TITLE

Thermal lensing in IO-components

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TASK

To provide LIGO II with active optical crystals that

- **can handle 150 W**
- **have a well known thermal lens**
- **do not degrade the spatial TEM00-mode by more than 2%.**
- **have a small spatial birefringence.**

That are

- **Faraday Isolators that**
  - **have an isolation of around 40dB**
- **electro optical modulators**
  - **can modulate the phase with a modulation index of 0.5 with reasonable drive voltage.**
  - **have a small RFAM (it's not as essential as in LIGO I)**
  - **with an amplitude stability of** $< 10^{-9}/\sqrt{Hz}$[a]

Started a program at UF to test different designs/components.

Present program and first results.

[a] all specs are subject to change without notice

INFRASTRUCTURE

Lasers:

- **55W-1053nm Nd:Ylf, arc lamp pumped (Photonics Industries)**
- **10W-1064nm Nd:YAG, diode pumped (Light wave)**
- **700mW NPRO, diode pumped (Light wave)**
- **15mW HeNe**

Ways to measure the beam shape:

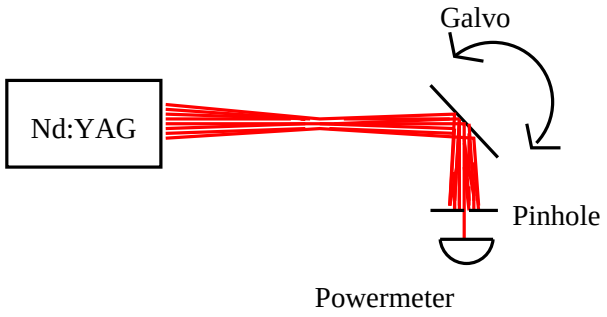
- **Chopper**
- **Galvos+Pinhole (MIT-Phase camera)**
- **Shack-Hartmann Detector**
- **beam scan (not yet)**
- **Interferometry**

Goal is to measure the:

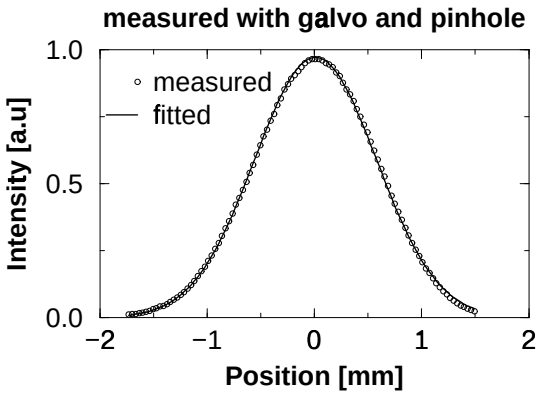
- **thermal lens**
- **thermal degradation of the beam**
  - **in shape**
  - **in polarization**
  - **phase (RFAM-in EOM)**
- **thermal time constant**
- **degradation of the crystal (if any).**

BEAMPROFILES

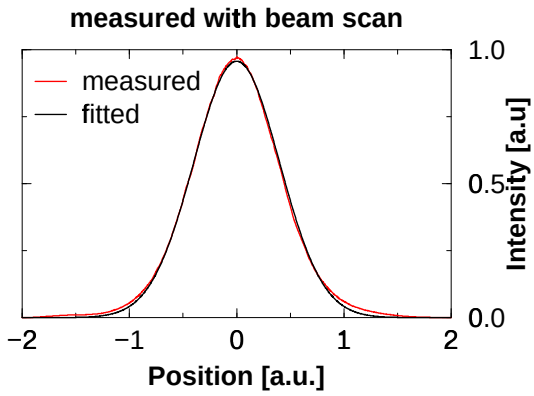
Profile measurement with Galvo



10W−beam profile



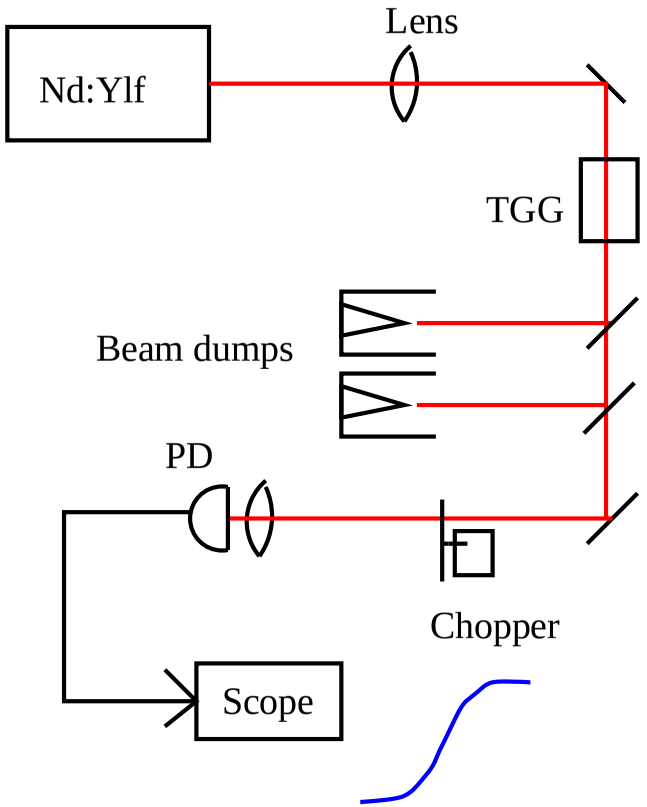
55W−beam profile



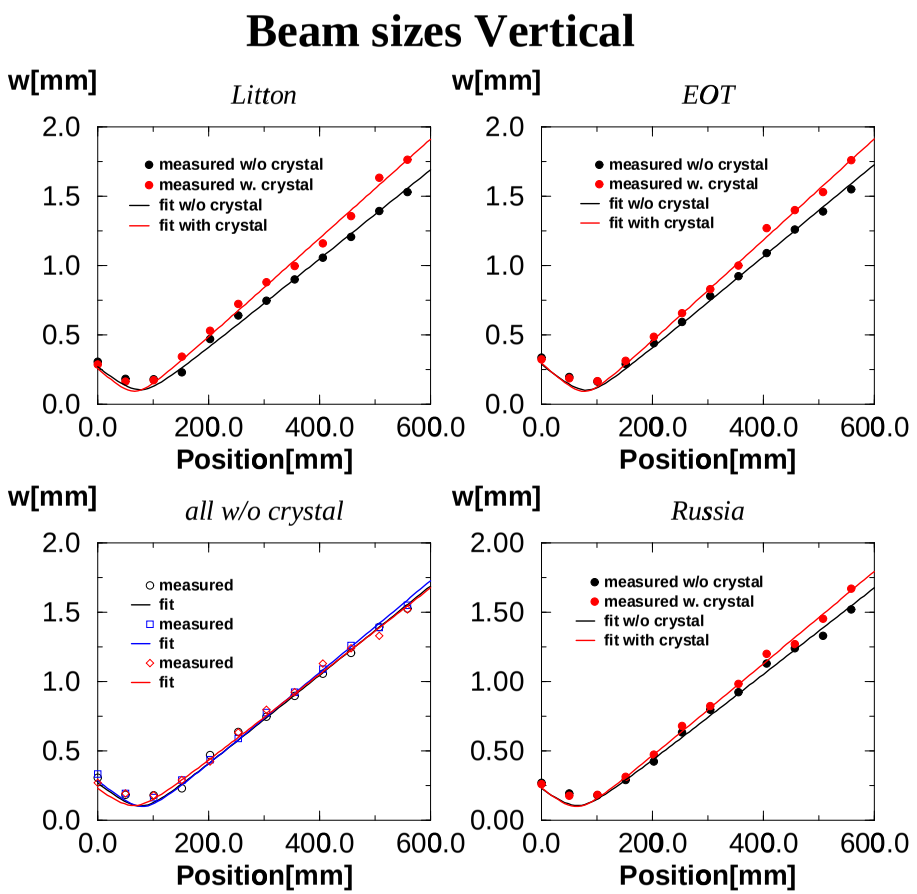
both profiles show the potential of the lasers and of the diagnostics.

Unfortunatly, the 55W is not long term stable yet.

THERMAL LENS IN TGG



Result: Thermal lens of 5000mm (+/-2000) for a 1mm-50W laser in 20mm TGG.



THERMAL LENS IN TGG

Results in 20mm TGG:

$$P = 50\ W \qquad w = 1\ mm \qquad \Rightarrow f = 5\ m \quad (+/-2m)$$
$$P = 150\ W \qquad w = 1\ mm \qquad \Rightarrow f = 1.5m$$

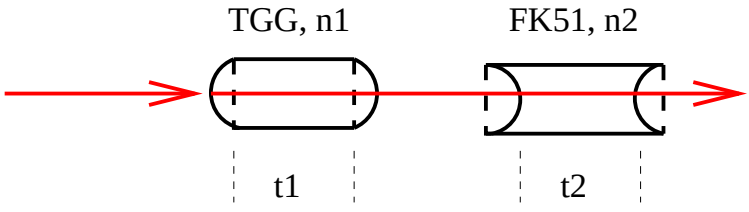
Can be included in mode matching calculation.

2 Problems:
Get a non Gaussian beam shape ?
Only mode match with full power ?

$$f = R/2(n-1) \approx R \qquad n_{TGG} = 1.55 \qquad ds = w^2/2R$$

$$P = 50\ W \qquad \Rightarrow ds \approx 100nm \qquad \Rightarrow TEM_{00} \approx 99\%^a$$
$$P = 150\ W \qquad \Rightarrow ds \approx 300nm \qquad \Rightarrow TEM_{00} \approx 95\%$$

Compensation:
Use of material with $dn/dT < 0$,
for example: FK 51, BBO, NaCl, ...



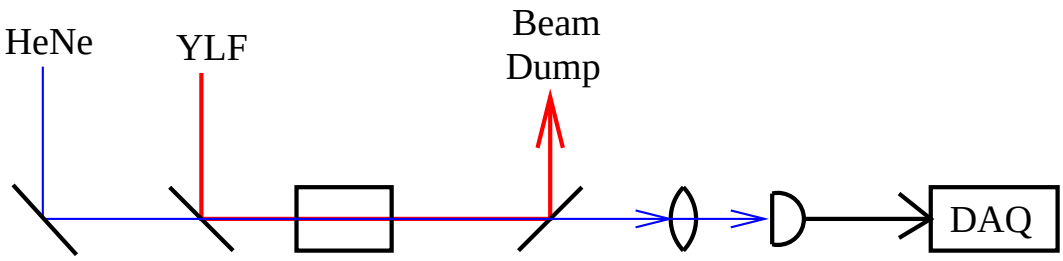
Optical Path length difference:

$$\Delta n_1(r)t_1 + \Delta n_2(r)t_2 = OPD(r)$$
$$\Delta n_i(r) = T_i(r)dn_i/dT$$

is a function of material, absorbed power and length.

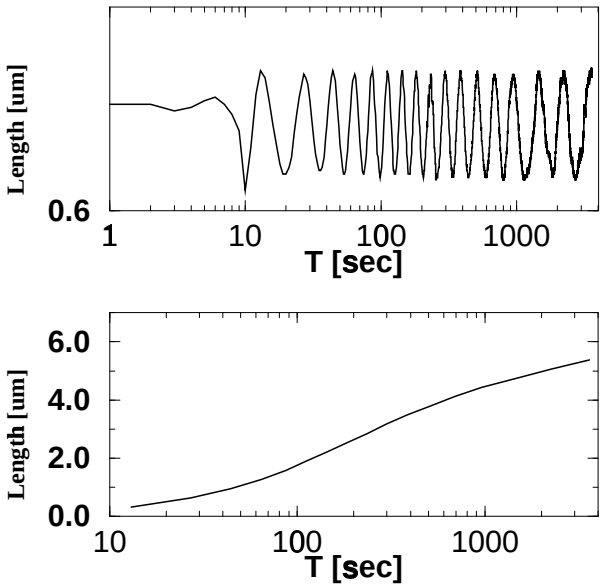
[a] D. Reitze, priv.comm.

THERMAL EXPANSION



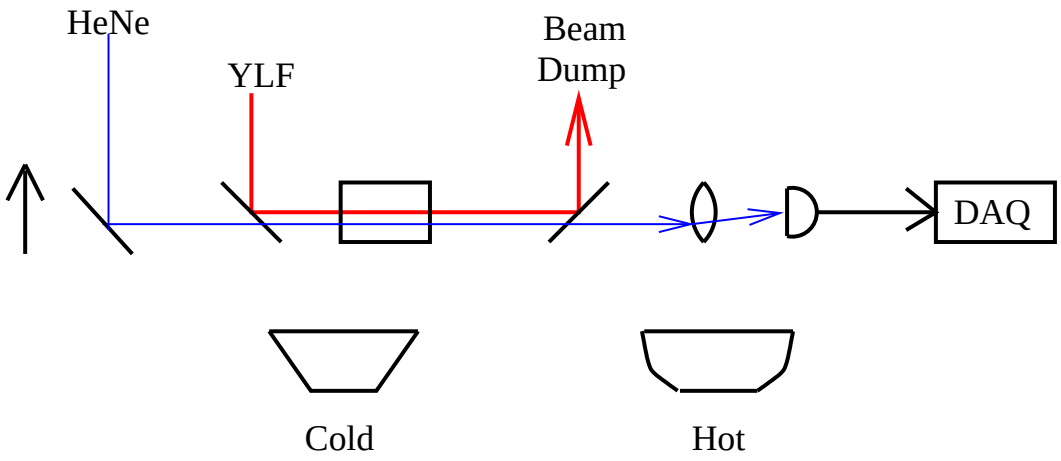
Count Newton fringes during thermal expansion.

Thermal Expansion of TGG at 50W



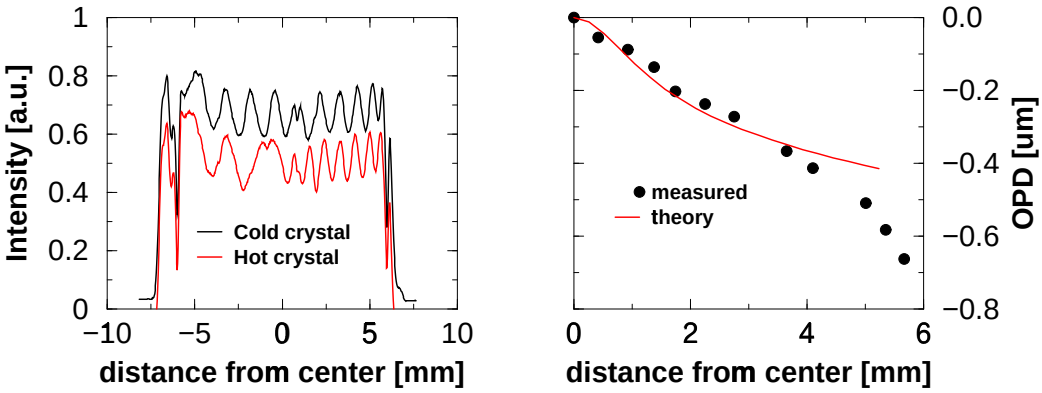
length change: 5.7 μm (+/-300nm)

OPD-PROFILES



Scan over crystal and compared location of max/min

Optical Path Length Difference (OPD):



Sagitta of 100nm at 1mm.

Similar to thermal lensing results.

SUMMARY

High Power testing program started with:

- **Characterization and optimization of the lasers, especially the 55W-YLF.**
- **Testing and comparing various detection methods.**
- **first experiments show: f=5m at 50W in 20mm TGG.**
- **more results in additional talks...**
- **started modelling the propagation**

It’s on its way.