First lasing at the ELBE mid IR FEL

Peter Michel , Forschungszentrum Rossendorf , PF 510119, 01314 Dresden , Germany
p.michel@fz-rossendorf.de

- ELBE facility - overview
- ELBE FEL
- First lasing and results
- What's next ?

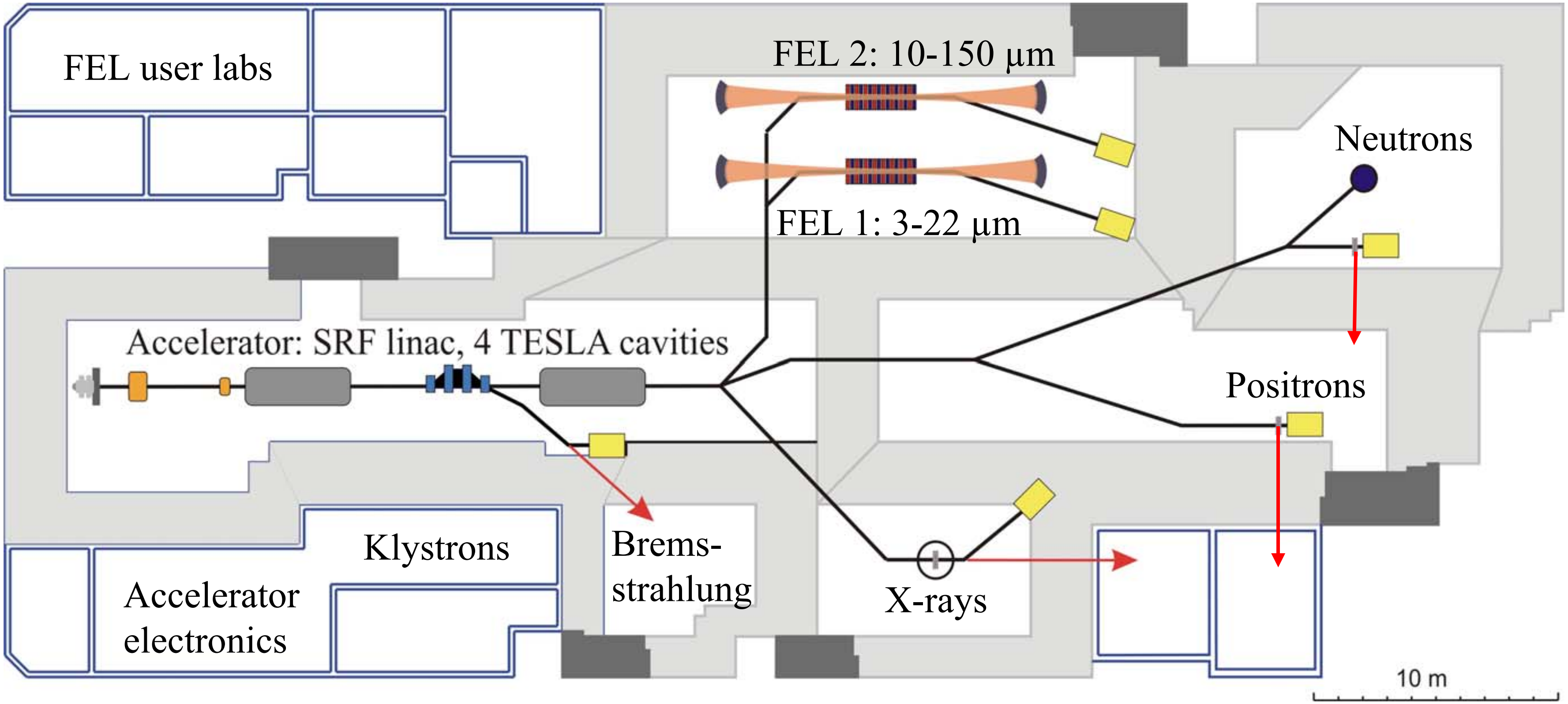
Radiation source ELBE

superconducting **E**lectron **L**inac of high **B**rilliance and low **E**mittance

Electron beam
40 MeV
1 mA
CW

γ-radiation	0 – 20 MeV	nuclear physics
X-rays	10 – 100 keV	radiation physics
Infrared	3 – 150 μm	FEL lab
Neutrons	0 – 30 MeV	neutron physics
Positrons	0 – 30 keV	materials research (EPOS)

The radiation source ELBE

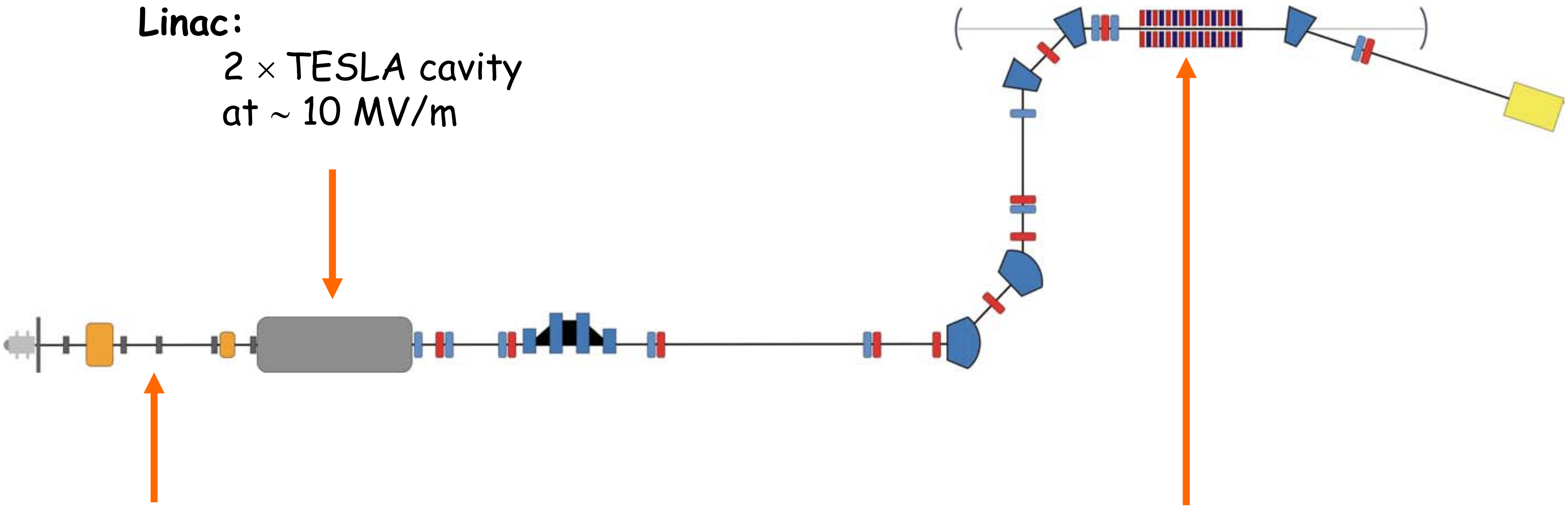


- Nuclear physics experiments are running since January 2002
- Channeling radiation since September 2003
- FEL 1 first lasing 7.05.2004; 3 W @ 19.8 µm (FEL 2 in the design phase)
- Neutron and Positrons planned for 2005

ELBE FEL layout

Linac:

2 × TESLA cavity
at ~ 10 MV/m



Injector:

250 keV
13 MHz CW
< 77 pC
8 mm×mrad @ 77 pC
450 ps compressed to 10 ps

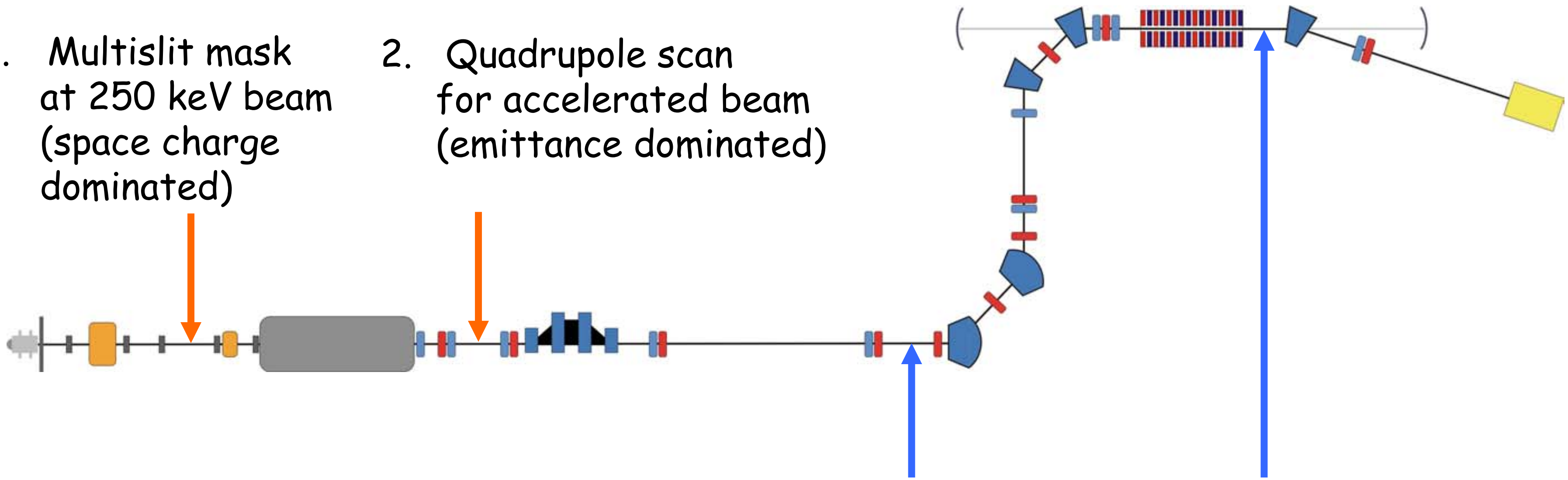
Undulator:

27.3 mm period
2 × 34 periods
K_{rms}=0.8 @ 12 mm gap

Electron beam diagnostics

I. Emittance:

1. Multislit mask at 250 keV beam (space charge dominated)
2. Quadrupole scan for accelerated beam (emittance dominated)



II. Bunch length:

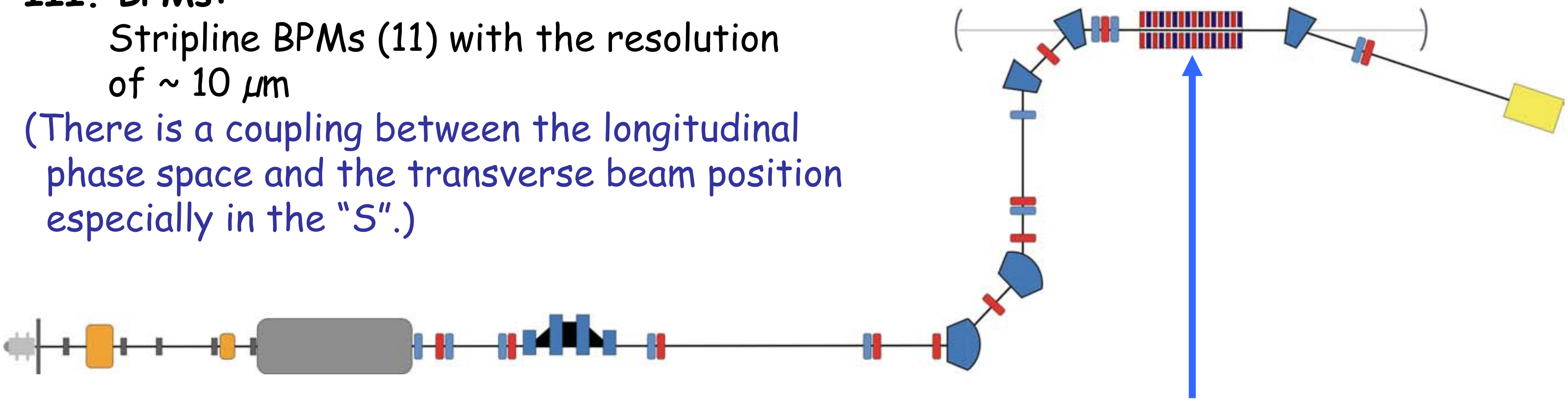
1. Martin-Puplett interferometer
2. Golay cell to minimize the bunch length observing CTR (Before the "S" and in the undulator vicinity)

Electron beam diagnostics (2)

III. BPMs:

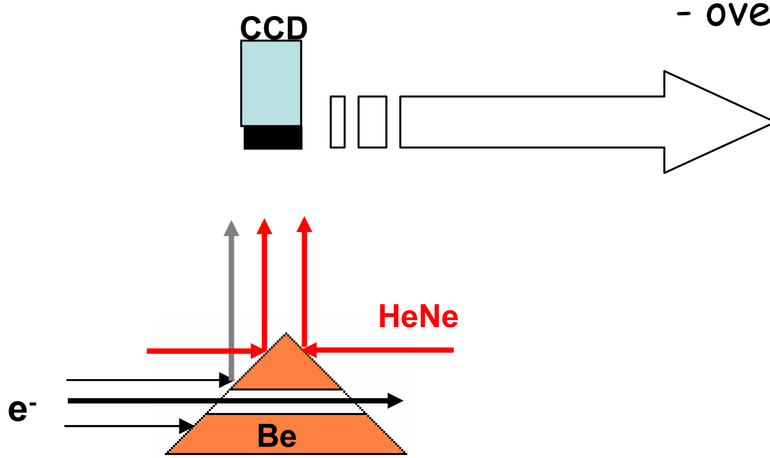
Stripline BPMs (11) with the resolution of ~ 10 μm

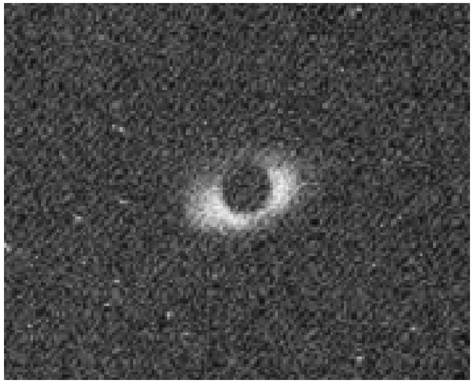
(There is a coupling between the longitudinal phase space and the transverse beam position especially in the “S”.)



IV. Precise view screens in the undulator:

- electron beam position
- betatron tune
- overlap with the optical mode





Main parameters of the ELBE FELs

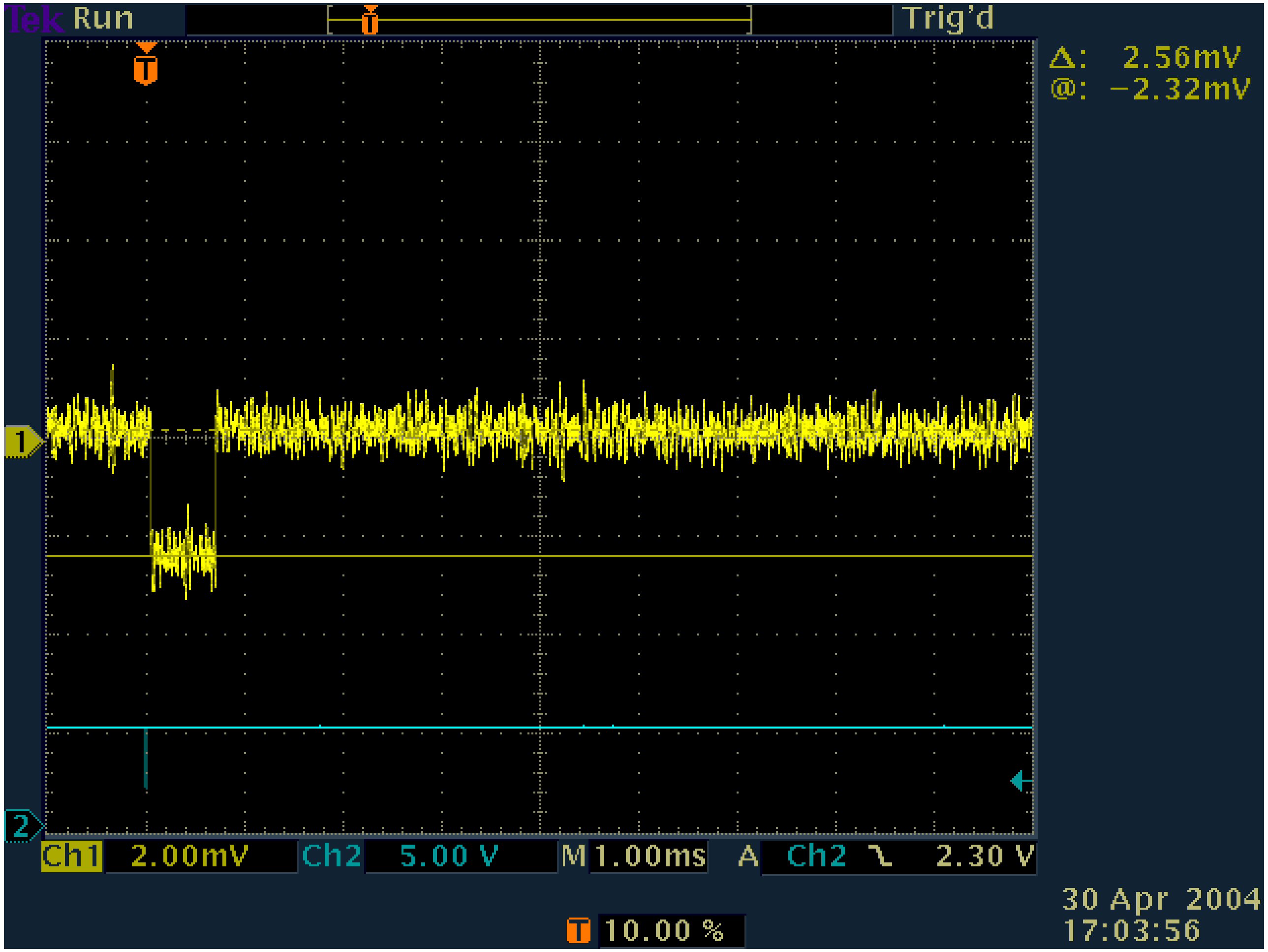
	FEL1(U27) in operation	FEL2(U120) planed for 2006
Undulator period	27.3 mm	120 mm
Number of periods	2 * 34	40
Undulator parameter	0.3 - 0.8	< 2.5
Undulator type	hybrid NdFeB	electromagnetic
Resonator length	11.53 m	11.53 m
Rayleigh length	1 m	2.5 m
Outcoupling holes	1.5 / 2.0 / 3.0 / 4.5 mm	6.0 mm
Mirror R(curvature)	5940 mm (h+v)	7689 mm, 6077 mm (h) 4700 (v) mm
Mirror diameter	70 mm	145 mm (h) 270 mm (v)
Mirror material	Au / Cu	Cu
Waveguide	no	partial (10 x 7460 mm)
Wavelength	3-22 μm	10 – 150 μm
Max. power (out)	60 W	35 W
Max. pulse energy	4.5 μJ	2.5 μJ

First lasing timeline

1. Set electron beam transport
2. Electron beam parameters measured
   ΔE and σ_z vs. phase cavity #1 and cavity #2
3. Observe the spontaneous radiation
   downstream of the undulator (Friday 30th April)
4. Complete the optical cavity (Monday 3rd May)
5. Observe the spontaneous radiation
   coupled out of the optical cavity (Monday 3rd May)
6. Set optical cavity length
   with the help of Ti:Sa (Thursday 6rd May)
7. First lasing (Friday 7th May)

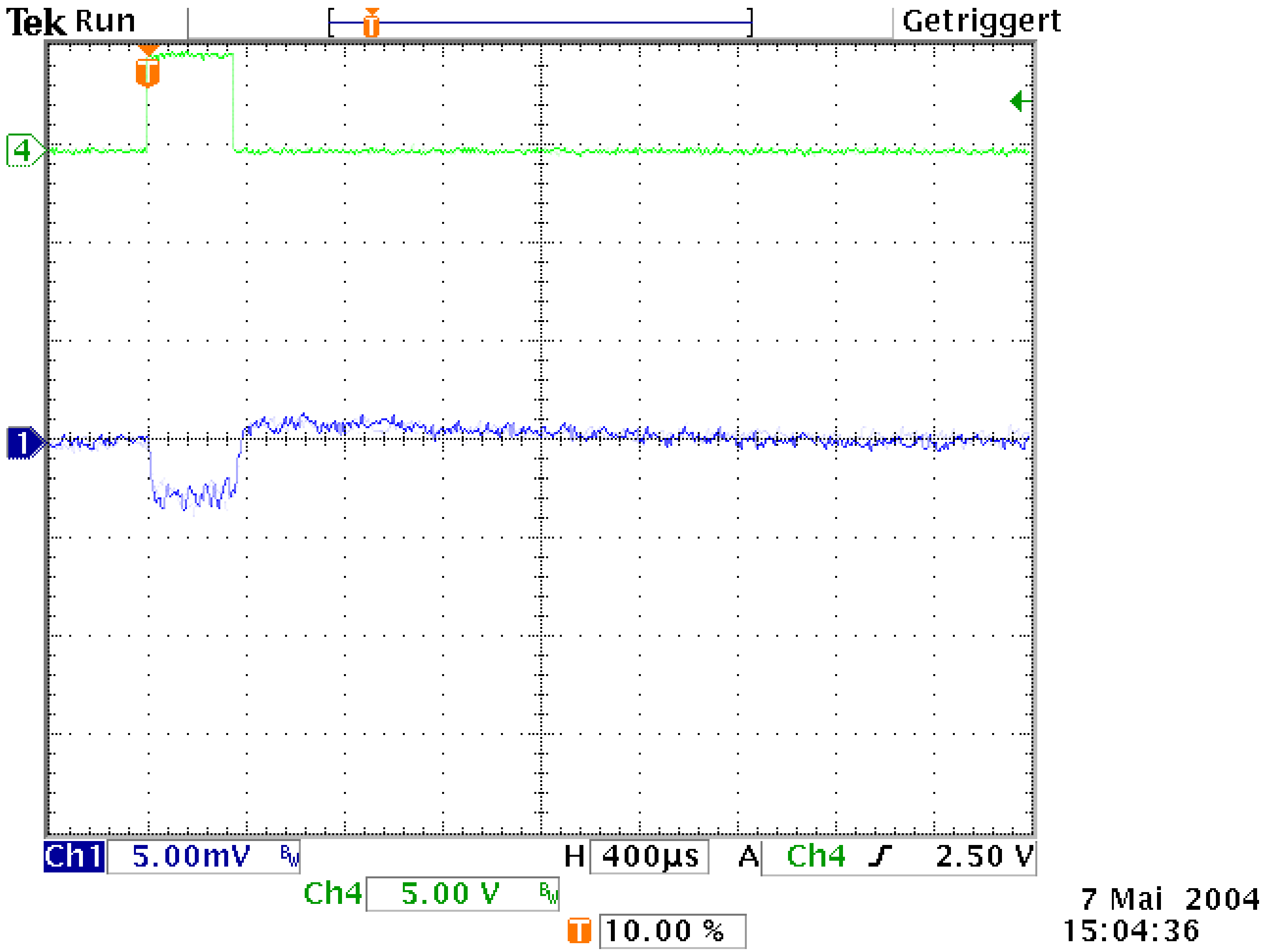
8. Open champagne and leave the FEL running alone as long as the champagne is not finished!

First lasing timeline



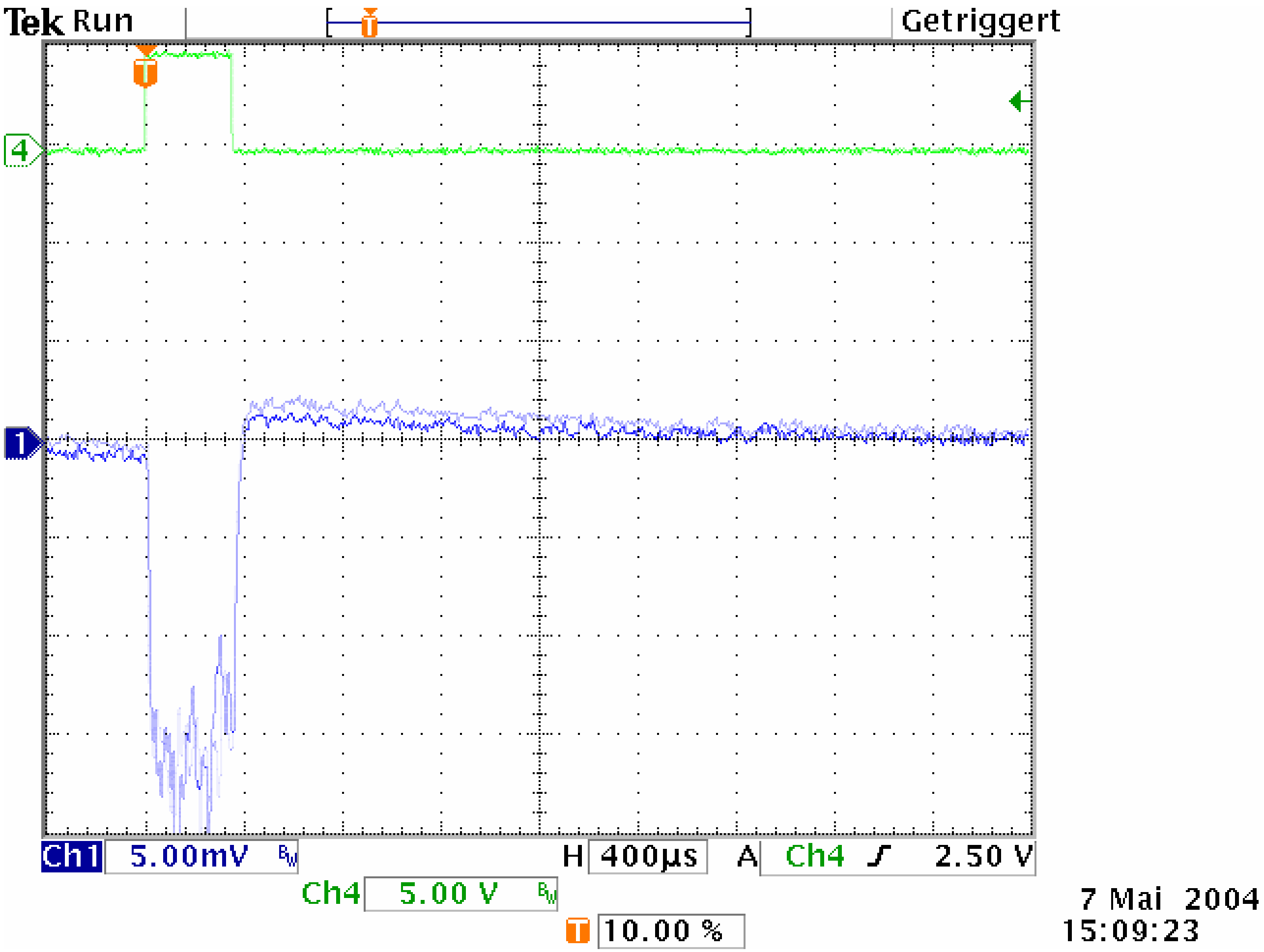
First spontaneous radiation downstream of the undulator

First lasing timeline



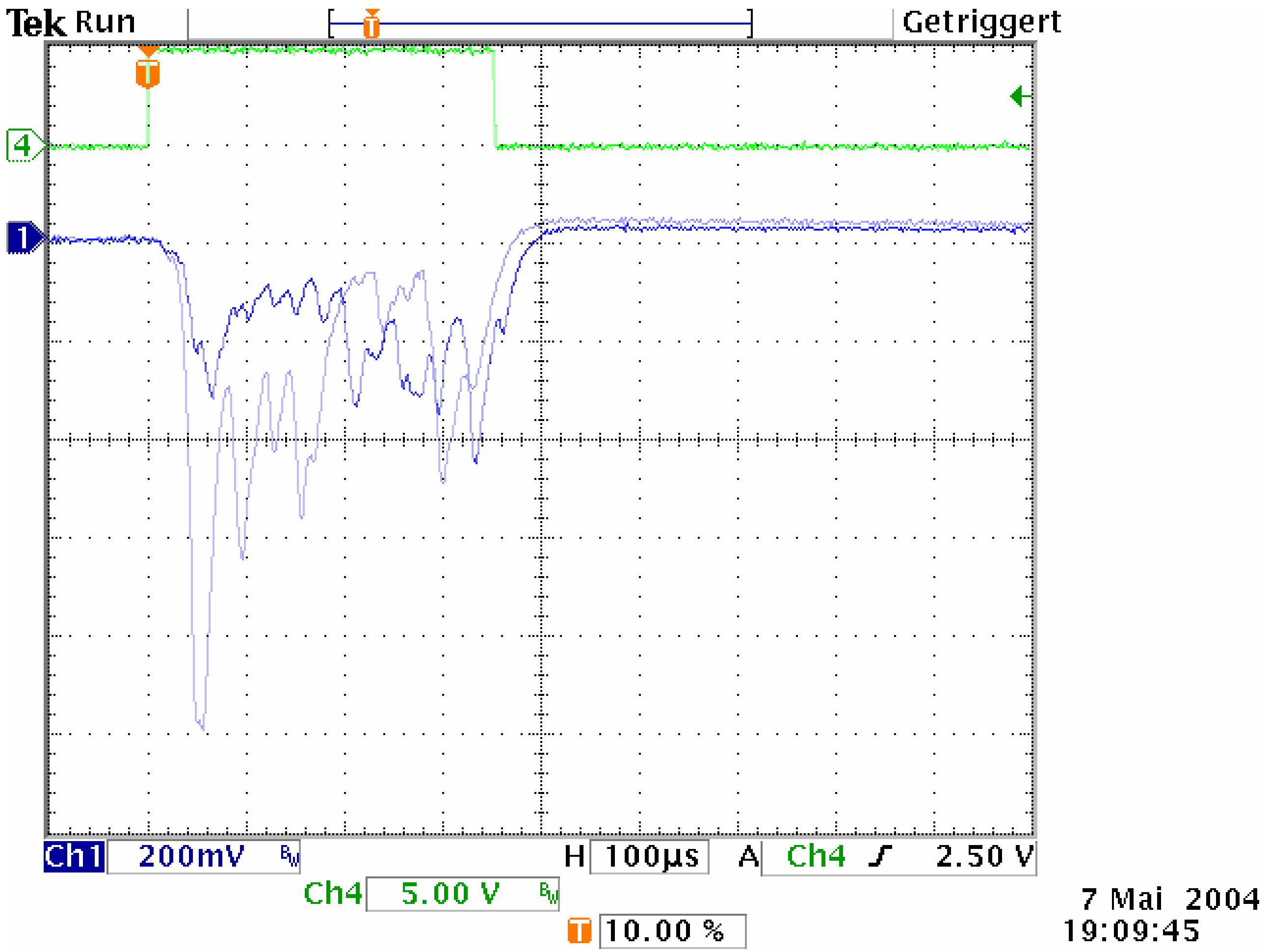
First spontaneous radiation coupled out of the optical resonator

First lasing timeline



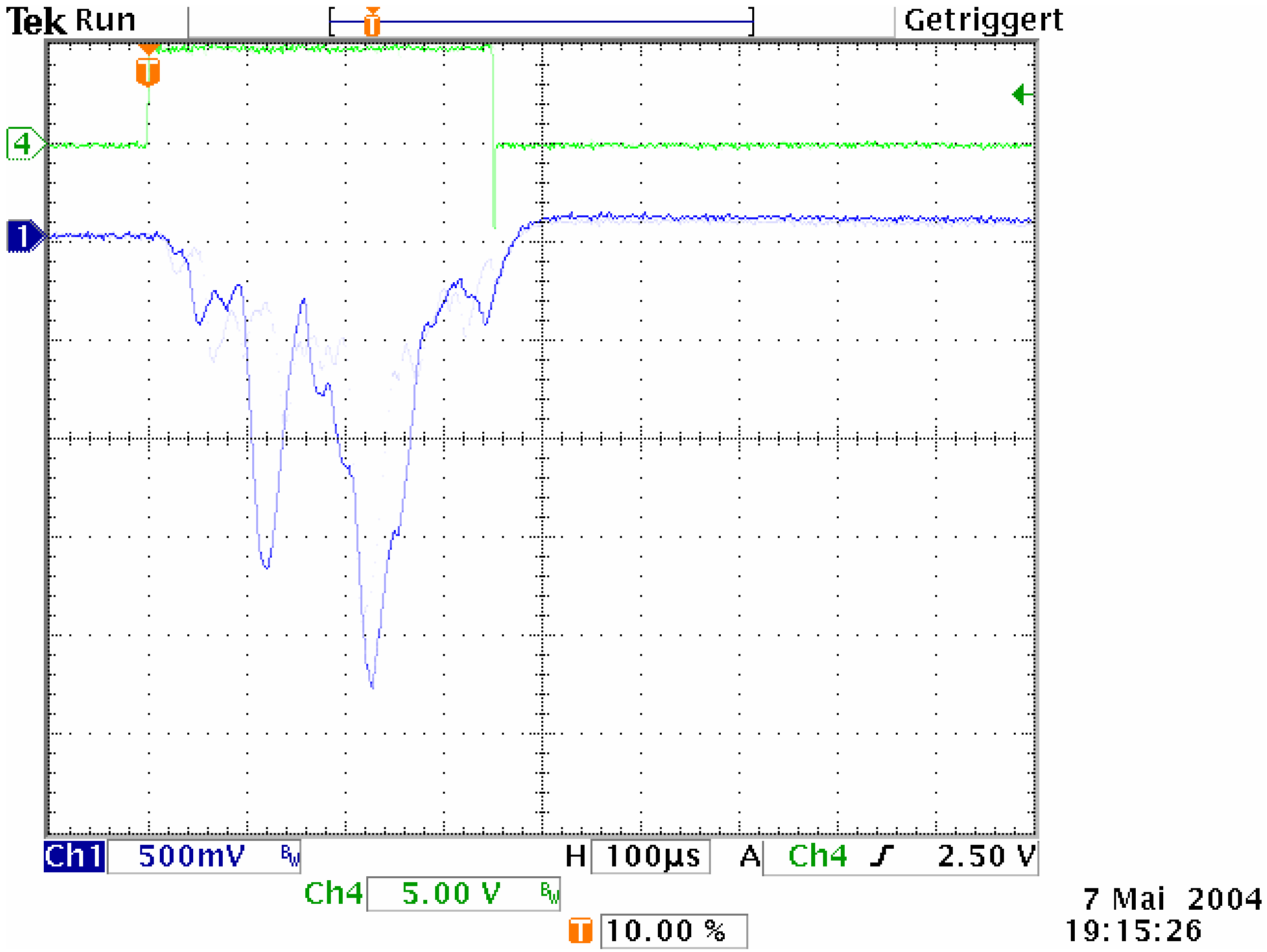
from 3 mV to 15 mV in 5 min.

First lasing timeline



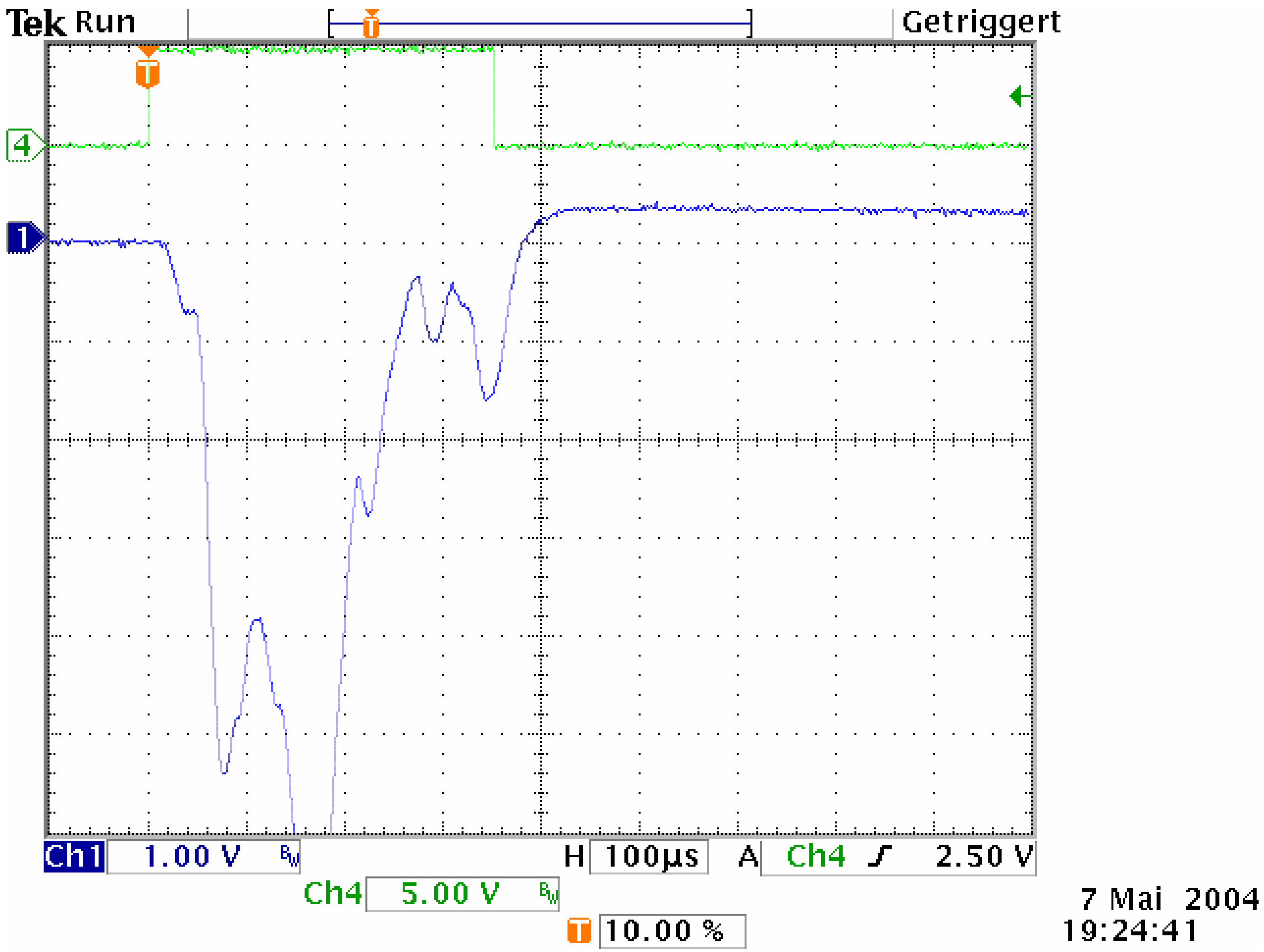
from 15 mV to 200 mV in 4 hours

First lasing timeline



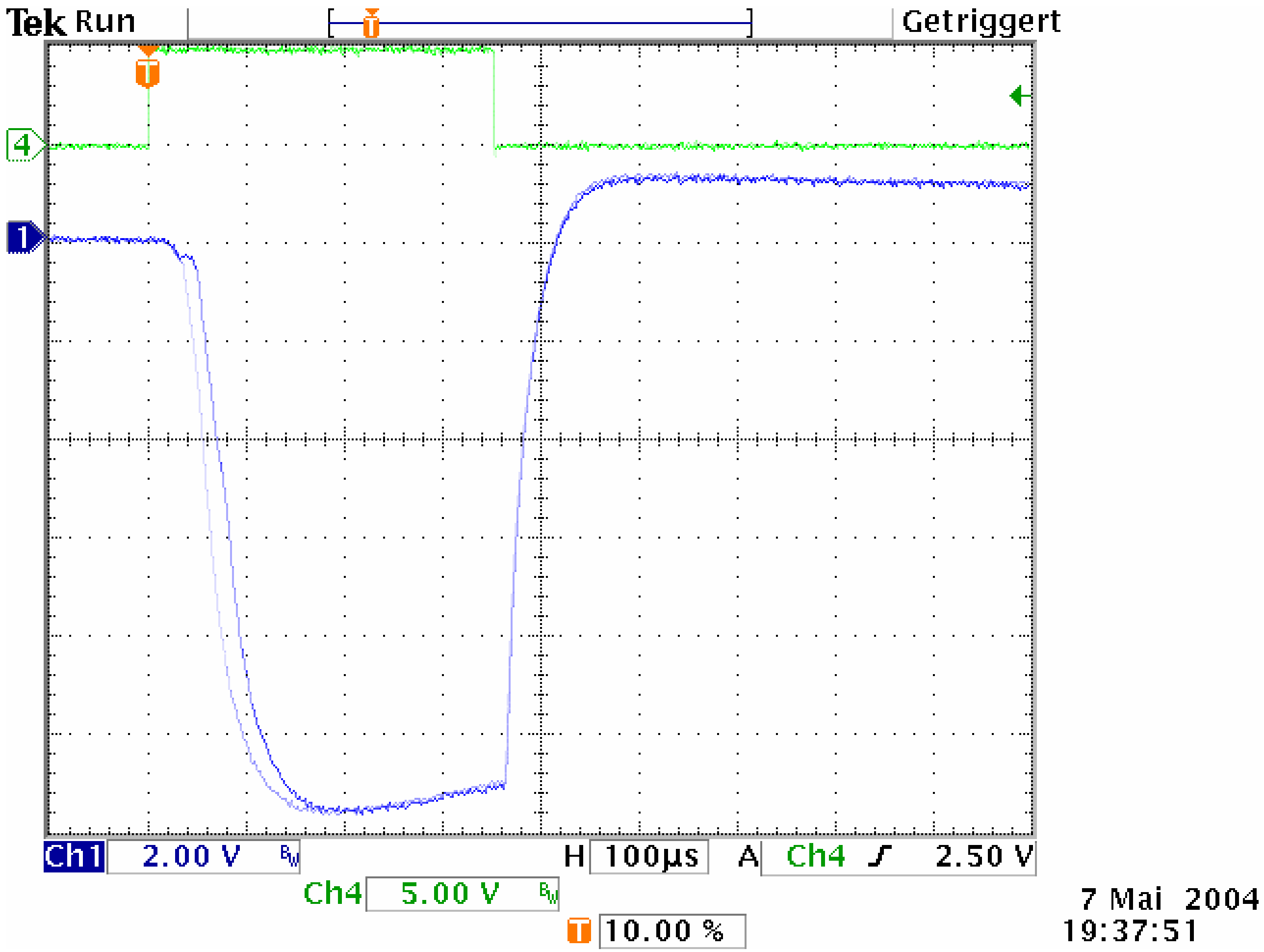
from 200 mV/div to 500 mV/div another 5 min.

First lasing timeline



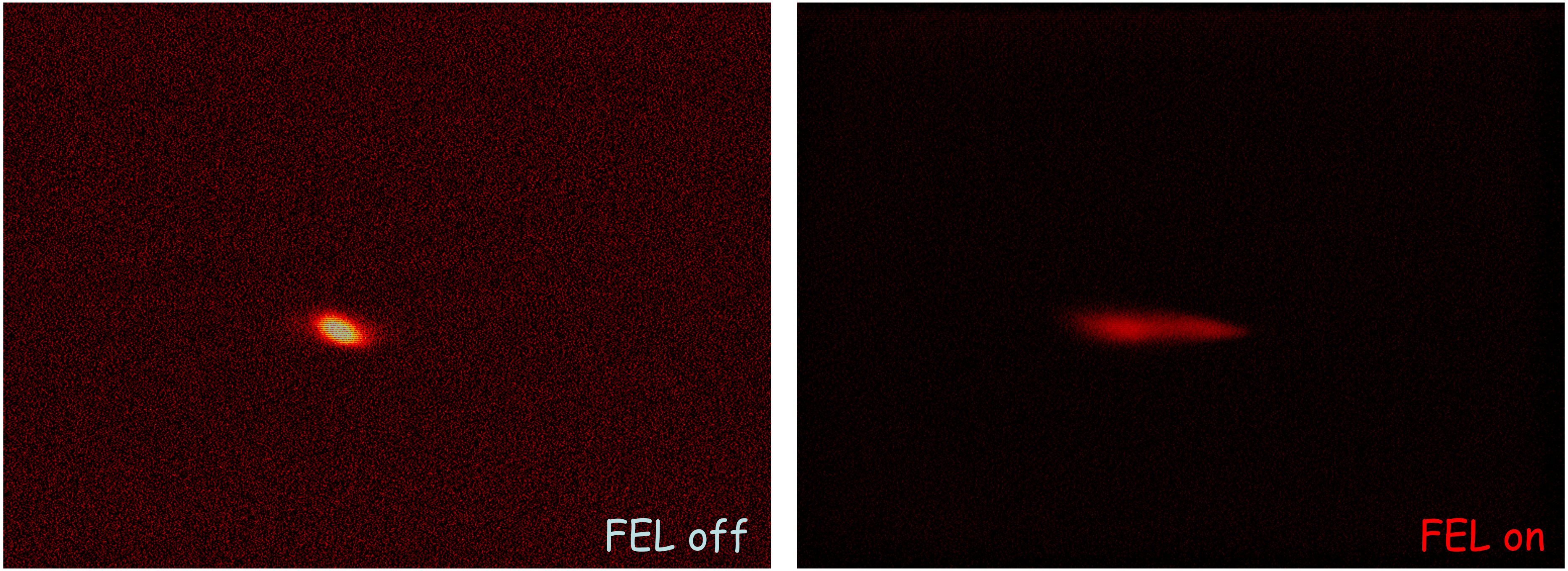
Wowh !!!!

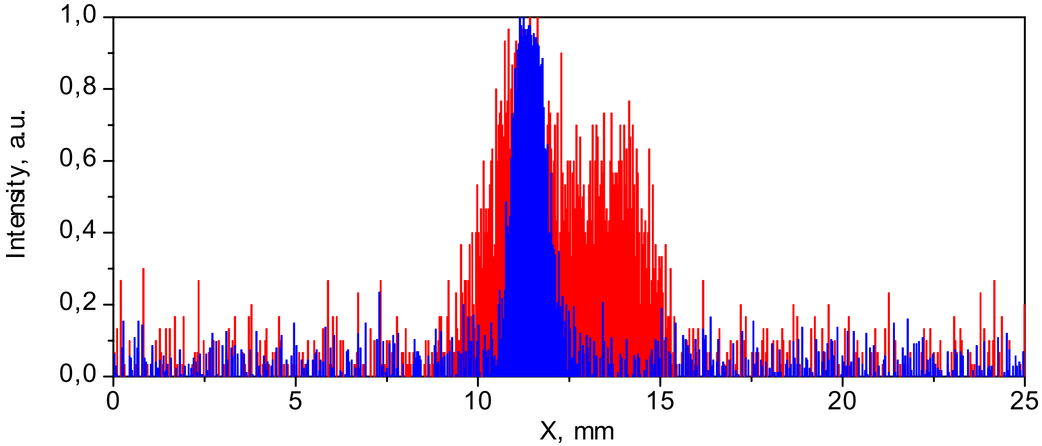
First lasing timeline



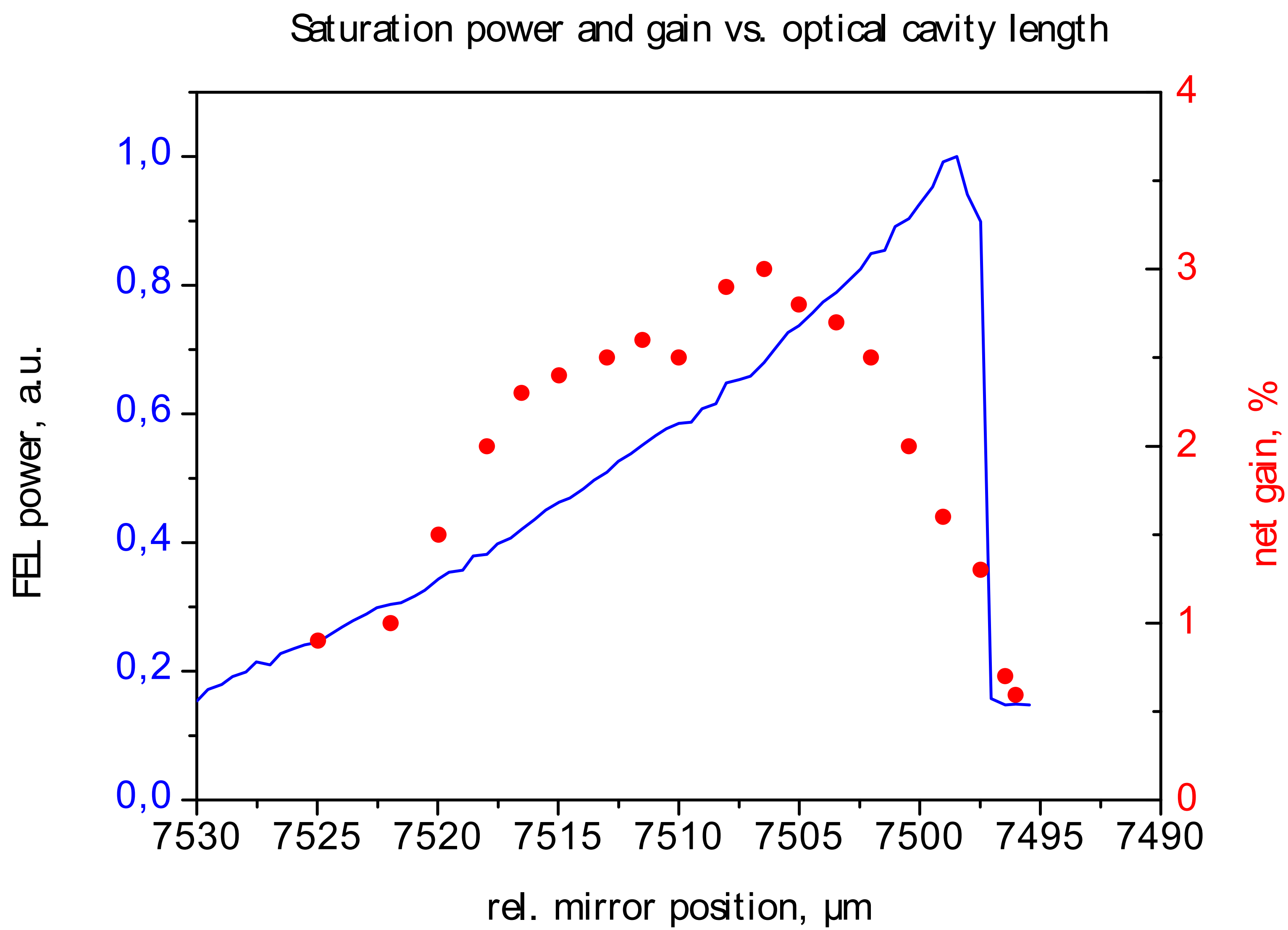
Yippee !!!!!!

Electron beam energy spectrum



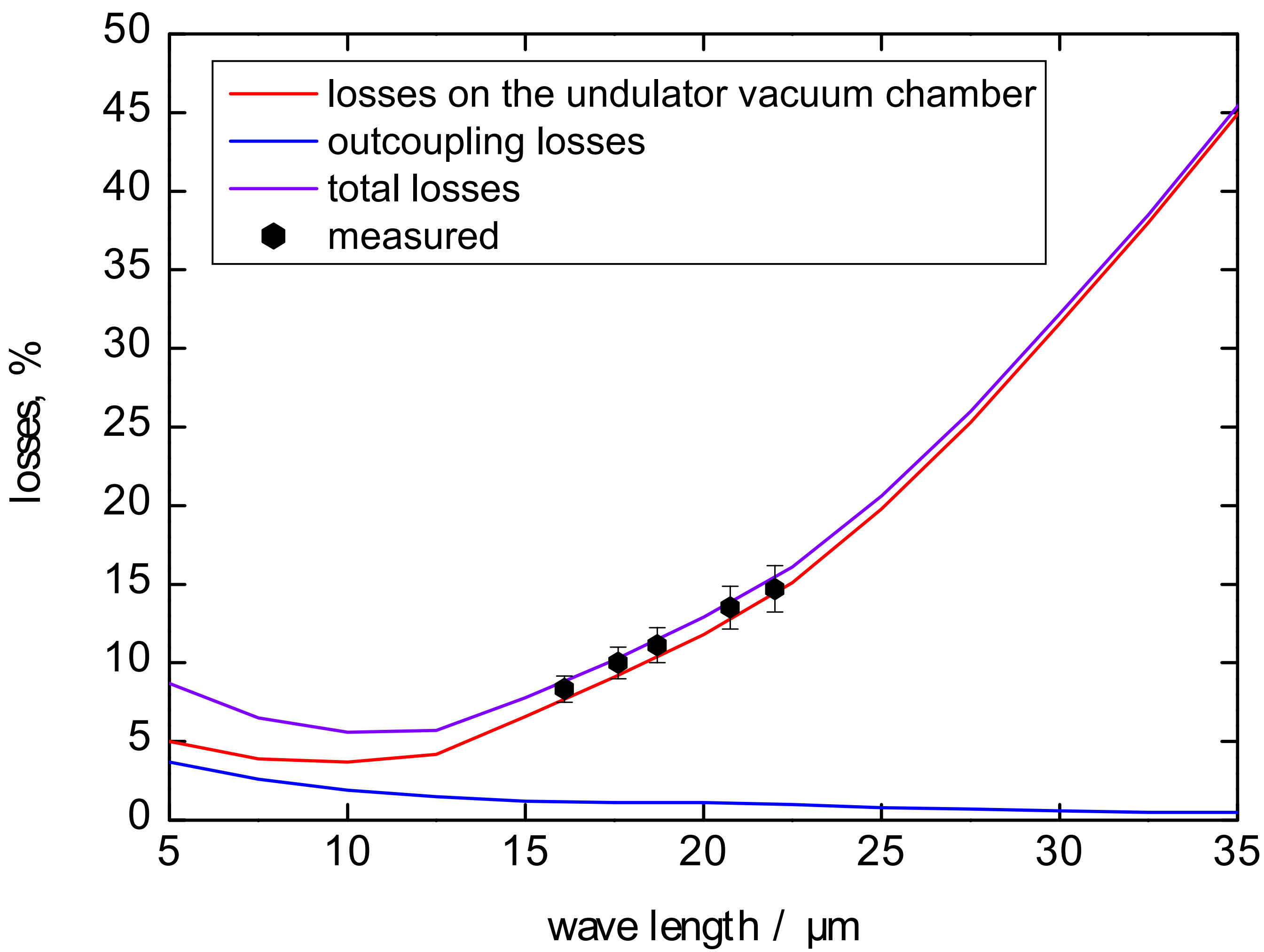


Detuning curve

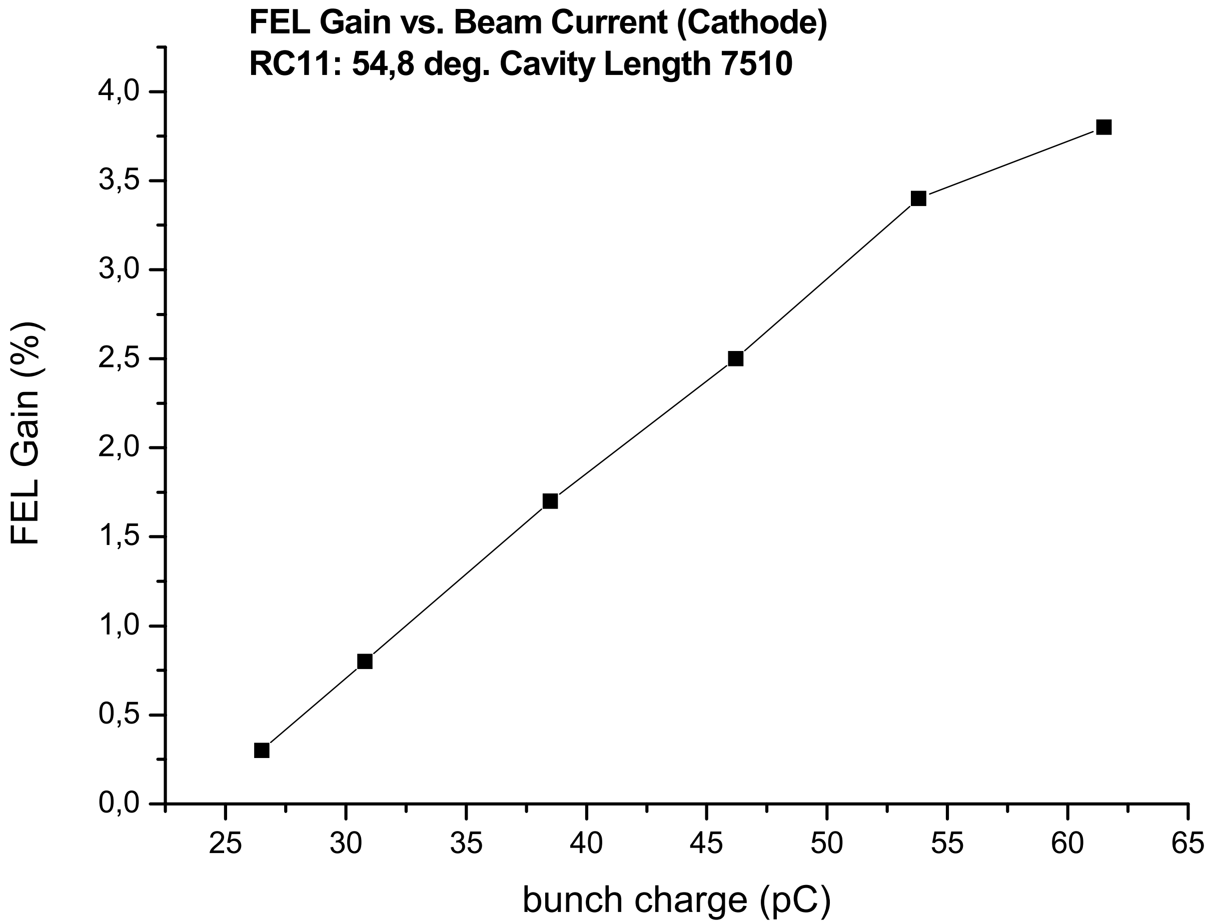


Optical cavity losses

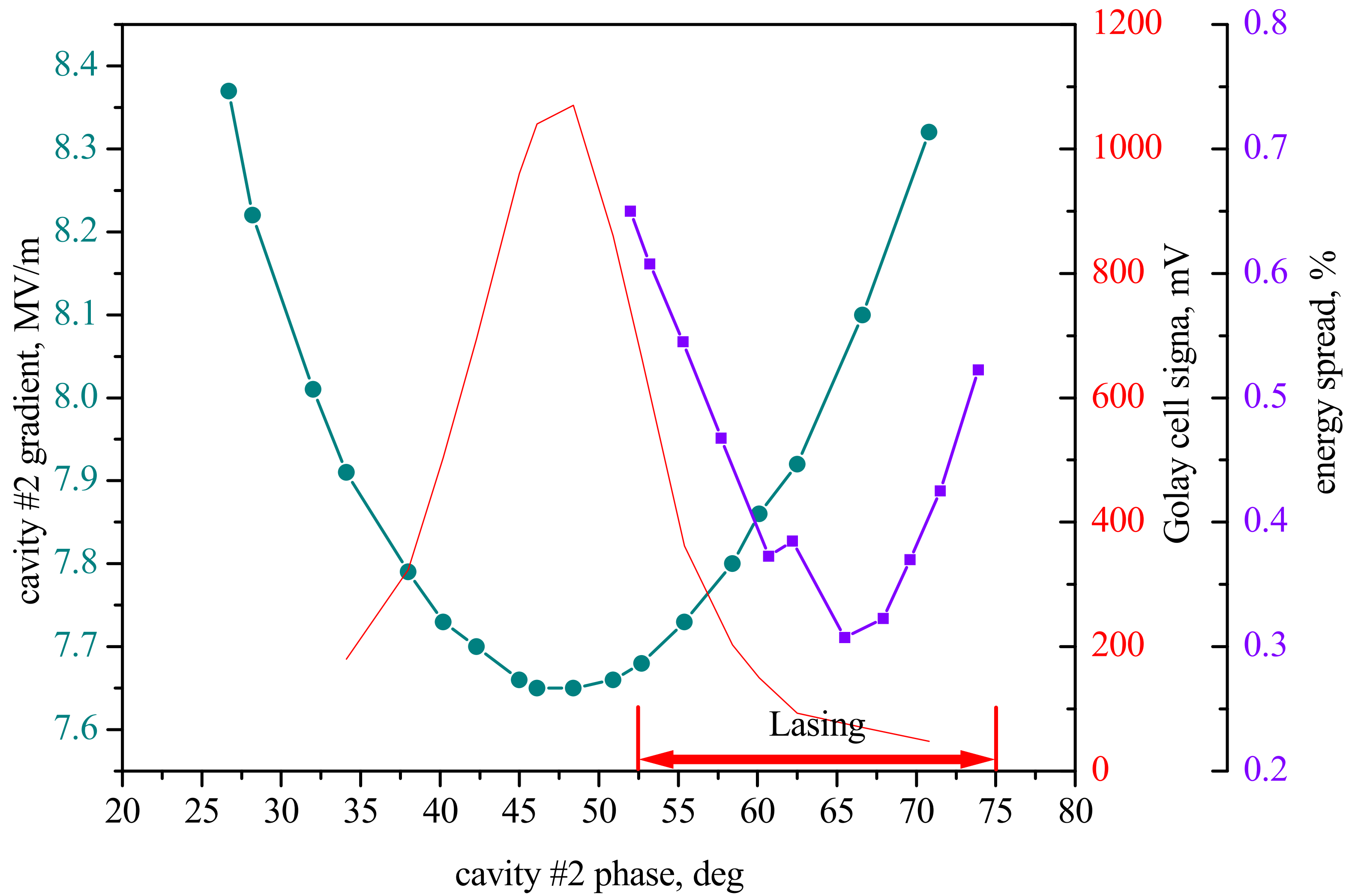
Calculations: R.Wünsch



Gain vs bunch charge

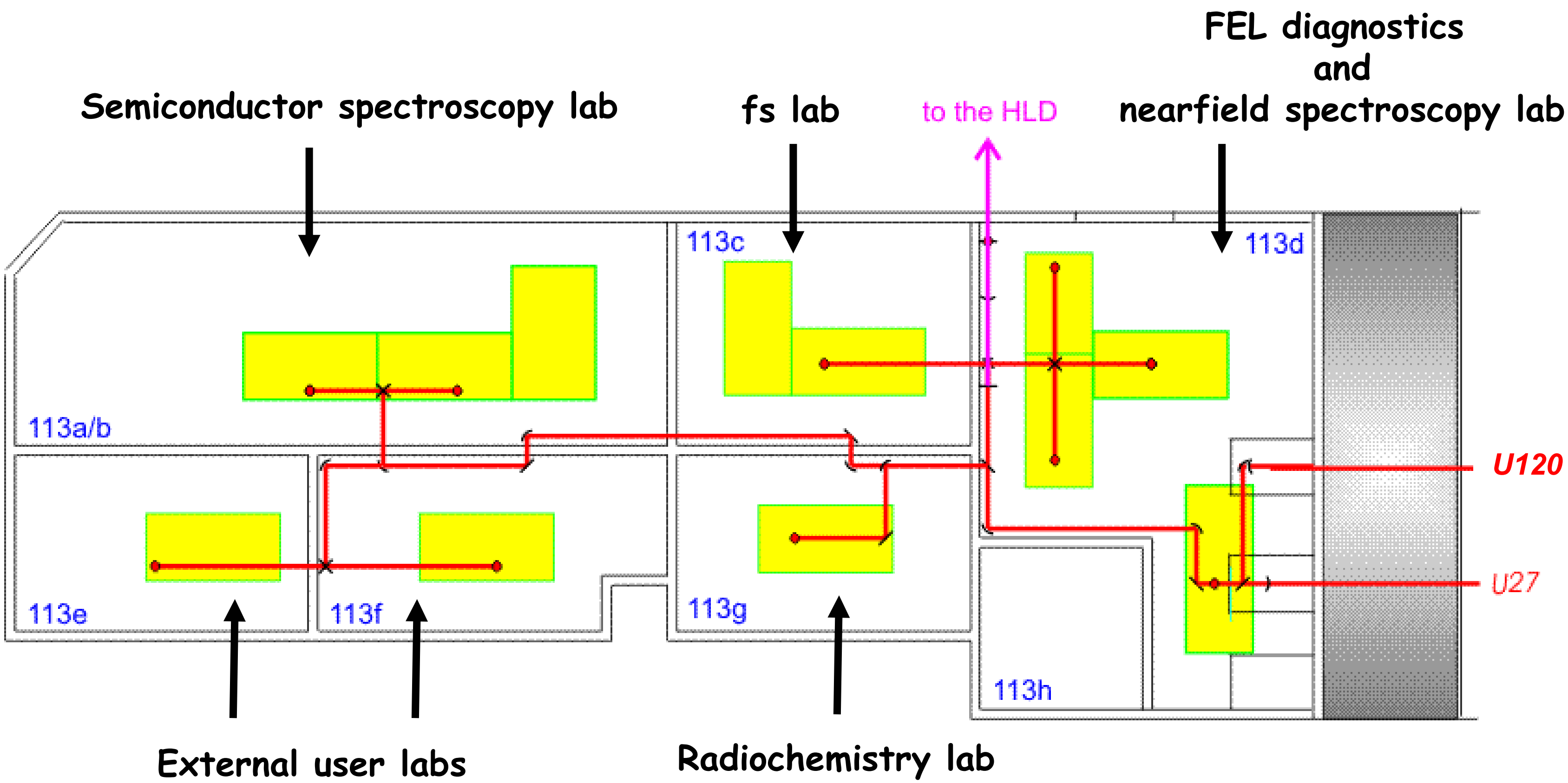


ΔE and σ_z vs. cavity #2 phase

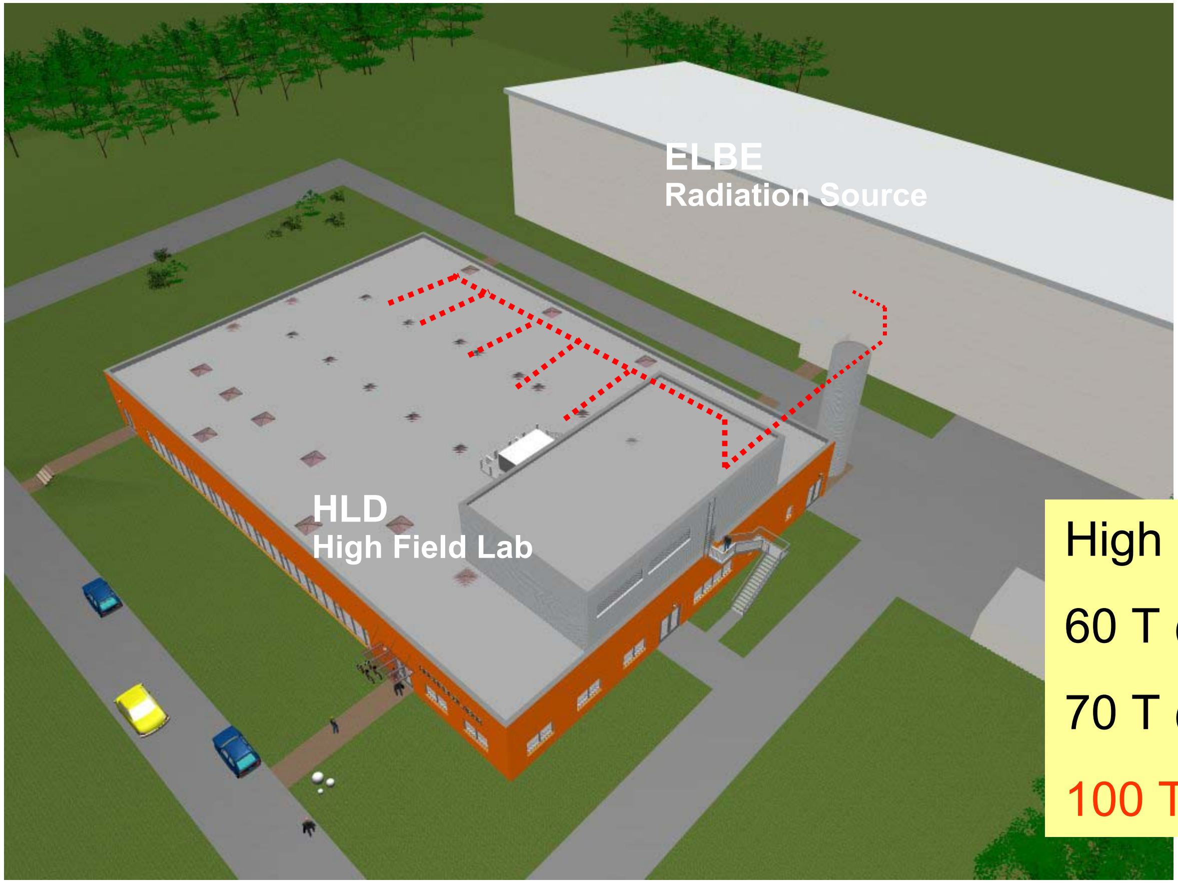


European FEL Userlabs start 2005 - FELBE

„Integrating activity on synchrotron and free electron laser science"



High Magnetic Field Lab & ELBE



High Field Lab Dresden

60 T @ 1000 ms

70 T @ 100 ms

100 T @ 10 ms

Combination of ELBE FEL (3 … 150 μm) and High Magnetic Field Lab
IR spectrosokopie at high magnetic fields

$2\mu_B \cdot 100\ T \;»\; h\cdot c\ /\ 100\ \mu m$

Acknowledgment

F. Gabriel
A. Büchner
F. Herbrand
R. Jaintsch
K. Leege
D. Pröhl
R. Schlenk
J. Voigtländer
A. Wolf
B. Wustmann

P. Michel
P. Evtushenko
M. Freitag
U. Lehnert
J. Teichert
A. Schamlott
C. Schneider
R. Schurig

E. Grosse
P. Gippner
B. Rimarzig
W. Seidel
D. Wohlfarth
U. Wolf
R. Wünsch

M.Helm
T. Dekorsy
M. Krenz

We had great support from all over the world:
HEPL Stanford, JLAB, DESY, SDALINAC, FELIX ...
(Todd Smith, Lex van de Meer, Kevin Jordan ...)

ID: 1306 - THPOS67 ELBE FEL - First Lasing

Thank you for your attention