ELBE

Primary and Secondary Beam Stabilization at the ELBE User Facility

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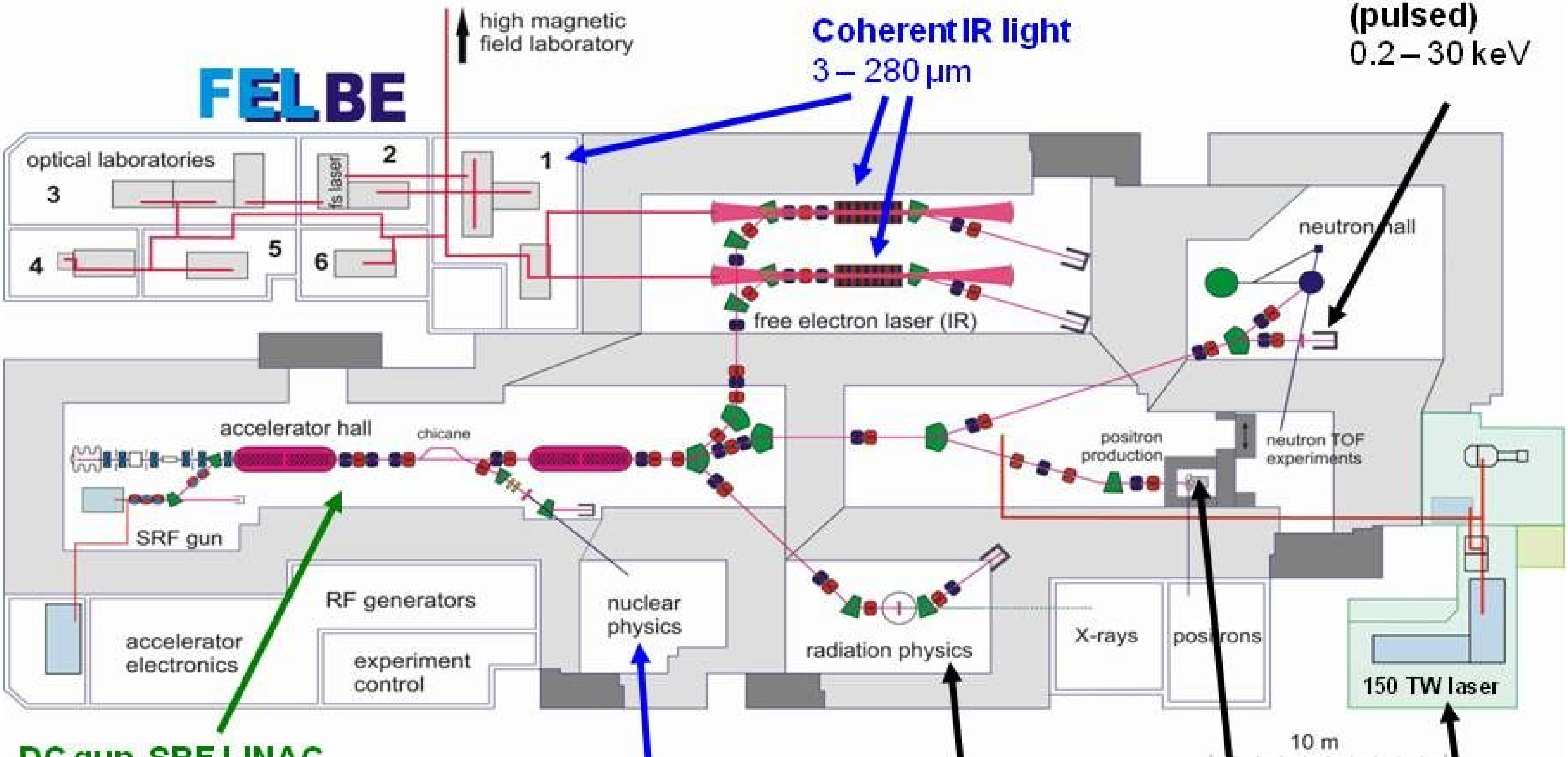
1 Introduction to ELBE

1 Introduction to ELBE:

Coherent IR light
3 – 280 µm

Neutrons (pulsed)
0.2 – 30 keV



DC gun, SRF LINAC
36 MeV electrons,
1 mA (77pC @ 13 MHz)
CW or macro bunch mode
SRF Gun under development

Bremsstrahlung (polarized)
0 – 17 MeV

X-rays (quasi monochromatic)
10 – 100 keV

Positrons (pulsed)
0.2 – 30 keV

High Intensity Laser

1 Introduction to ELBE: History

user operation

2010	Begin of ELBE upgrade
	Laser acceleration first tests (scheduled)
	SRF-Gun @ELBE (scheduled)
2008	position source operation – **ELBE finished**
2007	**1st beam SRF-Gun (standalone)**
	photo neutron source
2006	FEL II (U100, 20…280µm)
2005	2nd Accelerator module
2004	FEL I (U27, 3..22µm)
2003	channeling X-rays user operation
2002	Bremsstrahlung user operation
2001	**1st beam**
2000	injector operation (DC gun)
1998	cornerstone

24 / 7

24 / 5

2 shifts, 5 days

1 shift, 5 days

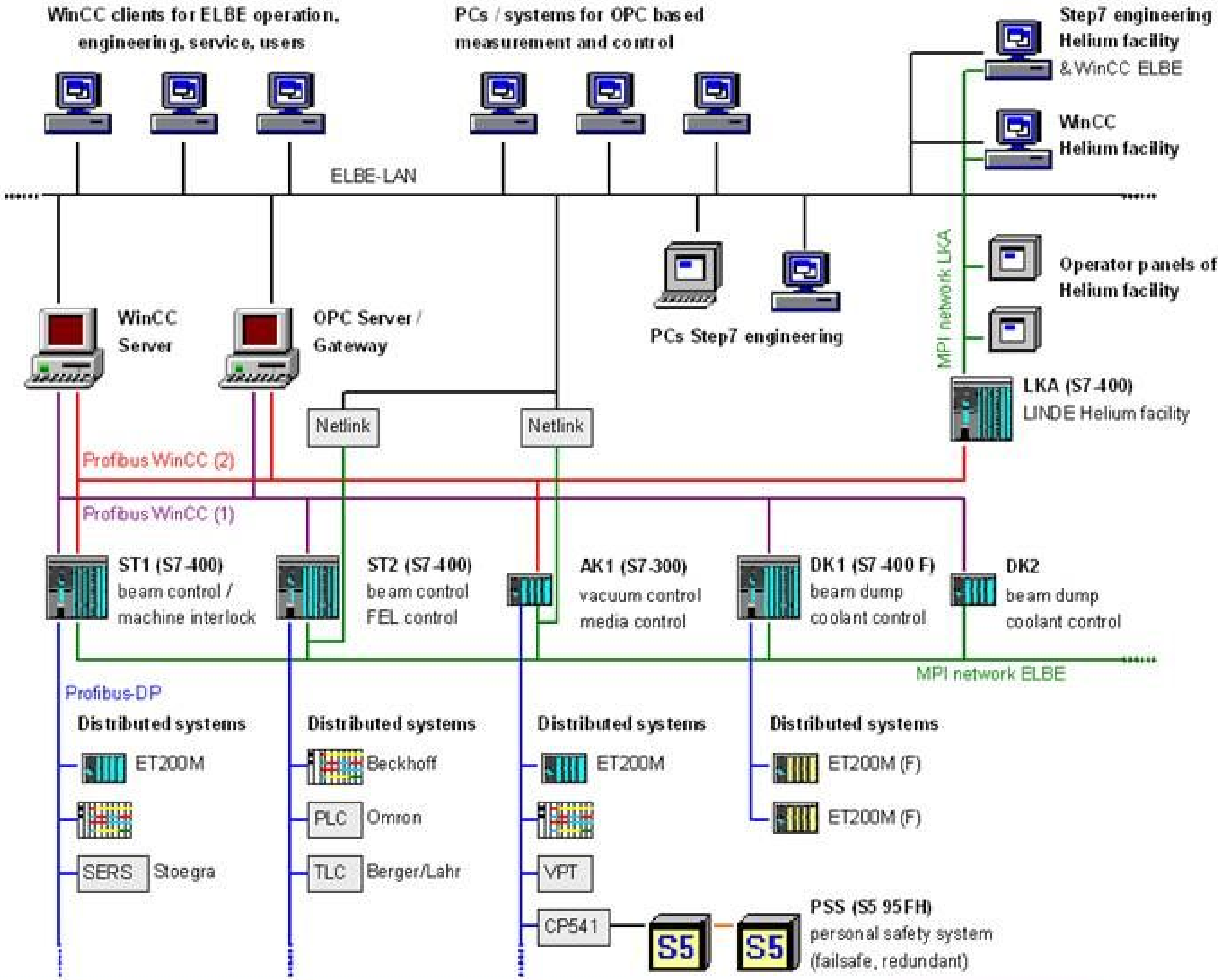
1 ELBE – Introduction: Control System

- PLC layer
  Simatic S7 ®
- Fieldbus interconnection
- SCADA layer
  WinCC® server / client system

not depicted:

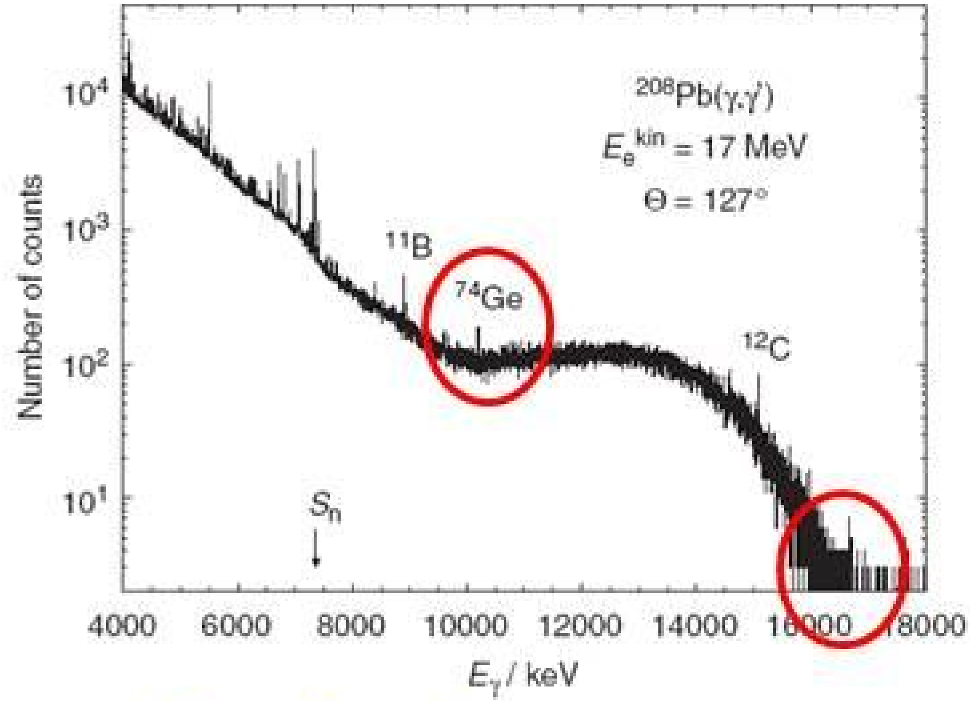
- fast DAQ (BPM, BLM,…)
- user interfaces

➔ use OPC connection

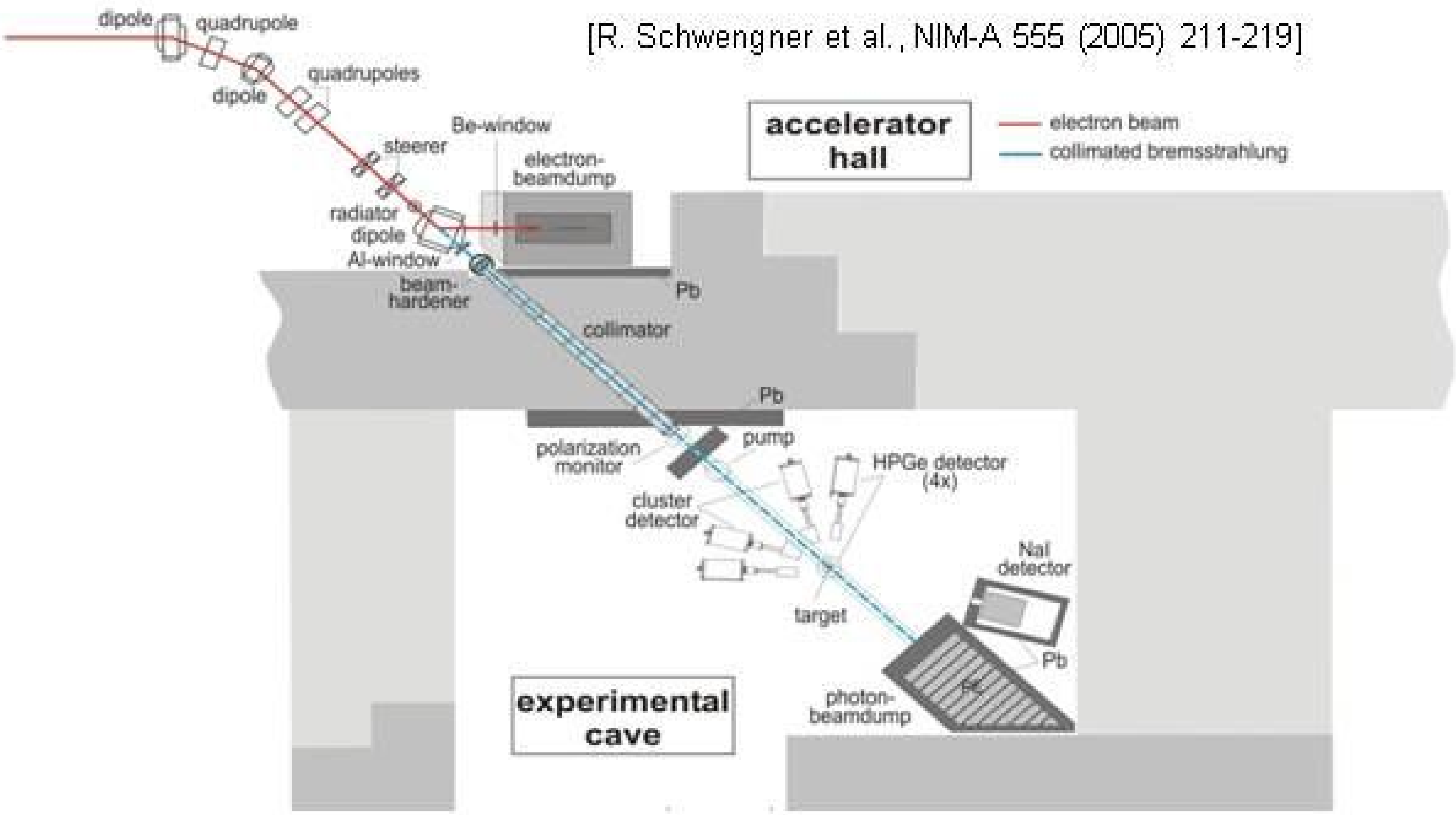


2 Beam stability demands

- resulting photon-nucleus interaction spectra at the Bremsstrahlung facility are determined by Bremsstrahlung spectrum
- high spectral resolution and accuracy only achievable by constant electron beam energy, low energy spread and sufficient statistics
- $dE/E \sim 10^{-3}$ is required



[R. Schwengner et al., NIM-A 555 (2005) 211-219]

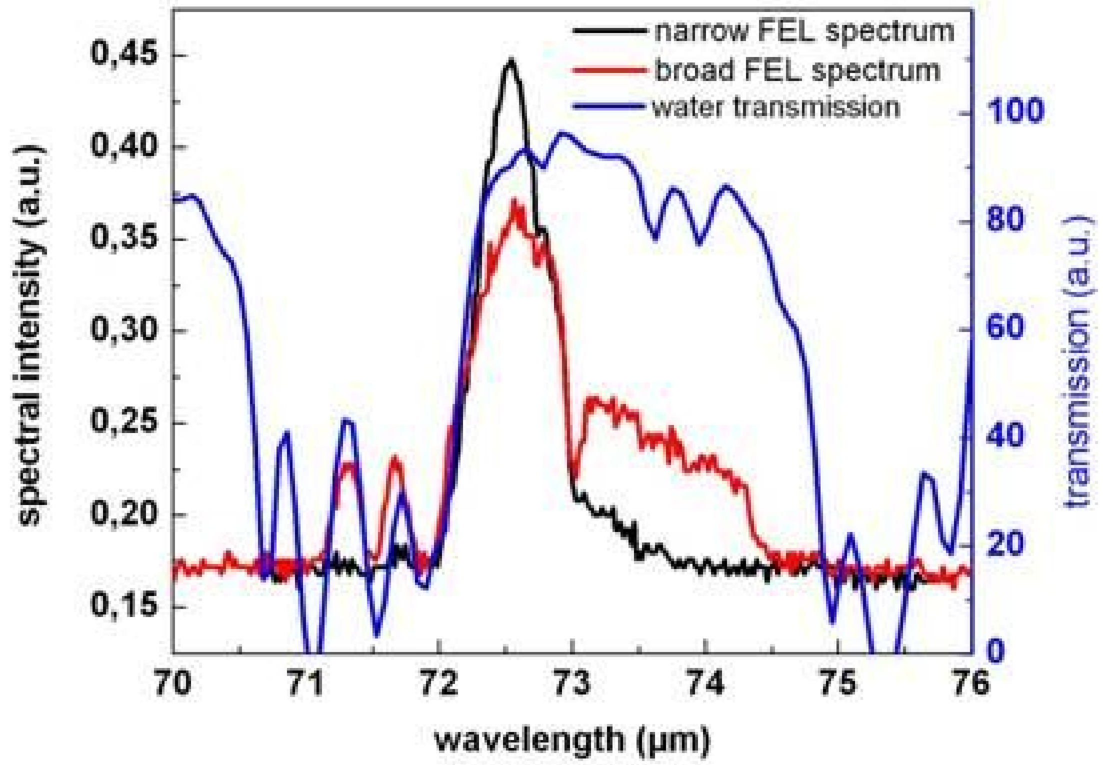


Experiments:
- photon scattering
- nuclear dipole strengths
- photoactivation of nuclei
- photodisintegration of nuclei (γ,p), (γ,n), (γ,α) *cross sections*

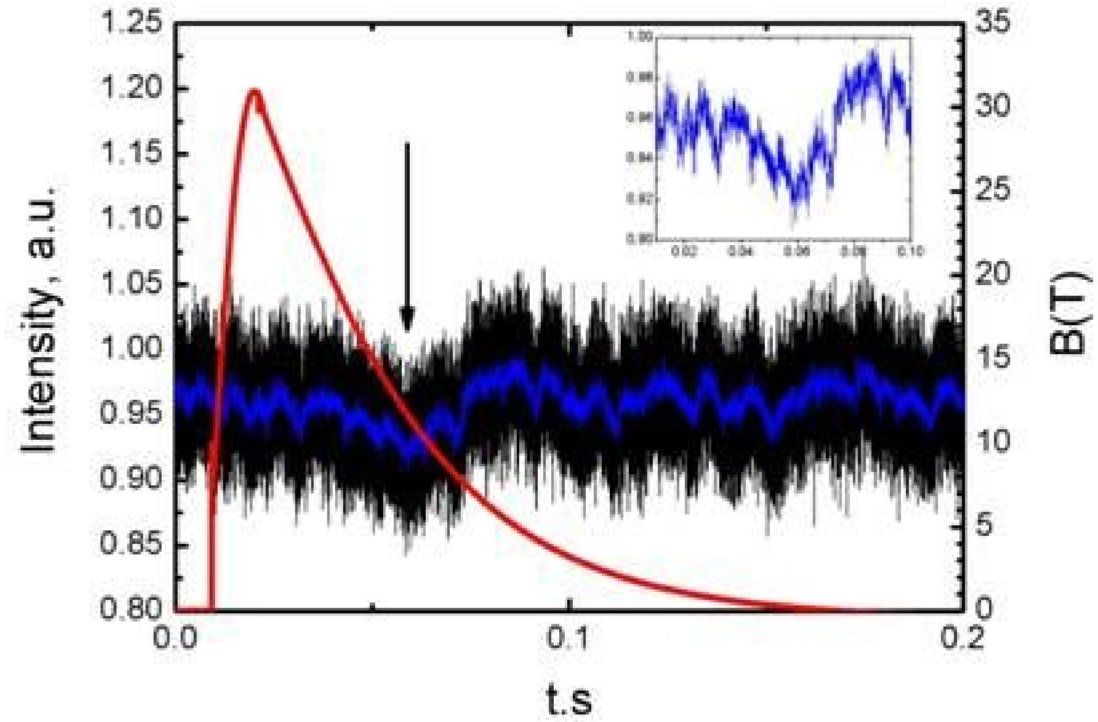
Properties	
Energy	0…17 MeV
Photon flux	10^8 γ MeV^{-1} s^{-1}

2 Beam stability demands

- measurements between water absorption lines or wavelength gaps of the U100 require wavelength stability of < 0.5%
- measurements with small bandwidth require constant wavelength and narrow spectrum
- in-pulse experiments at the High Magnetic Field Laboratory need intensity stability up to the kHz range



FEL Properties	FEL 1 - U27	FEL2 - U100
undulator period	27.3 mm	100 mm
design	2 x 34 periods vacuum chamber	38 periods waveguide
undulator param.	0.3…0.7	0.3…2.7 µm
wavelength	**3...22 µm**	**20...280 µm**
max. power (out)	**30 W**	**70 W**
max. pulse energy	**2 µJ**	**5 µJ**
pulse length	**0.5…4 ps**	**1…10 ps**



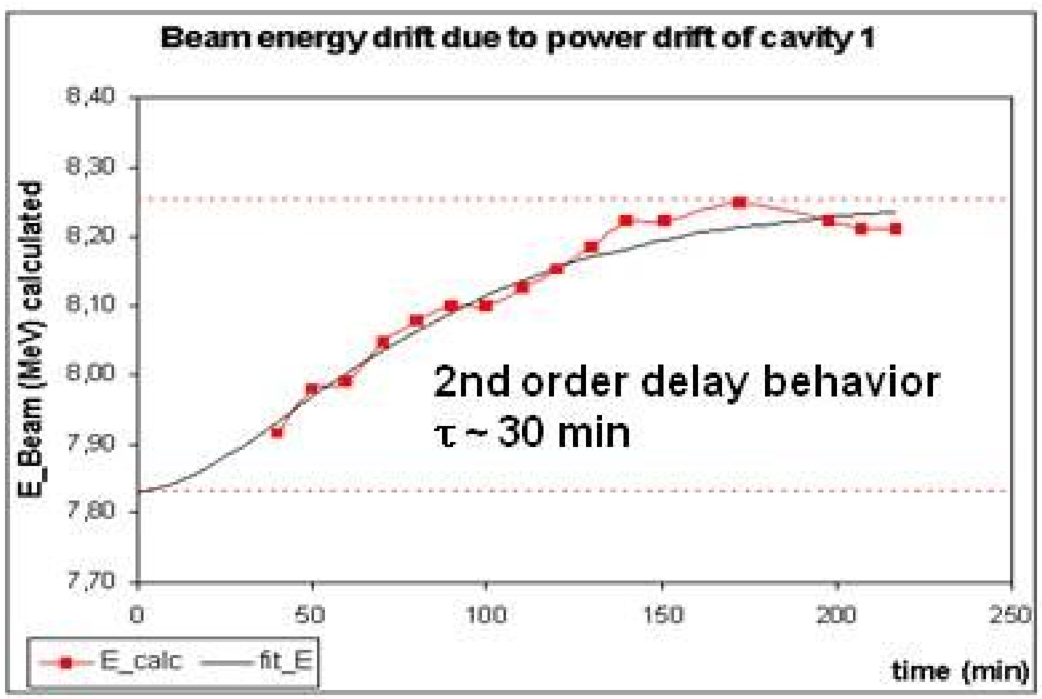
3 Electron beam stabilization

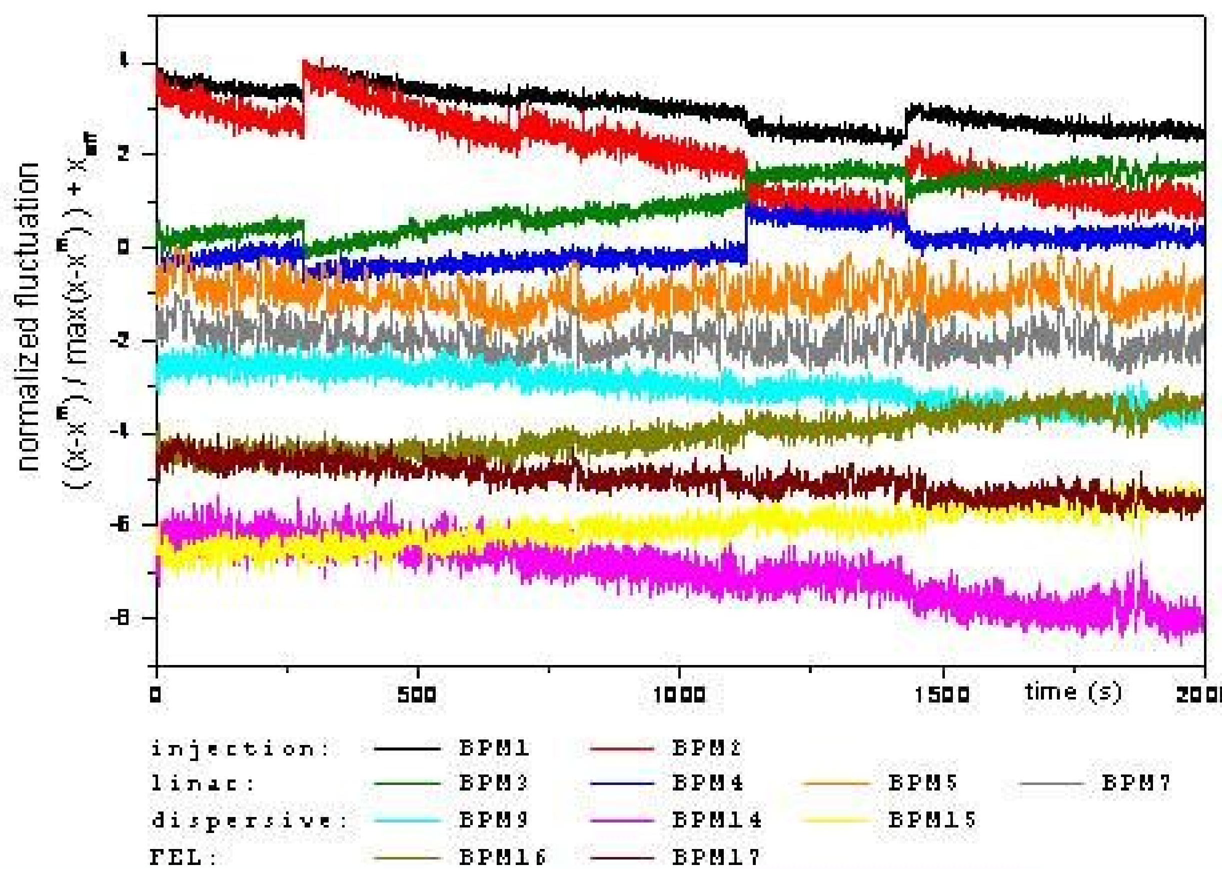
electron beam **energy** variations:

- slow thermal settling of the RF cavities
- fluctuations in the LINAC's RF field strength: microphonics, phase loop noise of the RF

electron beam **trajectory** variations:

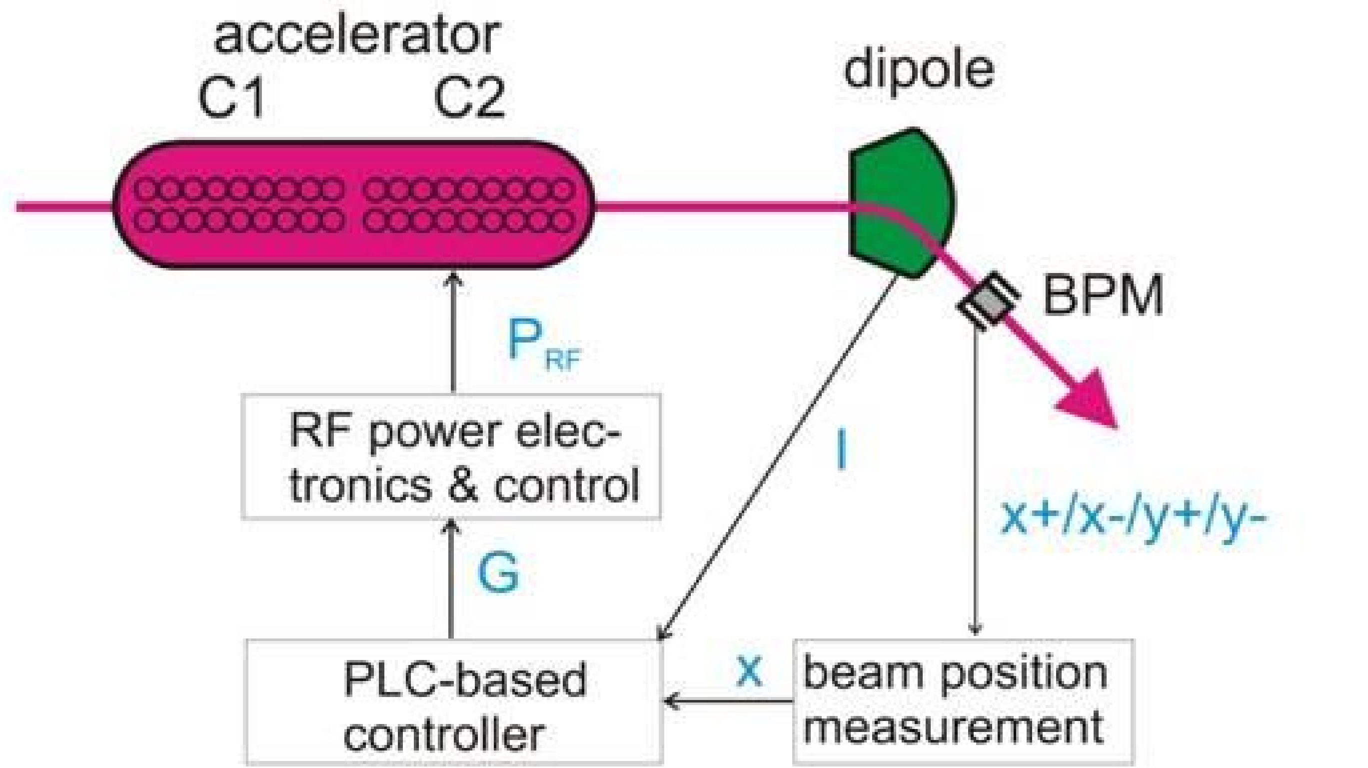
- Spontaneous position jumps due to charge-up effects in the injector area
- Slow effects due to energy drift

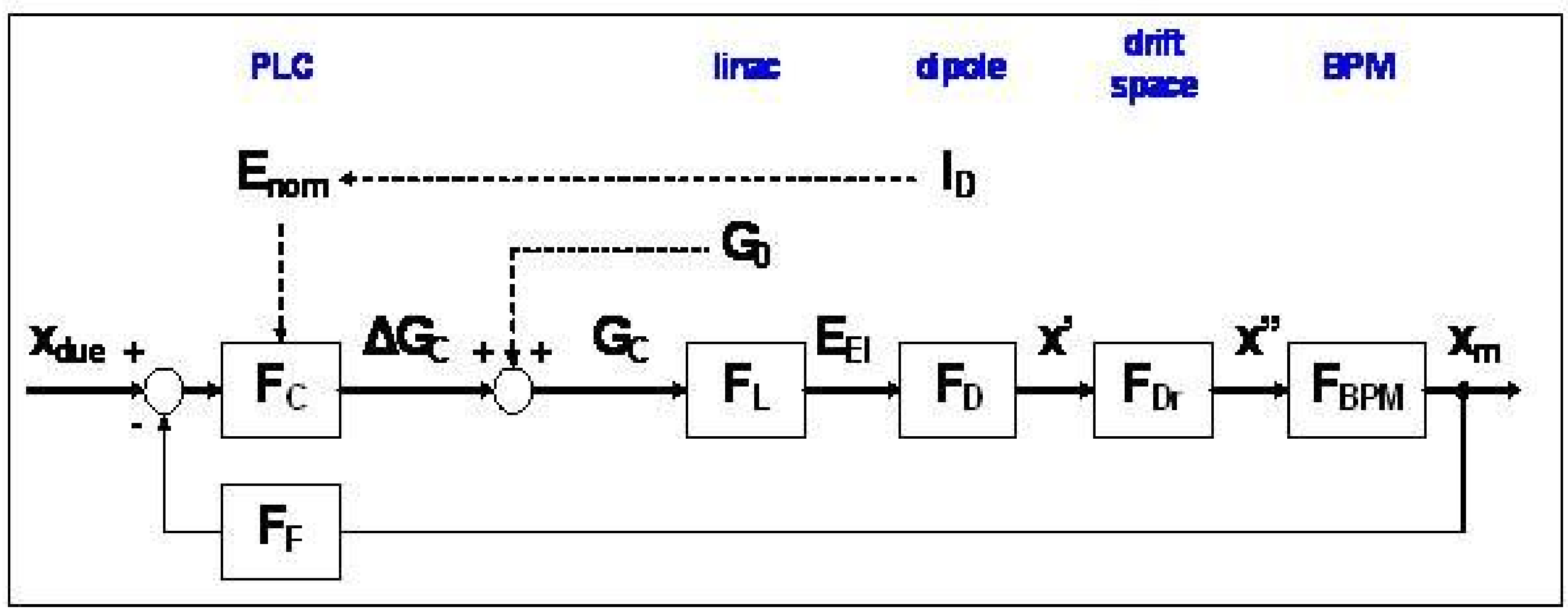




3 Electron beam stabilization

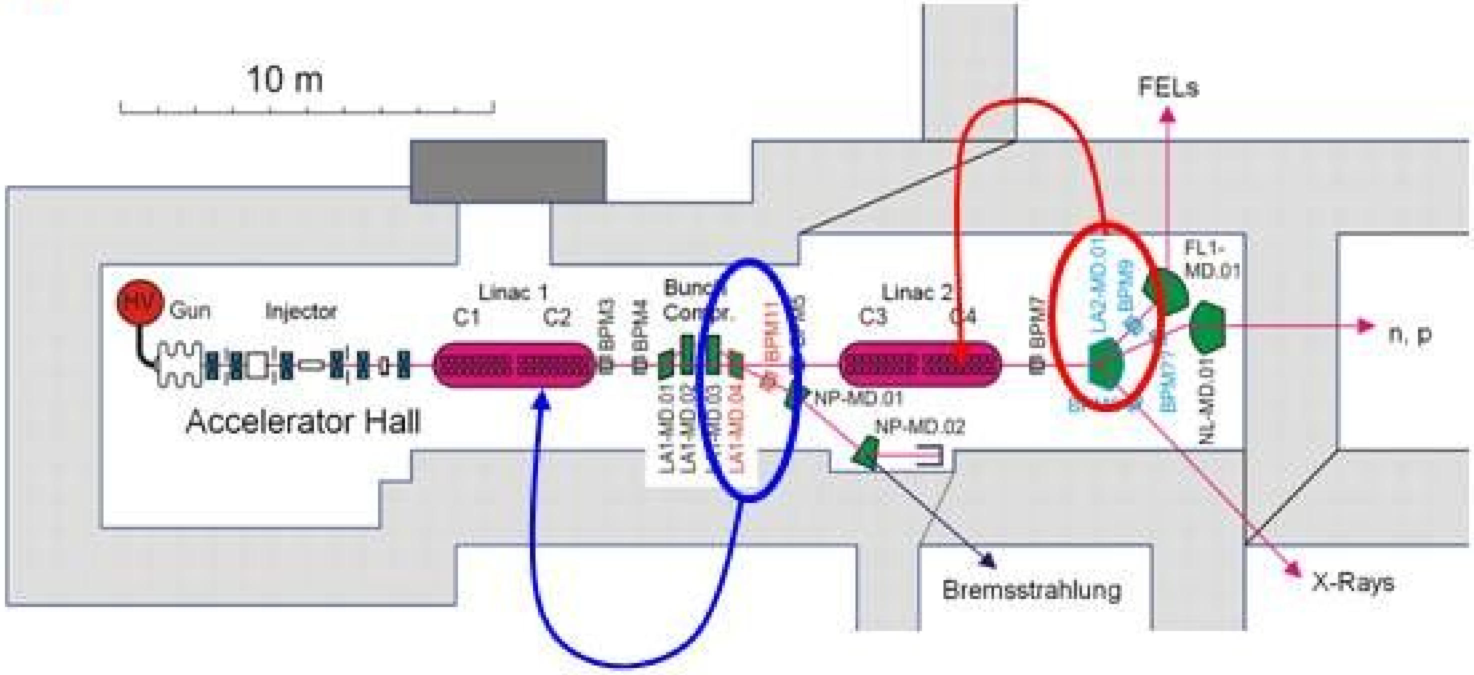
- beam energy measurement using stripline BPM
- adjustment of the RF gradient of the last cavity
- low pass filter for BPM data
- PLC based PI controller (S7-400, 50 ms sampling time) optimized towards zero overshoot
- LL RF control + klystron amplifier

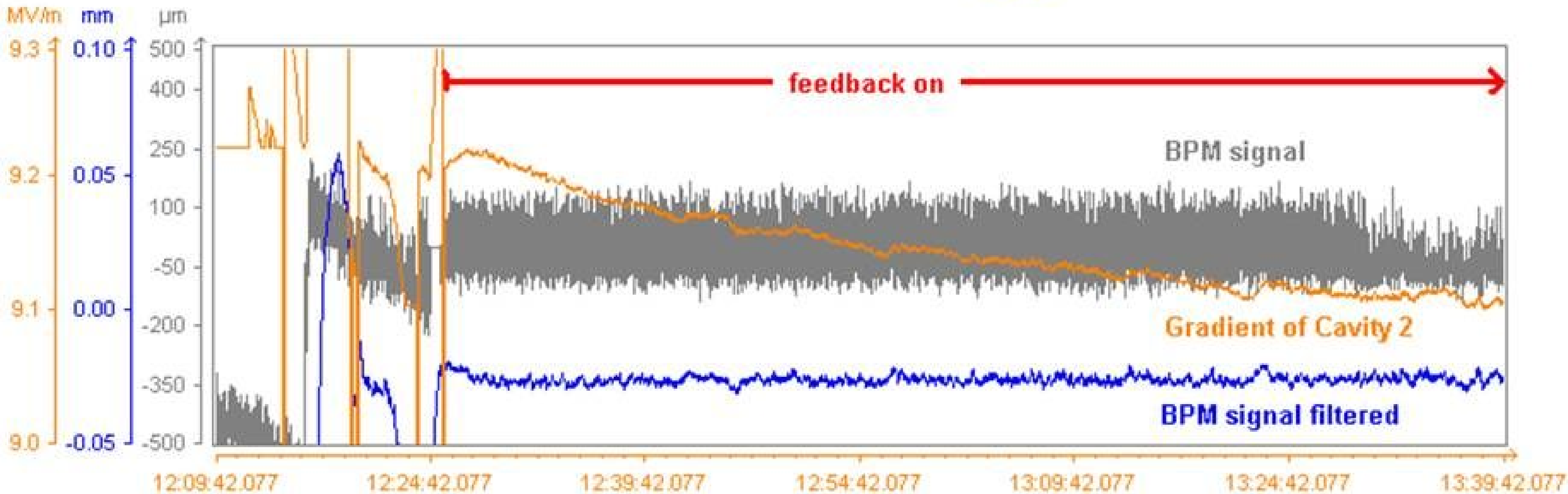




3 Electron beam stabilization

- performance ensures mean energy drift of < 0,5%
- applied to Bremsstrahlung facility and FEL beam line





2 Infrared beam stabilization

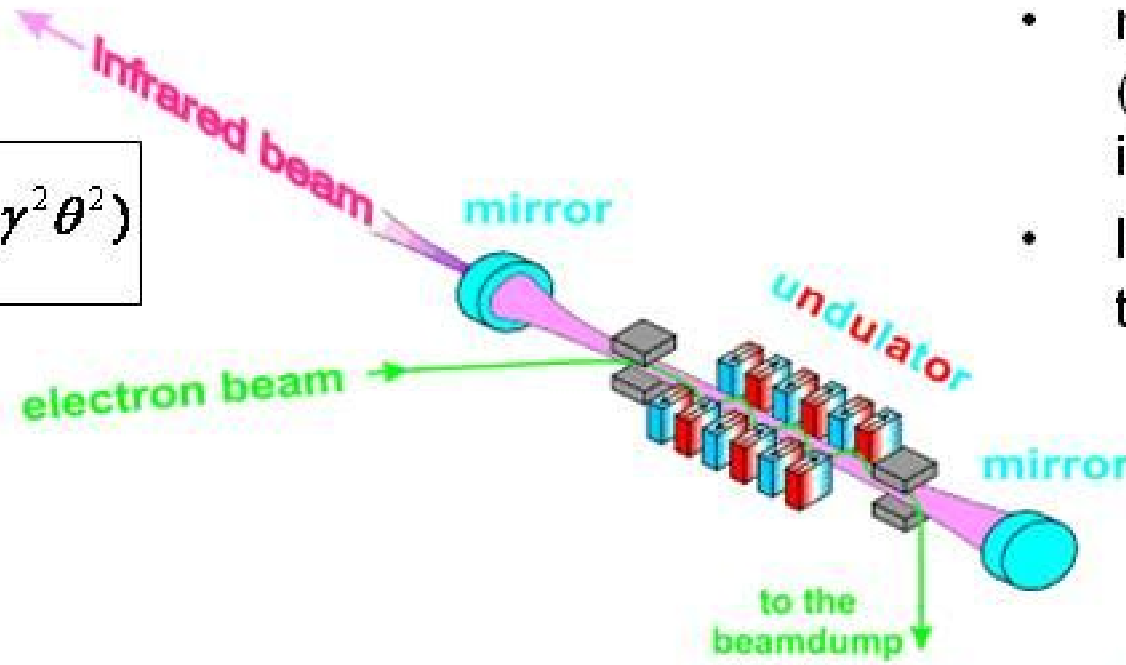
wavelenght instabilities:

- e-beam energy fluctuations
  ➔ **energy stability**

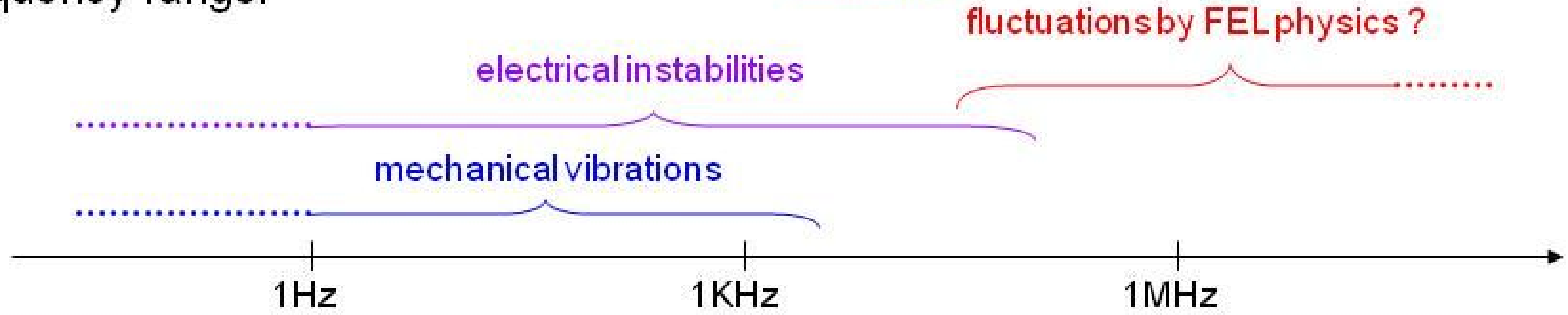
$$\lambda = \frac{\lambda_u}{2\gamma^2}\left(1 + K_{RMS}^2 + \gamma^2\theta^2\right)$$

power fluctuations:

- bunch charge fluctuations
- e-beam instabilities (energy, trajectory)
- longitudinal phase space jitter
- mechanical instabilities (vibrations), optical mode instabilities
- limitation phenomena of the FEL physics

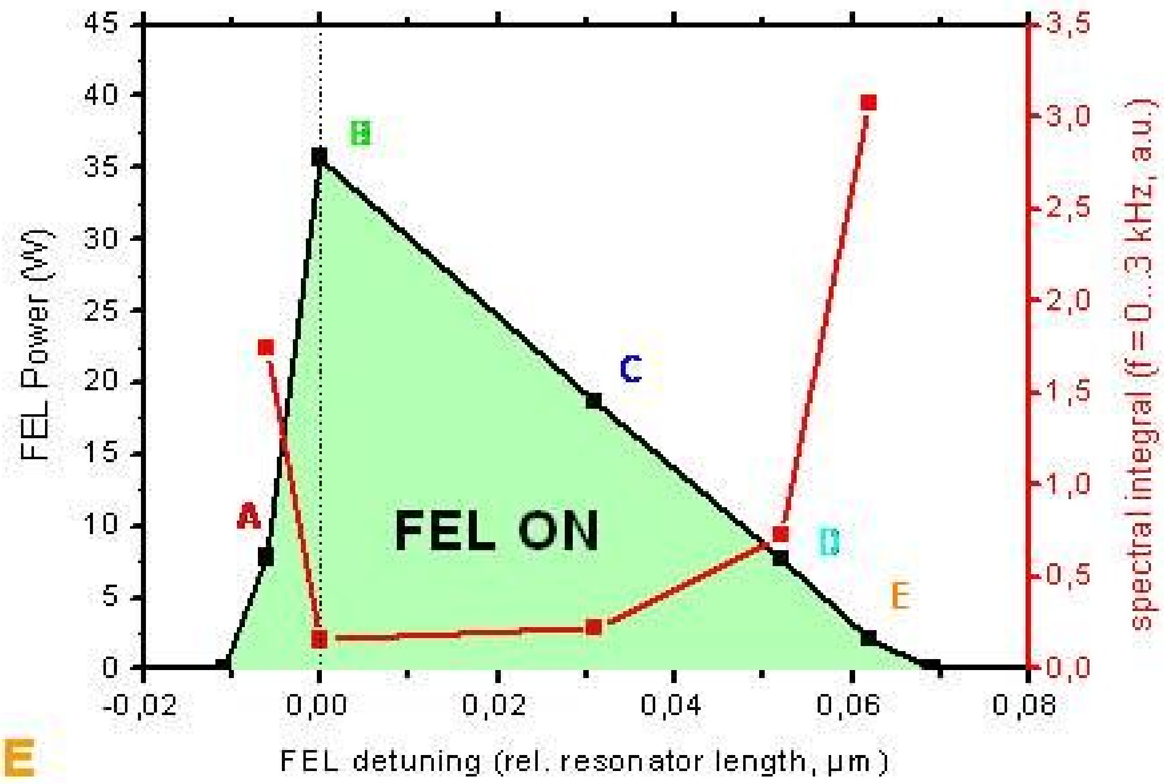


frequency range:

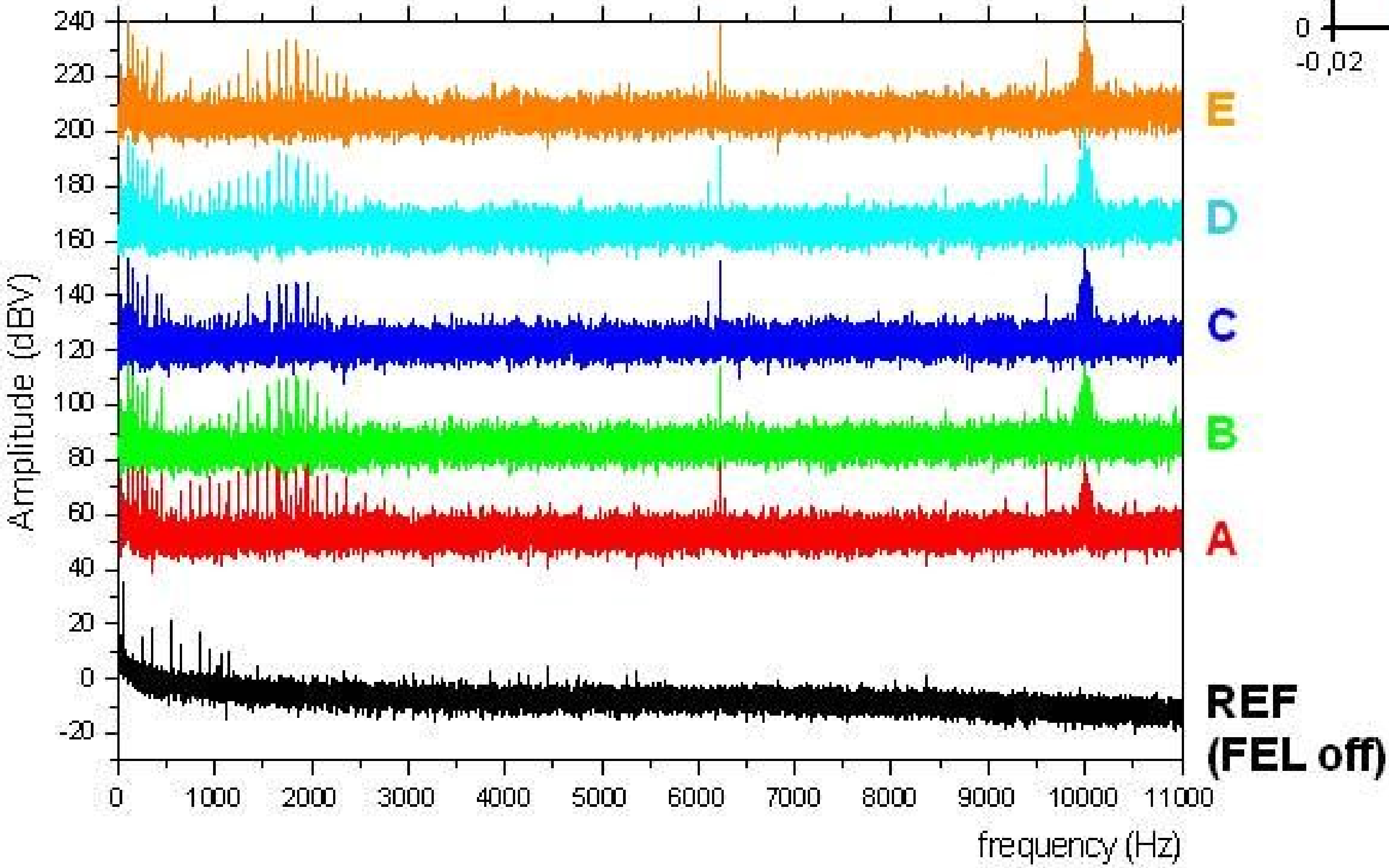


4 Infrared beam stabilizationn

- frequency analysis up to 11 kHz using a GeGa detector system
- integral of spectra from 0…3 kHz shows influence of the resonator detuning



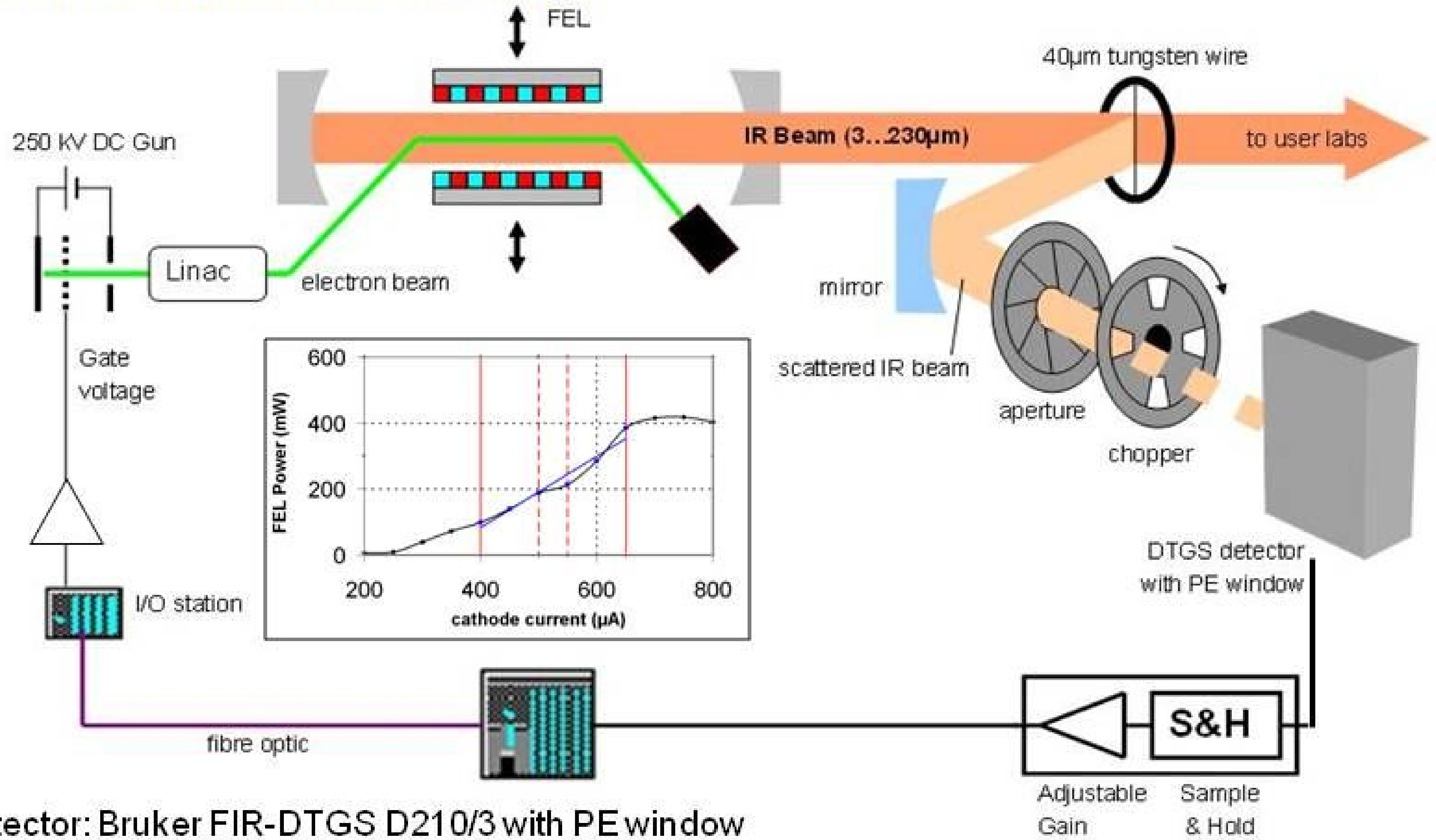
A…E normalized by „REF", offset added to each spectrum



identified noise sources:

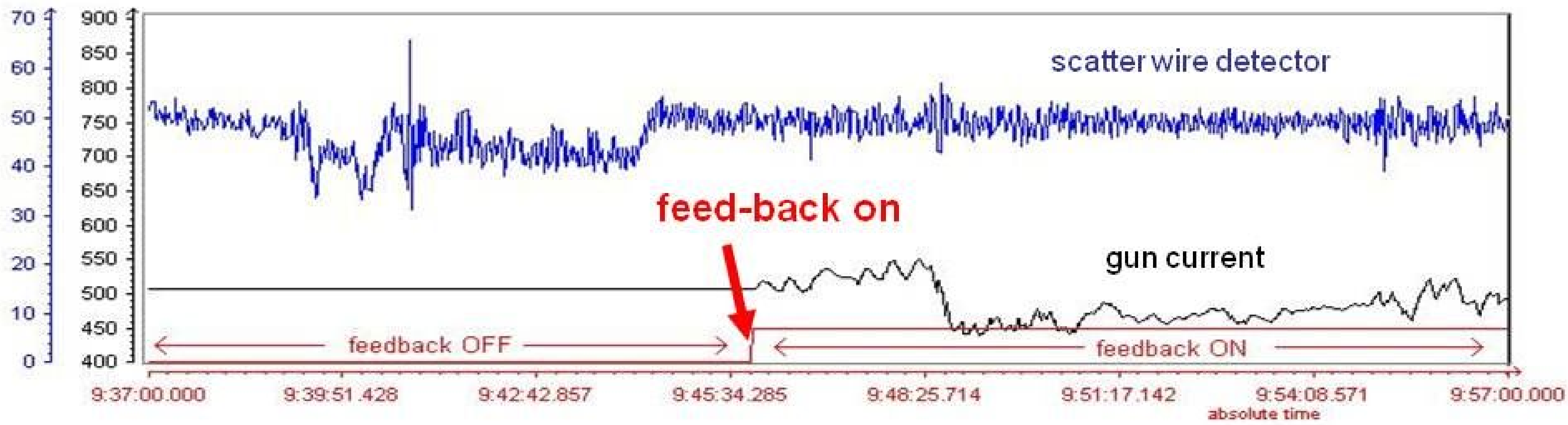
- 25 Hz & harmonics by macro-buncher
- 50 Hz noise & harmonics
- 10 kHz by macro-buncher
- 15.6 kHz by vidicon cameras

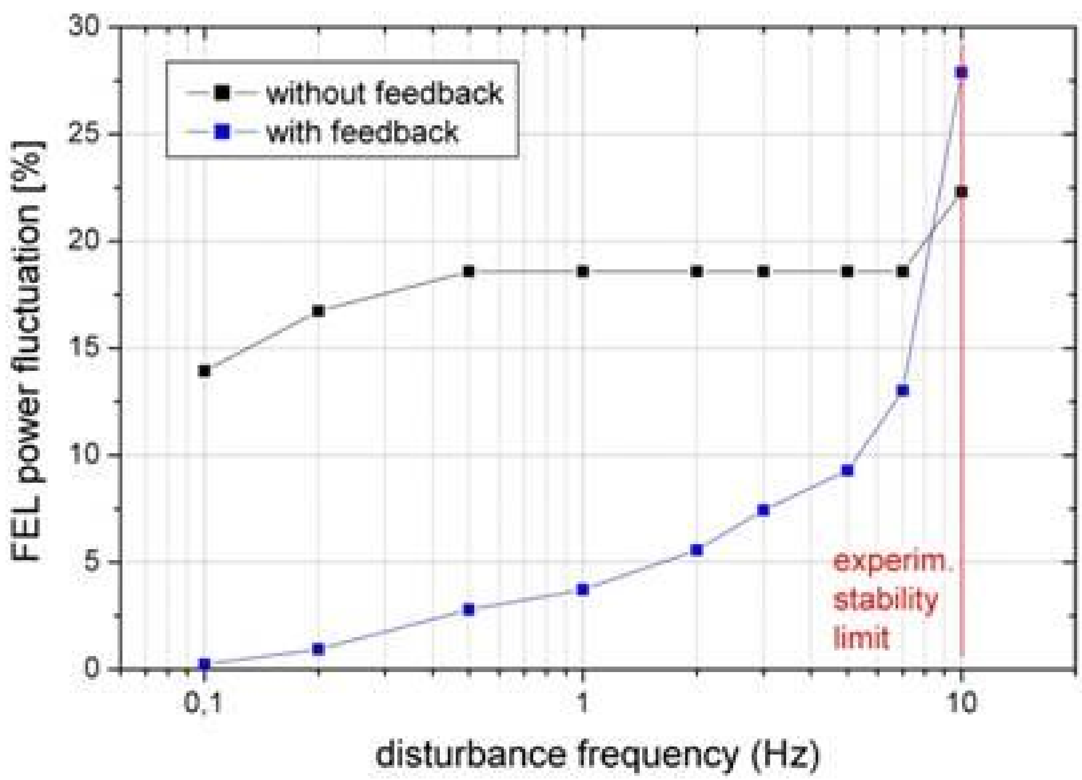
4 Infrared beam stabilization



- detector: Bruker FIR-DTGS D210/3 with PE window
- chopper frequency: 800 Hz
- PLC: ADC input 400 μs, sampling time, CPU Simatic S7-400 (cycle time 10 ms)
- output: Profibus® transmission and DAC conv. time 4.2 ms
- gun: gate voltage controller delay time 1.8 ms

4 Infrared beam stabilization

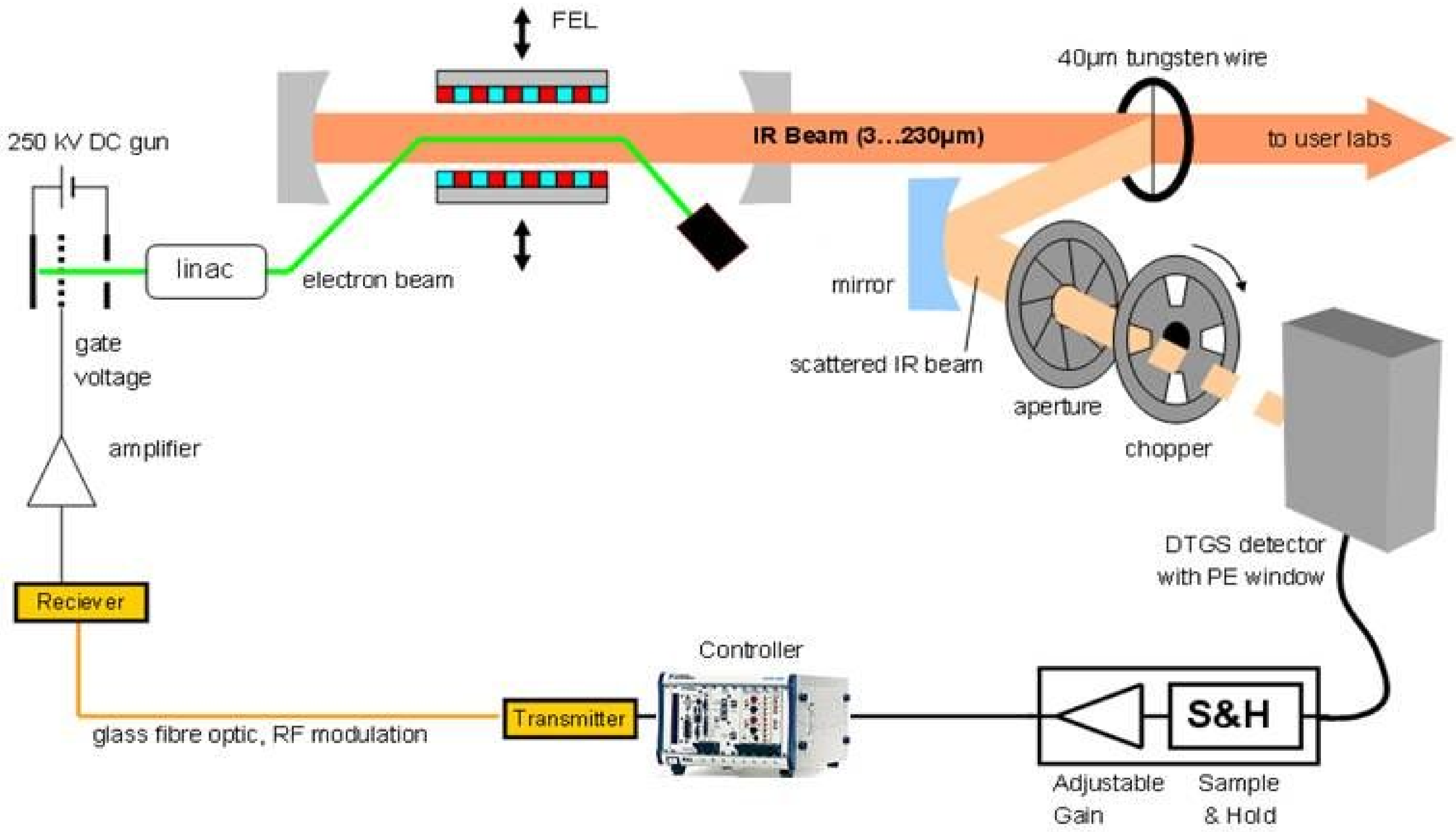




frequency response measured by vertical e-beam modulation

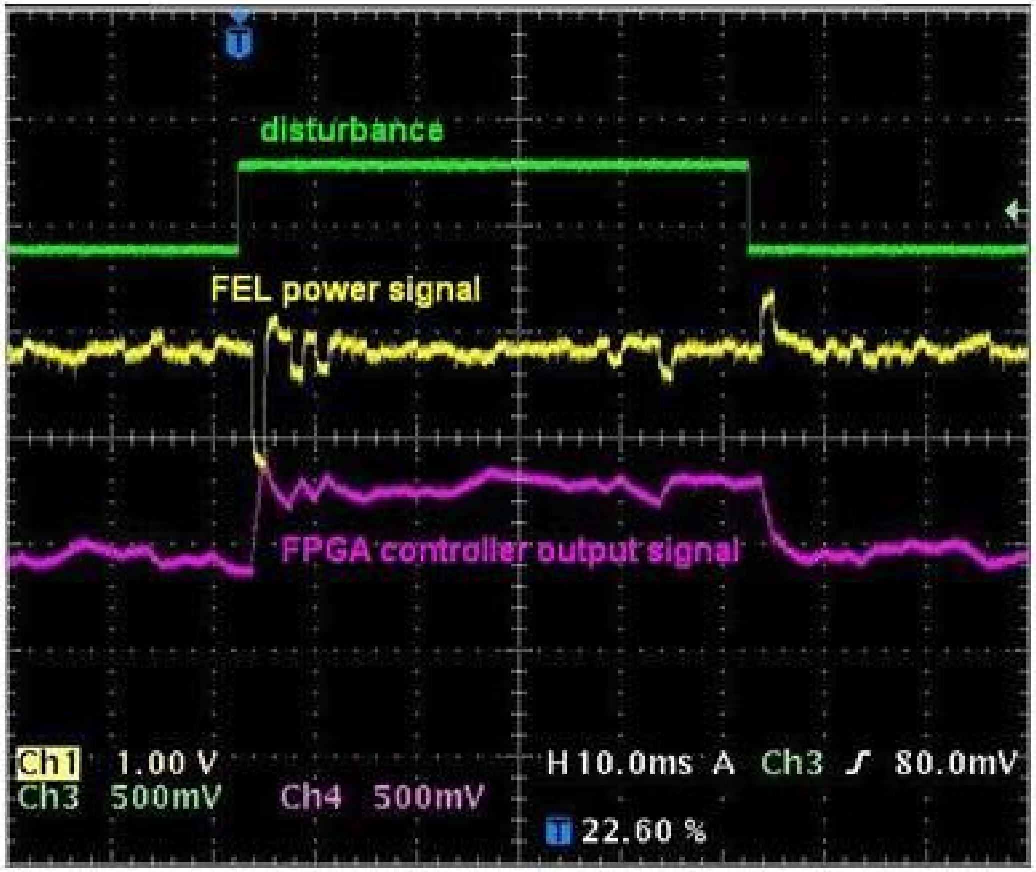
- bandwidth limit ~ 5 Hz (suppression 50%)
- suitable for compensation of thermal drifts in the optical cavity, sudden effects
- improvement for statistical & long term experiments

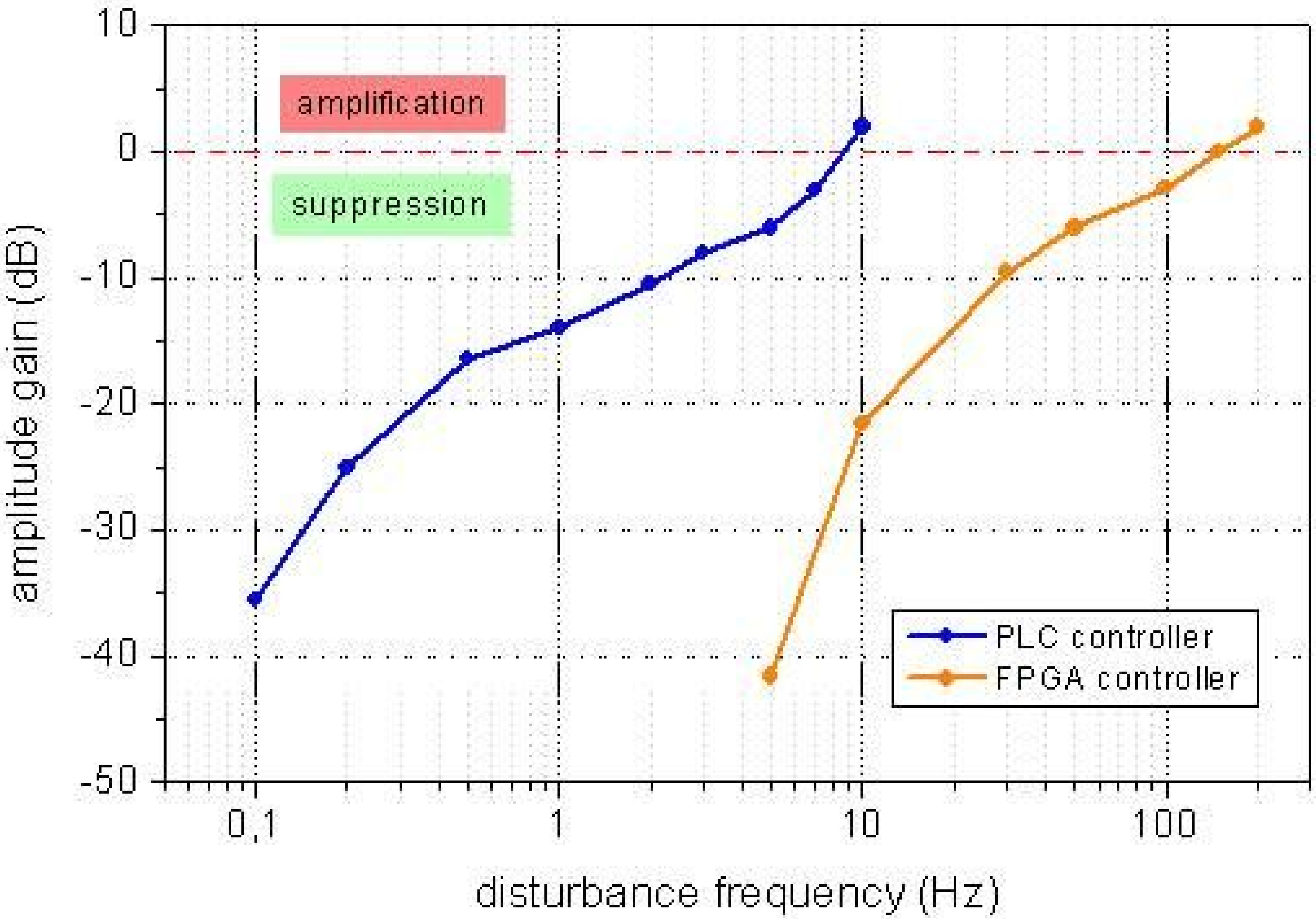
4 Infrared beam stabilization



- PLC technique replaced by FPGA-controller (NI-7833) and high performance optical transmission line (amplitude modulation)

4 Infrared beam stabilization

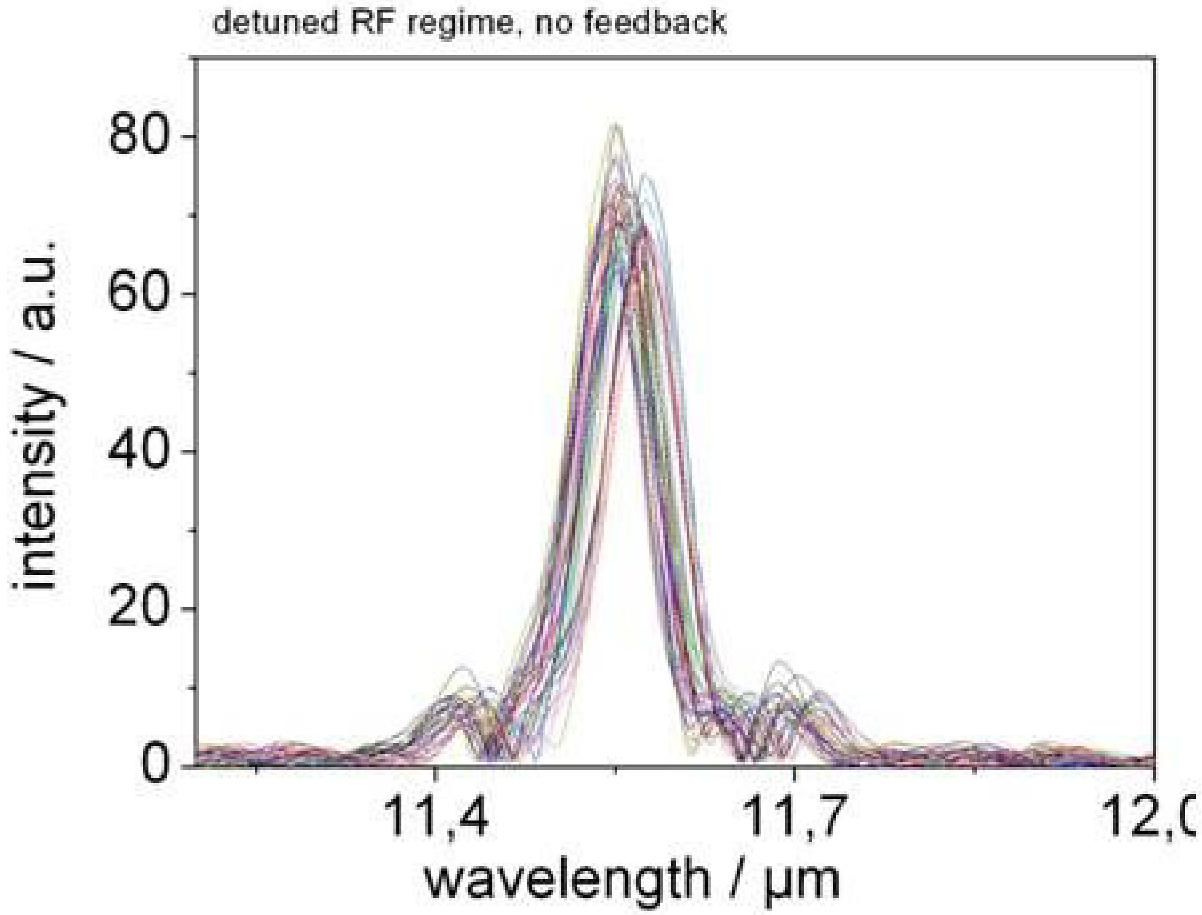


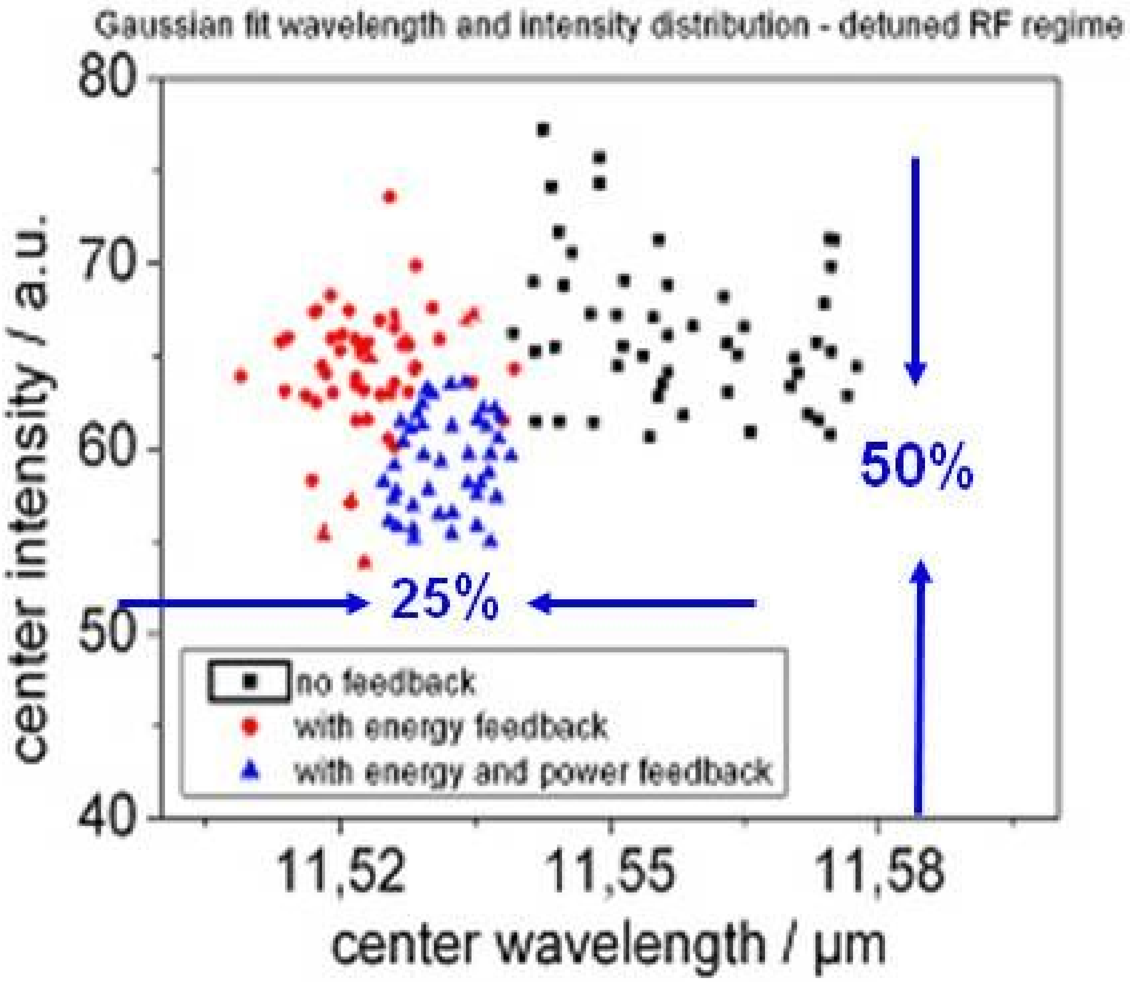


- improvement in frequency domain of ~ 1 decade
- current status is testing station
- test with chopper frequency of 2.4 kHz brought an improvement of only ~ 2dB @ 70 Hz due to limitation of the chopper phase stability and the DTGS rise time

4 Infrared beam stabilization

FEL regime with **artificially unstable e-beam**
U27, 11.55 µm, cw, 10W
FTIR scan (10 min total)
PLC controller





5 Summary & Prospect

- beam stability for electron beam as well as IR was improved, but does not yet meet our goals
- low frequency instabilities and sudden parameter changes can be compensated
- overall beam availability was improved by decreasing setup times (not the topic of this talk)

Current efforts & future plans:

- Absolute energy calibration by implementation of a spectrometer magnet (absolute calibration accuracy 10^{-3}, resolution 10^{-4})
- Combined energy & position feedback needed using faster hardware
- bandwidth improvement using LLRF electronics
- IR detector technology (dc coupled, upper kHz range, low maintenance, 3…280µm)
- auto-tuning, esp. for FEL feedback


Thanks to the ELBE team…
…and for your attention !