Florida (2)

LIGO-G980141-00-M

High-precision characterization of LIGO optical components

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- Alexander Sergeev, PI, at the Institute of Applied Physics, Nizhny Novgorod, Russia.

- Existing collaboration,
  - ›› High power testing of Faraday Isolator.
  - ›› Study of surface figure of pathfinder optic.

- Proposed research
  - ›› White-light Fizeau interferometer.
  - ›› Thermal lensing and depolarization.
  - ›› *In-situ* testing of optical components.

Fizeau interferometer

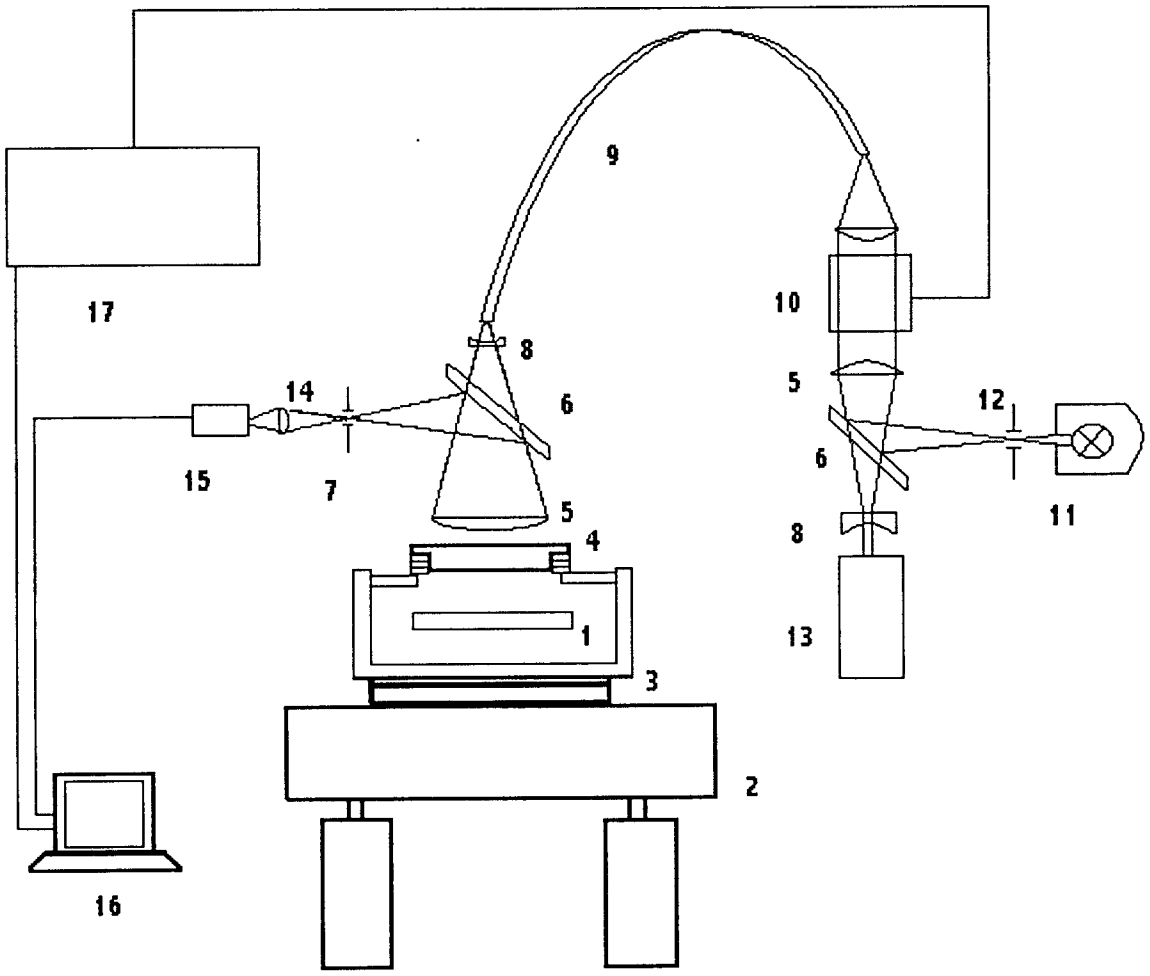
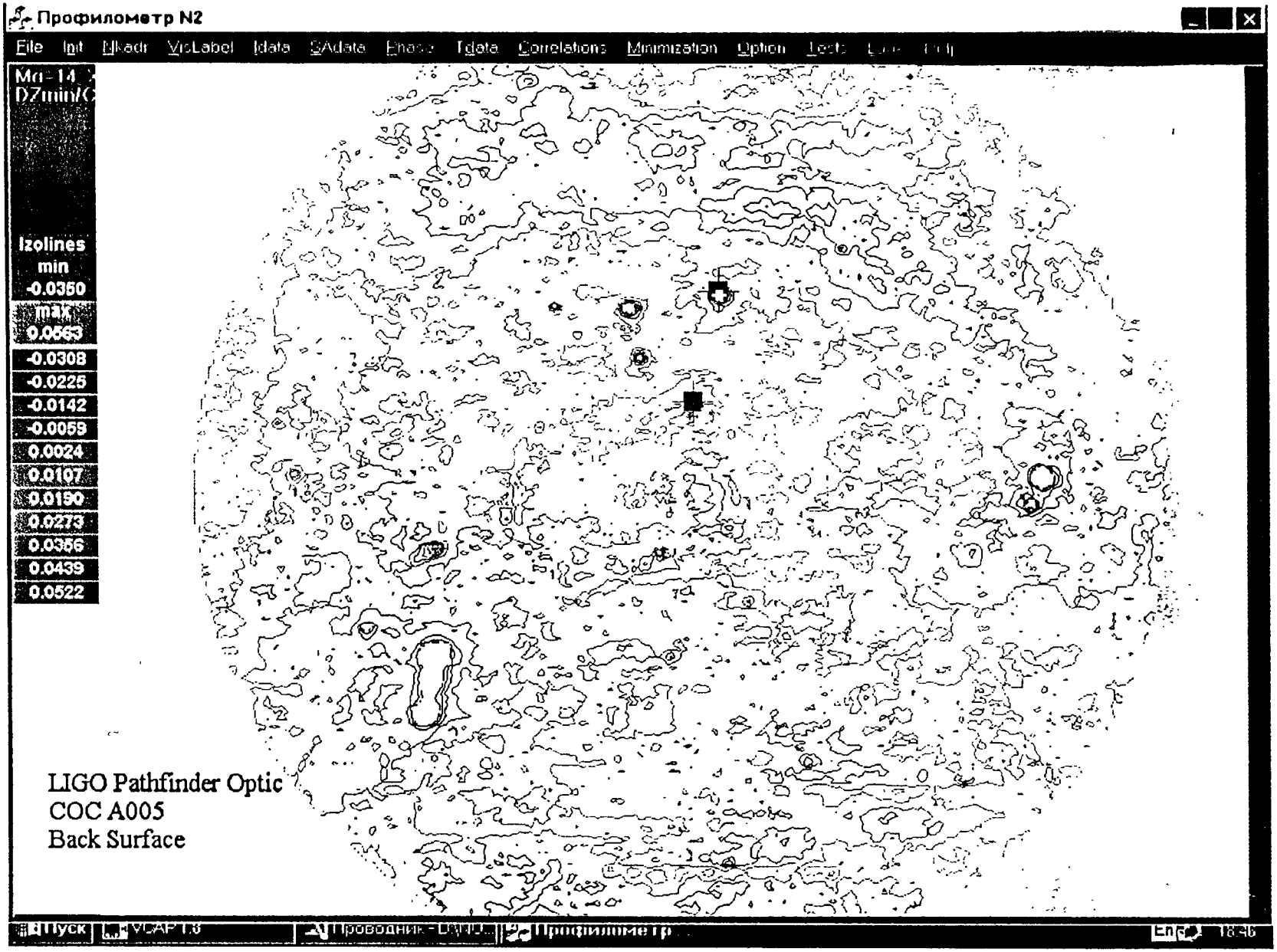


Fig.1. Scheme of interferometer.

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

Fizeau interferometer II

- "White-light" illumination.
  - ››Actually band limited by a Fabry-Perot (spectral modulator).
  - ››Wavelength may be tuned to minimize the effects of parasitic interferometers and to take advantage of coating reflectance spectra in the test surface.
- Scanned by spectral modulator.
  - ››Fixed separation of test/reference surface.
  - ››No heavy moving parts.
  - ››Lock-in detection of signal.
- Detailed algorithm for calibration of reference surface
  - ››Use 3 or 4 surfaces, compared pair by pair
  - ››Use shift/rotation of one surface relative to other.
- Possibility of active alignment and vibration isolation.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LIGO Pathfinder Optic
COC A005
Back Surface
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Проводник - LIGO
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Fizeau interferometer III

- Prototype interferometer tested at UF in Spring 98, on pathfinder optic COC-A005.
- Specs:
  - ››Area: 60 x 80 mm^2
  - ››Resolution 240 x 320 pixels; 1 pixel is 250 x 250 μm^2
  - ››Better resolution on smaller areas, perhaps 10 x 10 μm^2
  - ››$\lambda/1000$ vertical resolution
  - ››Optic surface deviations: $\lambda/500$ in center; $\lambda/130$ at edge.
- Goals of proposed upgrade:
  - ››Measure surface profile to $\lambda/2000$.
  - ››Aperture increased to 250 mm diameter.
  - ››Improvements in vibration and acoustic isolation
  - ››Better reference surfaces.
  - ››Software upgrades.
  - ››Capability to measure curved surfaces with $r > 3$ km.

Program

- Interferometer will be designed, constructed, and initially tested in Nizhny Novgorod.
- Then will be brought to UF for evaluation.
- After, will be available to LIGO for evaluation and use.

  ›› Wavelength agility allows for example one to characterize a substrate, coat it, and characterize the coated surface.

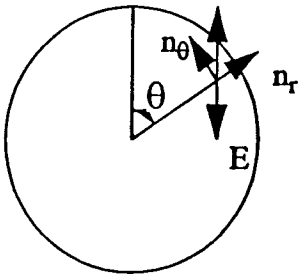
High-power study

- Initial emphasis on the in-vacuum Faraday Isolator.
  - ››Issue: depolarization due to thermal variation of Verdet constant.
  - ››Reduces isolation ratio.
  - ››Will become important as power levels increase.
  - ››Example: data for TGG at powers up to 8 W.
- Prior UF/Nizhny Novgorod collaboration on thermal effects.
  - ››Measurements at UF (and Stanford).
  - ››Modeling at Nizhny Novgorod.
  - ››Funds here to support modeling, visits by Nizhny Novgorod scientists to UF.

Thermally-induced depolarization in TGG

- Laser-induced birefringence

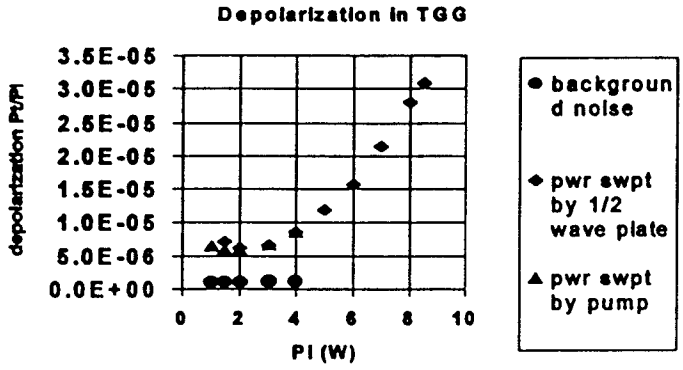
  ››Photoelastic deformation[1]



$$\delta = \frac{2\pi}{\lambda} L(\Delta n_\phi - \Delta n_r) = (n_0)^3 \frac{\alpha Q}{\kappa} C_B r^2$$

  ›› Induced Depolarization

$$\left(\frac{E_h}{E_0}\right)^2 = \sin^2 2\theta \cdot \sin^2 \frac{\delta}{2} \approx \left(\frac{\delta}{2}\right)^2 \sin^2 2\theta$$



[1]W. Winkler, A. Rudiger, R. Schilling, K. A. Strain and K. Danzmann, Birefringence-induced losses in interferometers, Opt. Com., 112, 245-252 (1994)

LIGO

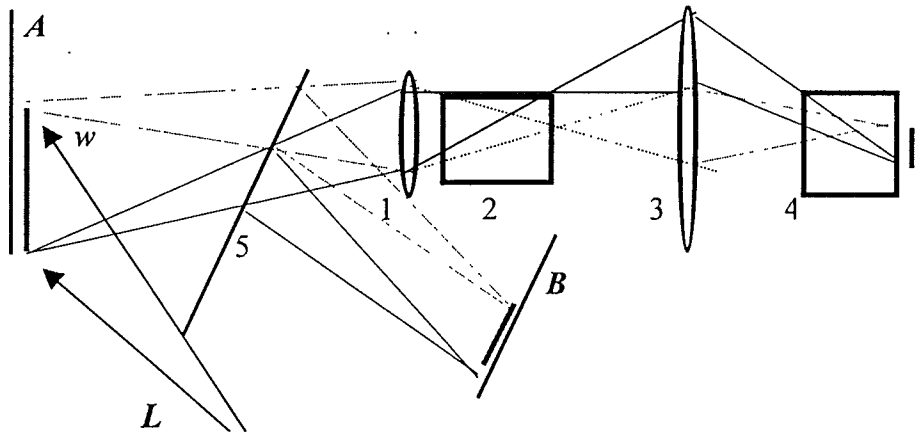
Remote testing.

- Need for *in-situ* testing of optical elements and surfaces.
  - ››Thermal effects hard to simulate.
  - ››Detect degradation/contamination.
  - ››Must be non-invasive.
- R&D is proposed on ways to use non-linear optical effects to this purpose.
  - ››Engineering evaluations to come from LIGO.

Approaches proposed:

- Optical angle difference.
  - ››Uses self-focussing of pulsed laser beam near detector to produce spot smaller than the waist
  - ››Measure deflection of beam as it is scanned across optic.
  - ››Self-focussing gives perhaps 5 to 10 X improvement in spatial resolution.

Phase conjugation



Laser Projection Image Receiver:

L – Laser beam

1 - input lens. 2 - quantum amplifier.

3 - PC-mirror lens. 4 - PC-mirror;

5 - beam-splitting mirror.

A - object plane, illuminated by laser beam.

B - image plane.

- Produces exact image of "A"---surface under test---at "B"
- If "B" is outside vacuum chamber, it can be examined for defects without having to open chamber.

Summary

Three part program:

- Optical surface interferometer.
  - ››Deliverable instrument; available to LIGO.
  - ››Unique white-light scheme.
- High-power testing.
  - ››Close collaboration with UF
  - ››Visits to UF
  - ››Modeling and characterization effort in Russia.
- Remote testing.
  - ››Uses non-linear optical approach.
  - ››Long-range R&D effort.
  - ››Device will be dependent on results.
  - ››Other approaches will be tried as they suggest themselves.