PROJECT SUMMARY

Firm: MetroLaser, Inc.
Contract No.: NNX08CA25C
Project Title: An Instrument for Inspecting Aspheric Optical Surfaces and Components

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Identification and Significance of Innovation:

A need exists for making measurements with interferometric precision on optical components that produce wavefronts that deviate from spherical or plane by fifty or more wavelengths. Measuring such a wavefront with interferomety produces more fringes than can be resolved accurately (if at all). Consequently, such components must be analyzed in small sections or with the aid of a specially produced holographic optical element that removes some of the excess fringes. This project solved that problem with a unique combination of Hartmann inspection and interferometry made possible with the application of a programmable spatial light modulator, acting as an adaptive optical component, that preconditions wavefronts. The resulting instrument enables straightforward inspection of a wide range of advanced optical components, including aspheric and other types of optics that do not lend themselves to conventional interferometric inspection.

Technical Objectives

The overall objective of this research was, by building upon a successful Phase I effort, to produce, demonstrate, and deliver a dynamic, combined Hartmann/Digital Holographic interferometry inspection system for a wide range of advanced optical components, including aspheric optics. Such optics do not lend themselves to conventional diagnostics for several reasons, such as asphericity and segmentation. The measurement will lead to the determination of the wavefront error, within a fraction of the wavelength of visible light, caused by the deviation of the optical component from a perfect geometrical shape. The system employs a combination of digital holographic interferometry, Hartmann sensing, and adaptive optics.

Work Plan

The work plan included the following elements:

1. Kickoff meeting
2. Define final target system specifications and produce a preliminary system design
3. Complete, refine, and apply optical model including practical effects
4. Breadboard and test the preliminary design
5. Develop and incorporate methods for dynamic range extension
6. Perform a critical design and design review
7. Acquire hardware
8. Assemble and write necessary software for system operation and data analysis
9. Integrate hardware and software
10. Assemble and test system
11. Training
12. Reporting

The plan included delivering the breadboard system to NASA.

Technical Accomplishments:

1. A universal, extended dynamic range optical inspection system was developed, constructed and demonstrated employing:
   a) Digital holography and Hartmann inspection technology
   b) Phase-shift interferometry, using the Pixelated PhaseCam technology, operating at a wavelength of 632nm
   c) A digital Spatial Light Modulator (SLM), calibrated and integrated into the measurement system to:
      - act as an adaptive optical component for preconditioning reference waves, and
      - act as a programmable shutter to provide scanning pencils of light to convert the system to Hartmann inspection methods.
2. Procedures have been developed and demonstrated to program the SLM with preconditioning wavefronts derived from any source, i.e.,
   - measured surfaces provided by the PhaseCam,
   - computed surfaces provided by ray tracing programs, such as Zemax, and
   - a library of functions including variable tilt and sphere.
3. Measurement procedures were developed for complex shapes such as aspheres and mandrels provided by NASA.
4. The system and concepts were modeled and tested in Zemax.
5. Calibration procedures were developed and tested.
6. Software was developed for stitching interferograms.
7. A system breadboard was assembled and is ready for delivery.

NASA Application(s):

The ability to evaluate modern optical components to high tolerances is required to provide new standards for manufacturing and quality control. This development will therefore have a corresponding and widespread impact on the performance capabilities of the many NASA systems that incorporate these components. The improvements gained by these measures may also provide substantial cost benefits compared to alternative, more complex, and expensive solutions. The versatile optical inspection system and concepts developed and demonstrated in this project will be extremely valuable to NASA in manufacturing and acceptance testing of a wide variety of optics.

Non-NASA Commercial Application(s):

This program can provide a unique system for high accuracy testing of test objects and optics vital to a variety of military seeker and sensor systems. Both the U.S. Army and the U.S. Navy have requirements to develop metrology procedures for a new generation of infrared aspheric transmitting test objects with aerodynamic shapes that can depart from spherical by as much as millimeters. Further potential applications and commercial possibilities are predicted for systems employed in security monitoring, marine observation, and metrology.

Name and Address of Principal Investigator:

James Trolinger, Ph.D.
MetroLaser, Inc.
8 Chrysler
Irvine, CA 92618-2008

Name and Address of Offeror:

MetroLaser, Inc.
8 Chrysler
Irvine, CA 92618-2008