TADPOLE for longitudinal electron-bunch diagnostics based on EO upconversion.

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1st EAAC Workshop

June, 4th 2013

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Contents.

Motivation

- Knowledge and control of the longitudinal electron-beam profile
  e.g. crucial for the operation of a free-electron laser and high temporal resolution

- Desired characteristics for electron-bunch diagnostic techniques:
  - Unambiguous
  - single-shot
  - non-destructive

- Today's techniques (e.g. EO sampling, CR, TDS, …) lacking at least in one
  - Phase reconstruction via Kramers-Kronig relation

Temporal Analysis by Dispersing a Pair Of Light E-fields

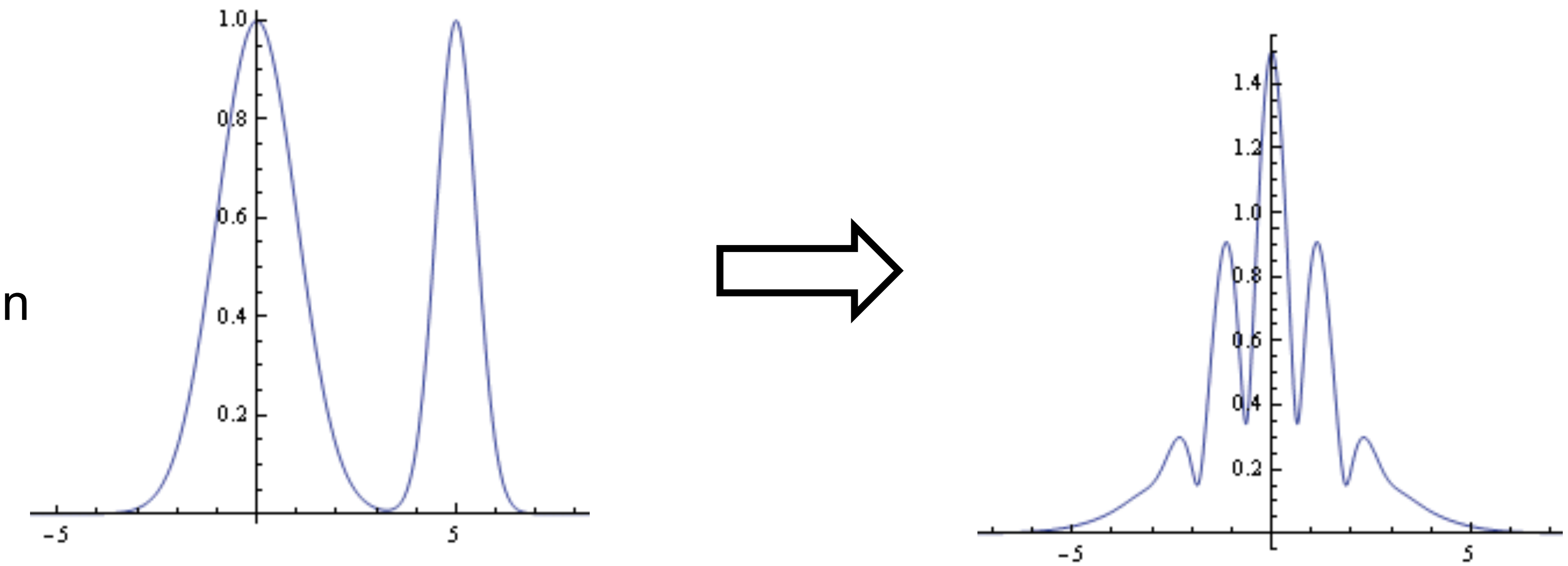
Trebino, R.: *Frequency-resolved optical gating: the measurement of ultrashort laser pulses* (2000)

- TADPOLE = Spectral Interferometry
  +
  Frequency Resolved Optical Gating (FROG)

- $S_{SI}(\omega)=S_{ref}(\omega)+S(\omega)+2\,(S_{ref}(\omega)S(\omega))^{½}\,\cos(\varphi_{ref}(\omega)-\underline{\varphi(\omega)}+\omega T\,)$

T: temporal displacement

time domain



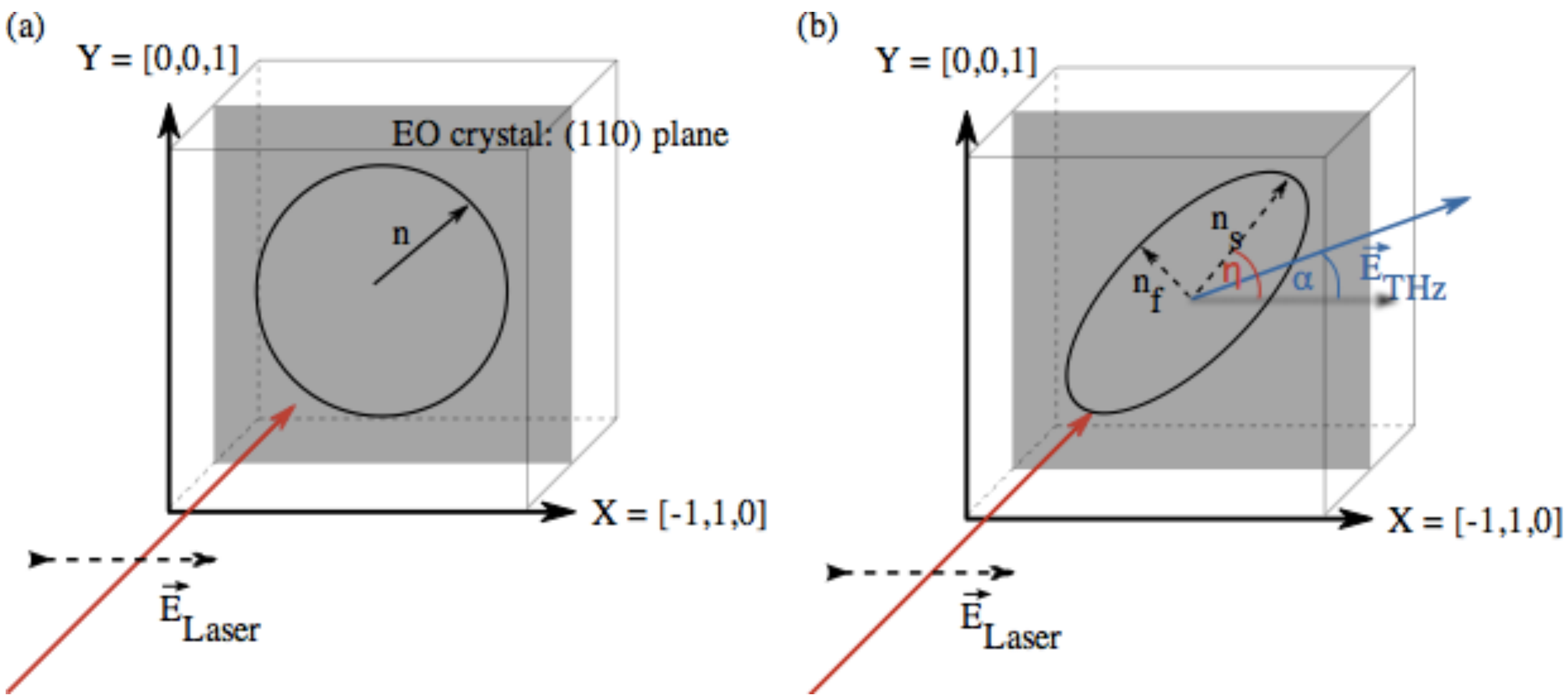
spectral domain

Electro-Optic effect (EO)

- Induced polarization in an optically active material (ZnTe, GaP, …) by an external electric field

$$\vec{P} = \epsilon_0 \chi \vec{E} = \epsilon_0 (\chi_e^{(1)} \vec{E} + \underbrace{\chi_e^{(2)} \vec{E}^2}_{\text{Pockels effect}} + \underbrace{\chi_e^{(3)} \vec{E}^3}_{\text{Kerr effect}})$$

- Change in refractive index $\Delta n \propto E$
- Change in refractive index leads to birefringence in an optically active crystal



EO upconversion

S.P.Jamison et al.: Opt.Lett. 31:1753-5 (2006)

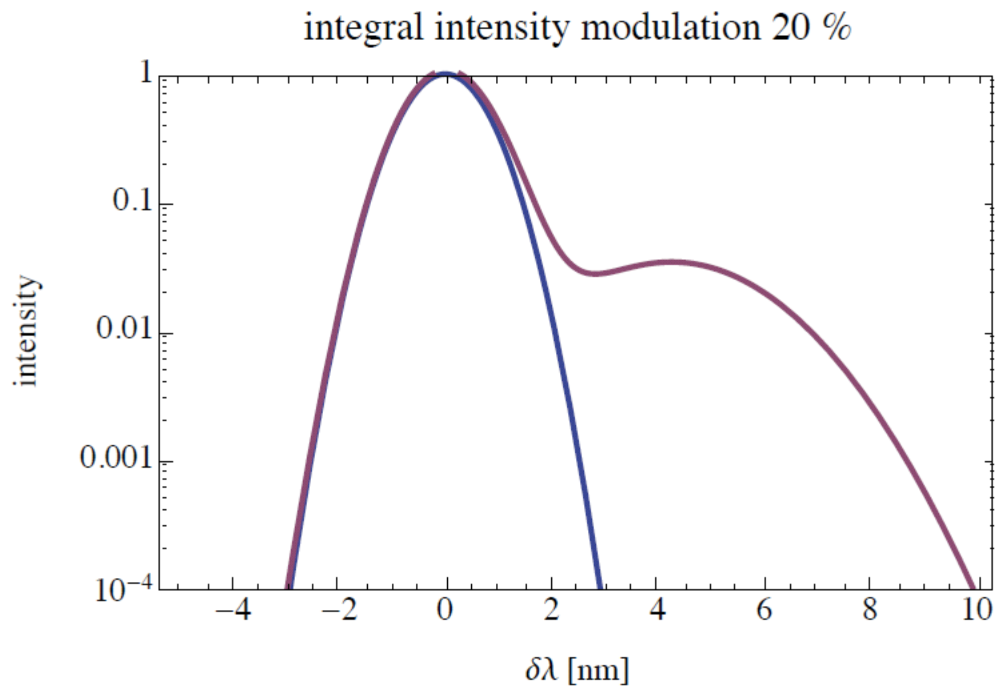
- Overlap a narrow-bandwidth laser with THz pulse
- frequency-mixing leads to the generation of new spectral components:

$$E(\omega) \propto E_{THz}(\omega) * E_{opt}(\omega)$$

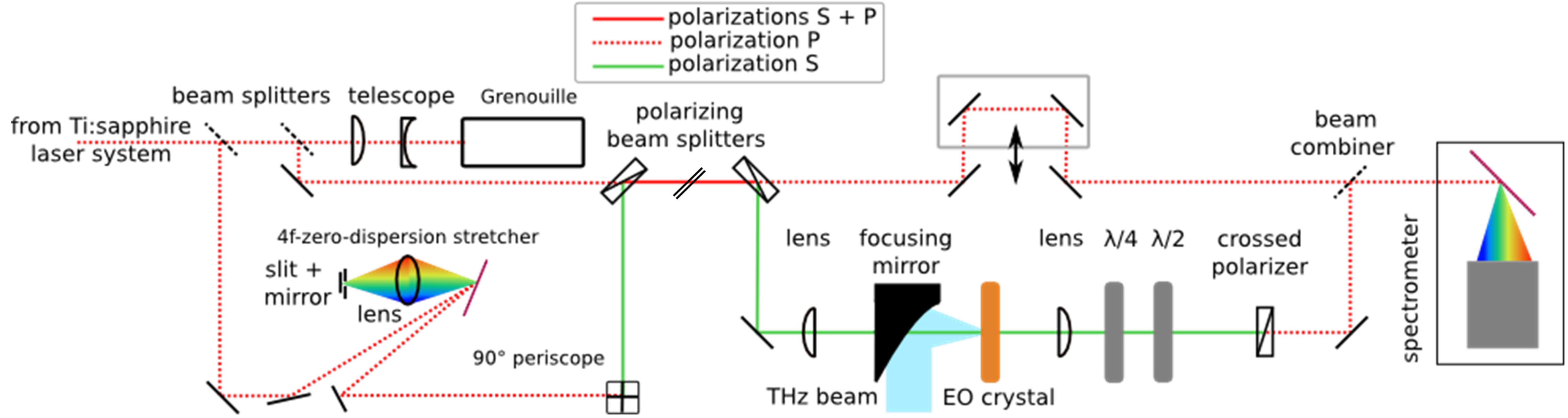
- Near crossed polarizer intensity modulation:
  $1\text{-}Cos(\Gamma+4\Theta)$

  Θ angle away from crossed polarizer,
  $\Gamma \propto |\boldsymbol{E}_{THz}|$

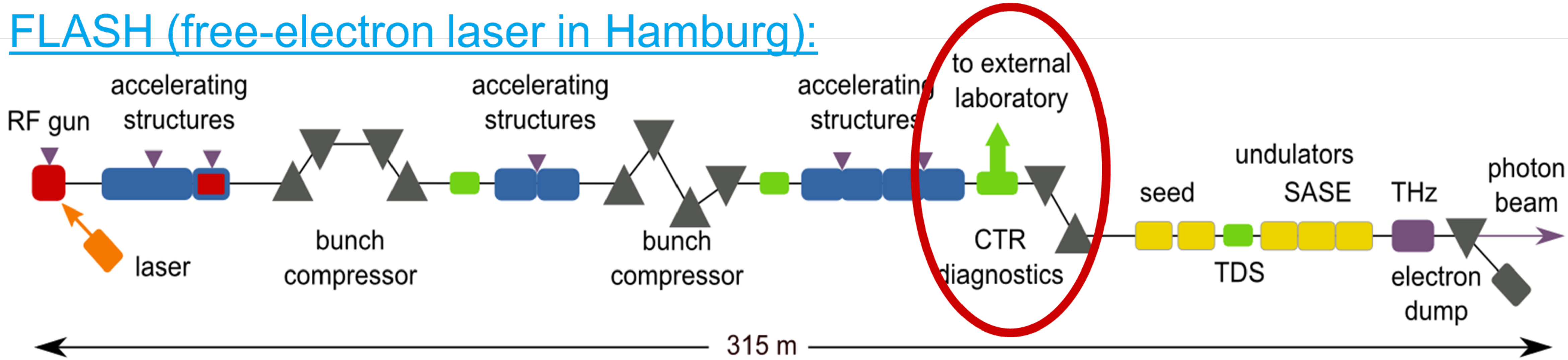
  B.Steffen et al.: Phys.Rev.STAB 12,1-16(2009)



Setup



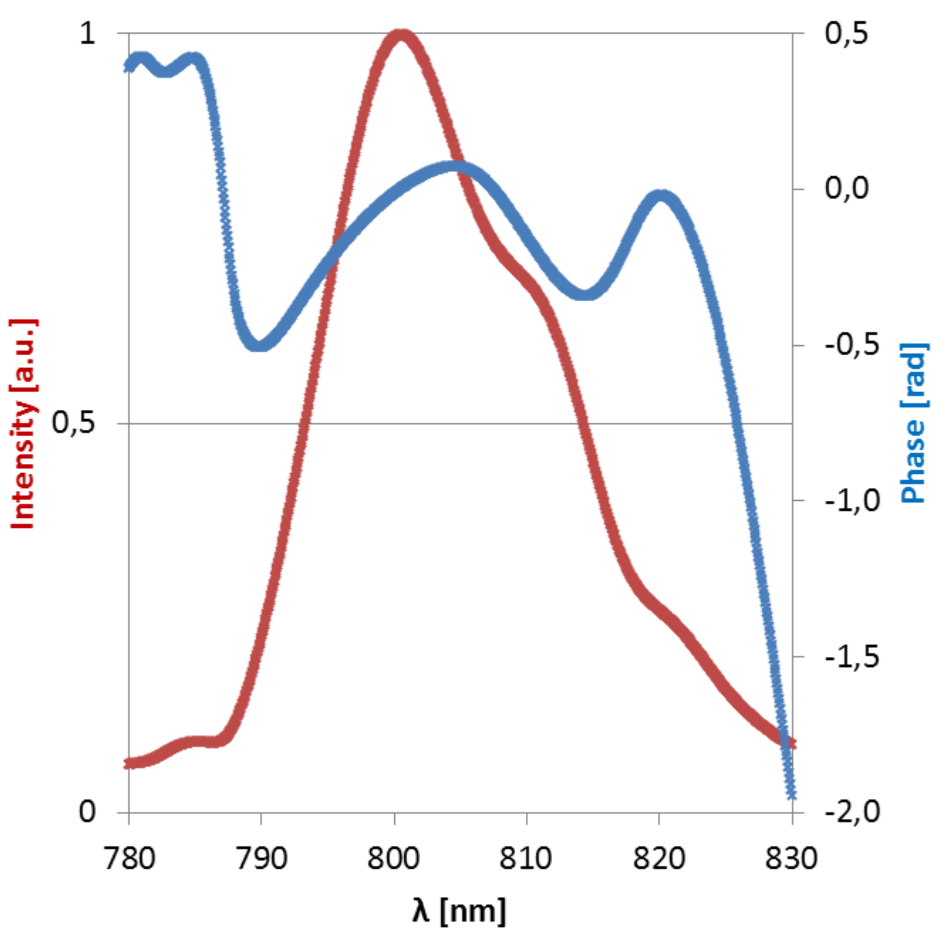
FLASH (free-electron laser in Hamburg):



Laser characterization

- commercial Ti:Sa amplifier system
- Synchronous to FLASH
- FROG-characterization by GRENOUILLE

- λ = 800 nm
- $\Delta\lambda$ ~ 21 nm
- t_{pulse}~ 65 fs
- f_{rep}=1 kHz
- P = 1.6 W



EO upconversion – Measurement (4mm ZnTe)

Spectral interferometry (4mm ZnTe)

Summery

For time-domain electron-bunch profile reconstruction

- Implemented Setup
- Measurement of spectral amplitude and phase

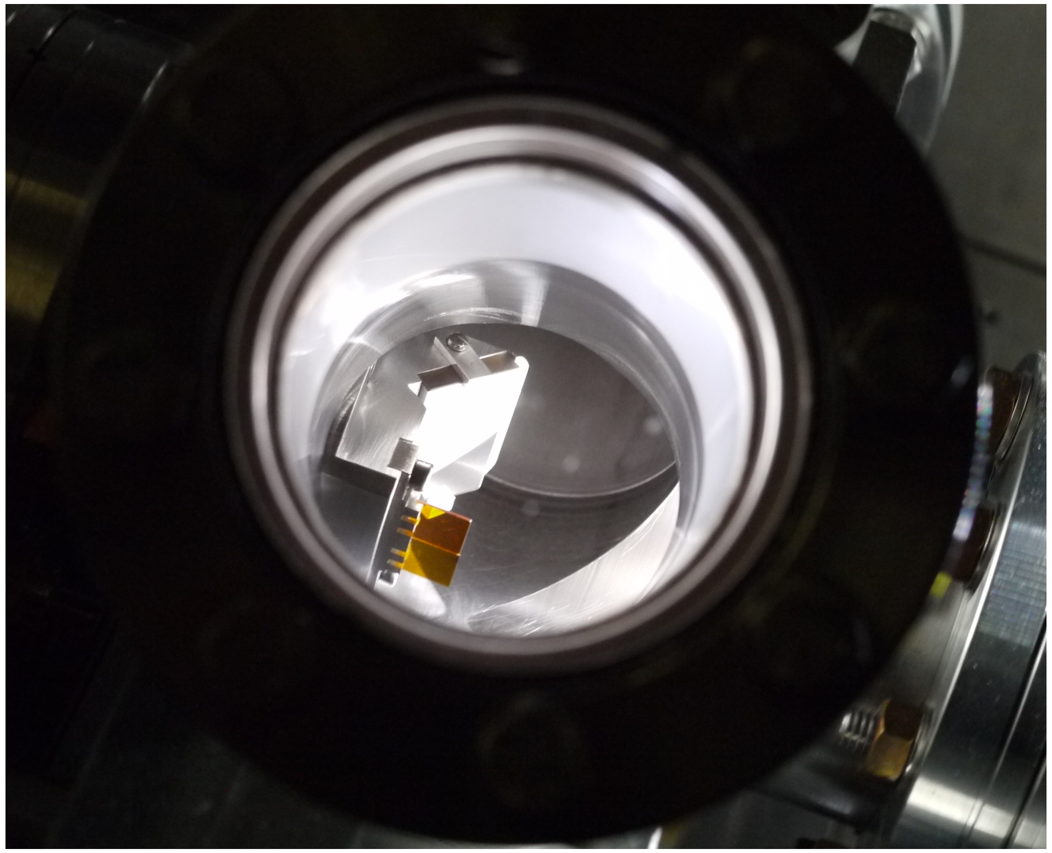
- Data analysis ongoing
  - TADPOLE → $\varphi(\omega)$
  - Measurement → $S(\omega)$

  → $E(\omega) \propto E_{THz}(\omega) * E_{opt}(\omega)$

- Deconvolution → $E_{THz}(\omega)$
- $E_{THz}(t) = FT^{-1}[E_{THz}(\omega)]$ long. CTR profile

Outlook

- Change Setup for direct interaction of electron-bunch E-field with EO-crystal to bypass THz-generation by CTR



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