Coherent radiation diagnostics at FLASH

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FLASH Seminar 5.12.2006

source characteristics (CSR,CTR,CER,CDR,SP..)

spectral energy density

$$\frac{dU}{d\omega} = C\ N^2 \left| F_{long}(\omega) \right|^2 T(\omega, \gamma, r_b, \theta, source)$$

$$F_{long}(\omega) = \int_{-\infty}^{\infty} \tilde{\rho}(t) \exp(-i\omega t) dt$$

normalized charge density

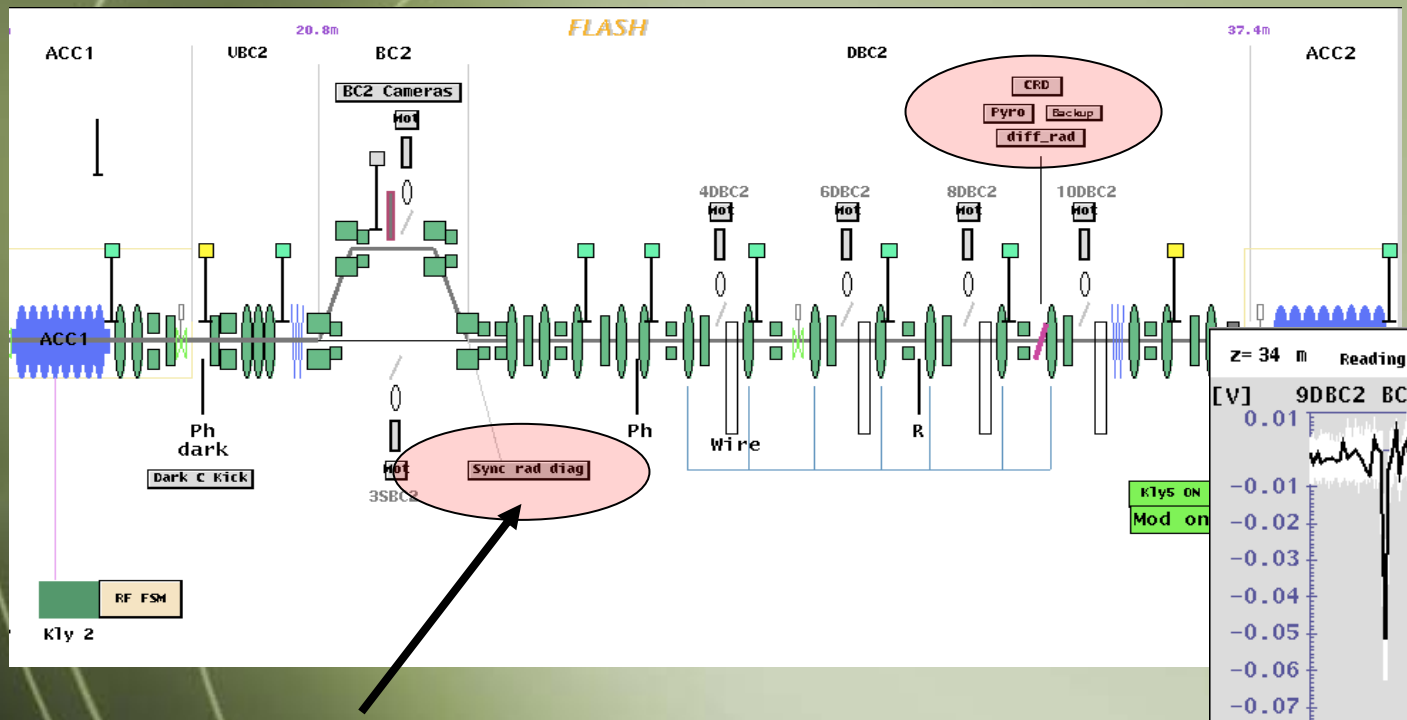
- integral intensity

⇨ 'compression factor', effective bunch length

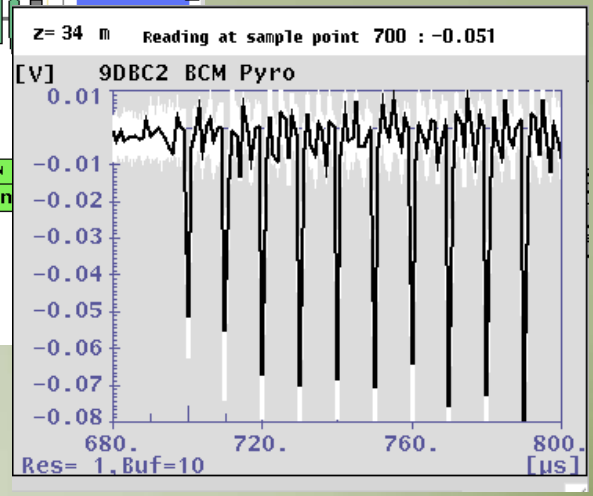
- spectrally resolved intensity

⇨ + bunch structure, 'longitudinal fingerprint'

CR ports at FLASH



BC2 CDR port

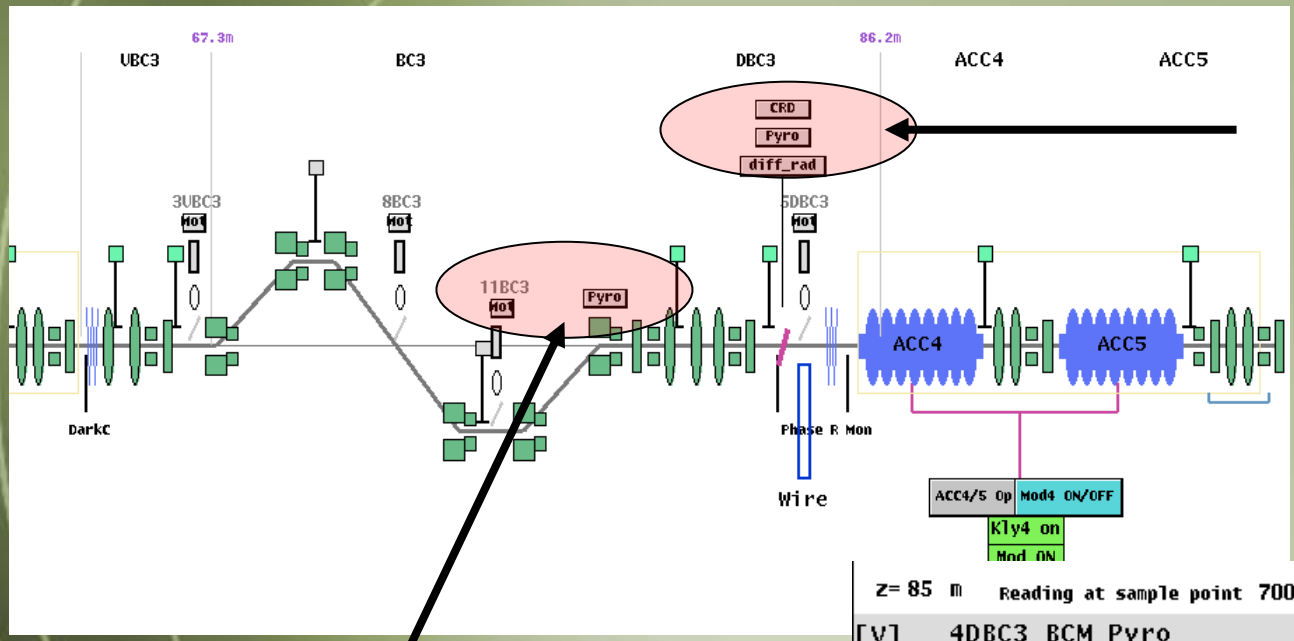


BC2 CSR port
feeding “TOSYLAB”

Beamline beeing ‘revised’
new optics, vacuum

Oliver Grimm

-5-10 mm diffraction radiator
- cryst. quartz window
- two pyro detectors
- used for ‘compression feedback’

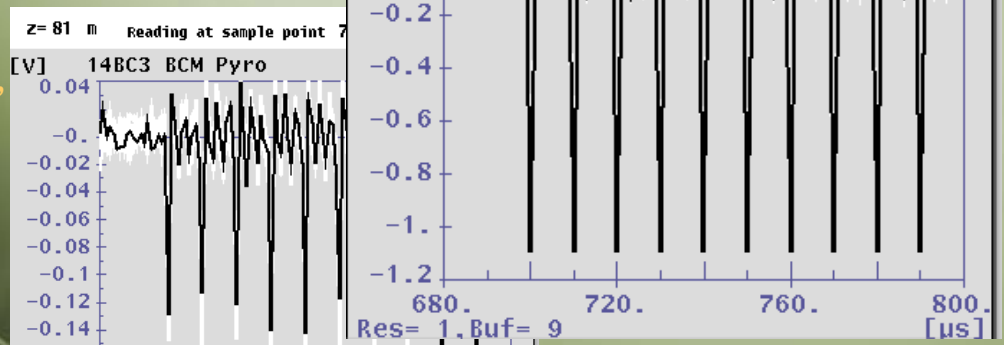


BC3 CDR port

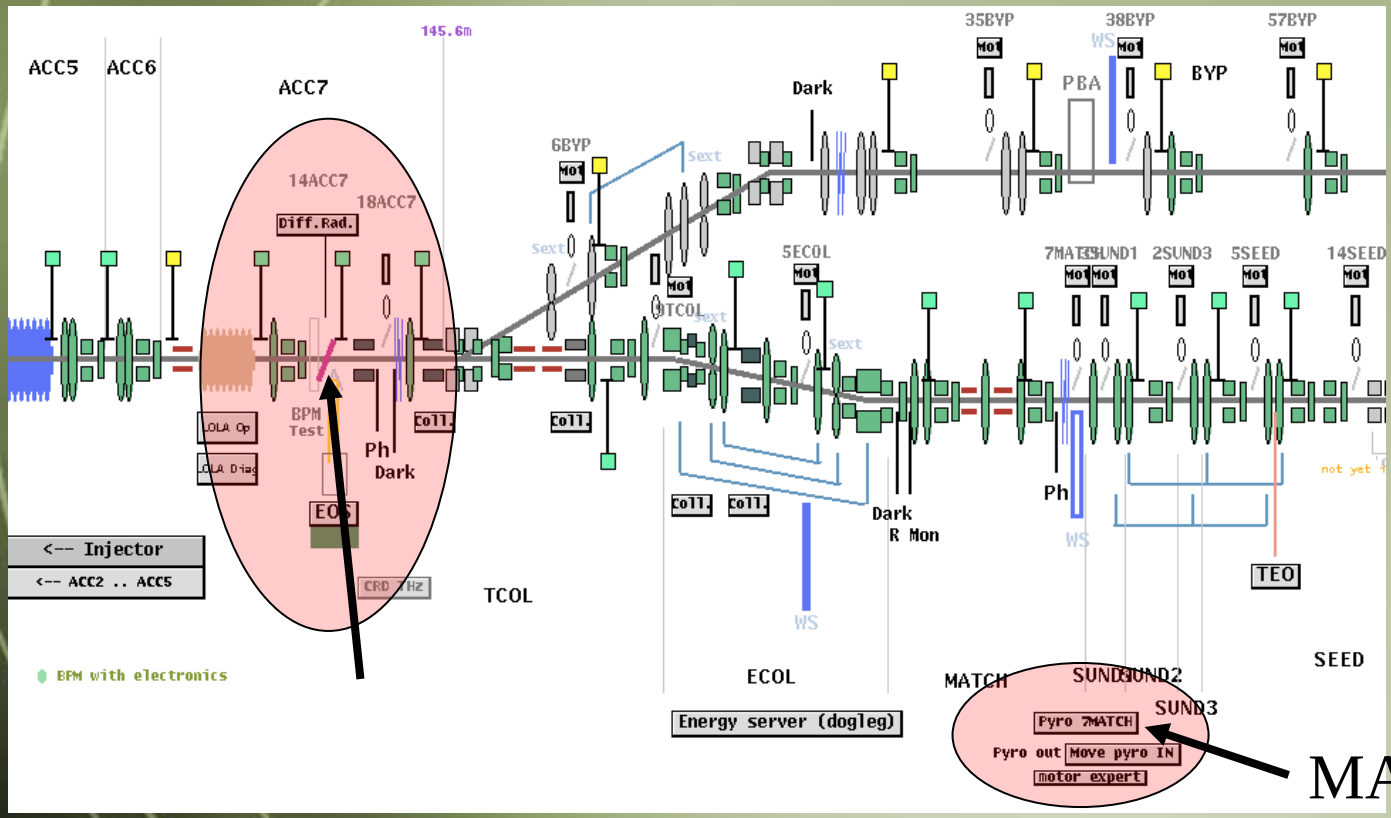
-5-10 mm diffraction radiator
- cryst. quartz window
- one pyro detectors
- at the moment saturated from single bunch

BC3 CSR port

Newly installed, not used so far



all stations are equipped with new fast and sensitive electronics with single bunch resolution

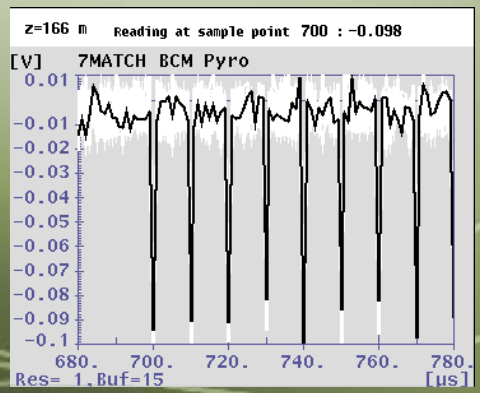


MATCH7 port

no radiator

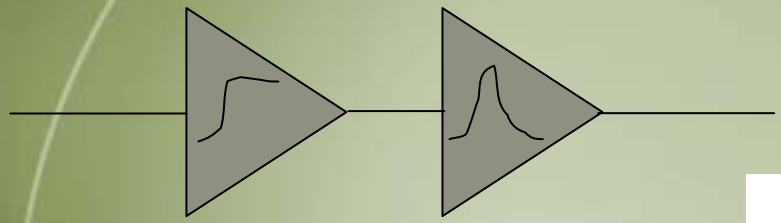
What does it see ?

- diamond window
- full vacuum system
- radiation guided to outside tunnel
- used for instrumentation development



The pyro crystal produces a surface charge
~ temperature change

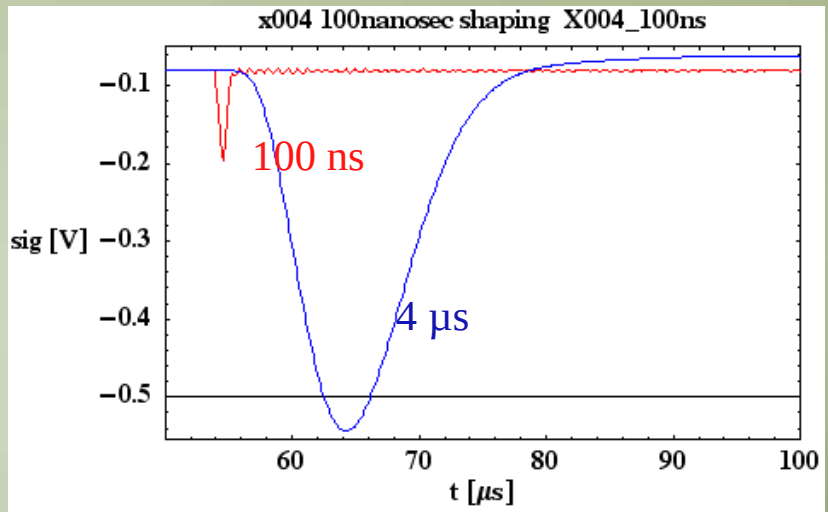
Ideal : charge sensitive amplifiers



integrating pulse shaping

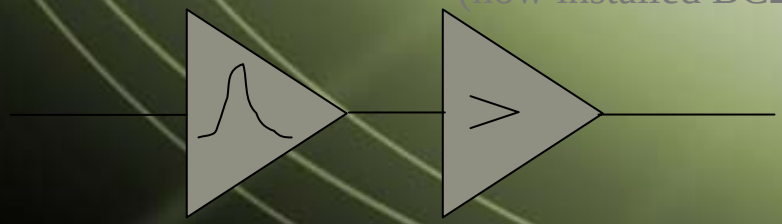
(used in spectrometer)

+ Best signal/noise
- pile up in 1. Stage prevents long pulse trains

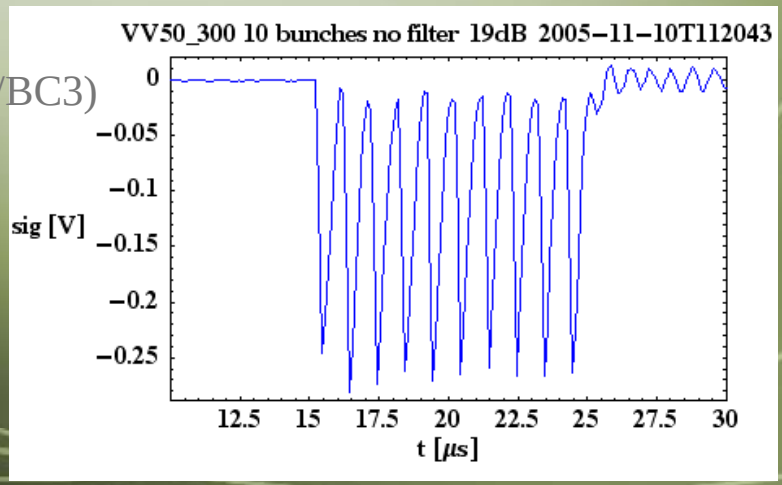


- reduced signal/noise
- NO pile up

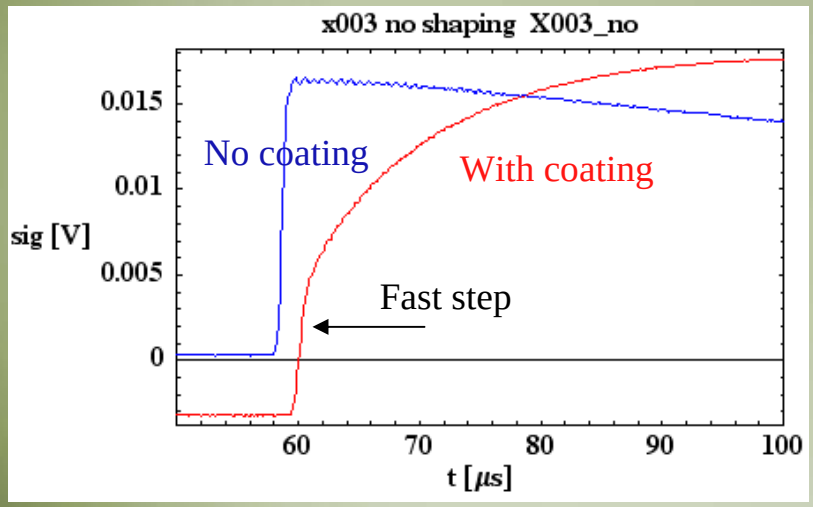
(now installed BC2/BC3)



Short time const amplification



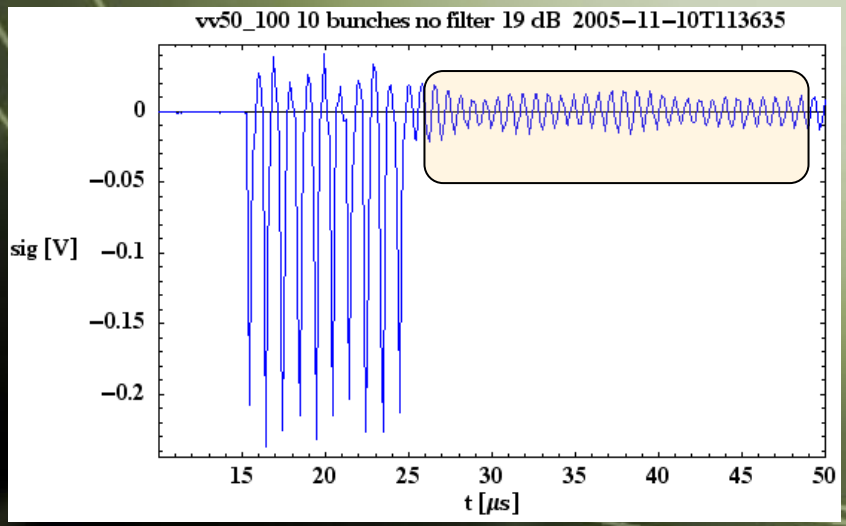
Some pyros have “black coating” for improved absorption



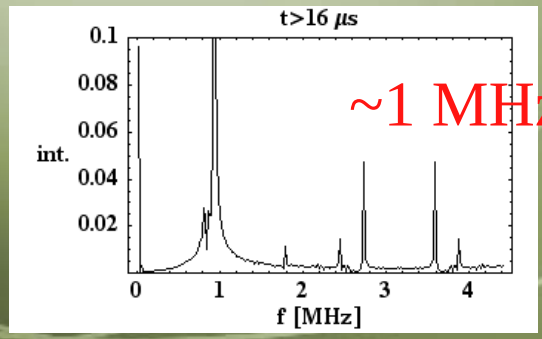
-introduces ~ 25 μs timescale for part of the signal
- NOT advisable for fast shaping

Measured at λ = 1 μm

The ringing phenomenon



-independent of type of electronics
- depends on size of crystal
- mechanical vibrations !
- (pyro crystals are piezo electric).



Classical approach :

- Michelson-Type spectrometer (autocorrelation function)
- scanning device, no single shot capability
- aim to reconstruct longitudinal profile

Jan Menzel

Enrica Chiadroni TTF/FLASH

Lars Fröhlich

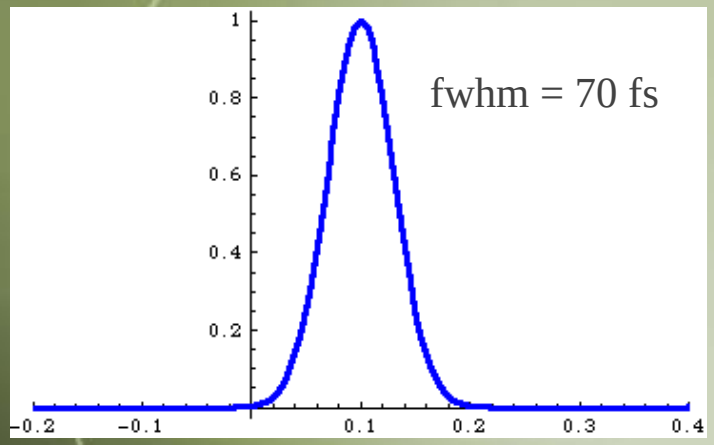
New approach :

- grating spectrometer (wavelength spectrum)
- multi-channel parallel readout
- single shot device
- aim to produce wavelength resolved fast feed-back signals (“fingerprint”)

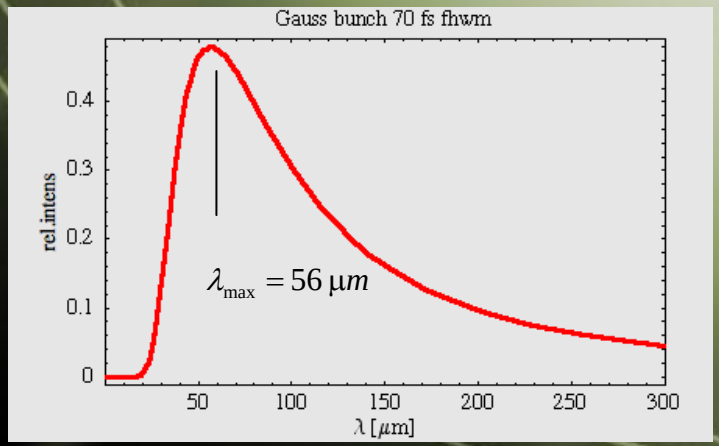
Hossein Delsim-Hashemi

BS

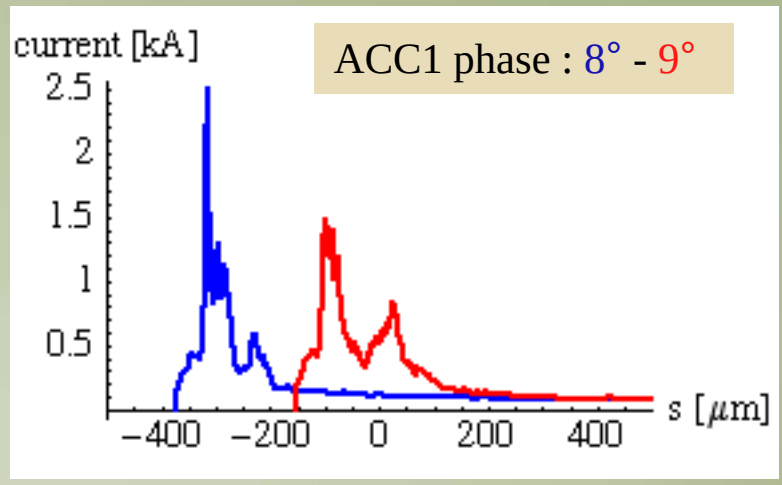
Gauss bunch

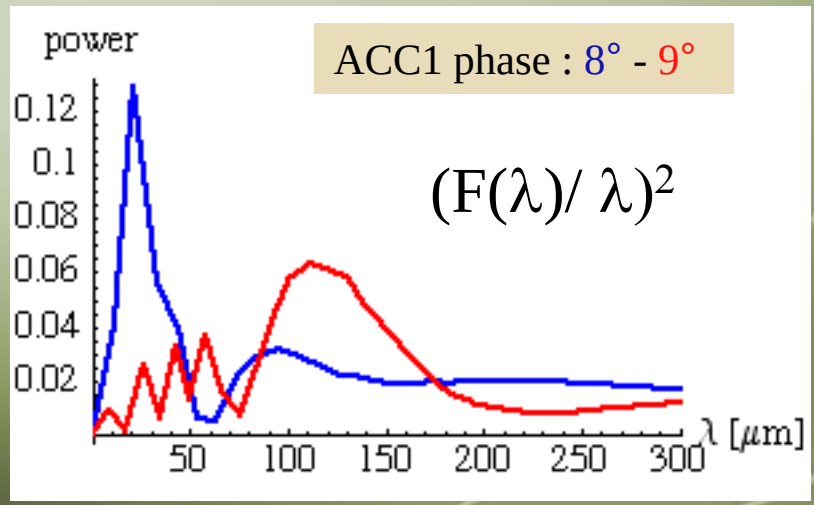


$$\lambda_{\max} = \frac{fwhm}{2\sqrt{2\ln(2)}}\frac{\mu m}{fs} = 0.80\, fwhm\,\frac{\mu m}{fs}$$

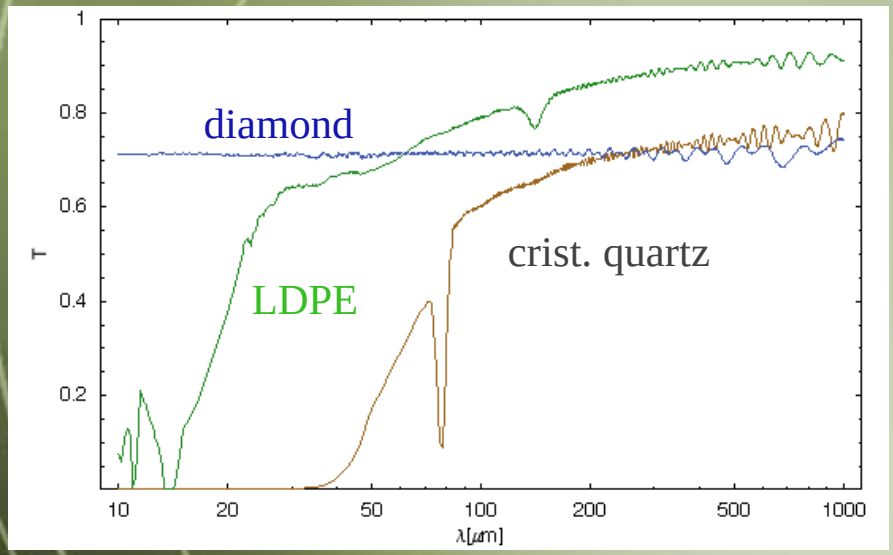


Simulations M. Dohlus

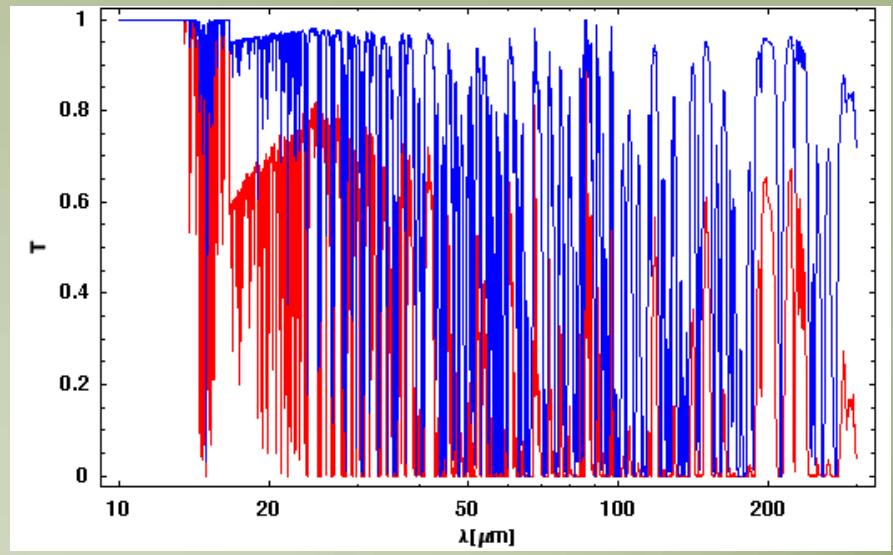


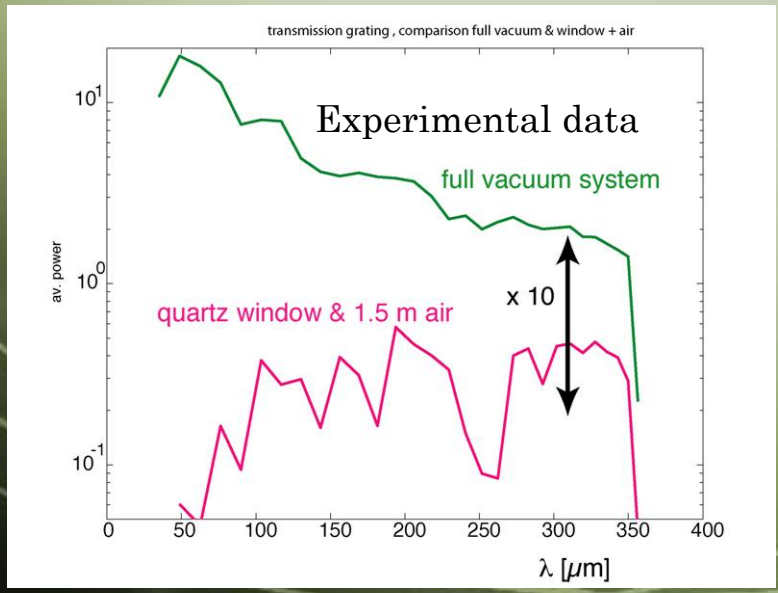


diamond window

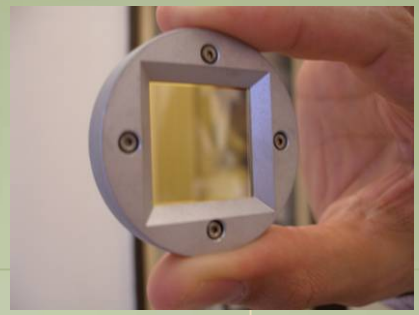


no humid air

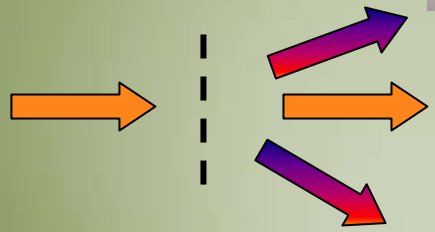




Gratings

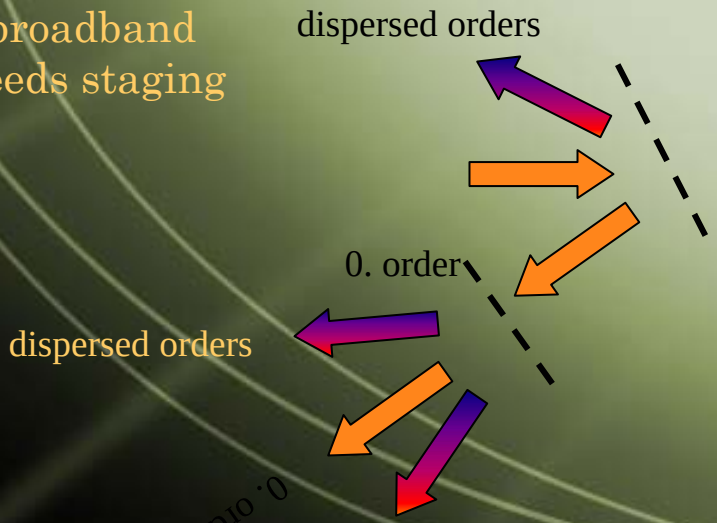


Transmission gratings

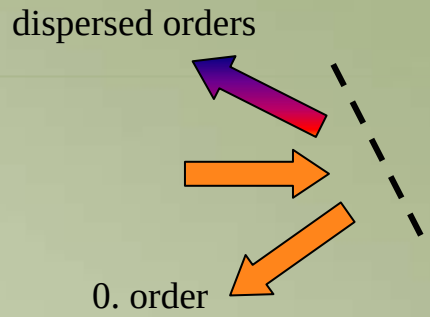


+ larger usable spectral range
- limited to λ > 20 μm
- poor dispersion efficiency (~15%)

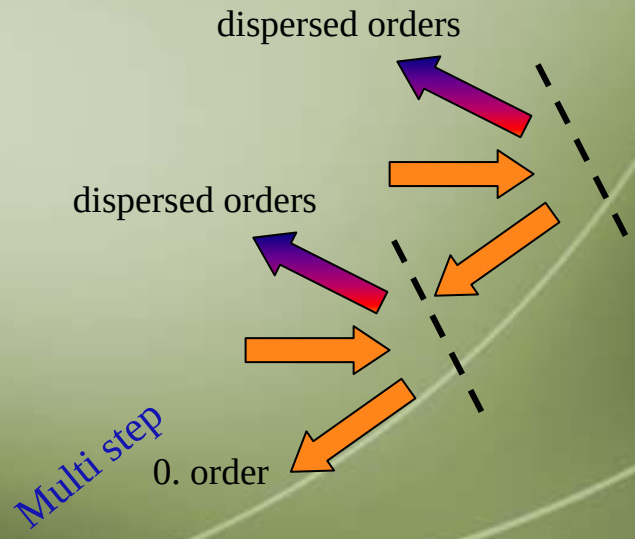
broadband needs staging



Reflective gratings



- smaller free spectral range (< 1 octave)
+ ANY λ
+ high dispersion efficiency (> 90%)



Requirements :

- fast, 200 ns for XFEL bunch spacing
- uniform spectral response
- broadband (1 µm - 1mm)
- robust ?

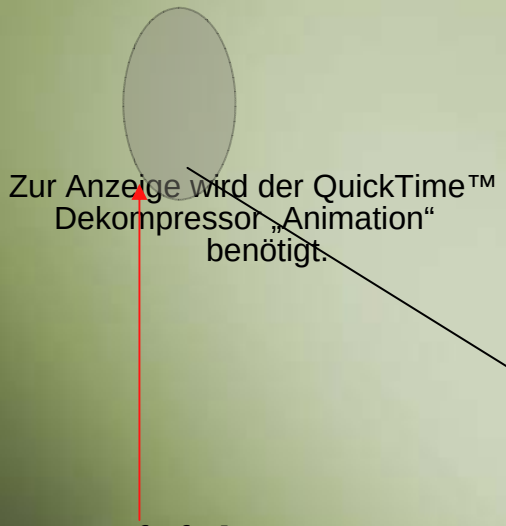
Recent development at DESY

Pyro-electric line detector from individual pyros

+ 30 channels
+ room temperature
+ no window, works in vacuum
+ fast read out
+ noise equivalent energy NEE : 60 pJ / pulse
+ smooth response function (suppresed resonances)

Up to now: single stage device

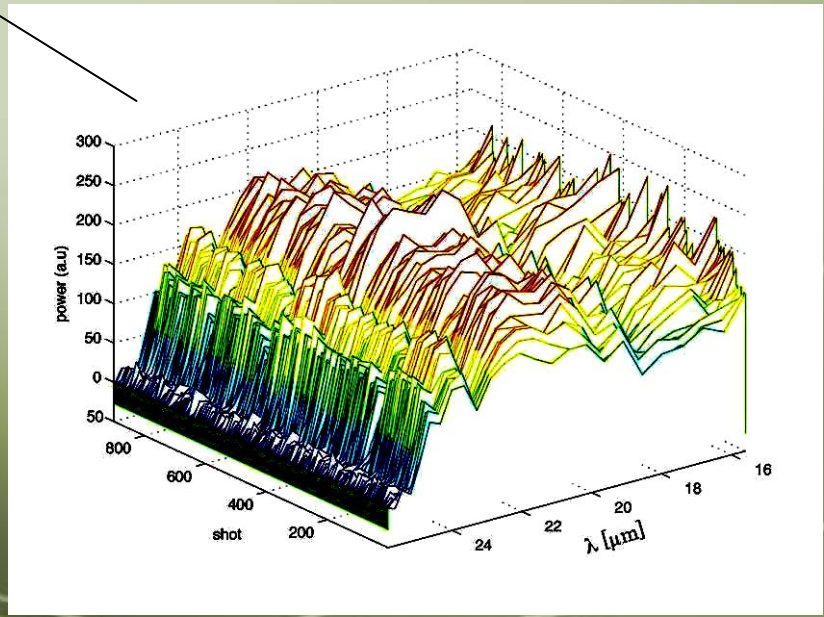
- simultaneous wavelength range limited
- patching problematic, machine fluctuations & calibration



~ 20 fs fwhm

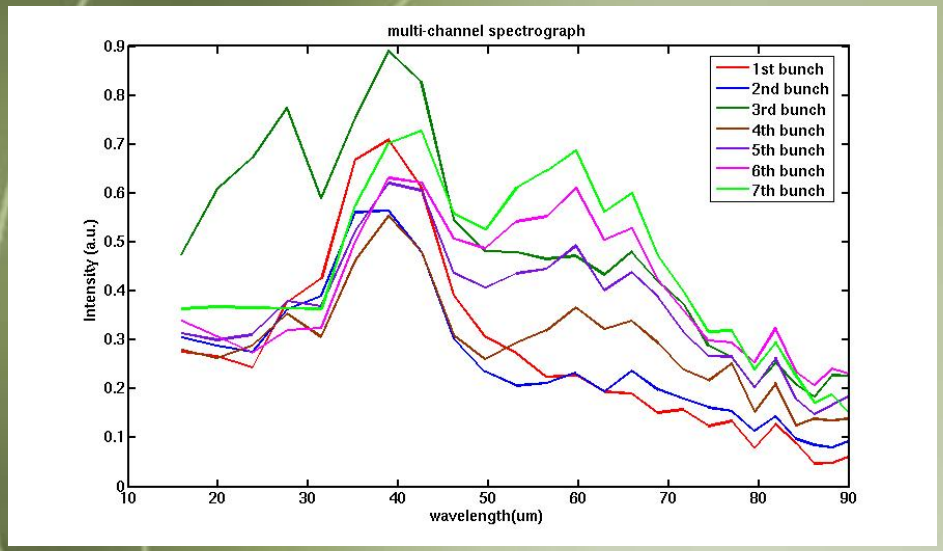
- single transmission grating
- during SASE conditions (5.10.06)

- single reflective grating
- during SASE conditions (20.8.06)

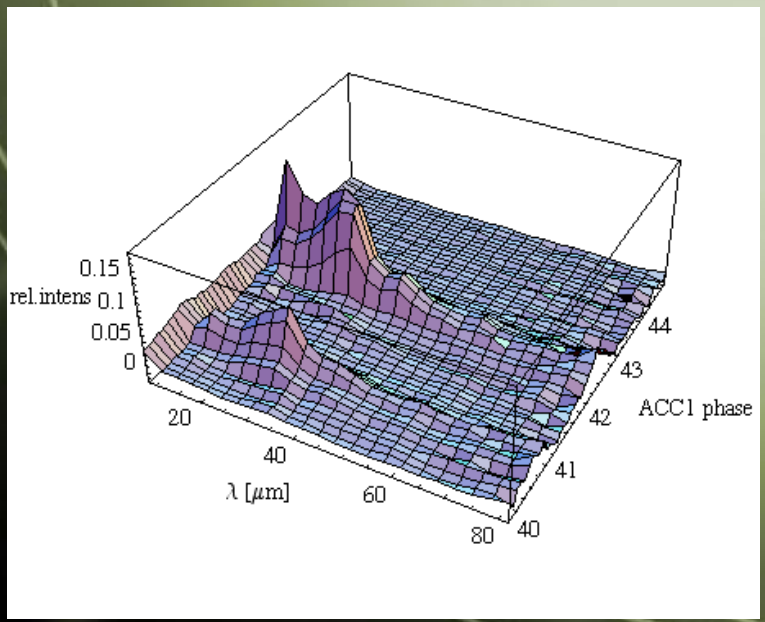


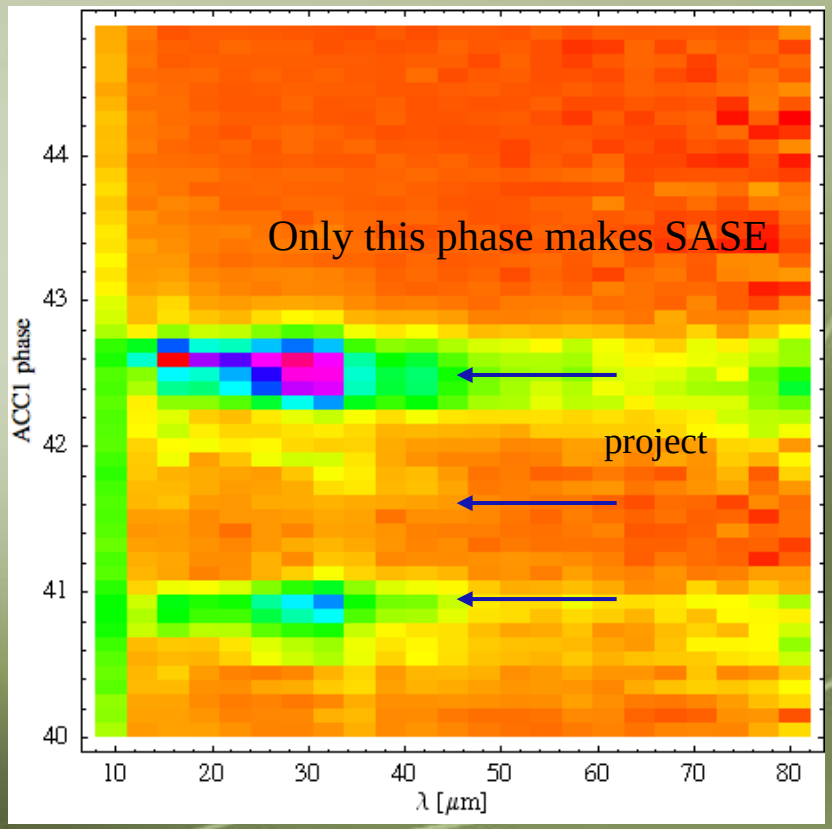
more spectra

spectra from different bunches in a train are different



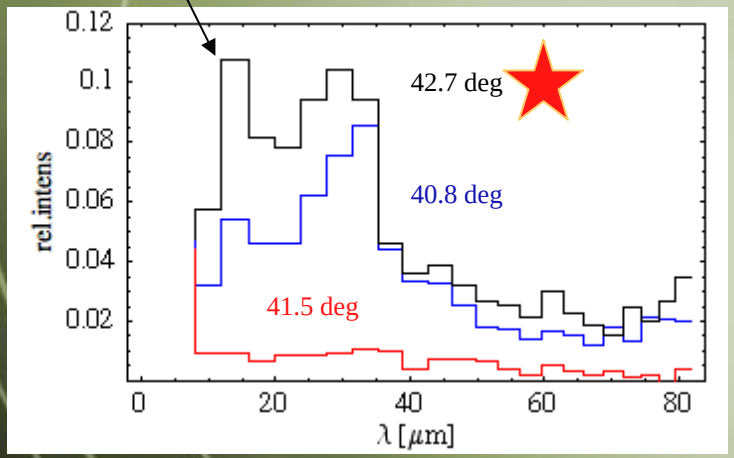
ACC1 phase scan

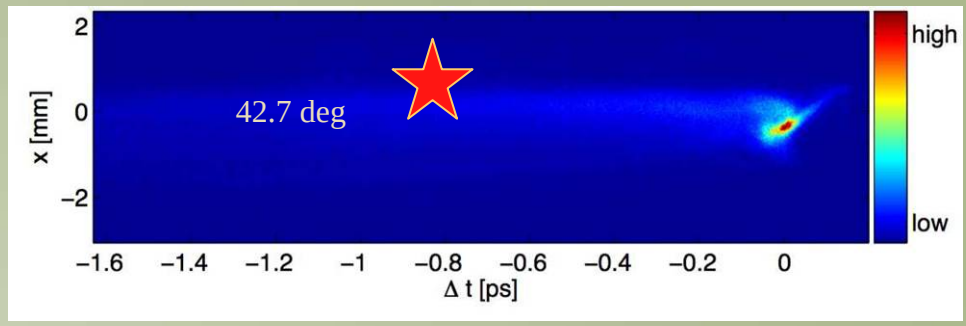


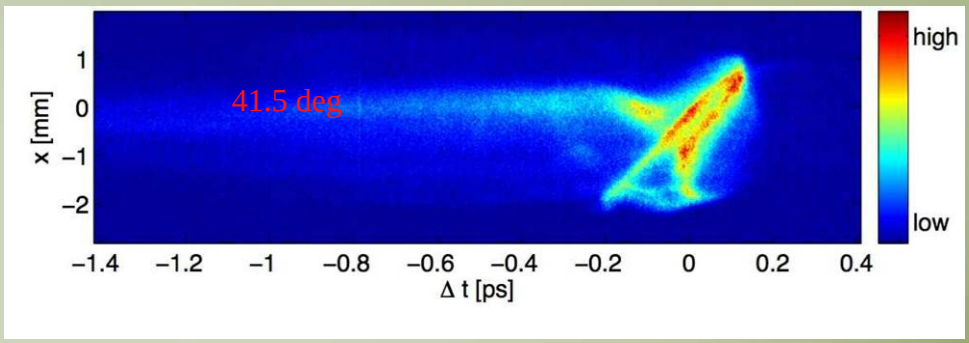


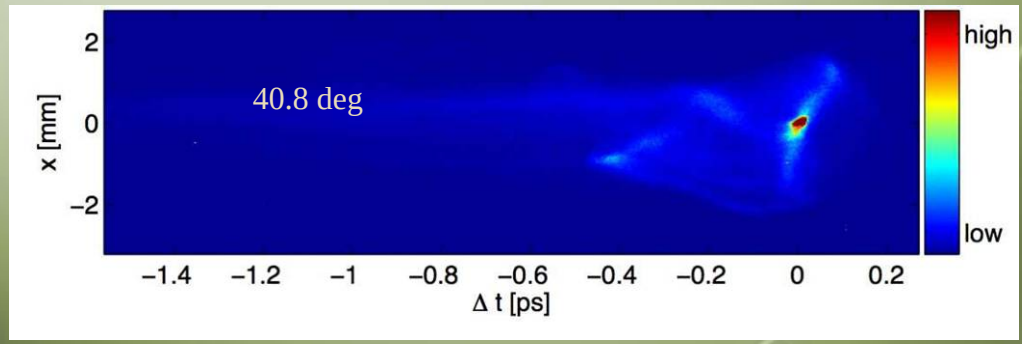
even more

Structures ~ 20fs responsible for SASE ?



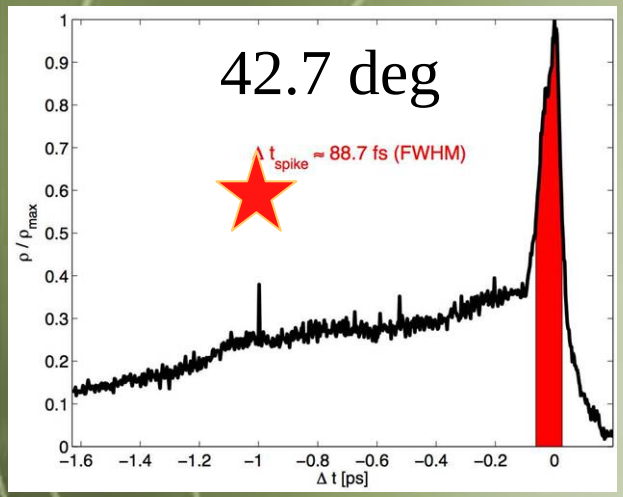


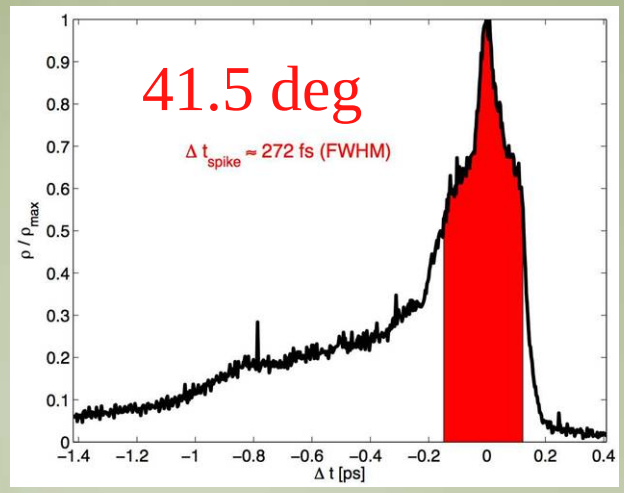


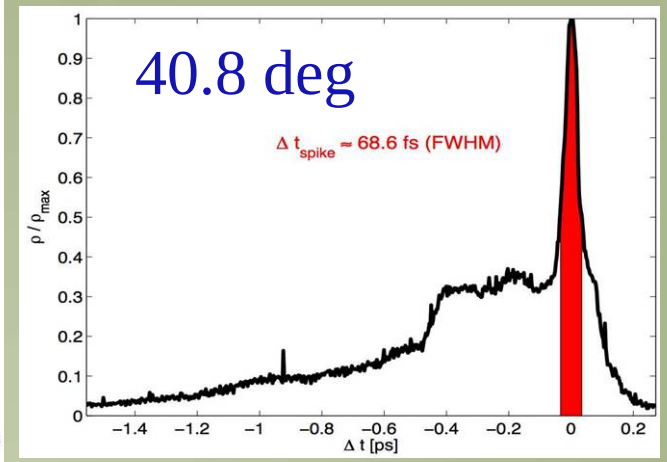


Thanks Michael Röhrs

LOLA profiles

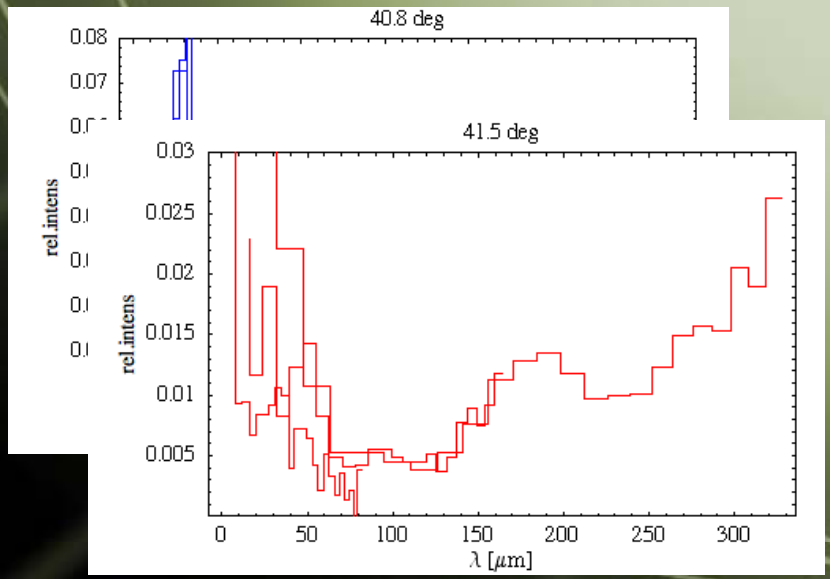


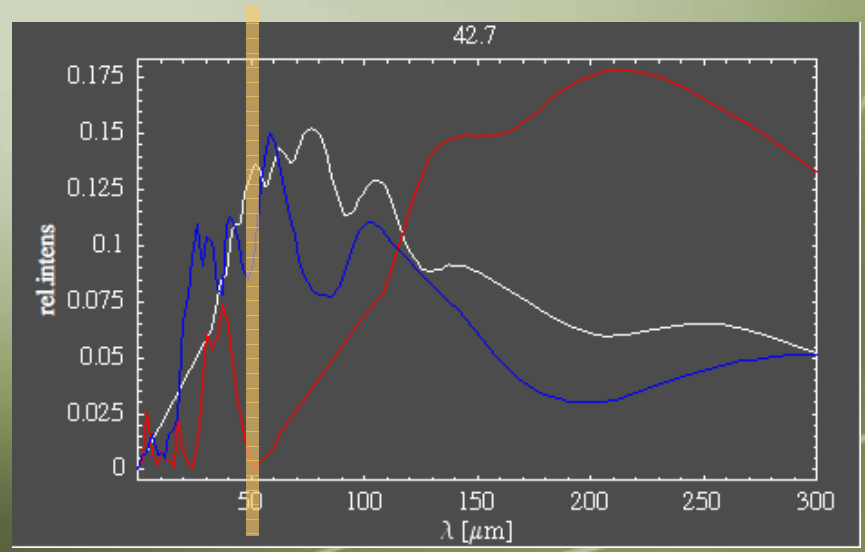




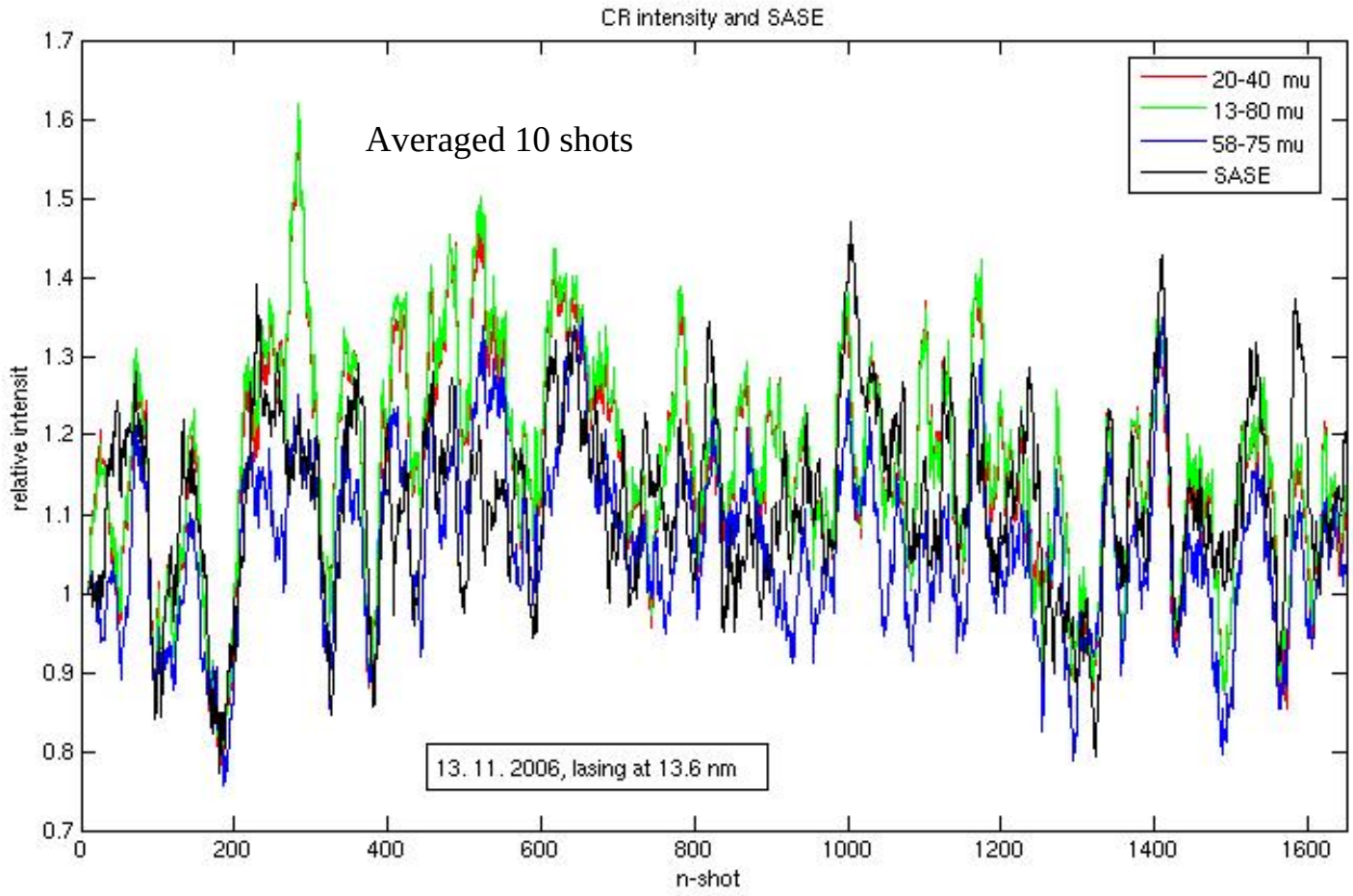
At SASE optics, LOLA resolution limited to ~ 70 - 80 fs ..

spike width ~ resolution
λ cut-off ~ 50 - 60 μm !

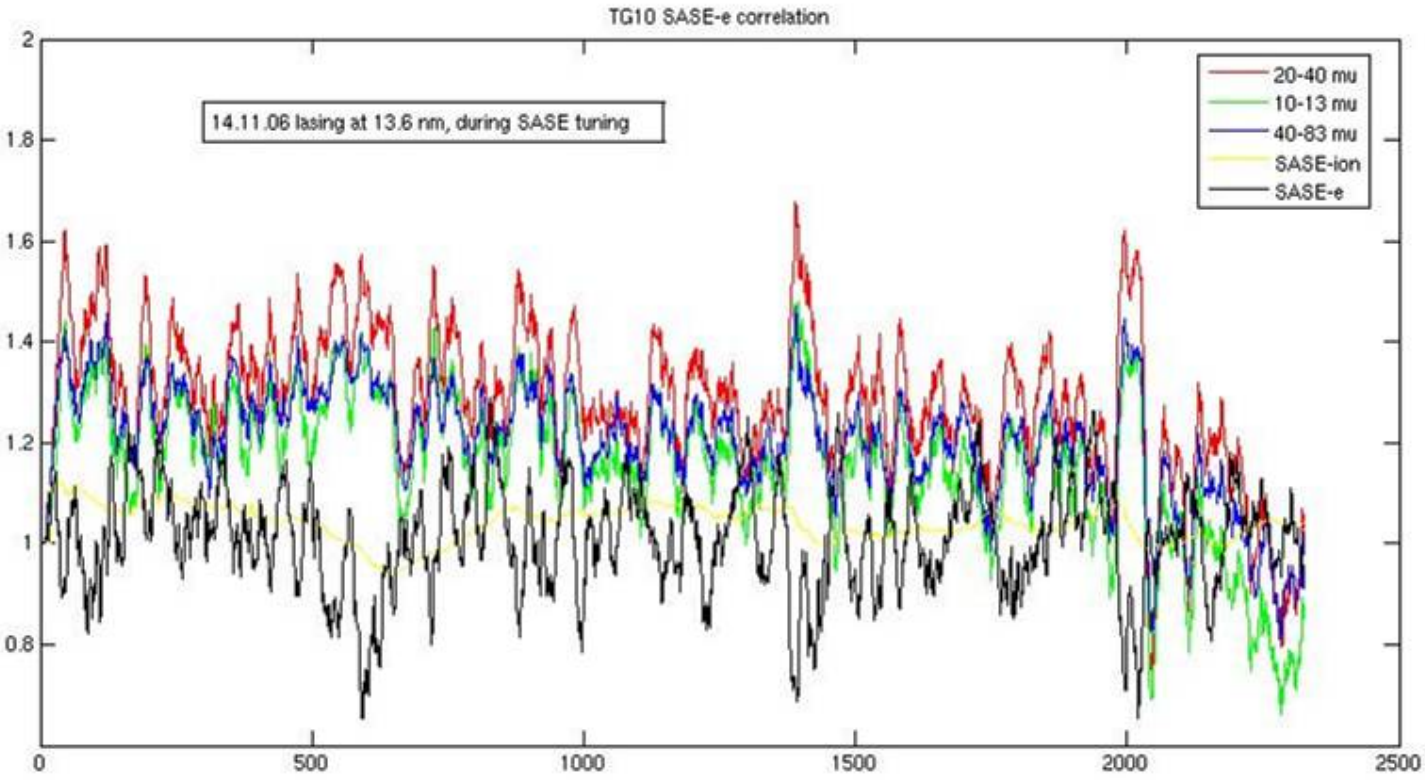




Short wavelength signals and SASE - e



.. the other day



There are non-trivial correlations

- broadband single shot spectroscopy is making progress
- still in experimental phase
- wavelength selected intensities will provide a fast ‘bunch shape fingerprint’

Next Steps

2-stage running since today !
See logbook :-)

- establish multi-stage version with larger spectral coverage
- develop experimental set-up to compact ‘device’ (CBSS)
- check and establish relevance for SASE operation

More THz diagnostics to come

- equip CSR ports at BC3 and dogleg dipol (?) with “CBSS”
- IR undulator !