Bunch Length Measurements at the Swiss Light Source (SLS) Linac at the PSI using Electro-Optical Sampling

A.Winter, Aachen University and DESY

Miniworkshop on XFEL Short Bunch Measurement and Timing

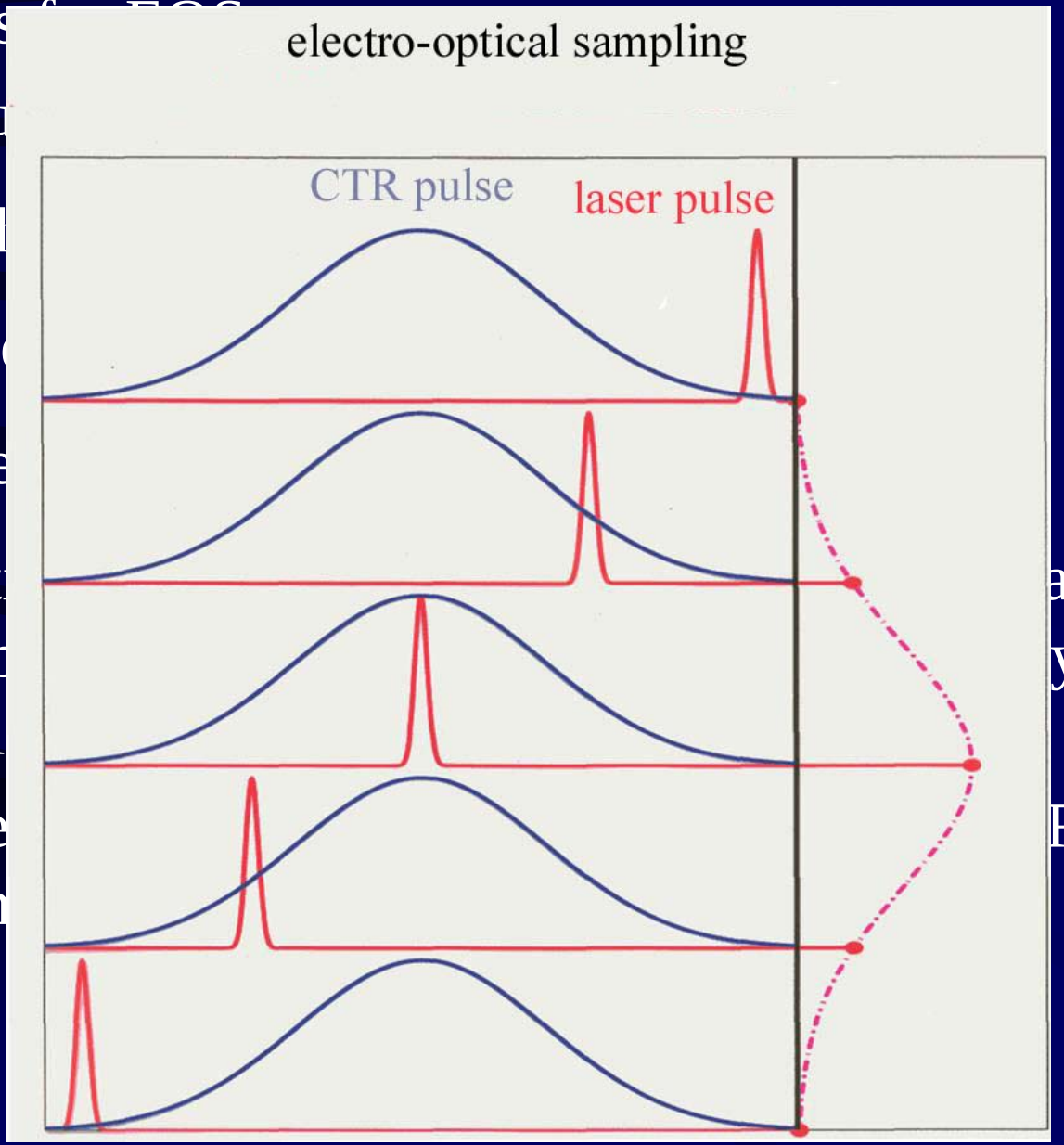
S. Casalbuoni, T. Korhonen, T. Schilcher, V. Schlott, P. Schmüser, S. Simrock, B. Steffen, D. Sütterlin, M. Tonutti

Overview

- motivation
- electro-optical sampling
  - general remarks
  - experimental setup
- results
- outlook

Motivation

- Requirements
  - •resolu
  - •few sl
  - •indep
  - •nonde
- feasible solut a short laser pulse due to b y the electric field of the el
- this experime R) reflected out of the vacuu



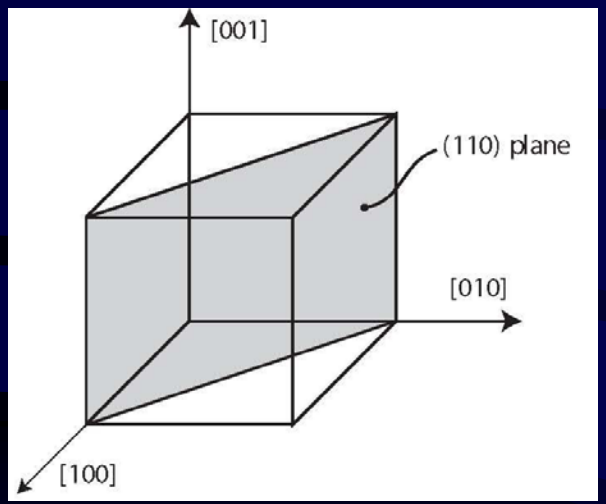
Axel Winter, 2004

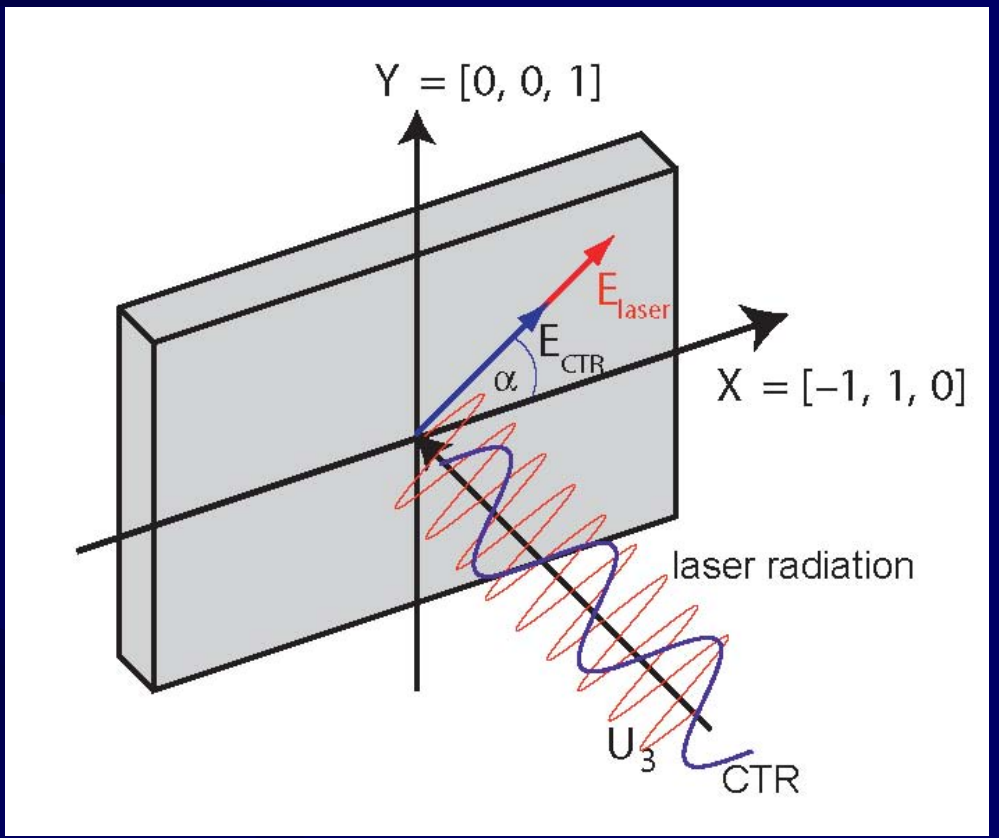
Overview

- motivation
- electro-optical sampling
  - general remarks
  - experimental setup
- results
- outlook

General Remarks

- Zinc-telluride crystal cut parallel to (110)-plane
- incident electric vector of CTR and probe laser pulse perpendicular to XY-plane
- $\mathbf{E}_{CTR}$ and E_{TiSa} lie in the (110)-plane with angle α with respect to X-axis





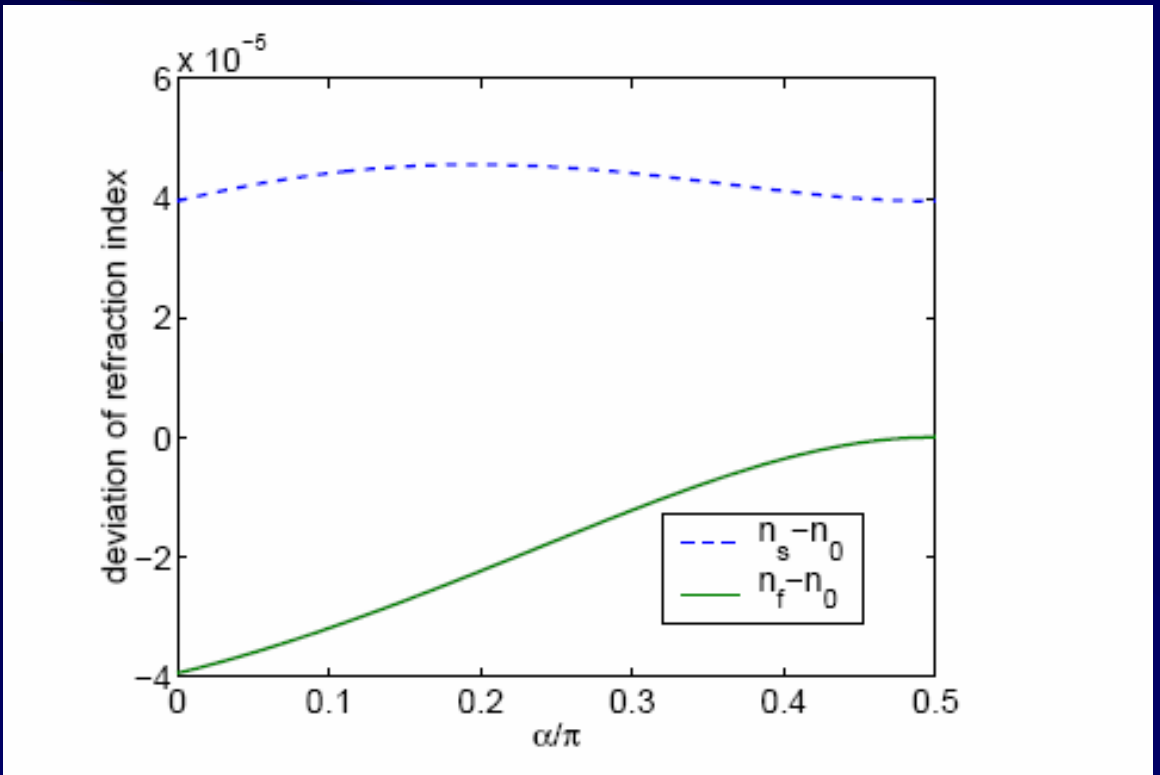
Axel Winter, 2004

General Remarks II

- due to the Pockels effect induced by the CTR, the probe laser pulse will experience a change in polarisation

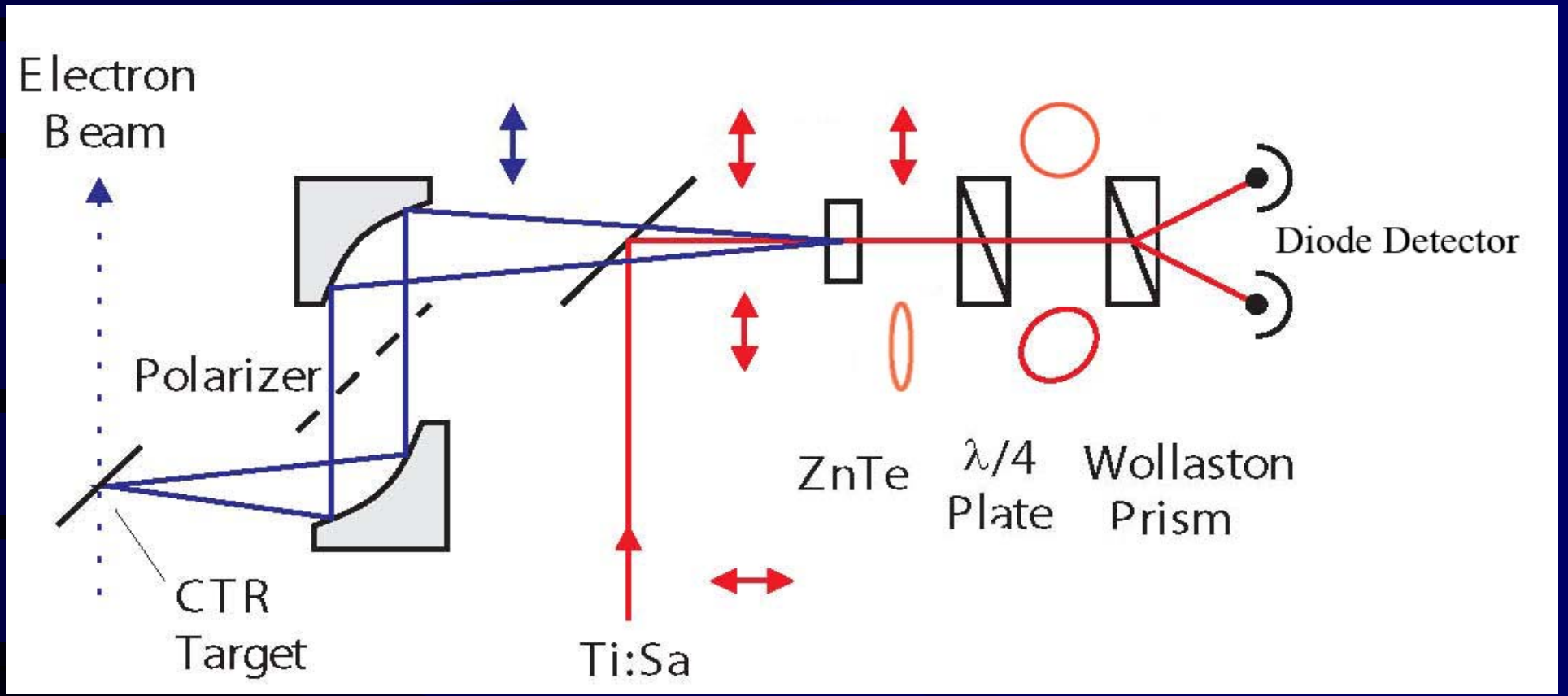
Phase shift:

$$\Gamma(\alpha) = \frac{\omega d}{c}(n_1 - n_2) = \frac{\omega d}{c} n_0^3 r_{41} E_{CTR} \sqrt{1 + 3\cos^2 \alpha}$$



Axel Winter, 2004

Polarization of Laser and CTR

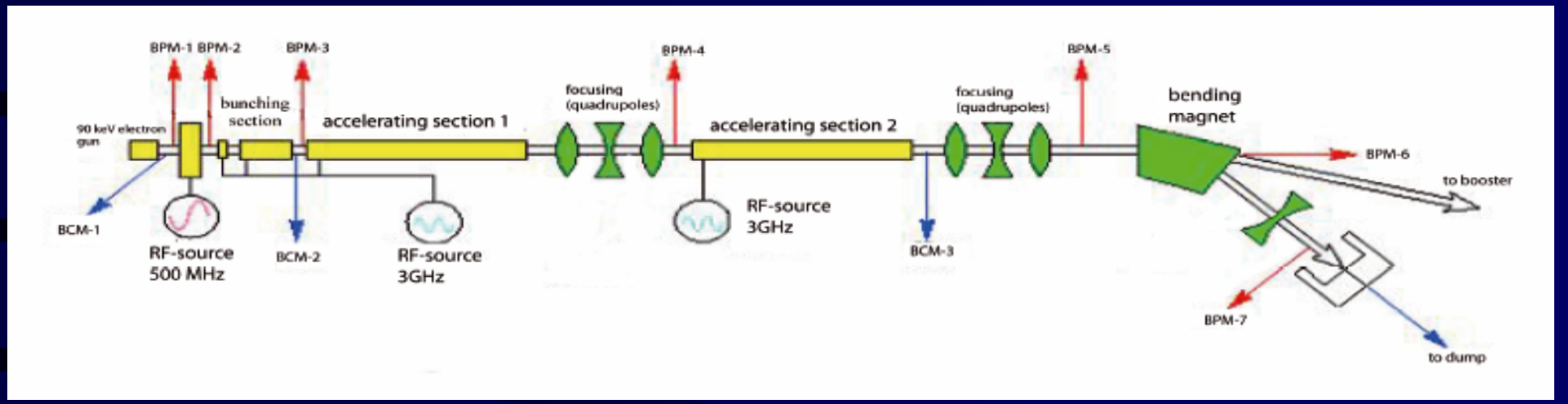


- Laser and CTR are horizontally polarized
- laser polarisation is slightly elliptical after ZnTe crystal
- elliptical (close to linear) laser polarisation is converted to an elliptical (close to circular) polarisation by quarter wave plate
- signal of balanced detector: $I \propto \sin(\Gamma)$ (remember: Γ is phaseshift)

Overview

- motivation
- electro-optical sampling
  - general remarks
  - experimental setup
- results
- outlook

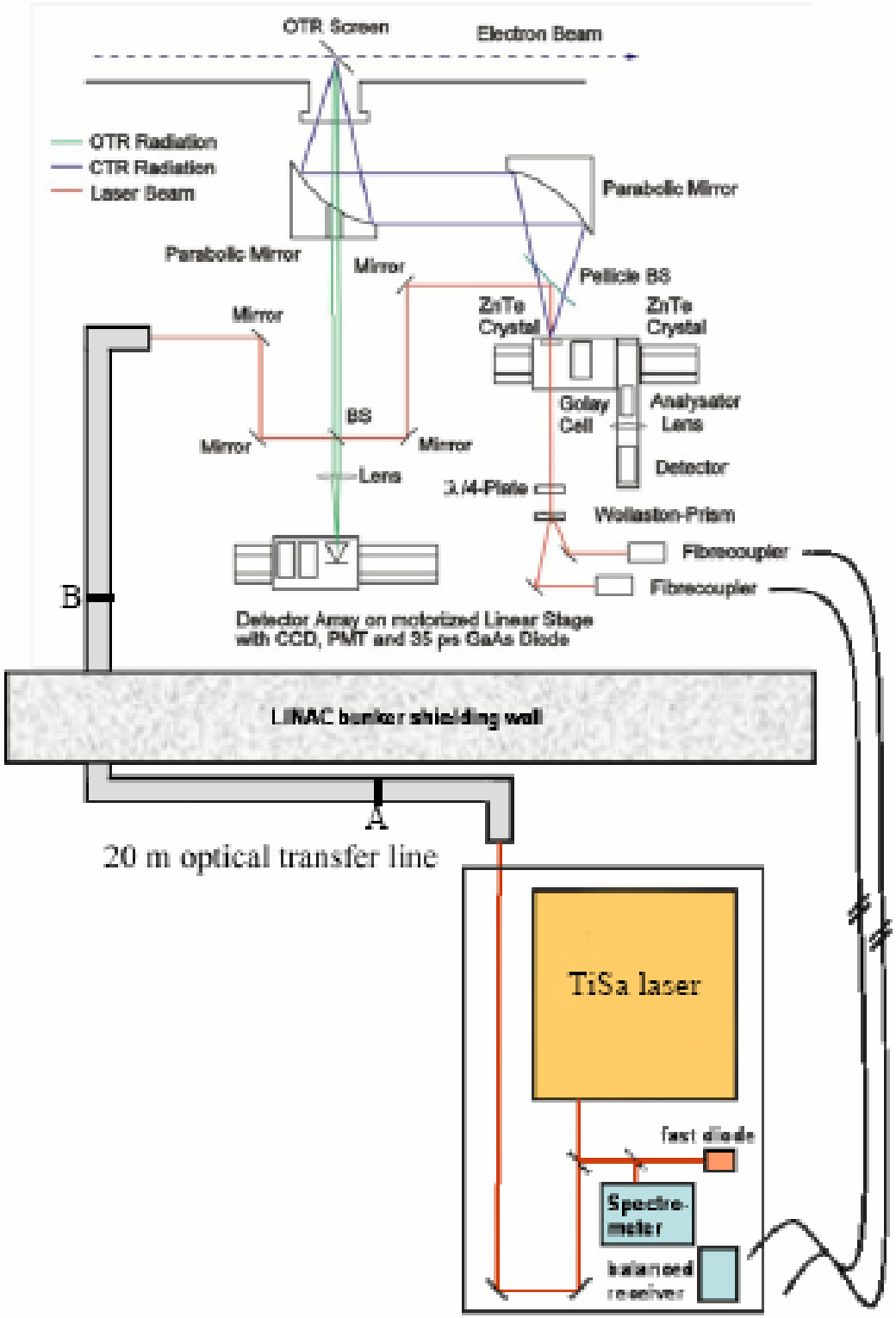
The SLS Linac



•electron accelerator used as injector for the SLS storage ring

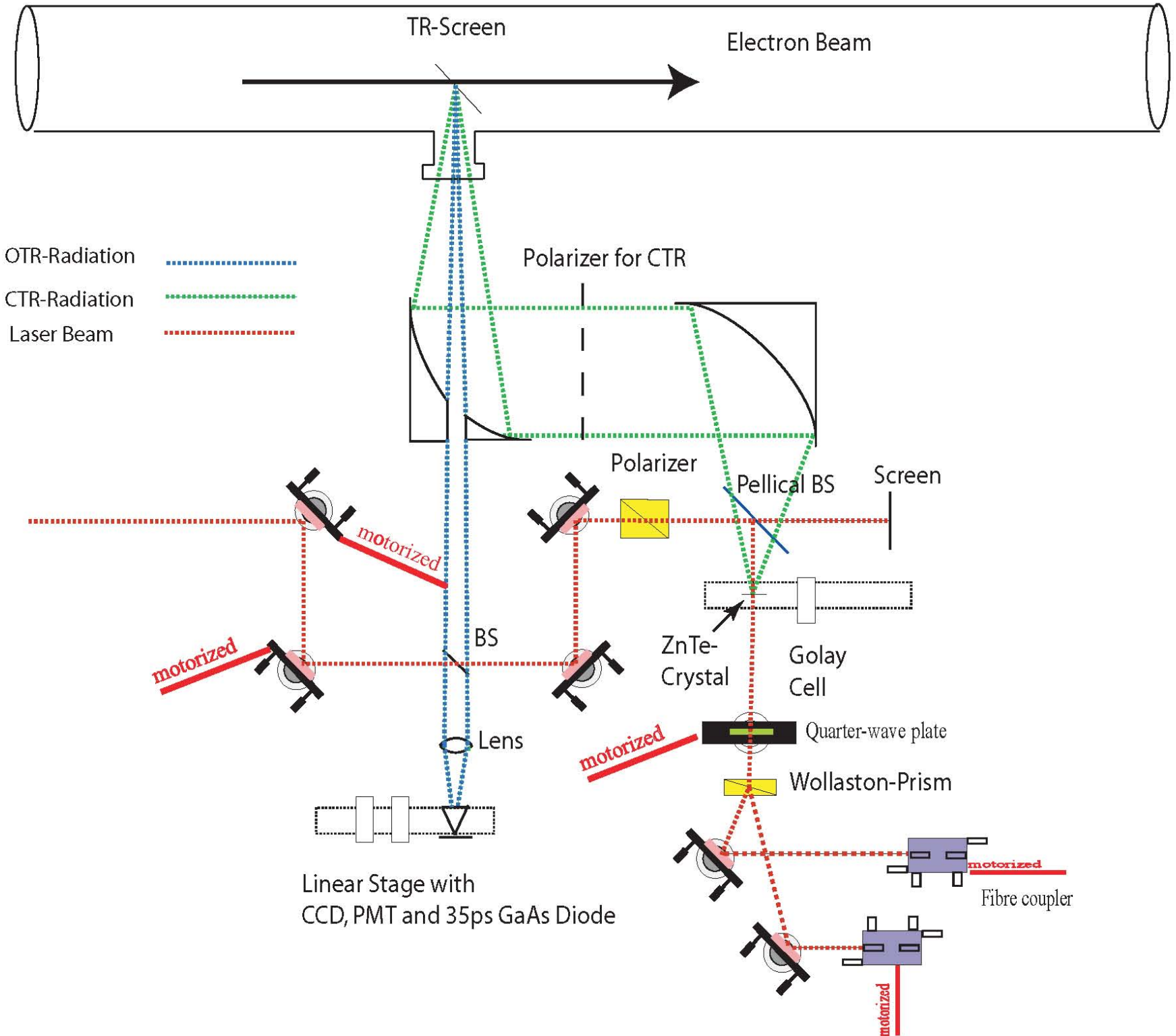
• final energy: 100 MeV through two 3 GHz travelling wave structures

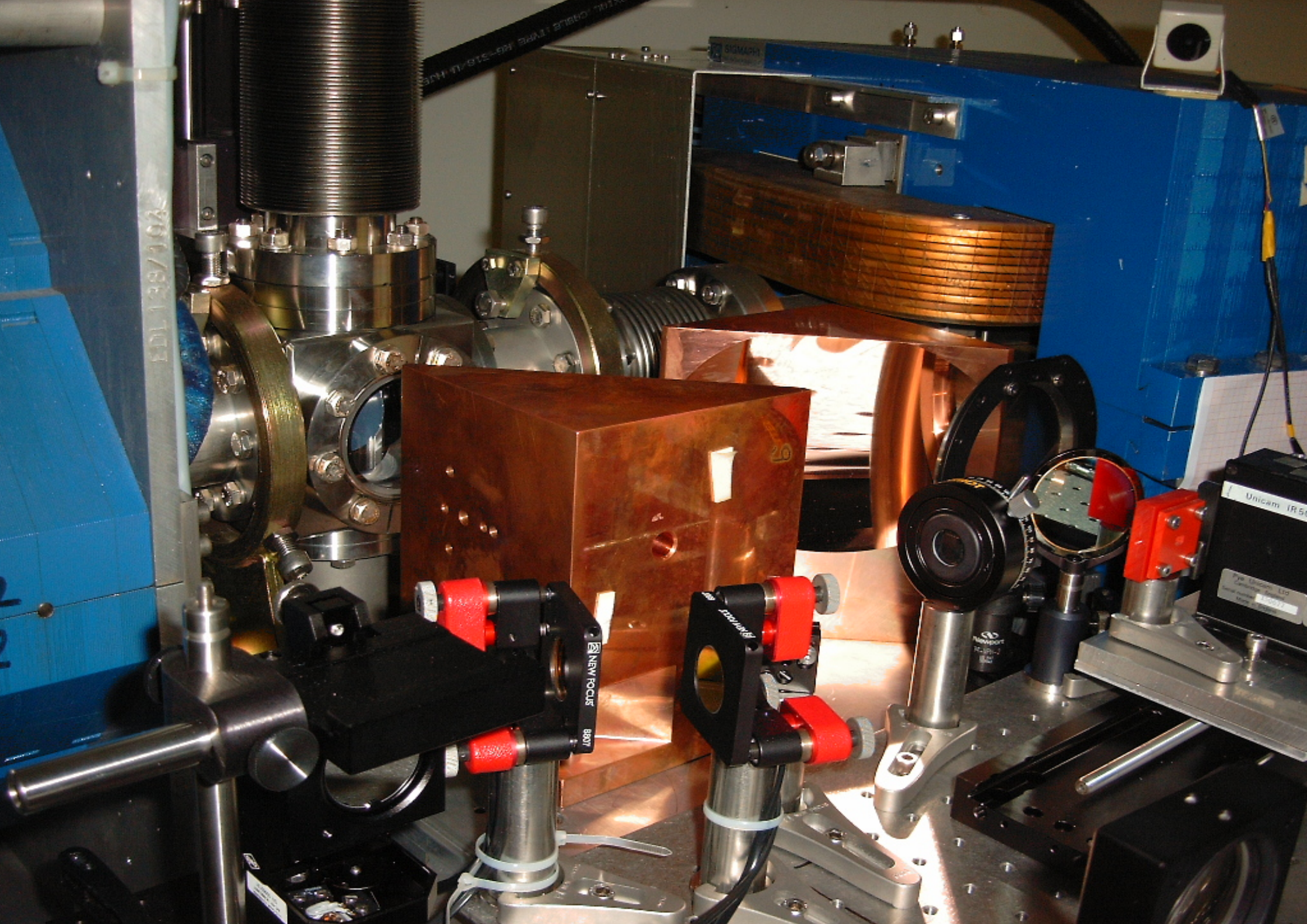
•bunch length of a few picoseconds



General Layout

- TiSa laser outside linac area on vibrationally damped optical table.
- 15m optical transfer line
- optical detector outside linac area.

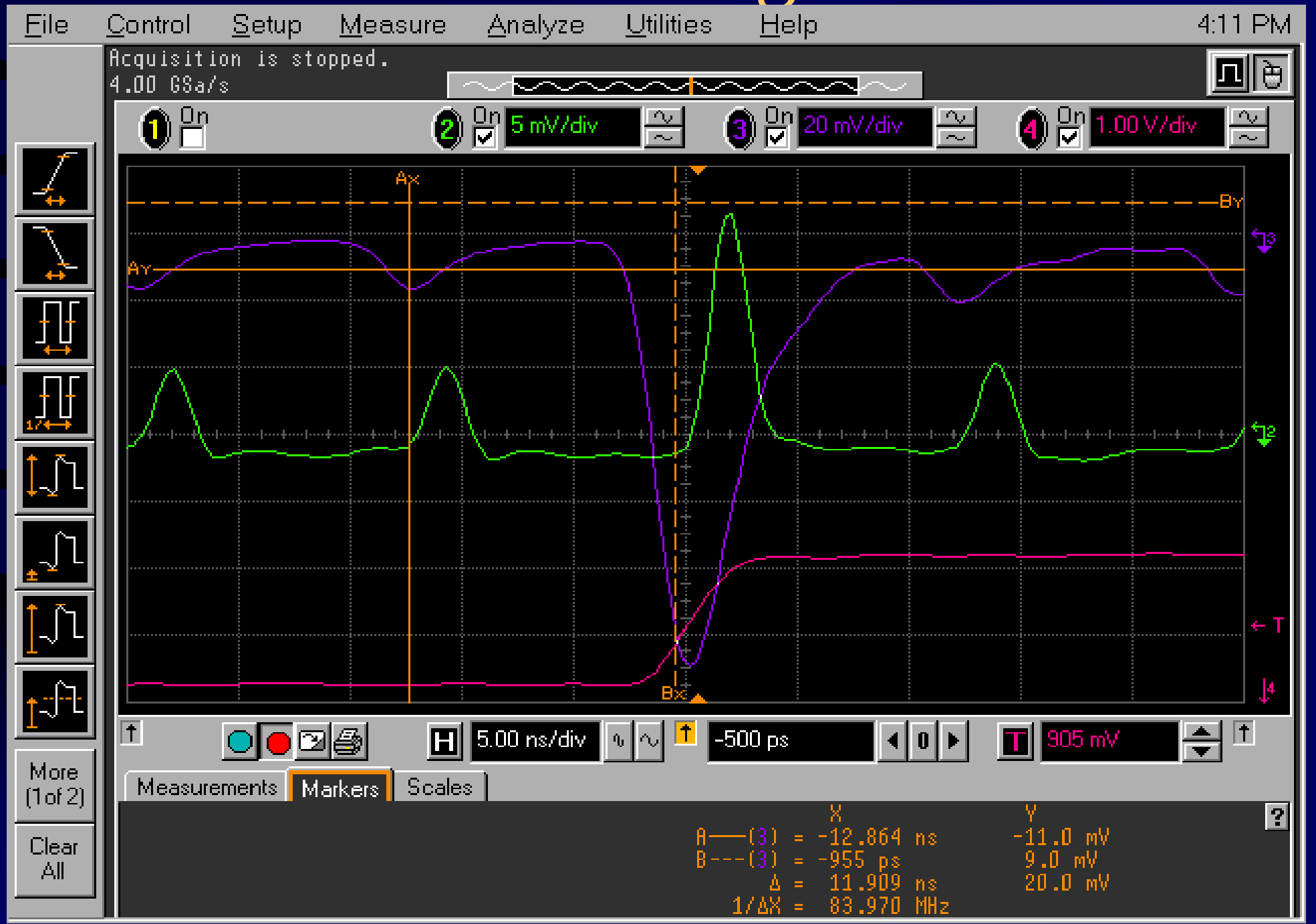

TR-Screen
Electron Beam
OTR-Radiation
CTR-Radiation
Laser Beam
Polarizer for CTR
Polarizer
Pellical BS
Screen
motorized
motorized
BS
ZnTe-
Crystal
Golay
Cell
Lens
motorized
Quarter-wave plate
Wollaston-Prism
motorized
Fibre coupler
Linear Stage with
CCD, PMT and 35ps GaAs Diode
motorized


NEW FOCUS
8807
Newport
Unicam

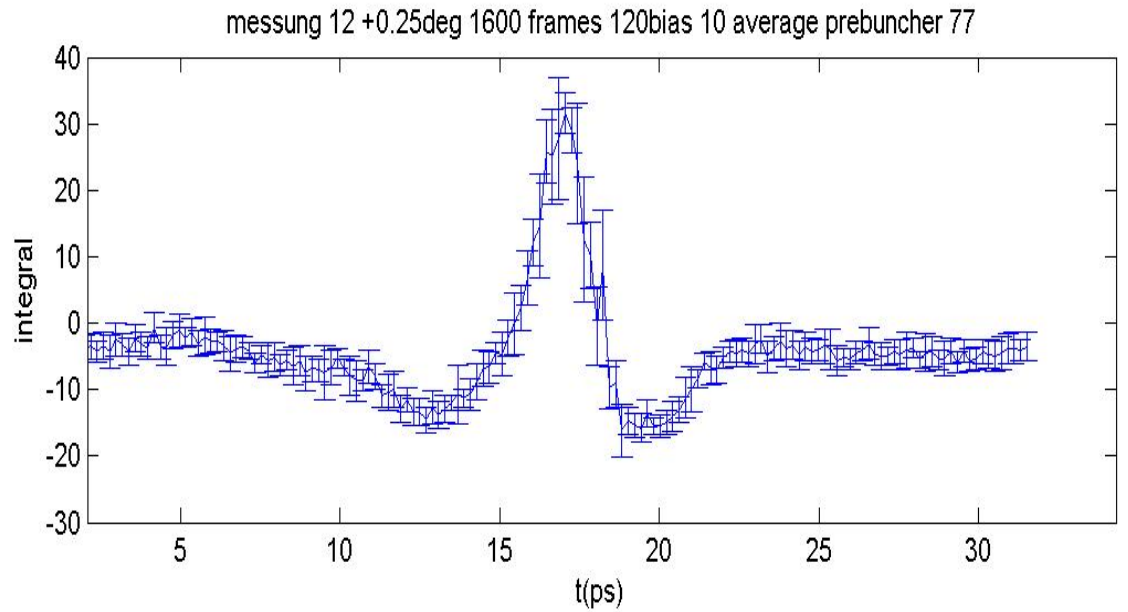
Overview

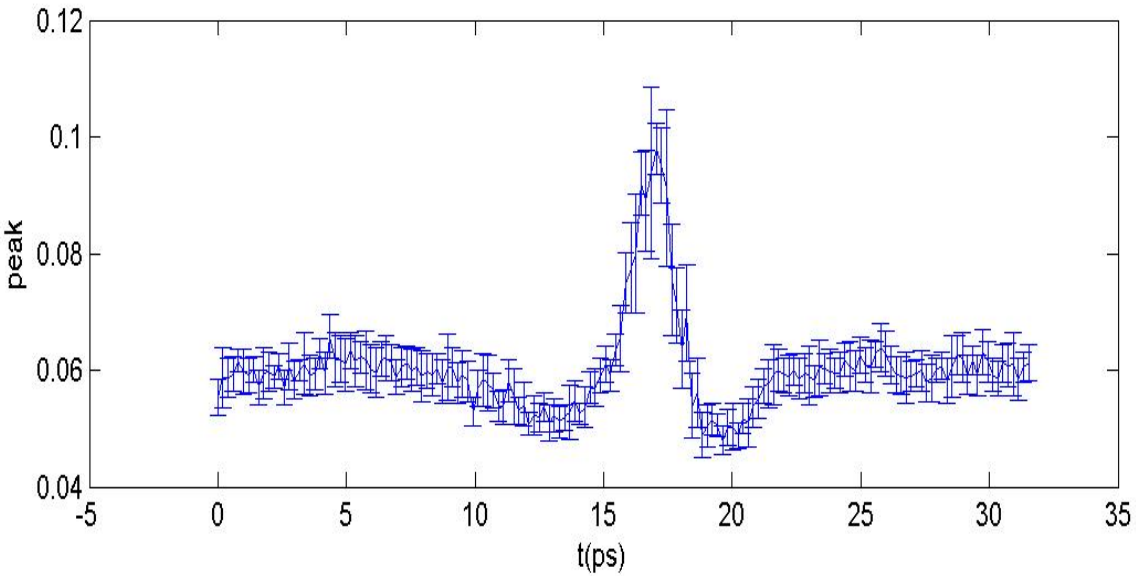
- motivation
- electro-optical sampling
  - general remarks
  - experimental setup
- results
- outlook

First Signal



Data





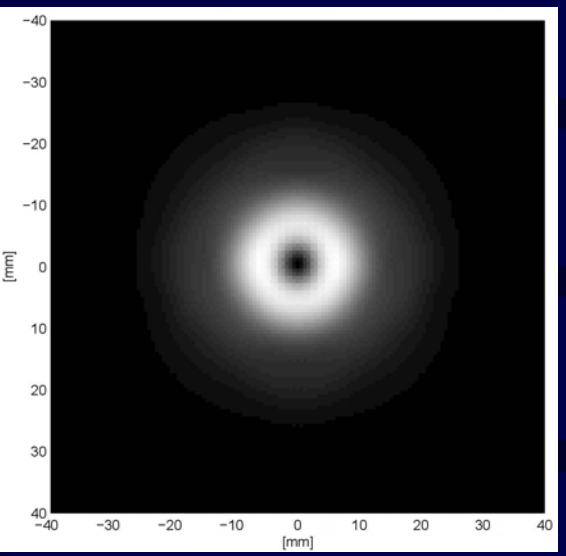
- scanning step width: 200fs
- averaged over 10 measurements per step
- expected bunch length from interferometric measurement with Golay-cell: 3ps-5ps FWHM

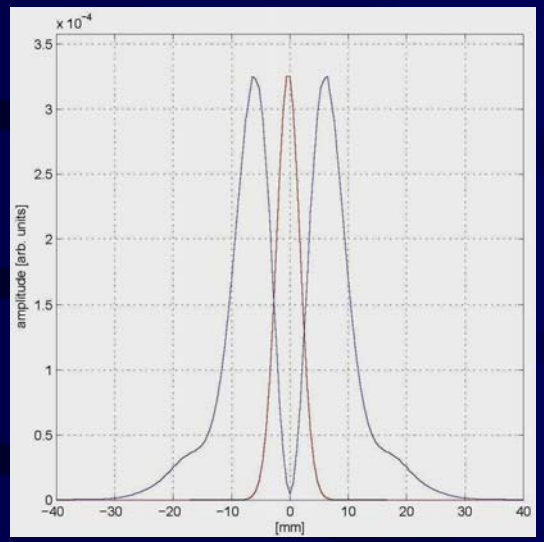
good agreement with expected bunch length

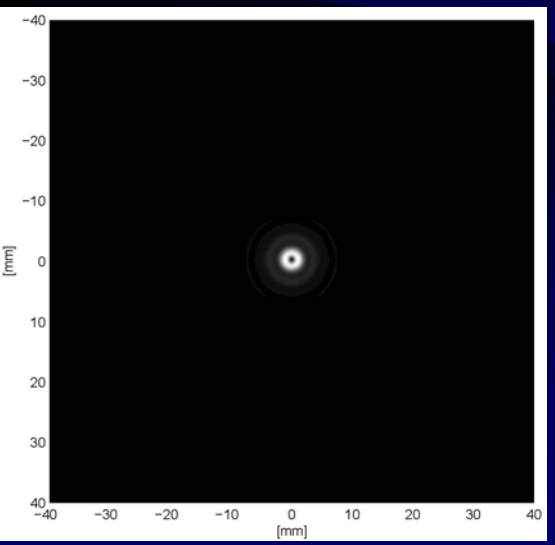
CTR Transfer Function

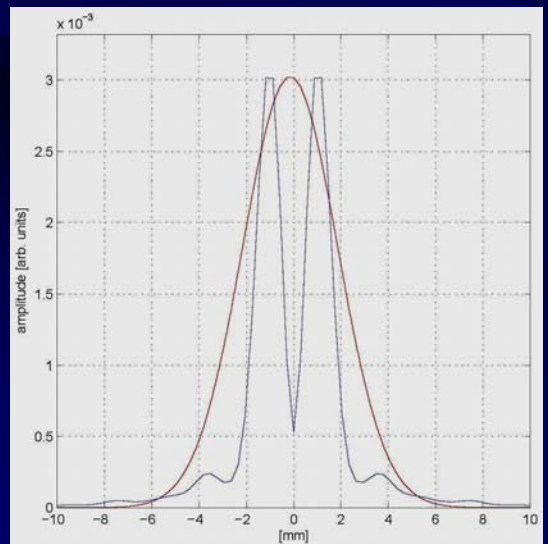
Model of CTR transfer function from source to crystal using ZEMAX:

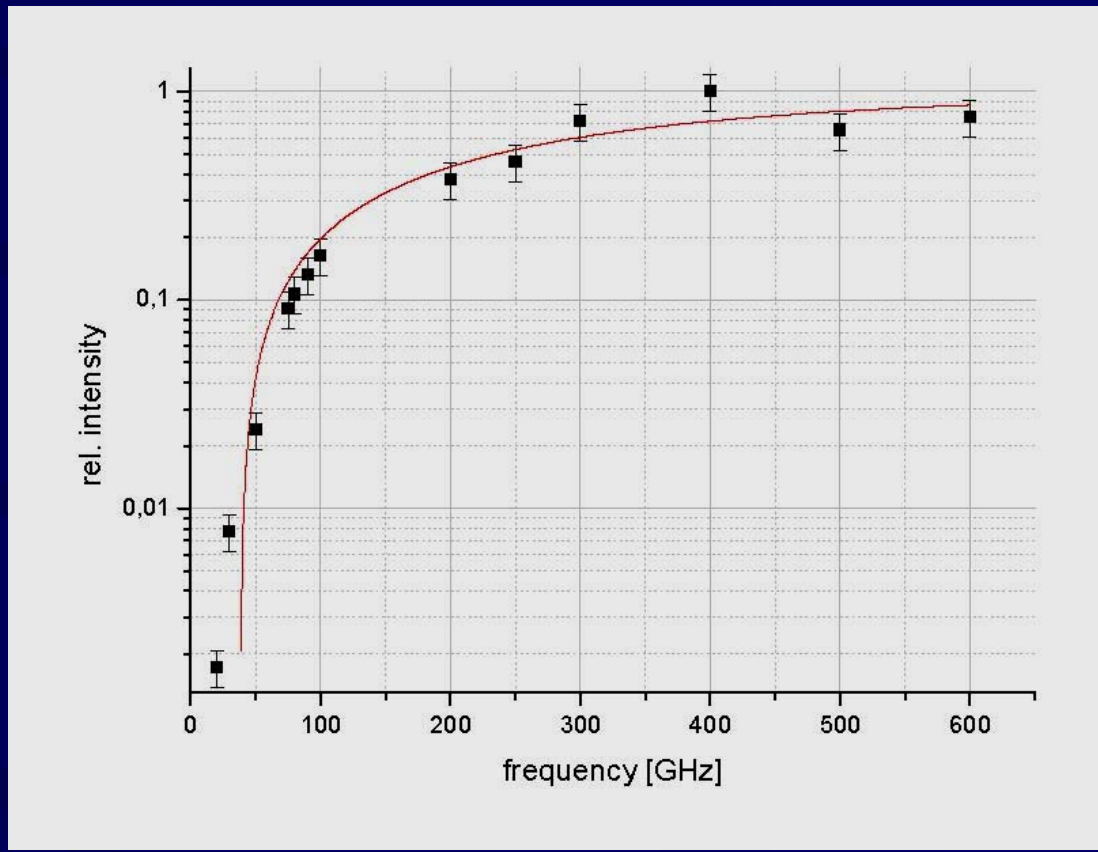
- aperture of vacuum window cuts frequencies below 30 GHz
- frequencies below 80 GHz do not contribute to signal due to laser spot size (diameter:2 mm) on crystal





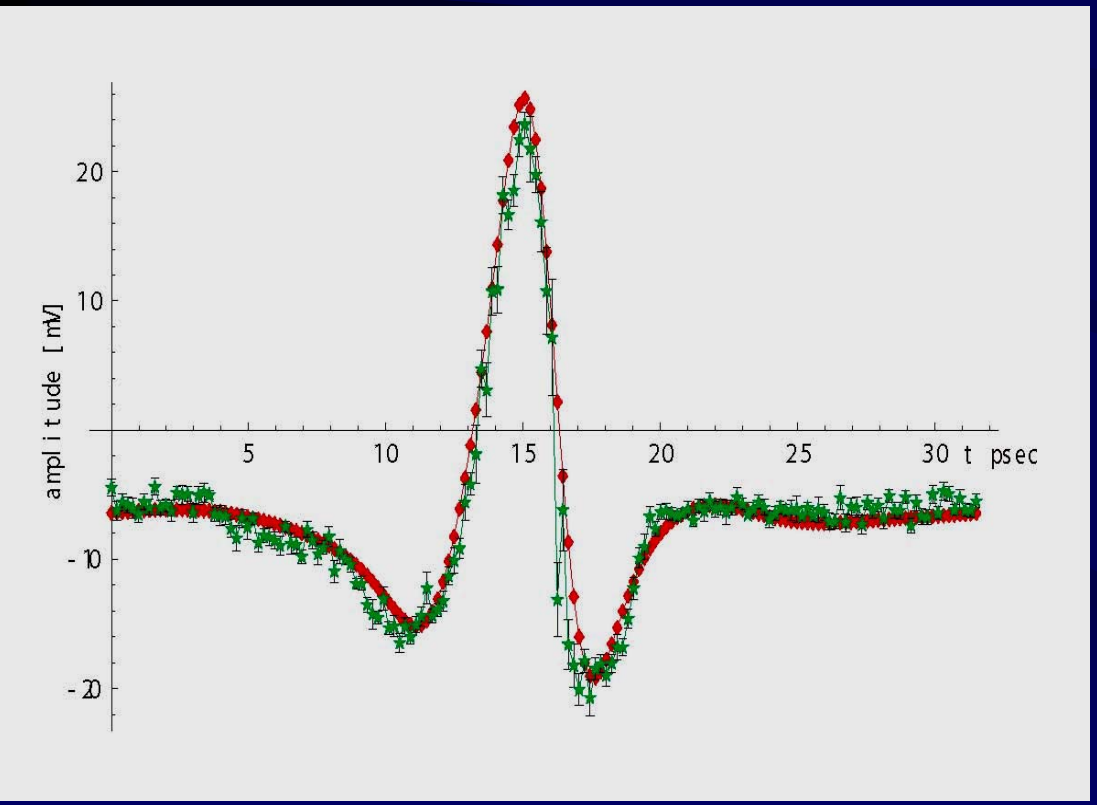


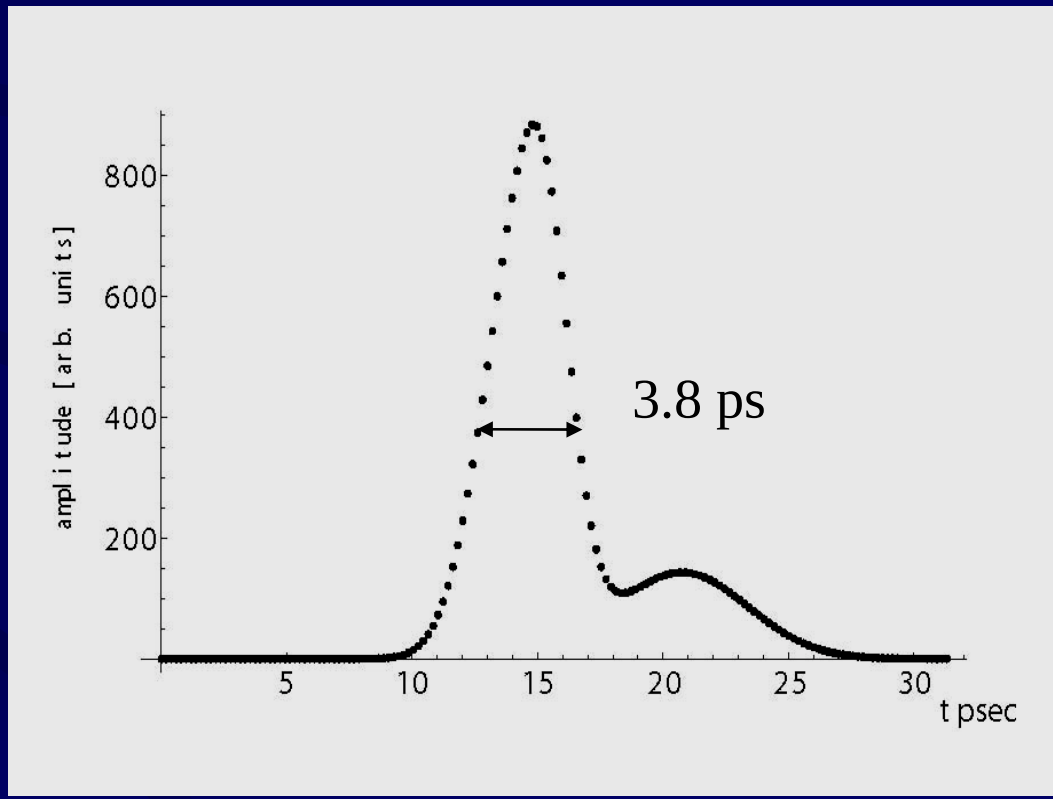




Fits

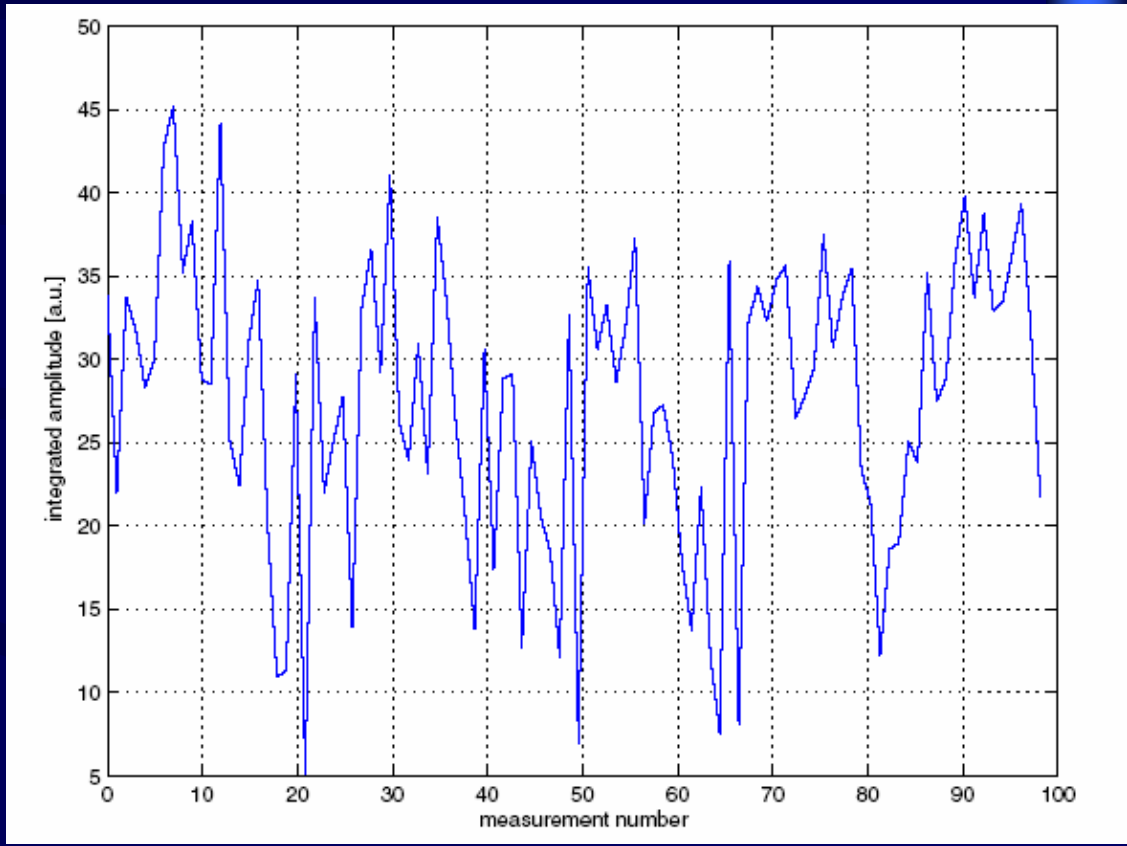
- Model for bunch shape: superposition of 2 or 3 Gaussians
  - apply Fourier transformation
  - convolute transfer function
  - transfer back into time domain and compare to data





Temporal Resolution

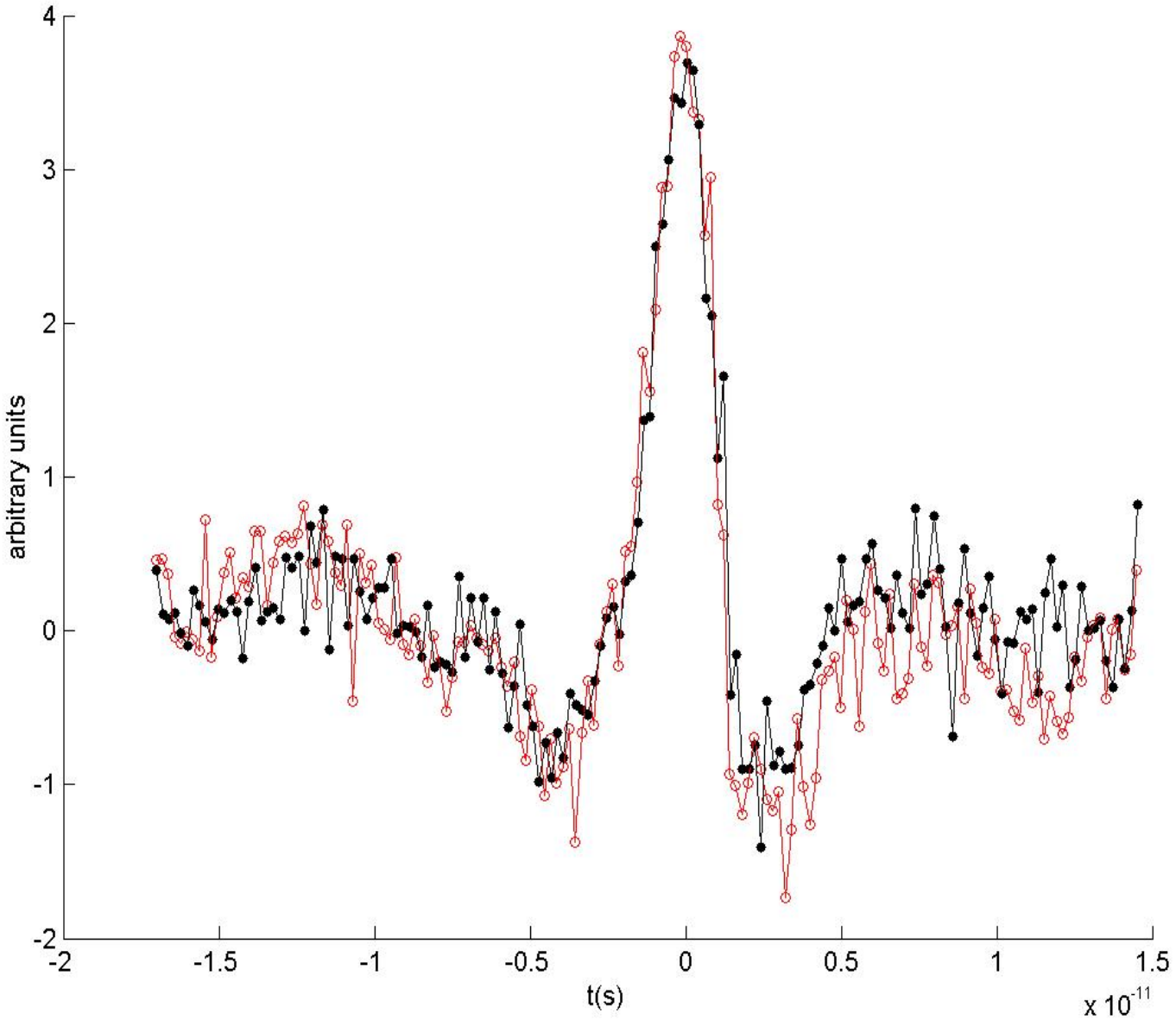
- phase between laser pulse and bunch is such, that the laser pulse is at the rising or falling edge of the CTR signal.
- amplitude jitter is dominated by arrival time jitter of consecutive electron bunches
- 100 bunches at 3.125 Hz



temporal resolution:

330 fs (rms)

Reproducibility of Measurements



red and black: scans with pos. and neg. phase steps taken directly one after the other

Summary and Outlook

- first EOS-signal seen in February 2004 in good accordance with expected SLS bunch length
- synchronisation between laser and RF with resolution of better than 40 fs achieved
- temporal resolution of EOS experiment better than 350 fs
- further EOS experiments to be conducted at DESY VUV-FEL in 2004/2005

Thank you for your attention !!

Contributions and Thanks

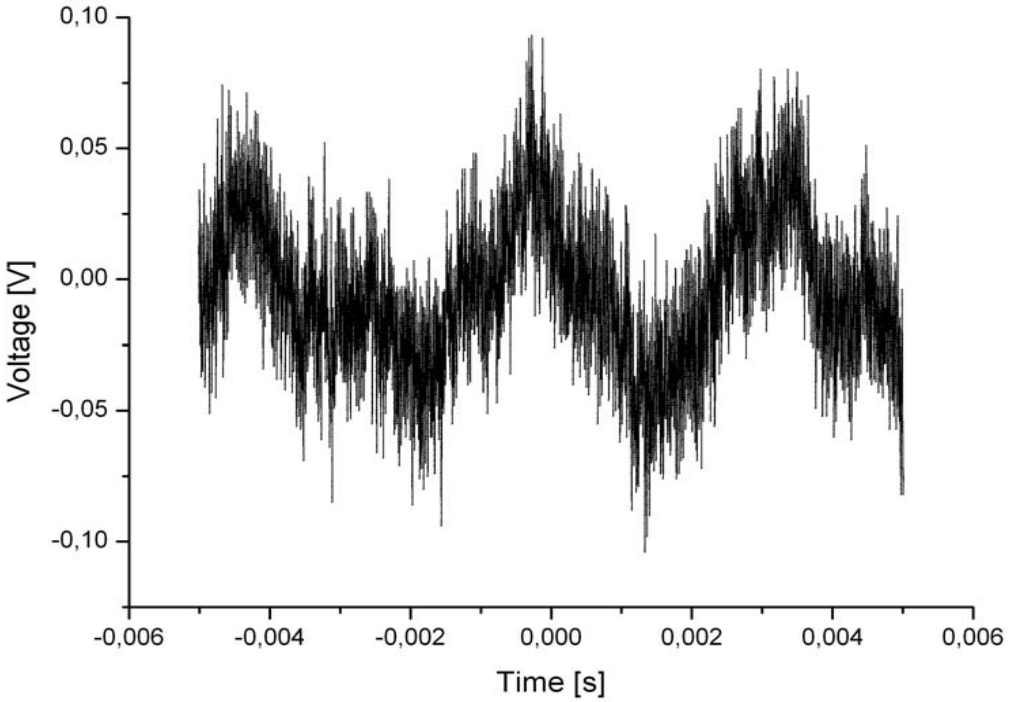
thanks to the EOS Team

- S. Casalbuoni, P. Hottinger, N. Ignashine, T. Korhonen, T. Schilcher, V. Schlott, B. Schmidt, P. Schmüser, S. Simrock, B. Steffen, D. Sütterlin, S. Sytov, M. Tonutti

Synchronisation Stability

- open loop: 230mV rms for 45° phase shift
  that is 5.1mV per degree phase shift

at 3.5 GHz: 1°~793 fs, so 1 mV per 155 fs jitter



measured rms value: 260 µV

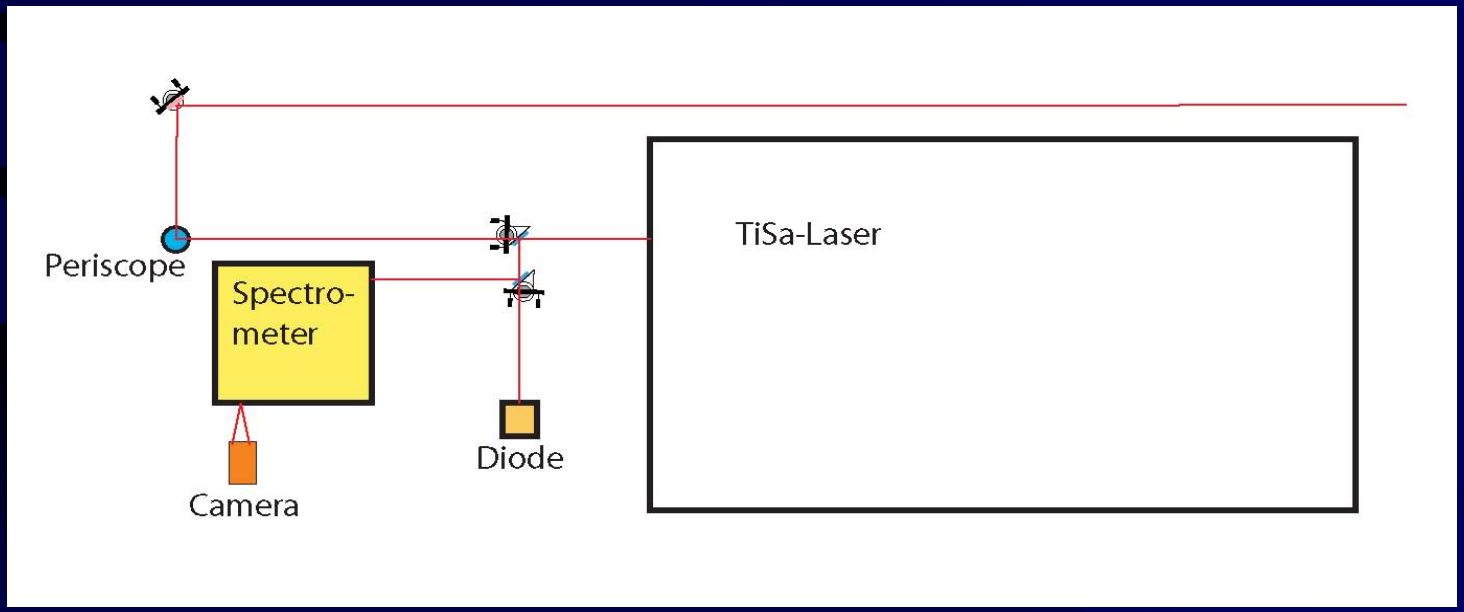
short term

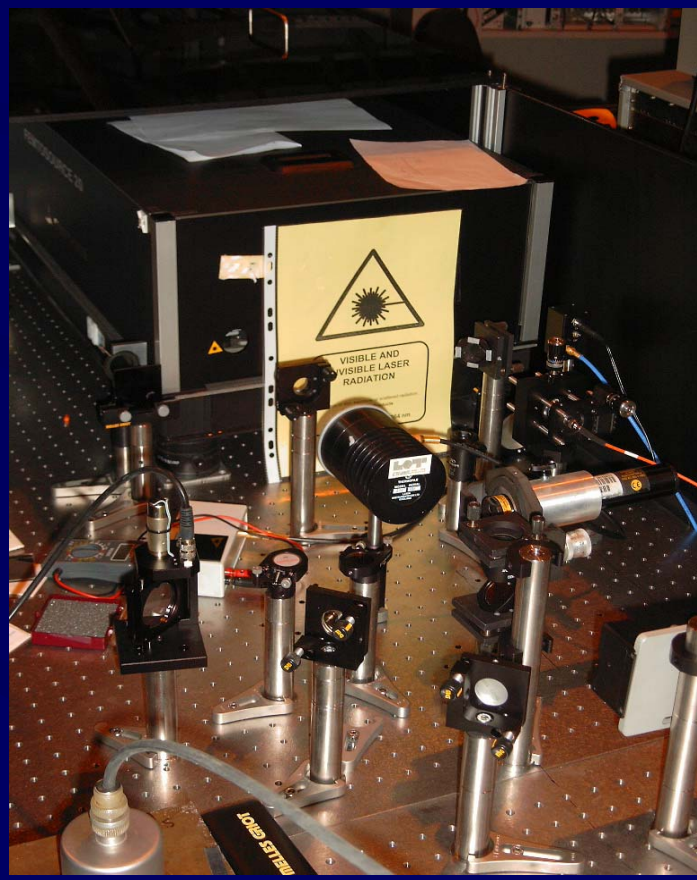
stability of 37 fs reached

Axel Winter, 2004

Outside Schematic

- optical table ouside linac bunker with the fs-Laser
- area is temperature stabilized to 24°



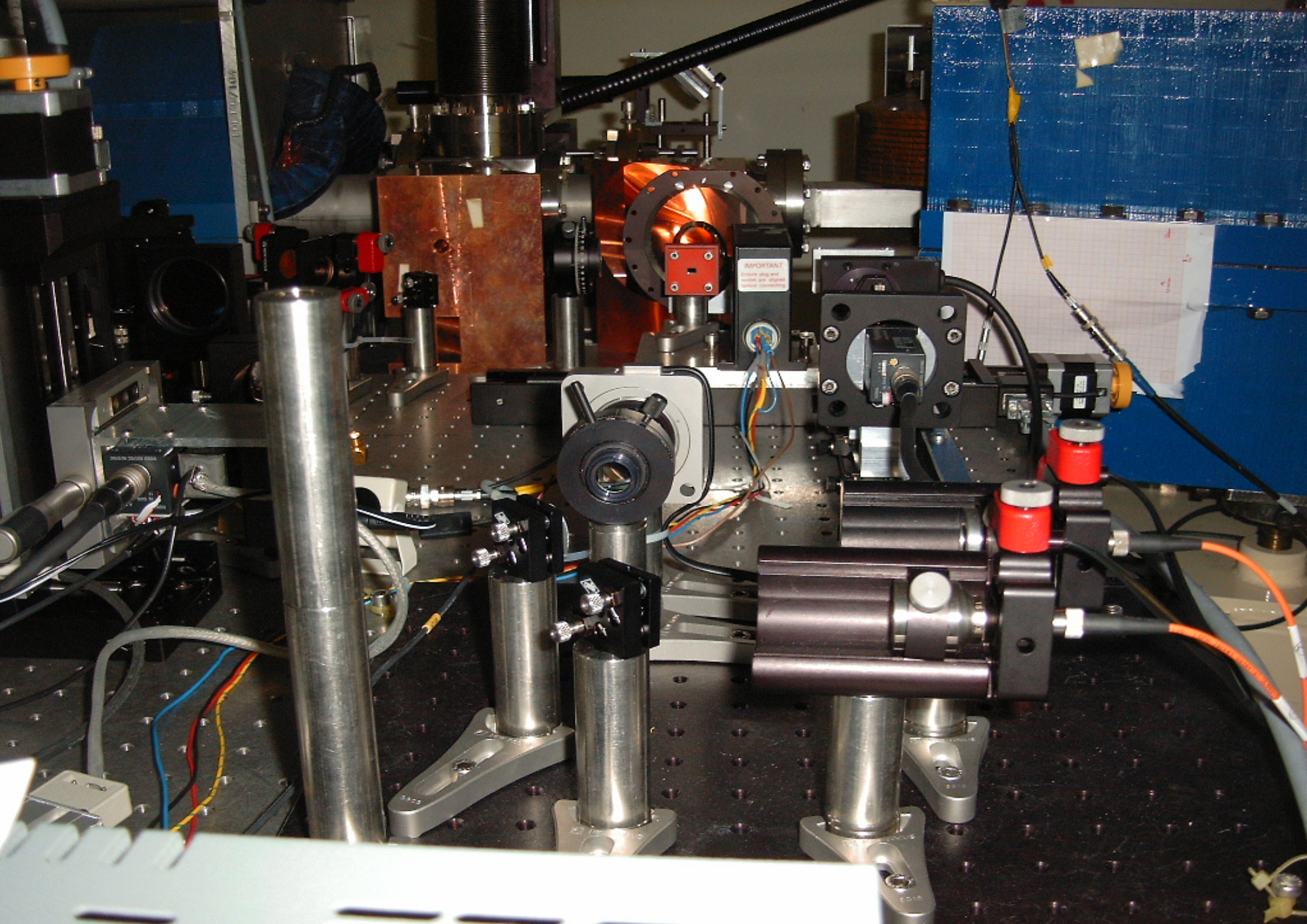


Axel Winter, 2004

experimental procedure

- scan interval of 12.5 ns with 1ps stepwidth @3.125 Hz: measurement time of 1 hour!

- solution: find coarse overlap between OTR and bunch (accuracy of about 100ps) and scan with high accuracy around that spot.

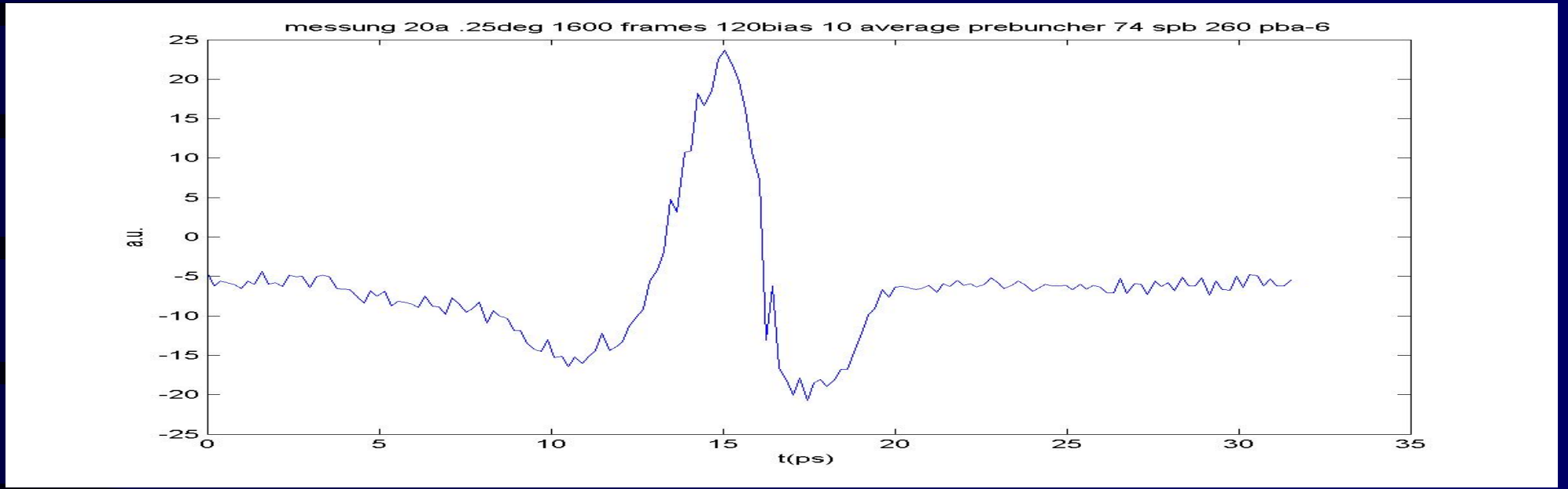


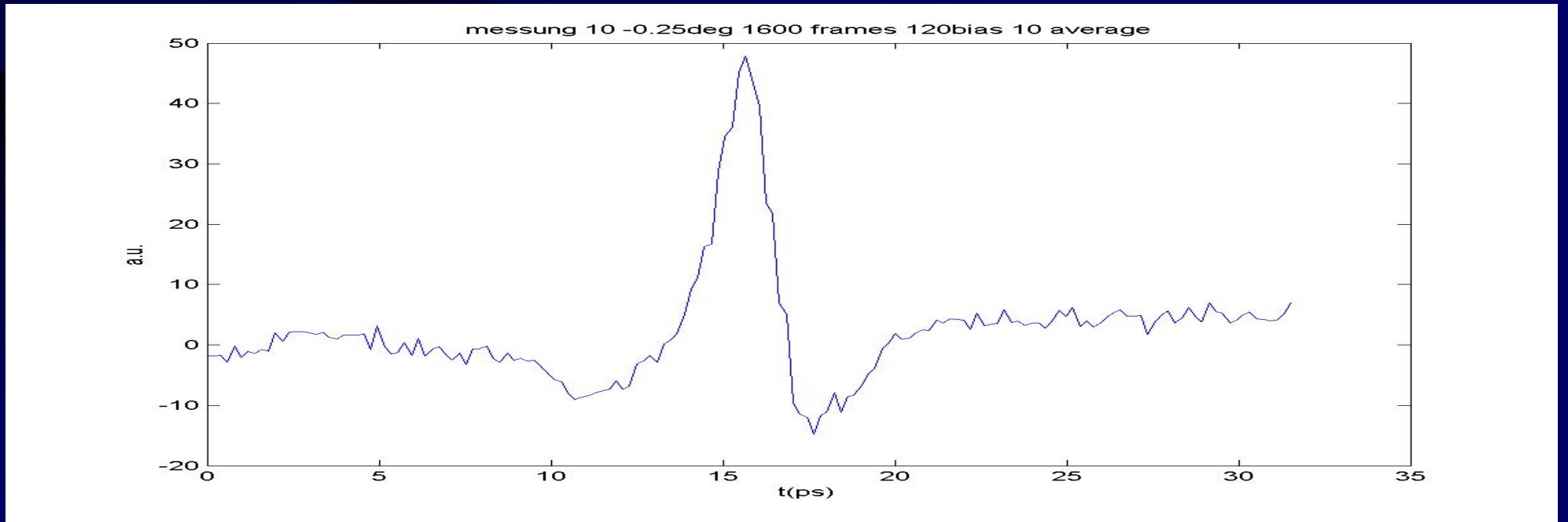
Timing

- only every 7th laser pulse is at the same spot relative to the linac RF (every 43rd RF cycle)
- problem: linac trigger must be synchronized to laser

- solution: downconverting of 81MHz to 11.65MHz (=81MHz/7) synchronising that to the 3.125 Hz Linac trigger

Data II


messung 20a .25deg 1600 frames 120bias 10 average prebuncher 74 spb 260 pba-6
a.u.
t(ps)


messung 10 -0.25deg 1600 frames 120bias 10 average
a.u.
t(ps)