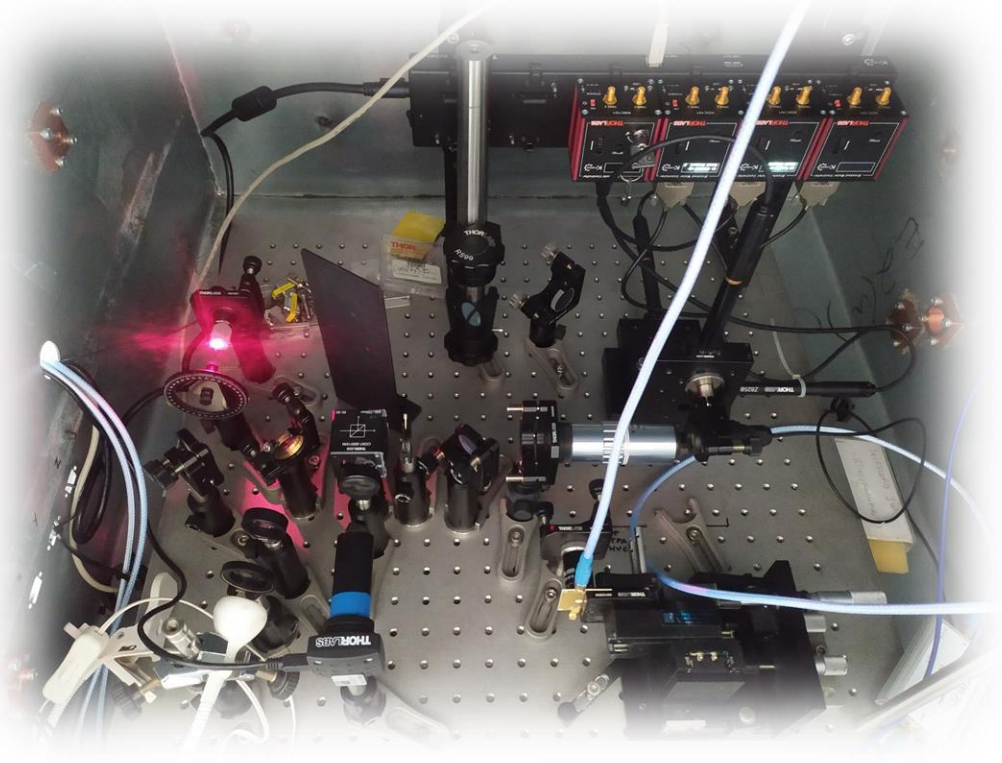
Optimization of the femto-laser facility in Bilbao for TPA-TCT in SiC

1st Workshop DRD3

CERN, June 10th, 2024



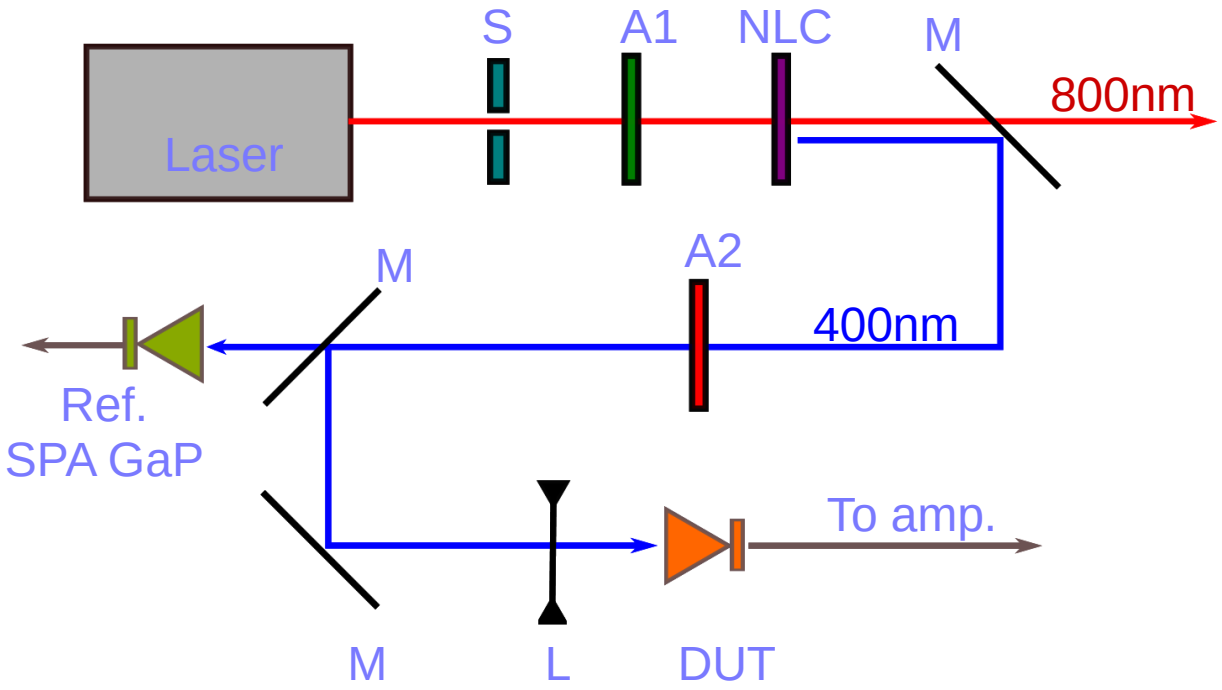
Jordi Duarte, Fernández, Michael Moll, Raúl Montero, Cristian Quintana, Diego Rosich, **Iván Vila,** Moritz Wiehe

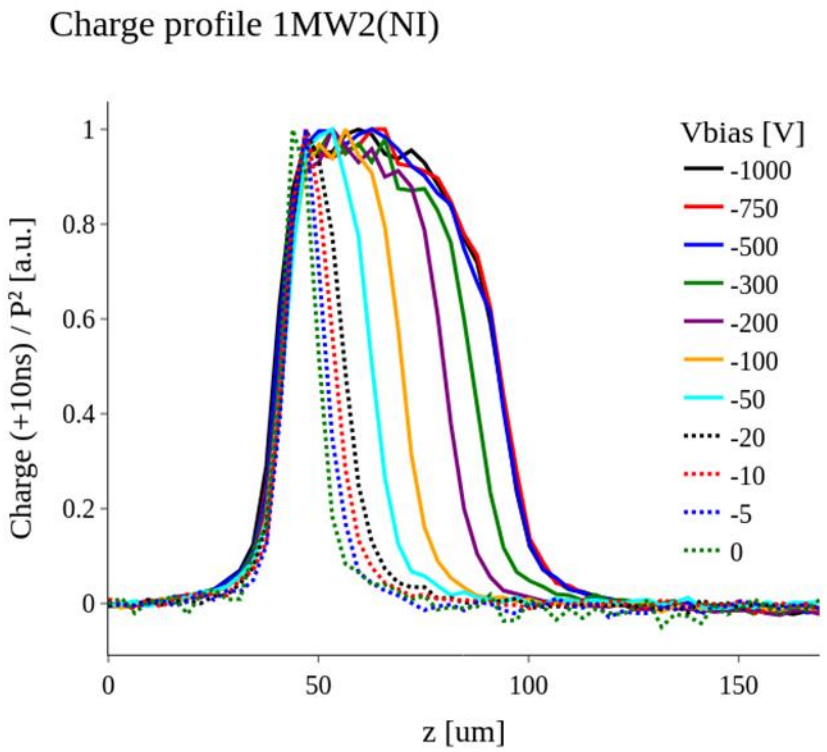
Instituto de Física de Cantabria (CSIC-UC)

Outline

- Recall of TPA-TPC in SiC
- Beam parameters determination (High-resolution TPA-TCT)
- Limitating Systematics Studies:
  - Pointing stability.
  - Spherical aberration.
- Proposal for a permanente TPA-TCT test stand for Wide Band semiconductor characterization.
- Summary

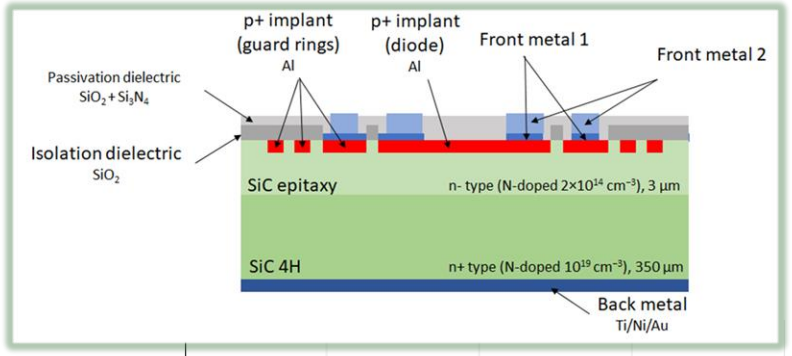
TPA-TCT method in SiC demostrated in Bilbao in 2022

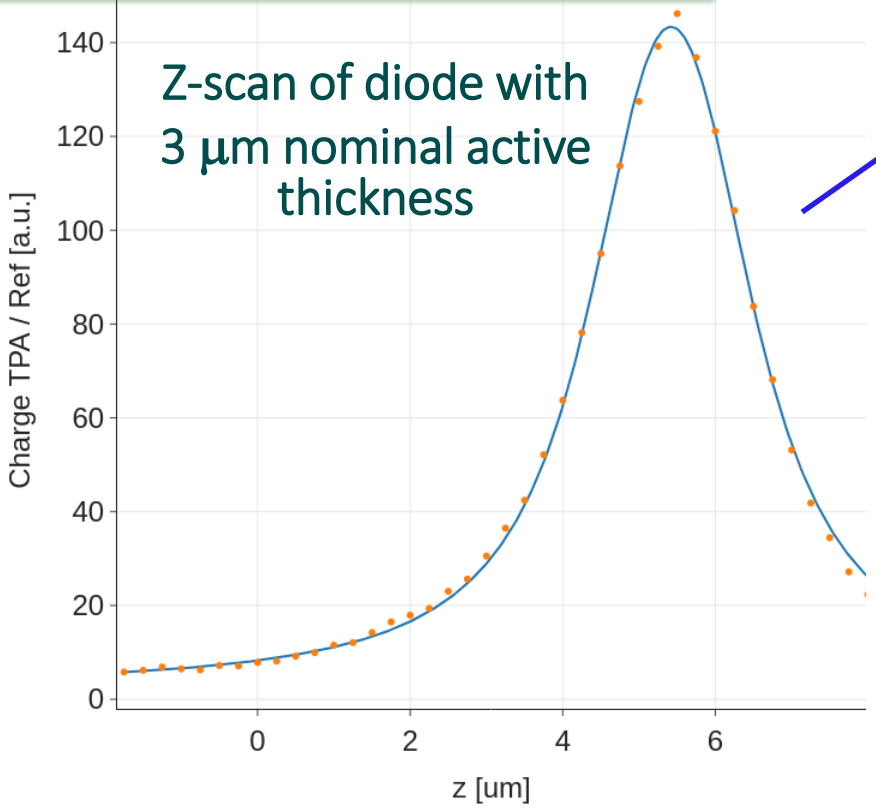




S: Shutter
A1: Attenuator
NLY: Non linear crystal
M: Mirrors
A2: Attenuator
Ref.: Laser power reference
L: focusing lens
DUT: Device under test

High-spatial resolution: beam parameters

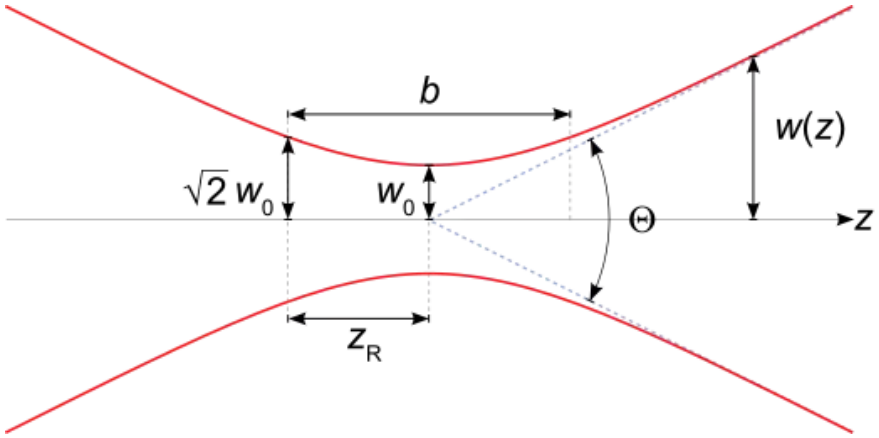




Fit

$$N^d_{tpa}(z) = 2\pi \int_{z-d}^{z} \int_0^{\infty} n_{tpa}(r, z')\, r\, dr\, dz'$$

$$= \frac{E_p^2\, n^2\, \beta_2 \sqrt{\ln 4}}{4\, c\, \hbar\, \pi^{\frac{3}{2}}\, \tau} \cdot \left[\tan^{-1}\left(\frac{(d-z)}{z_0}\right) + \tan^{-1}\left(\frac{z}{z_0}\right) \right].$$

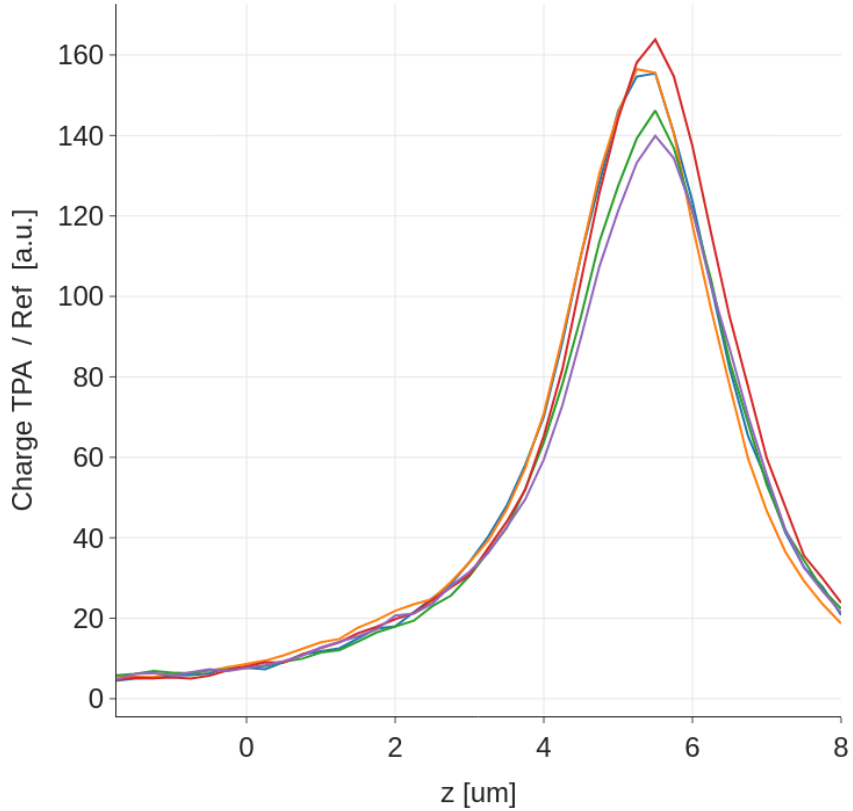


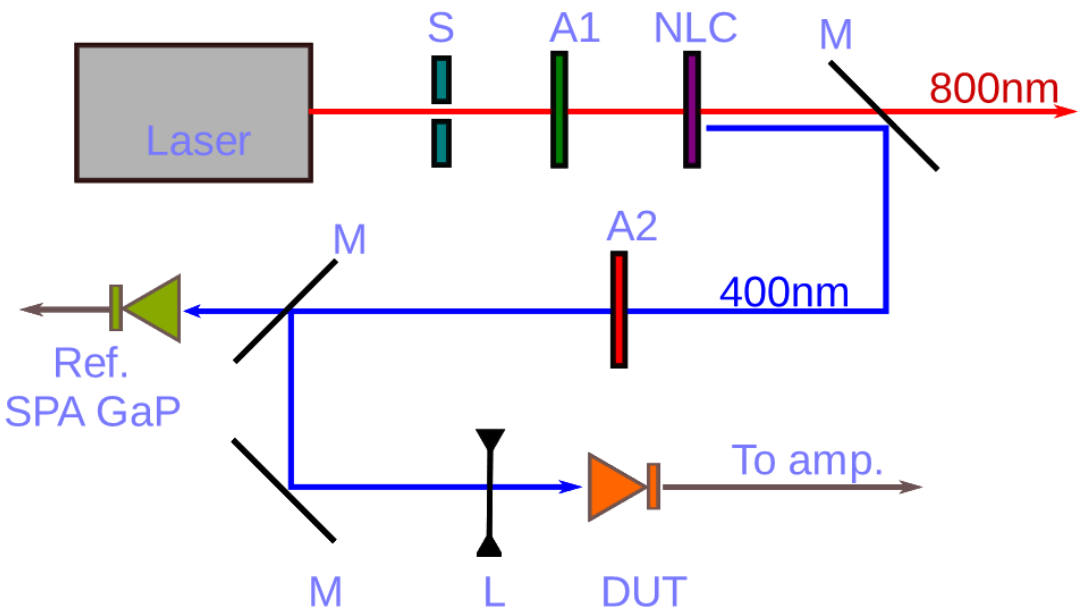
$$Z_R = 2.95 \pm 0.14\ \mu m\ (SiC)$$

$$W_0 = 215 \pm 0.01\ nm$$

$$d = 3.4 \pm 0.4\ \mu m$$

Systematics: Z-scan no reproducibility

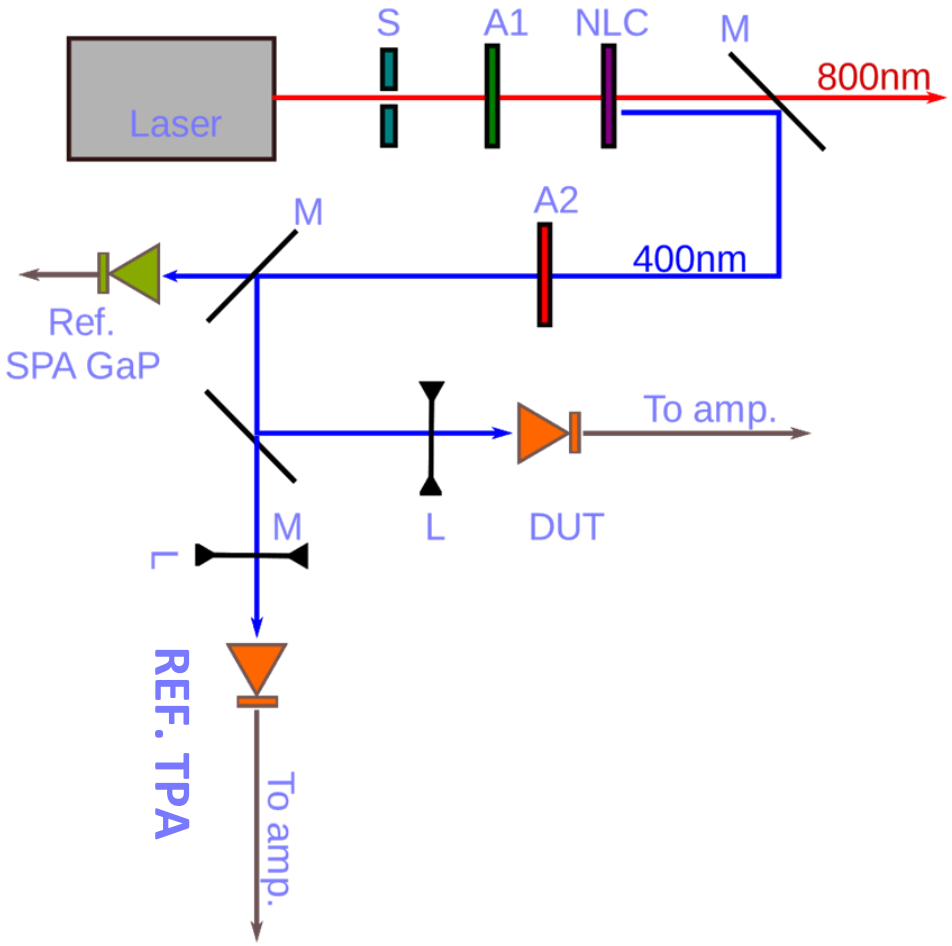


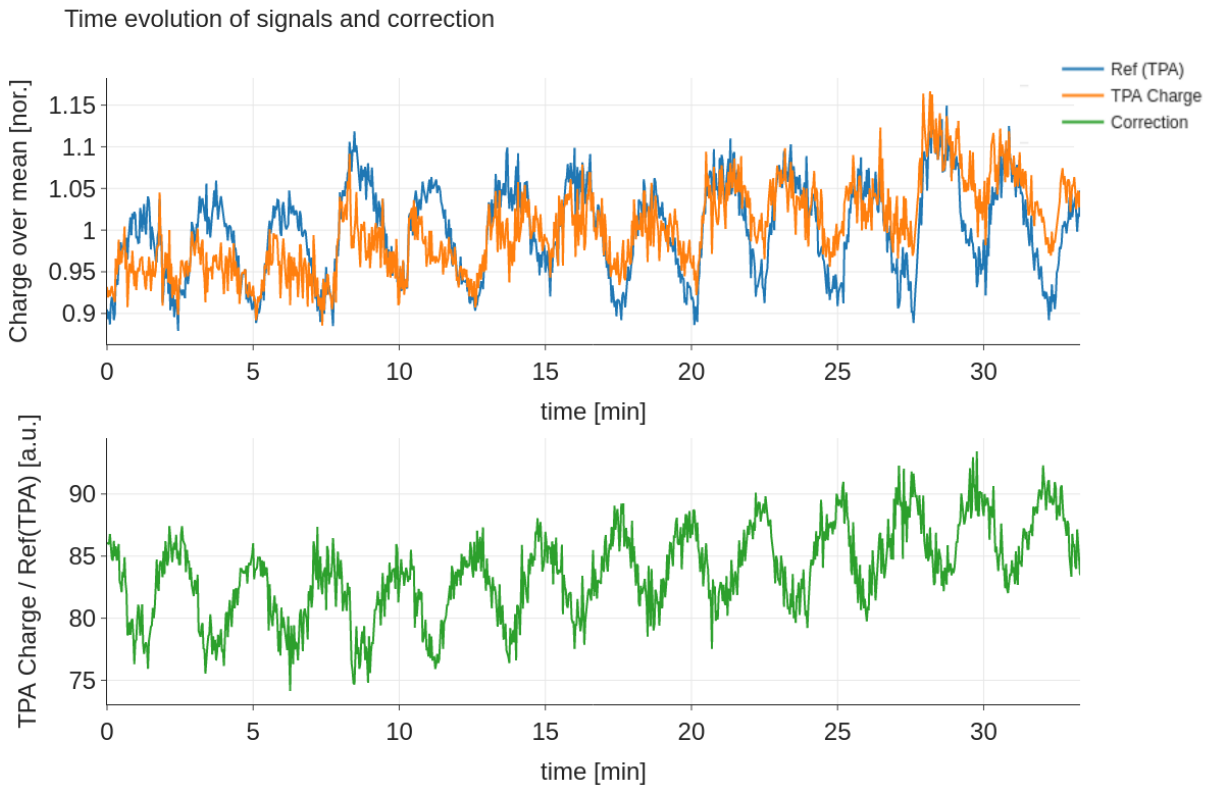


TPA Signal normalized using $(SPA)^2$ **does not** fully correct the laser instabilities

Systematics: Stability measurements

TPA Signal normalized using Reference TPA

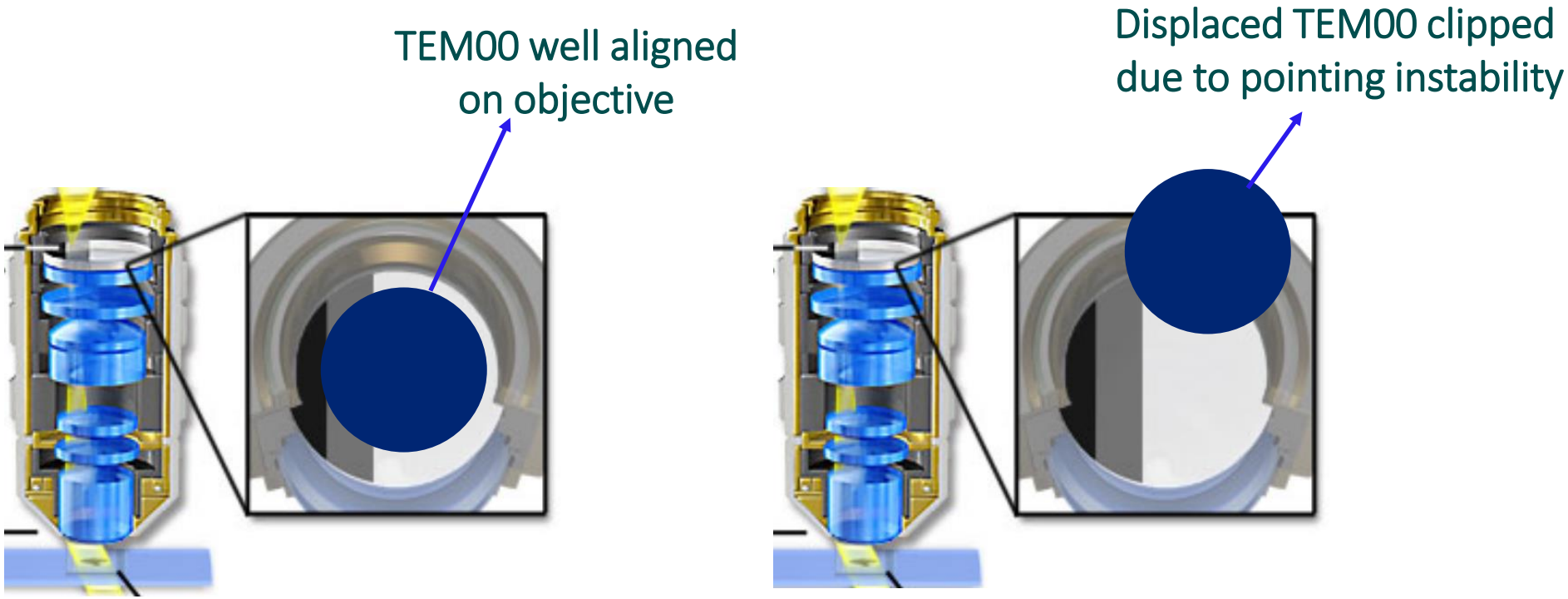




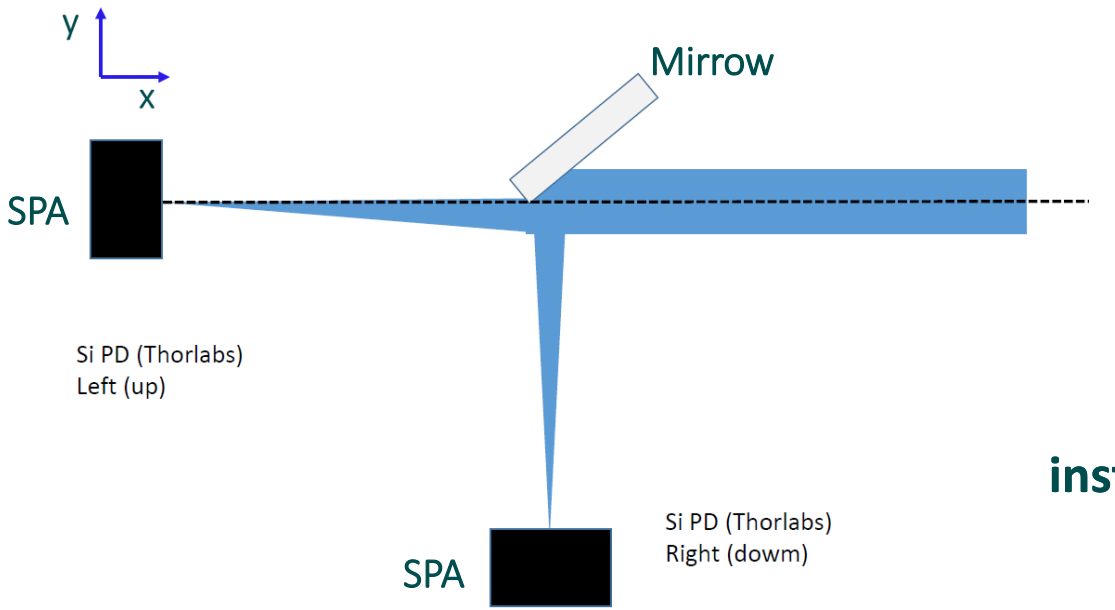
Signal instability remains, temporal profile instability ruled out

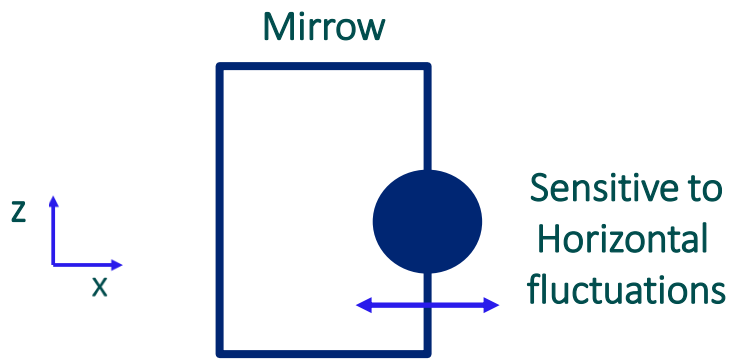
Systematics: Stability measurements – pointing stability studies

– Possible correlated intensity laser intensity fluctuations and pointing fluctuations -> Induced spatial mode clipping in microscope objetive

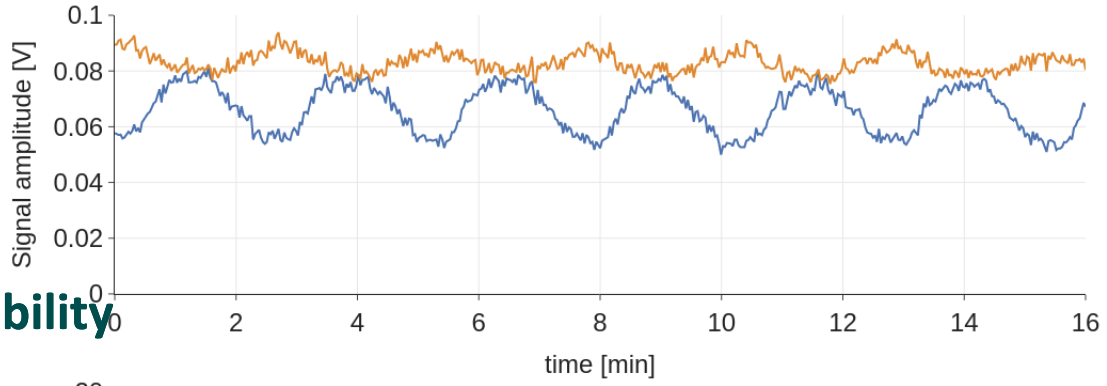


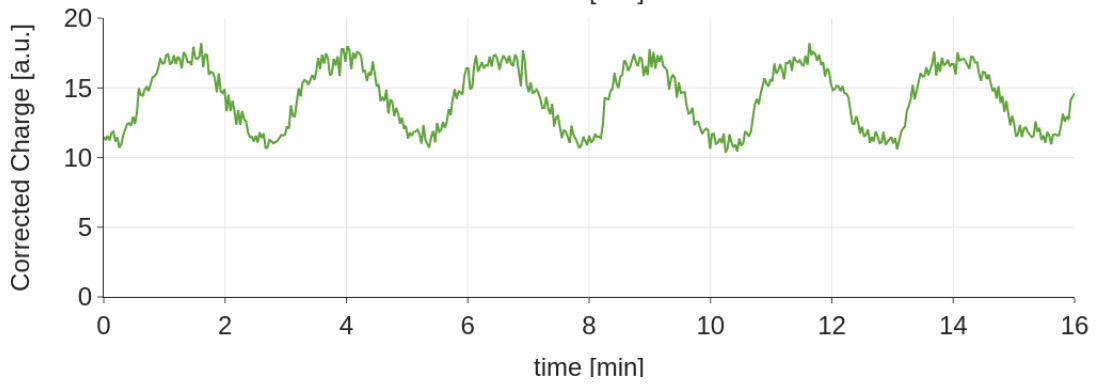
Systematics: Stability measurements – pointing stability studies





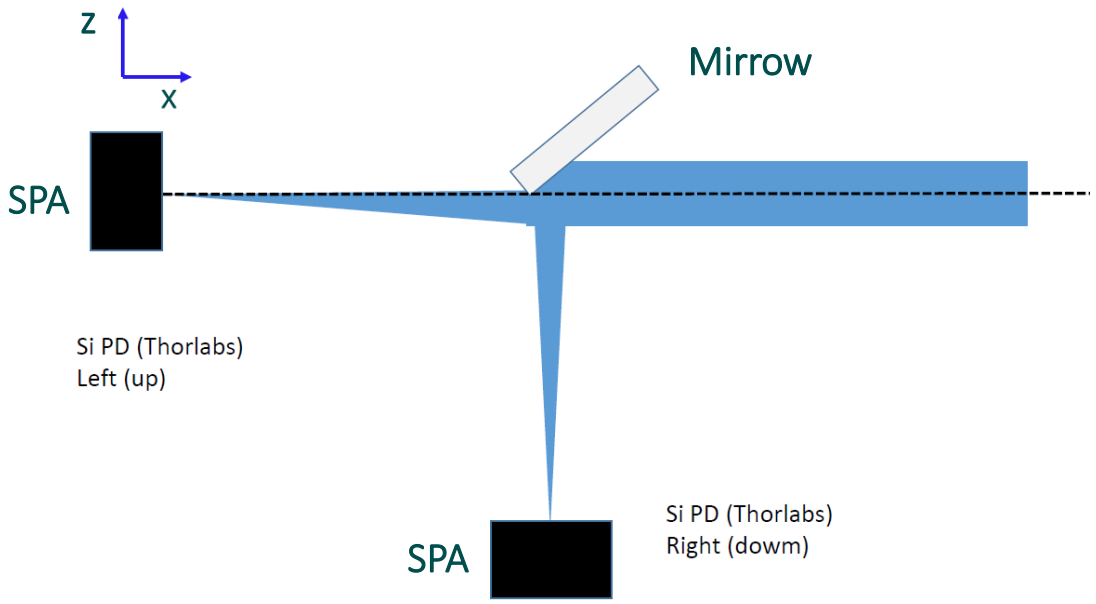
instability

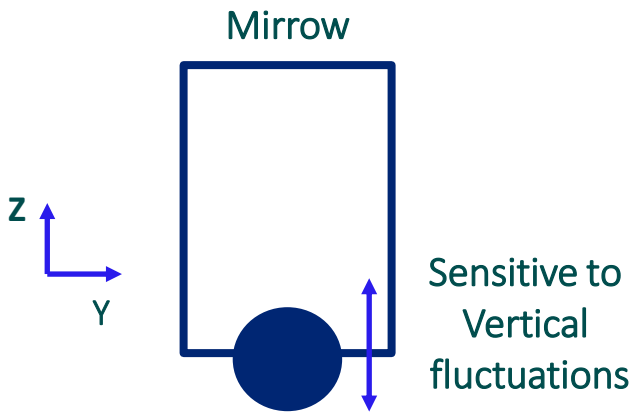




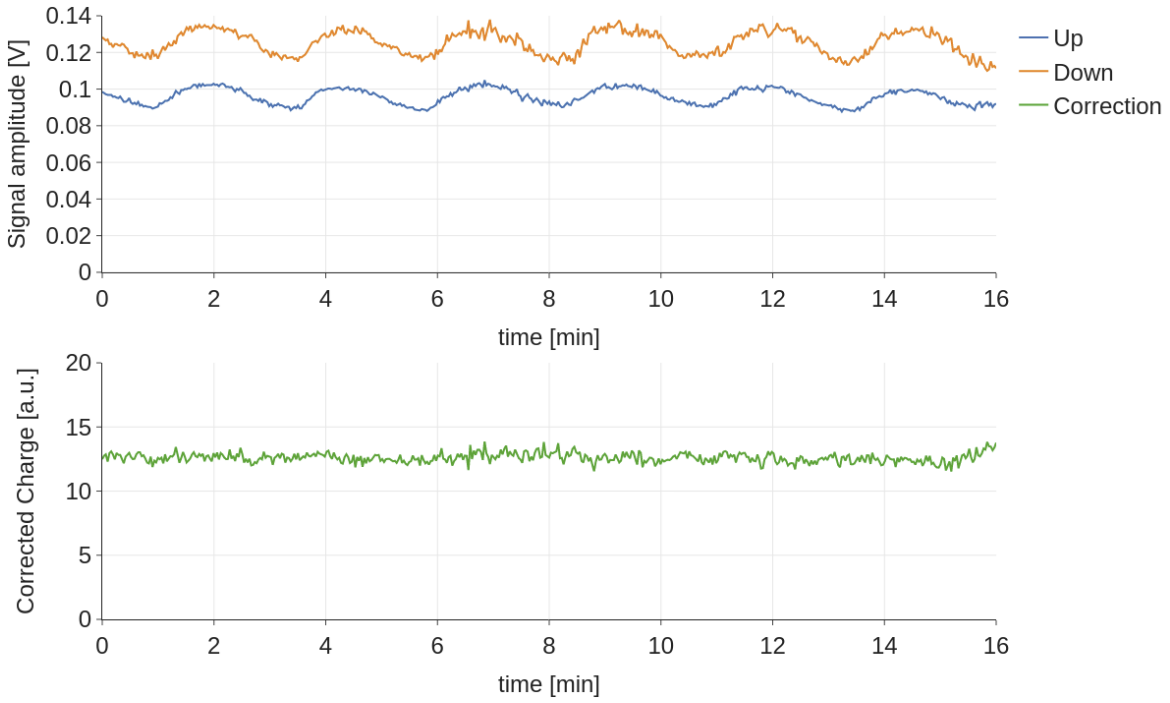
ANTI-CORRELATED LEFT/RIGHT SIGNAL

Systematics: Stability measurements – pointing stability studies



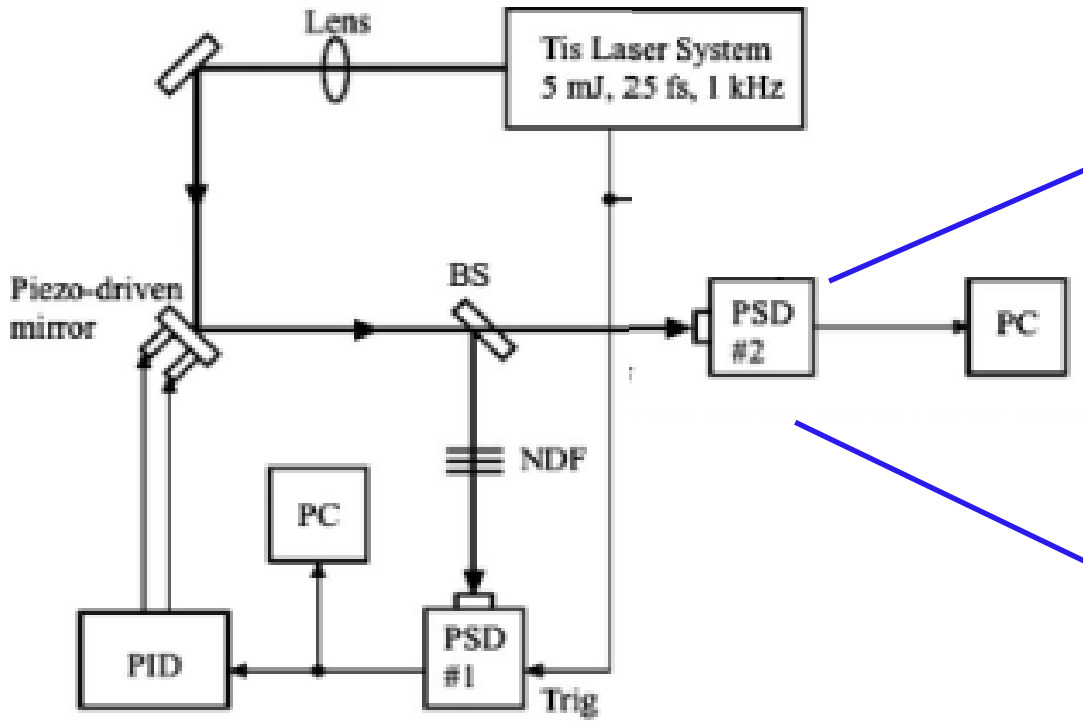


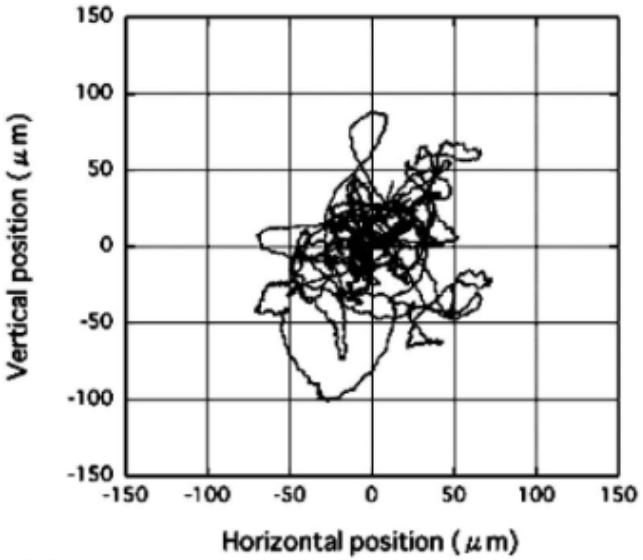
Sensitive to Vertical fluctuations



CORRELATED TOP/BOTTOM SIGNAL
EXCELENT CORRECTION

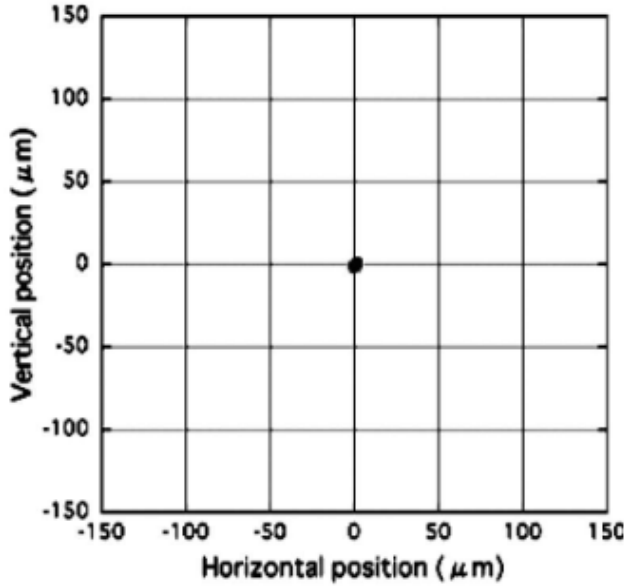
Systematics: Pointing stability Improvement, strategy.





Before

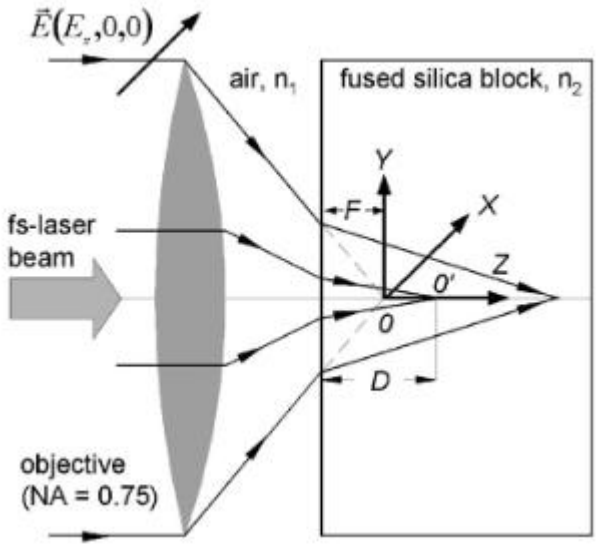
(b)

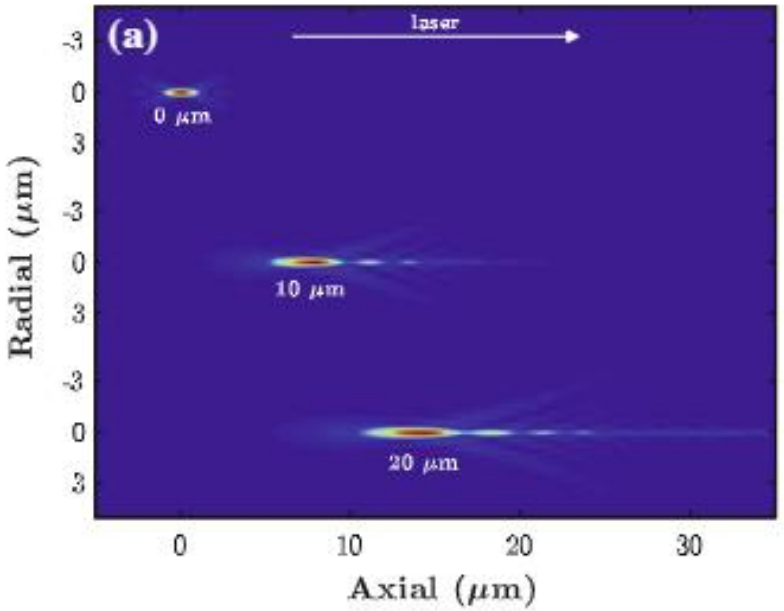


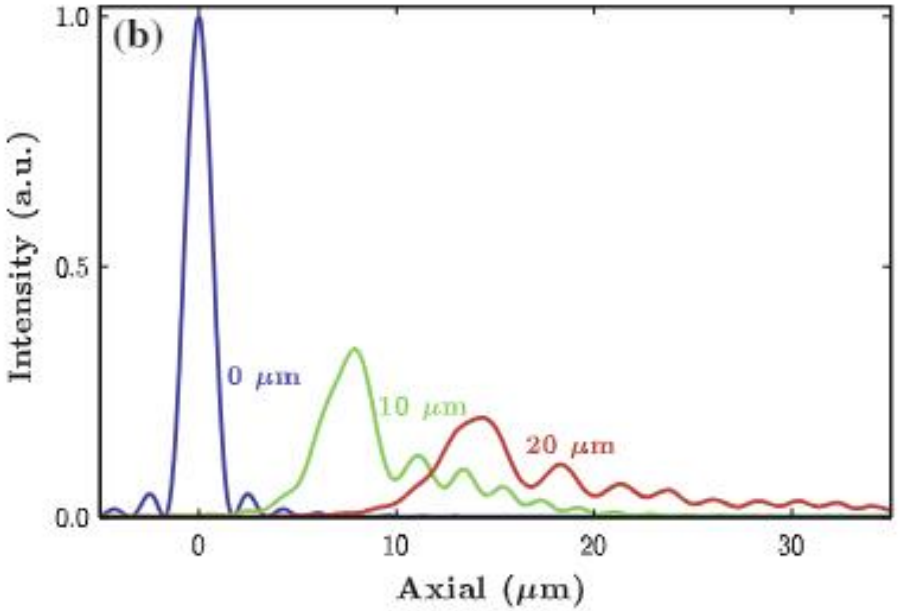
After dynamical Correction with piezo-driven mirrow

Besides: Reduce the z-scaning time and increase the number of averaged measurements

Systematics: spherical aberration

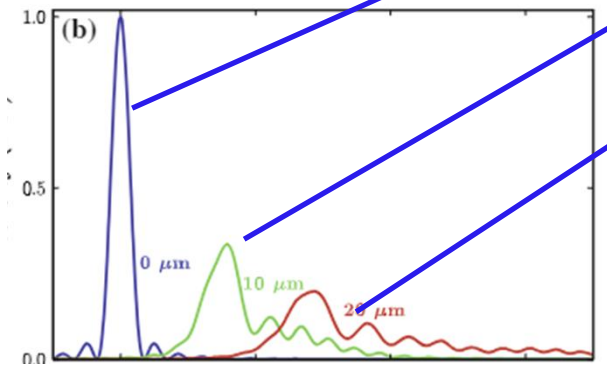




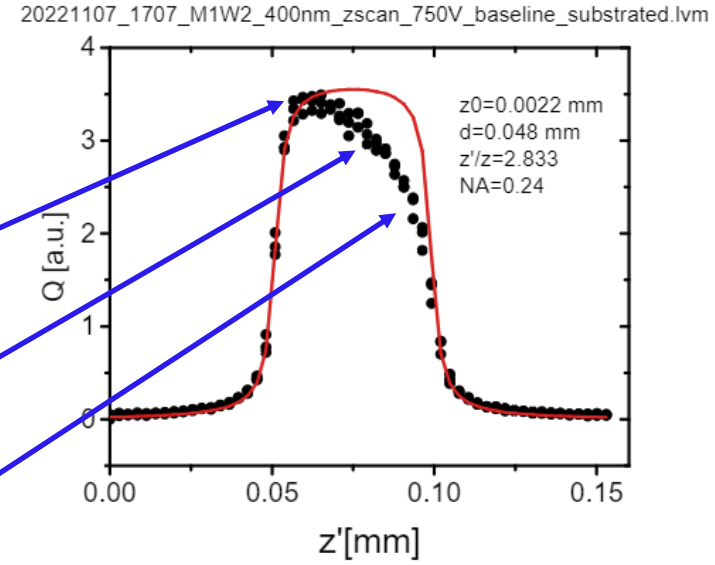


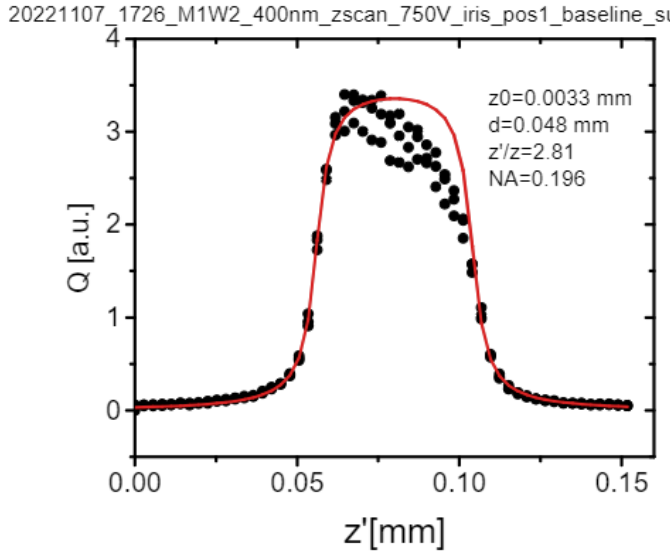
Calculated focal intensity distribution when the wave plane is focused to 0, 10 and 20 um with a large NA due to te spherical aberration (no SiC).

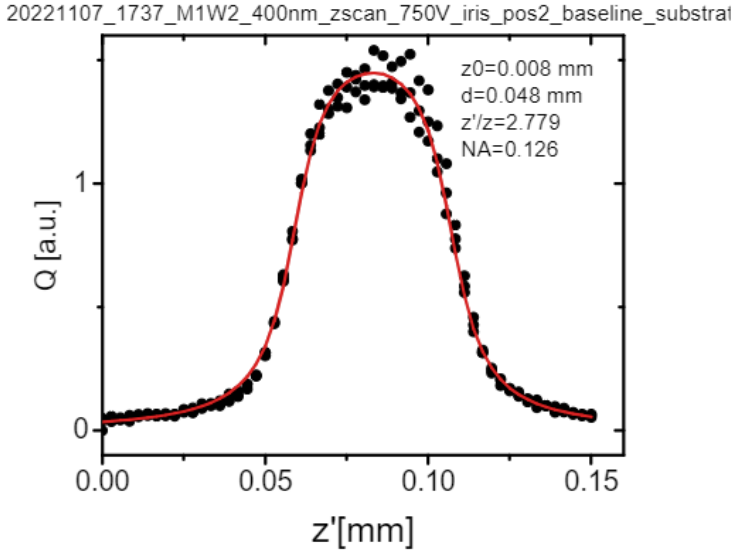
Systematics: spherical aberration (2)

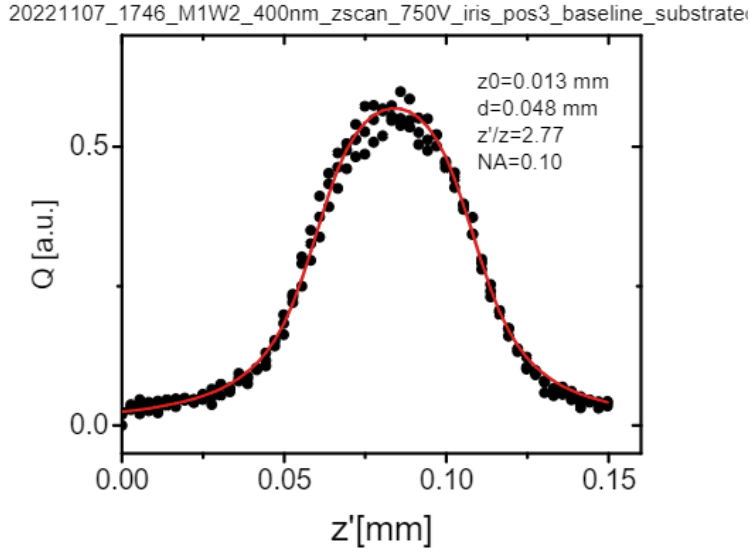


Axial intensity profiles





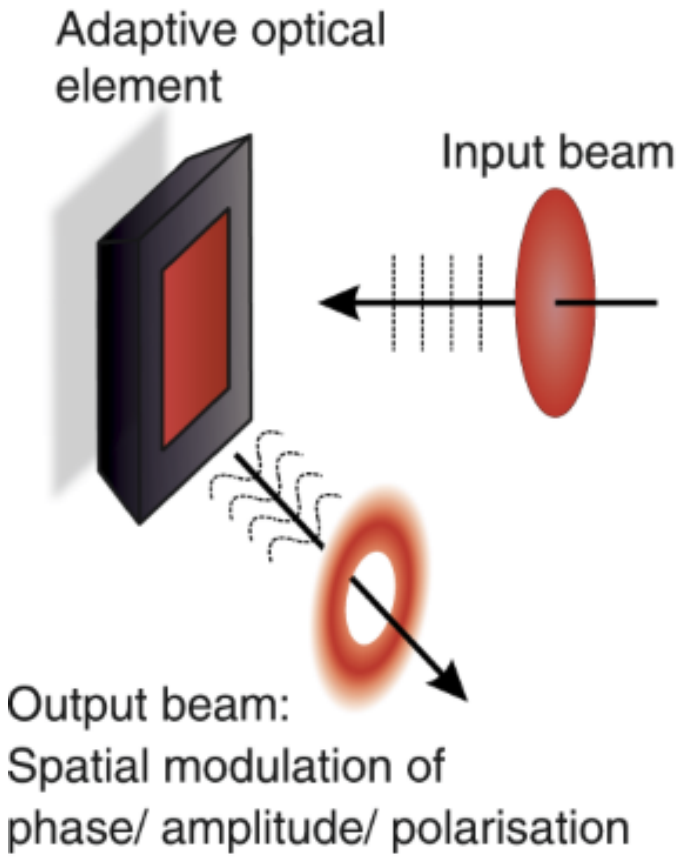


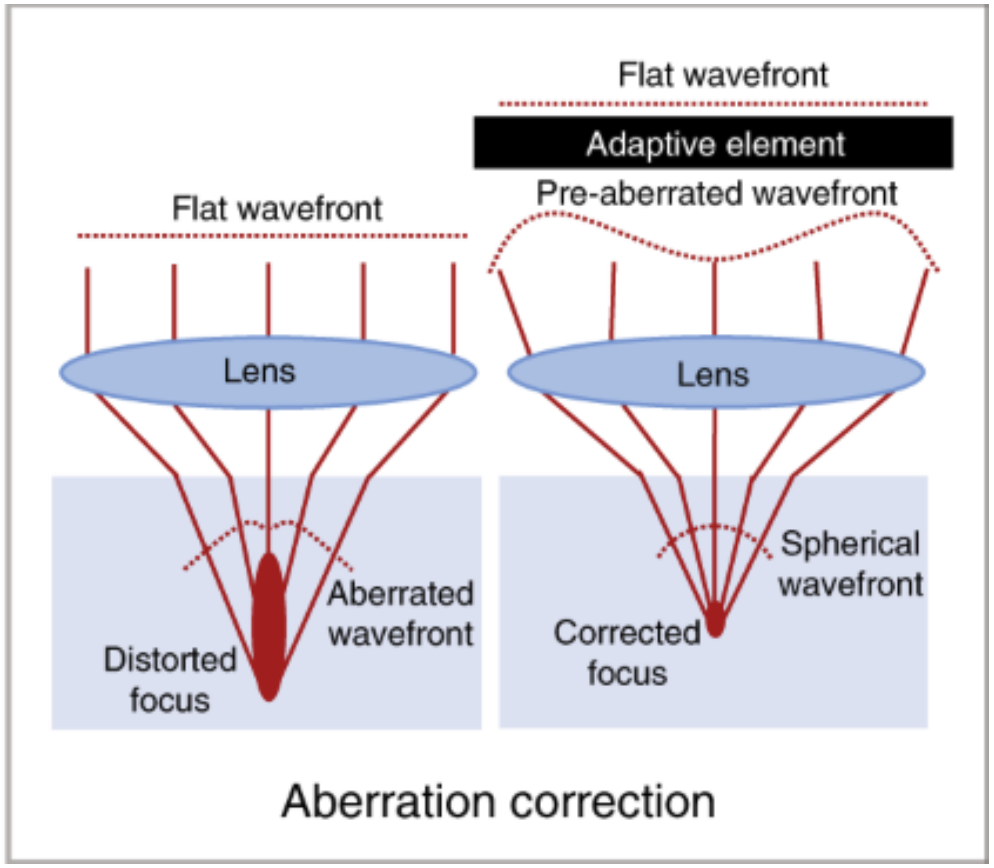


– z-scan profiles dependence with effective NA

Systematics: spherical aberration correction

– Implementation: The SLM is placed in the optical path to modify the wavefront of the laser beam, effectively cancelling out aberrations introduced by the system or sample.





Proposal for a permanent TPA-TCT test stand for the characterization of wideband semiconductors

- Laser facility at UPV/EHU open to DRD3 user about 4-5 weeks a year.
- Standard measurement campaign: 70% of the time invested in setup installation and commissioning.
- Common Project to create a permanent test-stand for wide band semiconductor TPA-TCT characterization (Diamond, SiC, GaN)
- Including:
  - Fluctuations corrections: TPA-TCT reference arm.
  - Beam stabilization: Piezo loop for pointing stability.
  - Aberration correction: Spatial Light Modulator for front shapping.
  - Scanning piezo electric stages for fast sample positioning.
  - Alignment laser and spot imaging camera.

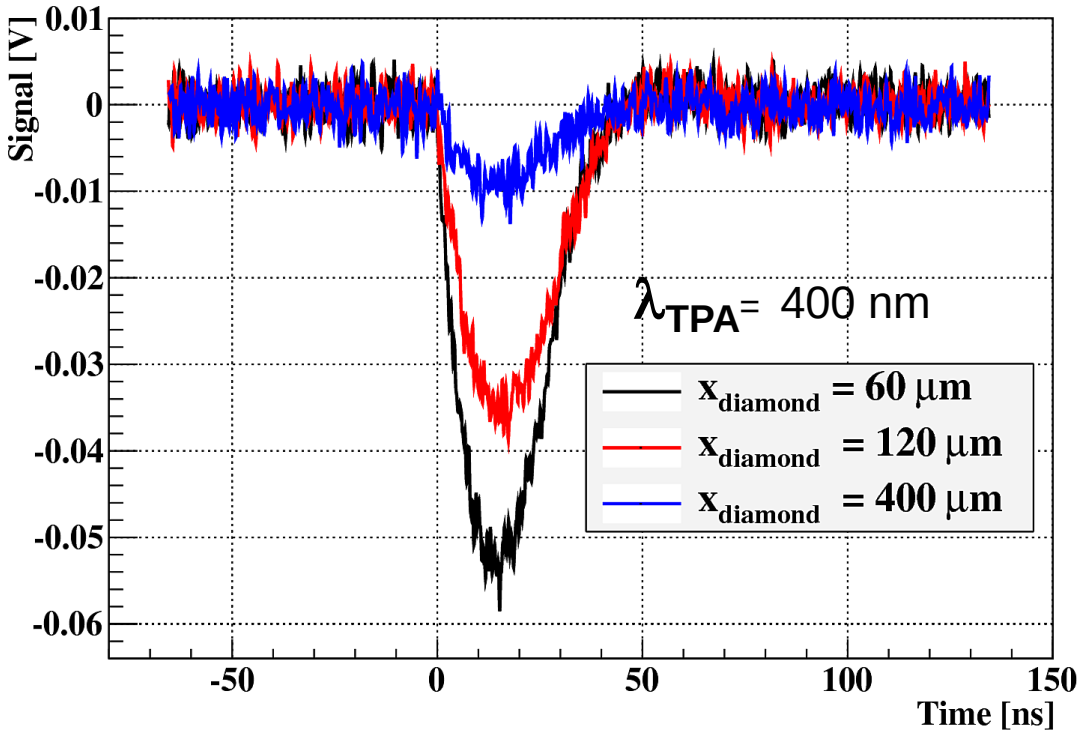
Summary

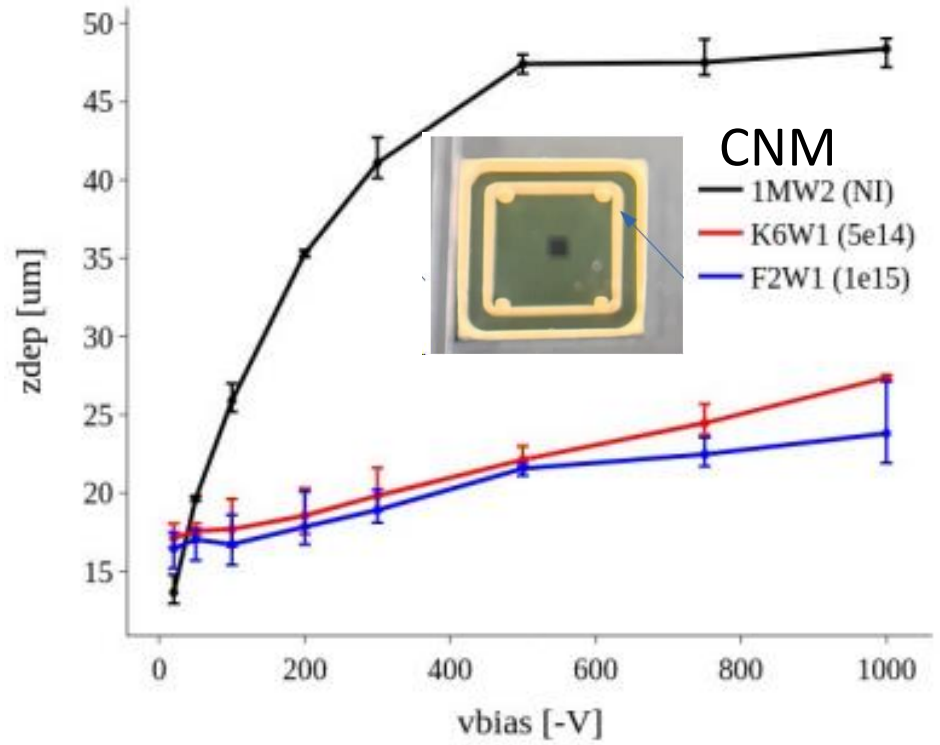
- TPA-TCT a high-resolution tools for SiC characterization.
- TPA-TCT quality currently limited by pointing stability and spherical aberration
- Dinamic beam stabilization to solve pointing inestabilities that drive the signal fluctuation.
- Spatial light modulation to remove optical aberration effects.
- A first introducion of a dedicated common project for stablishing a permanente TPA-TCT characterization setup for Wide Band semiconductors.

THANKS A LOT FOR YOR ATTENTION

TPA-TCT beyond silicon

TPA-TCT also used to study other materials. It has been demonstrated in **diamond** (RD42) and **SiC** (RD50), using 400 nm fs laser.





2016: proof of principle of TPA-TCT in **diamond** with 400 nm TPA at SGIKER (Bilbao).
See as well C. Dorfer,
https://doi.org/10.1063/1.5090850

2022: TPA-TCT in **SiC** with 400 nm TPA at SGIKER (UPV, Bilbao).
C.Quintana, 41st RD50 meeting