A SASE VUV/Soft X-ray Free-Electron Laser User Facility "BESSY III"

Roland Müller

Target for an FEL at BESSY:

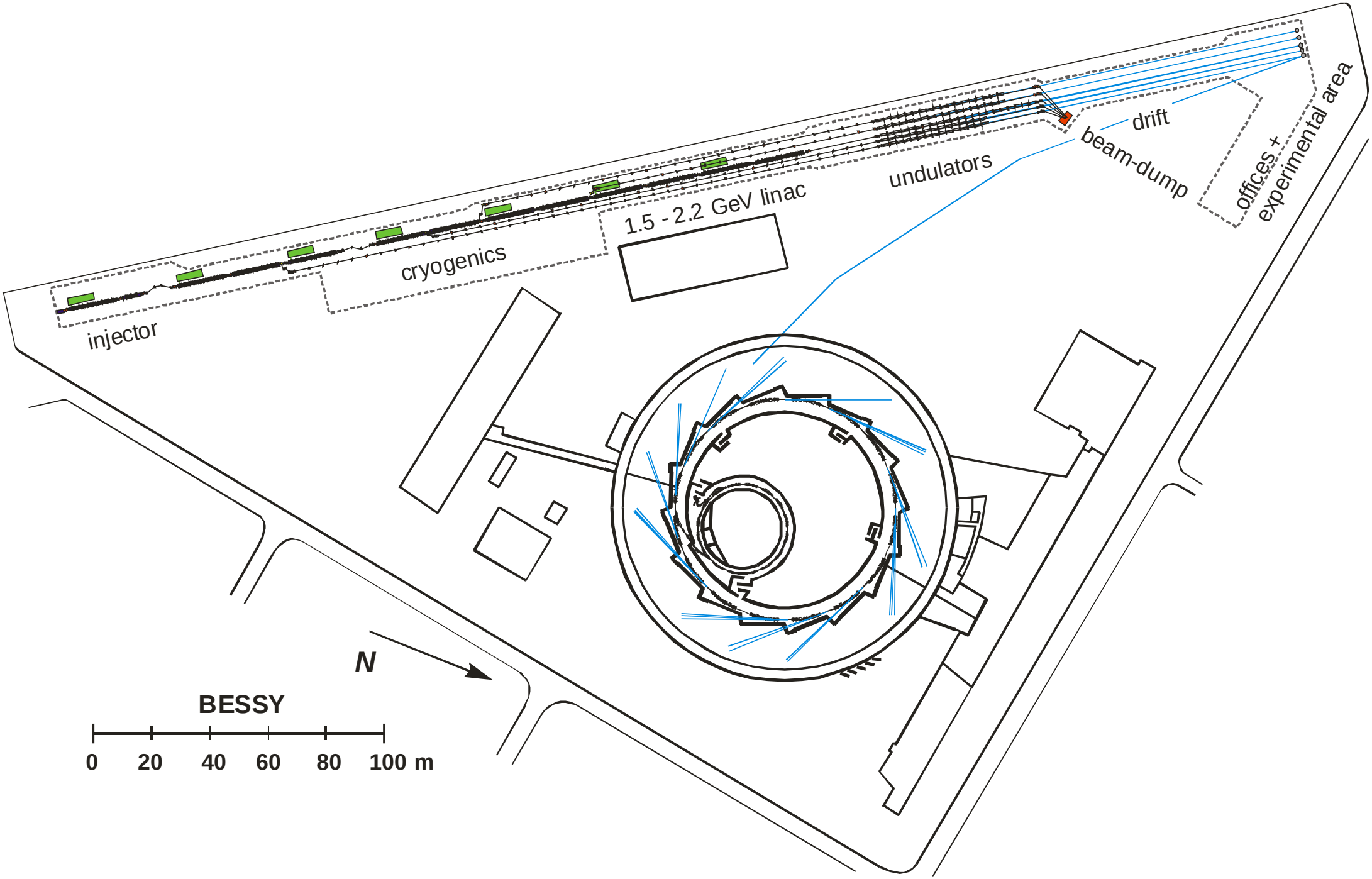
- Wavelengths down to 1.2 nm (1 keV).
- Short micro-pulses:

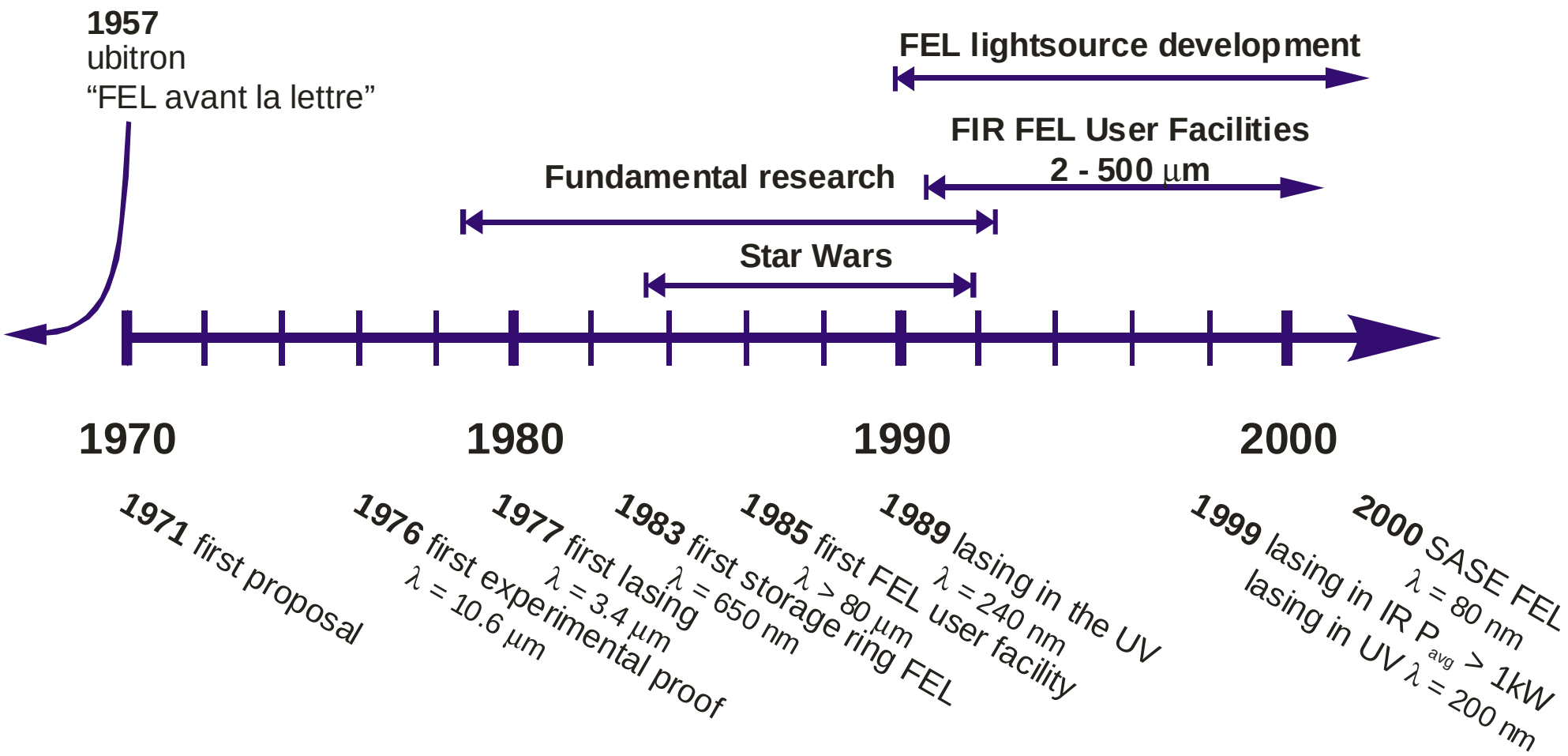
  - initially: τ = 250 fs (fwhm)

  - finally: τ = 20 fs (fwhm)
- $\Delta\lambda/\lambda = 10^{-2}$ (initial) down to 10^{-4} (final target).
- Synchronized operation with the BESSY II storage ring (pump – probe experiments)
- Time structure (macro-pulses)?

How?

- An accelerator based on the super-conducting technology developed at DESY
- Undulator technology from BESSY
- Building of the complete facility in multiple stages
  - Gradually decrease the shortest obtainable wavelength
  - Gradually include features to enhance the output of the FEL


injector
cryogenics
1.5 - 2.2 GeV linac
undulators
beam-dump
drift
offices +
experimental area
N
BESSY
0
20
40
60
80
100 m


1957
ubitron
“FEL avant la lettre”
FEL lightsource development
FIR FEL User Facilities
2 - 500 μm
Fundamental research
Star Wars
1970
1980
1990
2000
1971 first proposal
1976 first experimental proof
λ = 10.6 μm
1977 first lasing
λ = 3.4 μm
1983 first storage ring FEL
λ = 650 nm
1985 first FEL user facility
λ > 80 μm
1989 lasing in the UV
λ = 240 nm
1999 lasing in IR P avg > 1kW
lasing in UV λ = 200 nm
2000 SASE FEL
λ = 80 nm

Planning:

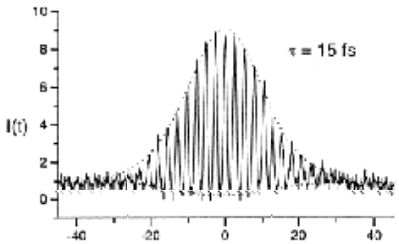
2000	First ideas
2001 – 2003	Detailed design and planning phase
2004 – ????	Construction and operation

The BESSY FEL: A Revolution in Soft X-Ray Science

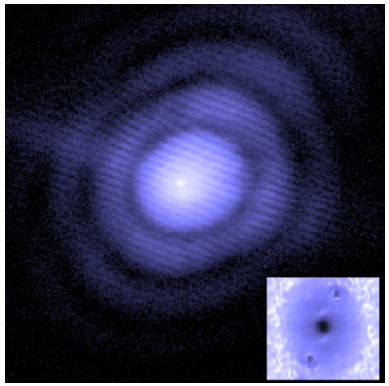
Photon Energy Range 20 eV to 1 keV

Peak Power 1mJ in 200 fs 5 GW

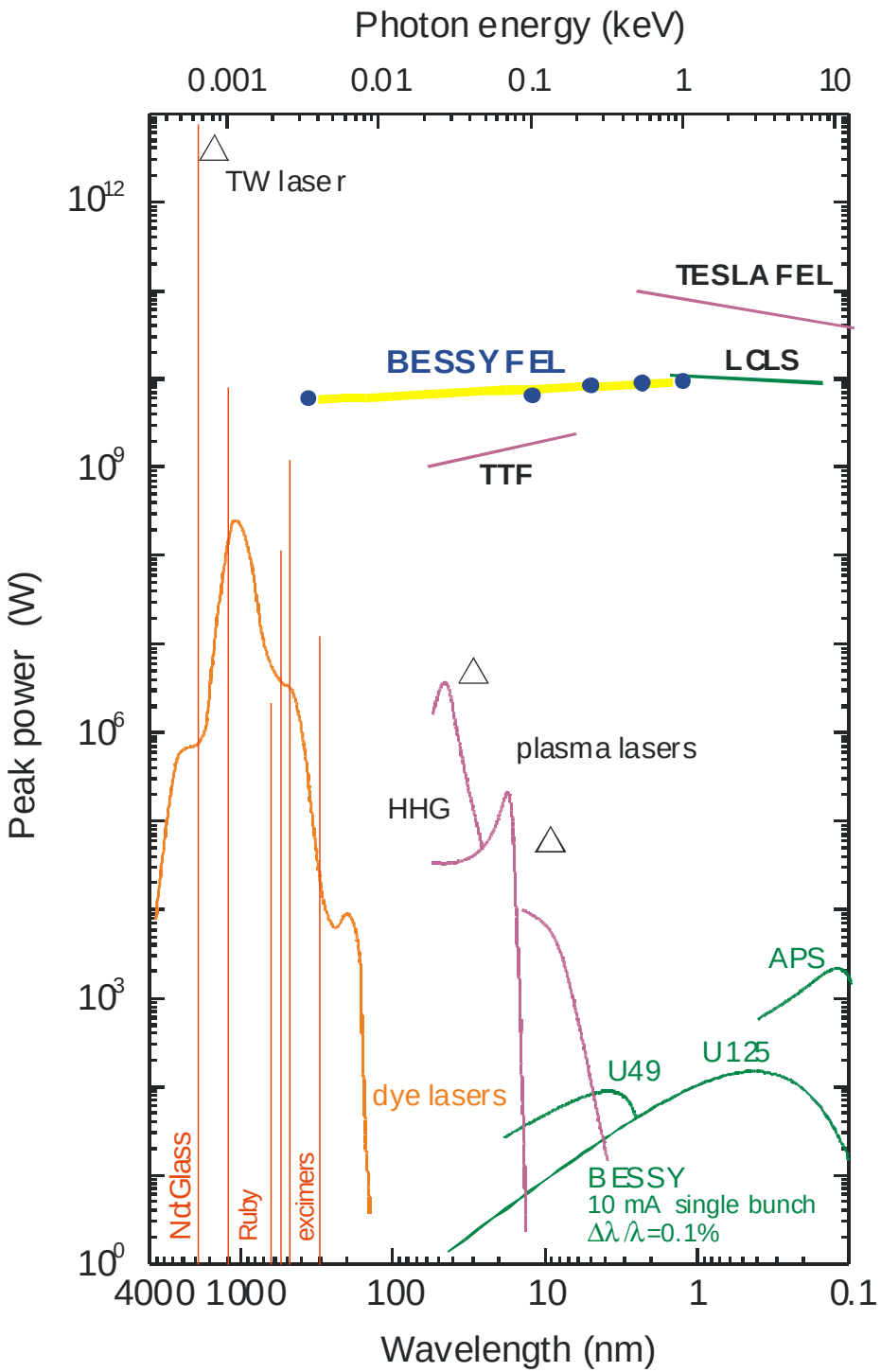
Time Structure 200 fs down to <20fs



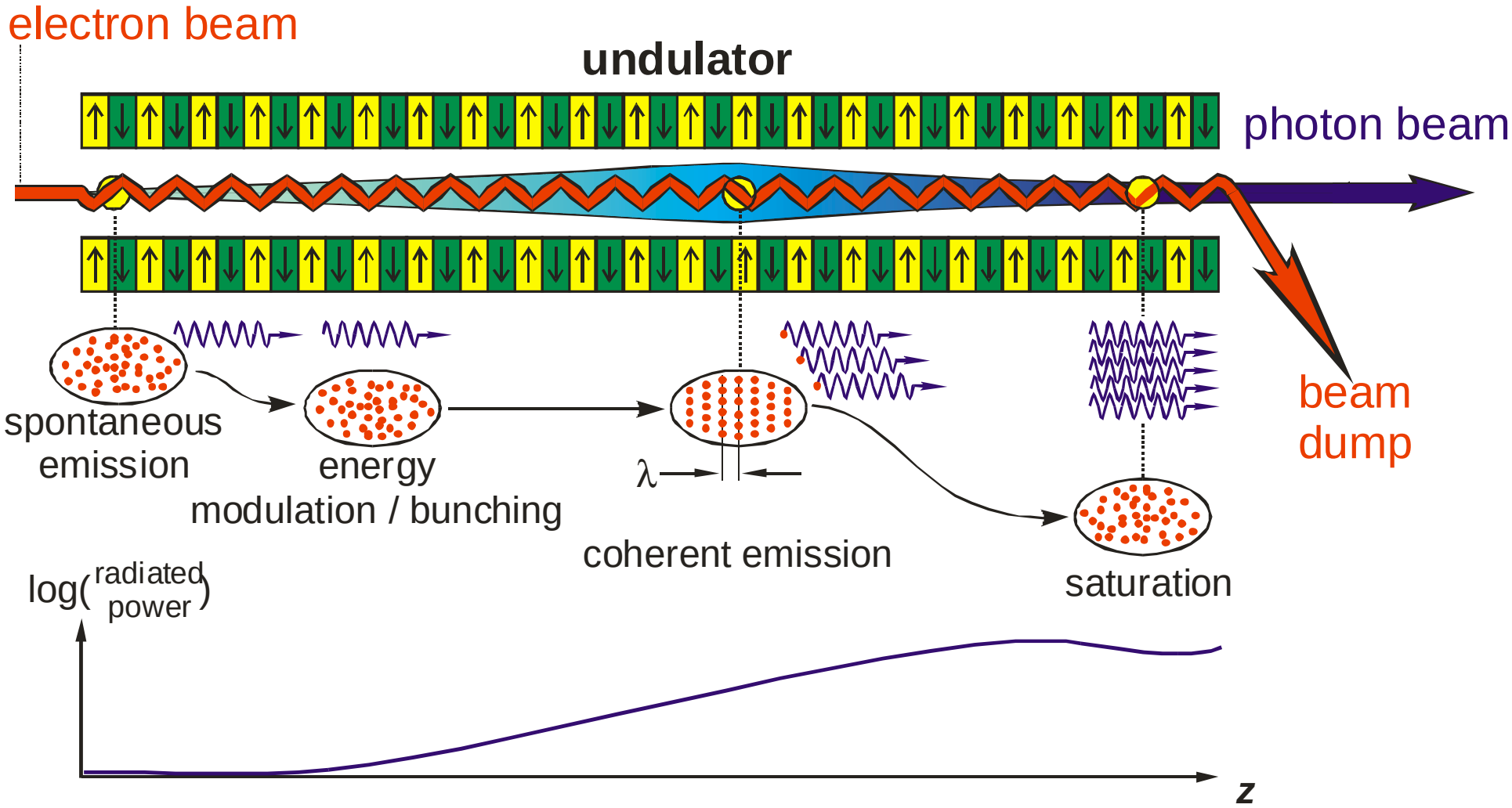
Coherence



Brightness that translates into
spectral-, spatial-, temporal- RESOLUTION

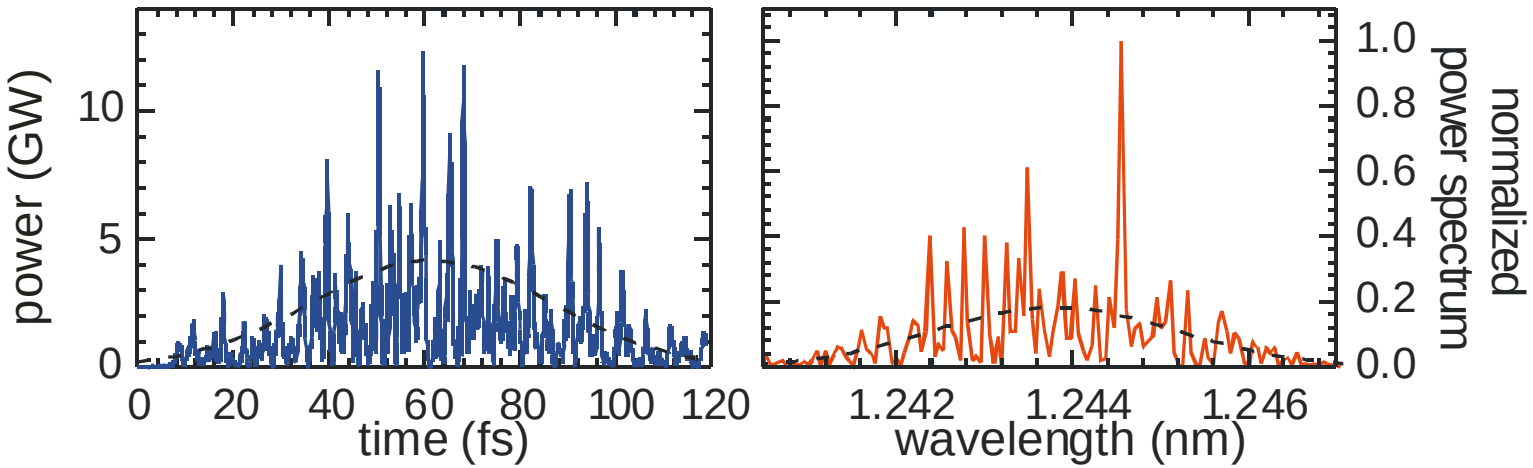

Photon energy (keV)
0.001
0.01
0.1
1
10
TW laser
TESLA FEL
BESSY FEL
LCLS
TTF
plasma lasers
HHG
APS
U125
U49
dye lasers
BESSY
10 mA single bunch
Δλ/λ=0.1%
Nd:Glass
Ruby
excimers
Peak power (W)
10^12
10^9
10^6
10^3
10^0
4000
1000
100
10
1
0.1
Wavelength (nm)

SASE FEL: *Self Amplified Spontaneous Emission*



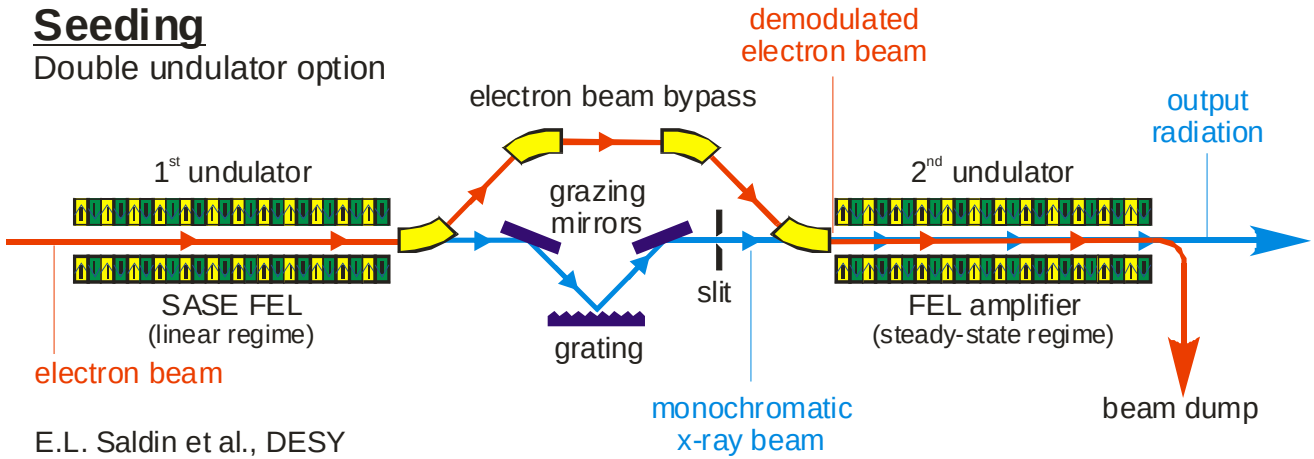
SASE FEL radiation output properties

- High power and brilliance
- Easily tunable
- Large fraction of harmonics (% level for planar undulators)
- Radiation on a pedestal of spontaneous emission
- Spiked (both in temporal and spectral domain)

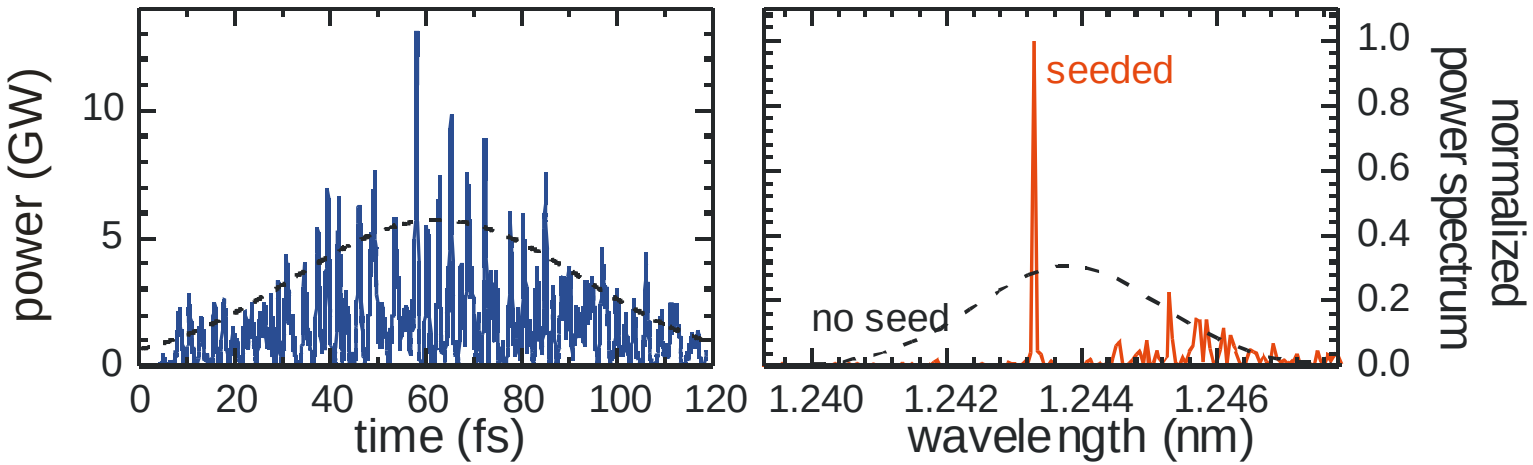


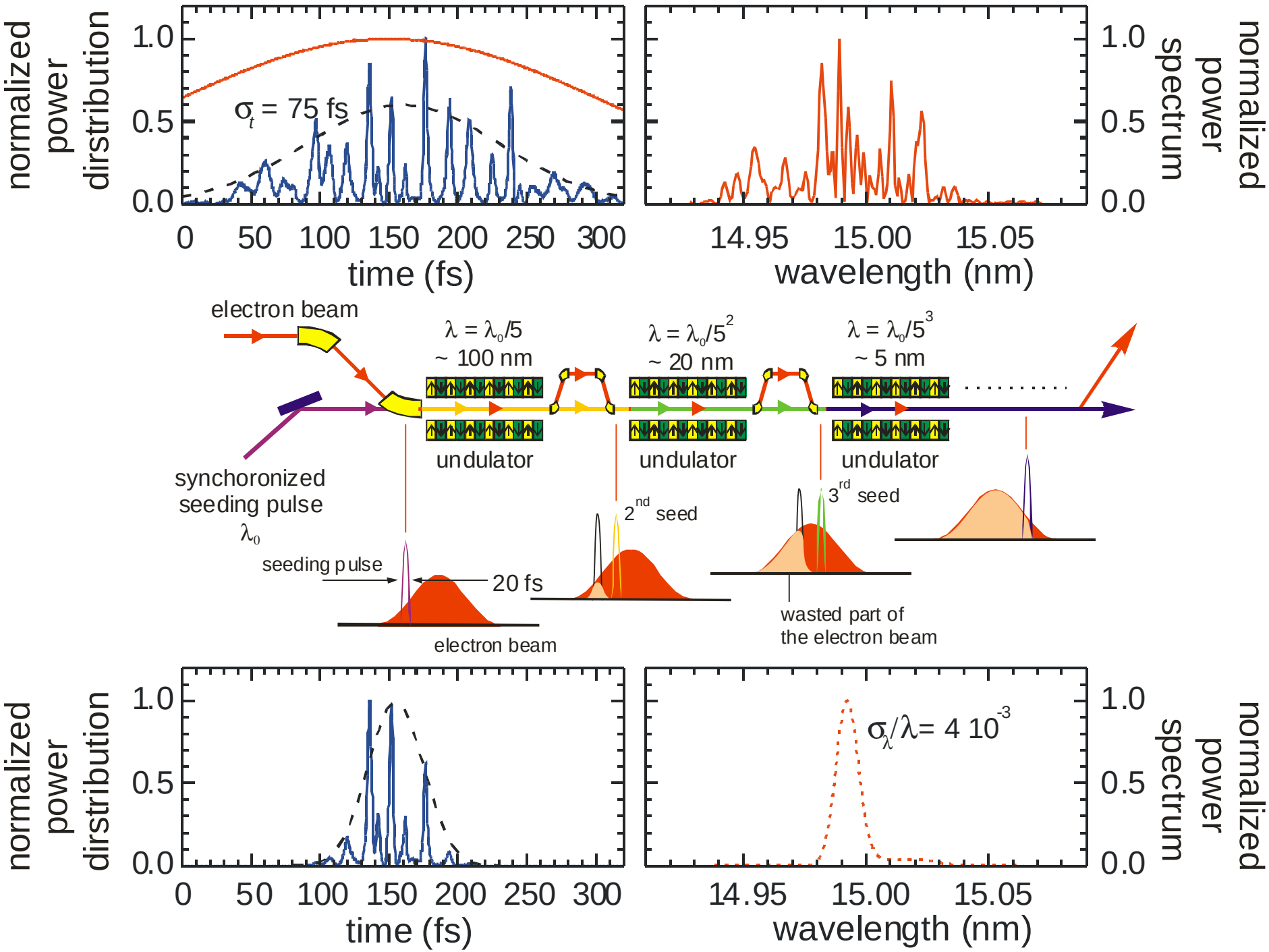
Seeding

Double undulator option



E.L. Saldin et al., DESY




normalized power dirstribution
1.0
0.5
0.0
σt = 75 fs
0
50
100
150
200
250
300
time (fs)
14.95
15.00
15.05
wavelength (nm)
normalized power spectrum
electron beam
λ = λ0/5
~ 100 nm
λ = λ0/5^2
~ 20 nm
λ = λ0/5^3
~ 5 nm
undulator
undulator
undulator
synchoronized seeding pulse
λ0
seeding pulse
20 fs
2nd seed
3rd seed
electron beam
wasted part of the electron beam
σλ/λ= 4 10^-3

Challenges for Controls

- Long undulators (50 m): stabilization to 1 μm
- Photo-injector: optimizing adaptive optics
- Fast machine protection system
- Timing: fs FEL pump pulses prepare sample for fs laser probe beam (laser jitter ≥ 200 fs)