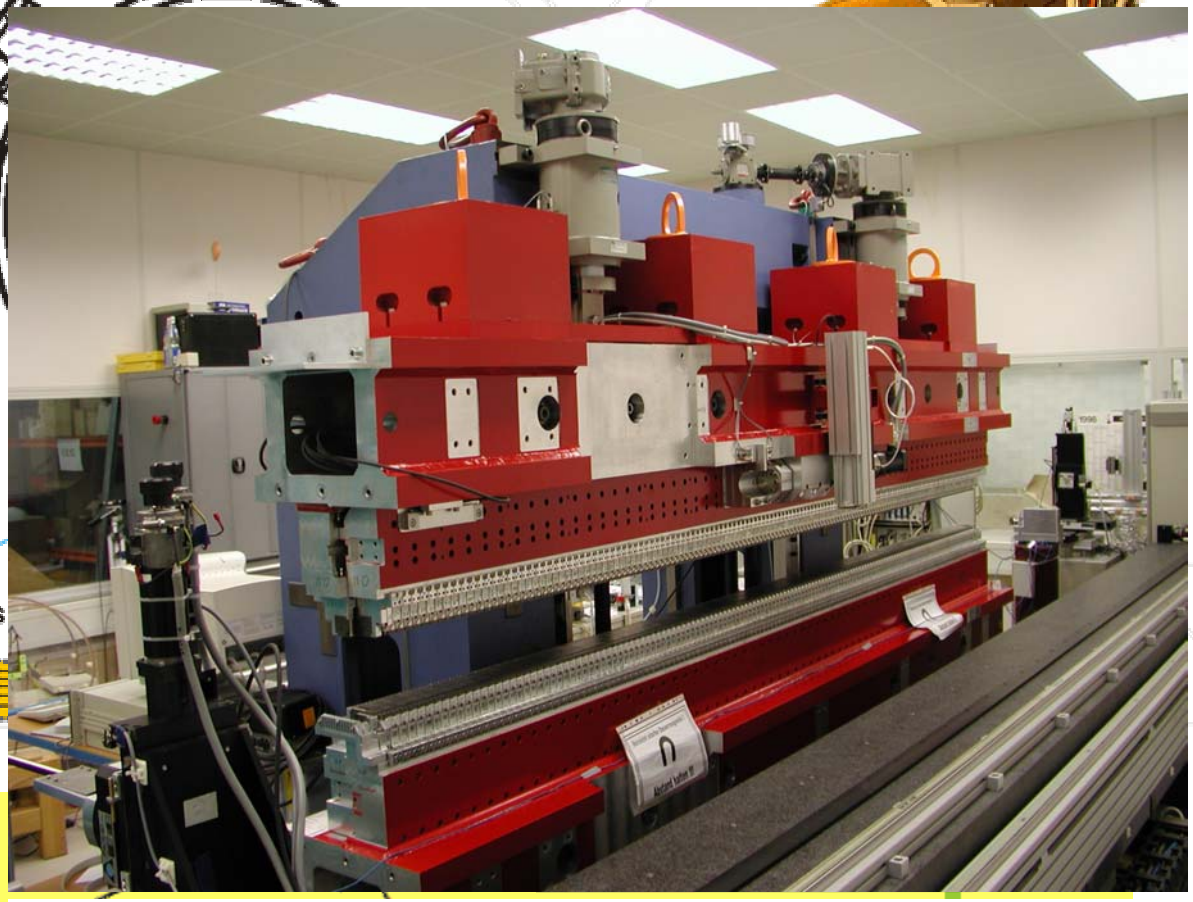


multiple undulators





drift for monochromators and beam-blowup

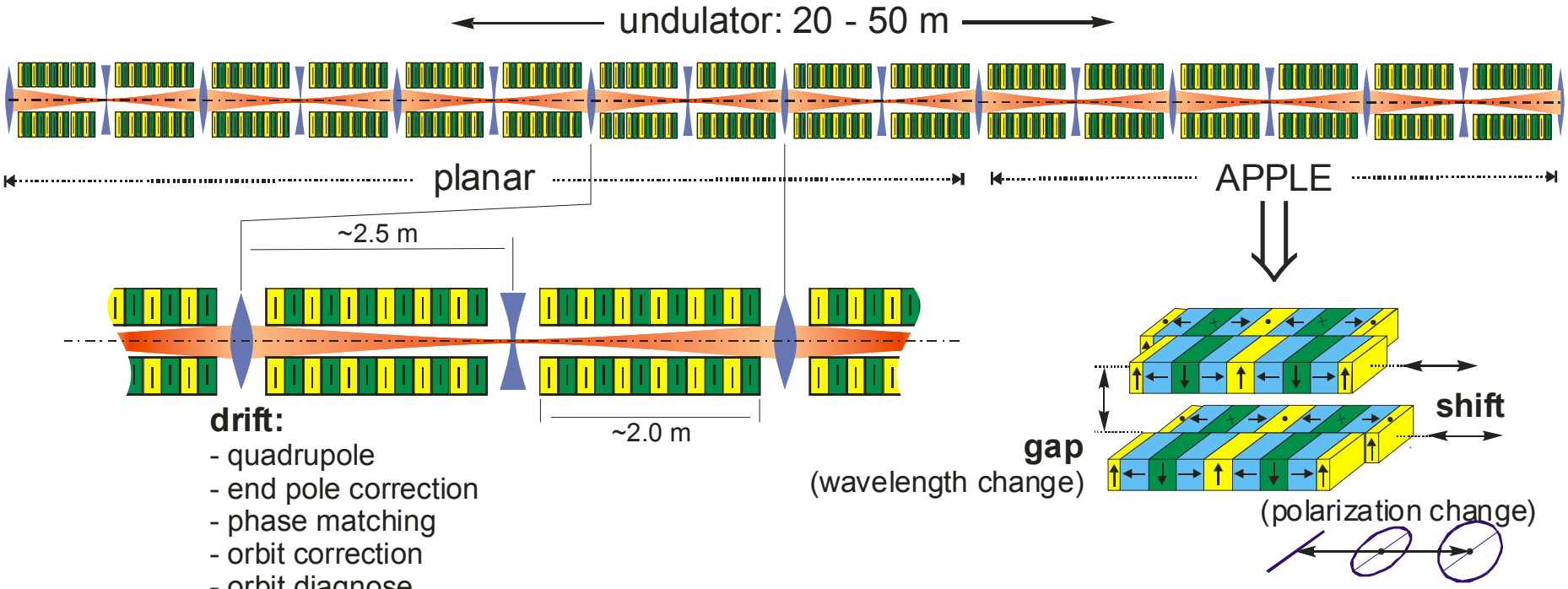


BESSY II undulator UE46

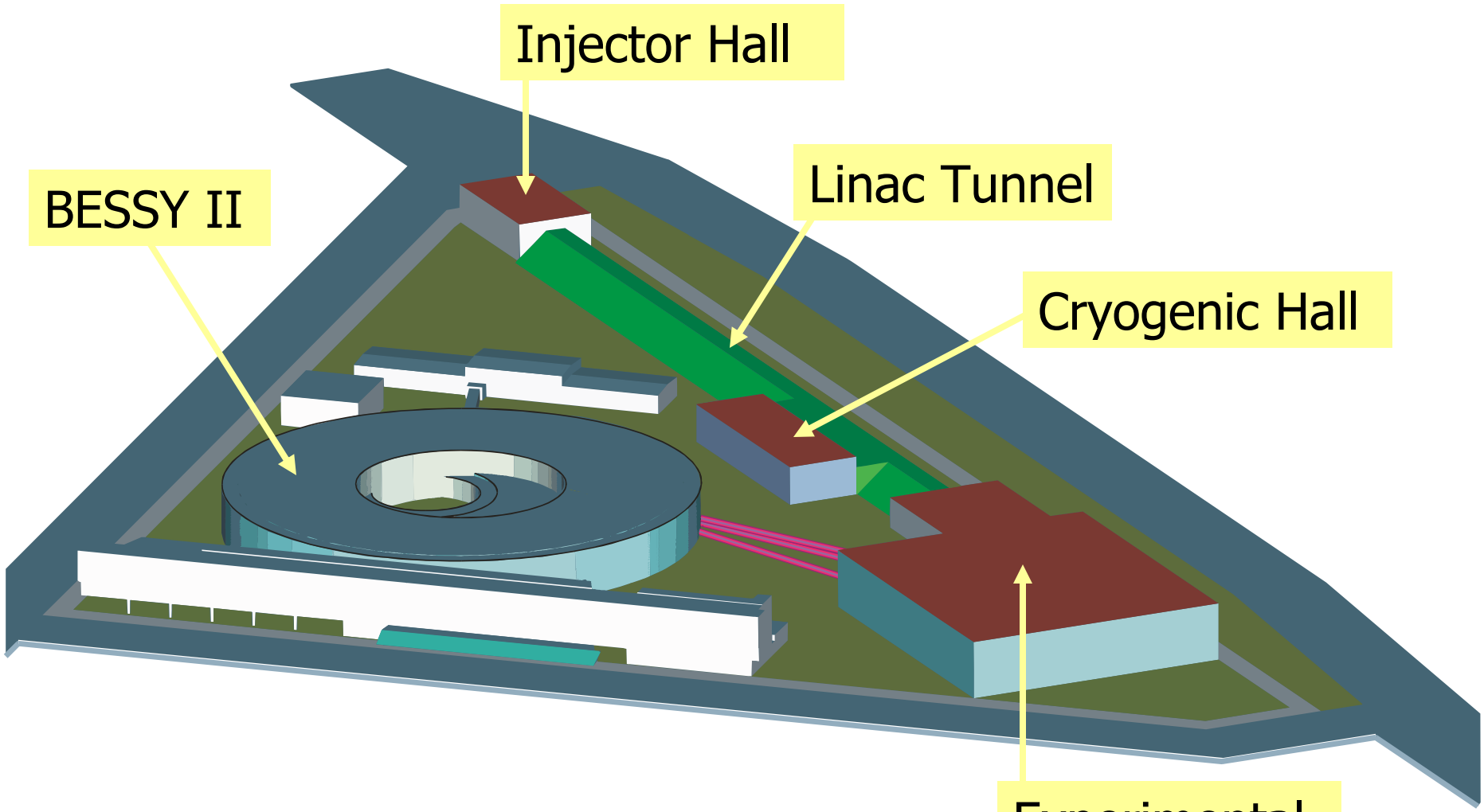
The BESSY FEL

Separate focussing undulator

(control of the β-function)

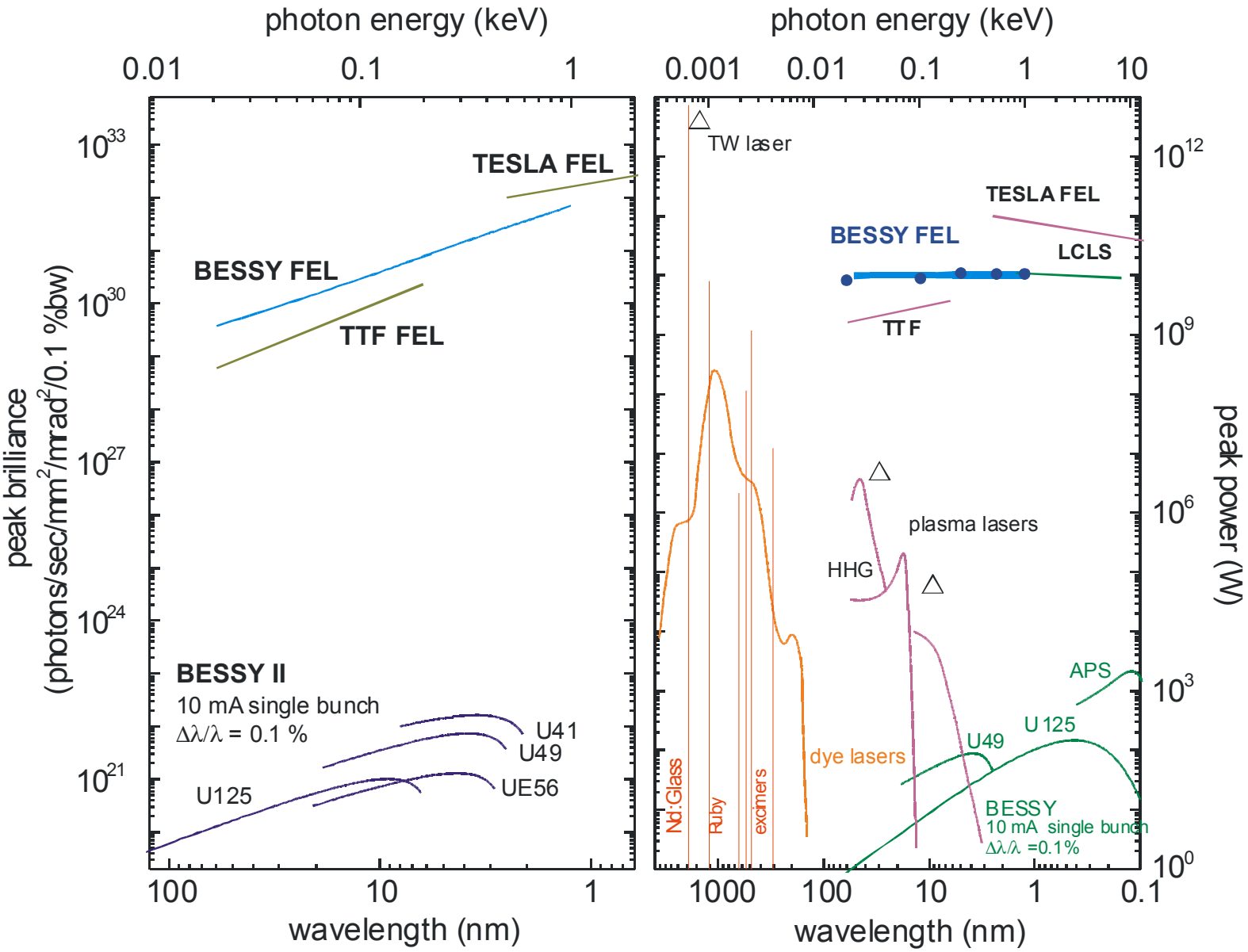


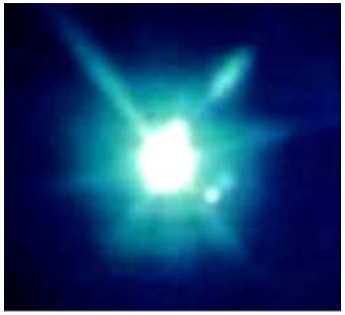
The BESSY FEL



λ > 1.2 nm (1 keV): VUV & soft X-rays

Performance

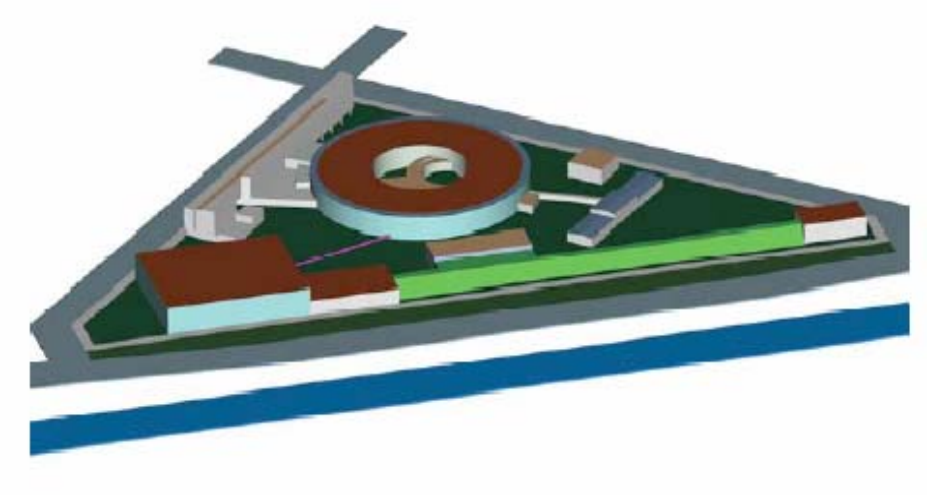




The BESSY Soft X-Ray SASE FEL

COMPLEMENTARITY of the VUV and X-RAY FEL

VUV and SOFT X-RAYS
BESSY FEL



X-RAYS
TESLA X-FEL

20 eV to 1 keV	**PHOTON ENERGY**	500 eV to 15 keV
1 mJ	**PULSE ENERGY**	1 mJ
200 fs to 20 fs	**PULSE LENGTH**	100 fs
1 kHz (1-25 pulses)	**REPETITION RATE**	5 Hz (7200 pulses)

Critical Issues

- **For any SASE-FEL Project:**
  - Stability of the electron beam
  - Diagnostics
  - Spiking nature of the SASE-FEL radiation
  - Synchronization with other laser sources
- **Specific for the BESSY SASE-FEL:**
  - Cryogenic requirements (15 MV/m, cw)
  - Optimization of the photo-injector
  - Beamlines

Summary (1)
Building of a "basic" FEL user facility
(based on super-conducting linac technology from DESY)

Goal:

- construction of a SASE-FEL for the UV to soft X-ray spectral range
- construction of three parallel SASE-FEL beamlines
- Synchronization with conventional fs laser-sources: jitter ≤ 200 fs (rms)

- $P_{peak} \geq 5$ GW*
- $\sigma_t \geq 35$ fs
- $\Delta\lambda/\lambda = 10^{-3}$

FEL	E_{max} (GeV)	λ_{min} (nm)	E_Φ (eV)
1	0.85	15.0	85
2	1.70	2.5	500
3	2.25	1.2	1000

*$B_{peak} \geq 10^{28}$ ph/sec/mm^2/mrad^2/0.1%bw)

Critical tasks:

- Injector system
- Bunch compressors
- Diagnostics
- Feedback (Microphonics, Timing ...)
- Beamlines

Major cost factors:

- Civil engineering
- Cryogenic plant
- Accelerators
- Undulators
- Beamlines

Summary (2)
Implementing FEL enhancements*

- Enhancing the spectral resolution:

  $\Delta\lambda/\lambda = 10^{-3} \rightarrow <10^{-4}$ (Seeding)

- Shortening the micro-pulse duration:

  $\sigma_t = 160$ fs $\rightarrow 20$ fs $\rightarrow$? fs

- Flexible FEL output (fast scanning, chirping, etc.)
- Increasing the average brilliance

*Not all enhancements can be obtained simultaneously