“Progress of the TEO experiment at FLASH”

VUV-FEL at DESY

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Armin Azima

S. Duesterer, J. Feldhaus, H. Schlarb, H. Redlin, B. Steffen, **DESY Hamburg**

K. Sengstock, **Uni Hamburg**

Adrian Cavalieri, David Fritz, David Reis, **Michigan University Ann Arbor, Michigan**

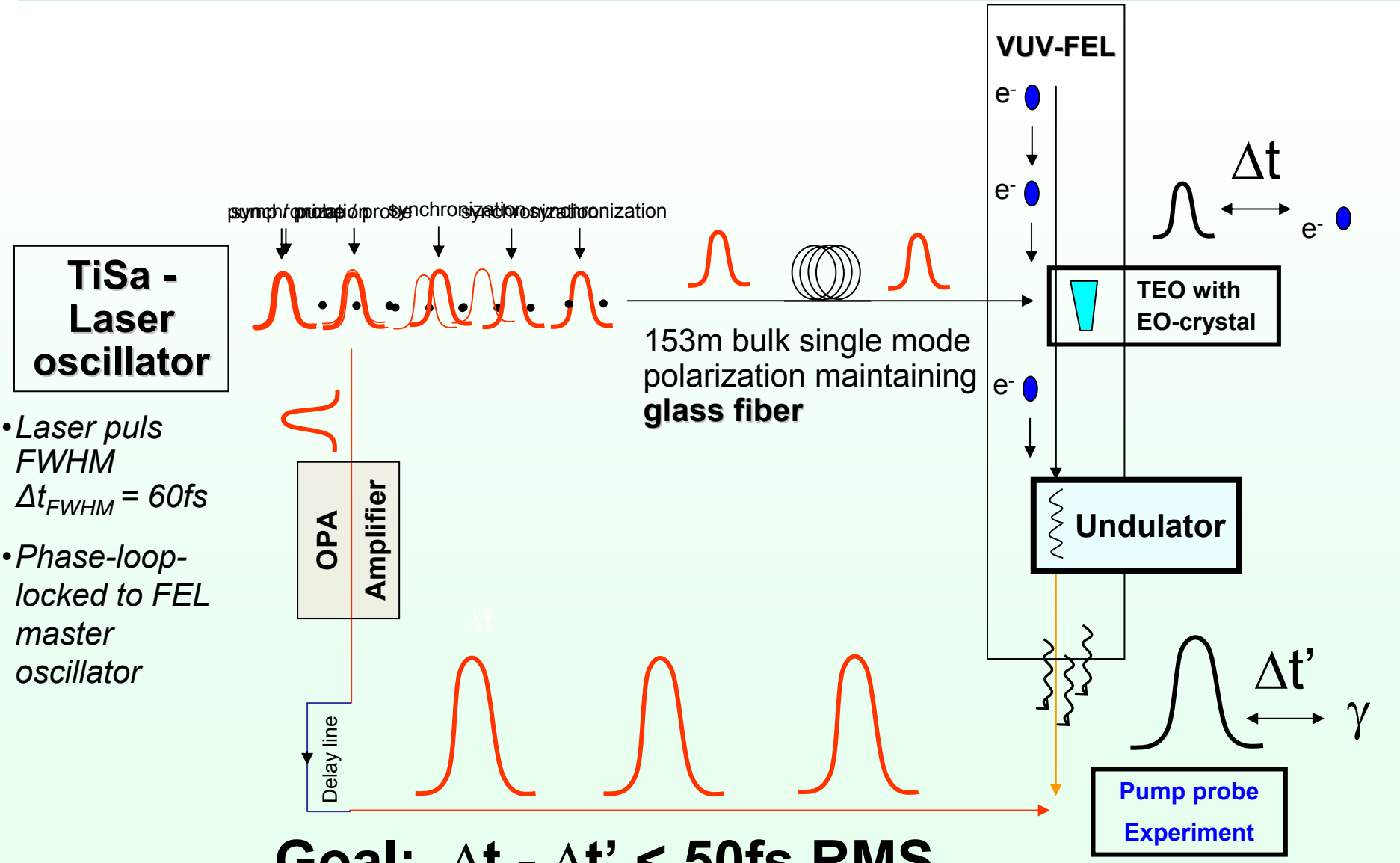
Motivation

FLASH

- TEO: “Timing by Electro Optical sampling”
  - correlation between an optical laser pulse and the electric field of an electron bunch
  - based upon Pockel’s effect
- Purpose:
  - jitter measurement for pump probe experiments
  - electron bunch analyzing

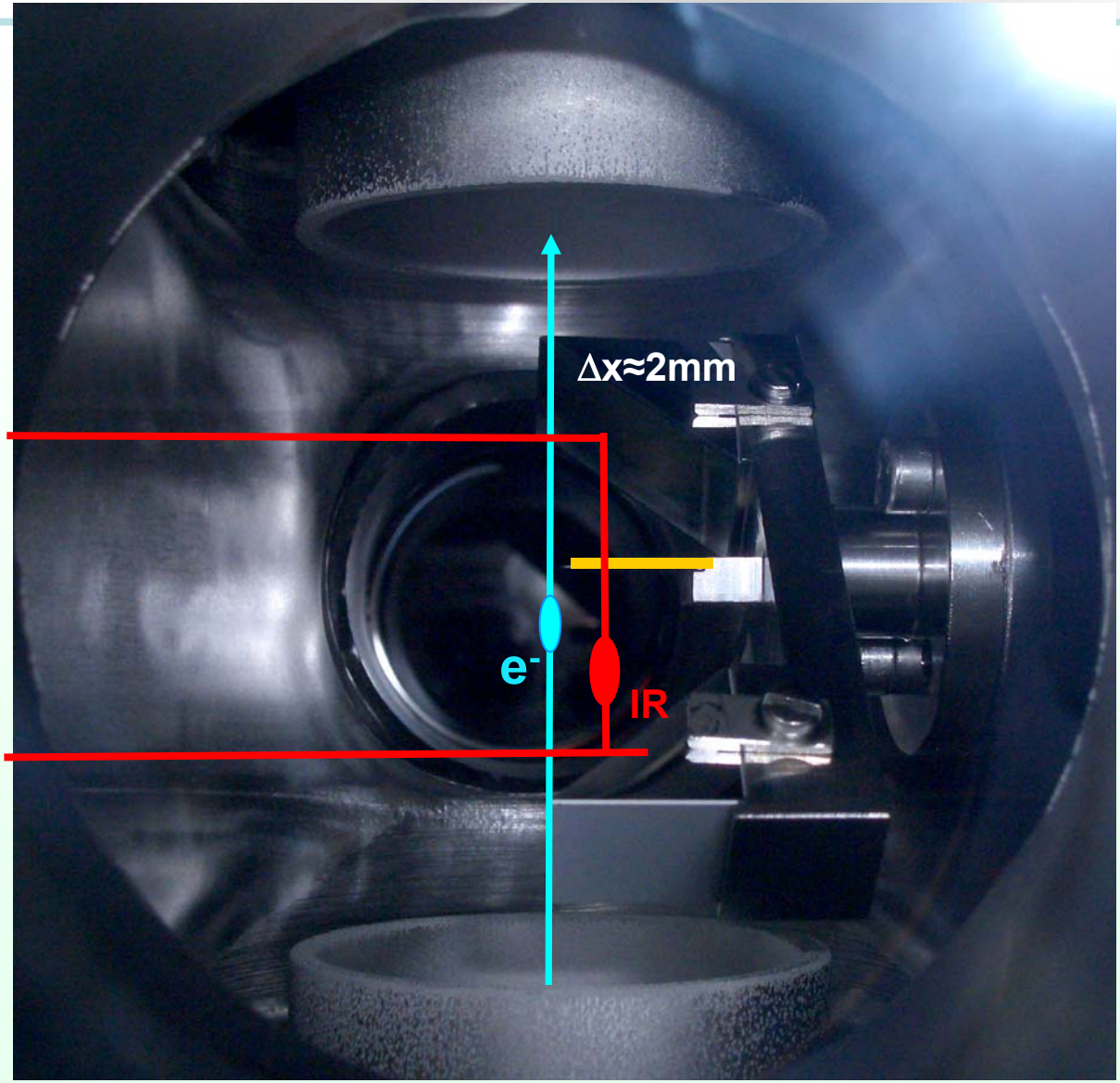
Timing of TEO experiment - principle

FLASH



TEO detection area - top view

FLASH



EO-crystal material

started with:
ZnTe 50-500μm, wedged

today, resolution optimized:
GaP 180μm

TEO signal detection – side view

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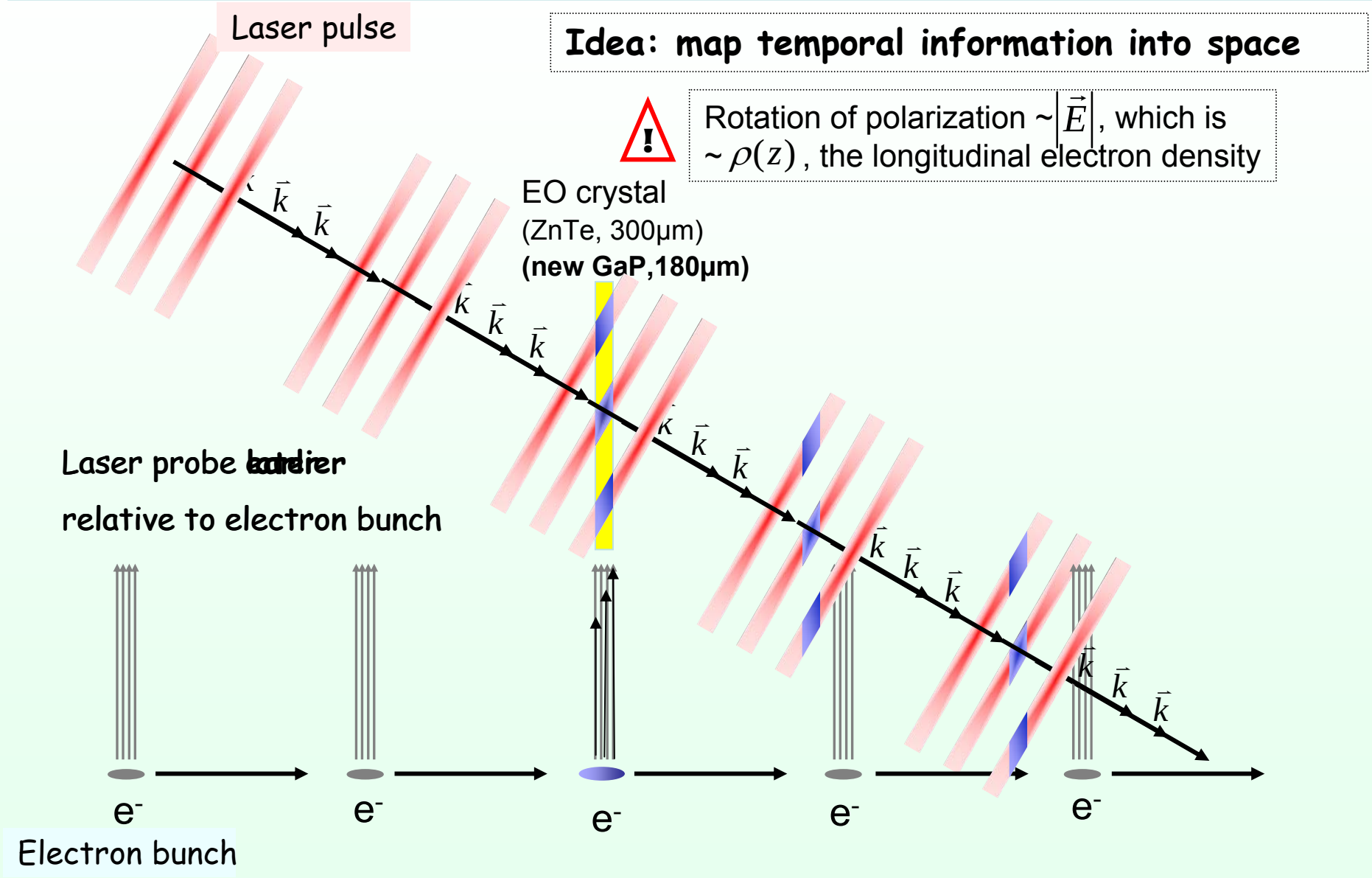
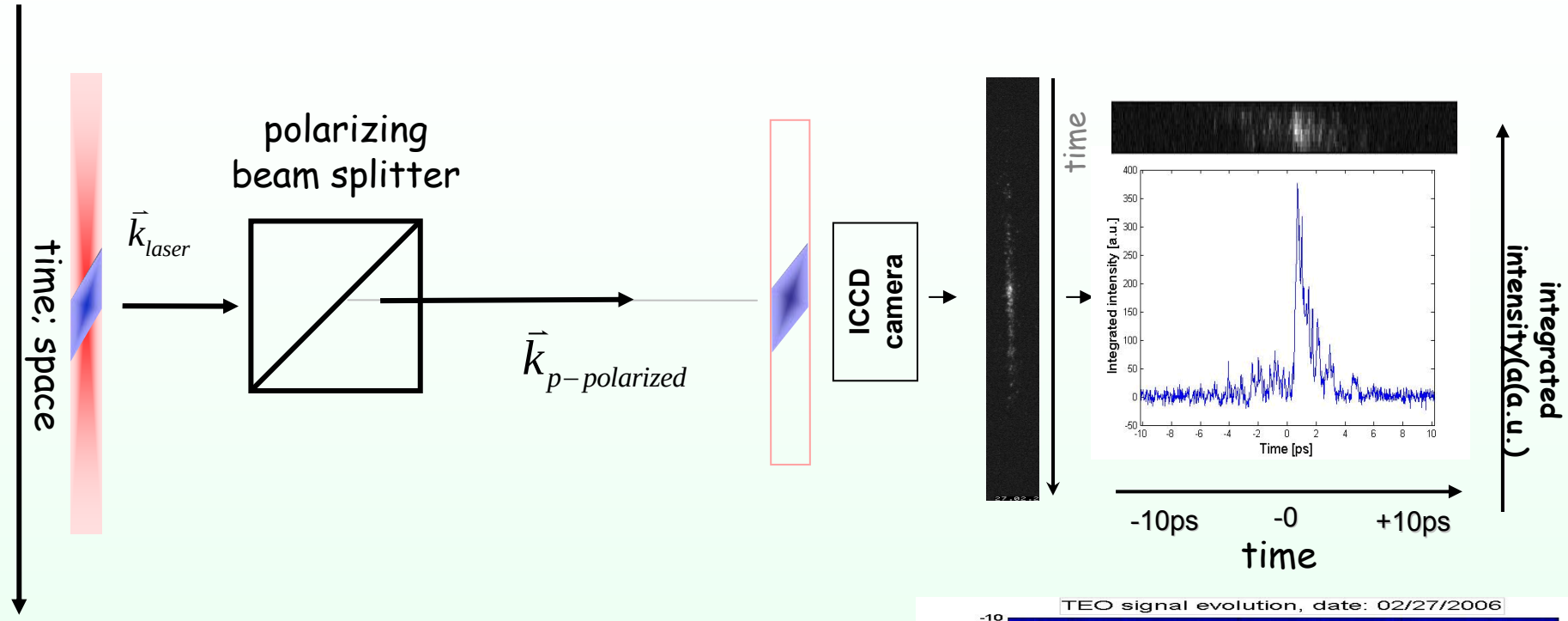
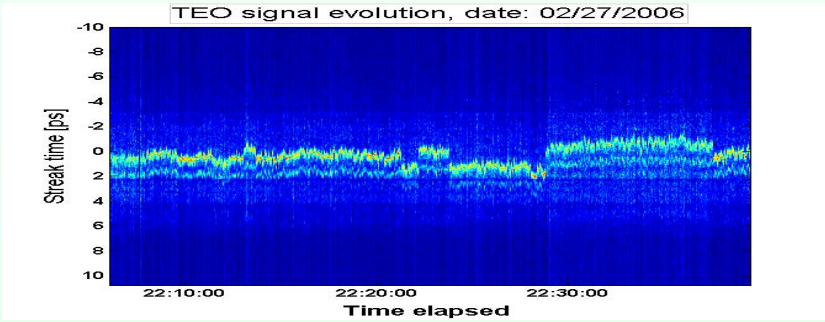


TEO signal detection

FLASH



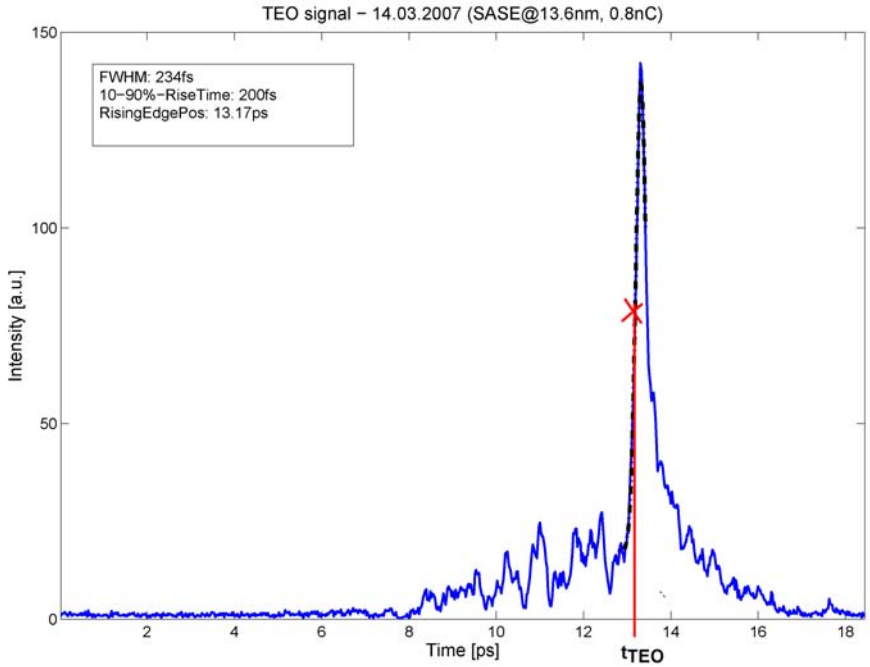
- **Arrival time and duration of bunch is encoded on profile of laser**

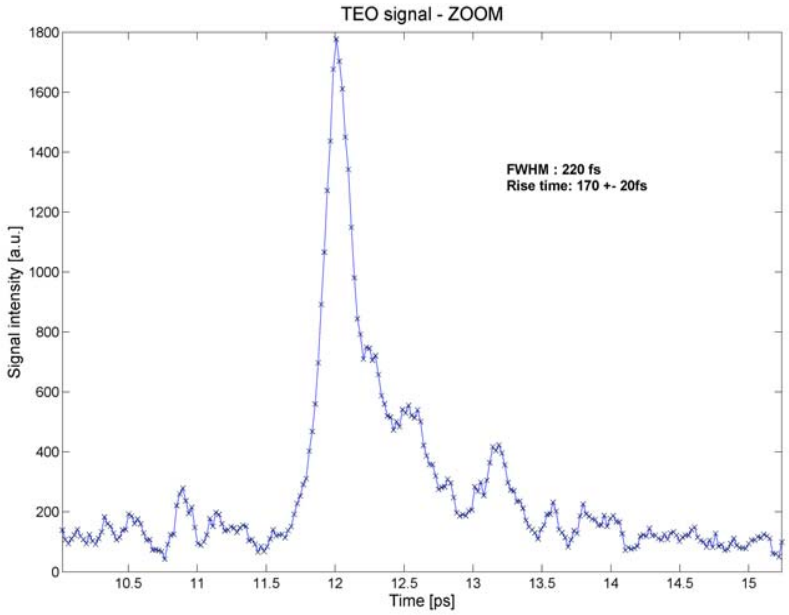


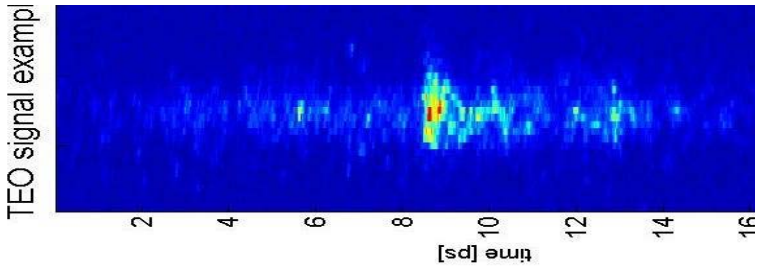
Temporal resolution of Pump-Probe exp. is given by the precision of the jitter measurement, actually 90 fs RMS.

TEO signal examples

FLASH





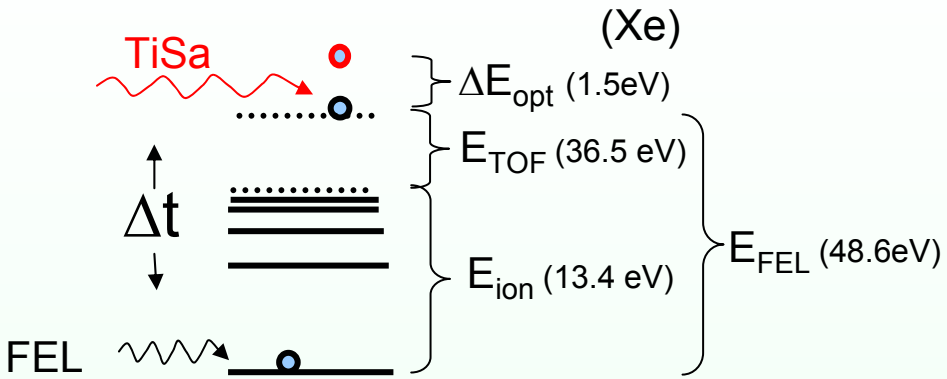


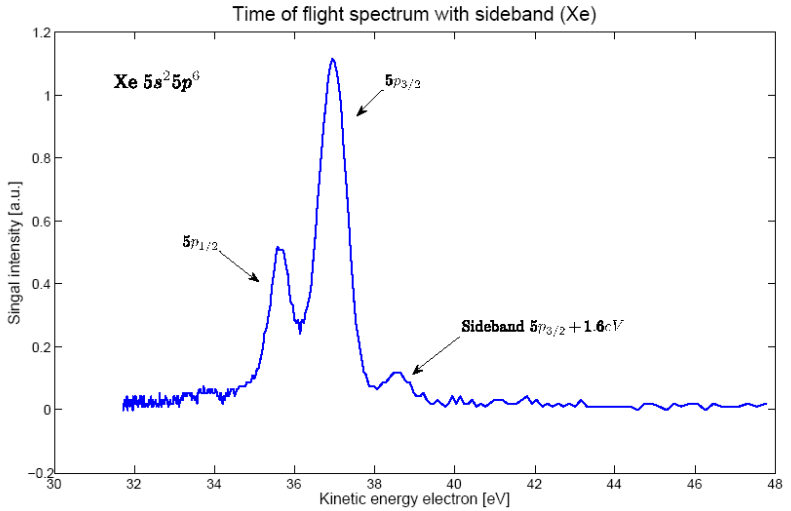
minimal width measured:
220fs FWHM **(95 fs RMS)**
⇔
temporal resolution of TEO

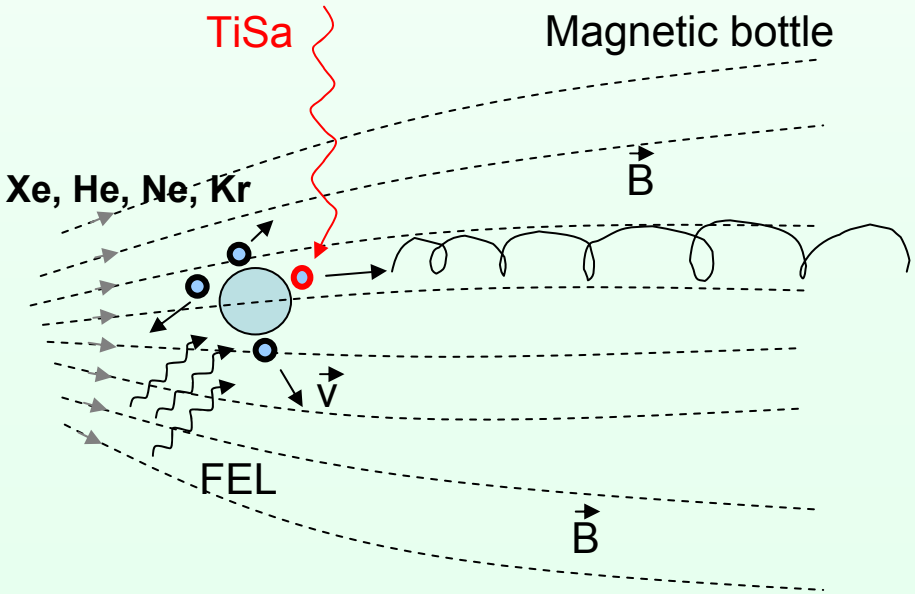
Having a peak of 220fs FWHM and 170fs rise time one expects to determine the temporal location of the peak approximately with at least 50fs FWHM (≈20fs RMS) precision.

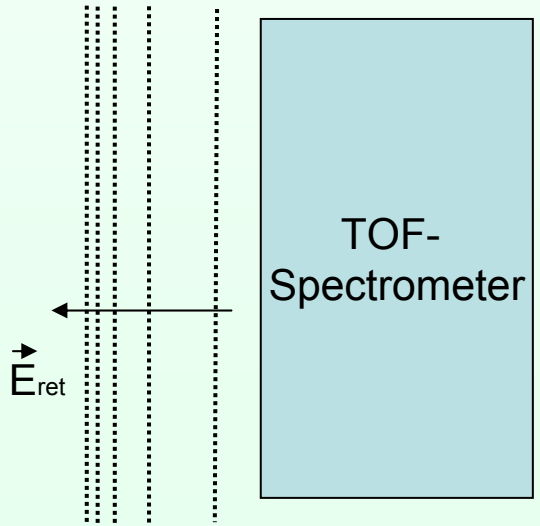
Pump-Probe experiment in gaseous phase

FLASH



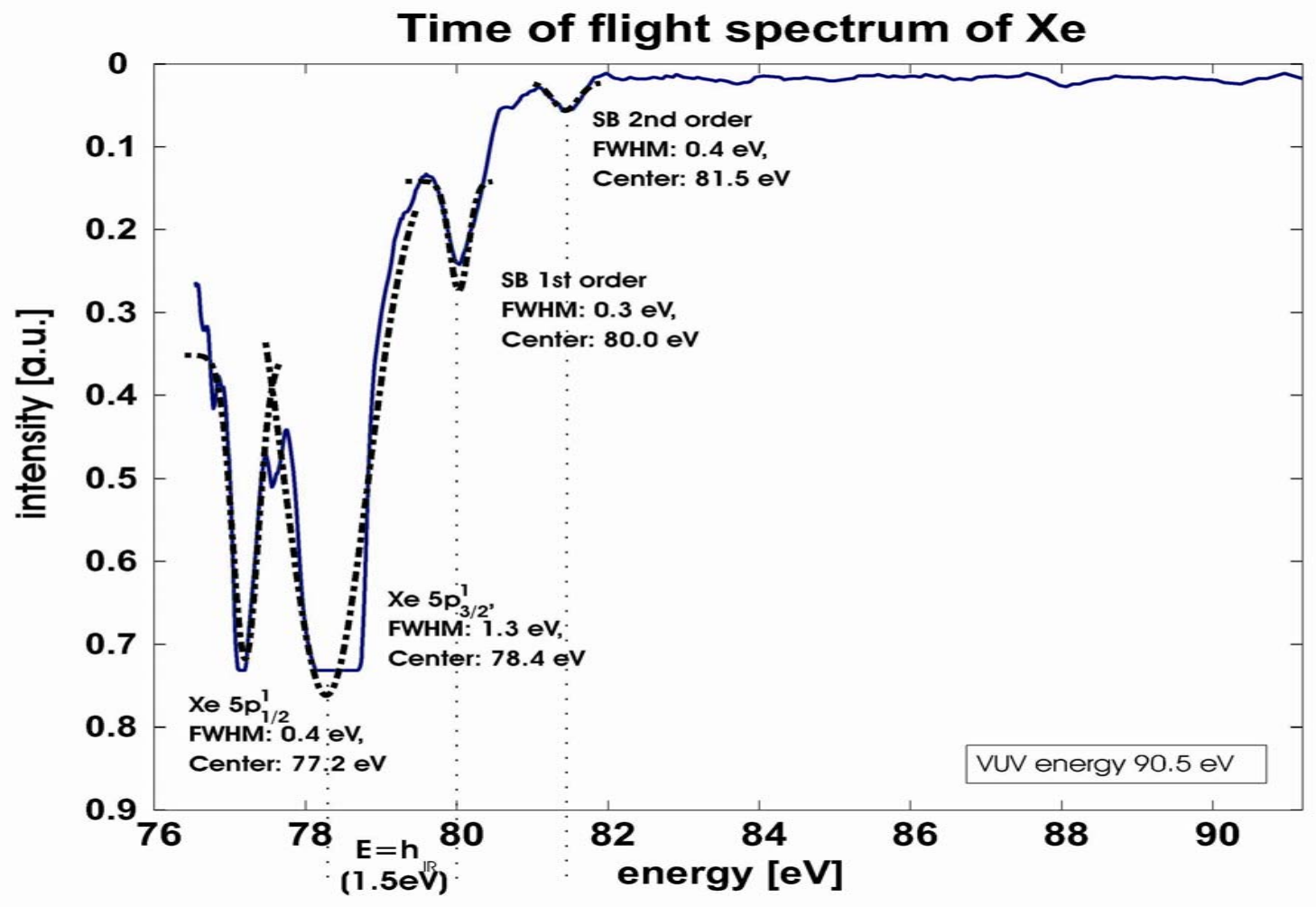






Time of flight spectrum at temporal pulse overlap

FLASH



Time of flight spectrum of one pump-probe event in Xenon at FLASH

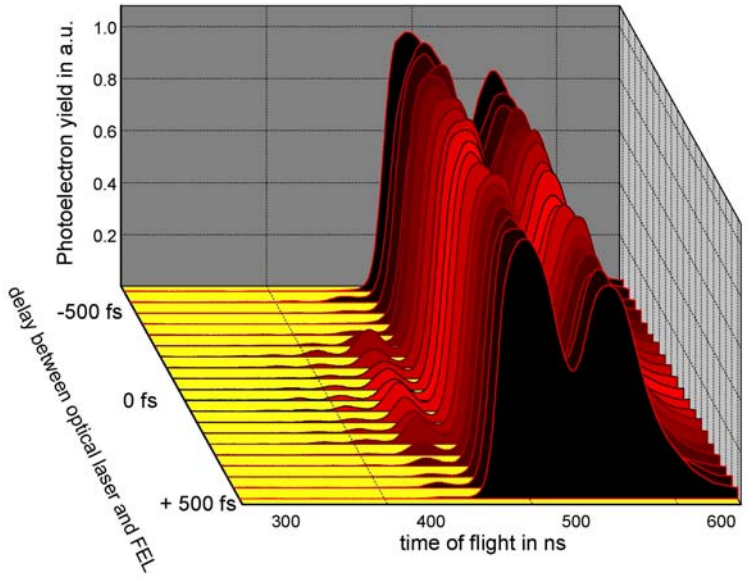
Pump-probe delay scan measurement

FLASH

Femtosecond two-color ATI – delay scan

Temporal overlap for 400 fs - Laser + FEL correlation width ~130 fs

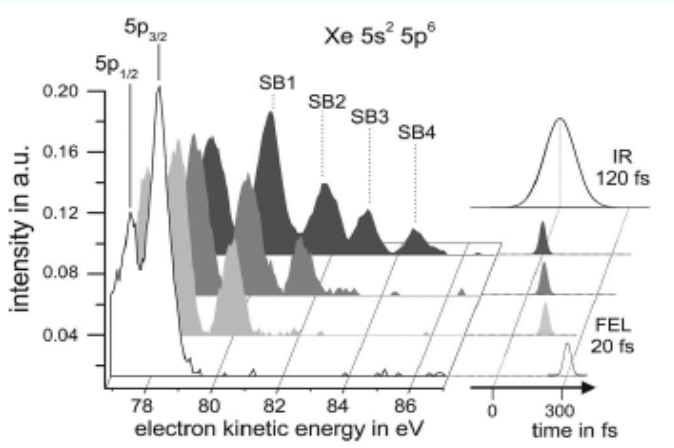
→ **jitter + drift = ~380 fs** (FWHM) - duration of measurement **~ 30 min**!



Each spectrum shows an average over 200 time-of-flight spectra per delay stage position.

Delay scan measurement of a Two-Colour Pump-Probe experiment in gaseous phase to generate sidebands of the main photo-emission lines of the spin-orbit split states $5p_{1/2}$ and $5p_{3/2}$ of Xenon.

The sideband amplitude is proportional to the degree of pulse overlap.

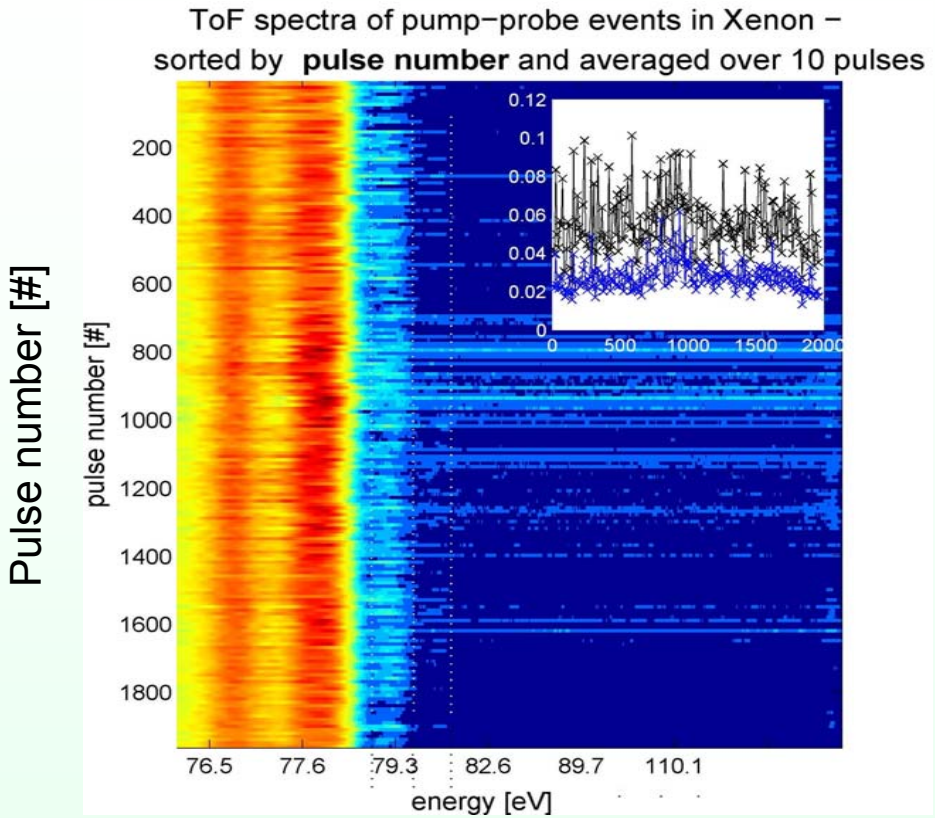


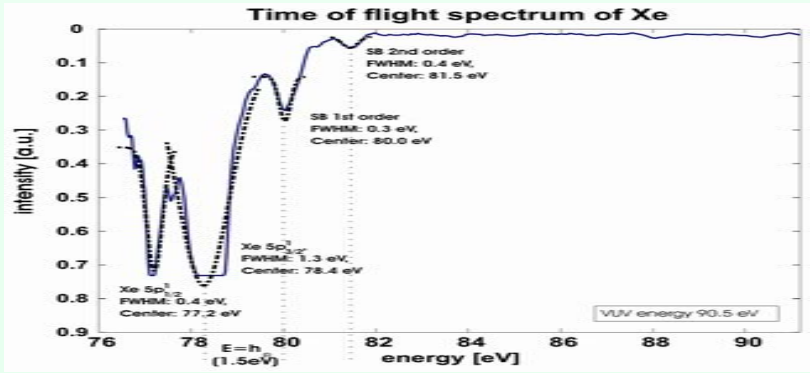
published in
P. Radcliffe, S. Düsterer, M. Meyer,
Applied Physics Letters 90, (2007)

courtesy: S.Duesterer

Pump-probe experiment with fixed delay stage

FLASH





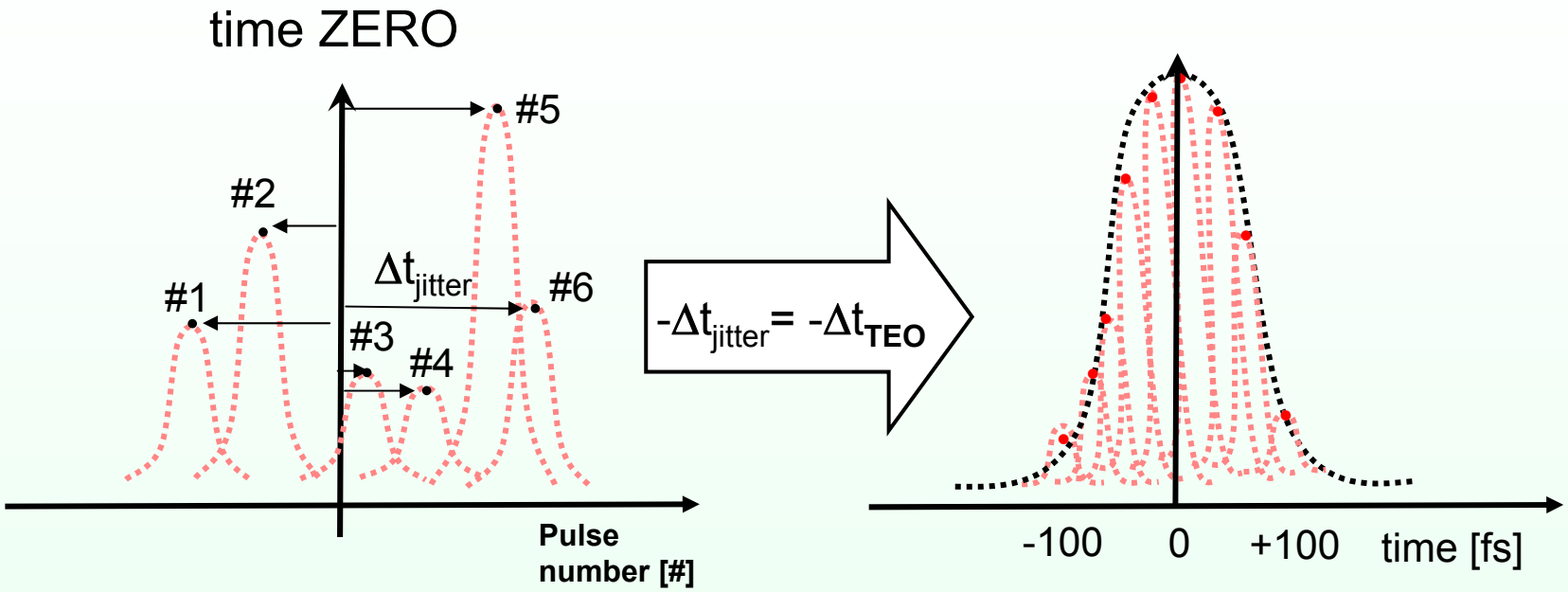
Single shot measurement of the previous pump-probe system, now with a fixed delay stage.

The ToF spectra are plotted in rows, while the spectral amplitude is colour-encoded

In this case the temporal “scan” is performed by the temporal jitter itself !!

Sideband amplitude at fixed delay time -TEO sorting

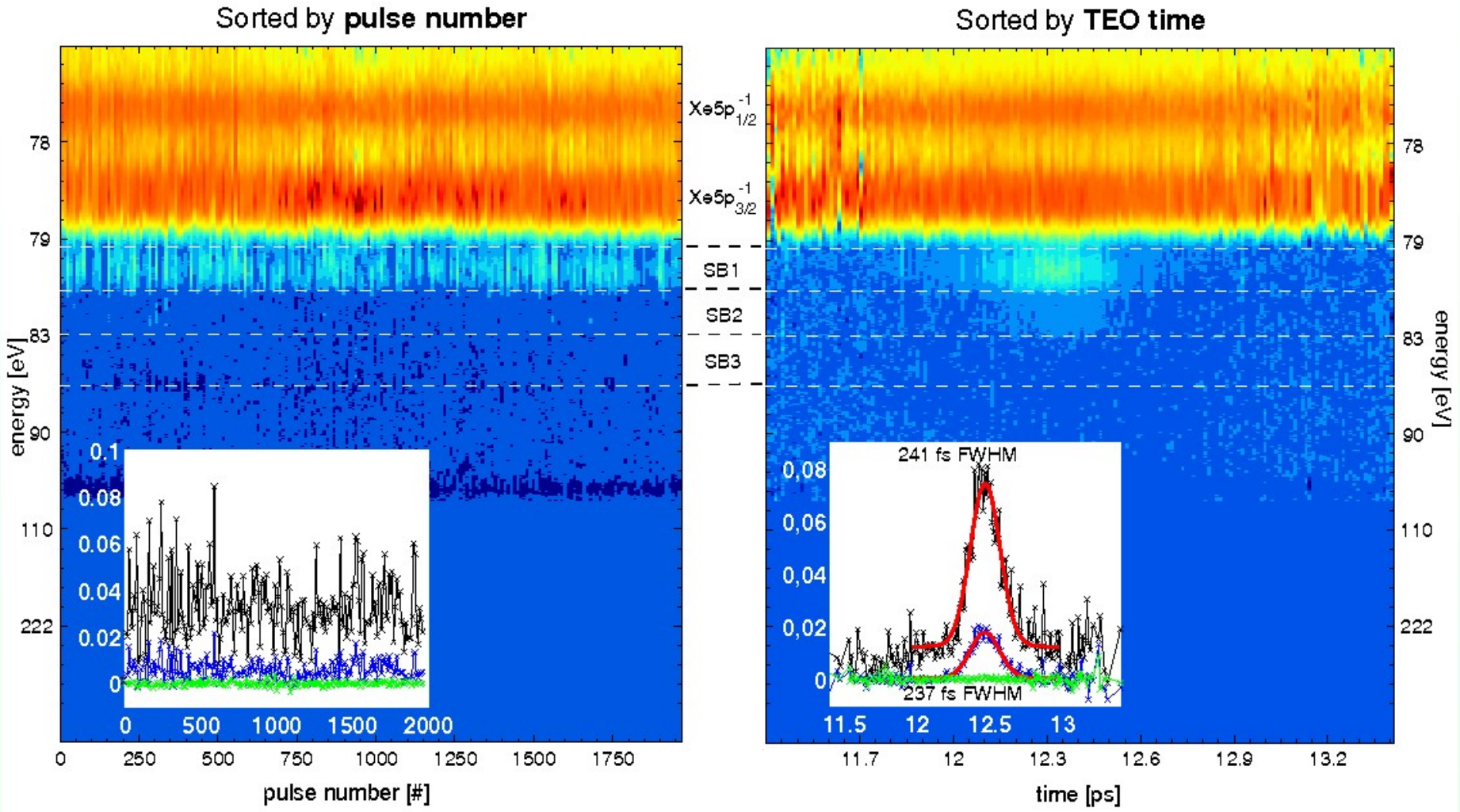
FLASH



Temporal jitter determines degree of temporal overlap and sideband amplitude.

With the information of the temporal jitter measured by TEO the temporal pump-probe signal trace can be reconstructed.

Temporal resolution is only limited by the detection error of TEO.

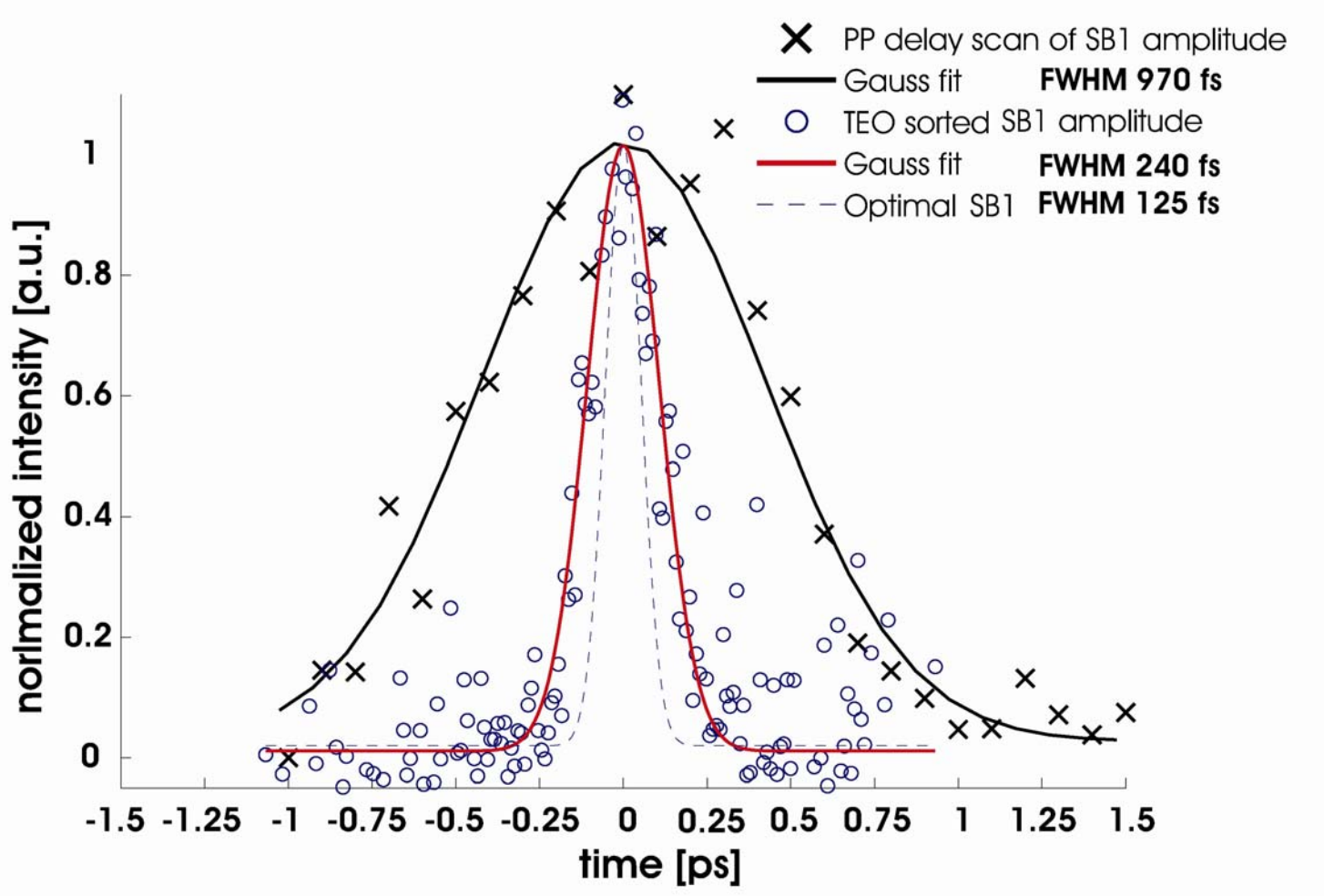


ToF data sorted by pulse number

ToF data sorted by TEO time

TEO benchmark

FLASH

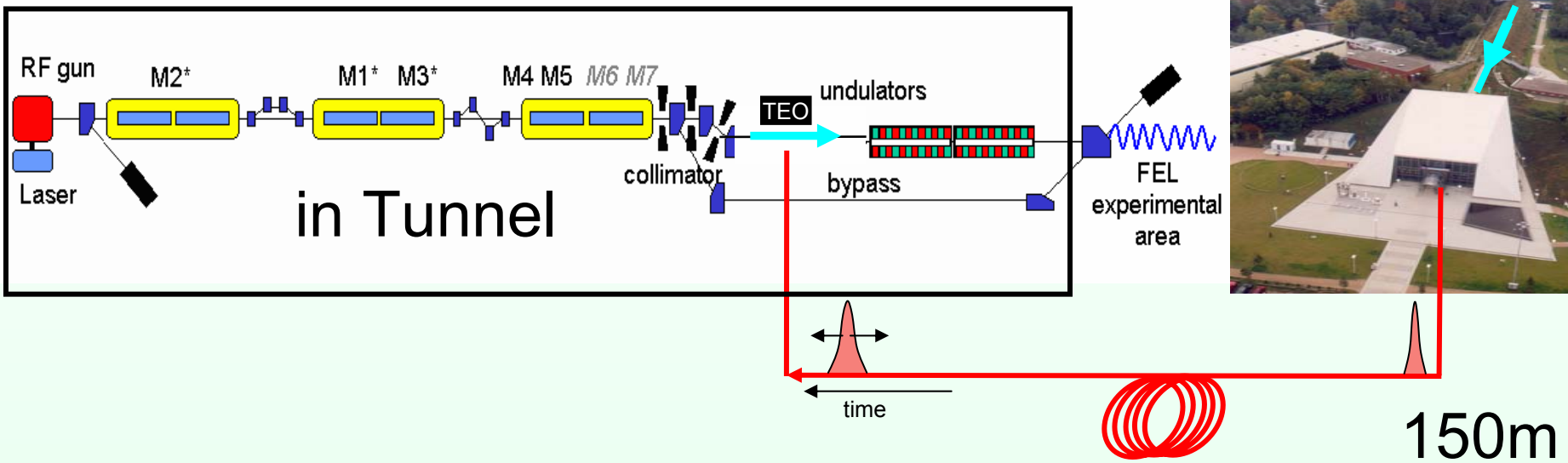


$$\Delta t_{TEO} = \sqrt{(\Delta t_{sorted})^2 - (\Delta t_{optimal})^2} = 204 \text{ fs FWHM (87 fs RMS)}$$

Dispersion during pulse transport

FLASH

- Transport of laser pulse

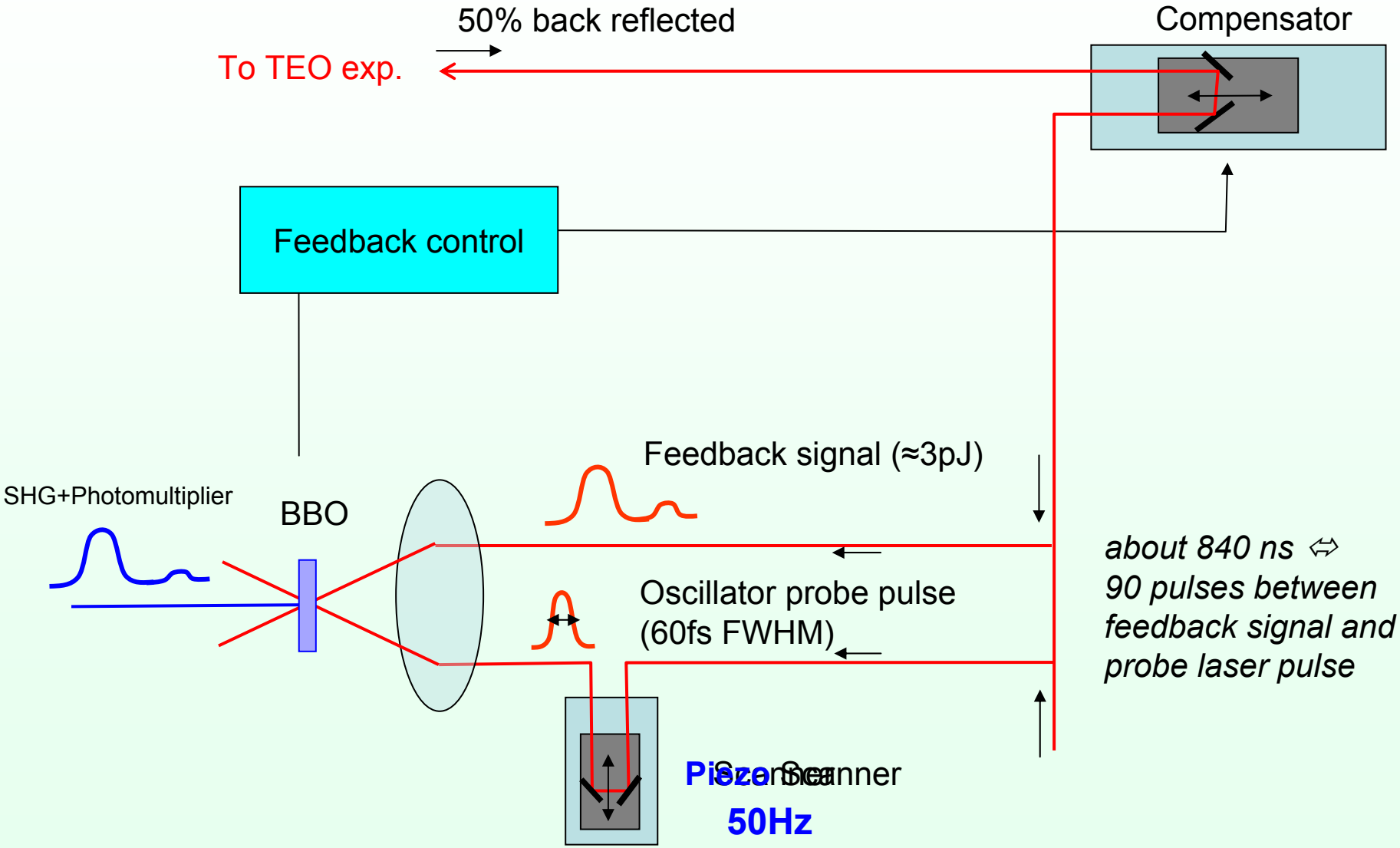


- Temperature change and micro-phonics in fiber changes the optical path length through the fiber and delays/accelerates the pulse for each event.

  This path length change is an error source for the arrival time measurement of TEO and must be compensated.

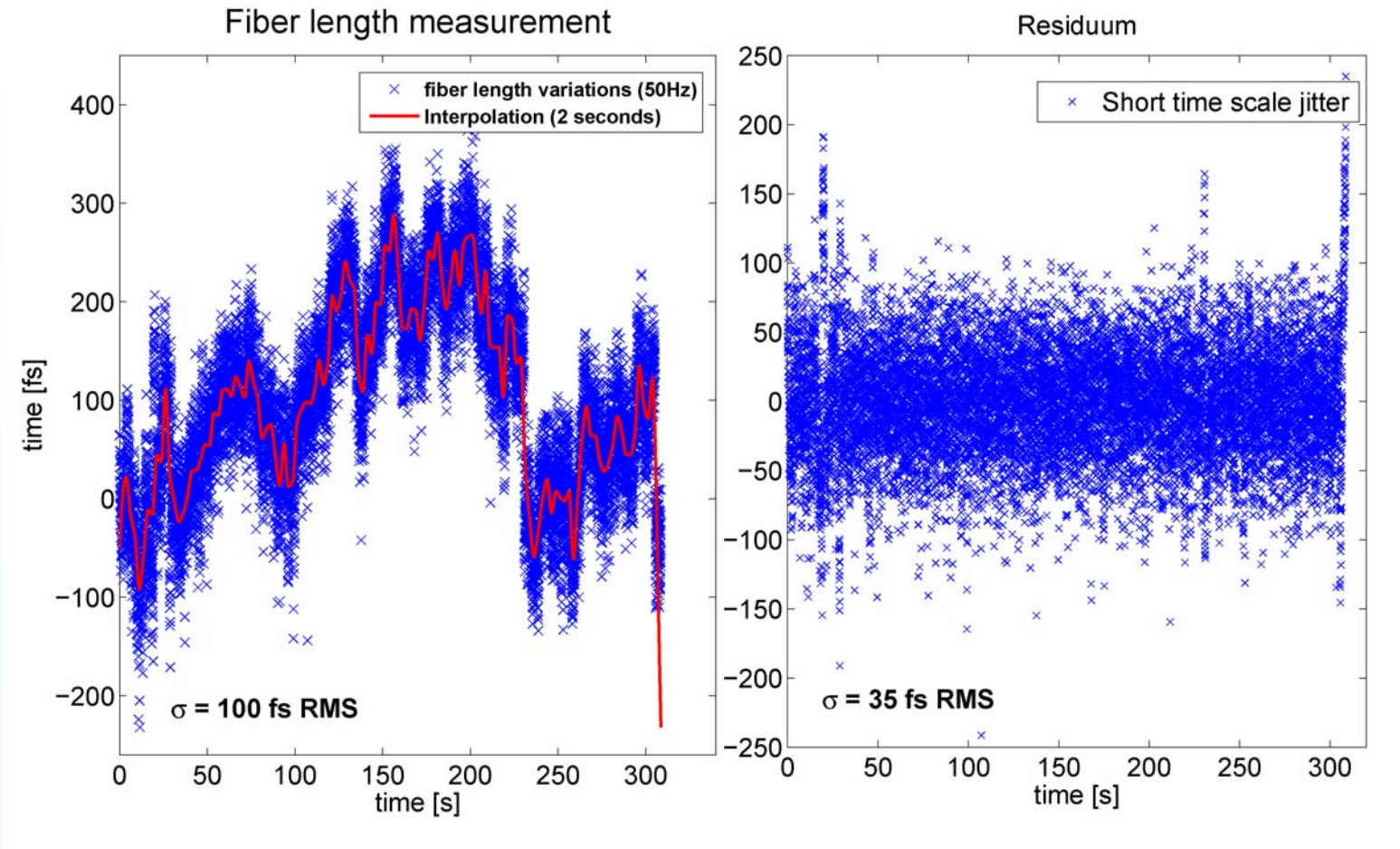
Feedback signal measurement

FLASH



Possible reason of TEO uncertainty

FLASH



Conclusion

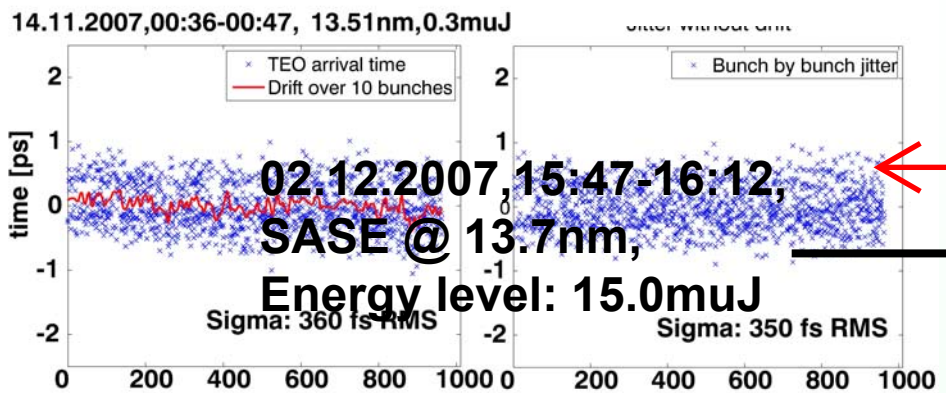
1. TEO is able to measure (indirectly) the relative arrival time between the NIR laser pulse used in a Pump-Probe experiment with the XUV pulse of FLASH. Presently the detection error for the XUV pulse arrival time is approx. **90 fs RMS**, which has been demonstrated in a pump-probe experiment.

2. ➔ From this one can conclude, that TEO is also able to detect the electron bunch arrival of FLASH with a precision of at least **90 fs RMS**.

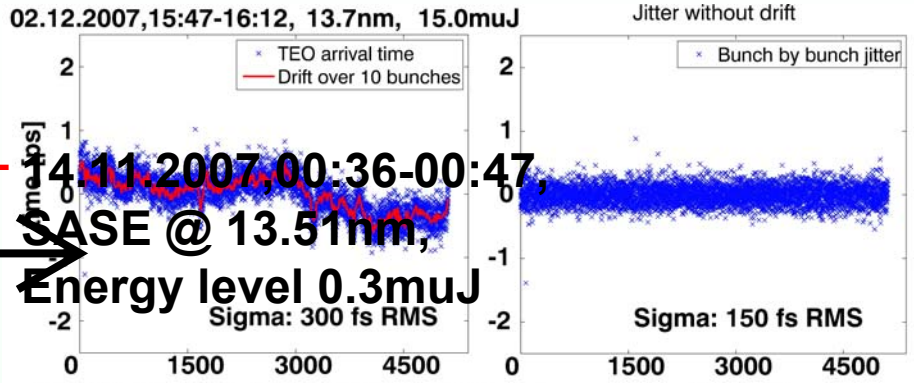
3. A possible error source, which limits the timing detection of TEO has been identified. The fibre length varies statistically with 10Hz – 100Hz by about 50-100 fs RMS.

Temporal jitter studies of FLASH during the first beam period after shutdown (Nov.,Dez. 2007)

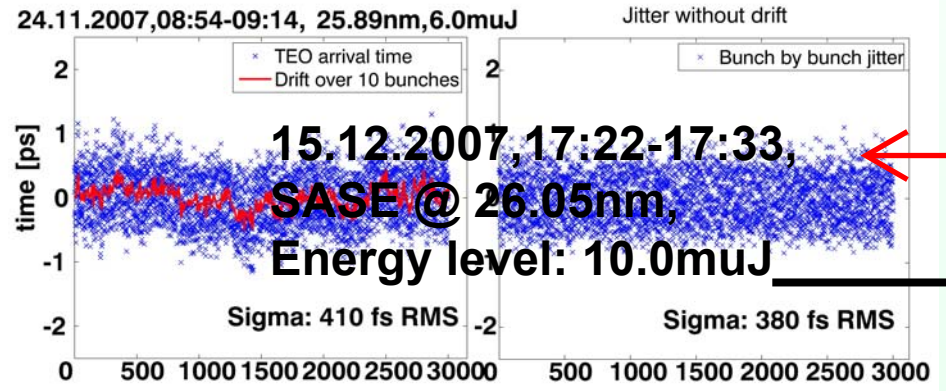
FLASH



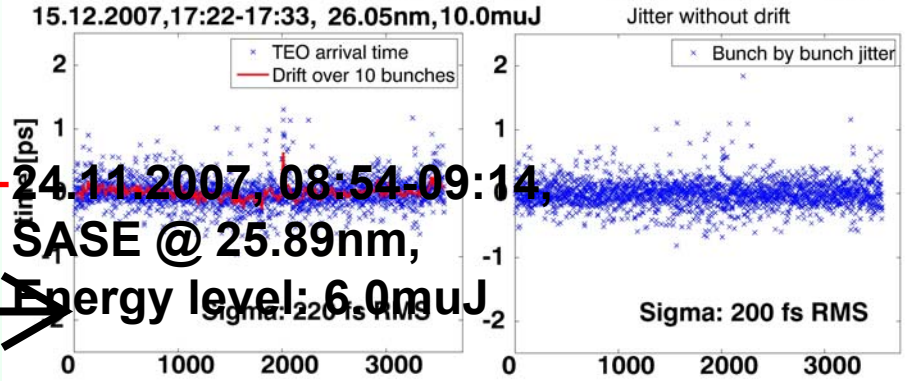
02.12.2007,15:47-16:12,
SASE @ 13.7nm,
Energy level: 15.0muJ



14.11.2007,00:36-00:47,
SASE @ 13.51nm,
Energy level 0.3muJ



15.12.2007,17:22-17:33,
SASE @ 26.05nm,
Energy level: 10.0muJ

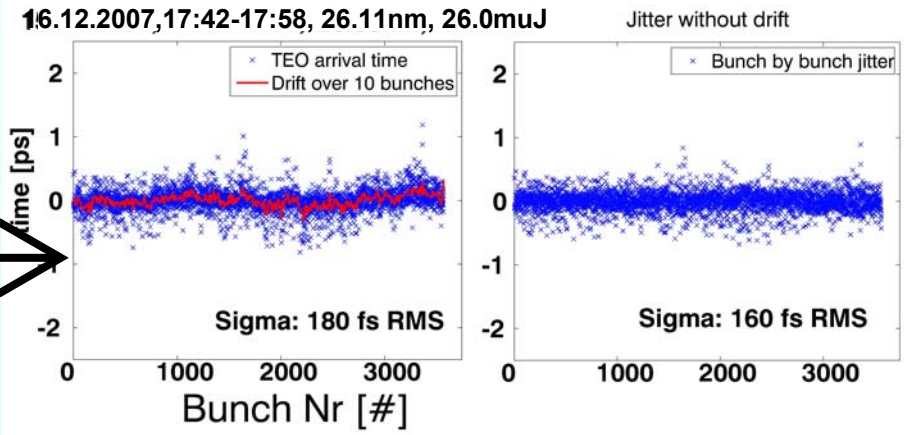


24.11.2007, 08:54-09:14,
SASE @ 25.89nm,
Energy level: 6.0muJ

During time period from 24.11. to 02.12. the machine jitter stabilized independently from the set wavelength.

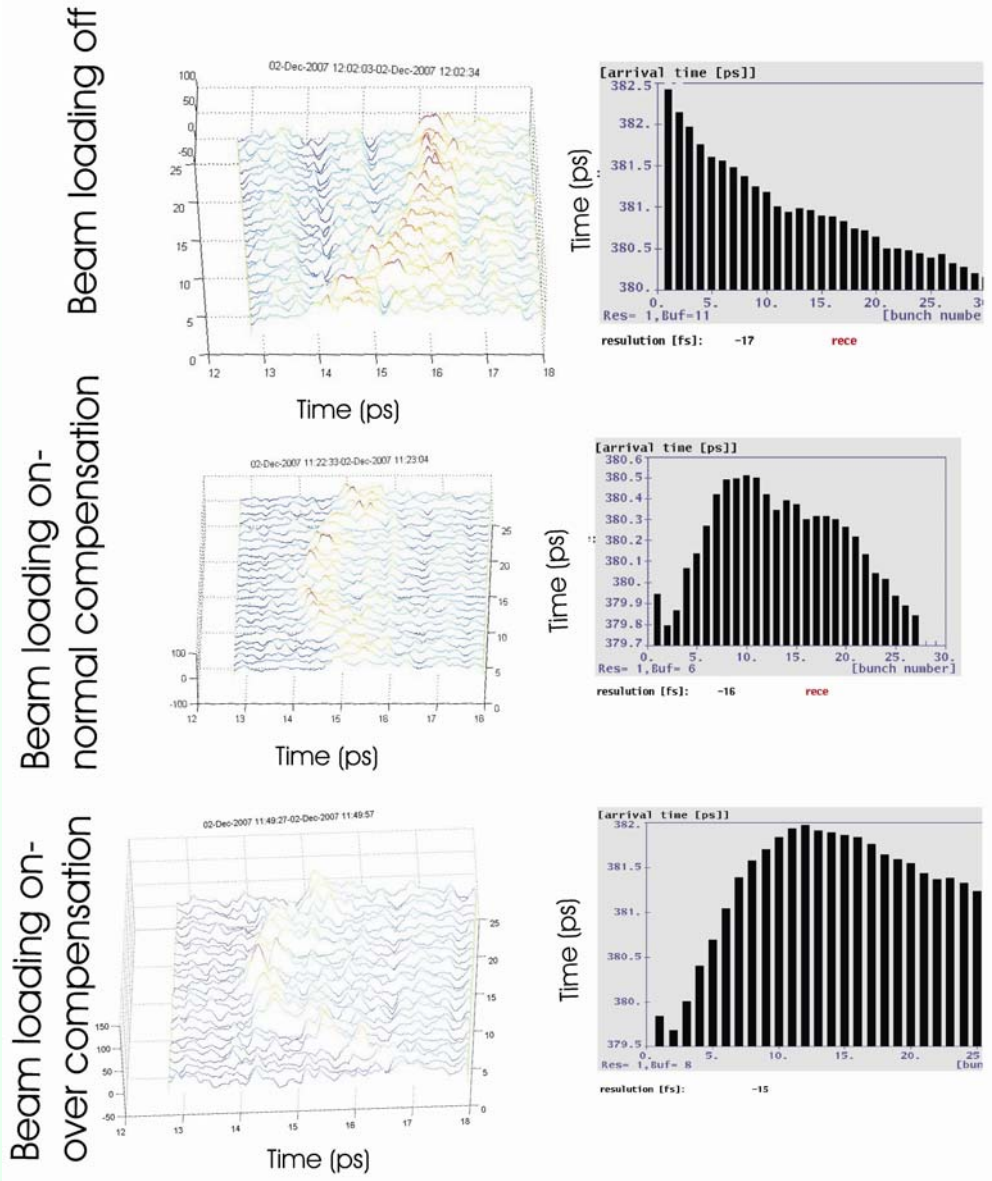
16.12.2007,17:42-17:58,
SASE @ 26.11nm,
Energy level: 26.0muJ

Reason unknown.



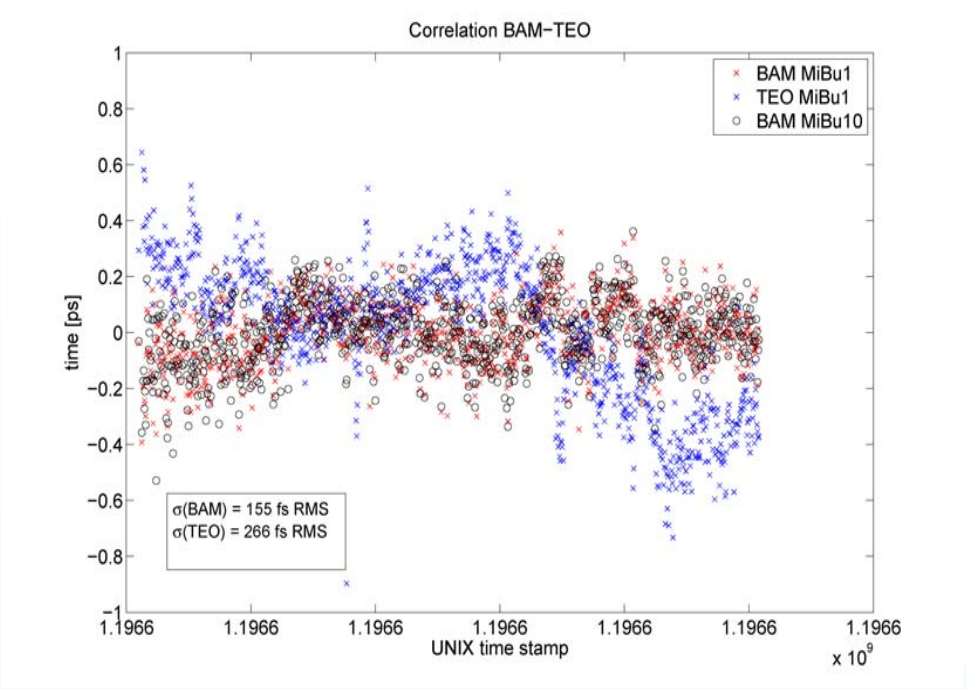
Micro Bunch correlations TEO-BAM

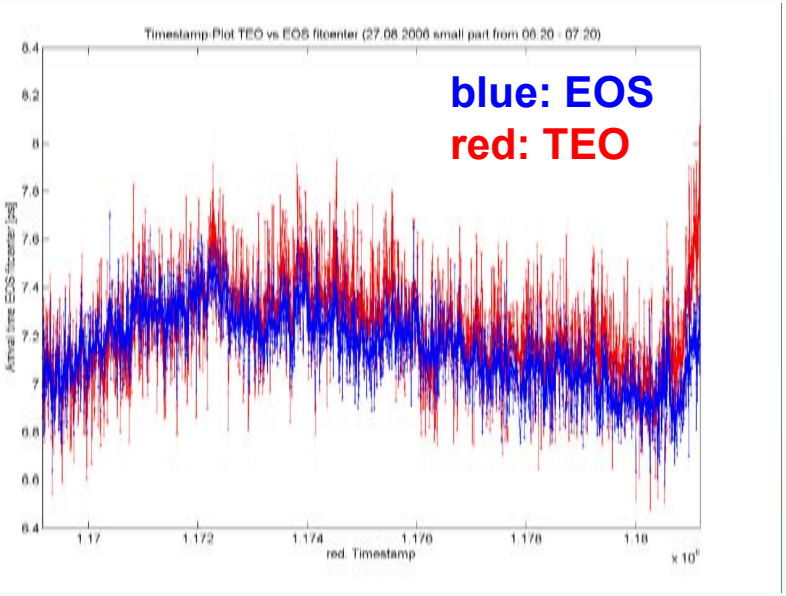
FLASH



Correlation BAM-TEO, EOS-TEO

FLASH





Nov. 2007
TEO fibre stabilization off

Okt. 2006
TEO fibre stabilization on
(every 30sec)

Outlook

FLASH

Still to do:

- Fast fiber stabilization system will be installed.
- TEO times shall be easier to achieve and online available.

New responsible scientist for TEO

Nikola Stojanovic, 4504

Acknowledgements:

Photon diagnostic:

Stefan Duesterer, Harald Redlin, Paul Radcliffe, Josef Feldhaus

Accelerator group:

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MSC4: ***Vladimir Rybnikov, Boris Fominykh, Vitali Kocharyan, Olaf Hensler, Gerhard Grygiel***

END