Karlsruhe Institute of Technology

ANKA THZ GROUP

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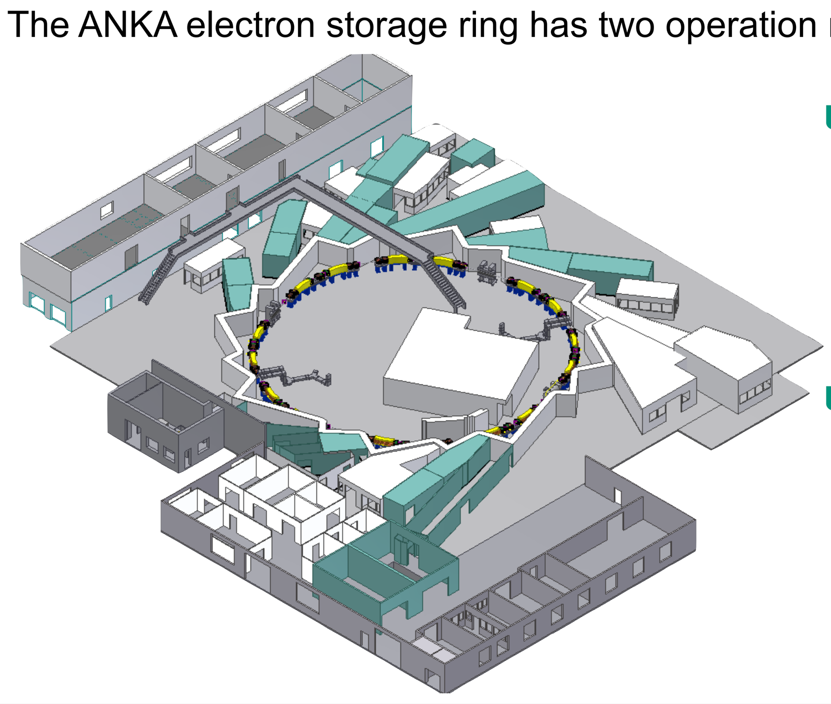
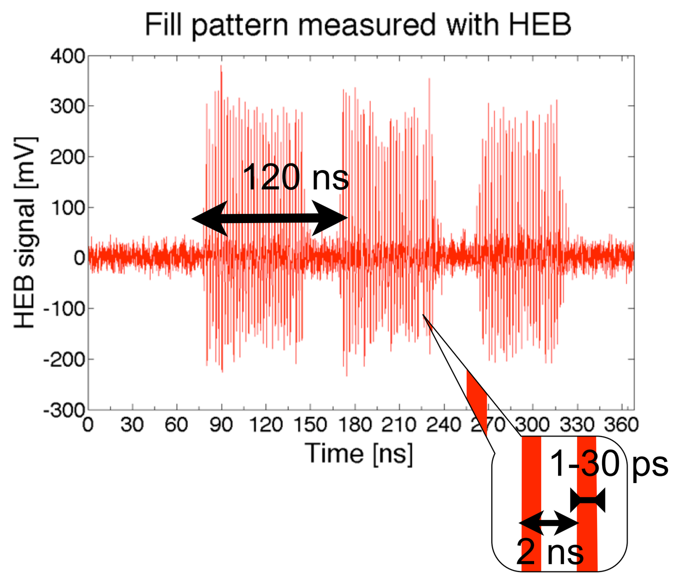
Bunch Length Measurement with an LED

ANKA Synchrotron Radiation Source at the KIT

The ANKA electron storage ring has two operation modes available for users:

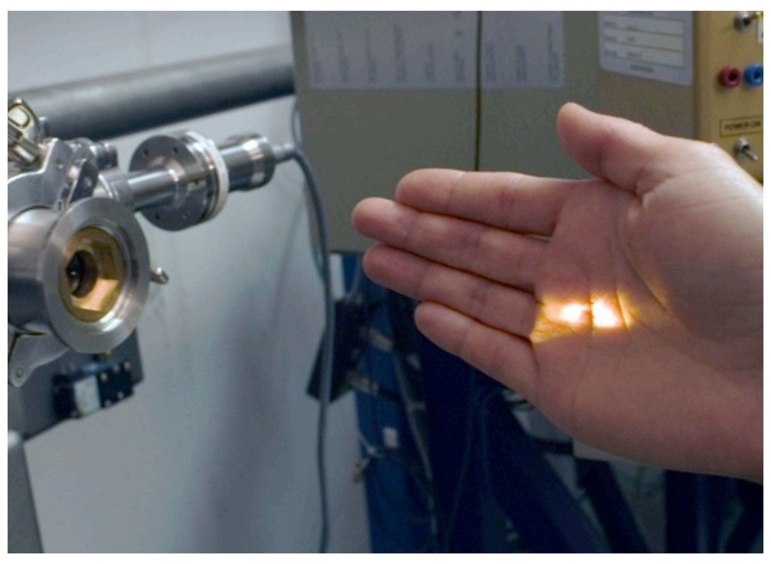


- **Normal operation:**
  - Energy 2.5 GeV
  - Current 200 mA
  - **Bunch length $\sigma \approx 10$ mm**
- **Low Alpha mode:**
  - Energy 1.3 GeV
  - Current ≈ 70 mA
  - **Bunch length $\sigma \approx 0.3$ - 4.5 mm**
  - Coherent THz radiation



The synchrotron radiation in the THz-range seen with a Hot Electron Bolometer.

- Filling pattern of the electrons is imprinted into the emitted synchrotron radiation
- Circumference 110 m = 368 ns
- 184 RF buckets
- 2 ns between bunches
- 1-3 trains with around 30 bunches each
- 120 ns between trains



The synchrotron radiation seen in the visible range at the diagnostics port of ANKA's infrared beamline 1.

Motivation

Current methods used at ANKA to obtain the bunch length:

- Derived from the synchrotron tune (electrons)
- Using interferometry in the THz-region (THz-pulses are shorter than expected from synchrotron tune)
- Streak Camera (visible light, but with jitter due to triggering and long integration time)

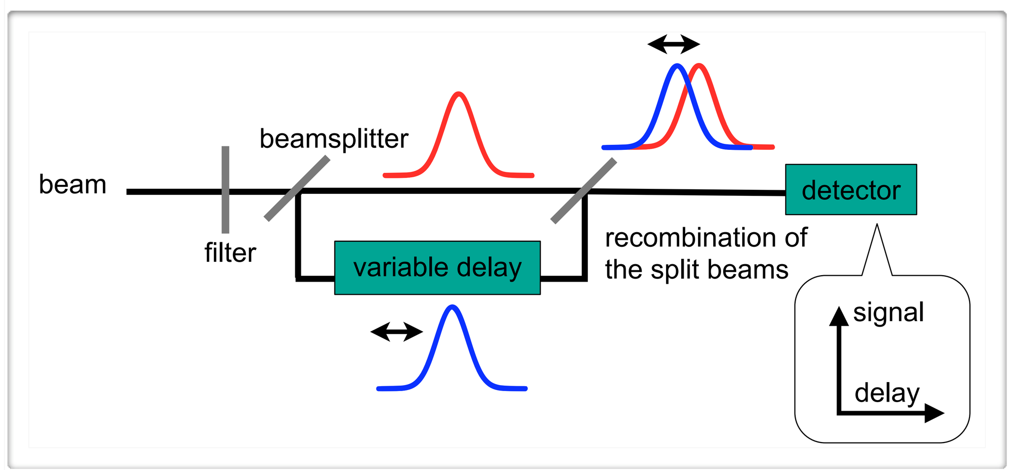
Using free carrier generation by two photon absorption processes in LEDs to perform an intensity autocorrelation has been done before to measure the pulse length of femtosecond lasers.

Goal:

- Obtaining an independent measurement of the synchrotron pulse length in the near infrared region using an intensity autocorrelation.
- Proving that an LED can be used as detector for an intensity autocorrelation with synchrotron radiation.

Idea & Detector

Intensity Autocorrelation:



Basic Idea:

- High energy photons are absorbed at the filter.
- One component of the split beam undergoes a variable delay.
- The recombined beam hits the detector

→ Intensity autocorrelation measurement (signal over delay time) yields the length of the initial pulse

How to extract the initial pulse length from the intensity autocorrelation:

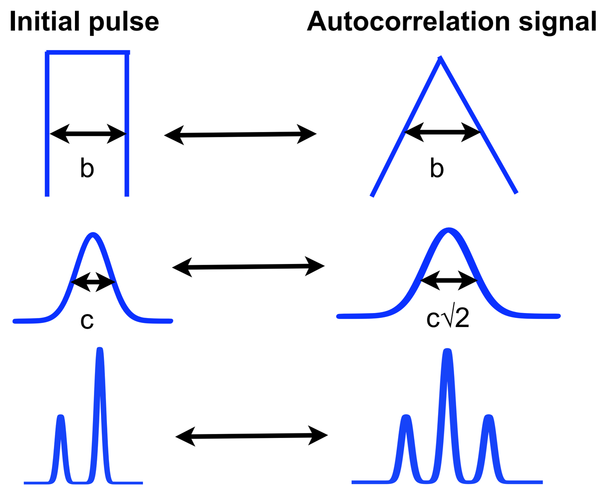
Intensity autocorrelation function:

$$I_M(\tau) = \int_{-\infty}^{\infty} I(t)I(t-\tau)dt$$

$$I(t) = |E(t)|^2$$

$I_M(\tau)$: Intensity measured on detector
$I(t)$: Intensity of initial pulse
t : Time
τ : Delay
$E(t)$: Electric field of initial pulse

The initial pulse shape needs to be known or assumed in order to retrieve the pulse length from the measured signal.

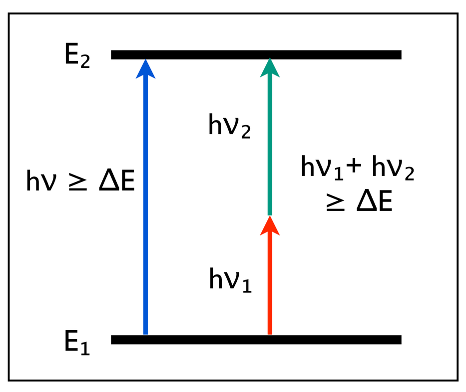


Detector:

LED → "LAD" ("light absorbing diode")

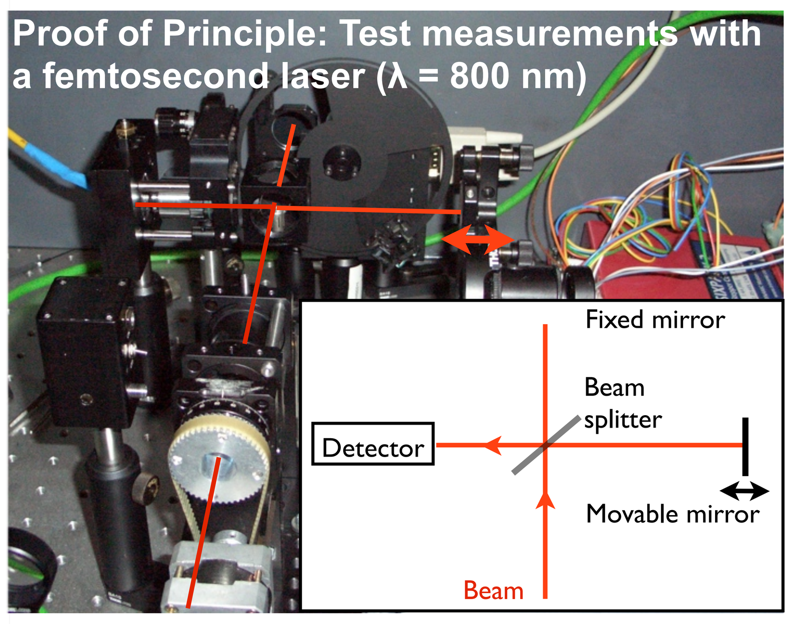
- Standard 5 mm GaAlAs LED (red) ΔE = 660 nm
- Tip cut off
- Glued into aluminium ring
- Polished the surface

An LED also works "the other way around", shining light onto it will create a measurable photocurrent.



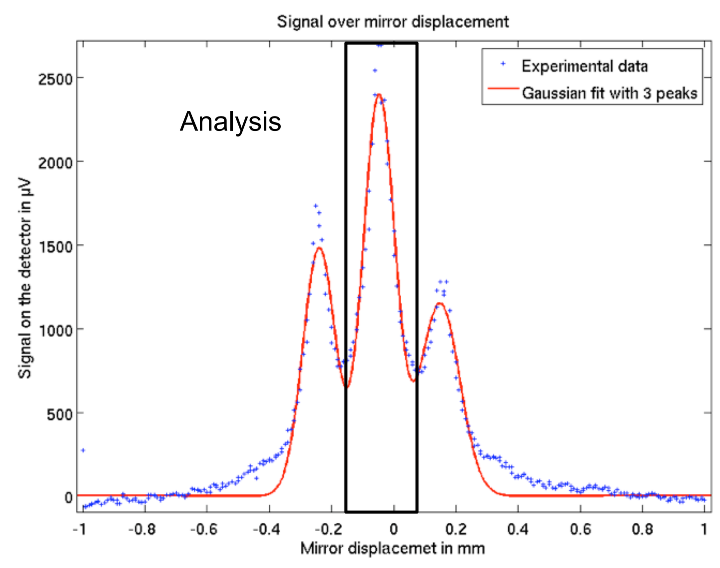
- Using free carrier generation by two photon processes in a semiconductor
- To suppress direct absorption: photon energy < band gap
- Signal ~ N^2/τ (N = # of photons, τ = pulse length)
- Rise time slow enough → Detector sees a constant beam → Signal only varies when delay is changed

Experimental Setup



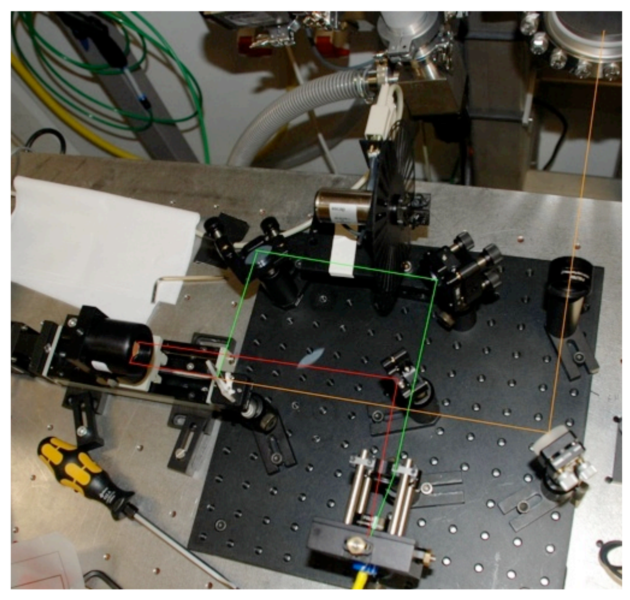
Proof of Principle Experiment:

- 3 peaks because of multiple reflections in the beam splitter.
- Initial pulse length measured to be 395 ± 25 fs (actual pulse length of the laser has not been validated with another experiment).
- Stretching of the pulse in the microscope objective.



Experimental setup at the infrared beamline (currently in progress):

- Using a 780 nm long pass filter, to exclude photons with higher energies.
- Slight change in the setup to have the beamsplitter and the recombination separated to minimize losses.
- Readout and motor steering is done via SPEC, the unbiased signal at the LED is amplified with a lock-in amplifier.



Challenges

- **Detector** (influence of band gap on signal; swap to photodiode?)
- **Source** (intensity of the synchrotron radiation is very low compared to the one of the laser; losses within the setup; focussing; dispersive broadening of the pulse length in media)
- **Analysis** (initial pulse shape to be assumed?)