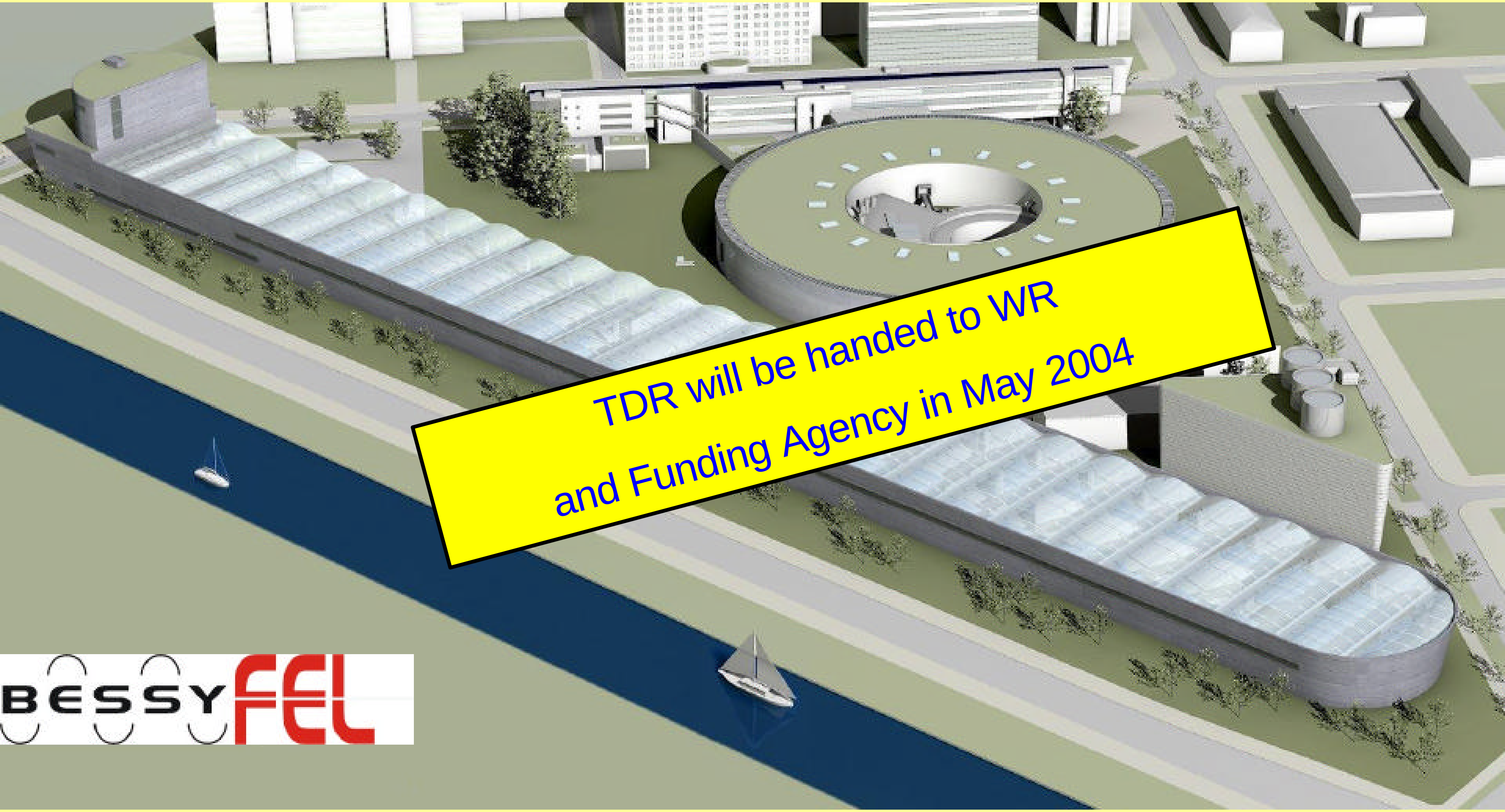
The BESSY Soft X-Ray FEL



The BESSY-FEL Design Team

since 2000

The Collaboration:

The BESSY-FEL Design Team:

M. Abo-Bakr, W. Anders, R. Bakker[$], J. Bahrdt, G. Bisoffi[&], K. Bürkmann, O. Dressler, H. Dürr, V. Dürr, W. Eberhardt, S. Eisebitt, J. Feikes, R. Follath, A. Gaupp, A. Goldammer, M. v. Hartrott, S. Heßler, K. Holldack, E. Jaeschke, Th. Kamps, S. Khan, J. Knobloch, D. Krämer, B. Kuske, P. Kuske, F. Marhauser, M. Martin, A. Meseck, G. Mishra[§], R. Mitzner, R.Müller, M. Neeb, A. Neumann, K. Ott, W. Peatman, D. Pflückhahn, H. Prange,T. Quast, M. Scheer, T. Schroeter, Senf, I. Will*, G. Wüstefeld, Y. Xiang

*[§]DVVA,Indore,, * Max-Born-Institut,[$] now Sincrotrone Trieste*
[&]INFN Legnaro

Visions of Science – the Scientific Case

Intensive Discussions with the User Community,
e.g. three major workshops
Blankensee (2000), Holzhau (2001), Motzen (2002)

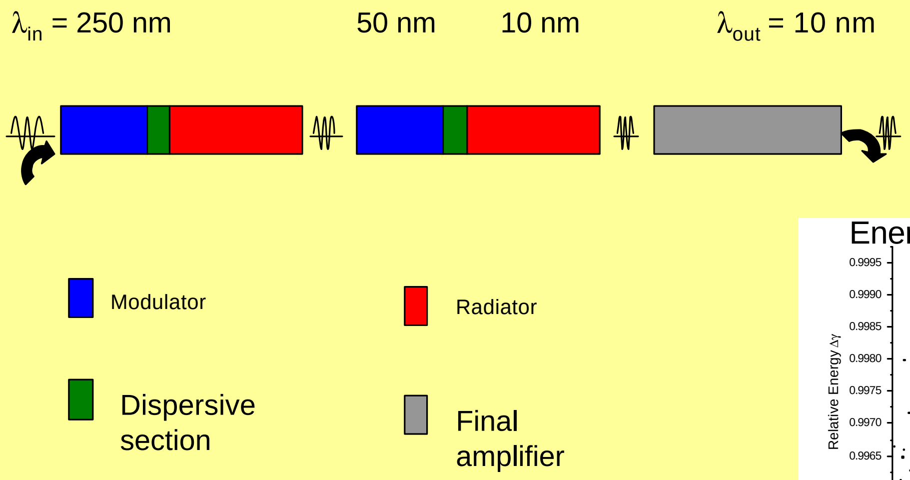
www.bessy.de/lab_profile/01.FEL/sc/index.php?language=en

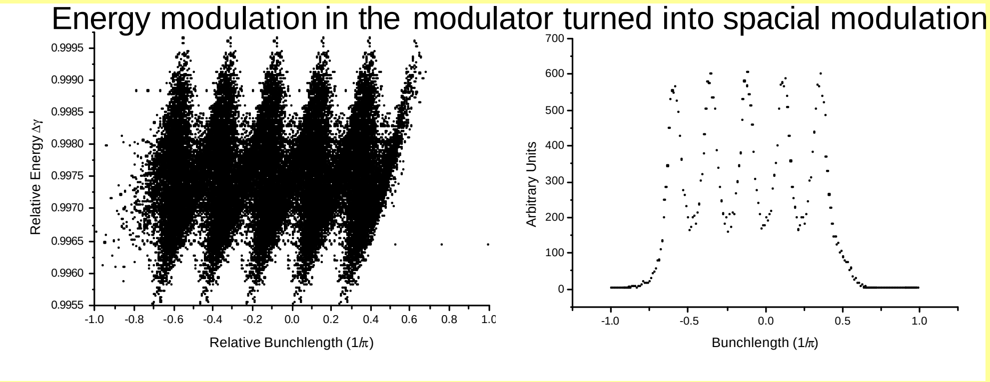
User Requirements for Next* Generation FELs

- Reproducible ultra short Pulses < 10 fs
- Shot to Shot reproducible Pulse Shape
- fs-Synchronization with Lasers for Pump/Probe Exp.
- **>> Seeded FELs**
- GW – Pulse Power
- Selectable Polarization Circularly polarized Light
- Freely selectable Pulse Repetition Rates Hz to MHz
- Freely selectable Pulse Patterns Single, Bursts, Continuous..
- Fast Switching Possibilities to different Undulators
- **>> CW-Superconducting Linacs**

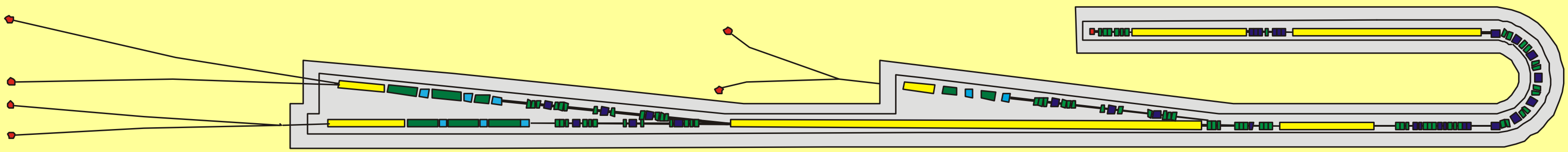
* with bias to a VUV – Soft X-Ray source

A Multi-Stage HGHG-FEL Multi-user Facility





3 FELs to span 24 eV to 1000 EV:

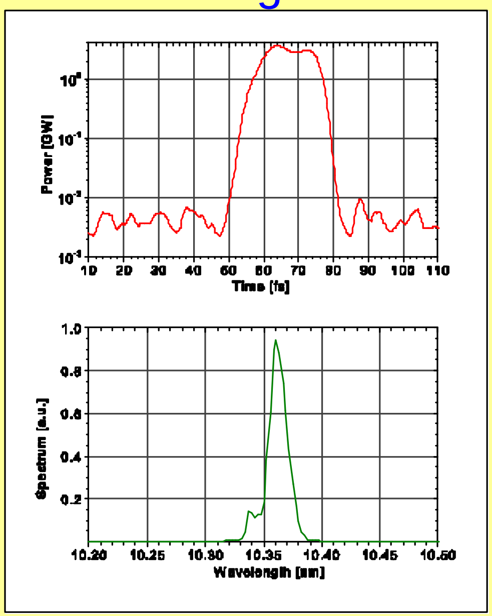


Pulse Duration and Spectra

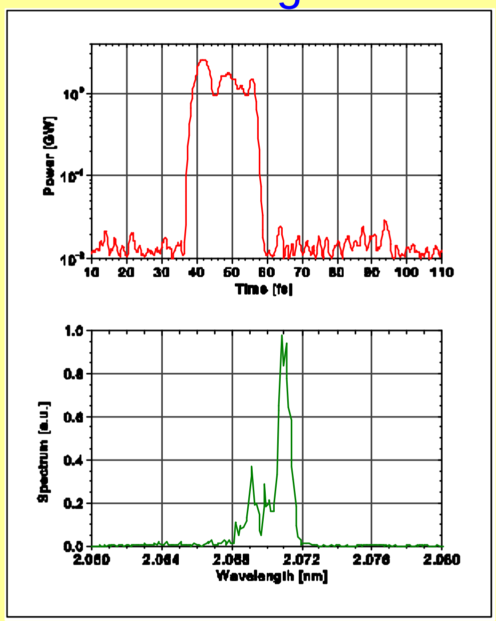
External Seed: Ti:Sa variable 460 – 230 nm, Profile:Gaussian σ_t = 17 fs

High energy end of :

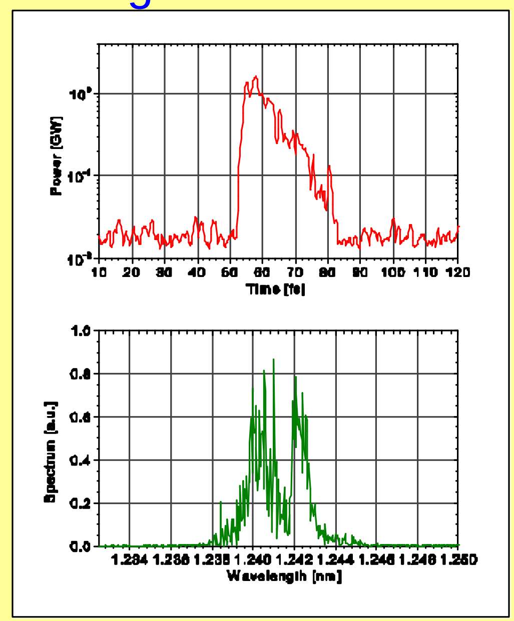
2 stage



3 stage

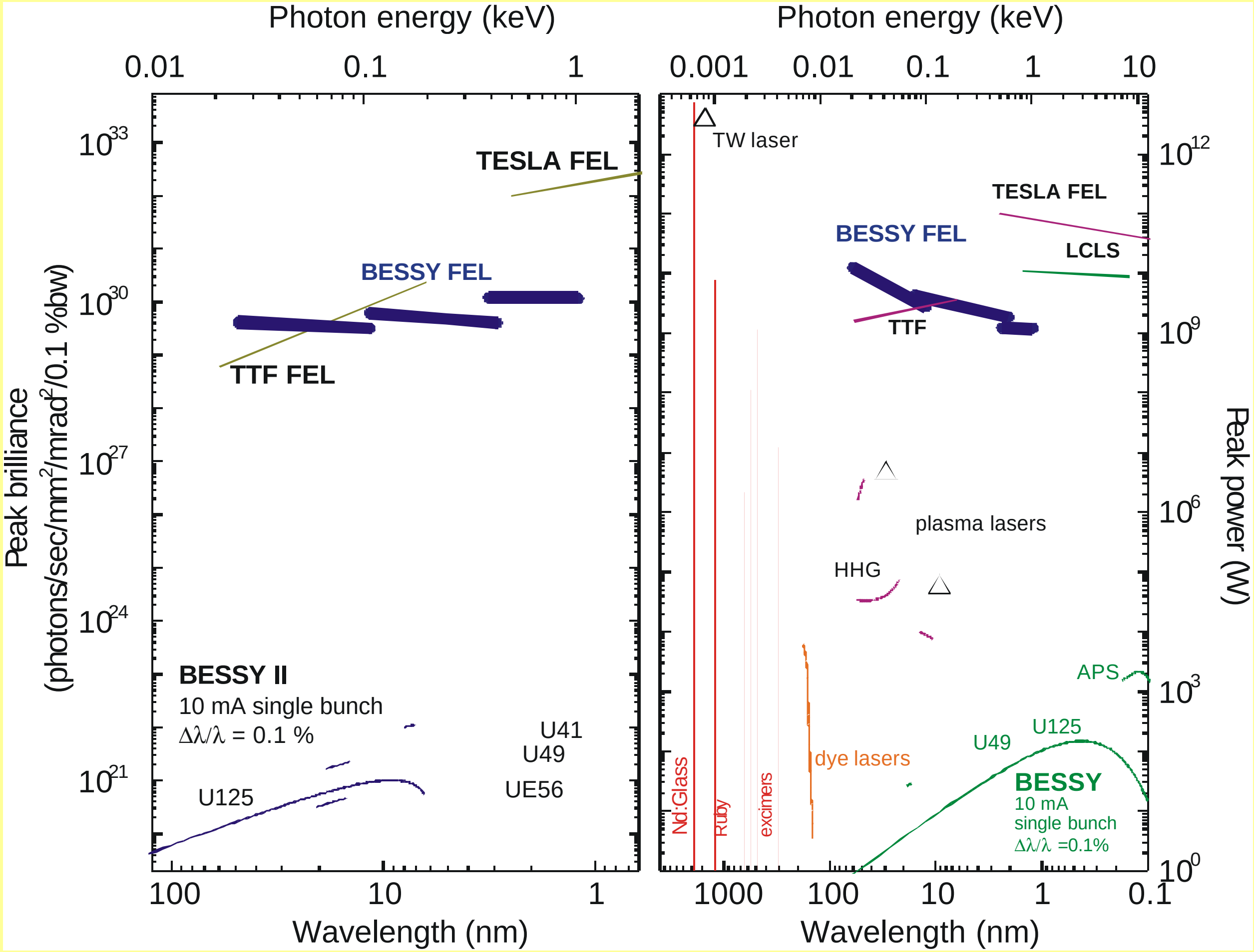


4 stage HGHG cascade

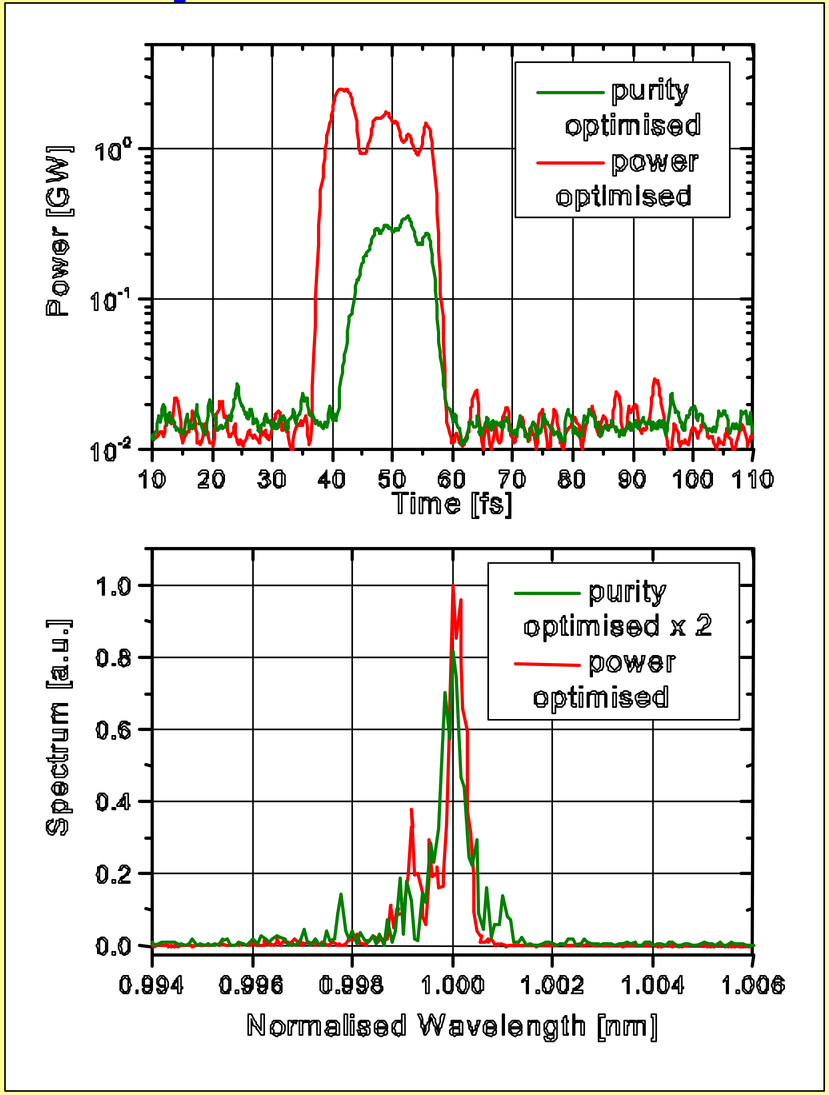


Note sidebands due to synchrotron oscillations of electrons with the strong seed field.

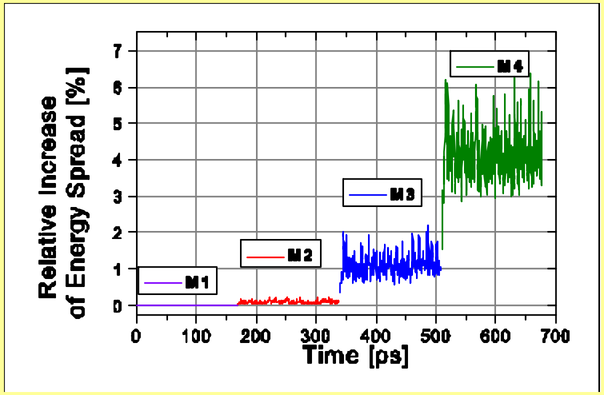
Peak Brilliance & Peak Power



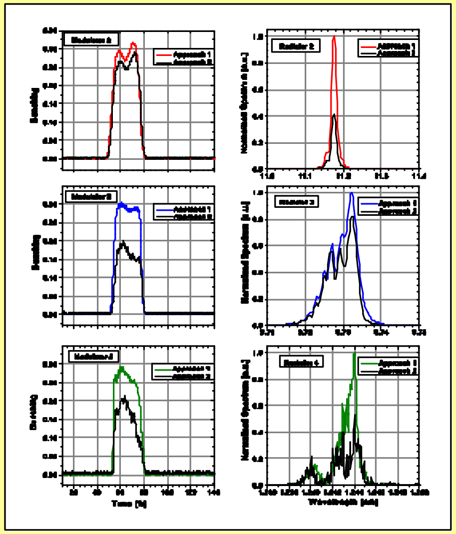
Power or Spectral Purity – what to Optimize for?

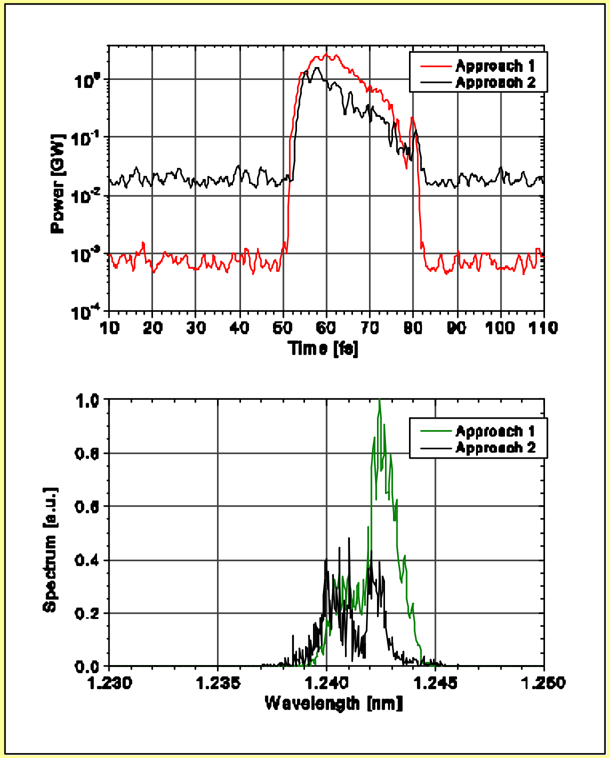


Detailed Tracking Required



Increase of energy spread while passing modulators & radiators (no seed interaction)





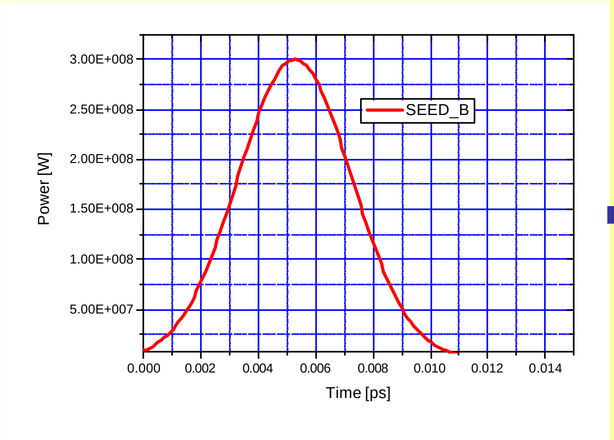
Output at 4 stage HGHG-FEL for „fresh ideal/tracked“ electron beam

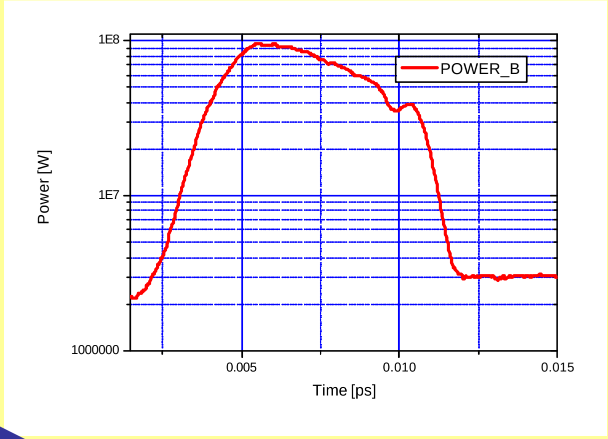
HHG Laser Seeded 2 Stage HGHG FEL

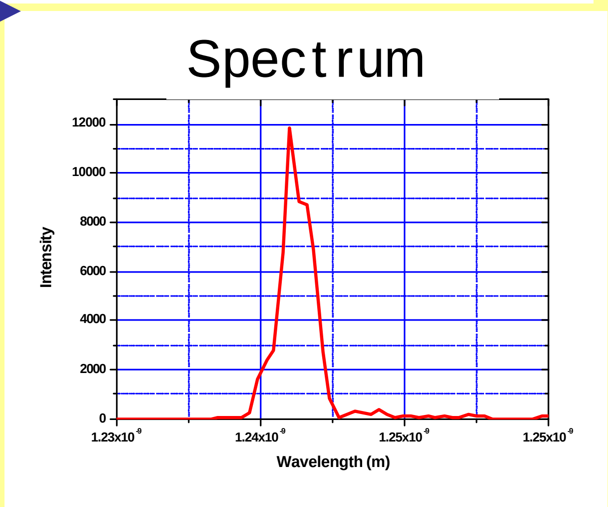
31 nm, 6 fs Seed Pulse, 300 MW

7 fs 1.24 nm FEL Pulse 100 MW

Option



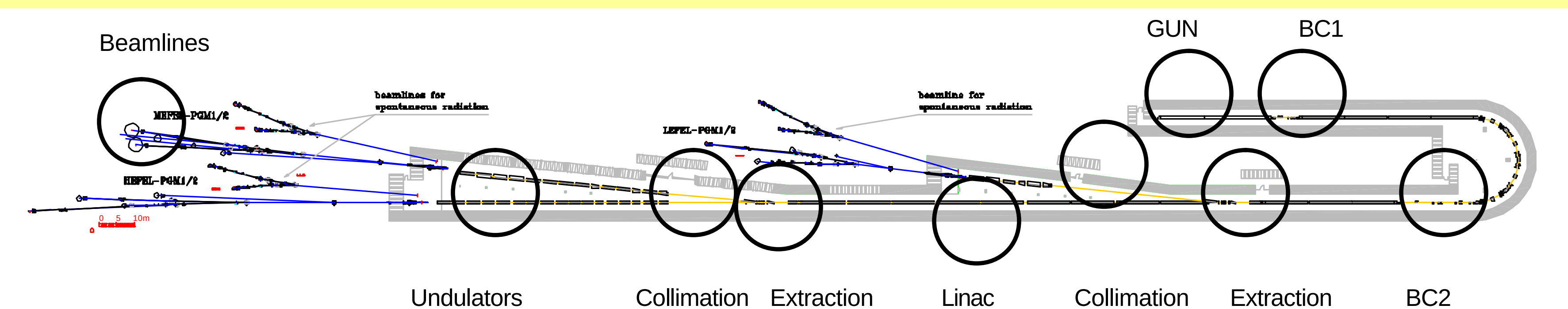




Preliminary

Technical Challenges

Gun: Low emittance PITZ-type RF photogun, later s.c. gun
Linac: TELSA modules modified for CW operation
Bunch compression: of a 2.5 nC bunch to 2kA, 1ps
Beam extraction: highly stable kickers to feed the FEL lines
Collimation: to shield the undulator sections
Undulators: APPLE II type (variable gap)
Beamlines: for short pulses, high resolution, direct beam



Pulsed and CW Photo Guns

S.C.-LINAC in CW Mode!

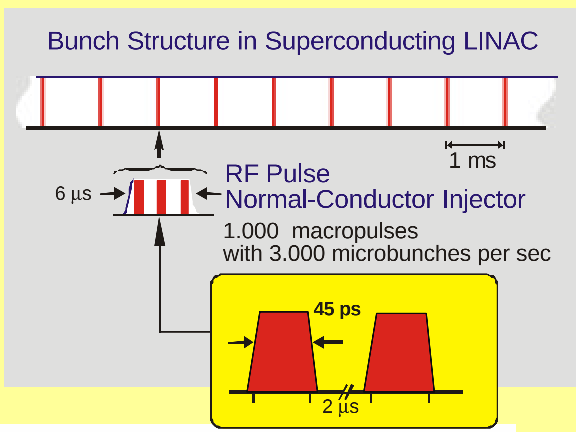
(1) Normal Conducting Photogun (PITZ Type):

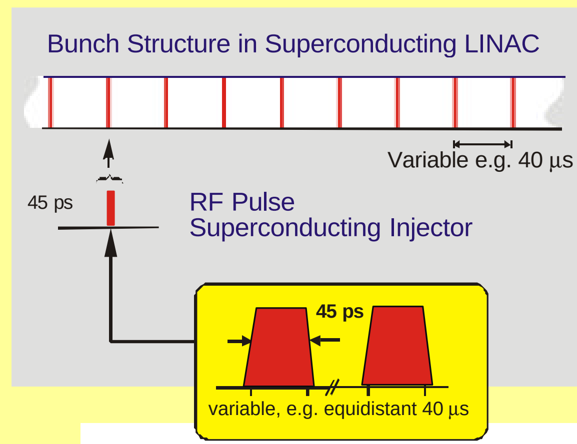
Macropulse w. Repetition Rate of 1 kHz (100kW!)

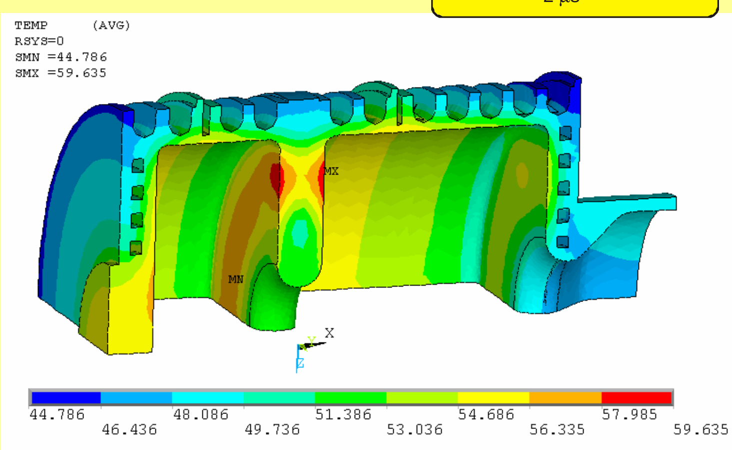
(2) Superconducting Photogun (CW):

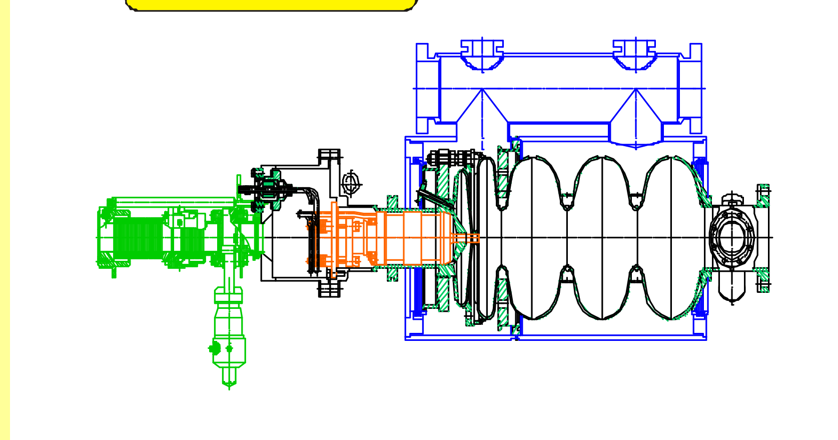
Freely selectable Pulses up to MHz Rep. Rate

Important for CW-FELs and ERLs

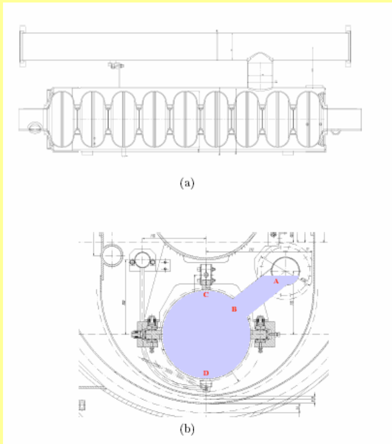








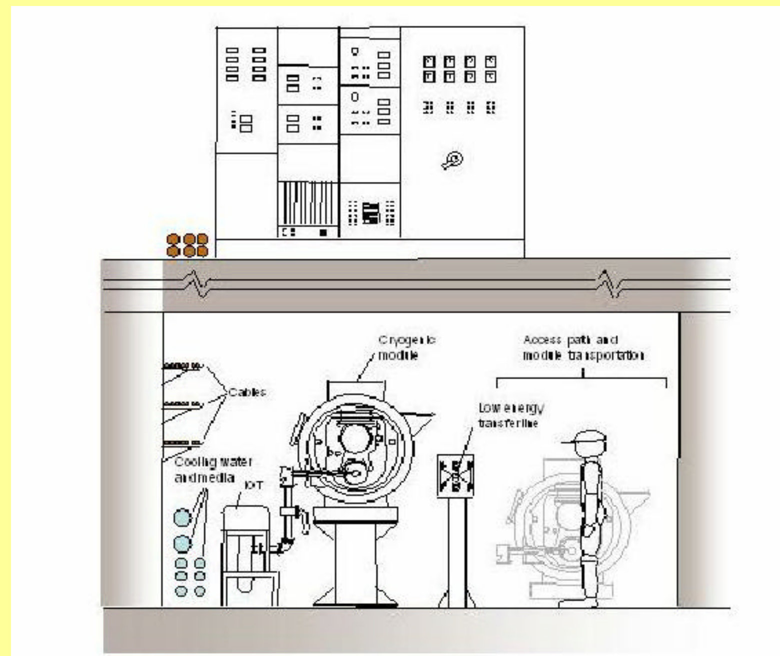
The TESLA Modules



Cross section of the modules

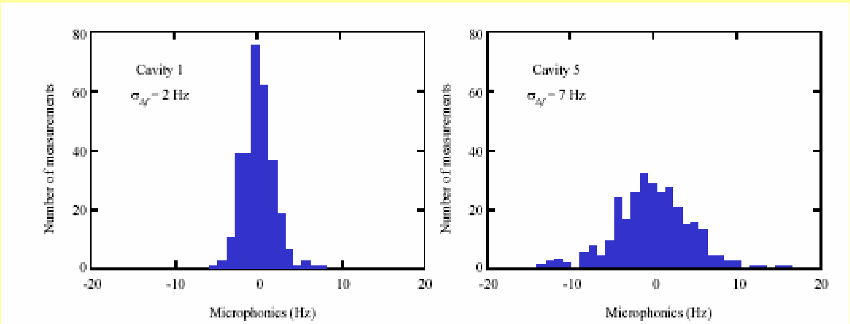
TESLA Modules at TTF

CW operation requires minor modifications at the 2pHe-line and “chimney” to cope with the 20 W heat load at 16 MV/m



Inside the BESSY CW Linac Tunnel

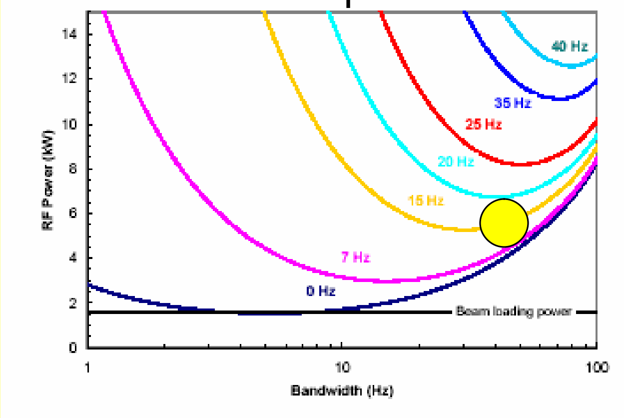
Microphonics in CW Cavities



Microphonics at TESLA cavities

Beamloading 1.2 kW/cavity
Microphonics 15 kW peak
HOM 3.5 W/cavity

RF Power Requirement

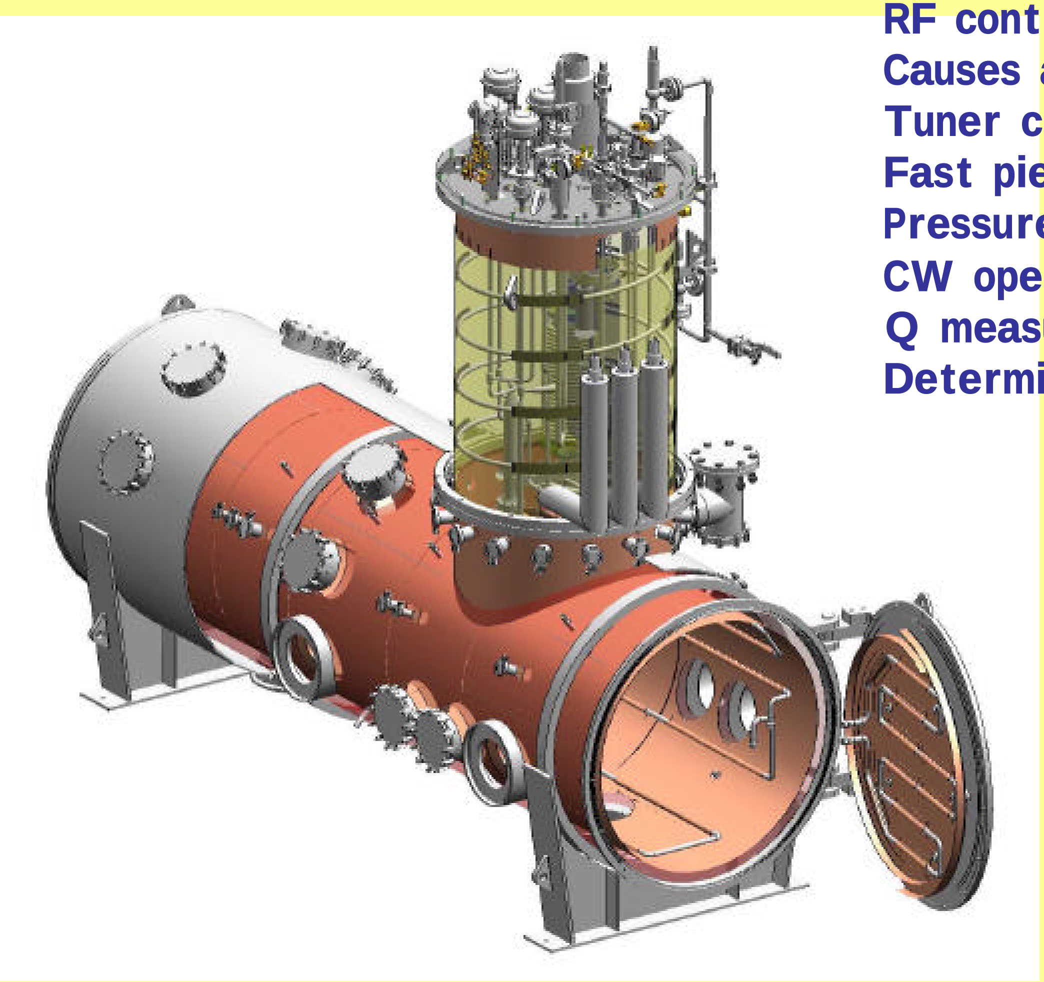


CPI IOT Prototype

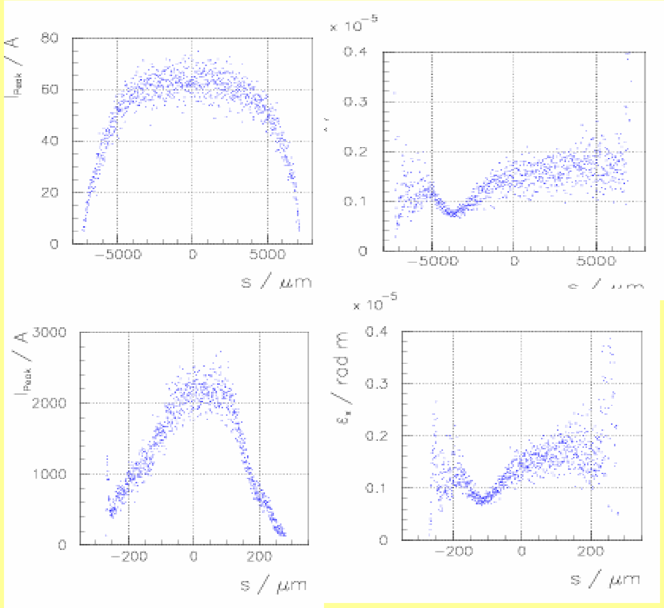
Microphonics is the dominant driving factor in dimensioning the BESSY CW RF system. (This is different to the pulsed systems such as TTF and TESLA.)

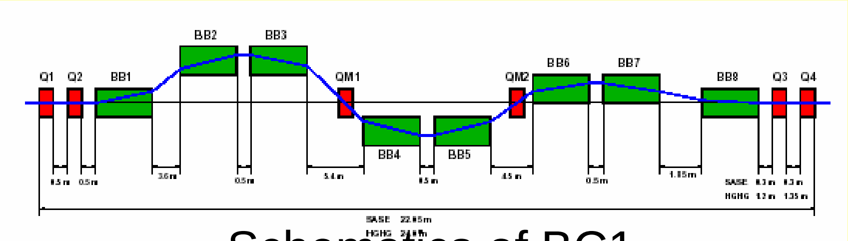
The HoBiCaT - Teststand

RF control at high loaded Q
Causes and impact of microphonics
Tuner characterization
Fast piezo tuning
Pressure stability and cryogenic operation
CW operation of input coupler
Q measurements as fn(T)
Determination of optimum bath temperature

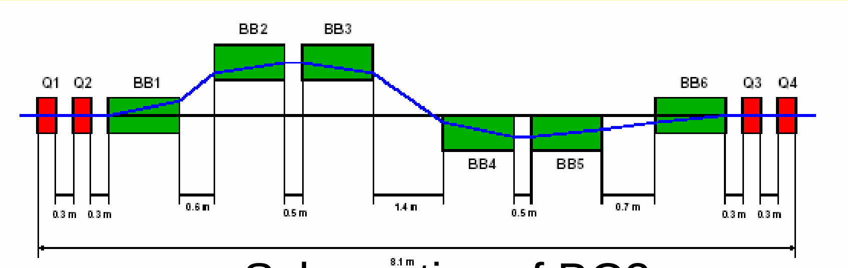


Bunch Compression





Schematics of BC1



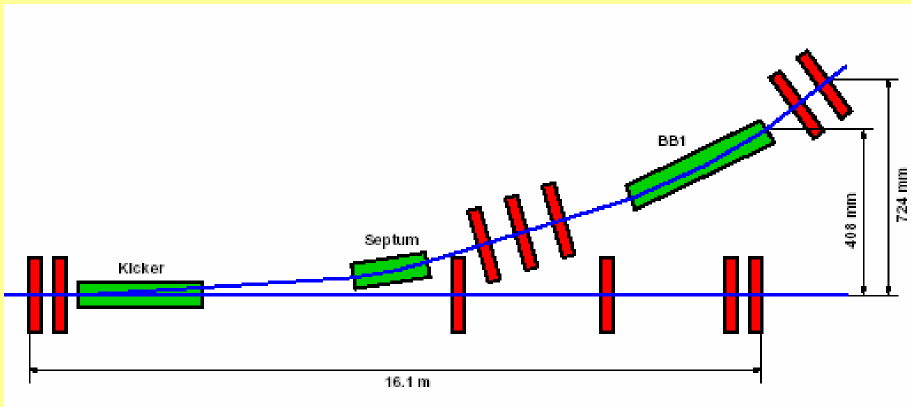
Schematics of BC2

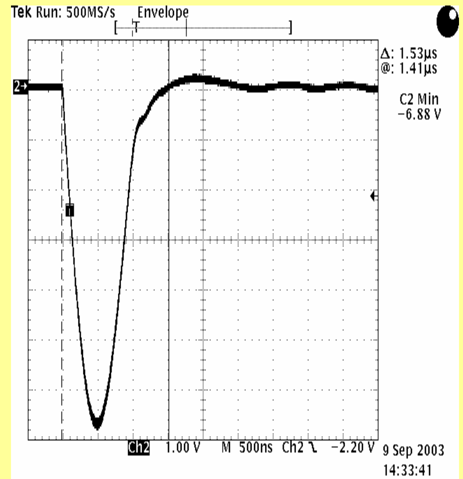
730 fs „flat top“ of < 1750 A
Incoherent energy spread: 0.01%
Av. Slice emittance: 1.6 mm mrad

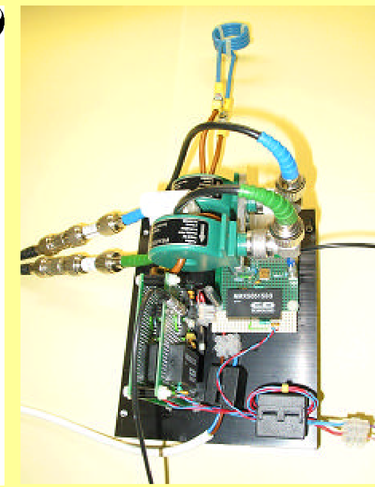
	E (MeV)	σ_l (mm)	I_p (A)	$\varepsilon_{x,n}$ (mm·rad)	$\varepsilon_{y,n}$ (mm·rad)	$\sigma_{p/p}$ (0.1%)
Before BC1	208	13.0	65	0.79	0.81	29.6
After BC1	208	2.6	300	0.80	0.92	29.5
After Arc	748	2.1	450	3.81	1.17	10.5
After BC2	748	0.4	2000	3.77	1.17	10.2
End of linac	2300	0.4	2000	3.77	1.17	3.9

Projected values

Extraction Kicker Stability







Kickers: 5 magnets of 2.5 m length, magnetic gap 12 mm.

Pulsers: IGBTs produce a sinus half wave at 1 kHz rep. rate

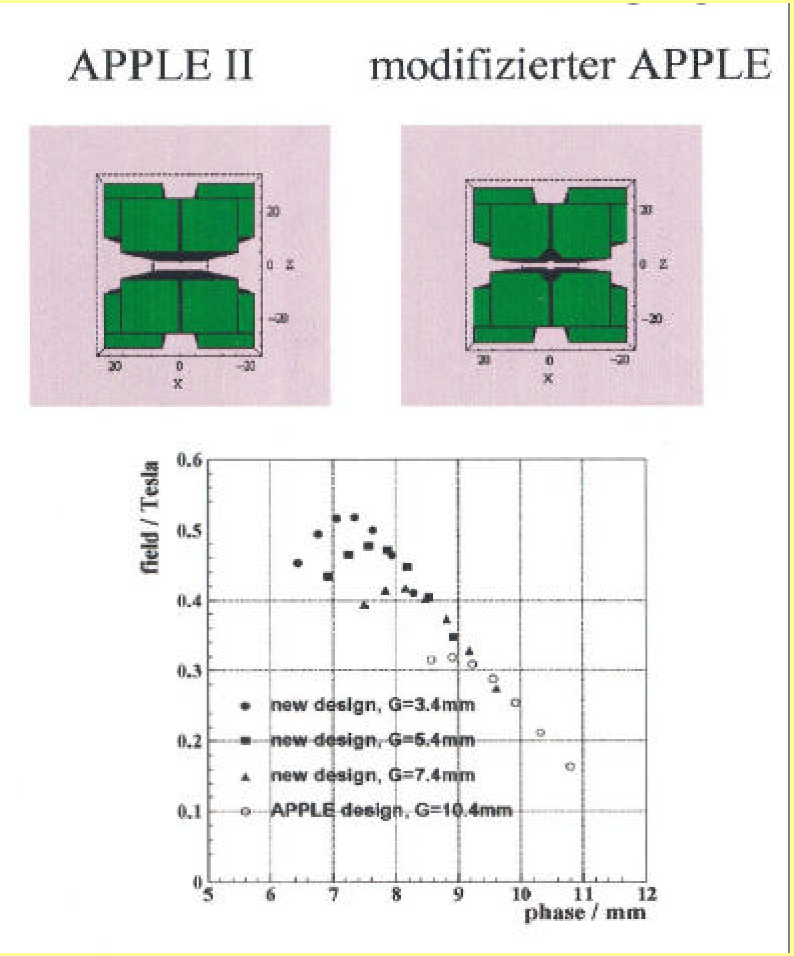
Relative amplitude stability needed : $5 \cdot 10^{-5}$

Stability already < $3 \cdot 10^{-4}$. Need Faraday Effect detection system to improve sensitivity.

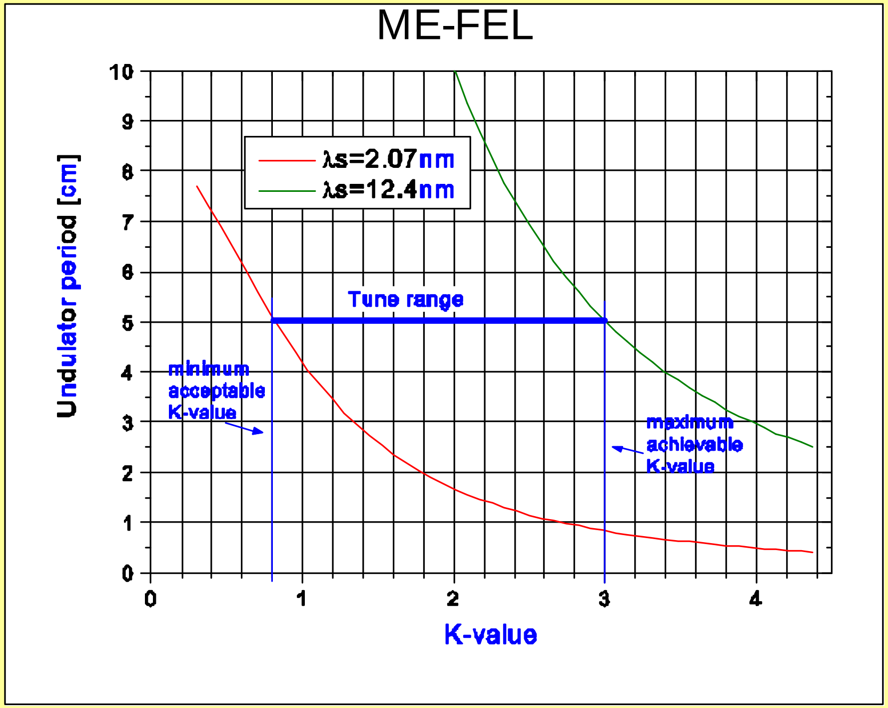
New Undulator Design

- 9 Modulators (planar)
- 6 Radiators (planar)
- 3 Radiators (helical)
- 3 Final Amplifieres (helical)
- 120 m in total

- Helical: APPLE II type and
- modified elliptical undulator
- increase of K by approx. a factor 1.5



Tuning Range and Wiggler Parameters



4 stage 500 – 1000 eV

Stage	MODULATOR l_U [mm]	MODULATOR L [m]	RADIATOR l_U [mm]	RADIATOR L [m]
1	122	2.196	92	3.680
2	92	2.024	70	6.020
3	70	2.100	50	9.000
4	50	3.450	28.5	6.413
Final			28.5	17.955

3 stage 100 – 600 eV

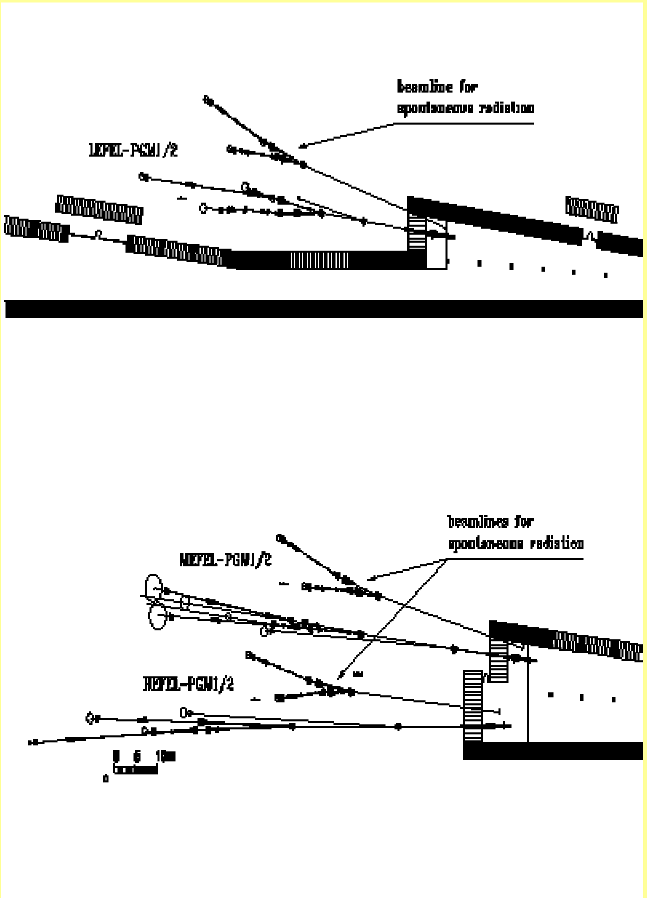
Stage	MODULATOR l_U [mm]	MODULATOR L [m]	RADIATOR l_U [mm]	RADIATOR L [m]
1	122	2.196	92	3.680
2	92	2.024	70	7.280
3	70	2.100	50	11.550
Final			50.	19.650

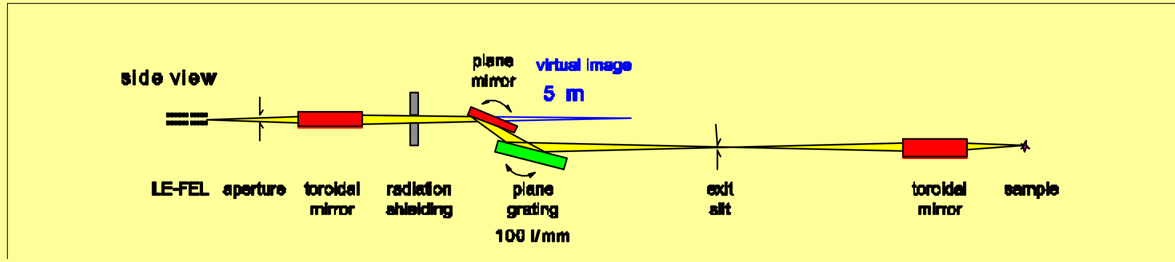
2 stage 24 – 120 eV

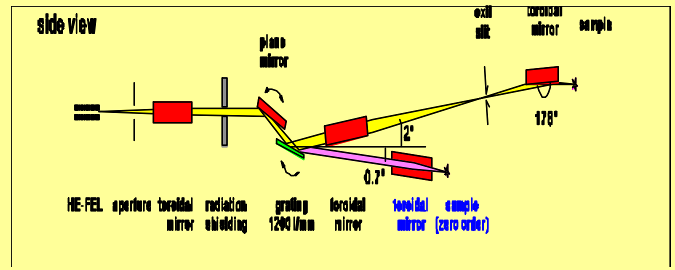
Stage	MODULATOR l_U [mm]	MODULATOR L [m]	RADIATOR l_U [mm]	RADIATOR L [m]
1	80	1.600	62	3.472
2	62	1.612	50	3.450
Final			50	8.100

Beam energy: 1.02 GeV for LE-FEL, 2.3 GeV for ME-FEL, 1.6 – 2.3 GeV for HE-FEL

Beamline Design

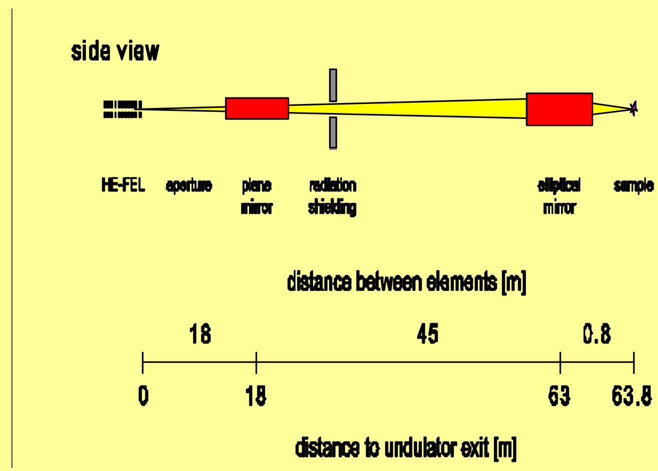




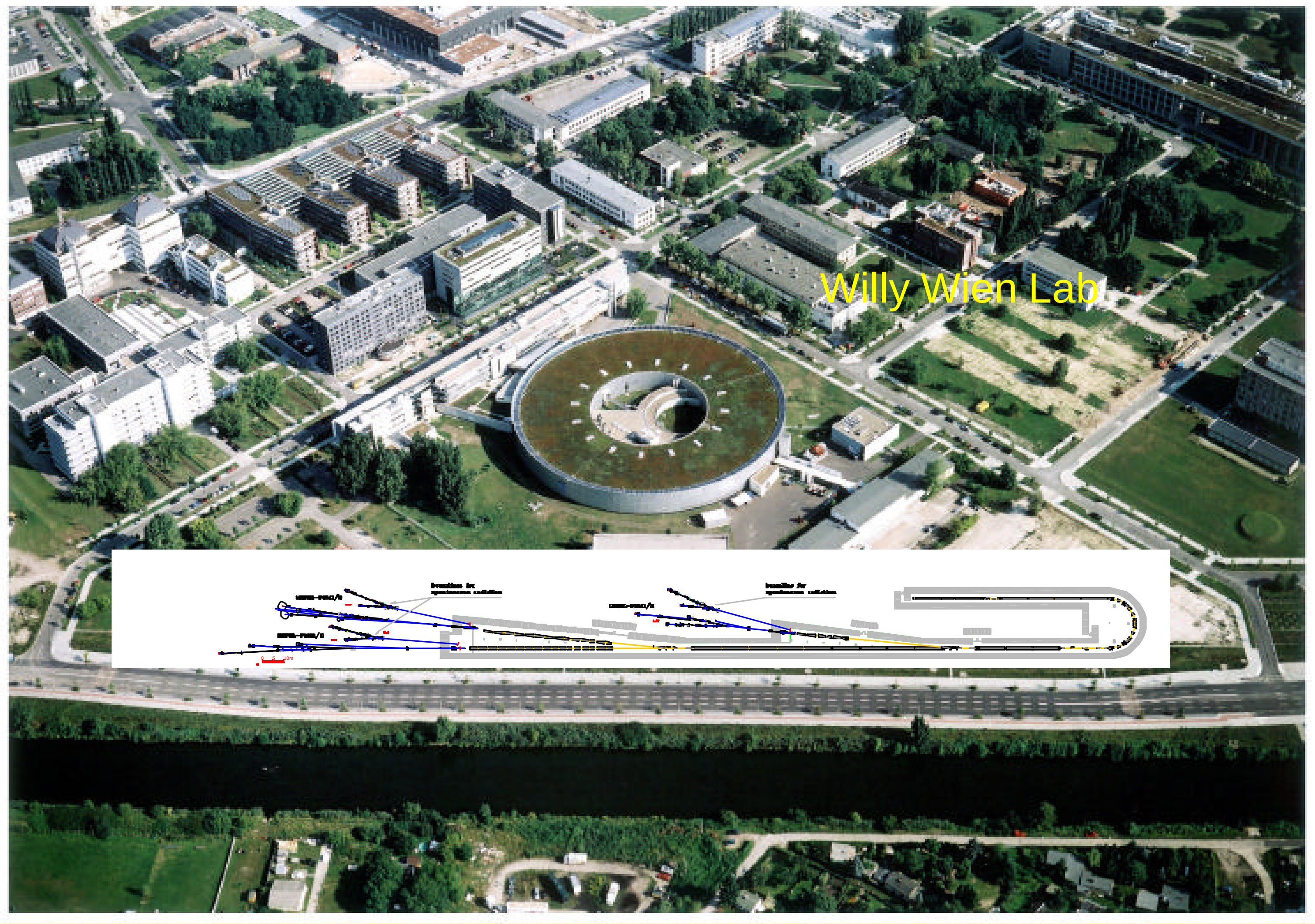


Beamlines for:

- High resolution
- Short pulse
- Direct beam



BESSY II & the Soft X-Ray FEL



D. Krämer, BESSY-FEL Design Team

BNL Workshop Feb. 18/19, 2004

Road Map

TDR ready	March 2004
WR meeting	May 2004
Decision	??
Planning	+ 2 y
Construction	+ 4 y
First experiments	

possible by end of 2010