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

A.Winter, Aachen University and DESY
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S. Casalbuoni, T. Korhonen, T. Schilcher, V. Schlott, P. Schmüser, S. Simrock, B. Steffen, D. Sütterlin, M. Tonutti

DESY RWTH PAUL SCHERRER INSTITUT PSI

Overview

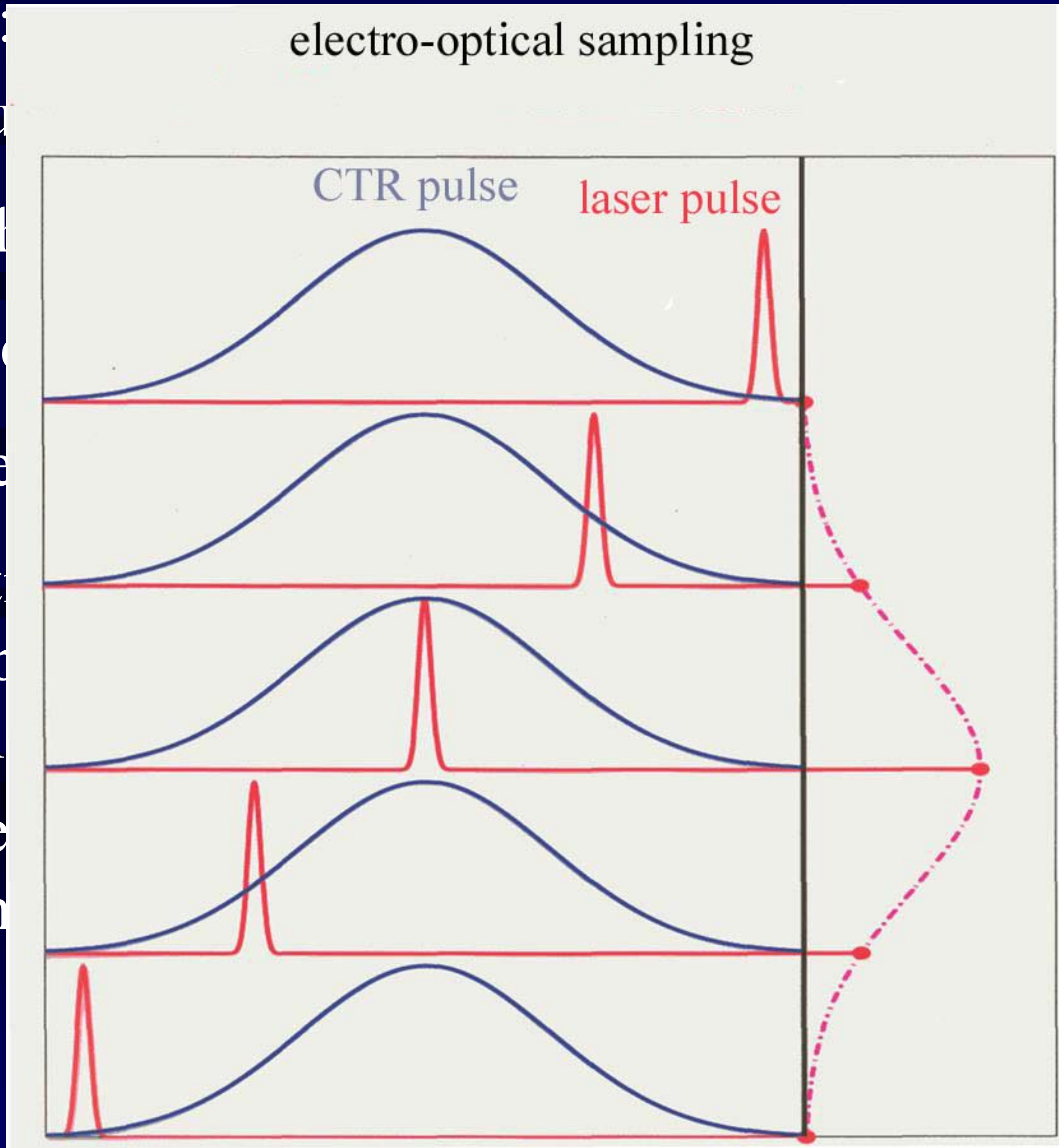
- motivation
- electro-optical sampling
  - general remarks
  - experimental setup
  - synchronisation between TiSa laser and linac RF
- results
- outlook

Motivation

- knowledge of the electron bunch structure is extremely important for both linear collider and free electron laser.
- electro-optical sampling (EOS) offers the possibility to obtain precise results on a realtime scale.
- challenge: synchronisation between TiSa-laser and RF

Electro-optical Sampling

- requirements:
  - •resolu
  - •few sh
  - •indepe
  - •nonde
- feasible soluti a short laser pulse due to b y the electric field of the el
- this experime R) reflected out of the vacuun



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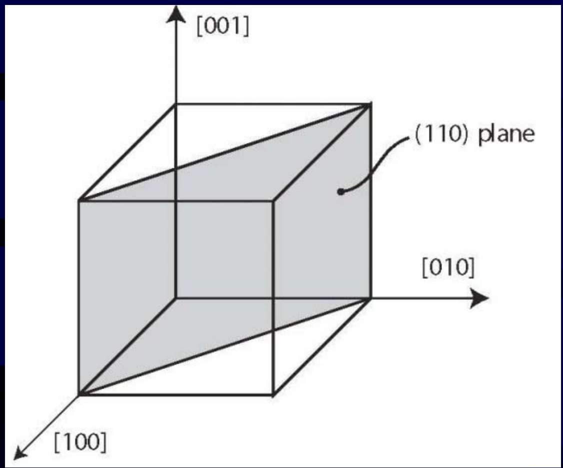
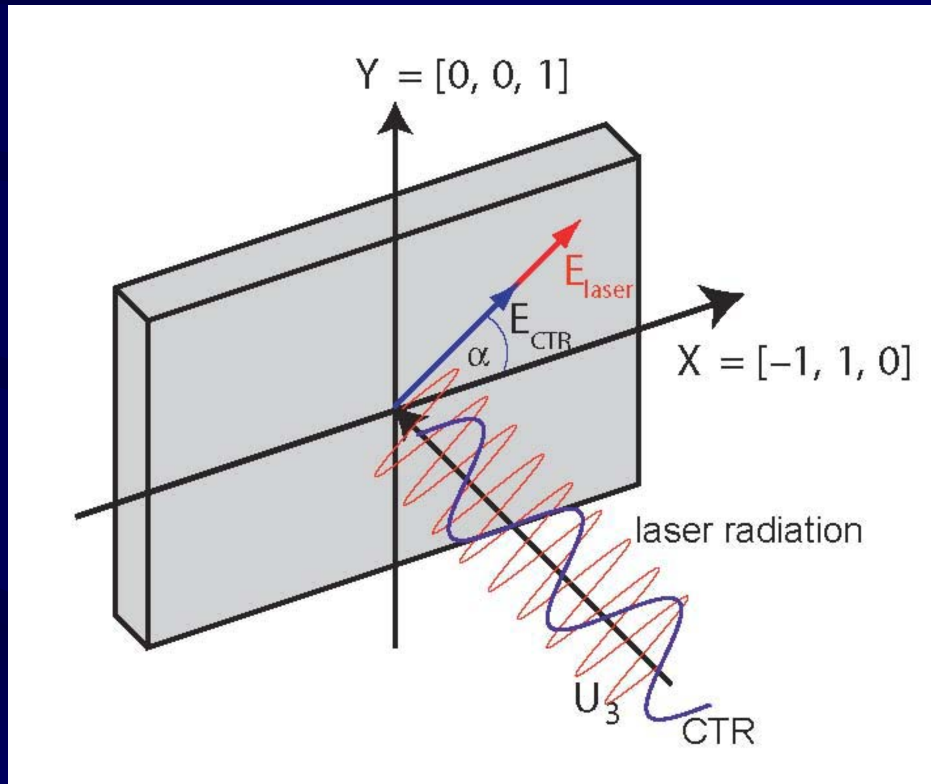
General Remarks

- 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





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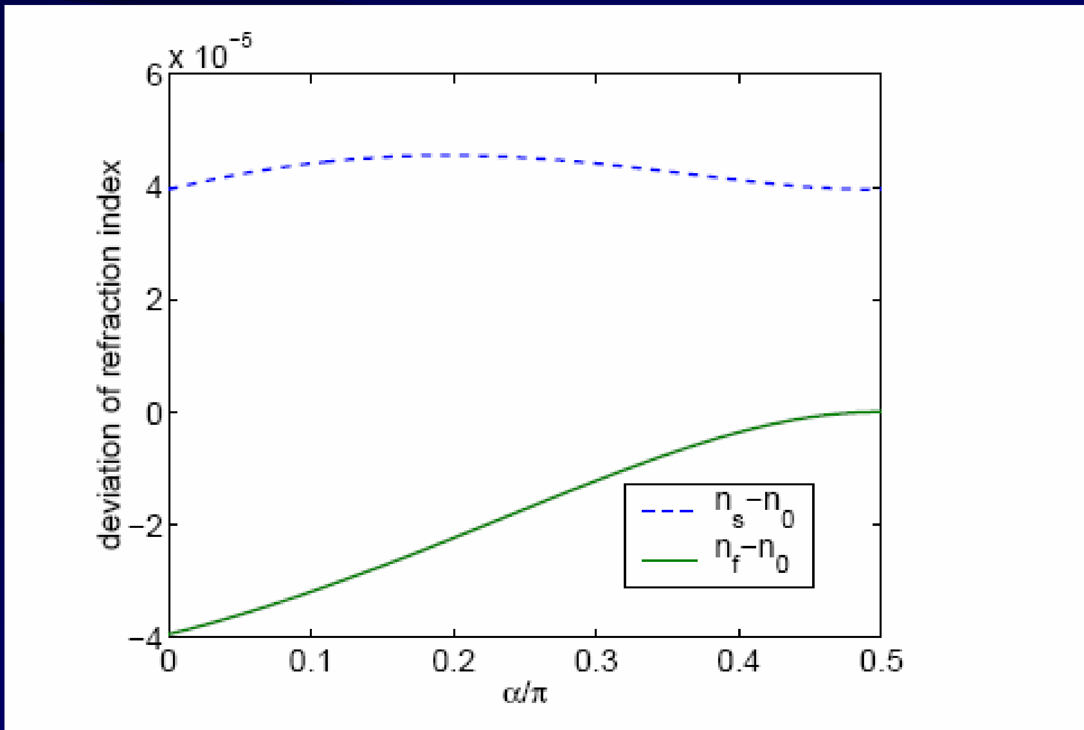
General Remarks II

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

Phase shift:

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



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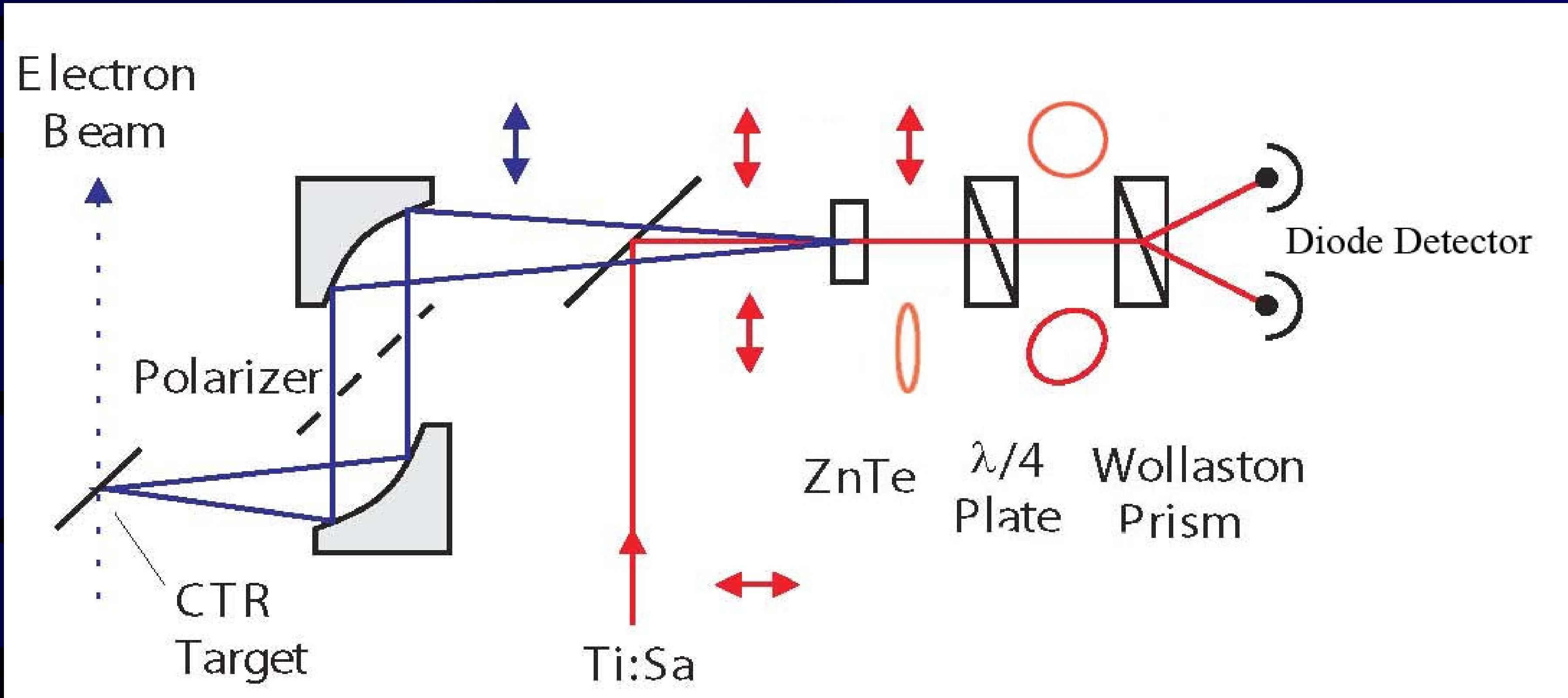
Polarization of Laser and CTR



- 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)

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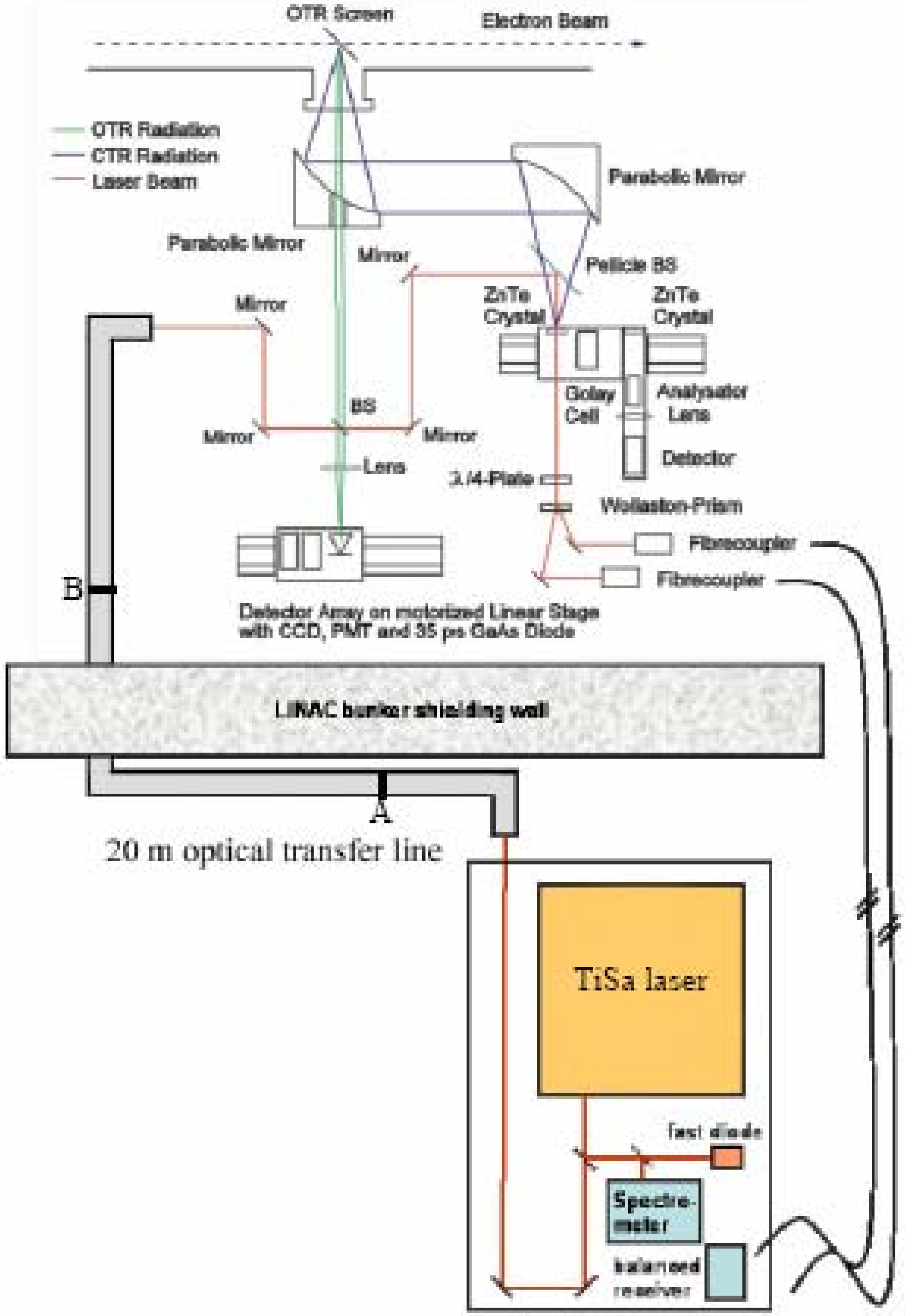
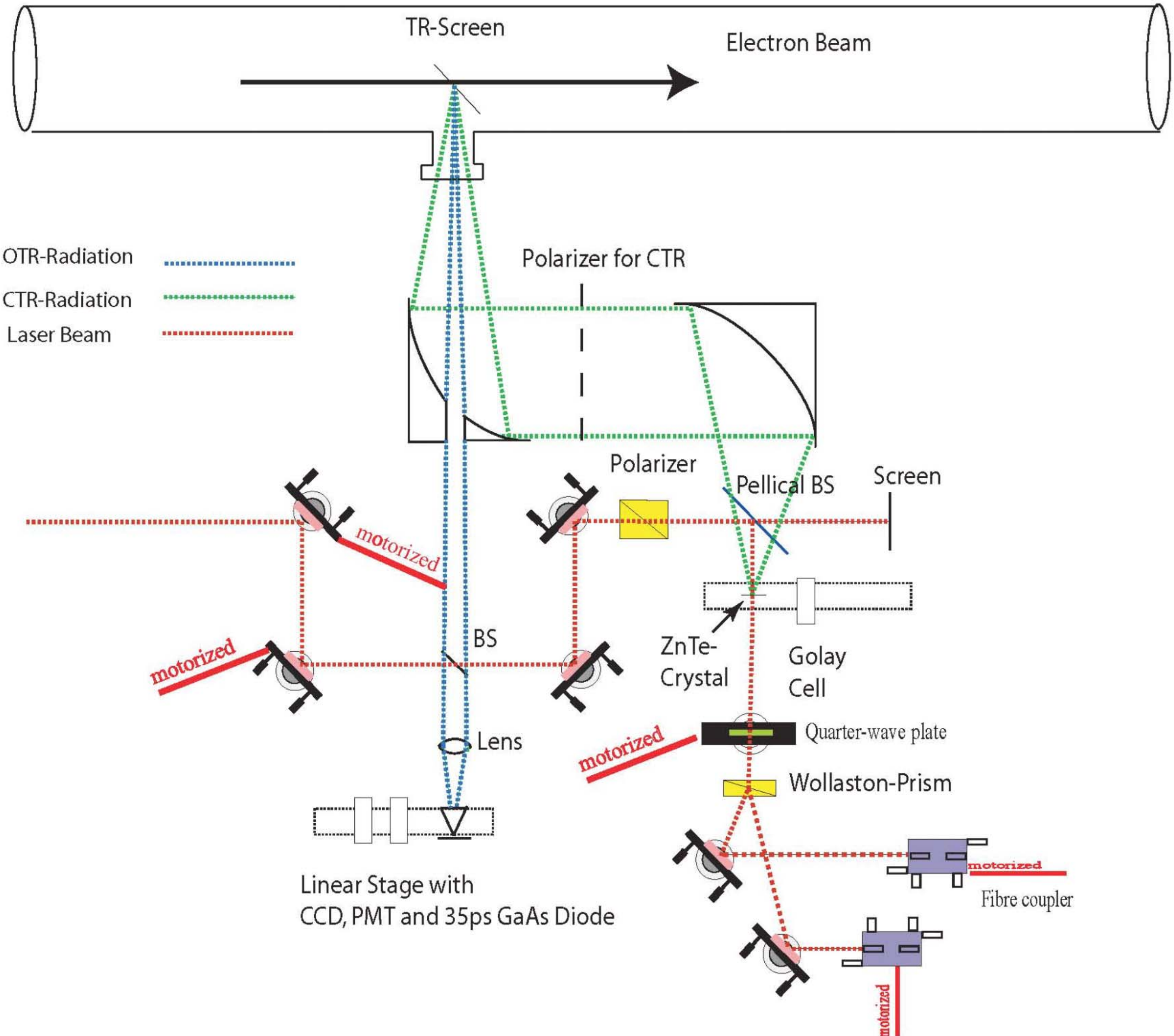


General Layout

- •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
motorized
Quarter-wave plate
Lens
Wollaston-Prism
Linear Stage with
CCD, PMT and 35ps GaAs Diode
motorized
Fibre coupler
motorized

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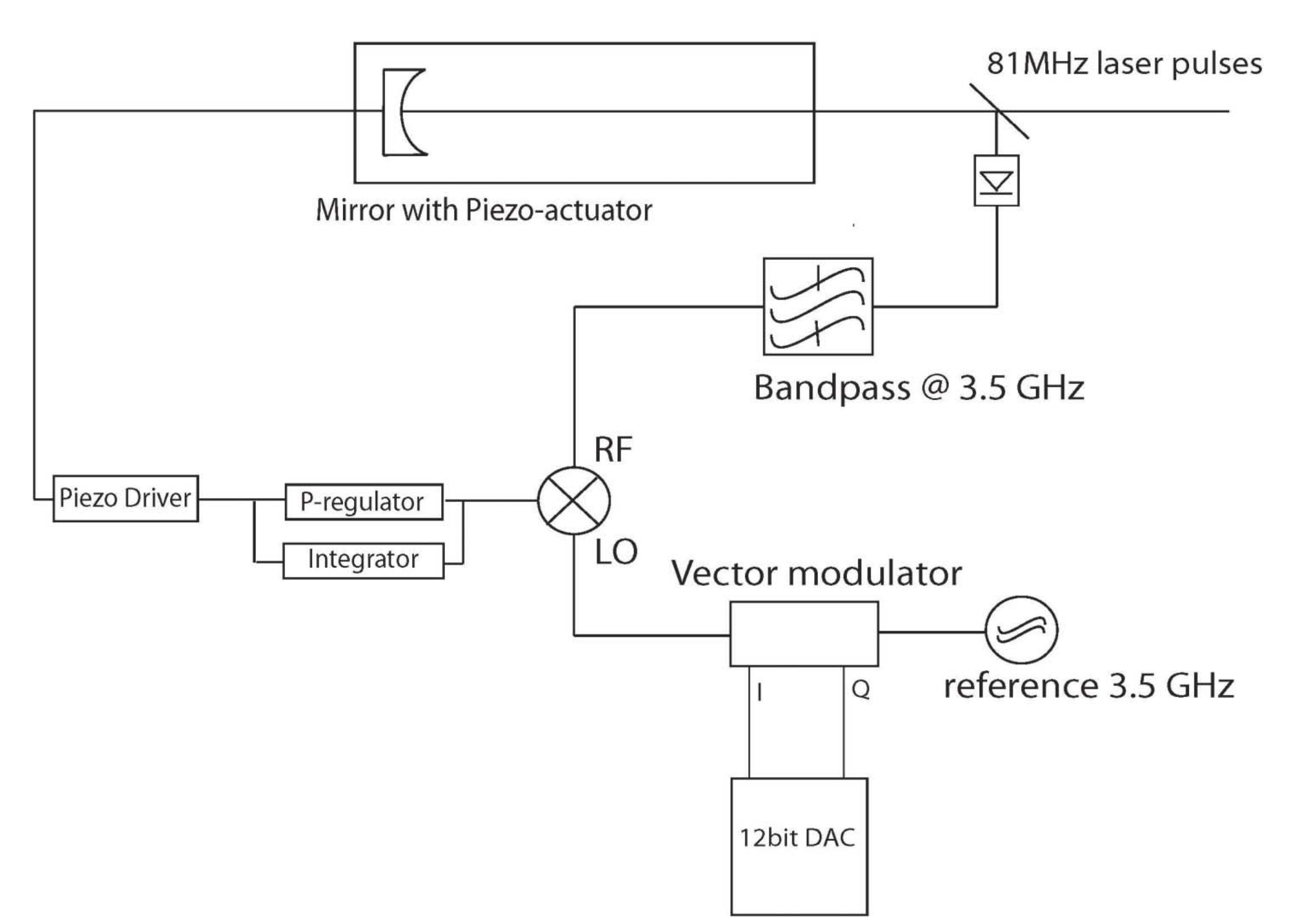
Synchronisation Scheme



phase-locked loop (PLL)

f_{laser} = 81 MHz

f_{RF} = 500 MHz

f_{common} = 3.5 GHz

scanning done by phase shift of the 3.5GHz local oscillator (LO) with a vector modulator

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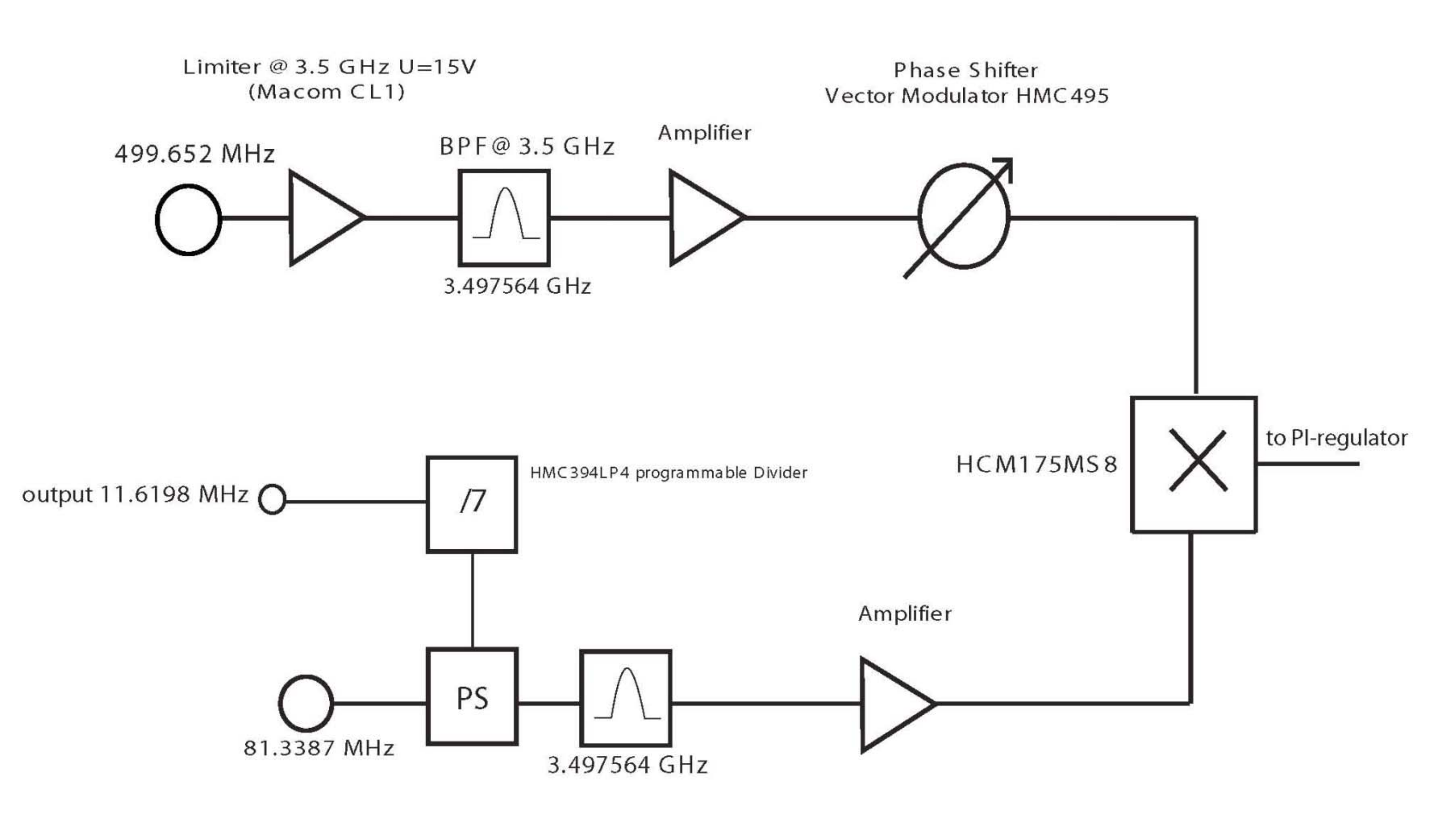
Synchronisation II



- 7th harmonic from linac RF generated through limiter amplifier
- mixed with 43rd harmonic of laser
- f_{laser}/7 generated for trigger synchronisation

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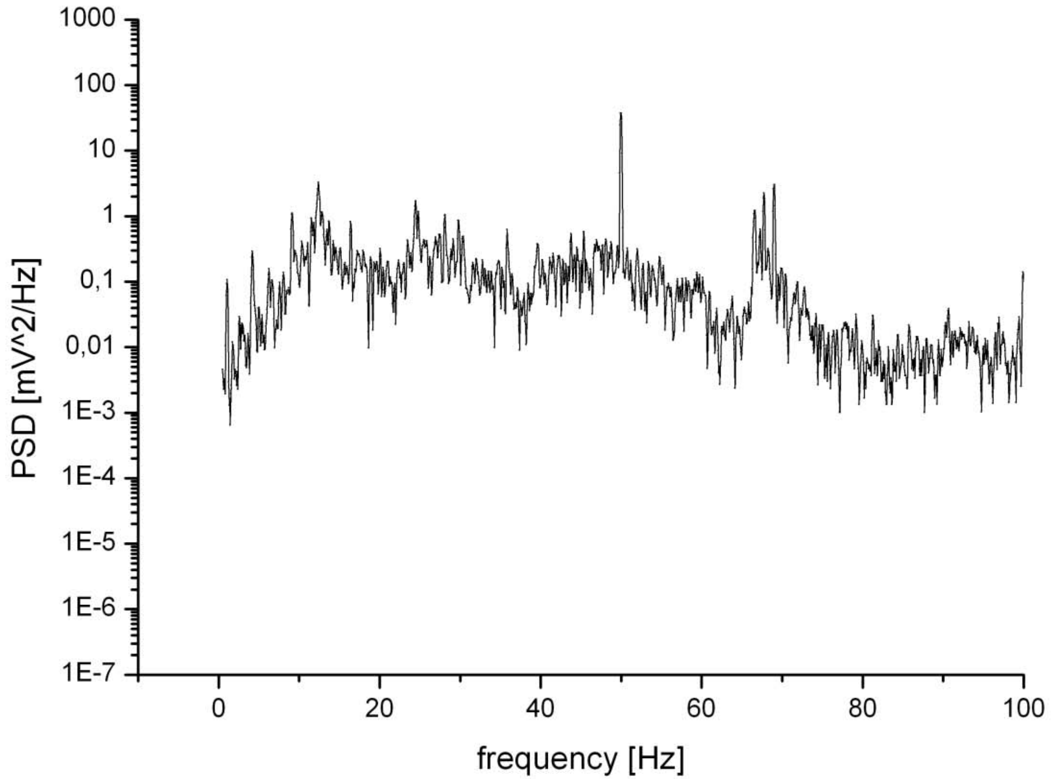
Synchronisation Stability



- Spectrum shows dominant peaks at 50Hz, 375Hz, 19 kHz and 30 kHz.

$$1\frac{mV^2}{Hz} = 2.4\frac{fs^2}{Hz}$$

stability of 37 fs

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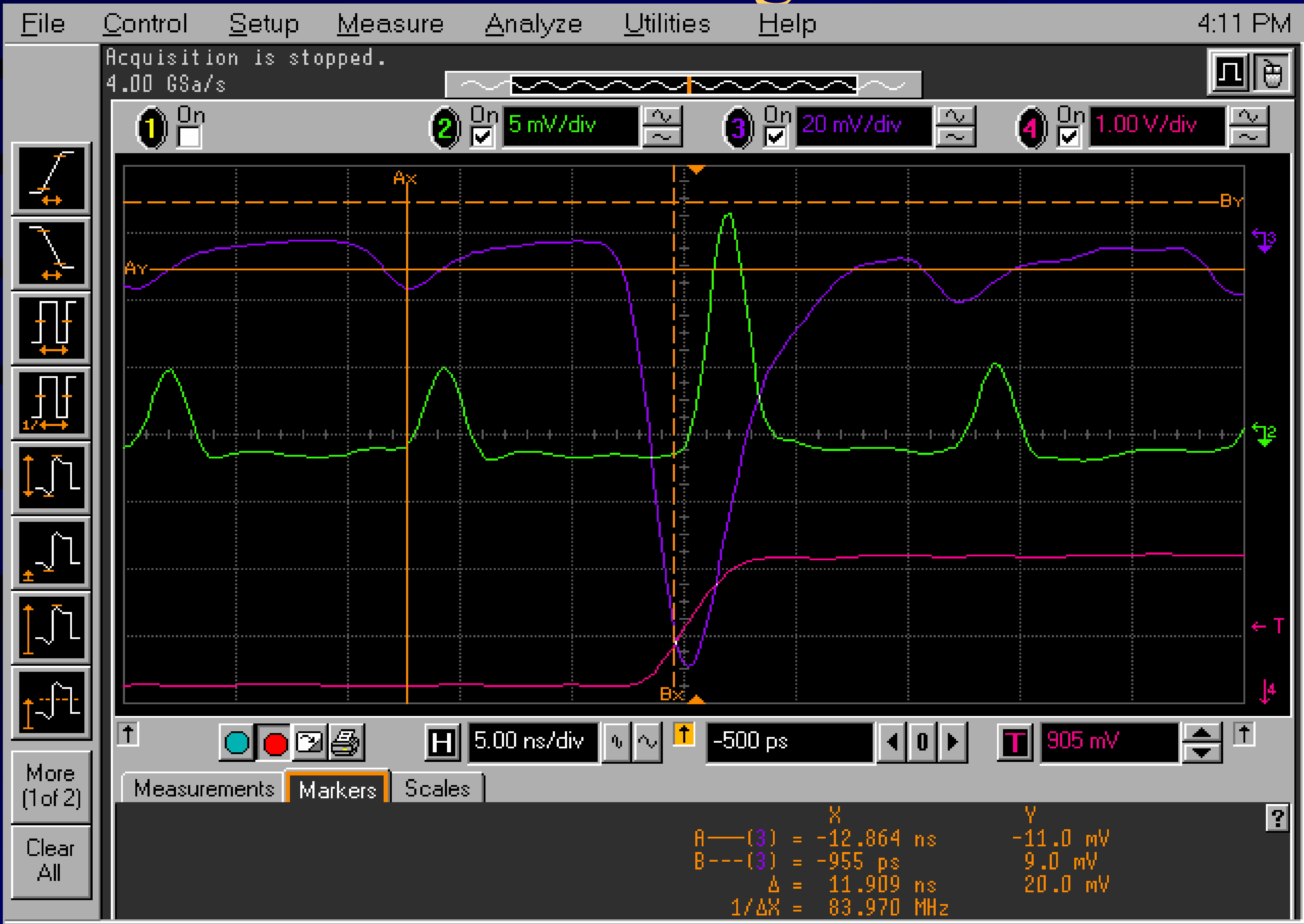
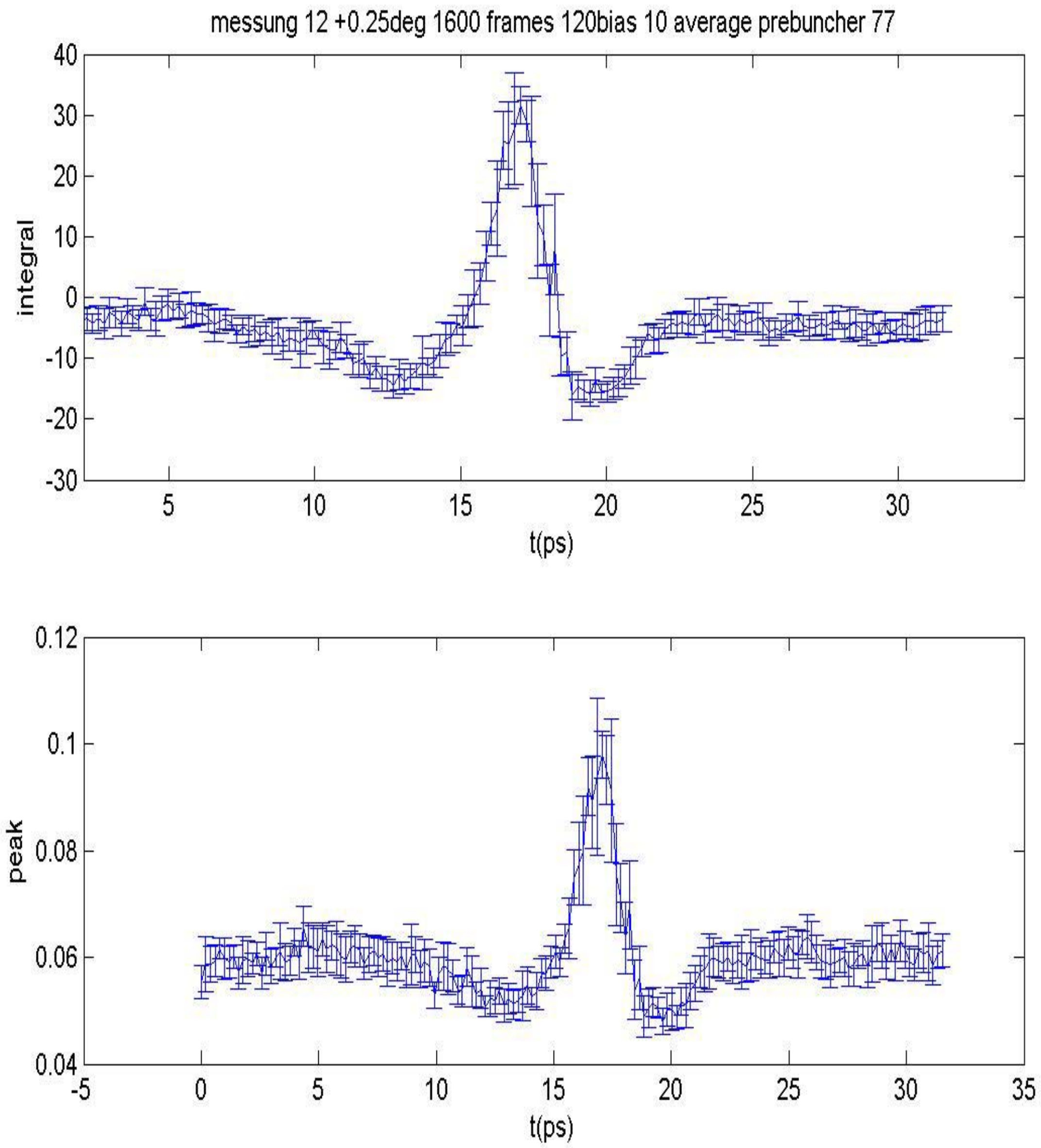
First Signal



Data



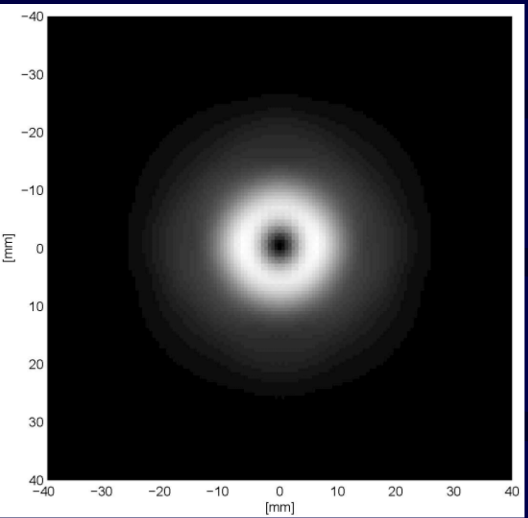
- scanning step width: 200fs
- averaged over 10 measurements per step
- expected bunch length from interferometric measurement with Golay-cell: 3ps-5ps FWHM

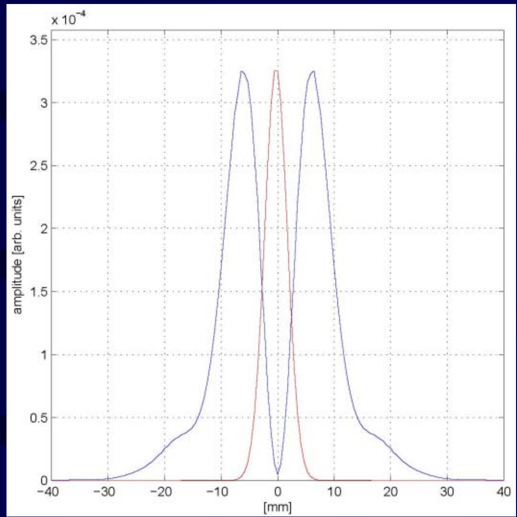
good agreement with expected bunch length

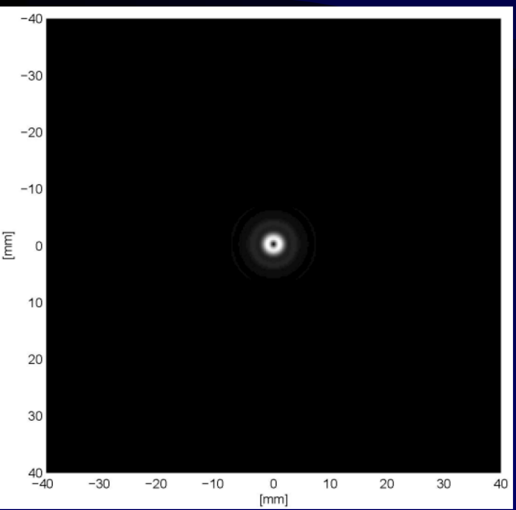
CTR Transfer Function

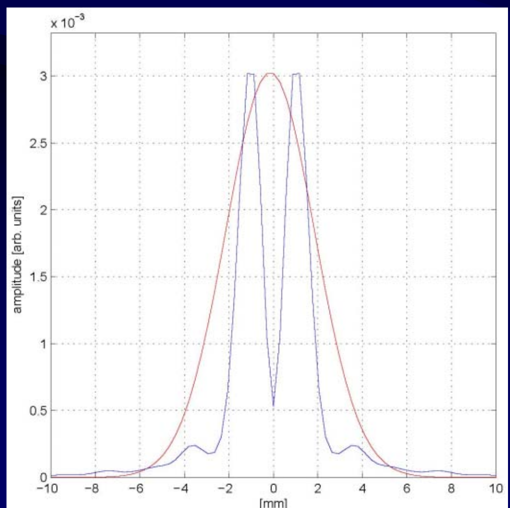
Model of CTR transfer function from source to crystal using ZEMAX:

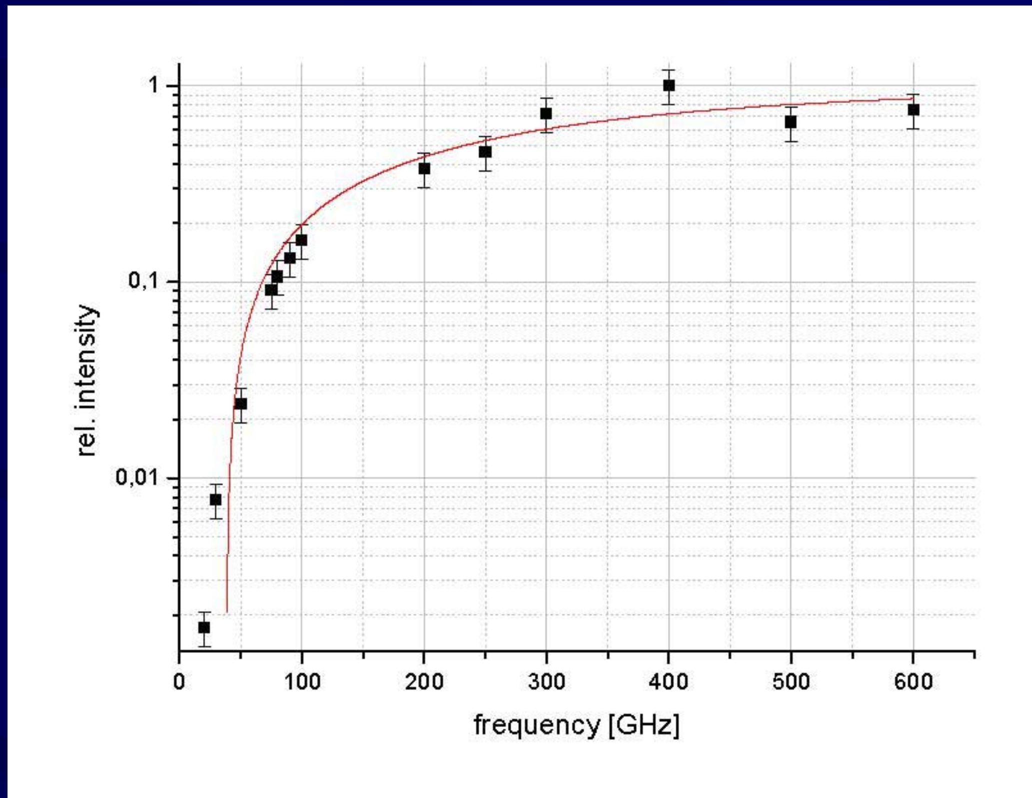
- aperture of vacuum window cuts frequencies below 30 GHz
- frequencies below 80 GHz do not contribute to signal due to laser spot size (diameter:2 mm) on crystal





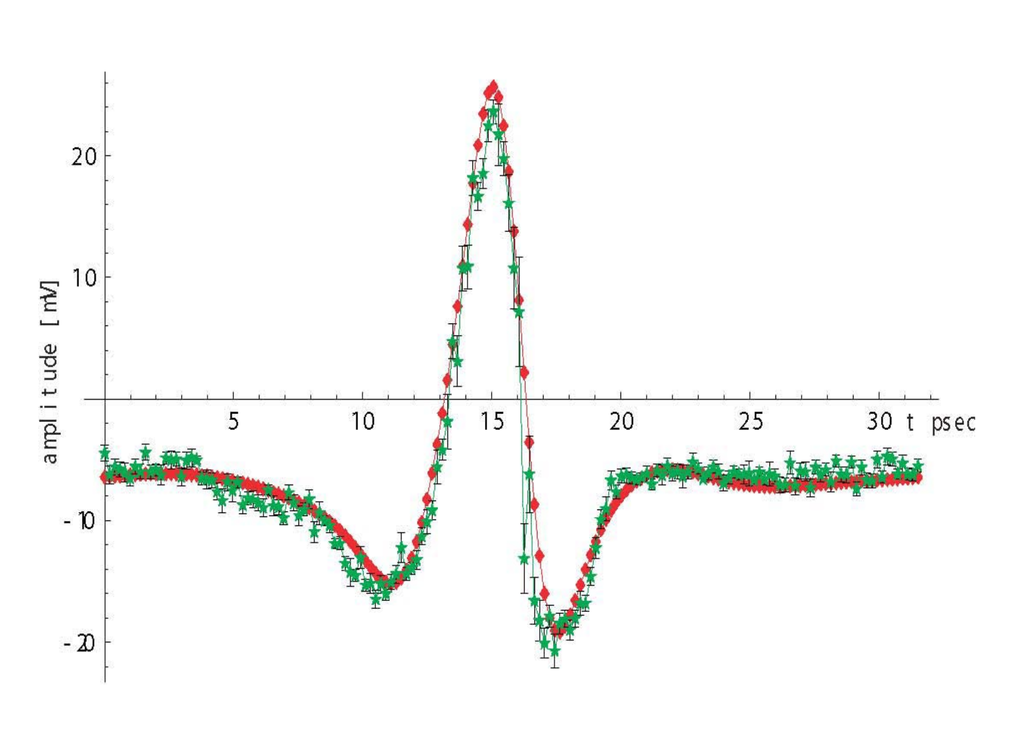


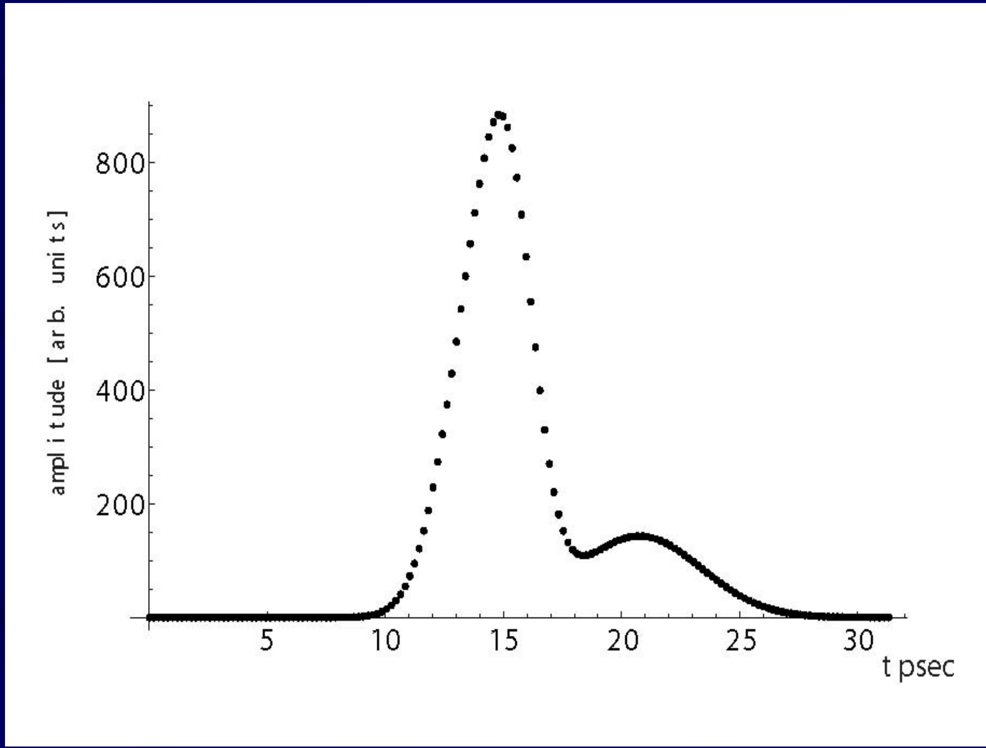




Fits

- 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



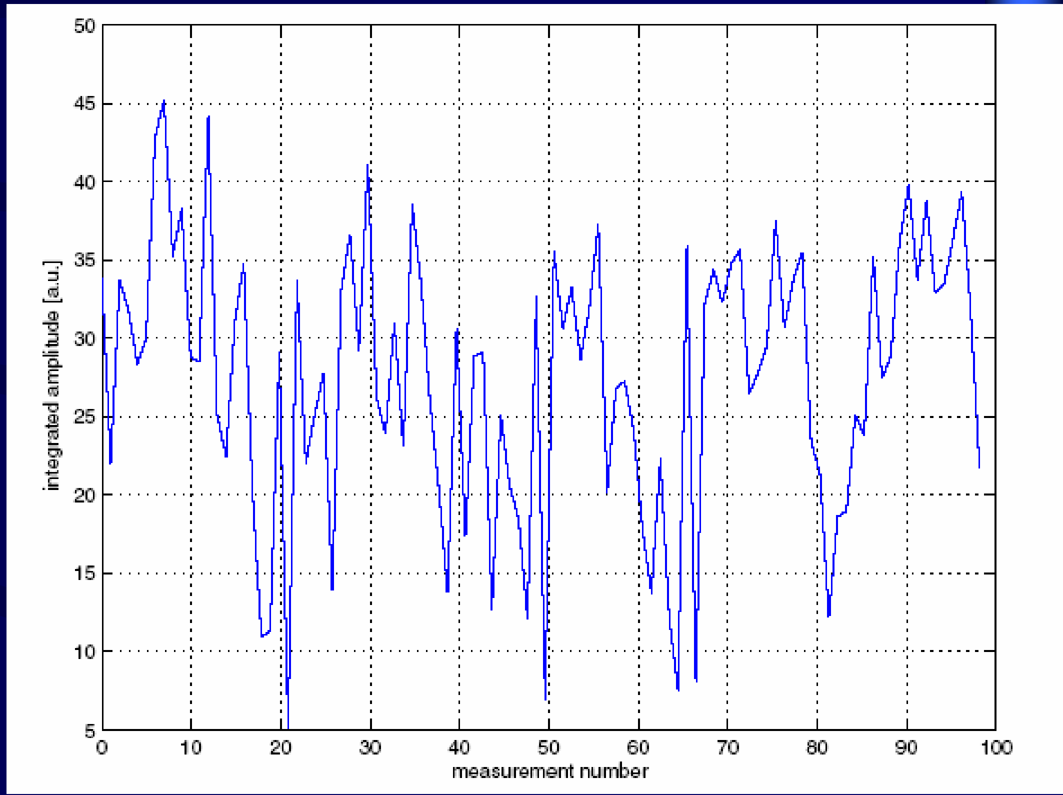


Temporal Resolution

- 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)



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 accomplished
- 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