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# Accurate characterisation of high power laser beams for real time PIC simulations

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# Motivation, purpose

- Temperature drift, air currents and mechanical vibrations

→ spectral and temporal phase fluctuations

→ pulse duration and focus radius

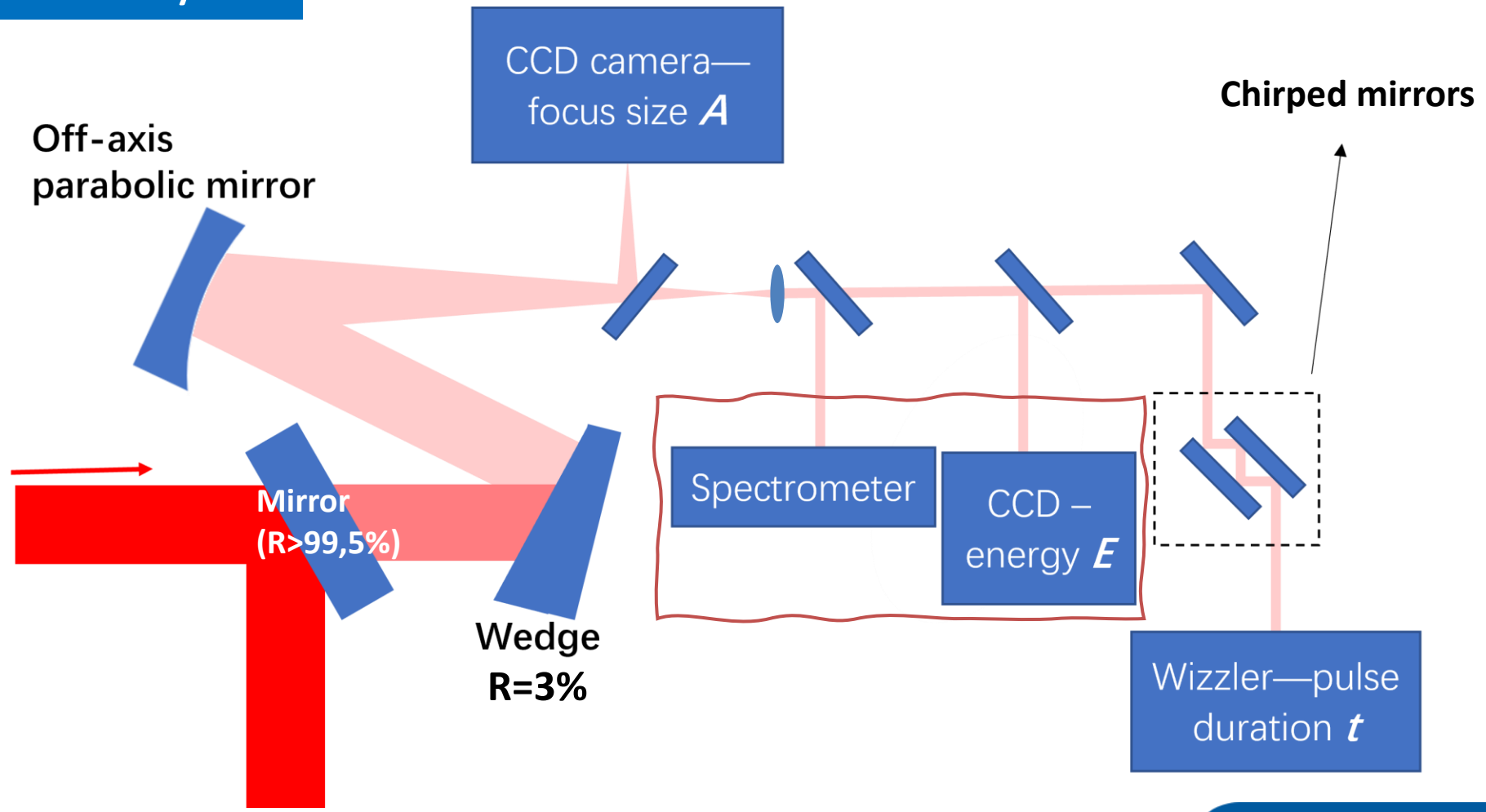
→ the focused laser intensity fluctuation.

- The aim is to develop a laser diagnostic system to monitor the shot-to-shot fluctuations with precision below 1%.

# Intensity diagnostic

$$intensity\ I = \frac{E}{t \times A}$$

## Experiment Layout

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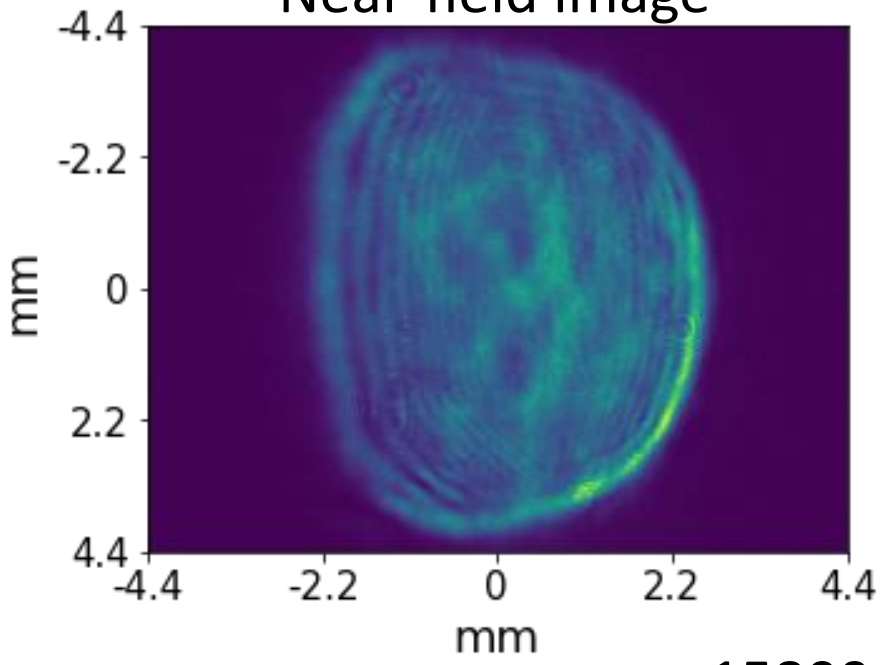
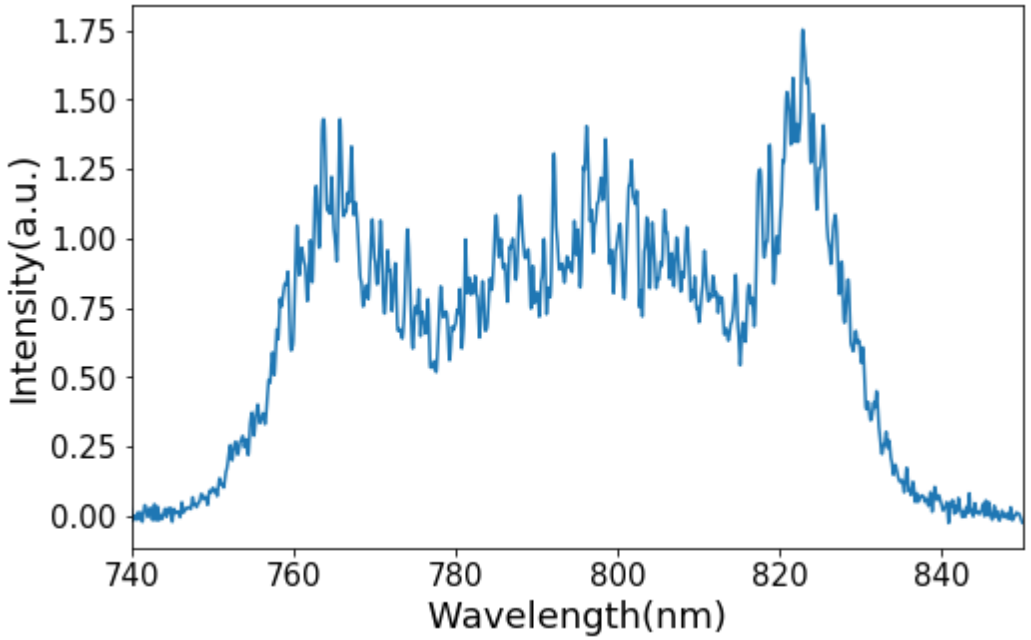
# Energy calculation

Near-field image




Laser spectrum




Camera specifications:
Saturation capacity 15800 e⁻
Bit depth 14 Bit

$$\frac{15800\ e^-}{2^{14}}\ electrons\ per\ grayscale$$

$$Sum\ up\ the\ value\ of\ each\ pixel$$

} Total electron number

$$n(\lambda) = total\ electron\ number/spectrum$$

$$E(\lambda) = \frac{hc}{\lambda} n(\lambda)$$

$$E_{total} = \int E(\lambda) d\lambda$$

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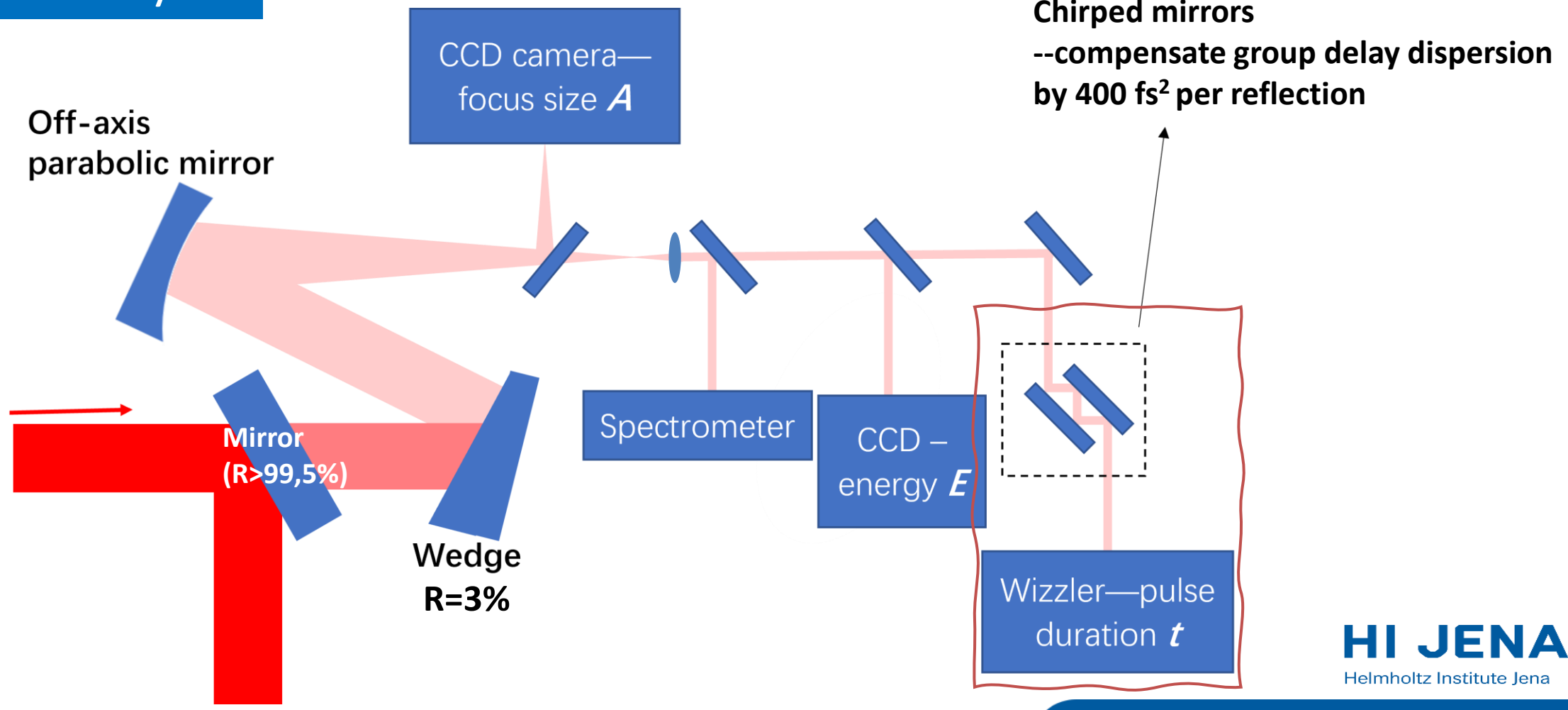
# Intensity diagnostic

$$intensity\ I = \frac{E}{t \times A}$$

## Experiment Layout

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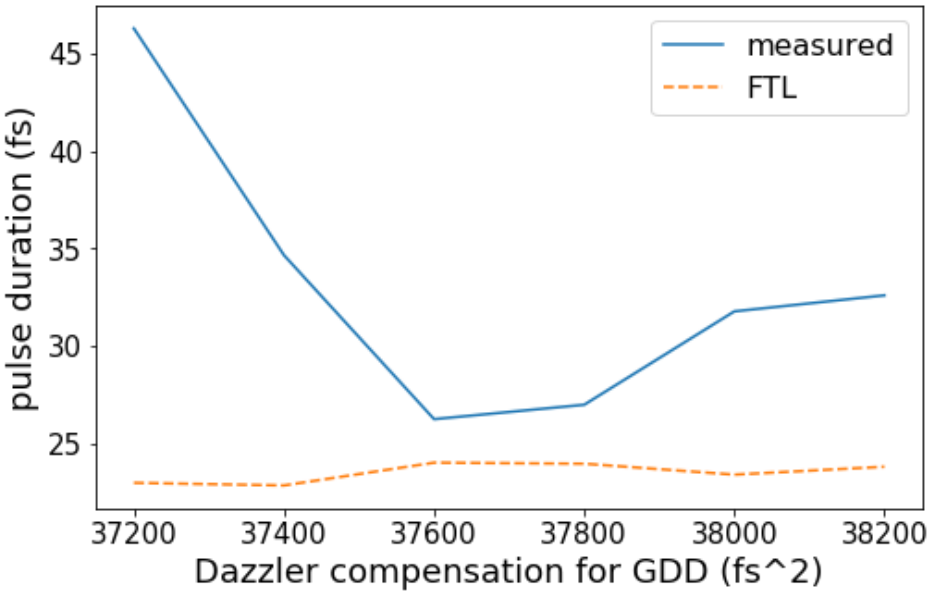
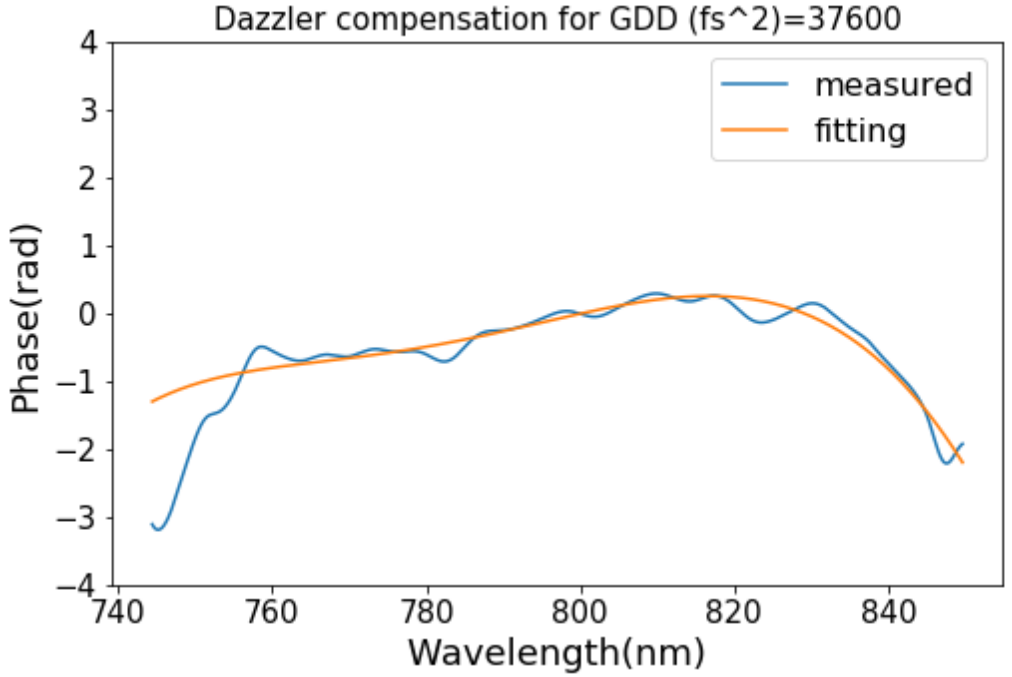
# Pulse duration

## Wizzler

- A device that accurately measures the spectral phase and pulse duration of ultra-short laser pulses.
- uses the technique: Self-Referenced Spectral Interferometry (SRSI).



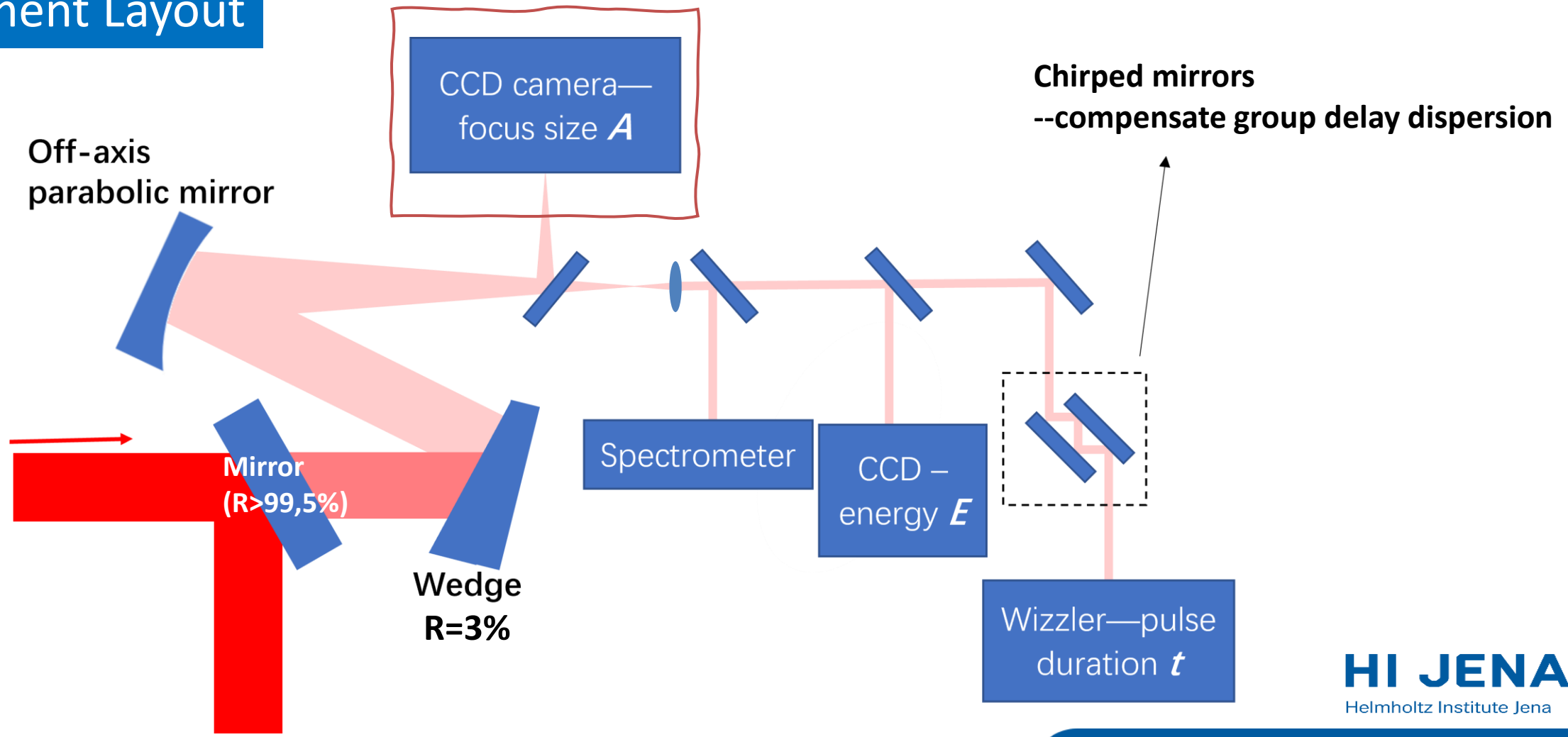




Spectral phase. Higher orders dispersion in spectral phase is not compensated.

# Intensity diagnostic

$$intensity\ I = \frac{E}{t \times A}$$

## Experiment Layout

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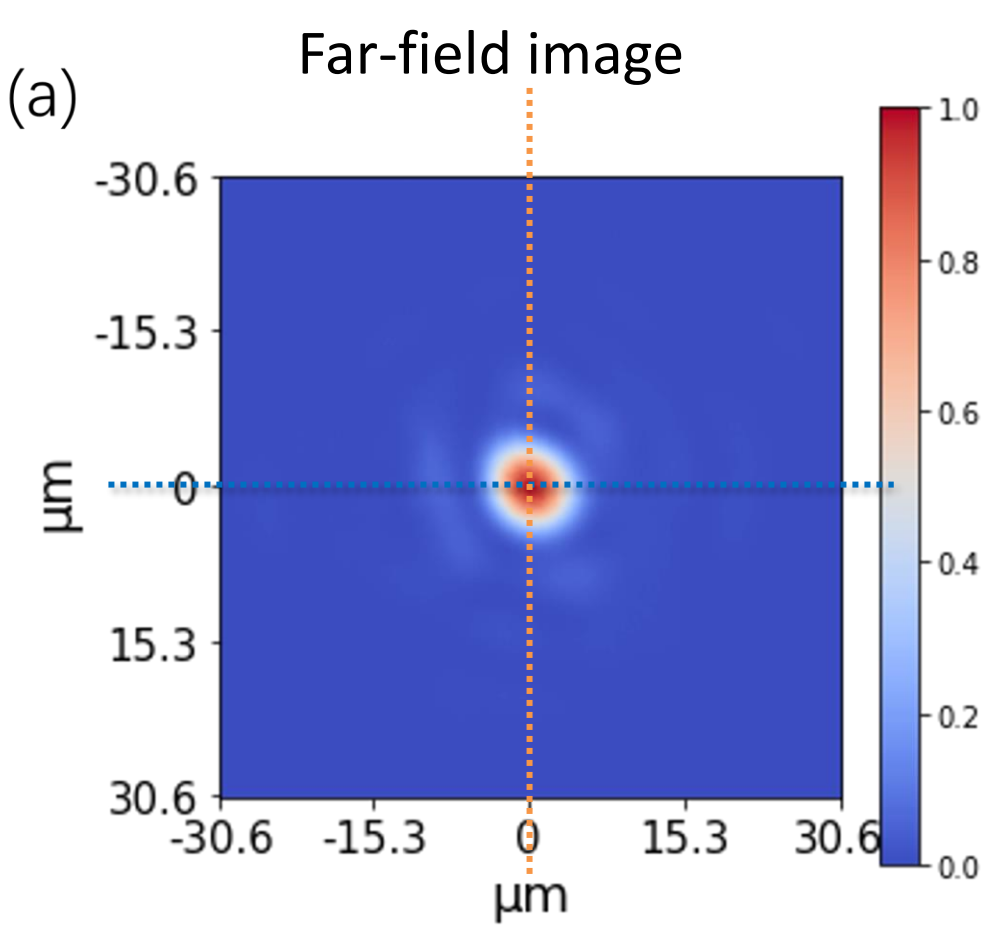
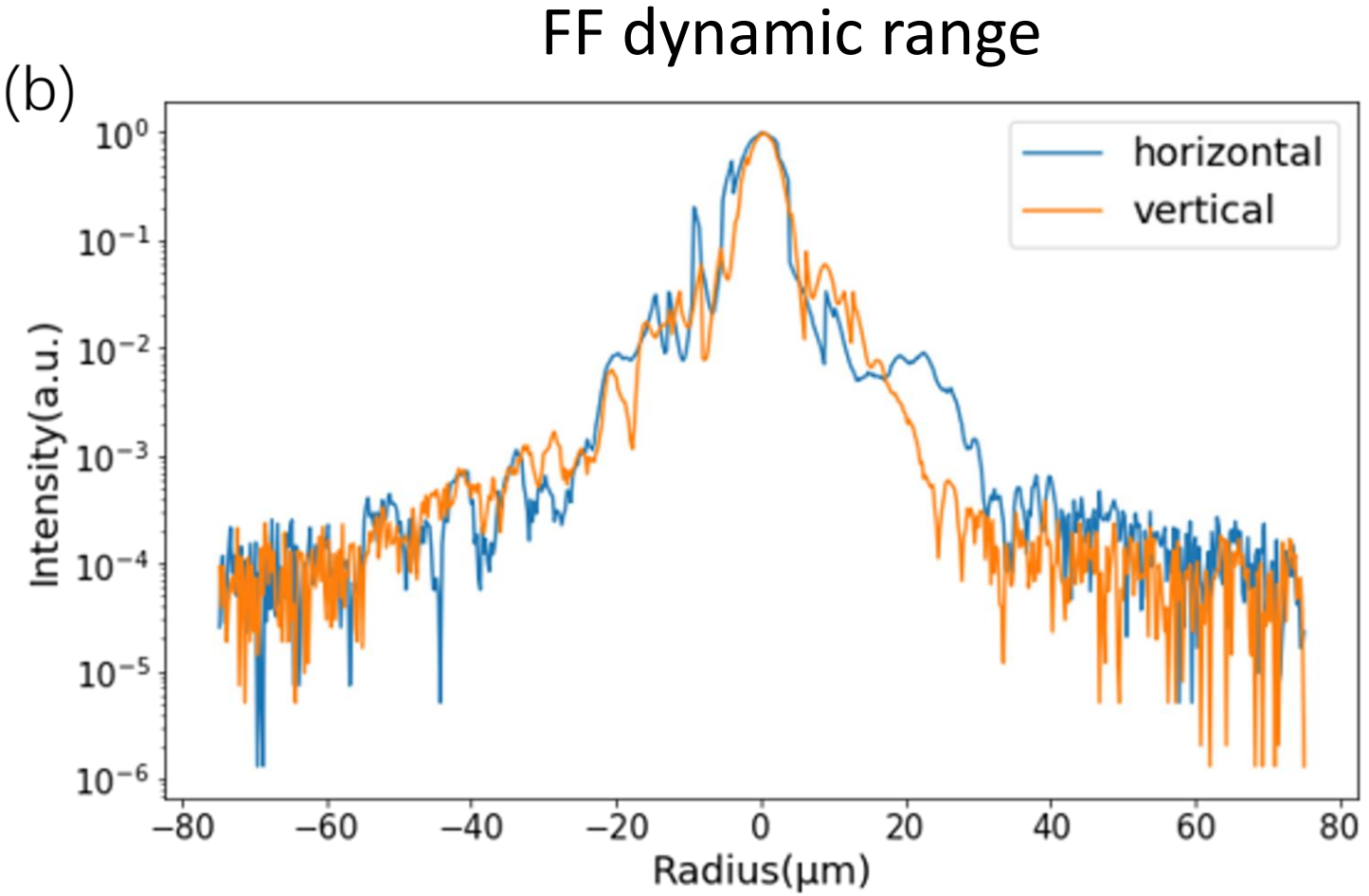
# Far-field

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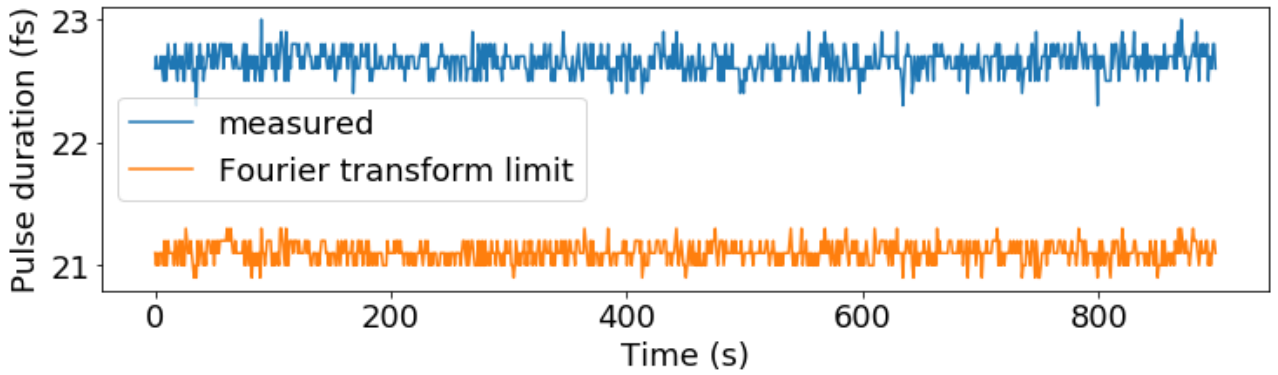
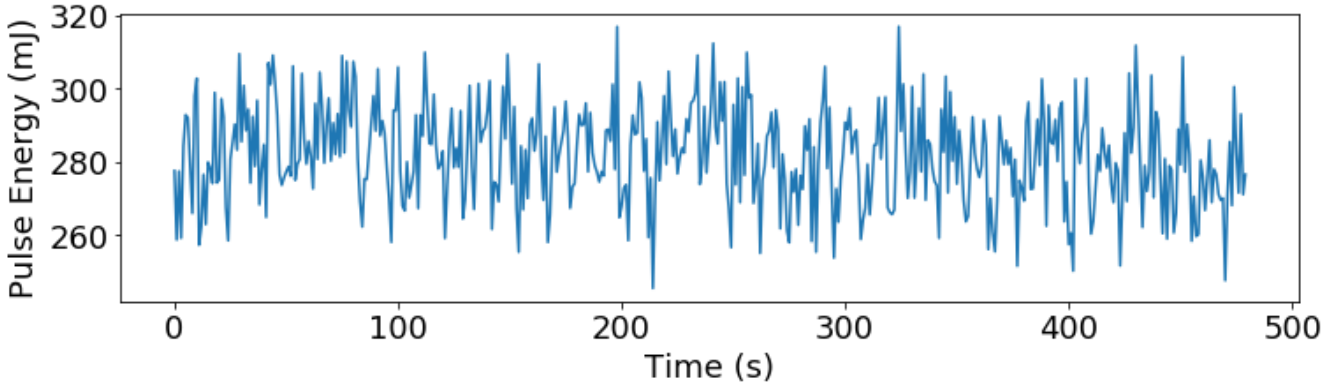
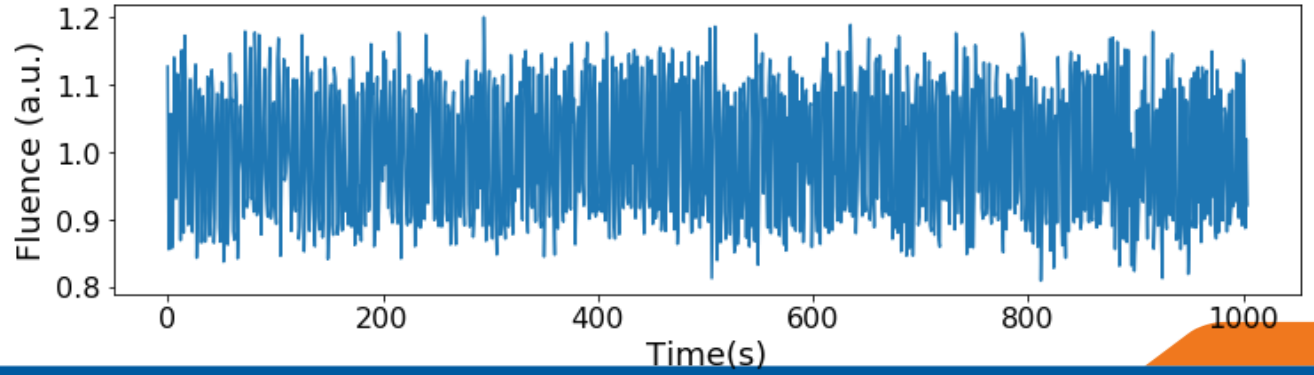
# Stability of JETI200 laser (1HZ)




Pulse duration
Mean = 22.6fs  RMS = 0.4%




Energy (with Titan 600mJ)
Mean =282mJ  RMS=0.4%




Fluence of focus peak
RMS=10%

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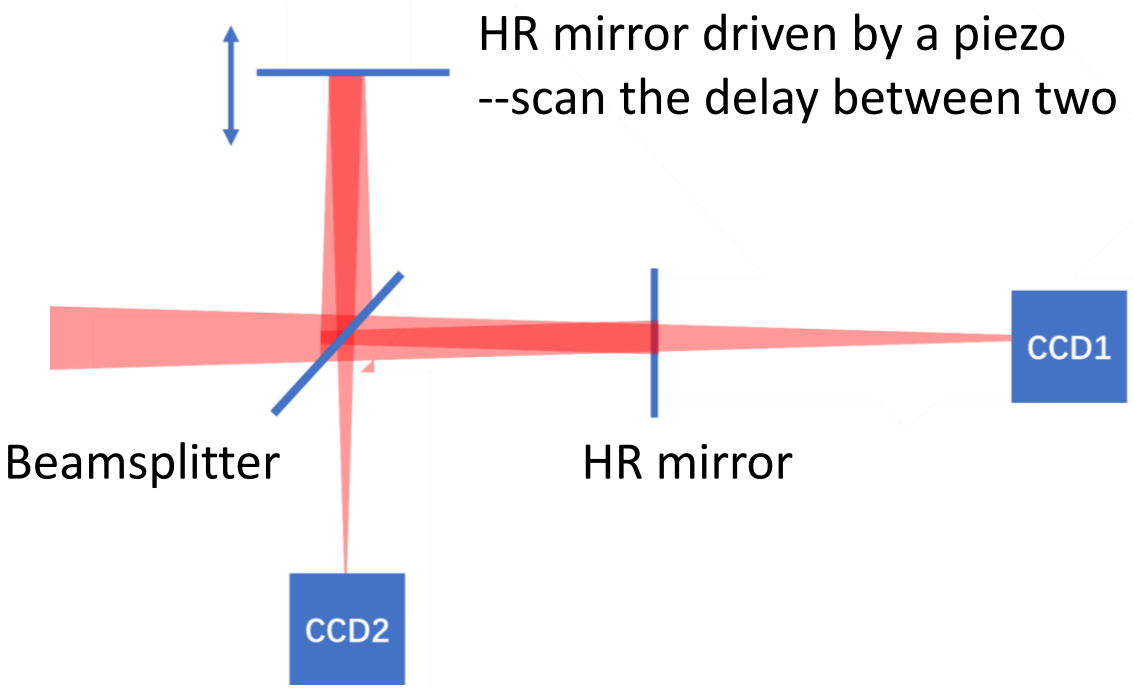
The spatial and temporal profiles of laser are not independent to each other.
The spatial-temporal couplings should also be investigated.

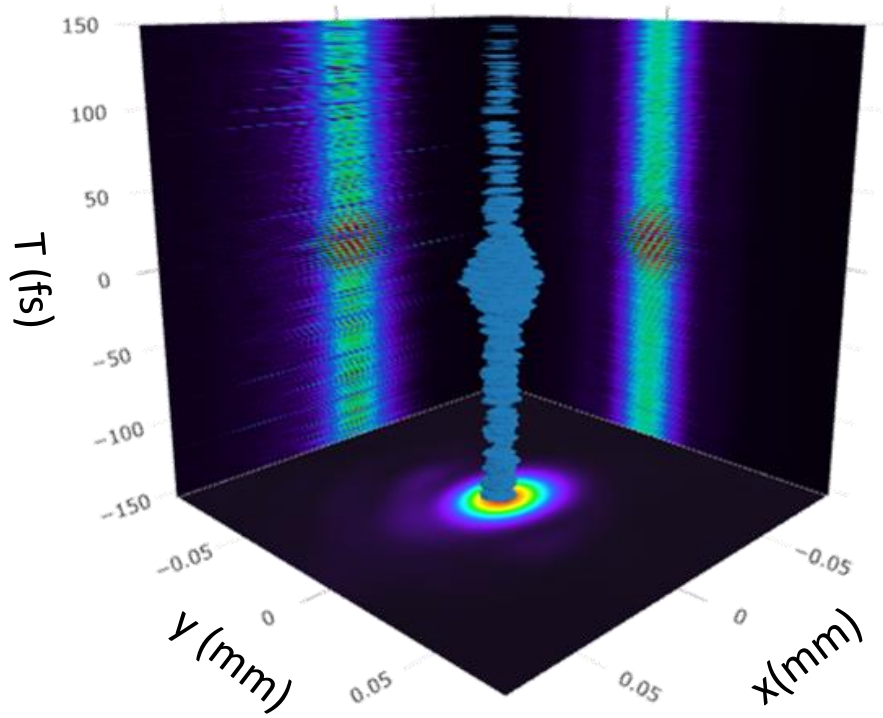
# 3D characterization

INSIGHT : Michelson or Mach-Zender interferometer

- Determines $\tilde{E}(x, y, \omega)$
- full 3D phase and amplitude reconstruction

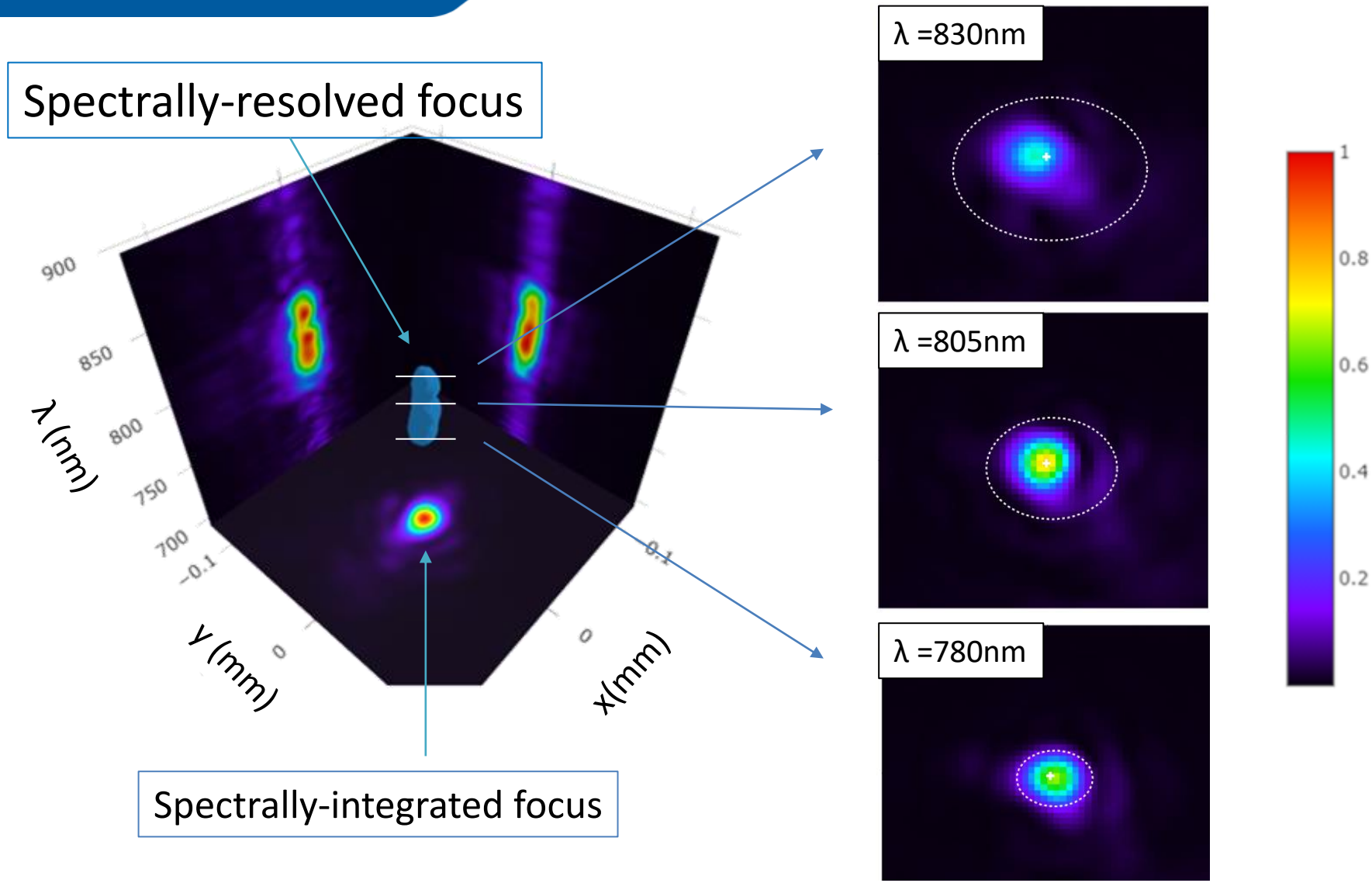



3D interferograms




A. Borot and F. Quéré, Opt. Express 26, 26444-26461 (2018).

# 3D characterization

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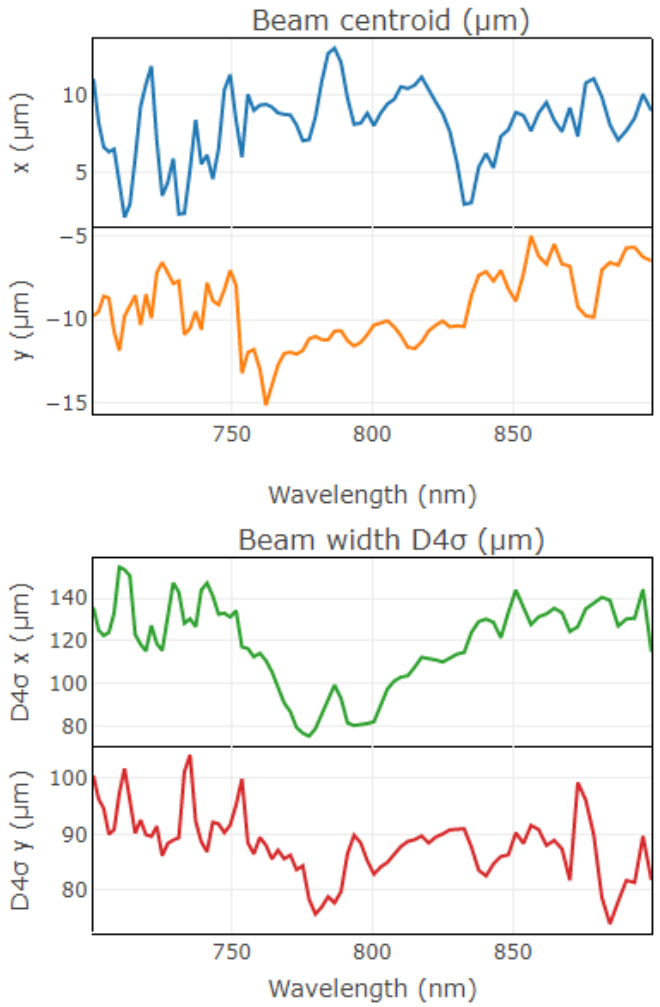
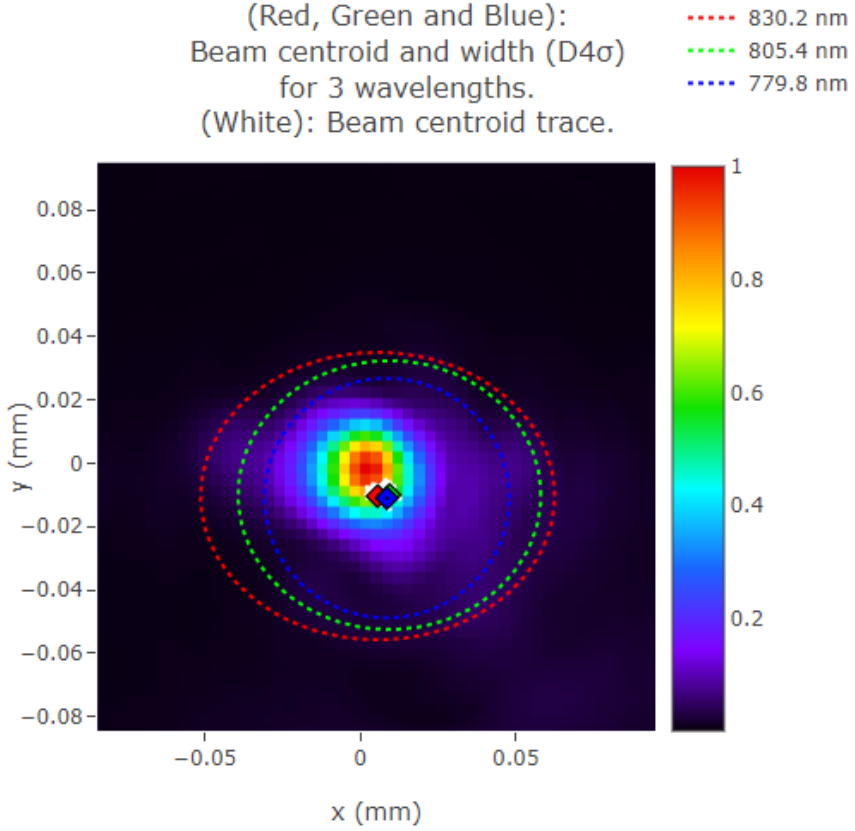
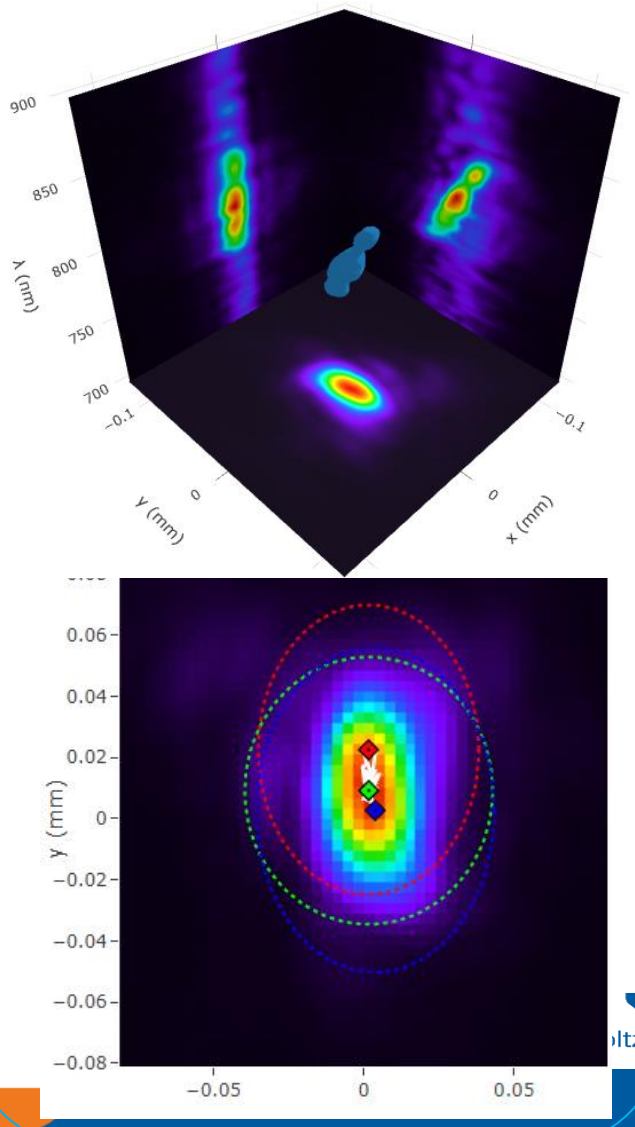
# 3D characterization--Transverse focal shift

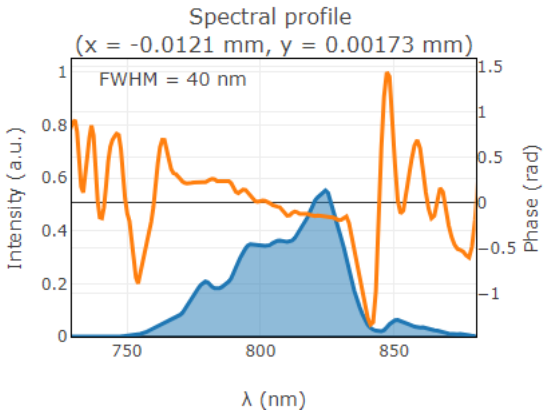


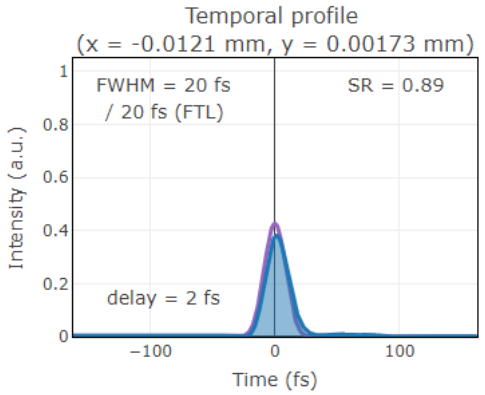



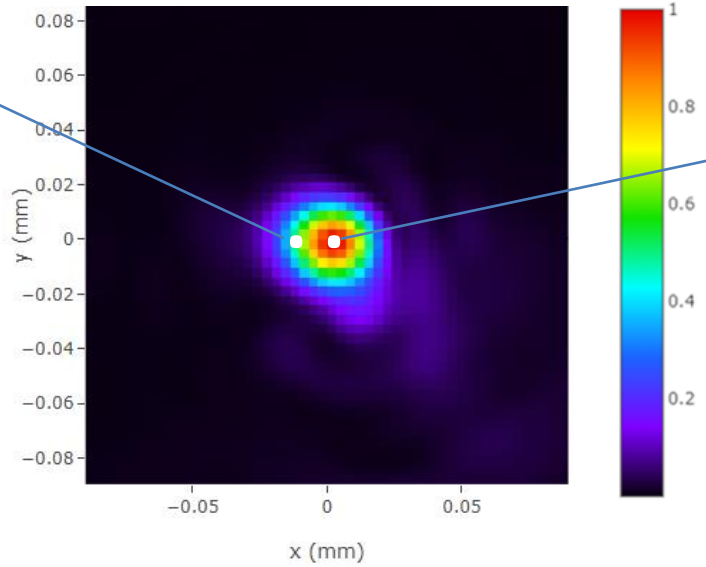

Beam with pulse front tilt



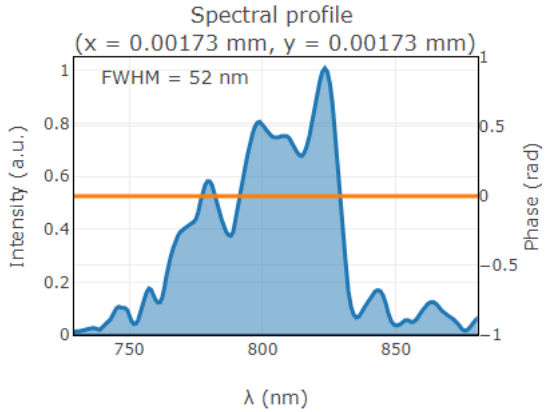
# 3D characterization--Local pulse duration

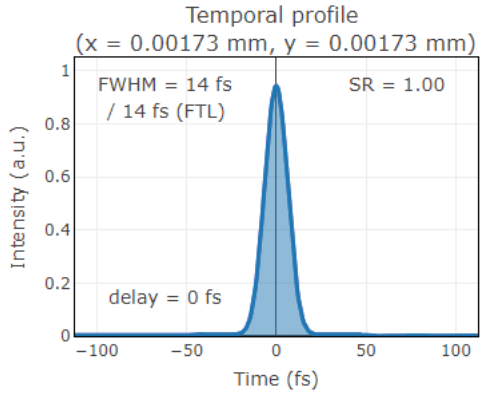



Spectrally-integrated beam focus intensity (a.u.)

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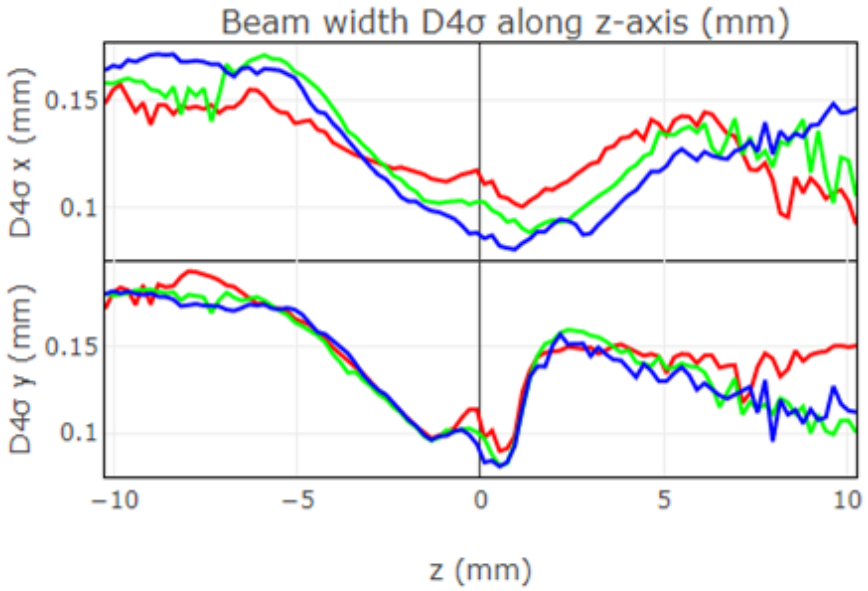
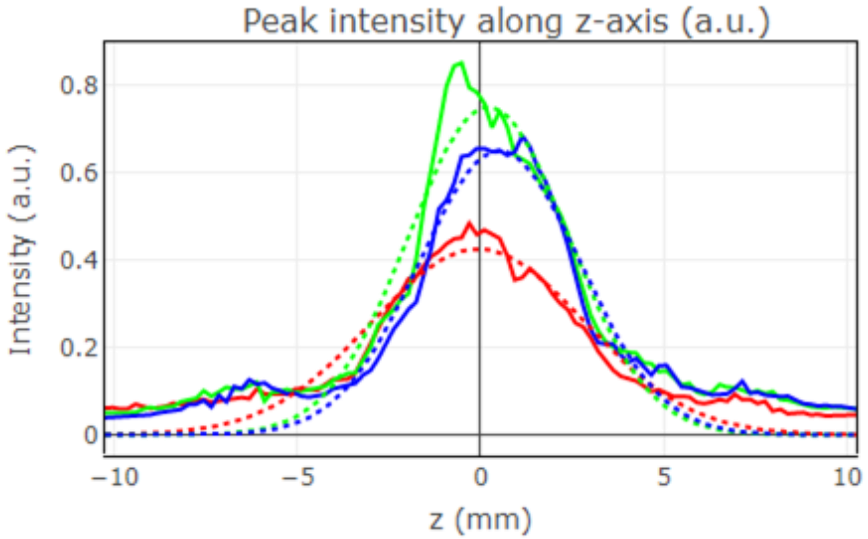
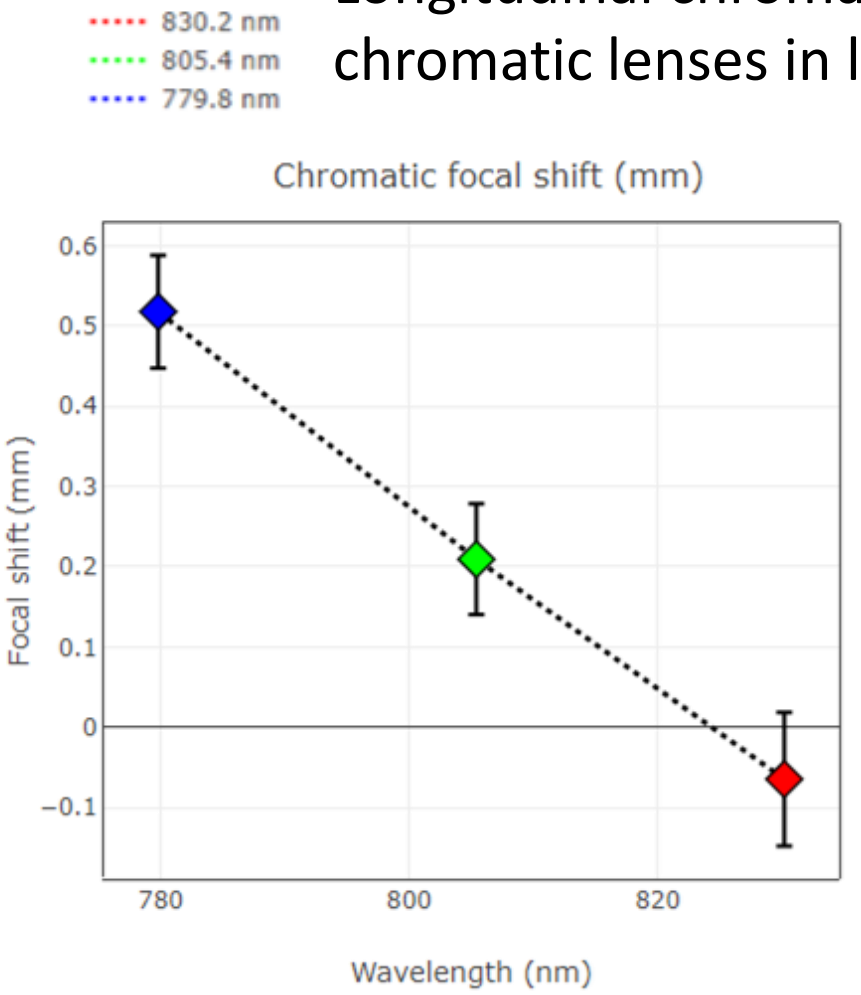
# 3D characterization--Longitudinal focal shift




Longitudinal chromatism, mainly due to chromatic lenses in laser system

Laser beam:
f/20
Rayleigh length~1 mm

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# Summary

- Intensity diagnostic (<1% precision measurement)
- Laser stability

  Fluence dominates the fluctuation
- 3D characterization – evaluate spatial-temporal couplings

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