Karlsruher Institut für Technologie

ANKA THZ GROUP

EOS at Storage Rings

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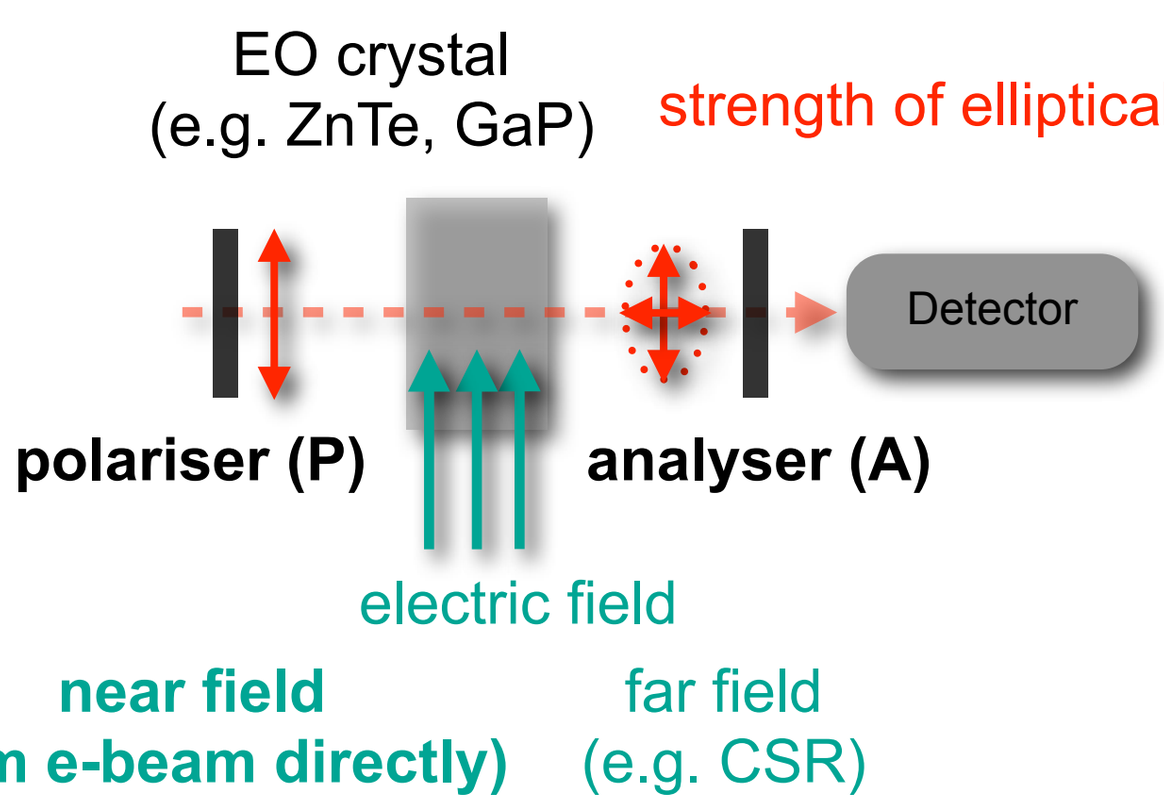
Electro-optic techniques - working principle

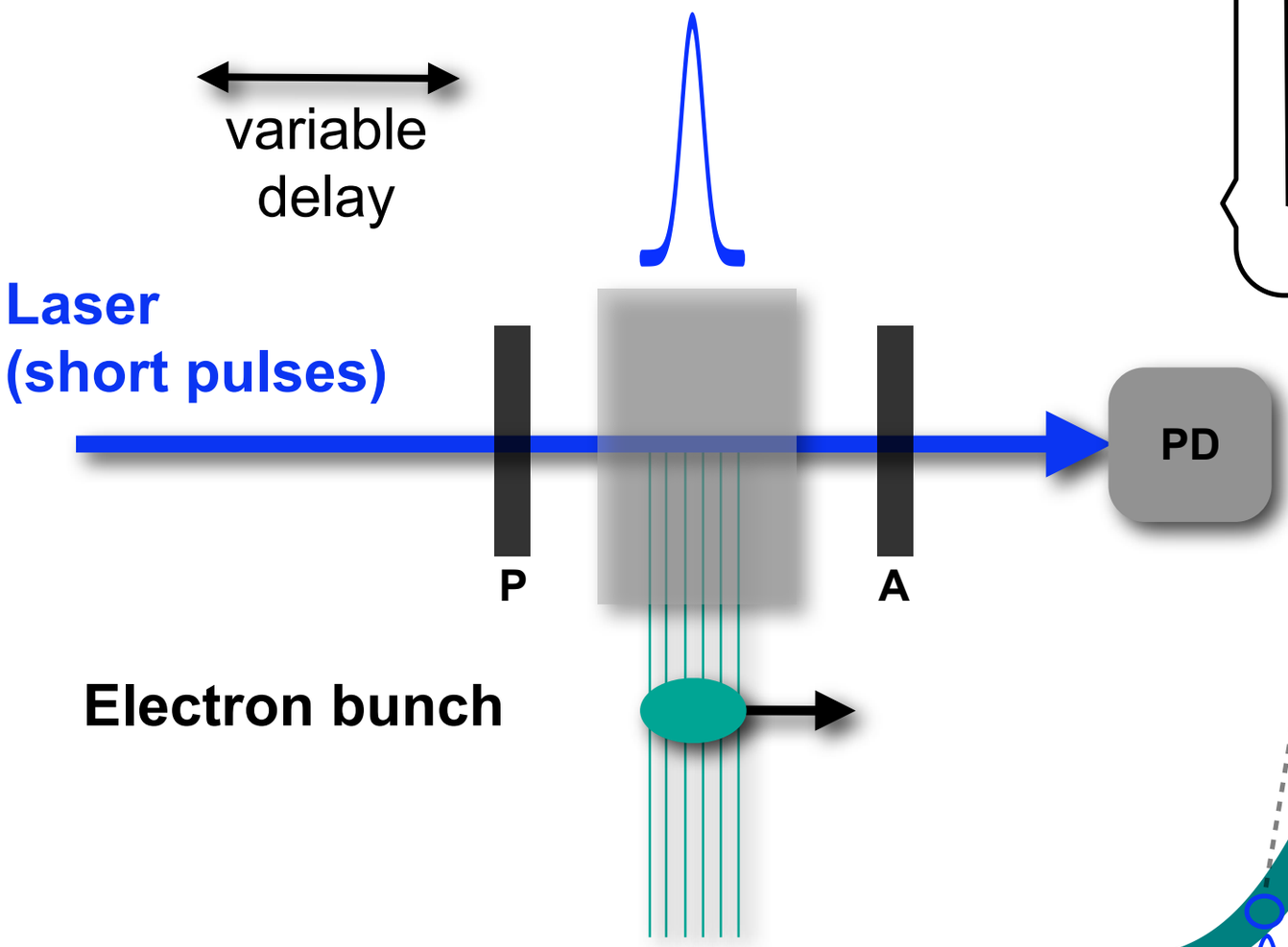
Intensity distribution of electron bunch is modulated onto laser pulse which is then analysed.

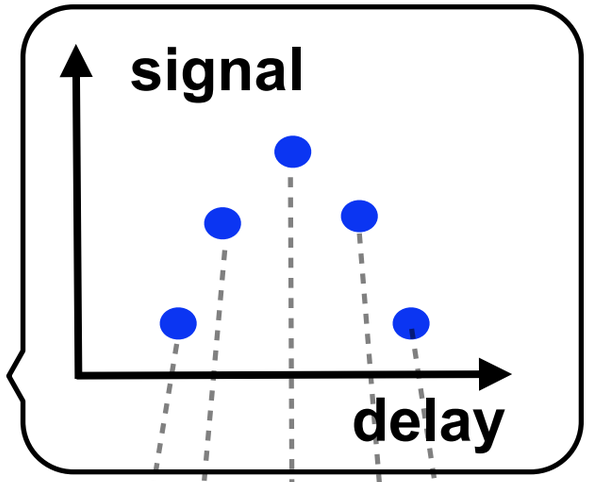
Modulation in electro-optic crystal:

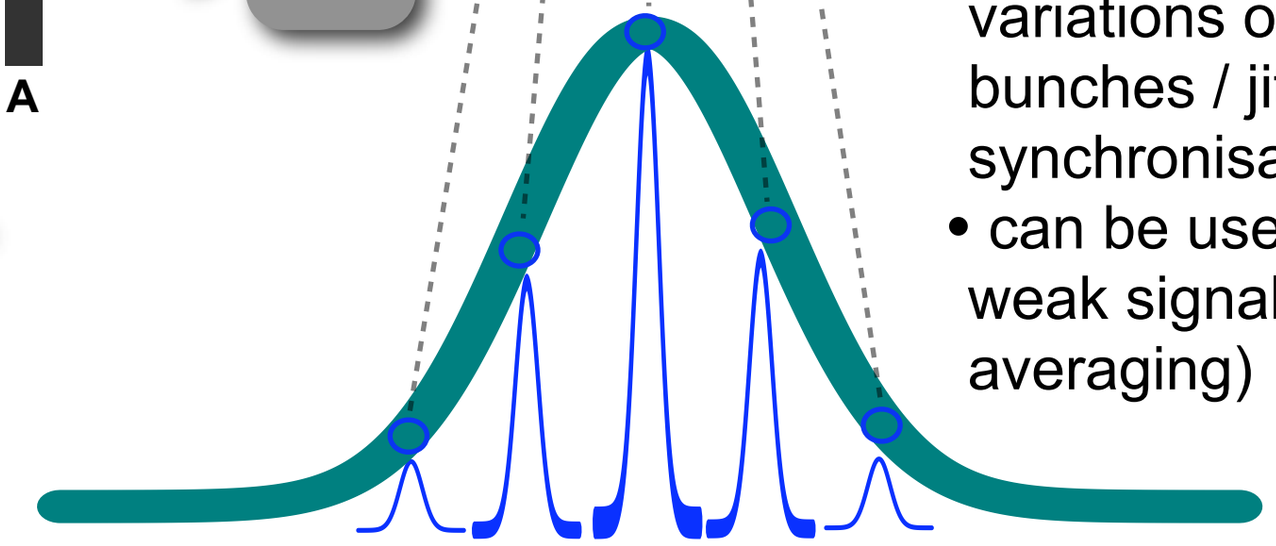


best S/N ratio for nearly crossed polariser and analyser angles

Electro-optical sampling (multi-shot)





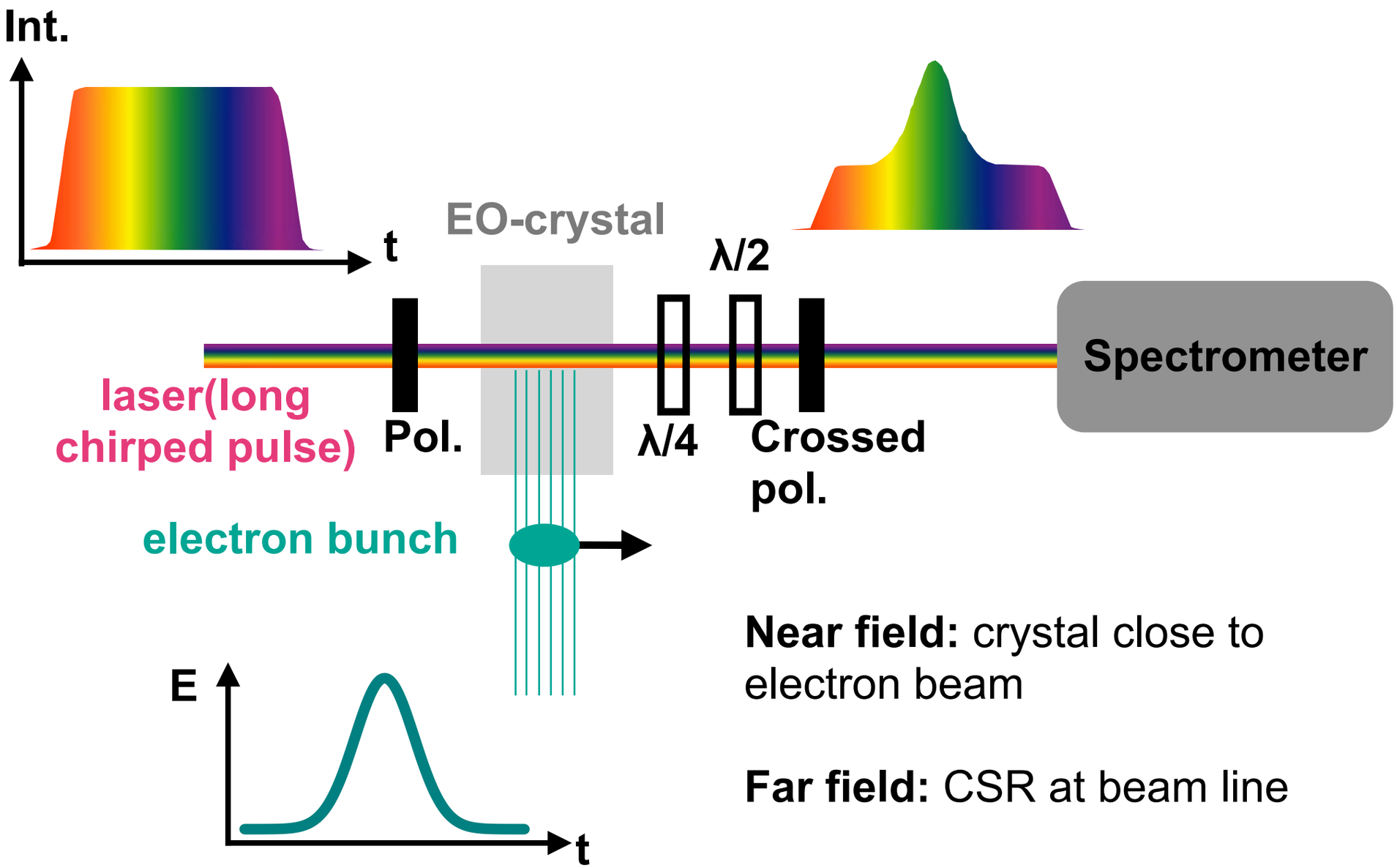


short laser pulses sampling the electron bunch at different delays over several revolutions / or different shots

- limited by ToA-variations of electron bunches / jitter of synchronisation
- can be used for very weak signal (long averaging)

Also possible to use “asynchronous sampling” for which the laser is slightly detuned from revolution frequency -> much faster

Spectral decoding (single shot) - EOSD



Near field: crystal close to electron beam

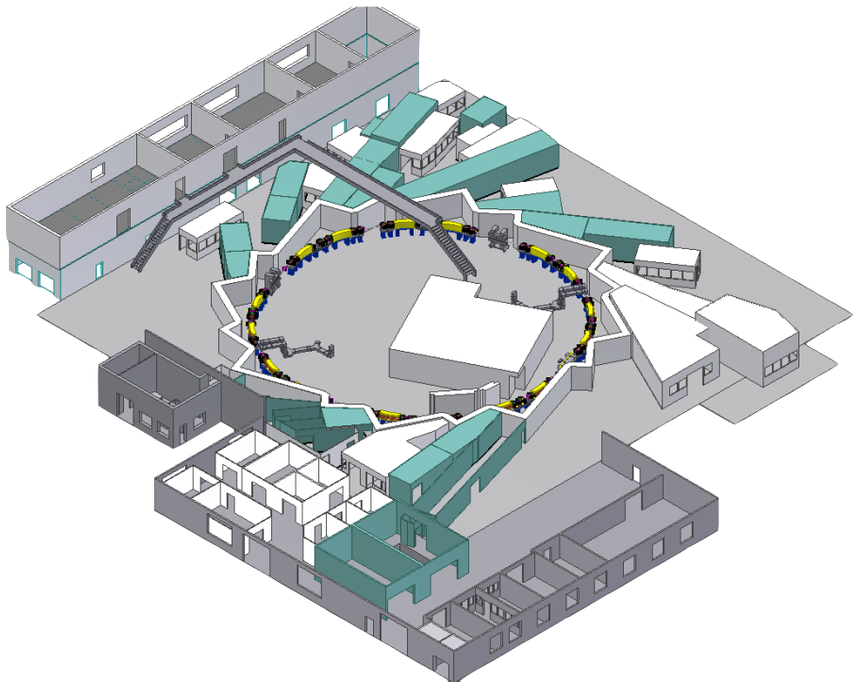
Far field: CSR at beam line

λ/4: compensate intrinsic birefringence of crystal
λ/2: control transmission through crossed polariser

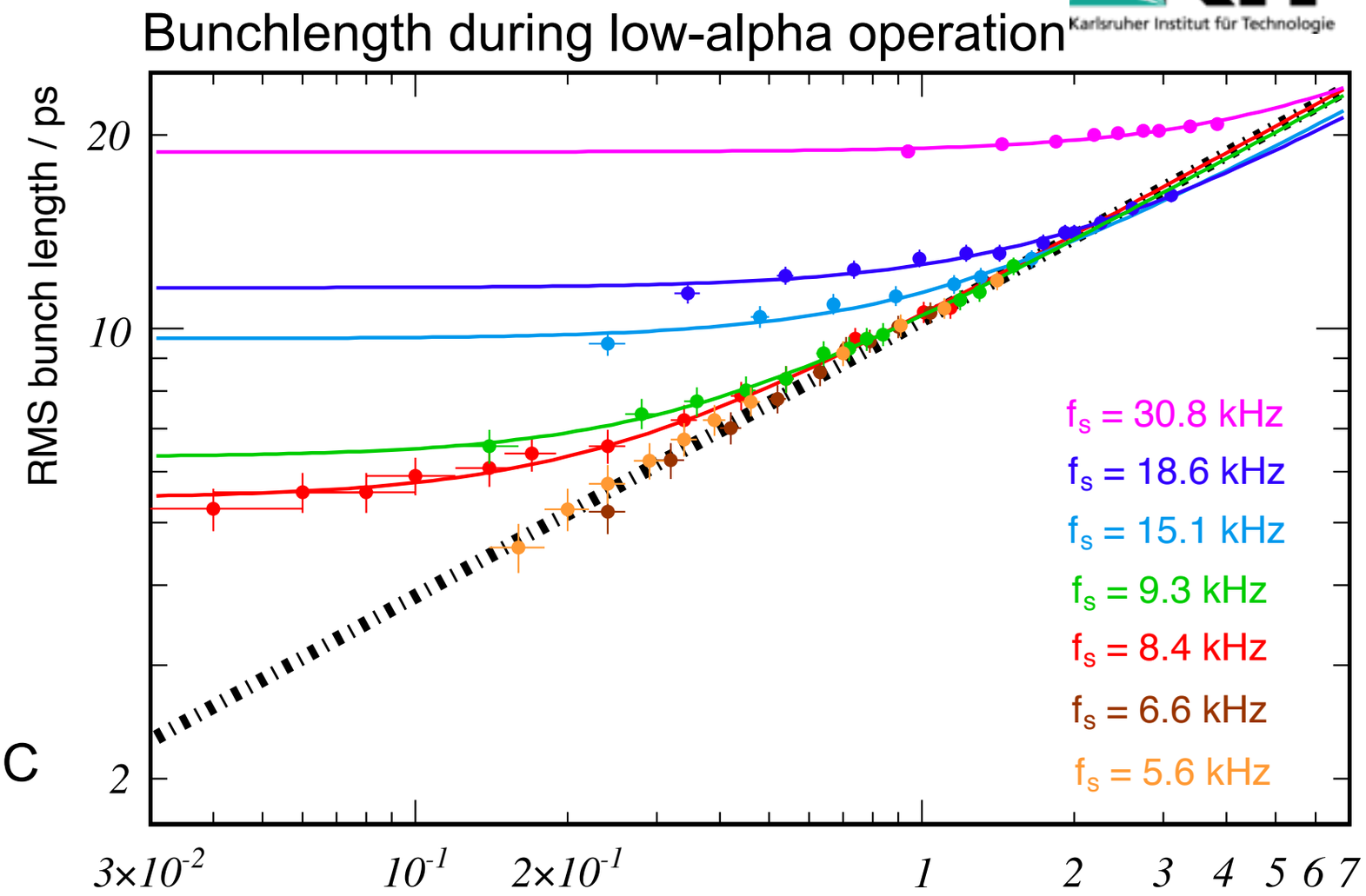
Some history of EO measurements

- **Measurement technique was used in laser physics:** EOS: Q. Wu, X.-C. Zhang in 1995; EOSD: Z. Jiang and X.-C. Zhang APL, 72(16):1945 –1947, April 1998; F. G. Sun, Zhiping Jiang, and X.-C. Zhang, APL, 73(16):2233 –2235, October 1998
- **FELIX** (1999-2002)**:** EOS, EOSD, EOTD, Spatial decoding (PRL, 85(16):3404–3407, Oct 2000; PRL, 88(12), 2002)
- **Fermilab Photoinjector** EOS: (PRL 87, 034801 (2001))
- **ATF (BNL)** EOS: J. Appl. Phys. 89, 4921 (2001)
- **DUVFEL SDL (NSLS):** EOS + EOSD: (PAC03 WPPB021)
- **VUV FEL (DESY):** EOS near field (PAC05 RPAT050)
- **SLAC linac** spatial decoding + EOS: PRL 94, 114801 (2005)
- **FLASH (DESY)** (2004-2007)**:** EOS, EOSD, EOTD (thesis B. Steffen)
- **SLS (PSI)** Injector (linac): EOS; far field (EPAC04 THOALH01) & near field (F. Müller thesis)
  SLS CSR from FEMTO-slicing (2010): EOSD (F. Müller thesis)
- **ANKA:** asynchronous EOS far field (PAC09 tu5rfp026)
- **UVSOR II (Japan):** EOS of femtoslicing: Katayama, CLEO proceedings 2010
- **ELBE (HZDR):** EOS (APL 100, 141103 (2012))

Introduction: The ANKA storage ring



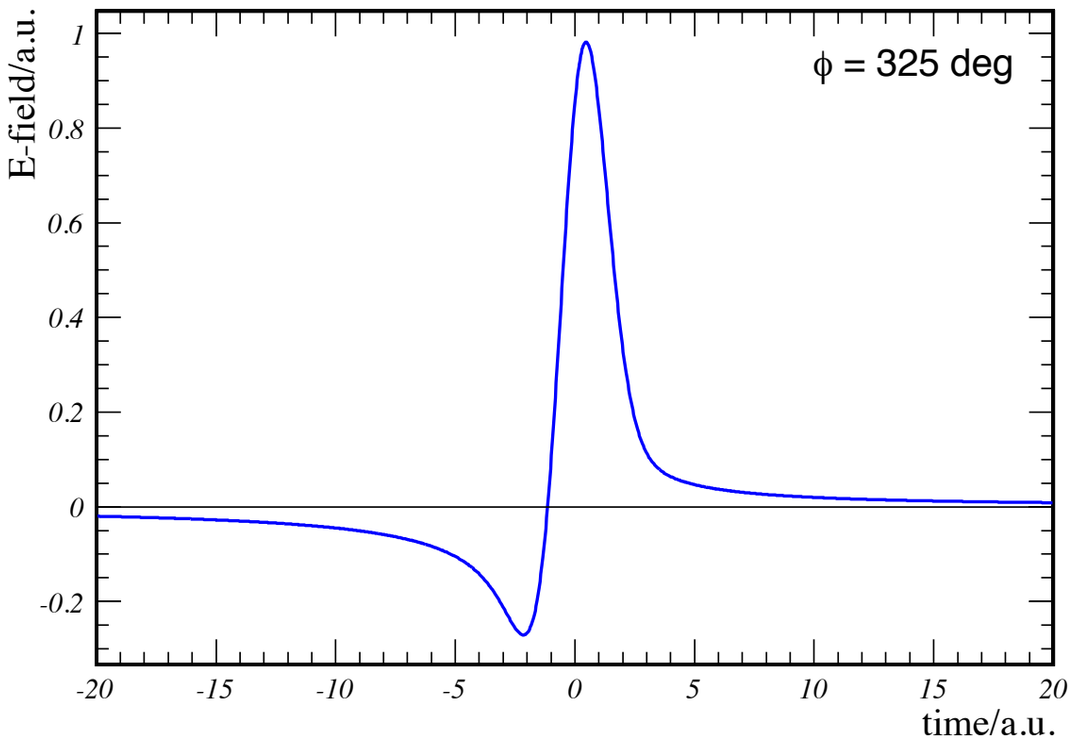
1 mA ≙ 370 pC



- Circumference 110.4 m
- f_{rev} = 2.715 MHz
- f_{RF} = 499.69 MHz
- Harmonic number h = 184
- Double bend achromat lattice
- Energy 0.5 - 2.5 GeV
  (0.8 - 1.6 GeV during low-α_c-mode)
- RMS bunch length 45 ps (for 2.5 GeV), down to 2 ps (for 1.3 GeV)
- Filling pattern: single- or multi-bunch

EOS with THz radiation at ANKA (far field)

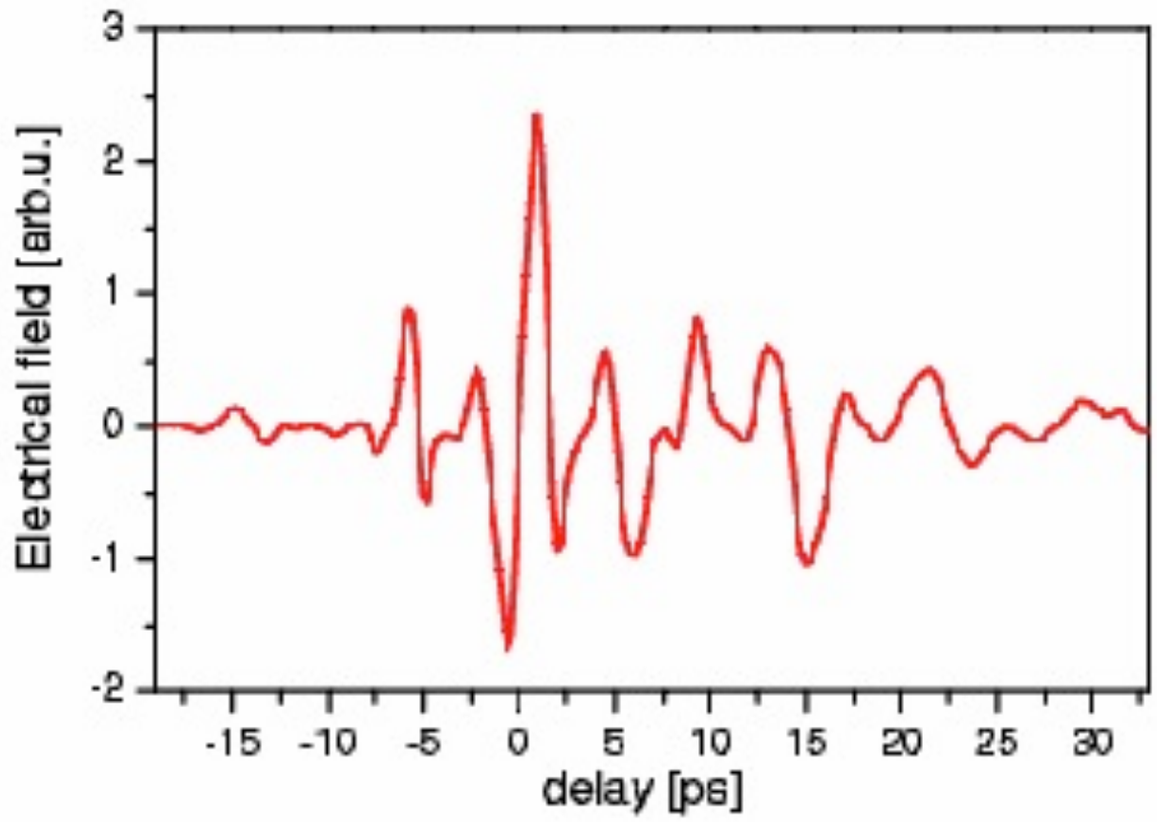
Model



A.-S. Müller et al.: Modeling the Shape of Coh.THz Pulses Emitted by Short Bunches in an El. SR, EPAC 2008

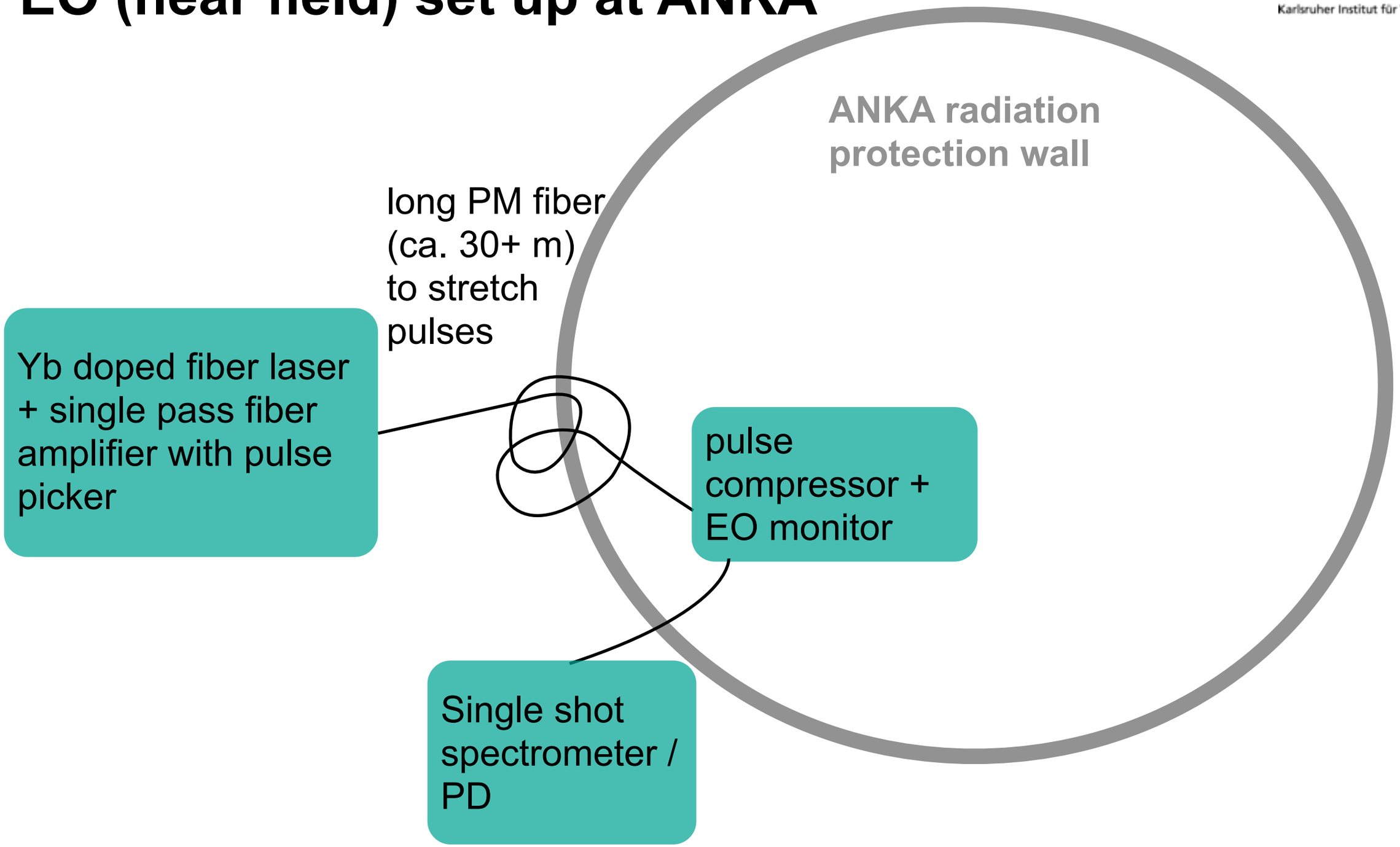
Measurement

Phase sensitive detection of THz radiation with electro-optical femto-second sampling (asynchronous sampling)



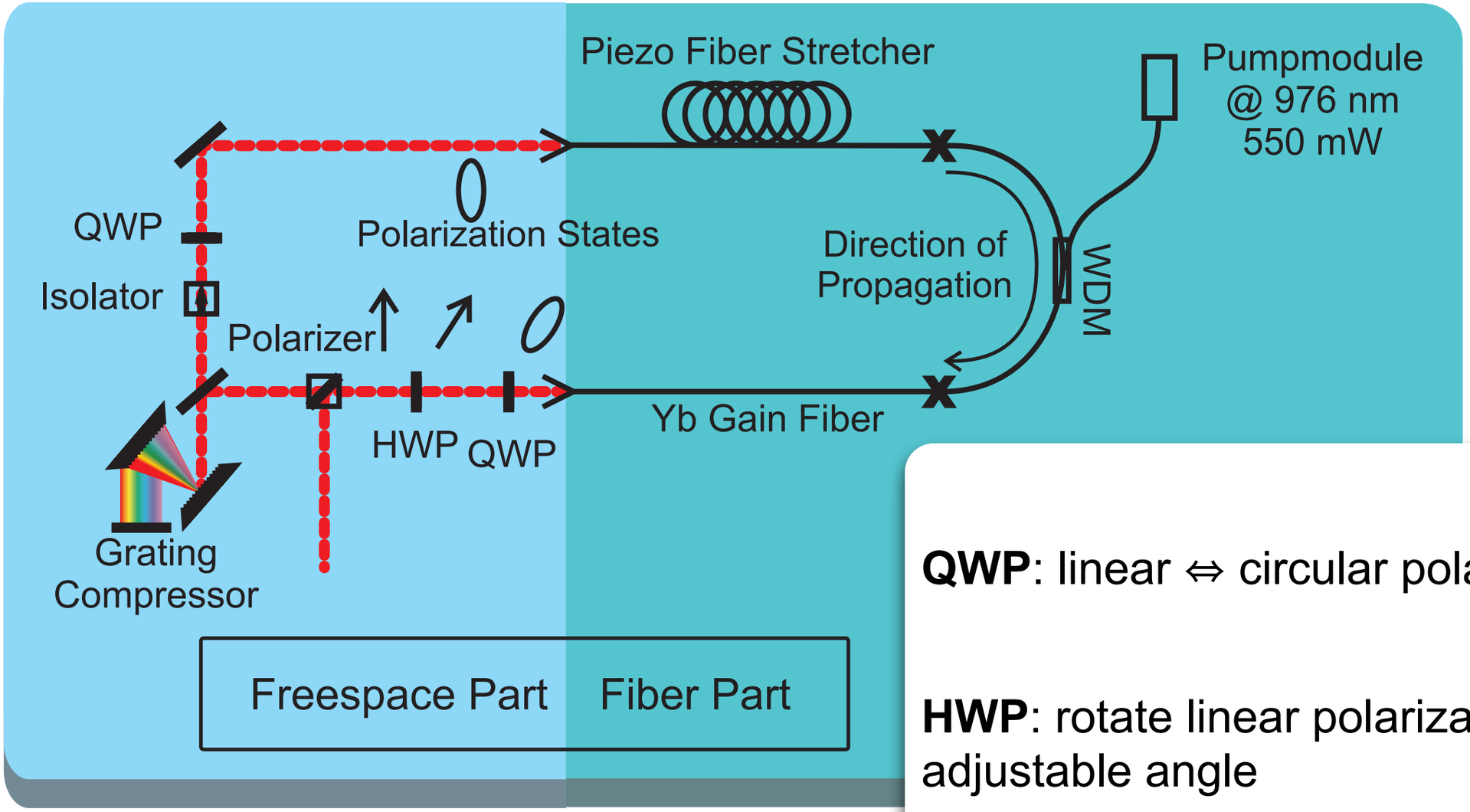
A. Plech et al.: Electro-Optical sampling of Terahertz radiation emitted by short bunches in the ANKA synchrotron, PAC 2009

EO (near field) set up at ANKA



ANKA-EO-Laser - Yb:GLASS Fiber Laser

- λ = 1030 nm (FWHM 30 nm FT pulse length 170 fs)
- Oscillator: f_{rep} = 62.5 MHz (500/8 MHz)
- Amplifier: f_{rep} = 1 kHz - 31.25 MHz
- P_{avg} at 62.5 MHz around 20 mW
- Pulse energy can be amplified up to 20 nJ



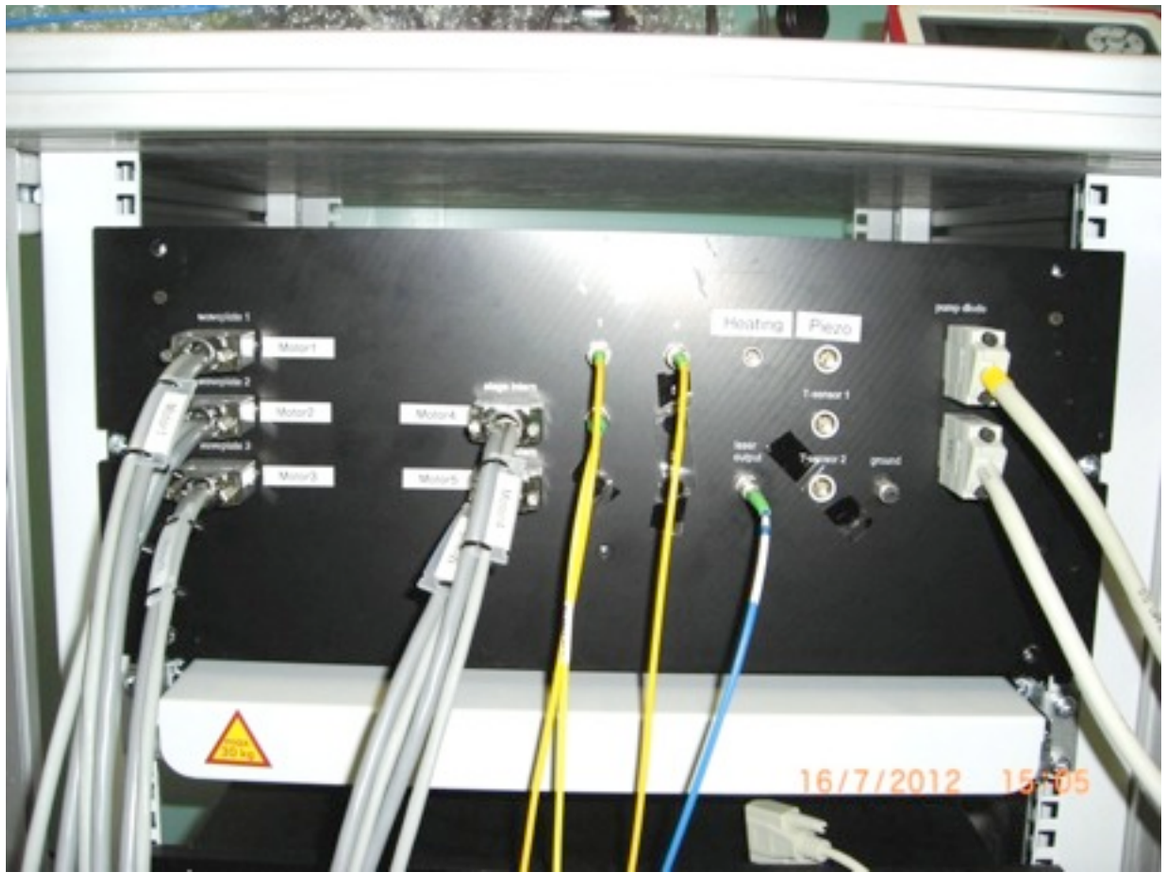
developed at PSI
adapted for use at ANKA

QWP: linear ⇔ circular polarization

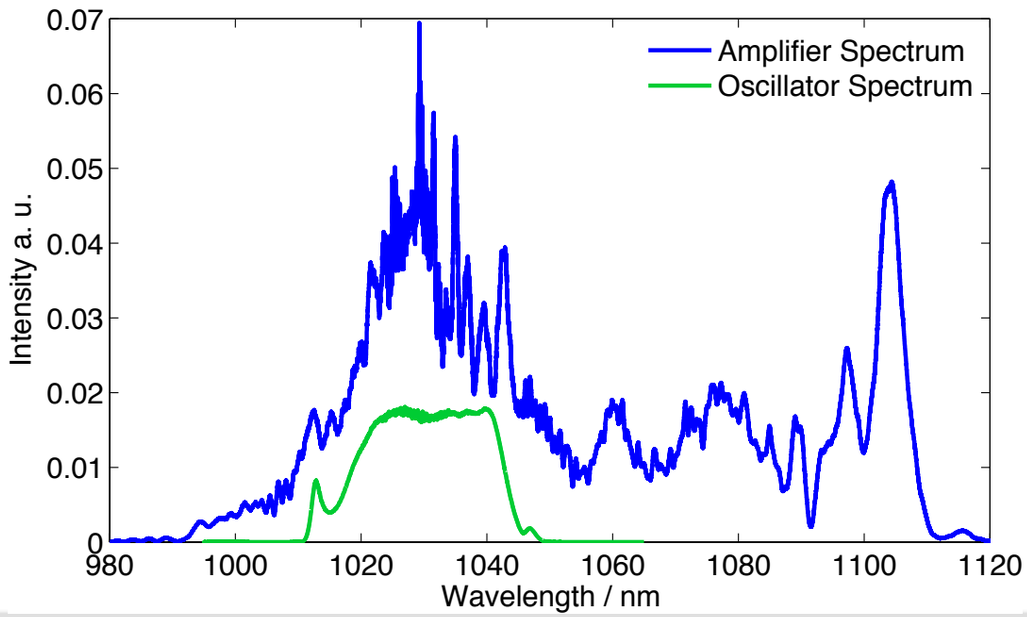
HWP: rotate linear polarization by adjustable angle

Courtesy: Felix Müller (PSI)

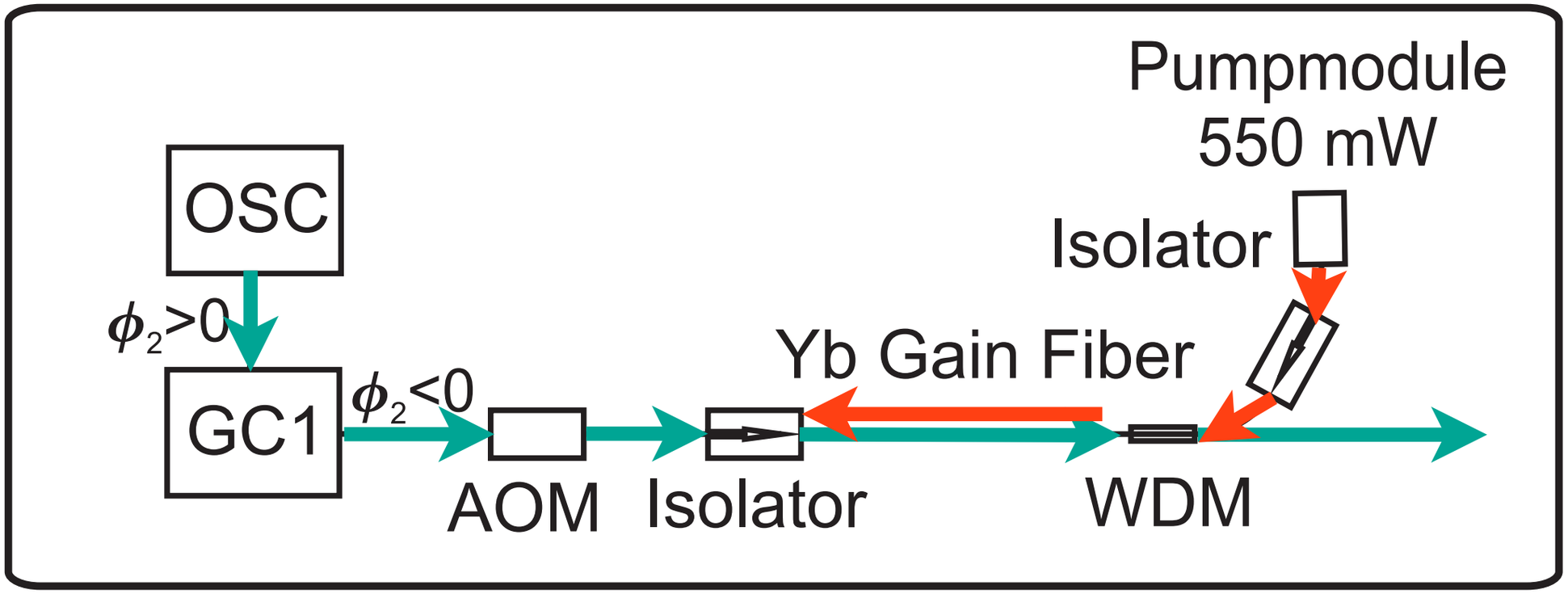
Yb doped fiber laser + amplifier



nonlinear amplification



Single Pass PM Fiber Amplifier

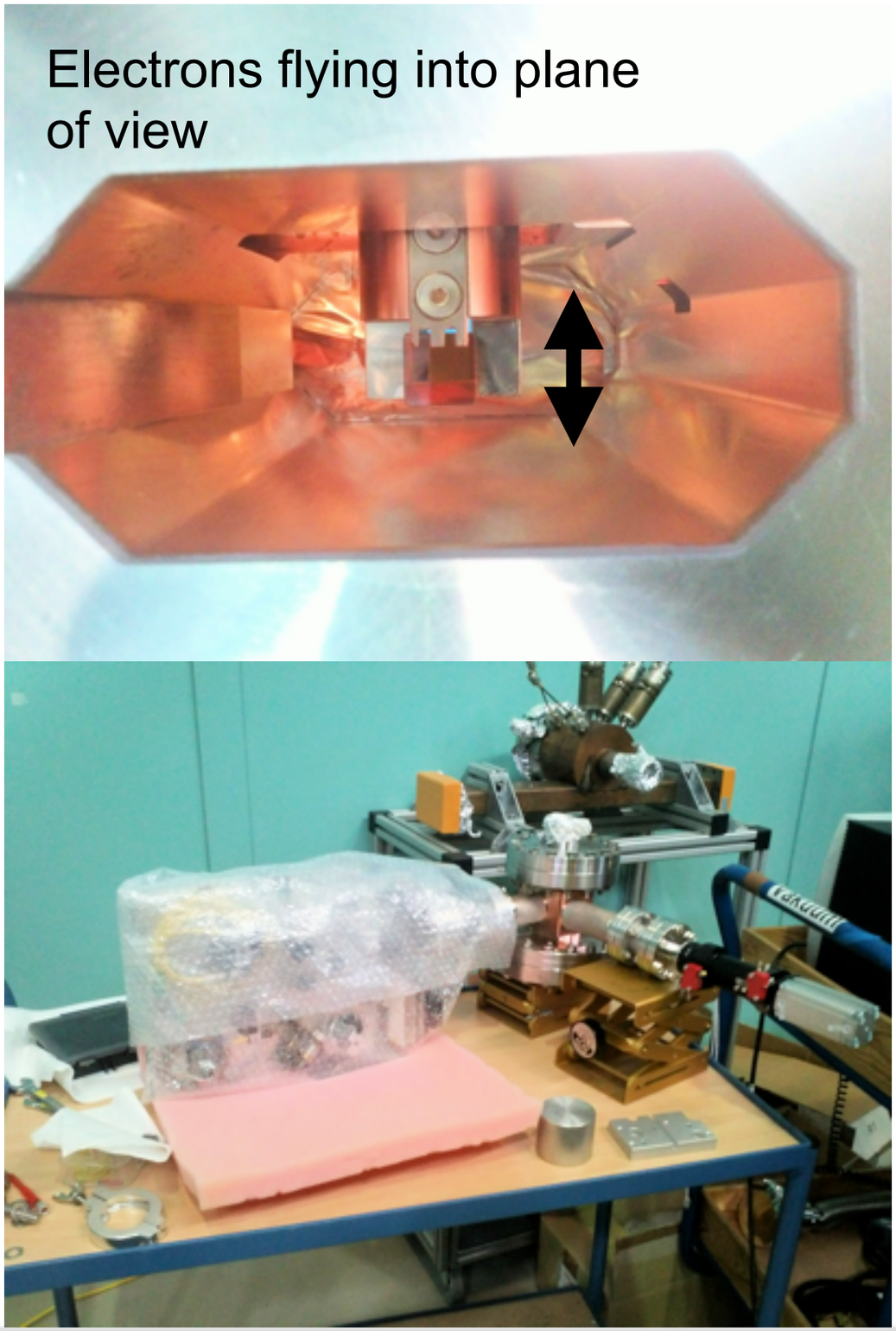


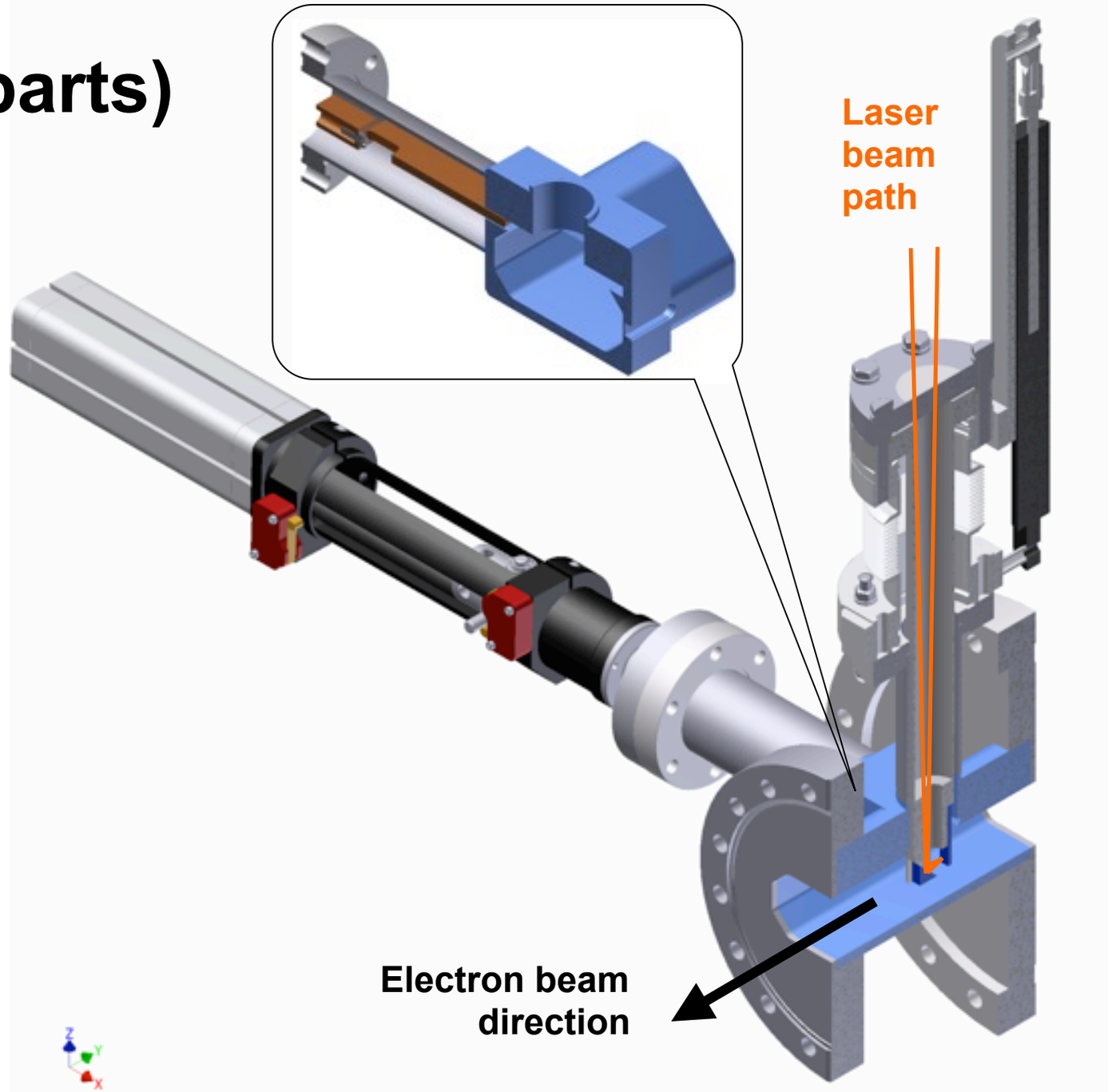
Courtesy: Felix Müller (PSI)

GC: Grating compressor
➔ pre-compensate for material dispersion ➔ shortest pulse length inside active fiber

Self-phase modulation: non-linear effect ➔ refractive index becomes a function of intensity)
➔ **spectral broadening** of unchirped or positively chirped pulses

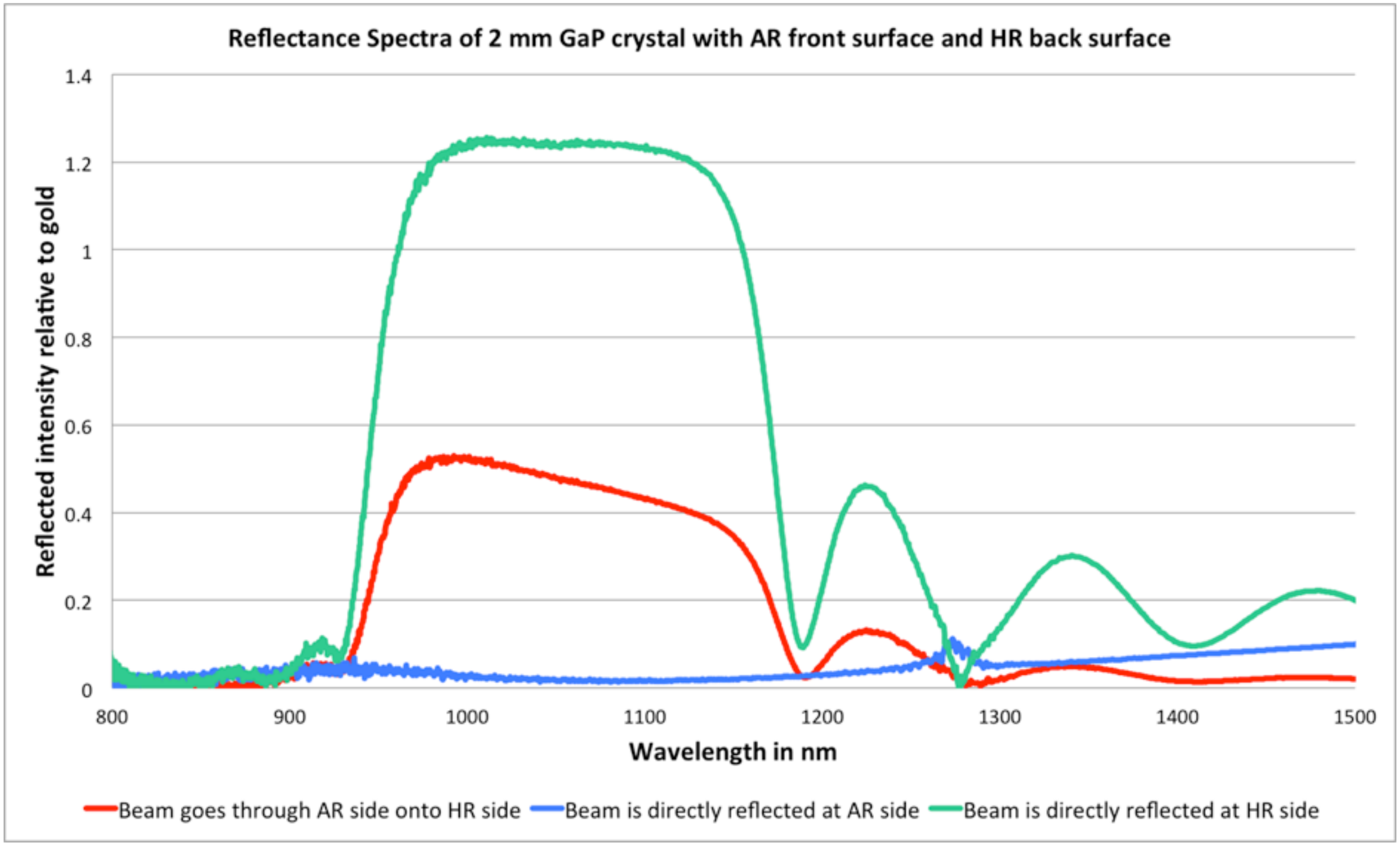
EO-Monitor (in vacuum parts)



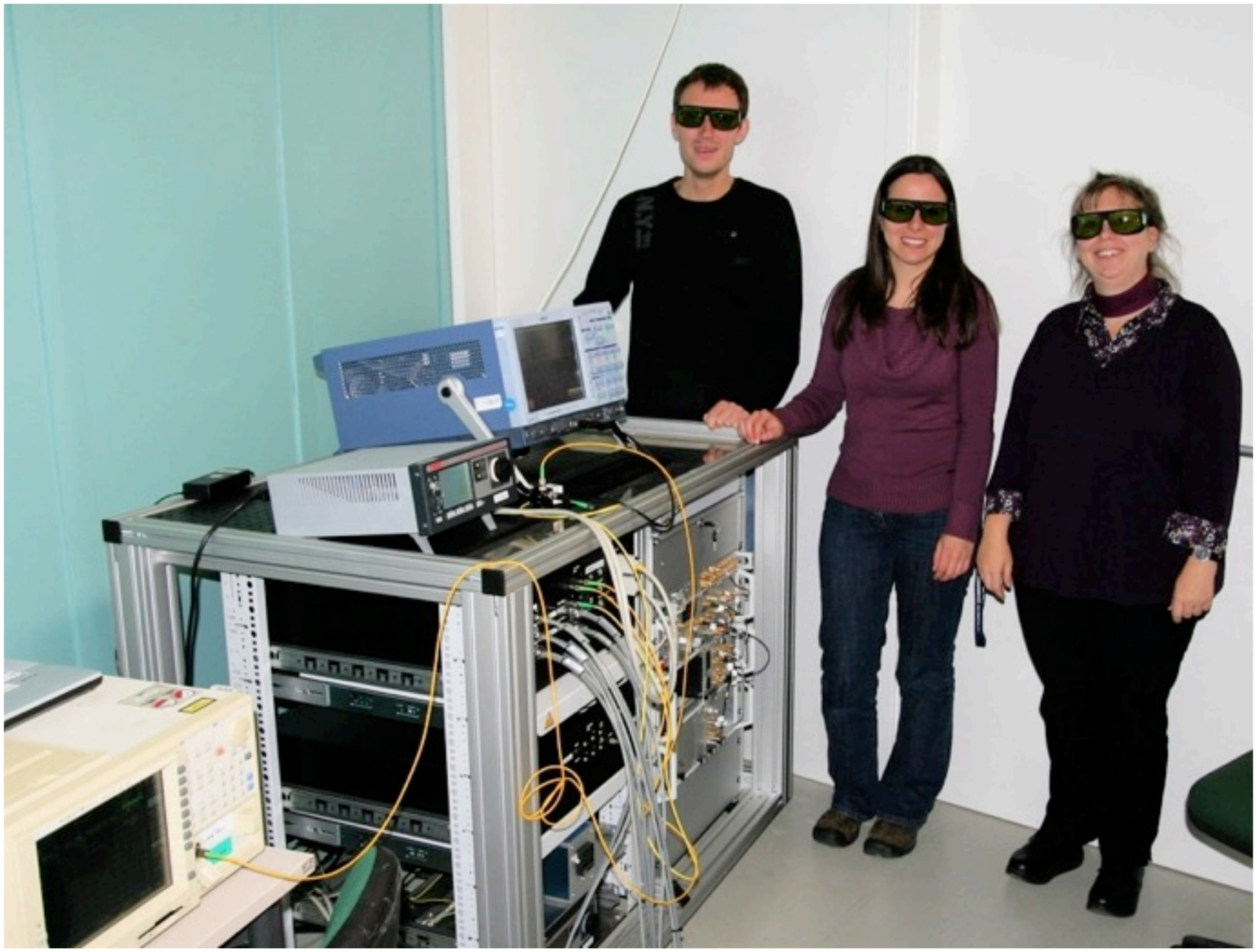


Drawing of the vacuum parts of the EO-monitor, also showing the impedance protection for the normal user operation (detail).

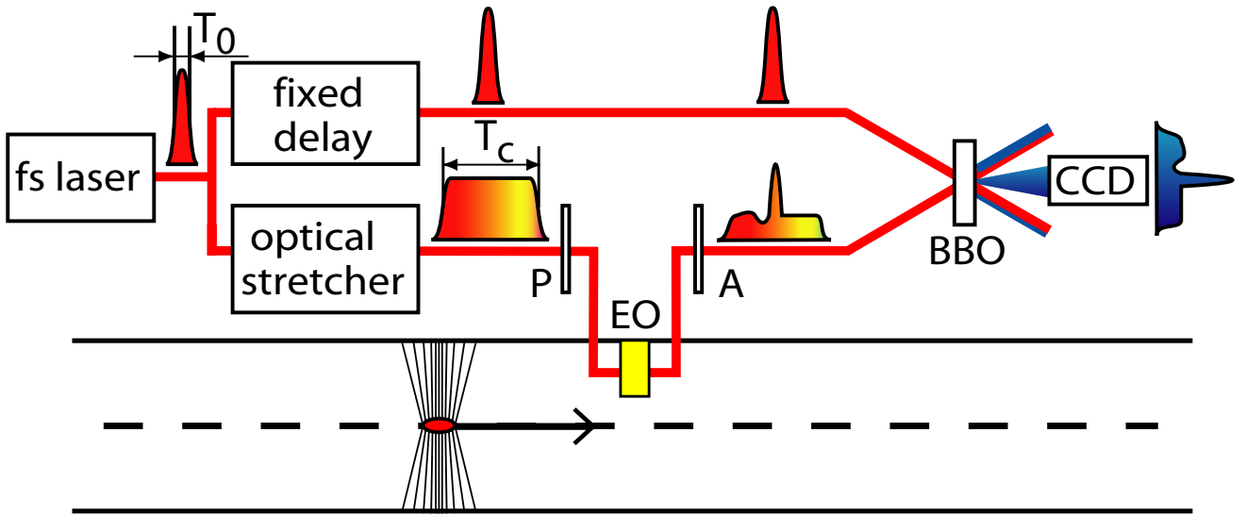
A crystal ~~clear~~ problem...



Thank you for your attention.

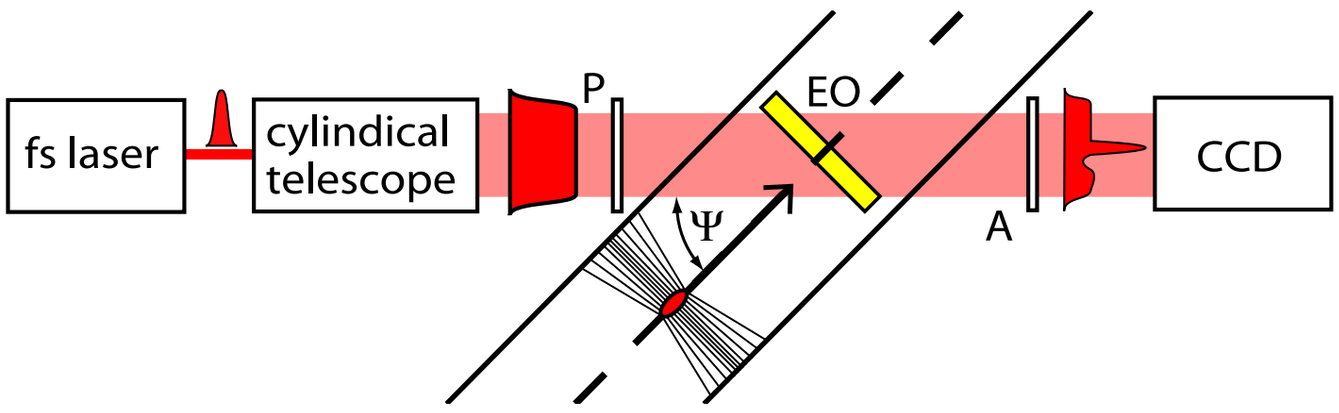


Temporal decoding



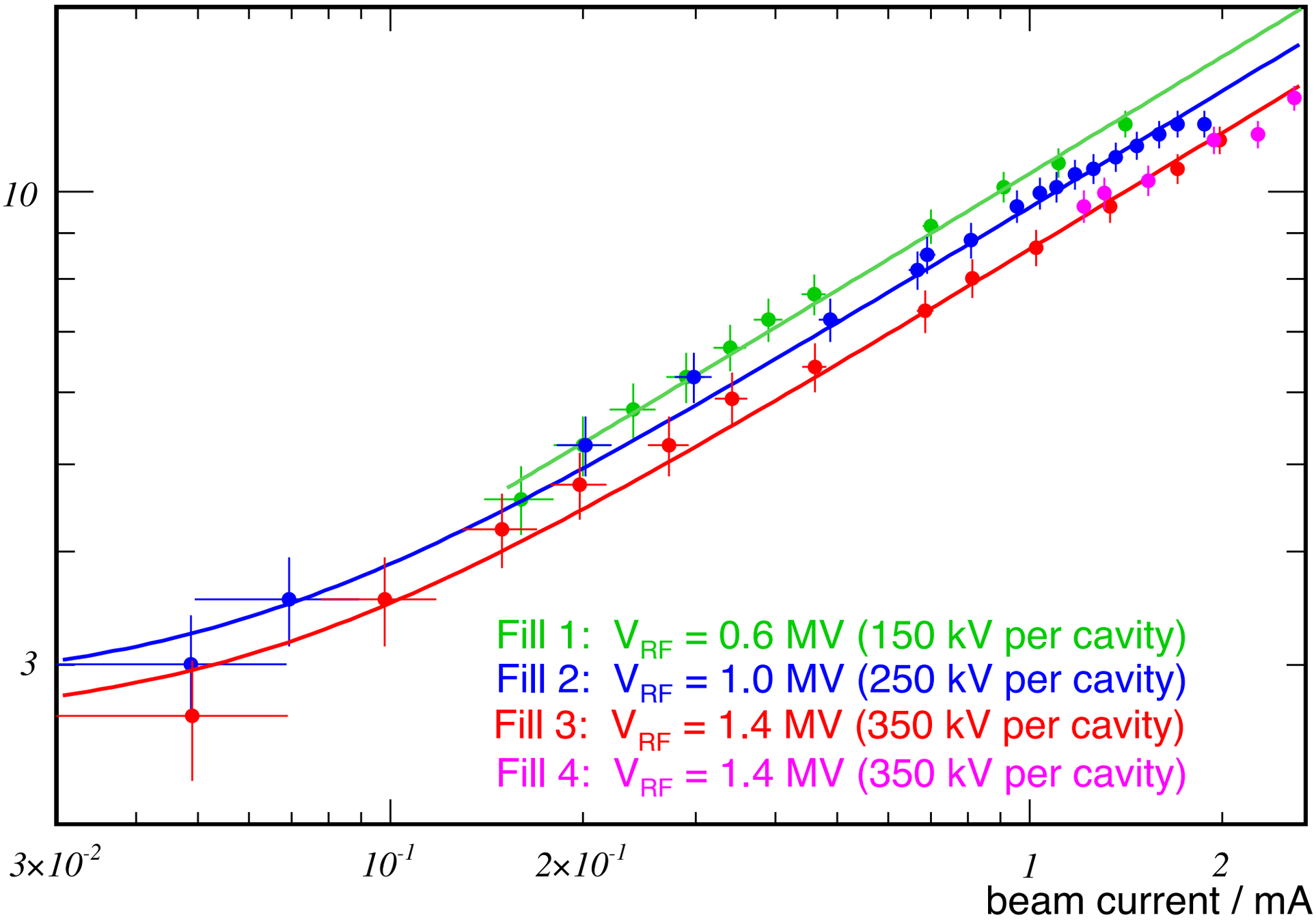
Courtesy of Bernd Steffen (DESY)

Spatial decoding



Courtesy of Bernd Steffen (DESY)

Bunchlength for different RF voltages



Bunch lengthening