Electro-optic Longitudinal Profile Diagnostics for EST-B wakefield experiments

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EO for SLAC experiments

Our motivation:

- Demonstration of electro-optic techniques being developed for CLIC… (targeting 20fs resolution)
- Demonstration of "proven" techniques with EST-B beam parameters (particularly high energy, high charge density)

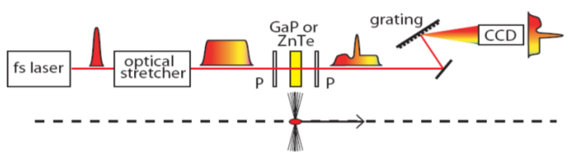
But clearly SLAC experiments must have trust in EO capability:

- propose options from range of EO techniques with some level of proven capability
- this is possible only if extreme time resolution not required
- time resolution main criteria for technique, with implications on complexity & cost

Electro-Optic Techniques…

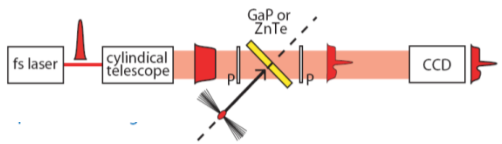
Variations in read-out of optical temporal signal

Spectral Decoding



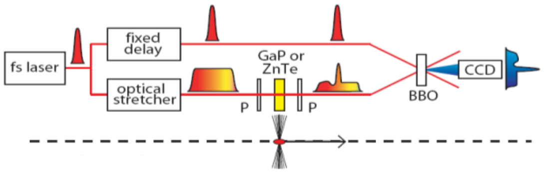
- Chirped optical input
- Spectral readout
- Use time-wavelength relationship

Spatial Encoding



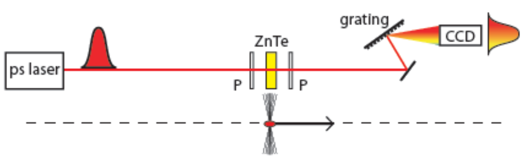
- Ultrashort optical input
- Spatial readout (EO crystal)
- Use time-space relationship

Temporal Decoding



- Long pulse + ultrashort pulse gate
- Spatial readout (cross-correlator crystal)
- Use time-space relationship

Spectral upconversion**

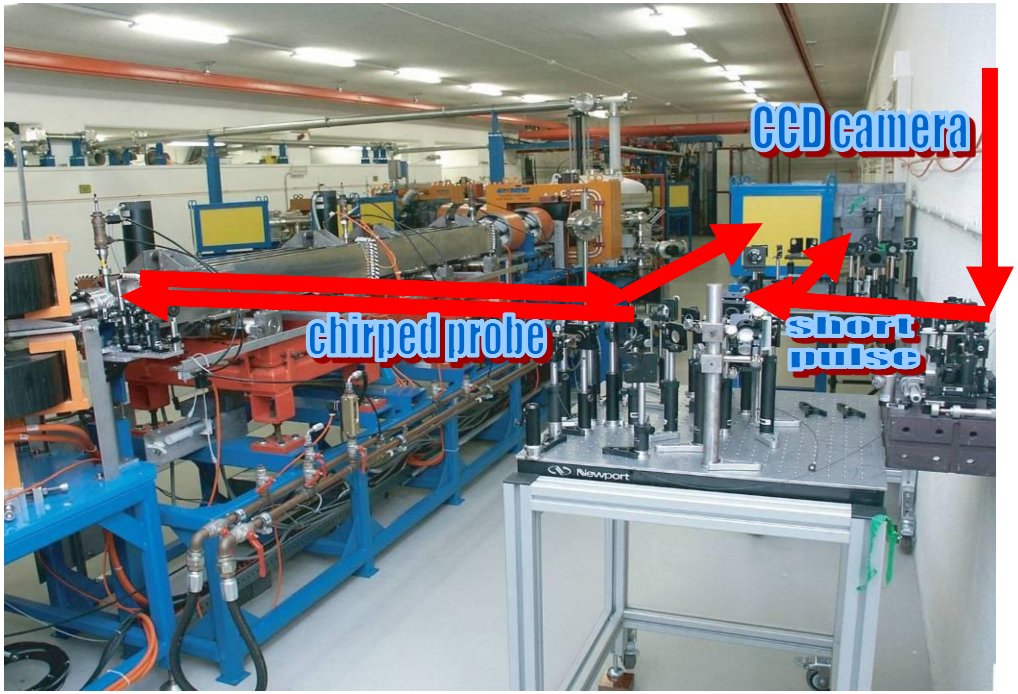


- monochomatic optical input (long pulse)
- Spectral readout
- ***Implicit time domain information only*

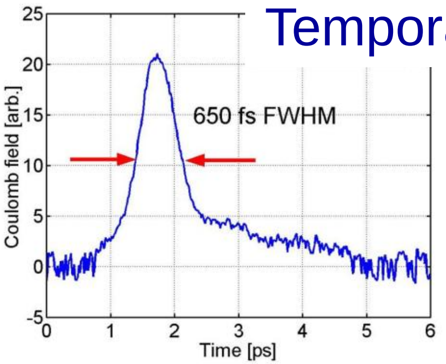
Temporal decoding: bare essentials implementation

FELIX FEL facility, Rijnhuizen, Netherlands

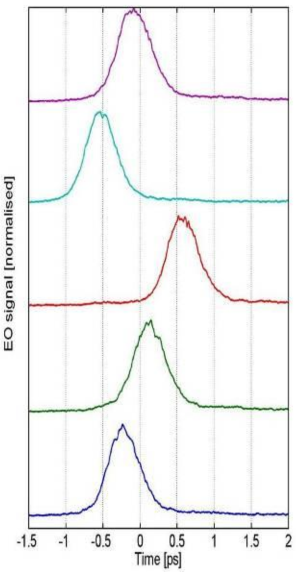
- Required easy access to accelerator area to make optical adjustments
- Able to be commissioned in ~1 week (with some infrastructure pre-installed)



bunch profile from Temporal Decoding



Electron-laser synchronisation jitter



PLUS: amplified TiS laser in remote (~30m) laser room

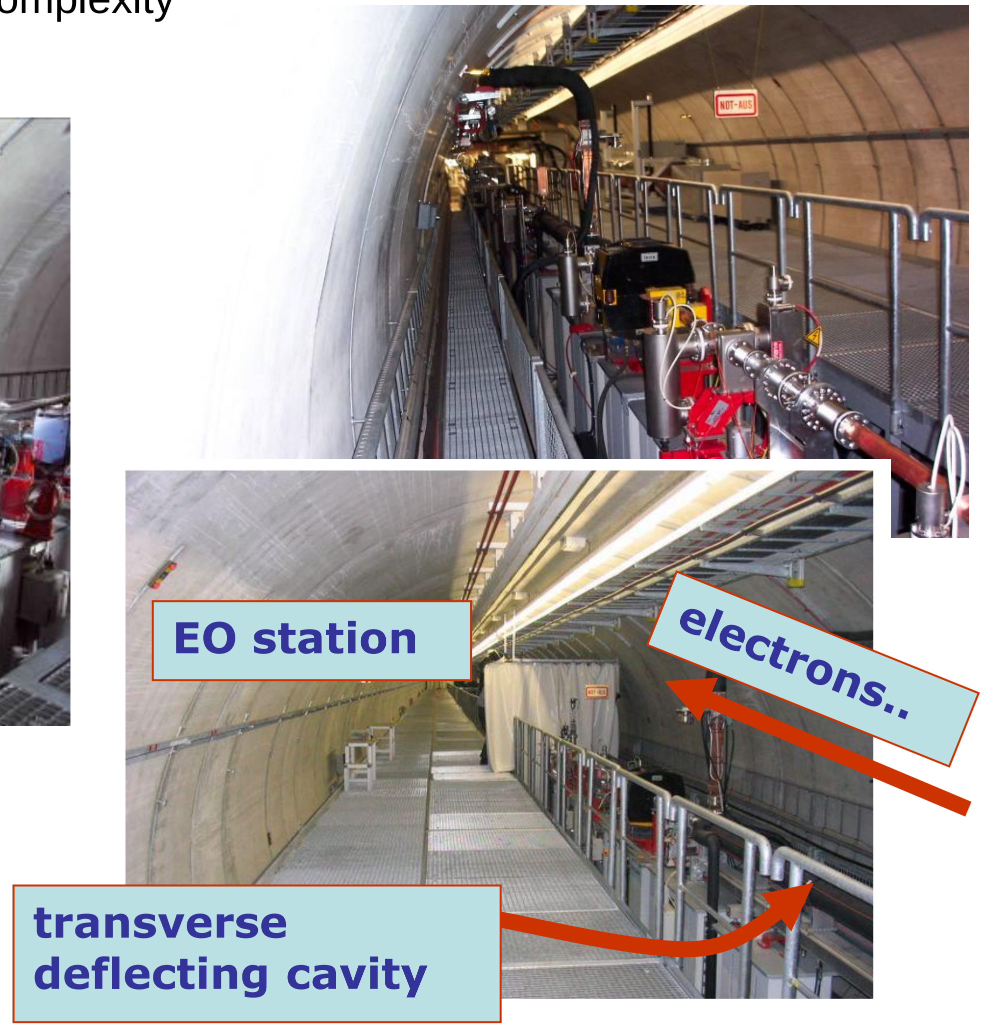
Berden et al Phys Rev Lett **93** (2004)

Temporal decoding: improved reliability implementation

FLASH – short bunch tests & benchmarking

- Significant extra complexity, cost from remote operation, and adjustment needs
- Longer commissioning time because of complexity

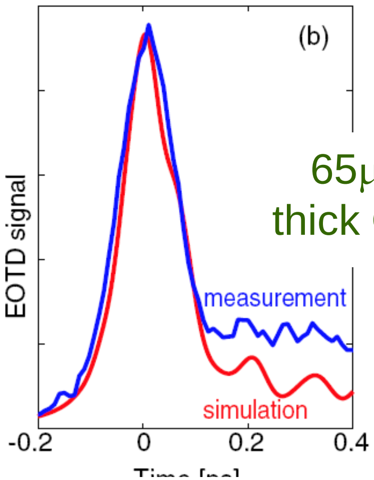
Temporal Decoding Diagnostic



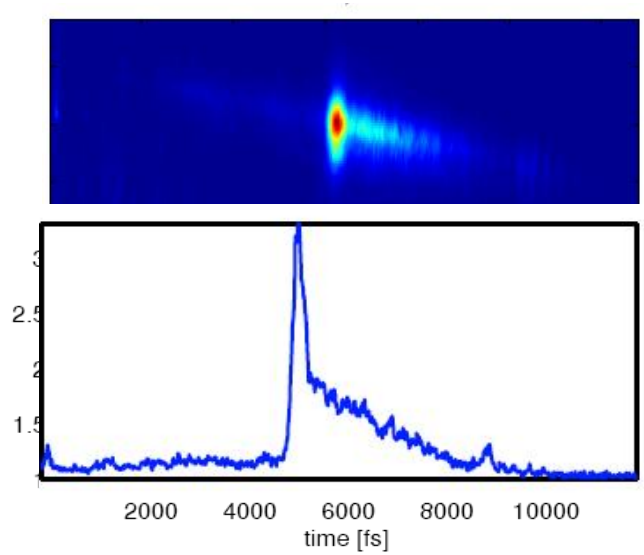
PLUS: amplified TiS laser in remote (~15m) laser room

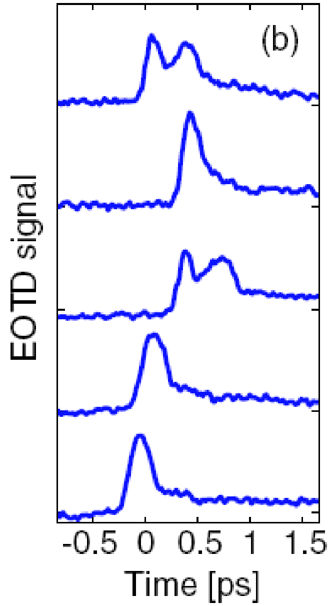
High Time resolution...

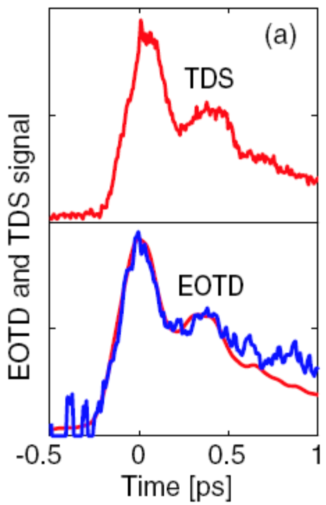
currently the highest time-resolution non-destructive diagnostic demonstrated



65μm thick GaP







Benchmarked against a destructive RF diagnostic technique

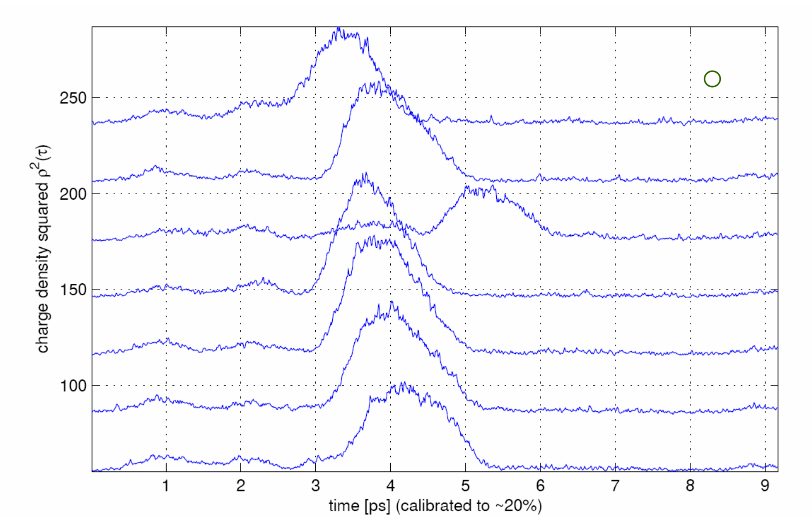
- provides a *unique* “calibrated” THz source...
- agreement confirms understanding of material properties

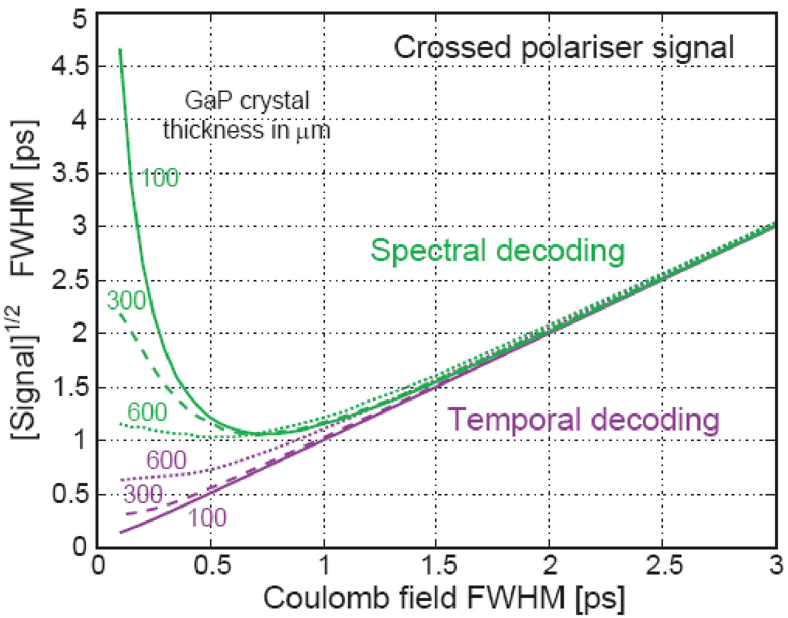
Berden et al. Phys Rev Lett. **99** (2007)

Spectral decoding

•Much simpler implementation
• less complex, cheaper, laser options
(fibre lasers, CTF3 system under development)
•LIMITED TIME RESOLUATION
• demonstrated at many accelerator labs [~10 (?)]

Spectral decoding results for 40pC bunch,
(ALICE ERL test accelerator at Daresbury)

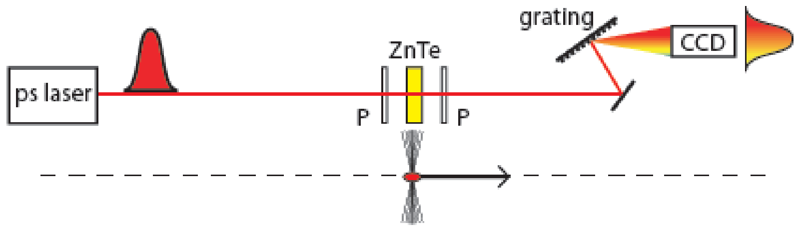




Could be readily commissioned with <1 week accelerator access

Spectral upconversion diagnostic

measure the bunch Fourier spectrum...



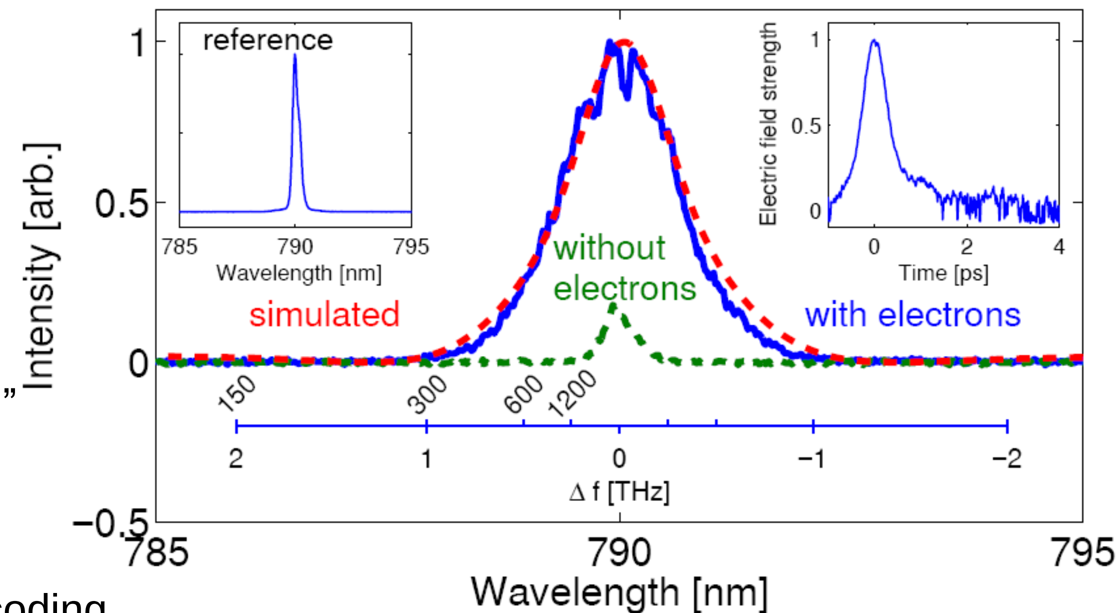
... accepting loss of phase information & explicit temporal information

... gaining potential for determining information on even shorter structure

... gaining measurement simplicity

Measures long wavelength components

non-propagating *spectral components which are not accessible to radiative techniques (CSR/CTR/SP)*



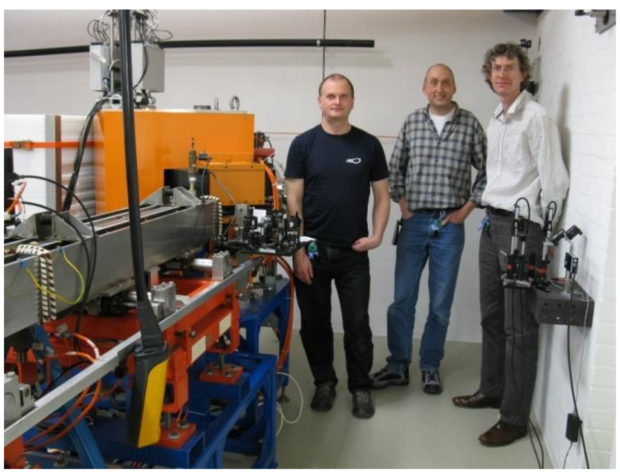
Will provide higher “time resolution” (i.e. fourier spectral components) than spectral decoding;

Will match or exceed temporal decoding

Could be readily commissioned with few days accelerator access

Spectral upconversion diagnostic

First (so far only) demonstration experiments at FELIX

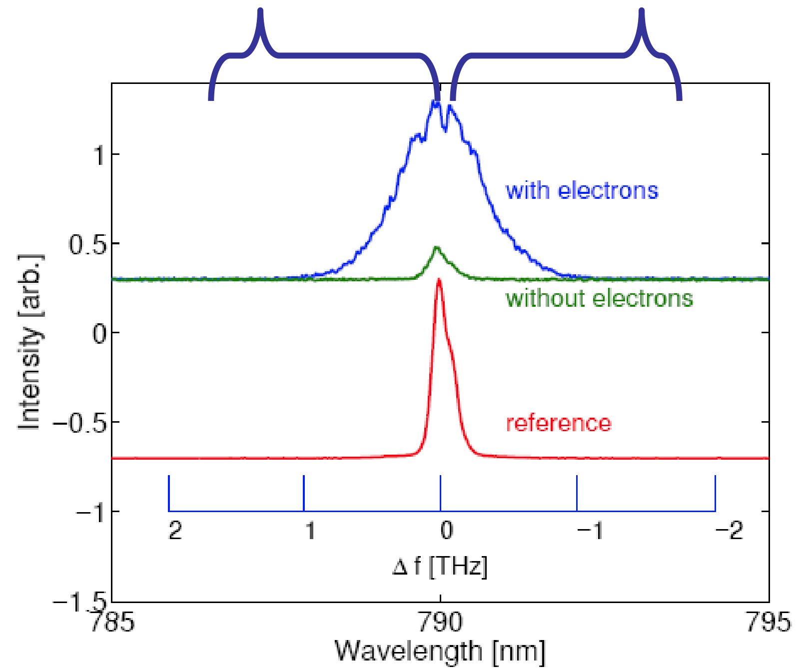


sum frequency mixing

$$\tilde{E}(\omega_0+\Omega) = i\omega a\tilde{E}(\omega_0)\,\tilde{E}^{\mathrm{Coul}}(\Omega)\tilde{R}(\Omega)$$

difference frequency mixing

$$\tilde{E}(\omega_0-\Omega) = i\omega a\tilde{E}(\omega_0)[\{\tilde{E}^{\mathrm{Coul}}(\Omega)\}^*\tilde{R}^*(\Omega)]$$



Applied Physics Letters, **96** 231114 (2010)

Summary

- Electro-optic techniques available for different parameter regimes
- Highest time resolution time-explicit techniques most complex, and probably not compatible with short run expt.
  Note: "spatial decoding" may provide solution – to be investigated
- Spectral decoding would be preference,
  limitations well known, well demonstrated,
  reasonable infrastructure requirements
  but only valid for longer bunches (~500fs rms or longer)
- Spectral-upconversion offers very simple solution but only provides bunch Fourier spectral information
- All options require a laser synchronised to EST-B at few ps level.
  What is available at SLAC? Elsewhere with compatible RF-laser phase locking?
- Resources, people…?
  Some overlap with existing PhD and post-doc positions (CLIC + ASTeC + university Dundee)
  laser is big cost….borrow compatible system, or significant extra funding