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LIGO-IAP Laboratory Research Report

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Currently:

3 year (1999-2002) NSF-supported UF/IAP collaborative project "Methods and Instruments for High-Precision Characterization of LIGO Optical Components"

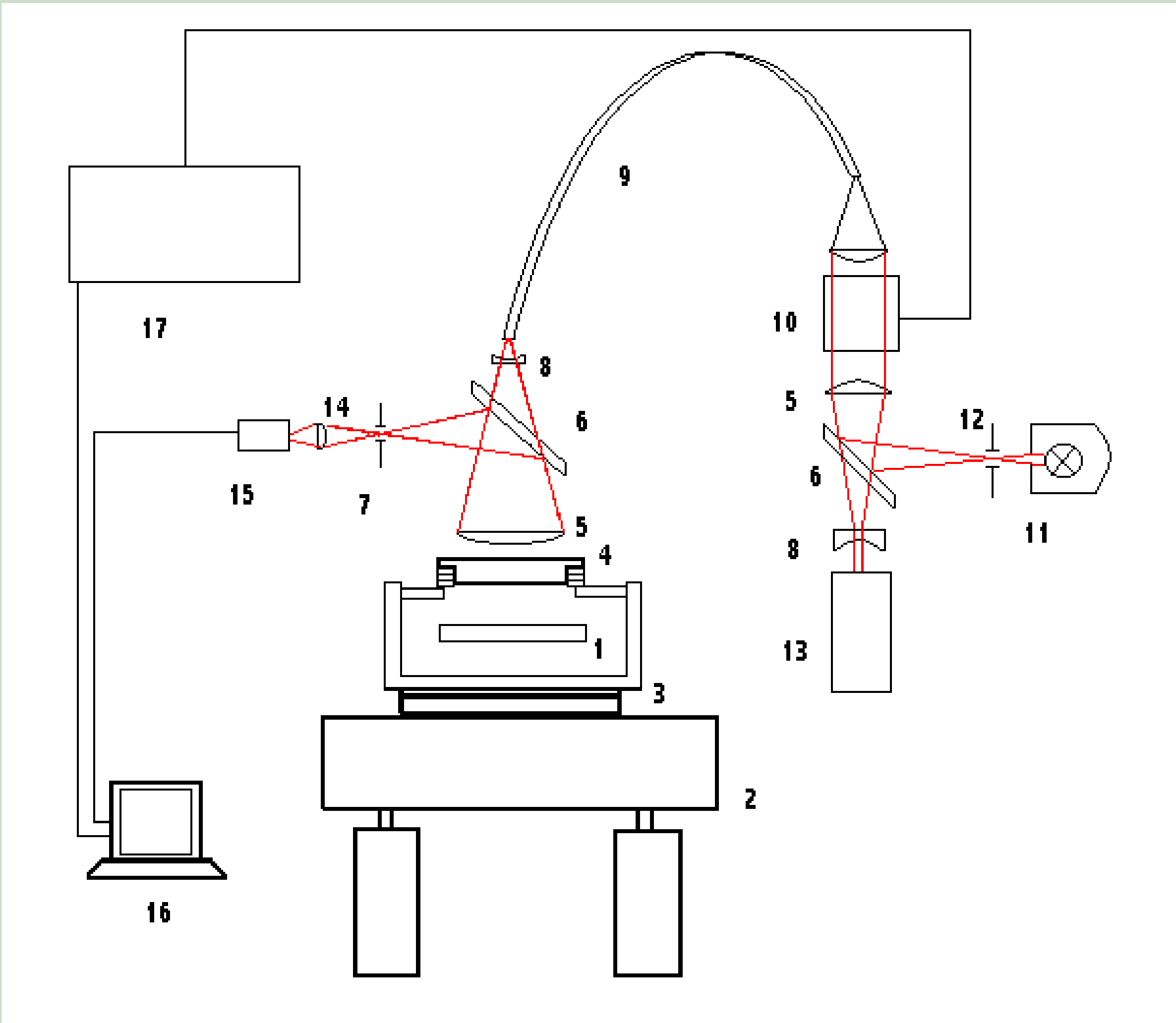
Livingston, 2002

Current Research

- **Large aperture white-light phase-modulated interferometer (WLPMI) for preliminary control of LIGO Core Optics**

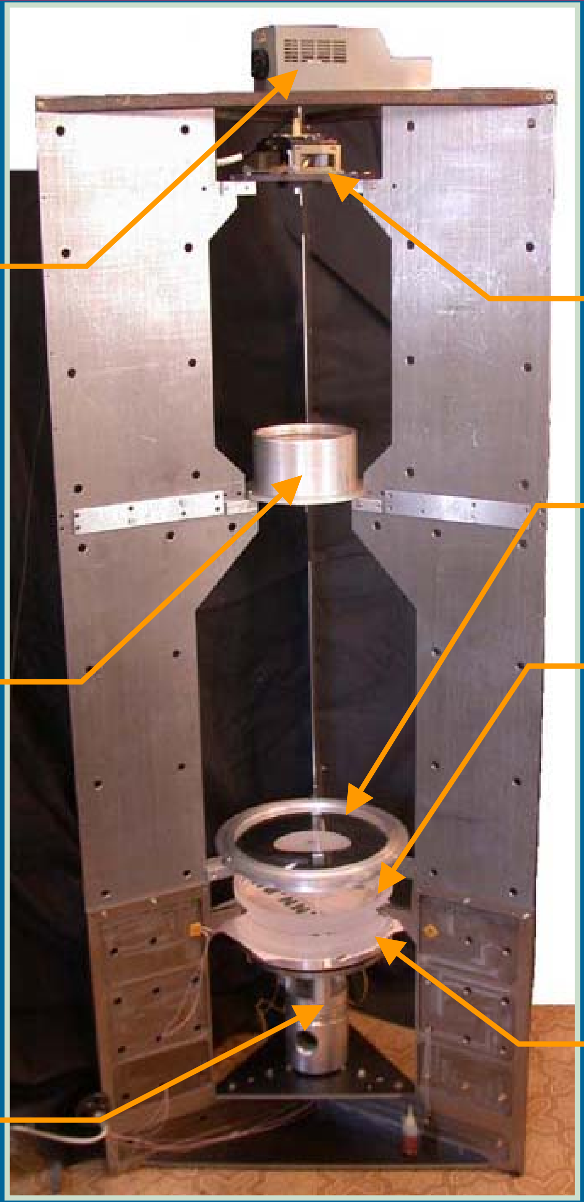
- **Remote *in situ* monitoring of weak distortions emerging under auxiliary laser heating similarly to what is expected in advanced LIGO core optics**

Large aperture white-light phase-modulated interferometer (WLPMI) for preliminary control of LIGO Core Optics



1 – sample
2 – optical table
3 – damping mount
4 – reference plate
5 – collimating lens
6 – beam splitters
7 – spatial filter
8 – lenses
9 – fiber bundle
10 – spectral modulator
11 – white light source
12 – aperture
13 – He-Ne laser
14 – projection lens
15 – CCD-camera
16 – computer
17 – control unit

Large aperture white-light phase-modulated interferometer (WLPMI) for preliminary control of LIGO Core Optics



White light source

Beam splitters

Collimating lens

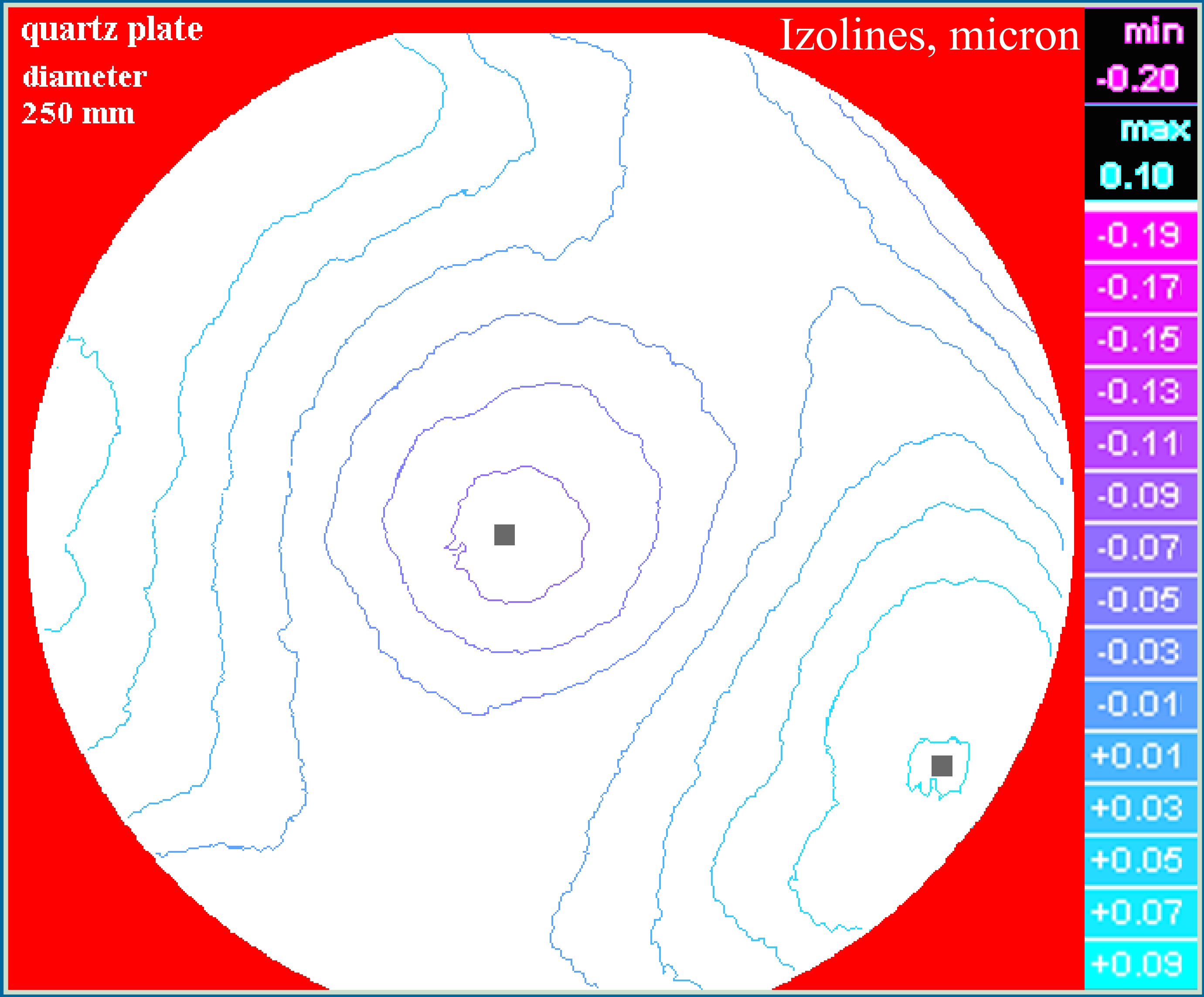
Lens

Reference plate

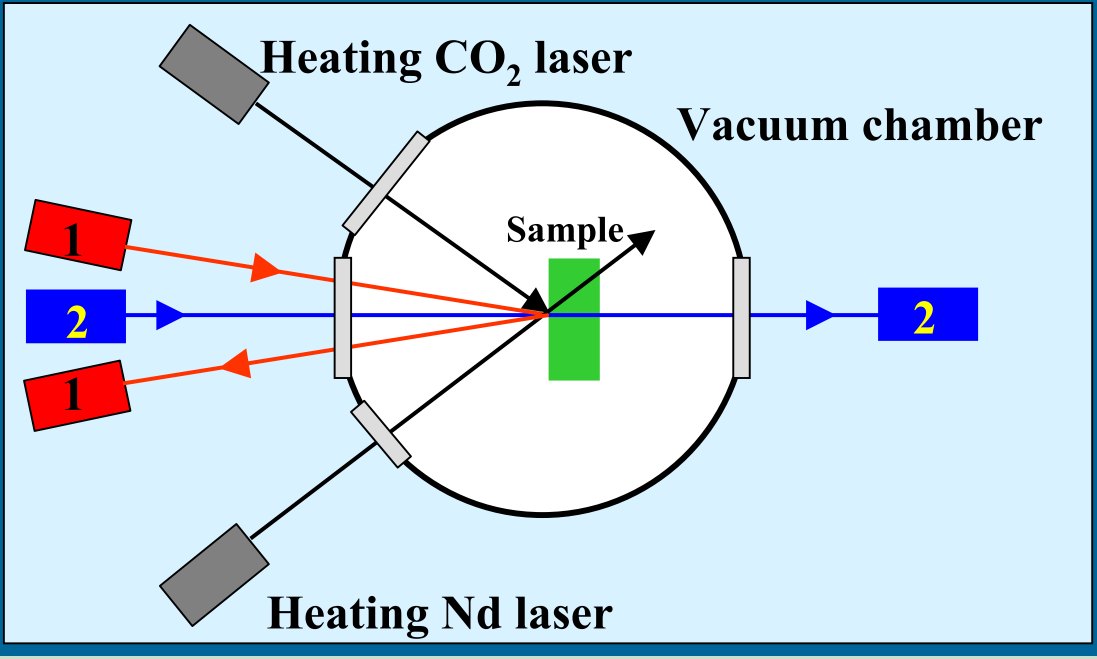
Sample, 25 cm diameter

Damping mount

25 cm aperture phase map of two quartz plate gap, recorded with white-light phase-modulated interferometer (WLPMI)



Remote *in situ* monitoring of weak distortions emerging under auxiliary laser heating



1 - WLPMI
2 - NHS and PIT

- Optical sample bulk heating by the fundamental or second harmonic of Nd:YAG laser at a power of 10-20 W
- Surface heating with the use of a CO_2 laser at power of several Watts
- Inducing contamination of a small region (characteristic size of 20-100 micron) on the optical element's surface and focusing of low-power laser radiation (<100 mW) on it

Remote *in situ* monitoring of weak distortions emerging under auxiliary laser heating similarly

Using vacuum environment and auxiliary laser heating we will induce controllable large-scale and small-scale surface and bulk heating effects and characterize them by constructing optical thickness and wave-front inclination maps

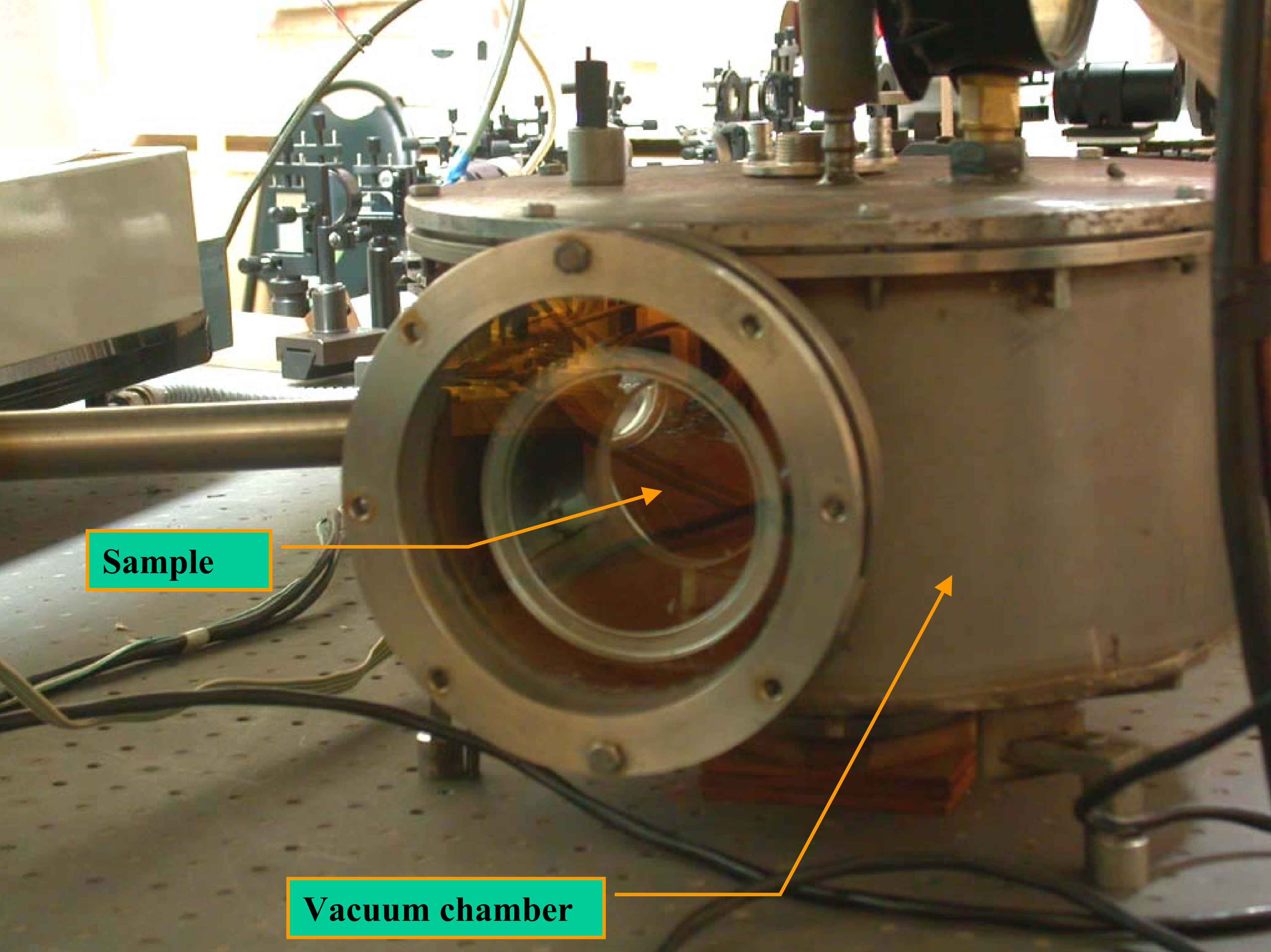
Following measurement techniques have been developed and used:

1. Scanning linear Hartmann sensor

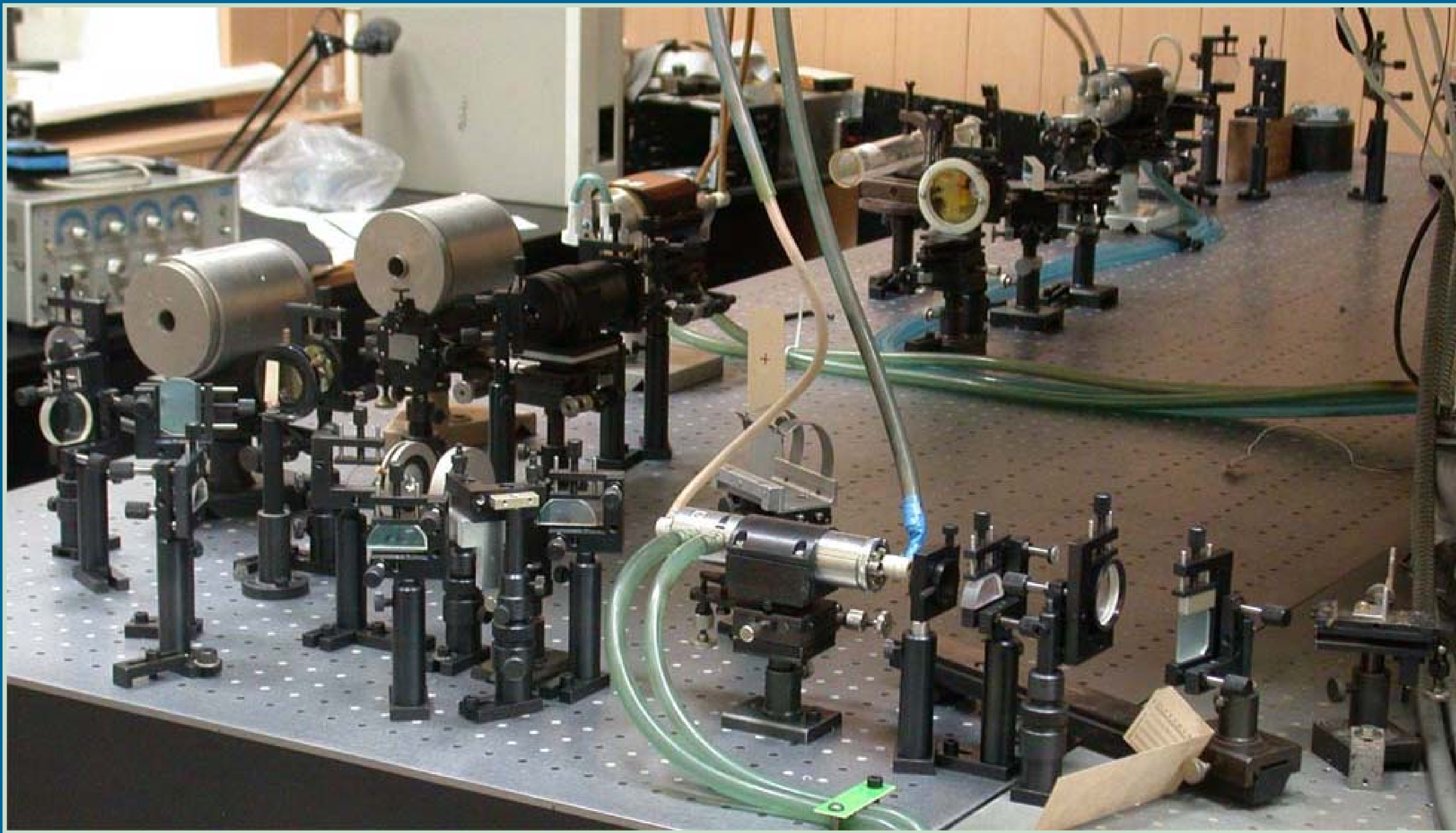
2. White light *in situ* measurement interferometer (WLISMI)

With these techniques, $\lambda/400$ precision was demonstrated and better than $\lambda/1000$ is expected in further *in situ* experiments

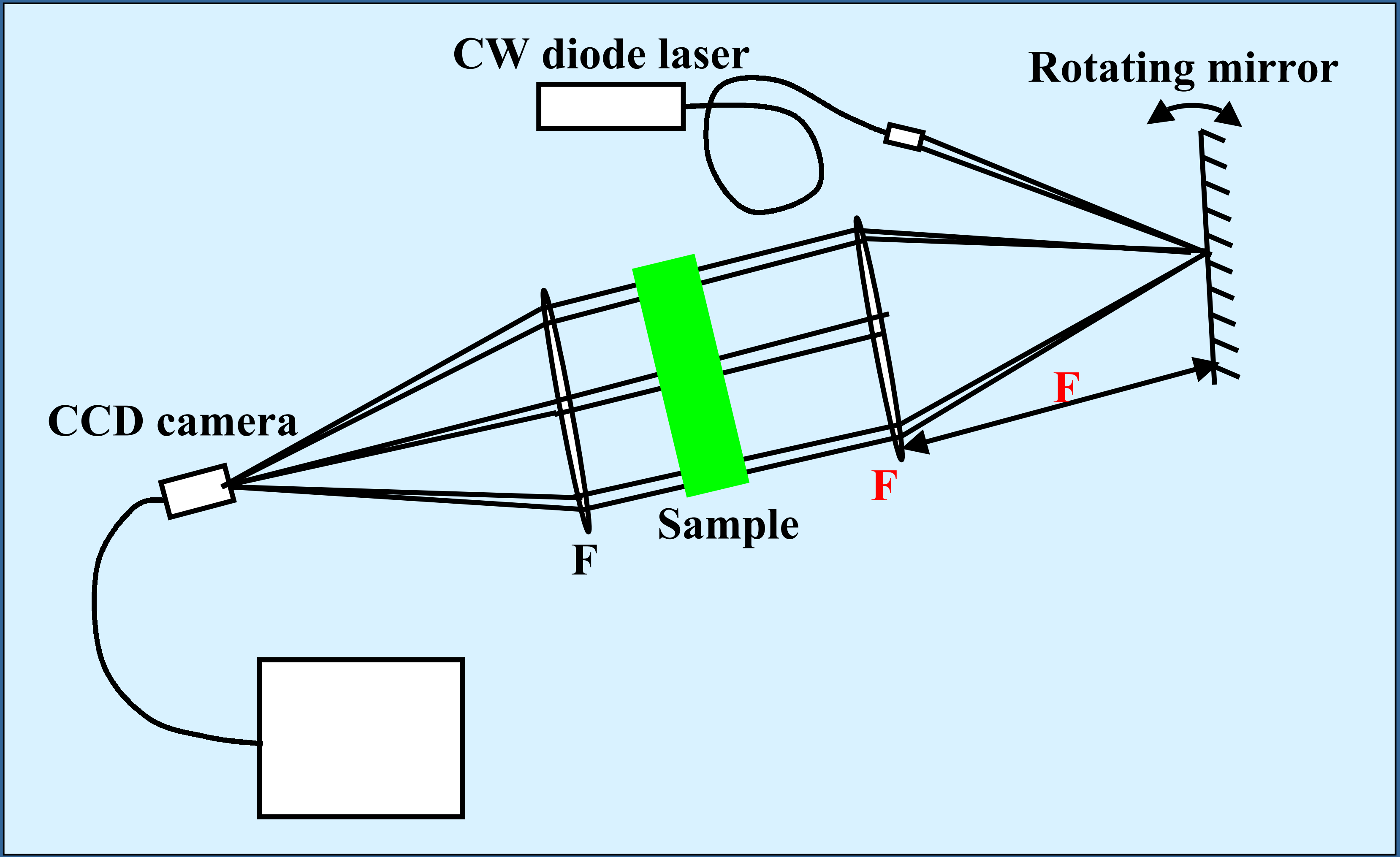
LIGO-IAP Laboratory


Sample
Vacuum chamber

50 W average power, 25 Hz Nd:YAG laser for auxiliary bulk heating of optical samples



Scanning Linear HartmannTechnique

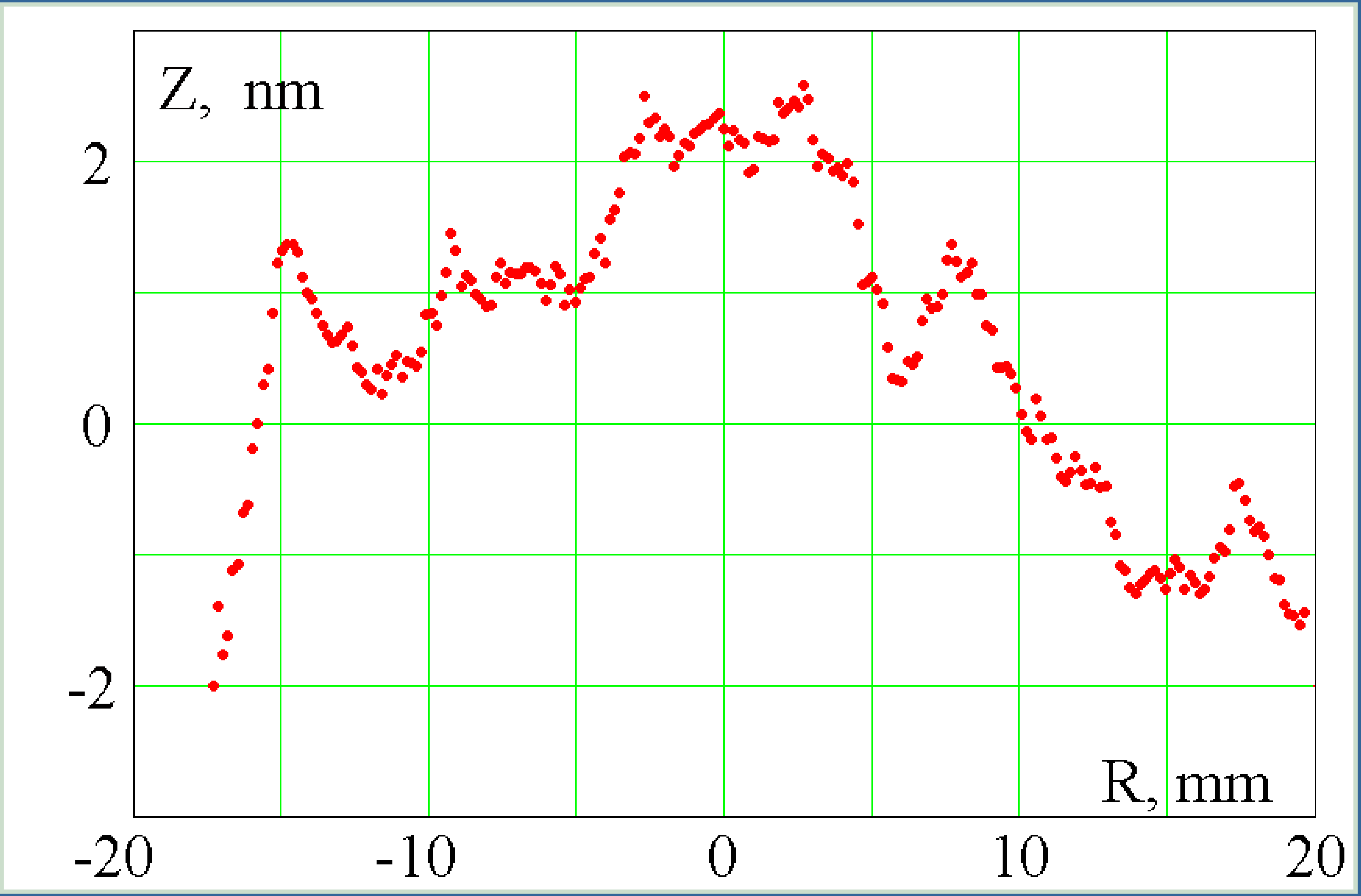


Scanning Linear Hartmann Technique Characteristics:

- 1d scan over 50 mm requires 60 s (120 data points), mainly due to computer processing (maximum extracting)
- 25 Hz standard video output CCD camera
- 1064 nm CW single-mode laser diode with few milliwatt in fiber output

Scanning Linear Hartmann Technique Accuracy:

- **Calibration by extracting two similar data sets, 24 hours in between**



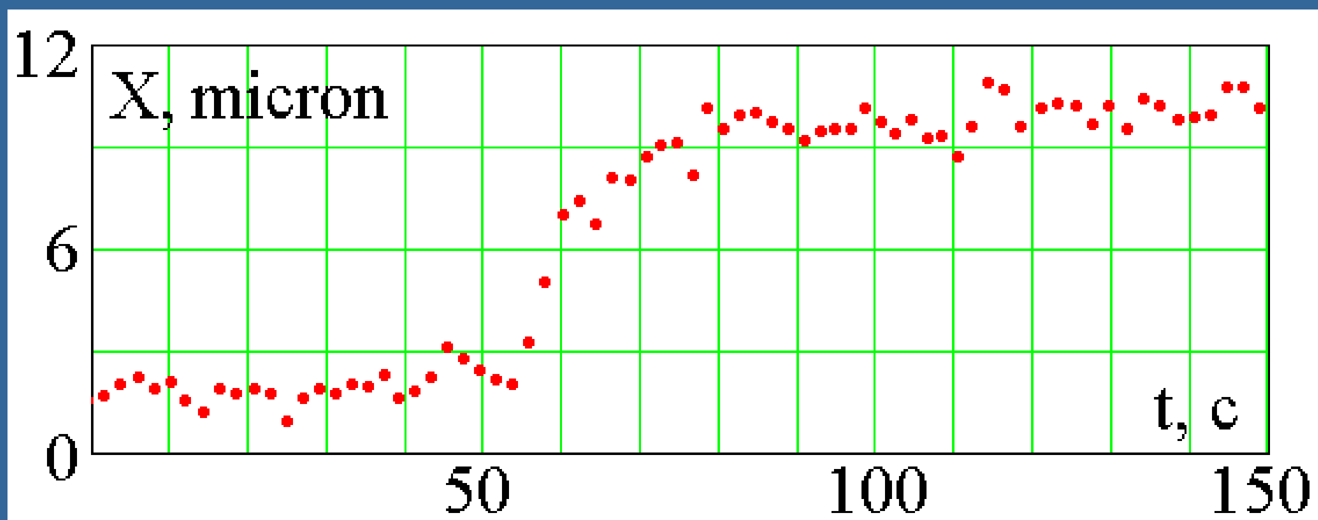
Measurement of temperature gradient set-up in two transverse directions:

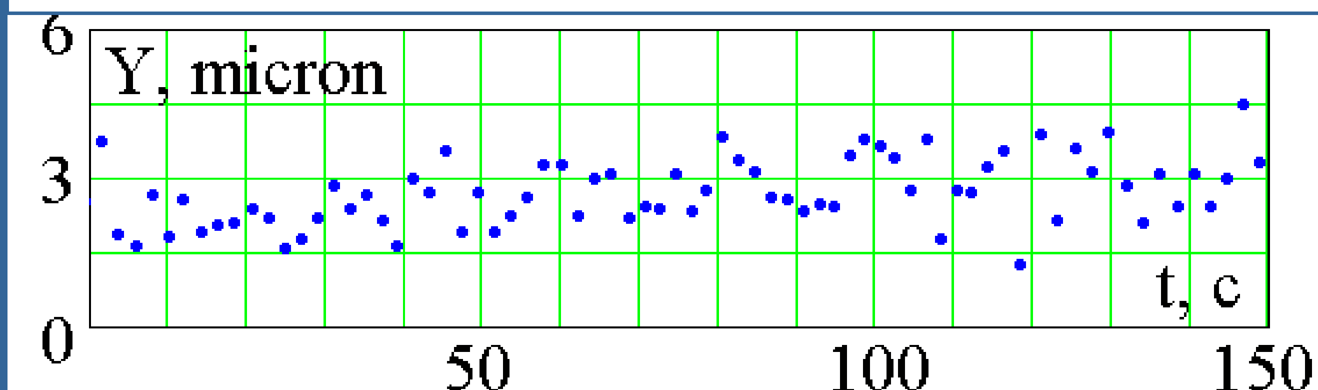
CO_2 laser - 120 mW

Central temperature increment estimate - 15-20 C^0

Beam size - 1 mm

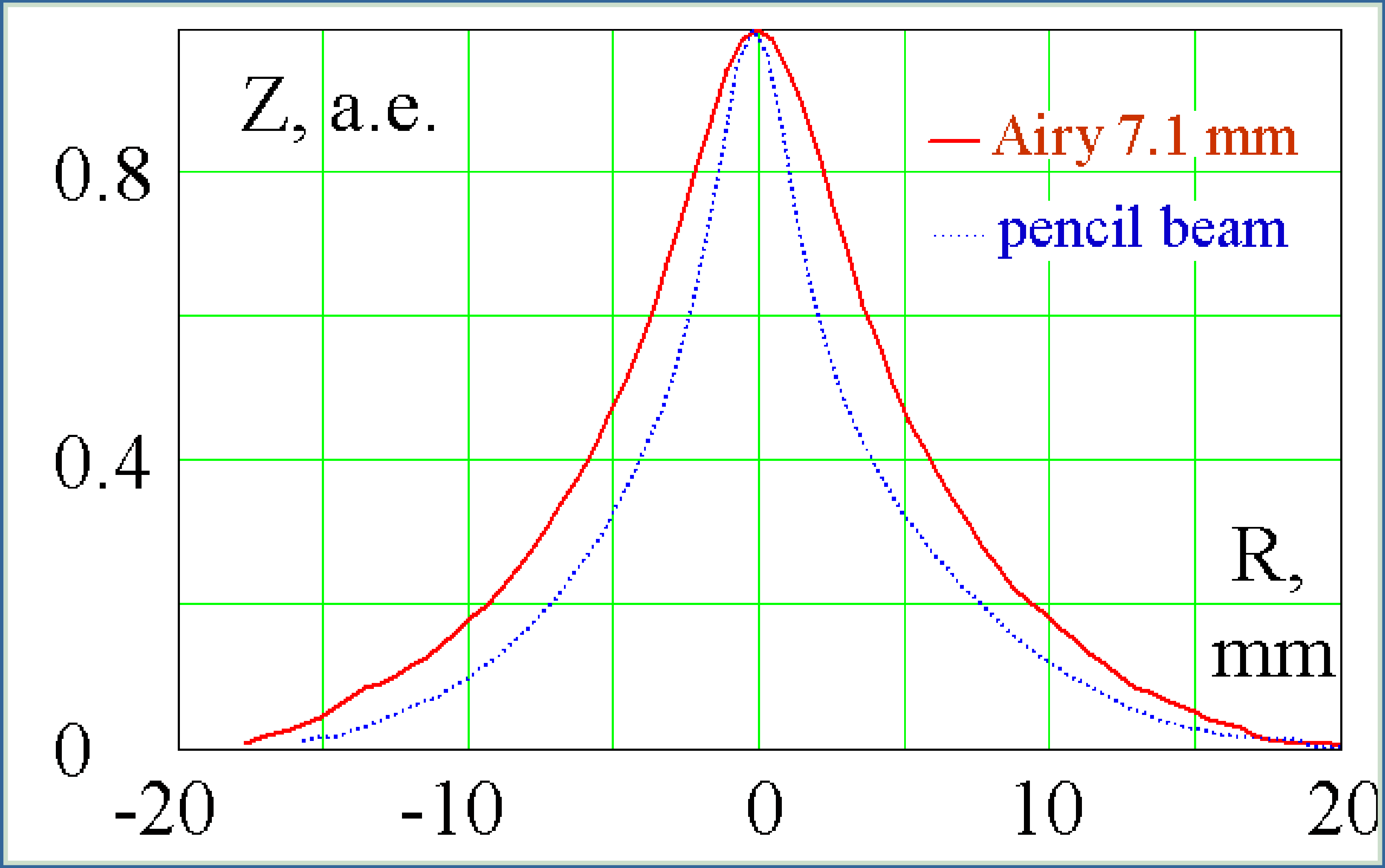
Maximal gradient shifted 5 mm from the center



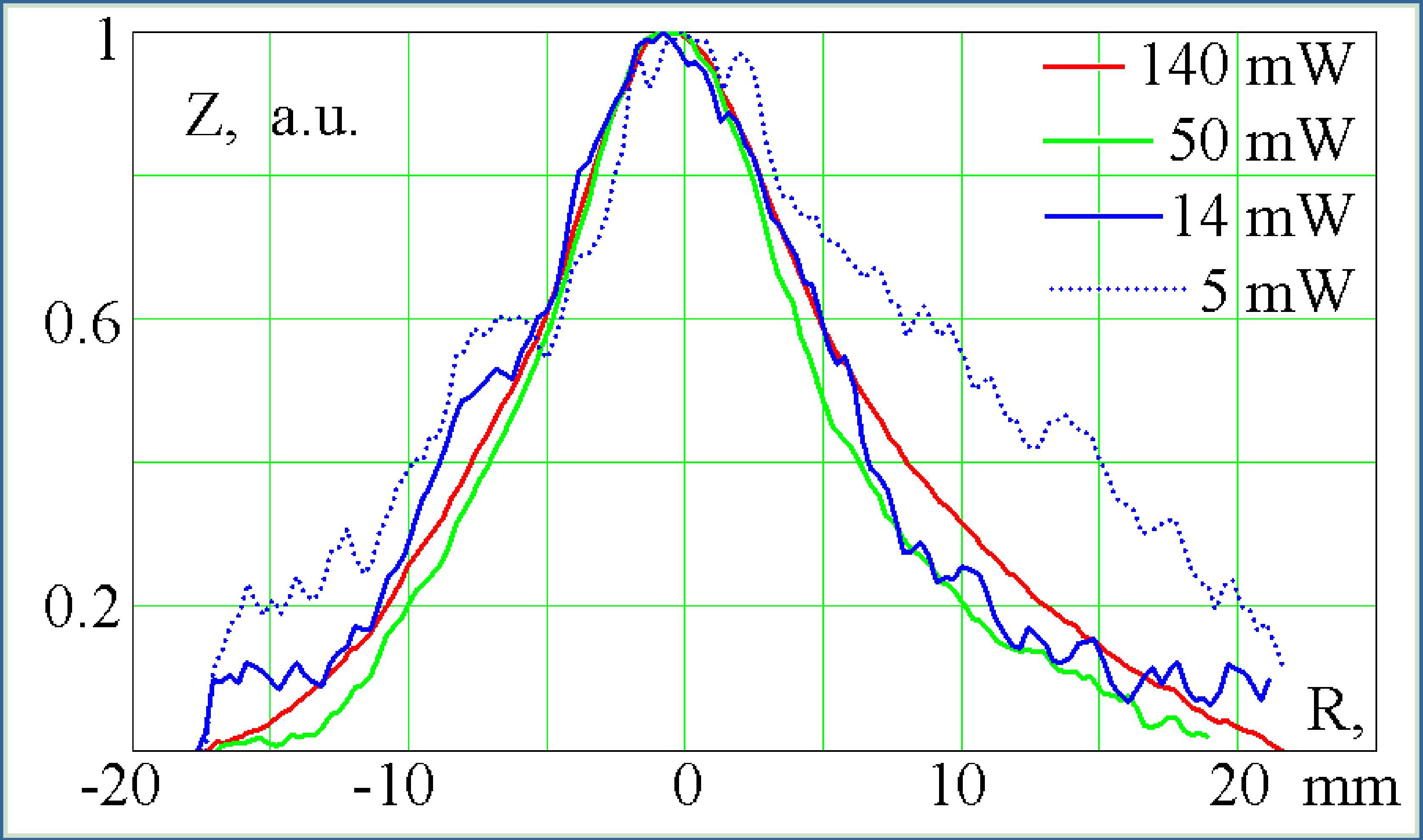


Optical depth profile measured with scanning linear Hartmann sensor for two heating beam :

7mm Airy and 1 mm pencil structures



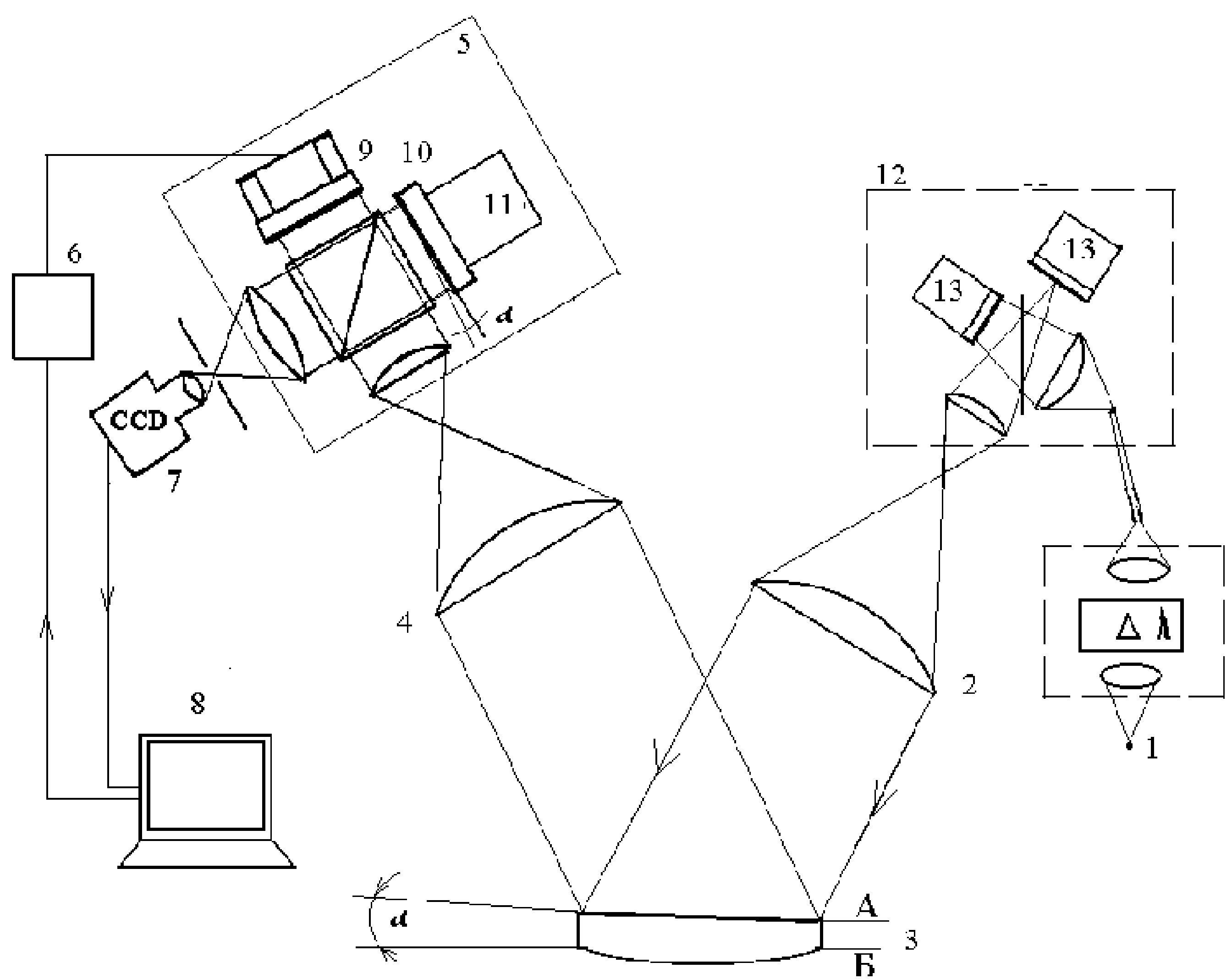
Optical depth profile measured with scanning linear Hartmann sensor for different heating power



White Light *In Situ* Measurement Interferometer (WLISMI)

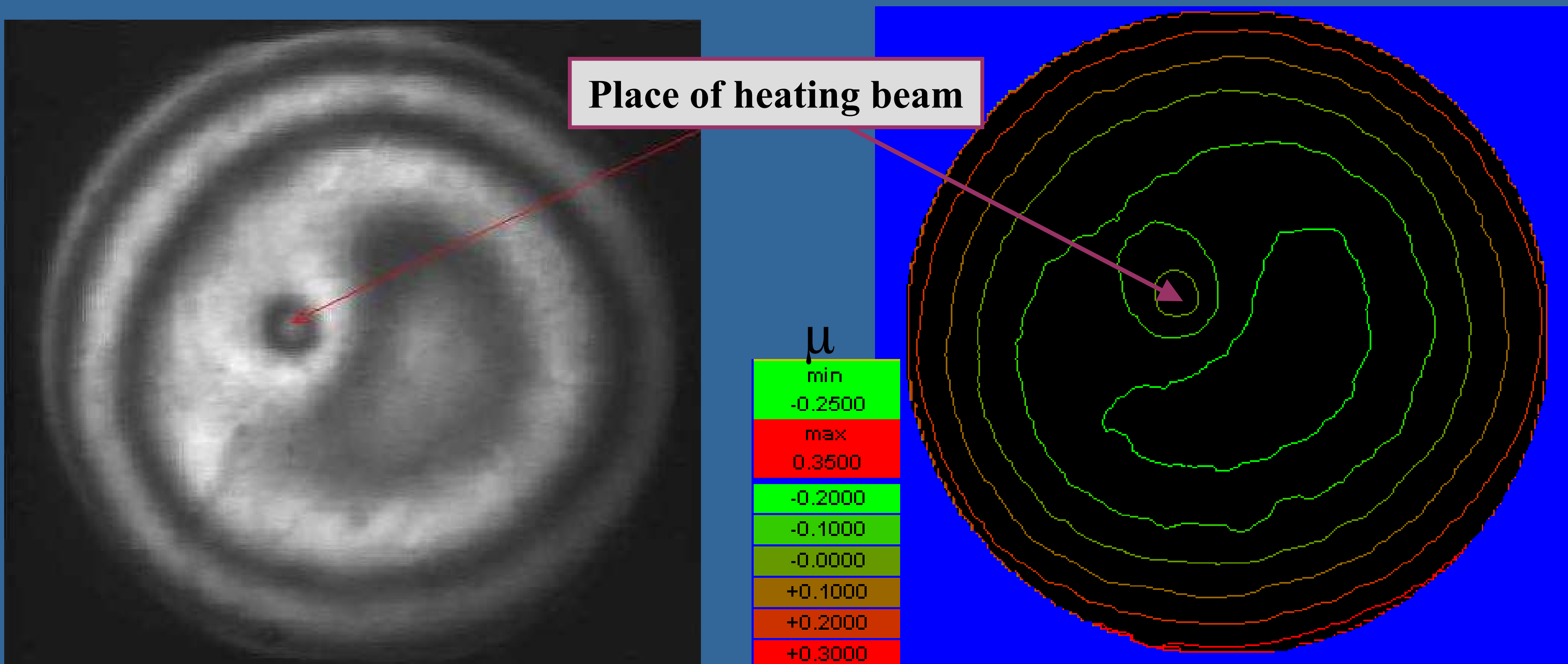
Standard interferometers	Proposed interferometers
Measurement of optical length of air spacing between two surfaces. In profilometers one of them is a sample surface, and the other is a reference surface. The problem of precise measurement of phase in the interferogram is solved by phase modulation according to a known time law.	The proposed method relies on measurements of the phase of interferogram of radiation reflected **from two surfaces of one sample** under study. The precise phase measurements are ensured by the **modulation** of the probing radiation **spectrum**. The method provides a two-dimensional pattern of a sample's **optical thickness distribution** simultaneously over the whole aperture. The method is applicable to **remote testing** of optical elements with flat, spherical and cylindrical surfaces, and also with a wedge between them.

White Light *In Situ* Measurement Interferometer. Experimental setup



1 - light source;
2 - objective;
3 - sample;
4 - ocular;
5 - measurement interferometer;
6 - unit for synchronization and control;
7 - CCD camera;
8 - PC computer;
9 - modulating mirror;
10 - adjusting mirror;
11, 13 - motors;
12 - wave front shaper

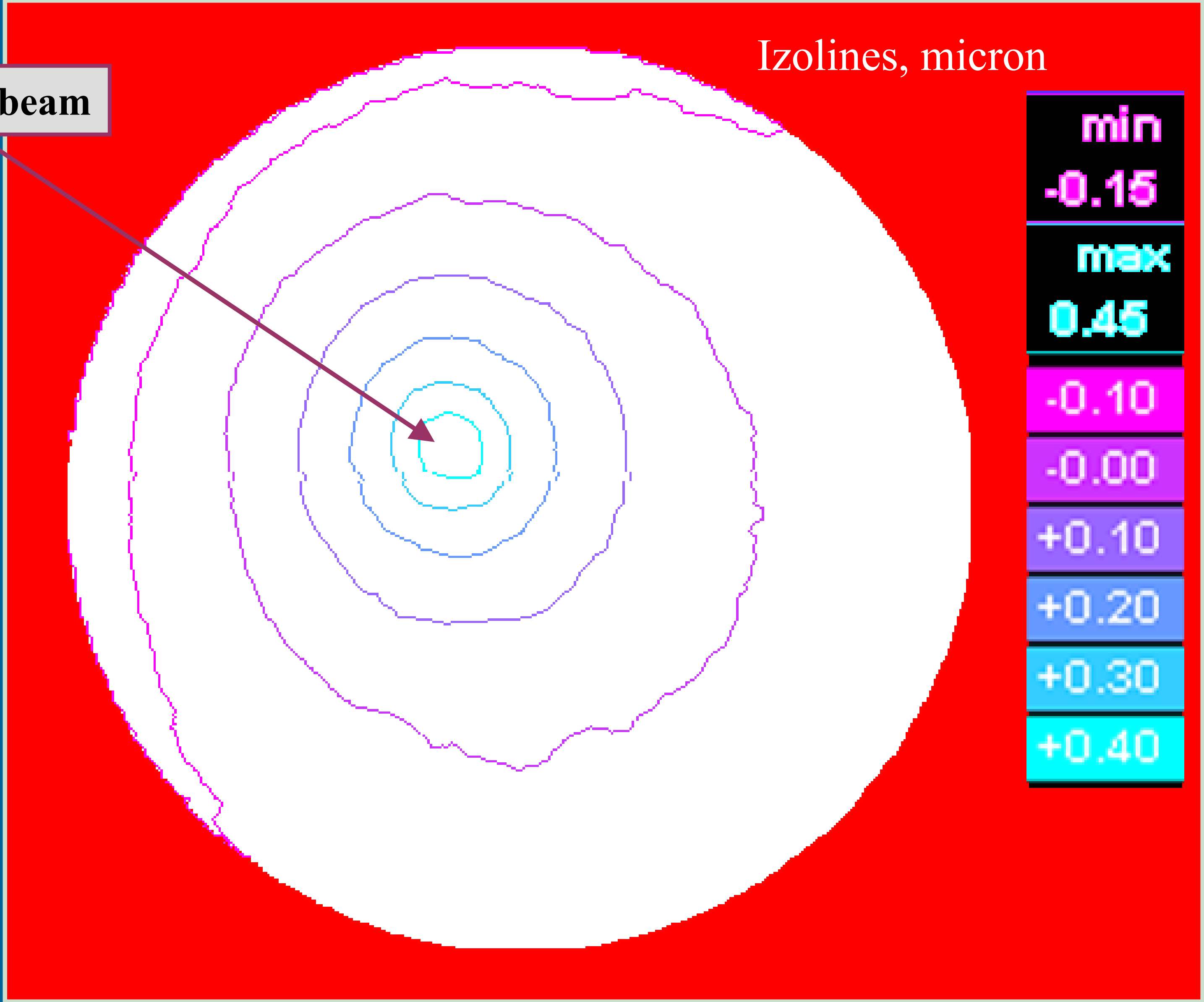
CCD camera image of optical sample heated by CO_2 laser



Thickness - 15 mm
Diameter - 85 mm

Phase map of optical sample heated by CO_2 laser

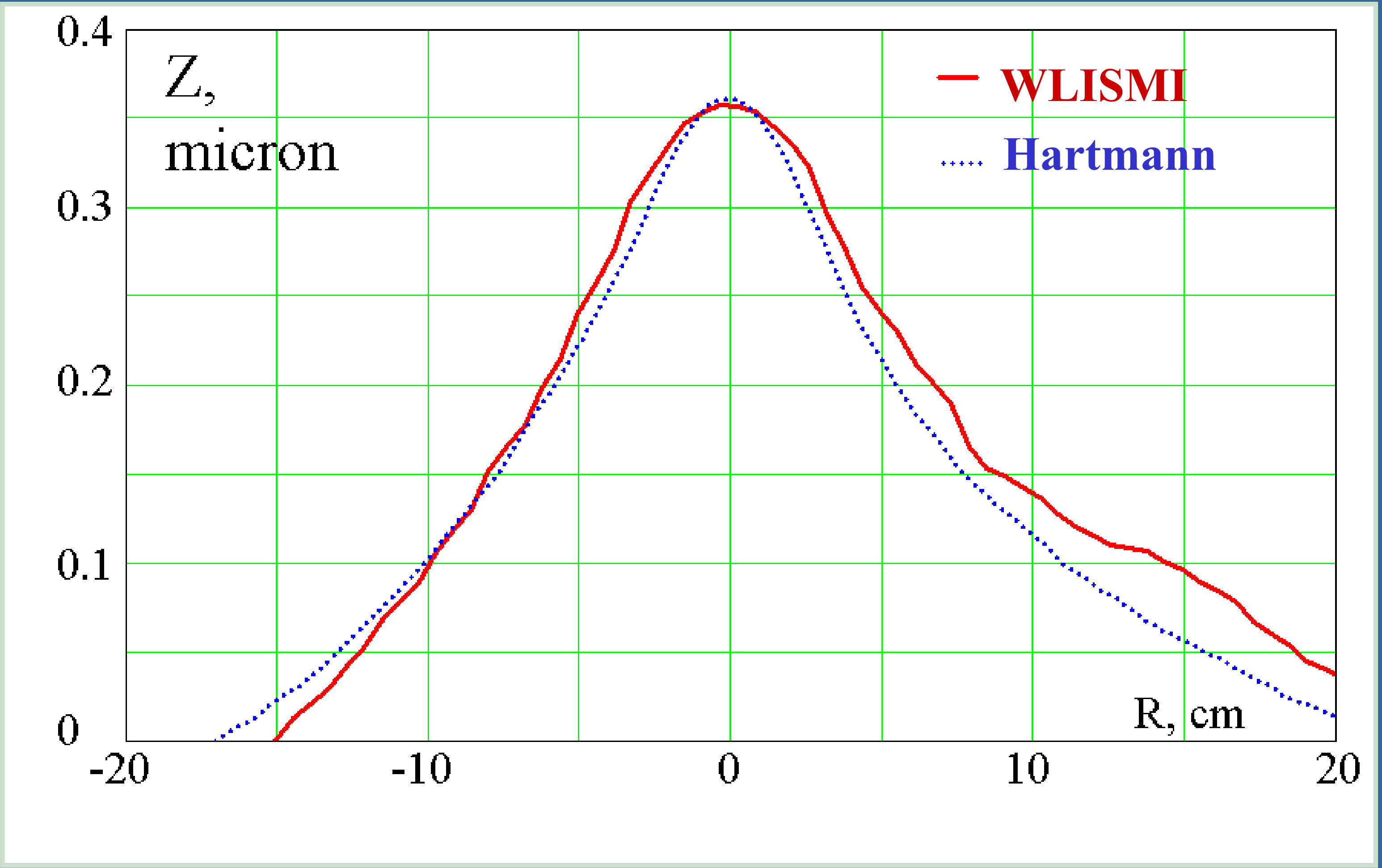
Place of heating beam



Simultaneous measurements of optical depth profiles under heating using two different techniques

CO_2 laser - 120 mW

Beam size - 7 mm



Conclusion

- LIGO-IAP Lab has been equipped with several instruments developed at IAP for high-precision characterization of LIGO optical components
- 25 cm aperture white-light phase-modulated interferometer (WLPMI) for preliminary control of LIGO Core Optics has been implemented
- White light *in situ* measurement interferometer (WLISMI) and Scanning linear Hartmann sensor have been constructed and integrated with the vacuum chamber
- Remote *in situ* monitoring of weak distortions emerging under auxiliary laser heating of optical samples in vacuum has been demonstrated
- Simultaneous measurements of optical depth profiles under heating using two different techniques have been performed