The Munich Stability Project

Garching, 10th May 2010

FOCES, a testbed for high stability spectroscopy

At the very beginning ...

Stability Project – Outline

- FOCES
  - A few words on the instrument
- Why
  - What degree of stability do we need
- What
  - Spectrograph stability
  - Illumination stability
  - Fiber stability
  - FOCES as testbed

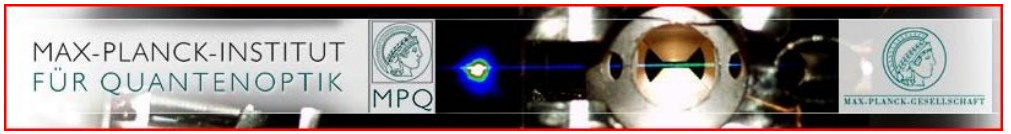
FOCES – an instrument introduction

- **Calar Alto** 2.2m (1997-2009)
- R=46000/64000 on 24/15µm CCD
- L-N2 cooled
- Moving parts (slit, grating, prisms..)
- Un-stabilized
- S/N=100 for 10th mag G-star: 1h

- **Wendelstein** 2m (2010/2010...)
- R=70000 on 13.5µm CCD
- Peltier cooled
- No moving parts
- P,T stabilized
- S/N=100 for 10th mag G-star: 1h

Who?

- MPQ + Lehrstuhl Hänsch (@LMU)
  - Theodor Hänsch
  - Thomas Udem
  - Tilo Steinmetz



- Menlo Systems
  - Ronald Holzwarth

- MPE + USM
  - Ralf Bender
  - Frank Grupp

- ESO

Why?

- Precission radial velocity work aims for sub m/s regime (planets, astro-seismology)

That's the speed of a pedestrian walking...

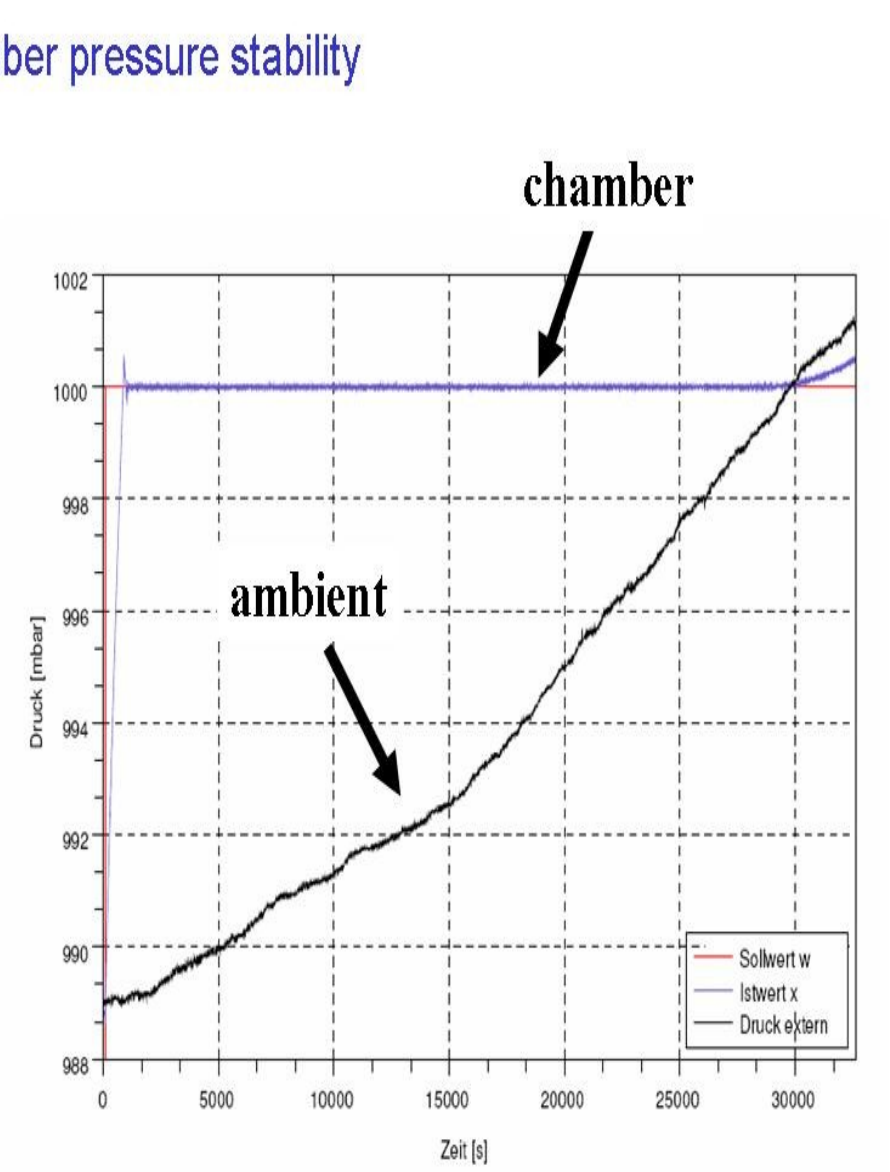
- 1m/s ≈ 1/3000 of a pixel on a R=70000 Échelle machine with 13.5µm pixel size
- We need enormous stability
  - Of the spectrograph itself (T,P,bend, …)
  - Of the spectrograph slit illumination
    - Fiber illumination stability (seeing, guiding, coherent-incoherent light coupling)
- Fiber “throughput” stability (modes)

Spectrograph stability (1)

- Two concepts:
  - HARPS is kept in vacuum and is very well thermalized
  - PEPSI is kept under constant – near environmen pressure – and also well thermalized
- FOCES based ZEMAX simulations on "what P,T stability do we need?"
  - Strongly simplified
  - Intention is to understand "where things happen"

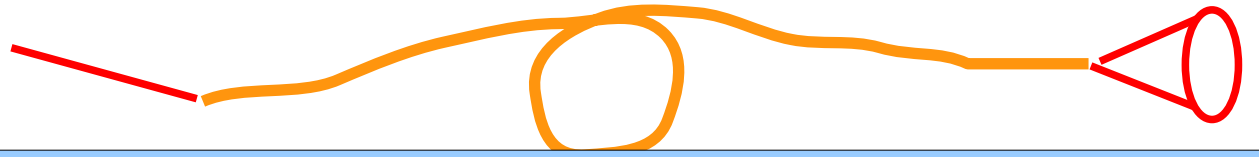
Spectrograph stability (2)

- A glimpse on the results (dx vs. dP)
- Almost linear
- “Problem” arises at the cross dis-perser prisms
- ±0.4hPa should be a good stability goal
- This is achieved by PEPSI



Illumination stability (1)

- A simple – non modal - view on the problem

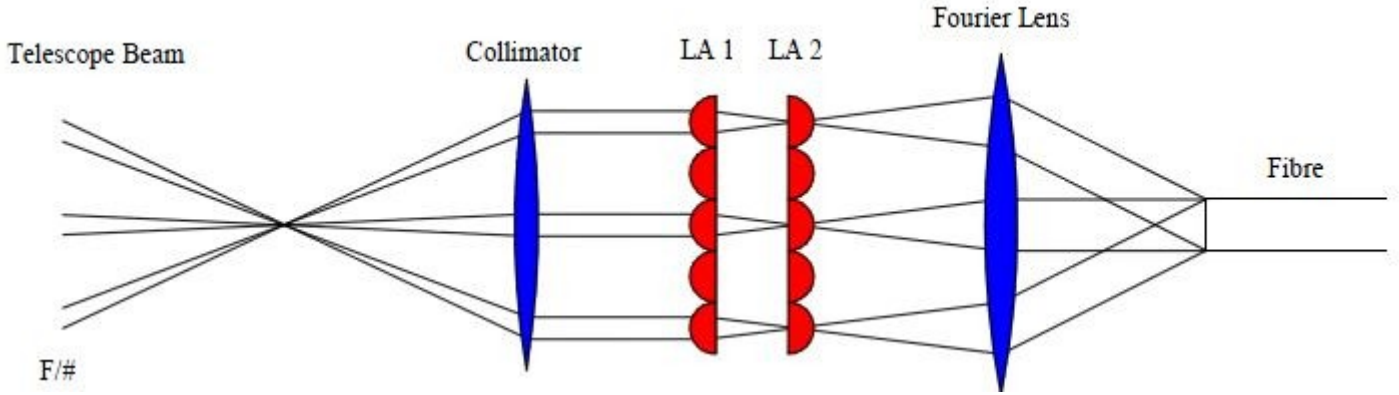


- Illum…le
  → co…
- Fibe…
- Chan…ging the input -angular- distribution of light changes the light distribution at the fiber exit
  → Slit illumination changes!!!

- With modes the situation even becomes more granular and complex

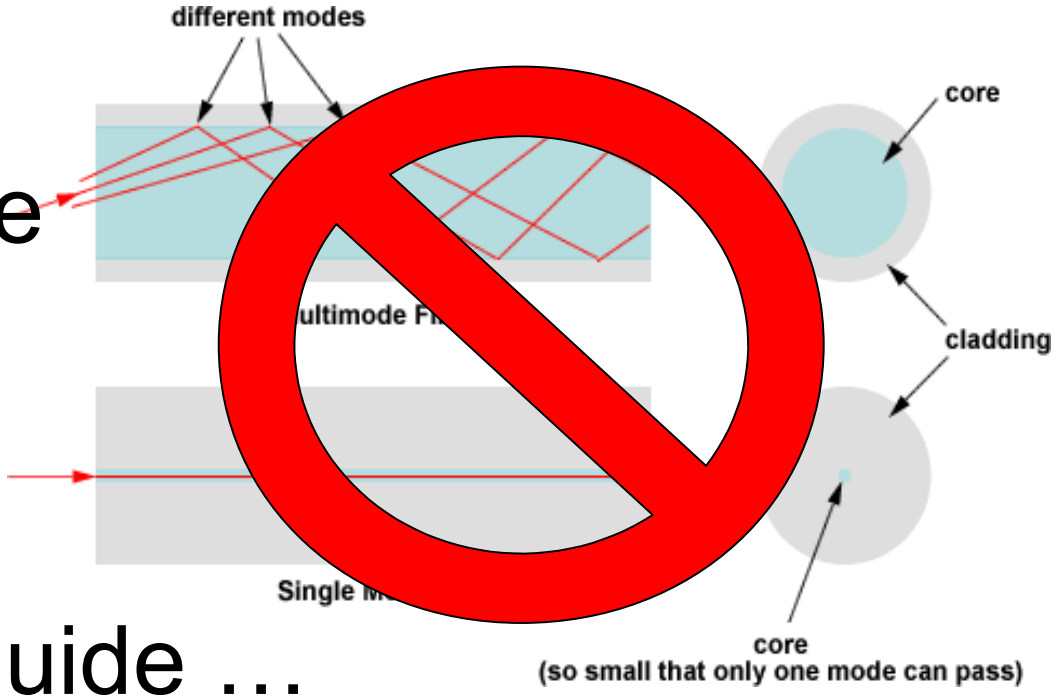
Illumination stability (2)

- As we will always experience seeing and guiding variations we need:
  - Means of making an inhomogeneous beam (more) homogenous



Throughput stability – modes (2)

- What are fiber modes
- Like microwaves are guided in a hollow waveguide …
- … light is guided in a dielectric waveguide …

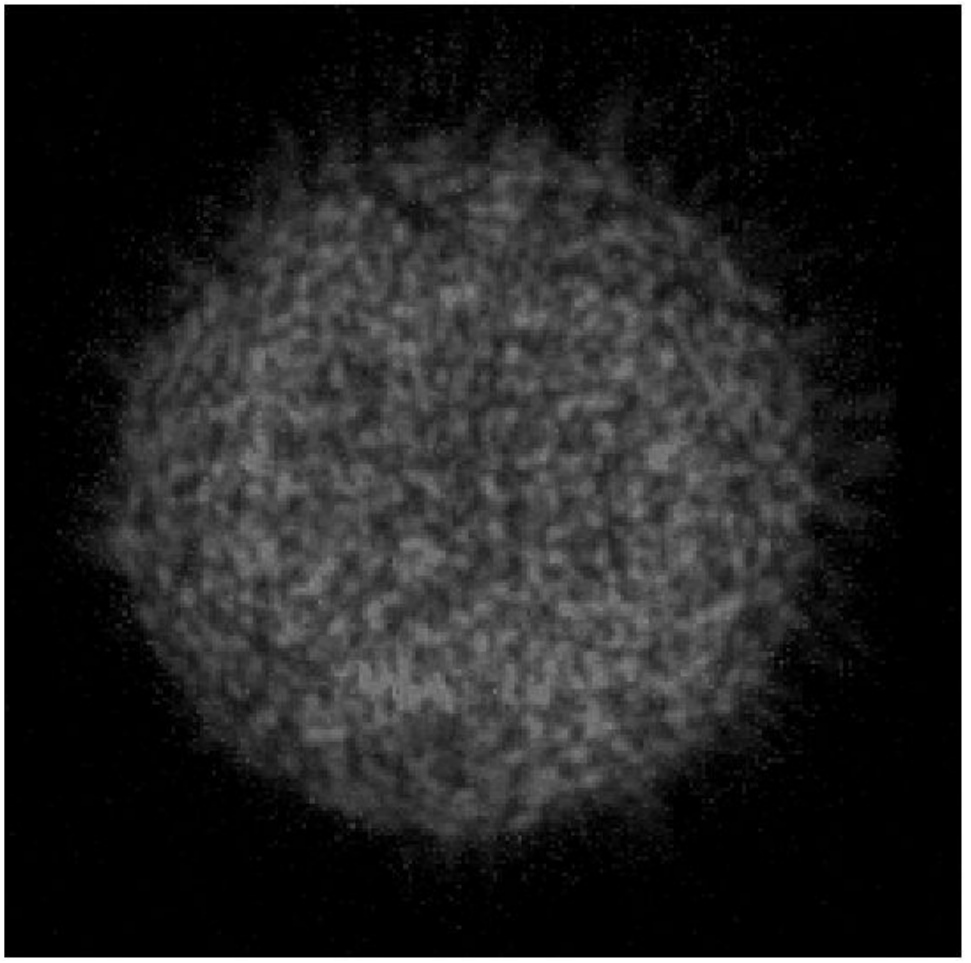


- Suddenly we leave the field of ray optics!!!
- Like in the hollow waveguide modes depend on geometry and size of the waveguide

Throughput stability – modes (3)

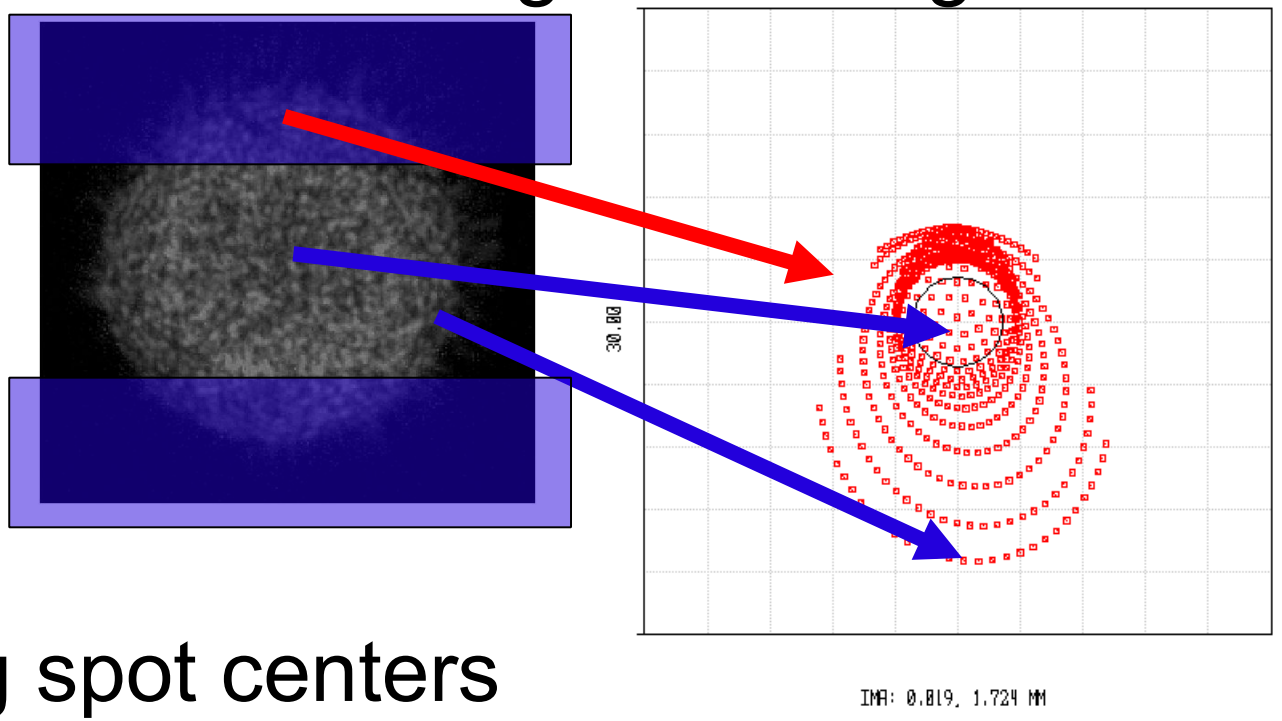
- How do fiber modes look like?
  - Number of modes: $M = 2\pi^2 \frac{R^2}{\lambda^2} \sin^2\left(\arctan\left(\frac{1}{2f}\right)\right)$

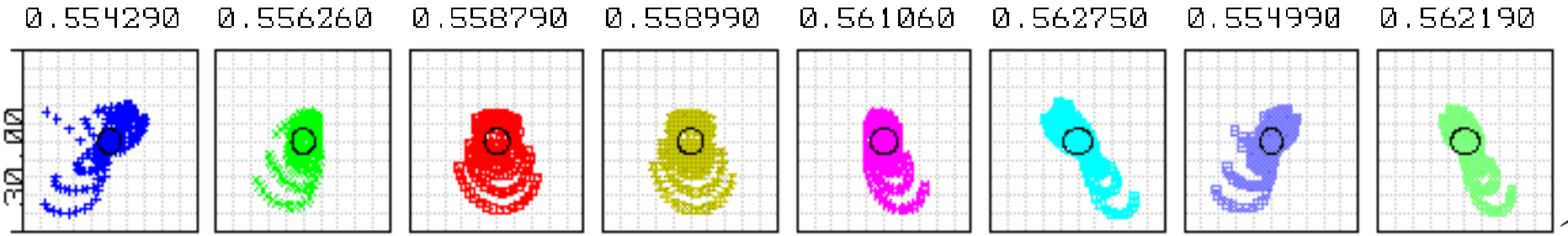
A real 100µm astronomical fiber, illuminated with a red laser pointer M>10000



Throughput stability – modes (4)

- Modes are correlated with angles feeding the spectrograph
- Each mode is imaged to a certain position on the CCD
- Moving modes result in moving spot centers
- A certain spot=wavelength jitters !





Status – Stability project

Outlook – Stability project

Stability – The end ....

- … or the beginning of a better understanding
- We (astronomers)need help!
  - The quantum optics view on fibers
  - Better means on “scrambling” light
  - New and better design ideas
- **Thank you for your time and dedication**

Advert for SummerSchool