NASA SBIR Subtopic S2.04
“Advanced Optical Components”

H. Philip Stahl, Ph.D.

Sub-Topic Manager

What I want to see in a Proposal

Define a customer or mission or application and demonstrate that you understand how your technology meets their science needs.

Propose a solution based on clear criteria and metrics

Articulate a feasible plan to:

- fully develop your technology,
- scale it to a full size mission, and
- infuse it into a NASA program

Deliver Demonstration Hardware not just a Paper Study, including :

- documentation (material behavior, process control, optical performance)
- mounting/deploying hardware

Customer / Application

Astro2010 Decadal Report specifically identifies optical components and coatings as key technologies needed to enable future missions, including:

X-ray imaging mirrors for the International X-Ray Observatory (IXO)
Active light-weight x-ray imaging mirrors for very large advanced x-ray observatory
Large aperture, light-weight mirrors for future UV/Optical telescopes
Broadband high reflectance coatings for future UV/Optical telescopes

As discussed in SIOSS, Heliophysics missions require advanced light-weight, super-polished precision normal and grazing incidence optical components and coatings:

Origins of Near-Earth Plasma (ONEP);
Ion-Neutral Coupling in the Atmosphere (INCA);
Dynamic Geospace Coupling (DGC);
Fine-scale Advanced Coronal Transition-Region Spectrograph (FACTS);
Reconnection and Micro-scale (RAM); and
Solar-C.

Earth Science GEO-CAPE coastal ecosystem imager requires technology for alternative solar calibration strategies including new materials to reduce weight, and new optical analysis to reduce the size of calibration systems.

X-Ray Mirrors

IXO requires 3 m^2 collecting aperture x-ray imaging mirror with 5 arc-second angular resolution.

Potential Heliophysic missions require

- collecting area of ~3 cm^2 for wavelengths 0.1 to 4 nm,
- 4 meter effective focal length,
- 0.8 degree angle of incidence and
- surface roughness of 0.2-nm rms.

Additionally future x-ray missions require:

- advanced multilayer high-reflectance coatings for hard x-ray mirrors (i.e. NuSTAR) and
- x-ray transmission/reflection gratings.

Note: Mirror areal density depends upon available launch vehicle capacities.

UVOIR Normal Incidence Mirrors

Potential Astrophysics missions require 4 to 8 or 16 meter monolithic and/or segmented primary mirrors with < 10 nm rms surface figures.

Potential Heliophysics missions require 0.35 to 1.5 meter monolithic mirrors with figure errors of 0.1 micro-radians rms slope from 4-mm to 1/2 aperture spatial periods, roughness of 0.2-nm rms and micro-roughness of 0.1-nm rms.

Note: Mirror areal density depends upon available launch vehicle capacities.

UVOIR Optical Coatings

Potential Astrophyscis UVOIR missions require high-reflectance mirror coatings with spectral coverage from 100 to 2500 nm

Potential Heliophysics missions require high-reflectance normal incidence spectral, broadband, dual and even three-band pass multi-layer EUV coatings.

PUSH Technology

PUSH technology has enables future missions which are not currently identified in any ‘official’ plan, including:

- 12 to 30 meter class segmented primary mirrors for UV/optical or infrared wavelengths and
- 8 to 16 meter class segmented x-ray telescope mirrors.

These have very specific mirror technology needs:

- UV/optical telescopes (such as ATLAST-9 or ATLAST-16) require 1 to 3 meter class mirrors with < 5 nm rms surface figures.
- IR telescopes (such as SAFIR/CALISTO) require 2 to 3 to 8 meter class mirrors with cryo-deformations < 100 nm rms.
- X-ray telescopes (such as GenX) require 1 to 2 meter long grazing incidence segments with angular resolution < 5 arc-sec down to 0.1 arc-sec and surface micro-roughness < 0.5-nm rms.

Earth Science

GEO-CAPE coastal ecosystem imager requires technology for alternative solar calibration strategies including new materials to reduce weight, and new optical analysis to reduce the size of calibration systems:

GEO-CAPE requires a light-weight large aperture (greater than 0.5 m) diffuse solar calibrator, employing multiple diffusers to track on-orbit degradation.

Typical materials of interest are PTFE (such as Spectralon® surface diffuser) or development of new Mie scattering materials for use as volume diffusers in transmission or reflection.

Heavy Lift

‘Officially’ NASA is developing heavy lift space launch system (SLS). SLS with a 10 meter fairing and 100 mt capacity to LEO would enable extremely large space telescopes.

But, there is still a certain level of uncertainty.

For now, it is necessary to invest in parallel technology paths:

EELV	5 m fairing and 20 mt to LEO (6.5 mt to SE-L2)
SLS	10 m fairing and 100 mt to LEO

The Problems

Cost

- Large Space Telescopes are Expensive.
- And Budgets are Constrained.

Performance

- Some desired capabilities do not yet exist:
  - Large Deployable Mirror Segments
  - Ultra-Stable Large-Aperture Segmented Mirrors
  - Optical Coatings

The Metric

For current launch vehicles, mass (areal density) is an important limitation, but this constraint could be significantly relieved via a heavy lift launch vehicle.

Therefore, areal cost (cost per square meter of collecting aperture) rather than areal density is the single most important system characteristic of future advanced optical system.

Currently, both x-ray and normal incidence space mirrors cost $3M to $4M per square meter of optical surface area.

This research effort seeks a cost reduction for precision optical components by 20X to 100X to less than $100K/m2.

Technical Challenges

The subtopic has three objectives:

- Develop and demonstrate technologies to manufacture and test ultra-low-cost precision optical systems for x-ray, UV/optical or infrared telescopes.

- Develop and demonstrate optical coatings for EUV and UVOIR telescopes.

- Large aperture diffusers (up to 1 meter) for periodic calibration of GeoStationary Earth viewing sensors by viewing the sun either in reflection or transmission off the diffuser.

Mirror Technology

Develop and demonstrate technologies to manufacture and test ultra-low-cost precision optical systems for x-ray, UV/optical or infrared telescopes.

Potential solutions include, but are not limited to:

- new mirror materials such as silicon carbide, nanolaminates or carbon-fiber reinforced polymer;
- new fabrication processes such as direct precision machining, rapid optical fabrication, roller embossing at optical tolerances, slumping or replication technologies to manufacture 1 to 2 meter (or larger) precision quality mirror or lens segments (either normal incidence for UV/optical/infrared or grazing incidence for x-ray).
- reflective, transmissive, diffractive or high order diffractive blazed lens optical components for assembly of large (16 to 32 meter) optical quality primary elements.

Coating Technology

Develop & demonstrate coatings for EUV and UVOIR telescopes.

- UVOIR telescopes require broadband (from 100 nm to 2500 nm) high-reflectivity mirror coating with extremely uniform amplitude and polarization properties.
- Heliophysics missions require high-reflectance (> 90%) normal incidence spectral, broadband, dual and even three-band pass multi-layer coatings over the spectral range from 6 to 200 nm.

Proposals include, but are not limited to:

- studies of improved deposition processes for UV reflective coatings,
- investigations of new coating materials, and
- examination of handling processes, contamination control, and safety procedures related to depositing coatings, storing coated optics, integrating coated optics into flight hardware.

In all cases, an ability to demonstrate optical performance on 2 to 3 meter class optical surfaces is important.

Diffuser Technology

Large aperture diffusers (up to 1 meter) for periodic calibration of GeoStationary Earth viewing sensors by viewing the sun either in reflection or transmission off the diffuser.

Diffuser material needs to be stable in BTDF/BSDF to 2%/year from 250nm -2.5 microns and highly lambertian (no formal specification for deviation from lambertian.

Deliverables

Phase I deliverable will be:

- at least a 0.25 meter near UV, visible or x-ray precision mirror or lens or replicating mandrel,
- optical performance assessment and
- all data on the processing and properties of its substrate materials.

This effort will allow technology to advance to TRL 3-4.

Phase II deliverable will be:

- at least a 0.50 meter near UV, visible or x-ray space-qualifiable precision mirror or lens system with supporting documentation,
- optical performance assessment,
- all data on materials and processing,
- plan for how to scale-up to 1 to 2 meter, and
- thermal and mechanical stability analysis.

Effort will advance technology to TRL 4-5.

S2.04 & S2.05 Award Statistics Total

	Phase 1	Phase 2
2005	21% (8/38)	71% (5/7)
2006	28% (8/29)	63% (5/8)
2007	36% (4/11)	50% (2/4)
2008	59% (10/17)	50% (4/8)
2009	56% (9/16)	50% (4/8)
2010	50% (11/22)	
Total	38% (50/133)	57% (20/35)

S2.04 Award Statistics

	Phase 1	Phase 2
2005	22% (2/9)	100% (1/1)
2006	29% (6/21)	50% (3/6)
2007	33% (1/3)	100% (1/1)
2008	75% (3/4)	50% (1/2)
2009	66% (2/3)	66% (2/3)
2010	33% (4/12)	
Total	35% (18/52)	62% (8/13)

2009 SBIR S2.04

Phase I	3 Submitted	2 Funded

Very High Load Capacity Air Bearing Spindle for Large Diamond Turning Machines, Dallas Optical Systems, Inc.

Minimally Machined HoneySiC Mirrors for Low Areal Cost and Density, Trex Enterprises Corporation

Phase II	3 Submitted	2 Funded

Silicon Carbide Lightweight Optics With Hybrid Skins for Large Cryo Telescopes, Optical Physics Company (actually a 2008 SBIR Phase 1)

Minimally Machined HoneySiC Mirrors for Low Areal Cost and Density, Trex Enterprises Corporation

NASA SBIR/STTR Technologies

Proposal No. 09-2 S2.04-9652

Silicon Carbide Lightweight Optics With Hybrid Skins for Large Cryogenic Telescopes

Phase I Contract No. NNX09CF38P

PI: Marc T. Jacoby

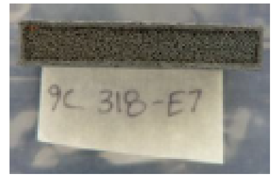
Optical Physics Company - Calabasas California

E | R | G

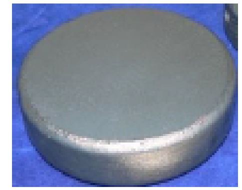
Identification and Significance of Innovation

- Hybrid SiC fiber reinforced/SiC CVD facesheet coupled with SiC open-cell foam core to allow uniform cooling
- 500-750 µm thick SiC fiber reinforced layer ground finish with near net shape
- Post coat with a 125-250 µm thick, 100% dense CVD SiC polishing layer thus completing SiC foam core substrate
- Near net shape mirror reduces cost and schedule by 50%
- Scalable to meter class lightweight, athermal mirror

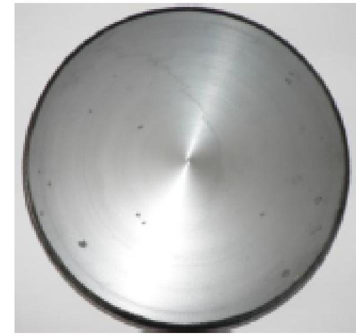
Expected TRL Range at the end of Contract : 5



1.5" Coupon



4" Pathfinder



12" Prototype

Hybrid skin technology developed for application to 22" dia. SiC foam core on Phase I contract

Technical Objectives

- Design and manufacture a 22" dia. X 2" thick f/2 spherical SiC foam core substrate with a hybrid skins
- Polish substrate surface to < λ/10 rms figure and < 10 Å rms roughness producing a mirror for cryo testing at MSFC/XRCF facility
- Determine cost and schedule path to meter class mirrors

Work Plan

- Manufacture a 22" dia. x 2" thick SiC foam core
- Create fixturing and tooling for application of hybrid skin
- Apply SiC fiber reinforced layer to SiC foam core
- Grind SiC fiber reinforced layer to near net F/2 spherical shape
- Apply thin layer of 100% dense CVD SiC to complete hybrid skin
- Polish 22" dia. hybrid skin substrate into a precision mirror
- Ship 22" dia. SiC mirror to NASA/MSFC for cryogenic testing
- Provide cost and schedule to produce meter class mirrors

NASA and Non-NASA Applications

Lightweight cryogenic telescope mirrors: SAFIR, SPIRIT, SPECS, TPF-I.

DOD requirements for IR/Vis imaging, surveillance and reconnaissance missions, e.g., MDA, AFRL DE/VS/ML/SN, NRO and commercial industry – Ball Aerospace, Boeing SVS and Phantom Works, Brashear, Lockheed Martin, Northrop Grumman and Raytheon

Firm Contacts

Marc Jacoby: mjacoby@opci.com ; 818-880-2907 x204

NON-PROPRIETARY DATA

Minimally Machined HoneySiC Mirrors for Low Areal Cost and Density

Trex Enterprises Corporation – San Diego, CA
PI: Dr. William A. Goodman
Proposal No: S2.04-9341

- Molded, Near net-shape T-300 carbon fiber prepreg is converted to silicon carbide. Web thickness <1-mm, core geometries (pocket depth, pocket size) easily tailored. **Minimizes machining and lightweighting**.
- Estimate HoneySiC Net Production cost ~$38K/m^2. **~40 to 100 times lower cost** than current mirror technologies ($3-4M/m^2).
- **H-SiC material with specific gravity ~0.25 g/cm^3, corresponding to ~92% lightweighting with respect to bulk SiC & 85% lightweighted Beryllium.**
- Estimate that large mirrors could be produced in a matter of weeks; coupons were produced in ~3.5 months the first time round.
- Enter: Phase II @ TRL 3; Exit: Phase II at TRL 5

Honeycomb Silicon Carbide (HoneySiC orH-SiC)

Demonstrate processes for rapid and inexpensive production of large, high quality, lightweight silicon carbide mirrors. Specific objectives are:

1) Optimize fabric selection for ultra-lightweight, isotropic, vented H-SiC panels.
2) Generate materials properties database for H-SiC for thermal/structural analysis.
3) Demonstrate 33-38 cm diameter directly molded concave mirror substrate
4) Clad H-SiC mirror substrate with superpolishable Trex CVC SiC™ and polish to high figure accuracy.

- Proposed innovations are directly relevant to the Technology Taxonomy for the Advanced Optical Component Systems subtopic – a) Sensors and Sources: High-Energy (ATLAST-16, ultraviolet), Large Antennas and Telescopes (ATLAST-16,ICESAT, LISA, SAFIR, CALISTO, JDEM, and ST-2020), and Optical (aspheres, off-axis aspheres, large segments); b) Materials: Ceramics, Composites, Optical and Photonic; and c)Structures: Kinematic-Deployable

1) **HoneySiC Fabrication –** Optimize fabric selection for ultra-lightweight, isotropic H-SiC mirrors that will be dimensionally stable.
2) **Generate Material Properties Database –** Temperature dependent (77-425 K) materials properties required include Young's modulus, thermal conductivity, thermal expansions coefficient, density, heat capacity and Poisson's ratio.
3) **Design and Manufacture Prototype Mirror -** Use optimal design to fabricate 33-38 cm concave H-SiC sphere, clad with CVC SiC and polish to $\lambda/10$ PV figure accuracy. Deliver test article to MSFC XRCF for cryo-testing.

- DoD Imaging, Surveillance and Reconnaissance
- Giant Ground Based Telescopes

Dr. Bill Goodman, PI, 858.437.3899
bgoodman@trexenterprises.com

Non-Proprietary Data

2010 SBIR S2.04

Phase I 12 Submitted 4 Funded

Scale-up of Nano-Engineered AR Coating Process for Large Plastic Optics, Nanotrons

Low Cost High Specific Stiffness Mirror Substrate, United Materials and Systems

Silicon Carbide Corrugated Mirrors for Space Telescopes, Trex Enterprises Corporation

Enhanced ORCA and CLARREO Depolarizers Using AR Microstructures, TelAztec

Phase II 2011

NASA SBIR/STTR Technologies

Title of Proposal: Scale-up of Nano-Engineered Anti-Reflection Coating Process for Large Plastic Optics

PI: Dr. Sangyup Song/Nanotrons – Woburn, MA

Proposal Number: S2.04-8337

Identification and Significance of Innovation

Antireflection coatings are important for all lens-based imaging systems but some substrates, wavelength ranges, and environments present greater challenges than others. The coating material itself must be transparent at the wavelengths of use, which is relatively easy to achieve in the near-IR or visible but challenging in the UV spectrum. Finally it must lend itself to a well controlled deposition process capable of very uniform, conformal coatings over large areas. Very few stable materials have such low refractive indices. One approach is to incorporate air into the film (porosity) but this must be done in such a way as to achieve a stable, solid, and very smooth film on a nanometer scale.

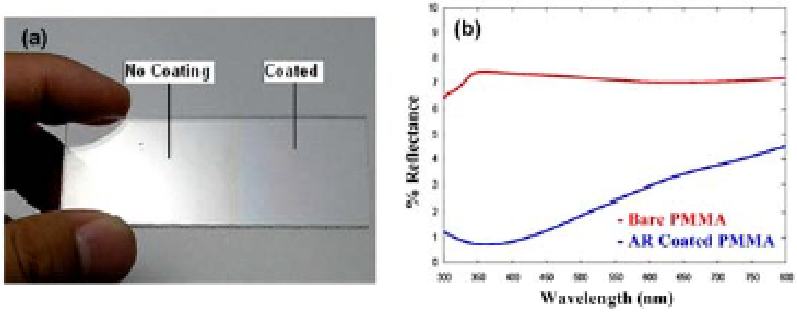


Figure : (a) A PMMA substrate with coated and non-coated areas, (b) Reflectance of AR coated and non-coated PMMA.

Technical Objectives and Work Plan

The goal of this program is to develop a scaled up coating process for large-size PMMA fresnel lenses for the NASA EUSO program

Work Plan includes the following tasks:

Task 1. Preparation of SiO_2 Nano-Particle Solutions, PMMA plates and Fresnel lenses
Task 2. Surface Modification of PMMA by Block Copolymer (BCP)
Task 3. Large scale Spray Coating process development
Task 4. Optical and Structural Characterization of SiO_2 Nano-Particle Coatings
Task 5. Report

NASA and Non-NASA Applications

NASA Applications: Anti-reflection coatings for regions of the electromagnetic spectrum from UV to Visible to Far-IR/Sub-MM.
Non-NASA Applications: The proposed dual functional (anti-reflection/anti-fogging) coatings will have a paramount impact on a wide spectrum of industrial technologies, such as coatings on solar panels and green-house enclosures, auto windshields, Sun-Wind-Dust goggles.

Firm Contacts

Dr. Geoffrey Burnham
Nanotrons Corp.
12A Cabot Rd.
Woburn, MA 01801

P: 781-935-1200 x137
F: 781-935-2040
gburnham@agiltron.com
www.agiltron.com

NASA SBIR/STTR Technologies

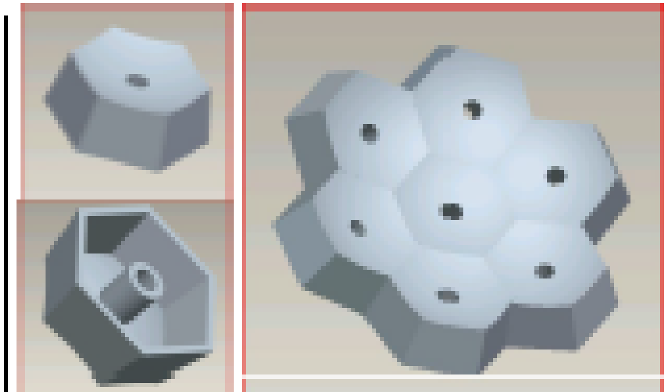
SBIR S2.04-8758
A Low Cost, High Specific Stiffness Mirror Substrate

PI: Mark Tellam, P.E.; United Materials and Systems, Inc. Orlando, FL

Identification and Significance of Innovation

The use of a new polymer derived ceramic methodology for creating mirrors from amorphous SiCN will create significant cost and performance benefits for NASA, as well as commercial and military optics consumers and exporters in the U.S. economy.

Expected TRL Range at the end of Contract (4-5):



Technical Objectives and Work Plan

Assess Full Density Coating for Optical Figure on Replicated Mirror Substrate Faces

- Use Replication Process to Create Substrates
- Use Less Expensive Precursor and Scaffold Materials
- Determine Best Method to Manufacture the Mirror Figure
- Metalize A Prototype Mirror
- Measure Amorphous PDC Properties

NASA and Non-NASA Applications

- Space telescopes,
- Laser optics,
- Telecomm;
- Highly Integrated electro-opto-mechanical platforms
- Rapid Ceramic Tooling
- Armor

Firm Contacts:
Arnold Hill, President / CTO (ahill@ceramicore.com)
Mark Tellam, Director / COO (mtellam@ceramicore.com)

NASA SBIR/STTR Technologies

Low Cost, Scalable Silicon Carbide Corrugated Mirrors for Space Telescopes

Trex Enterprises Corporation

San Diego, CA

Proposal No.: S2.04-9269

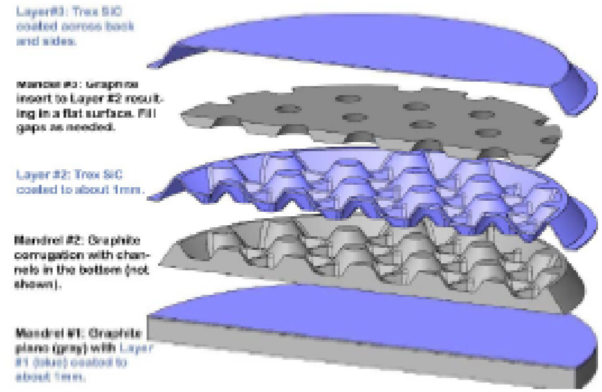
Identification and Significance of Innovation

- High performance, lightweight silicon carbide corrugated mirrors (SCCM) formed using three thin layers of CVC SiC™, suitable for NASA space optics.
- Low cost, rapid manufacture of mirror blanks.
- Highly scalable approach suitable for meter-class optics.
- Mirrors suitable for visible/UV, cryogenic IR, and x-ray applications

Estimated TRL

Beginning of contract: TRL3

End of contract: TRL 4



Technical Objectives and Work Plan

- Overall objective: Cost-effective, rapid, scalable manufacturing process for lightweight, monolithic silicon carbide mirrors.
- Trex will work with ITT Geospatial Systems to develop modular, graphite assemblies that will be used to form the SCCM.
- Scalable SCCM process to be demonstrated by fabricating ~25cm spherical SCCM prototype.
- Finishing of the hollow core SCCM will also be addressed using computer controlled polishing to mitigate print through issues.

NASA and Non-NASA Applications

- SCCM Technology suitable for low cost space mirrors for NASA observatories ranging from IR to visible/UV to x-ray, (*e.g.*, SAFIR, CALISTO, ATLAST, IXO).
- Non-NASA Applications in DoD space and airborne surveillance systems, missile defense systems, and directed energy.
- Civilian applications in ground based telescopes, commercial laser optics.

Firm Contacts

Clifford T. Tanaka, Ph.D. (PI) 808-245-6465, ctanaka@trexenterprises.com

Debra Doyle, VP& Director of Contracts, 858-646-5462, ddoyle@trexenterprises.com

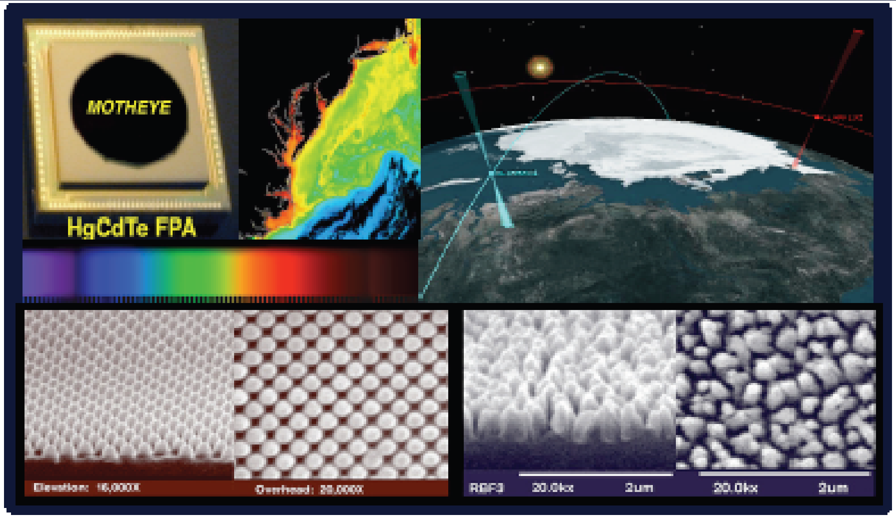
NASA SBIR/STTR Technologies

Proposal: S2.02-8250 Improved Stray Light Suppression For ORCA and CLARREO Optical Elements Using AR Microstructures

PI: Douglas Hobbs, TelAztec LLC, Burlington, MA

Identification and Significance of Innovation

- The hyper-spectral imagers ORCA and CLARREO require both depolarized light and ultra-low levels of stray light noise over a wide optical bandwidth. Conventional internal reflection suppression technology based on thin-film material coatings cannot meet the mission requirements of 0.1% back reflection loss. As a result, compound reflections within the optical path cause increased system noise, image "ghosting", and polarization instability.
- An antireflection (AR) treatment based on surface relief micro-structures (ARMs) can meet the glare suppression specifications and maintain the incident polarization state, for both the ORCA and CLARREO missions
- Expected TRL after Phase II: 4 to 5



Technical Objectives

- Determine optimum process parameters to adapt existing ARMs fabrication processes for use with fused silica and other lens and filter materials.
- Demonstrate a mission specific ultra-low reflection loss lens operating over specific mission bands, as well as a broad band lens covering the wavelength range of from 320 to 2300nm.
- Determine the critical fabrication issues to be resolved in Phase II.

Work Plan

- Design and Fabricate ARMs in fused silica coupons and lenses.
- Conduct Theoretical Modeling for microstructure depolarizers.
- Measure the scattered light level produced by ARMs - NIST.
- Deliver ARMs treated lens components to NASA GSFC.
- Develop a Phase II Work / Commercialization Plan.

NON-PROPRIETARY DATA

NASA Applications

- **ORCA** - Carbon Radiometer
- **CLARREO** – Imaging Spectrometers (IR, Hyperspectral)
- LIDAR (ACE, Calipso), LADAR (HgCdTe arrays- ALHAT)
- **ACCLAIM** (Hyper-spectral imaging), **GLORY** (solar irradiance measurement), **GEO-CAPE** (spectrometer); **ASCENDS**

Non-NASA Applications

- ARMs Treatment for imaging sensors, display films, optics, filters, and windows, PV energy conversion, and sold state lighting (OLED)

Firm Contact

Douglas S. Hobbs, President, dshobbs@telaztec.com
TelAztec LLC 15 A Street, Burlington, MA 01803 Ph. 781-229-9905

S2.05 Award Statistics

	Phase 1	Phase 2
2005	21% (6/29)	67% (4/6)
2006	25% (2/8)	100% (2/2)
2007	38% (3/8)	33% (1/3)
2008	54% (7/13)	50% (3/6)
2009	46% (6/13)	33% (2/6)
2010	70% (7/10)	
Total	38% (31/81)	52% (12/23)

2009 SBIR

Phase 1 13 Submitted 6 Funded

- **Springback-Compensated, Submillimeter Reflectors,** Vanguard Composites Group, Inc.
- **Rapid Mandrel Fabrication of X-Ray Telescope**, OptiPro Systems LLC
- **Coherent Laser Radar Metrology System for Large Scale Optical Systems**, Pyxisvision Incorporated
- **In Situ Metrology for the Corrective Polishing of Replicating Mandrels**, Zeeko Technologies, LLC
- **Removing Mid-Spatial Frequency Errors with VIBE**, Optimax Systems, Inc.
- **Advanced Lightweight Metal Matrix Composite Segmented Optic Manufacture**, Hardric Laboratories, Inc.

Phase II 6 Submitted 2 Funded

- **Coherent Laser Radar Metrology System for Large Scale Optical Systems,** Pyxisvision Incorporated
- **Removing Mid-Spatial Frequency Errors with VIBE,** Optimax Systems, Inc.

NASA SBIR/STTR Technologies

Phase II Proposal No.: 09-2 S2.05- 8780

Coherent Laser Radar Metrology System for Large Scale Optical Systems

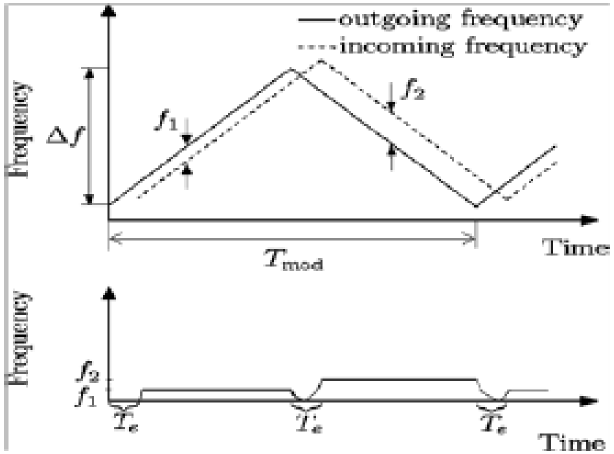
PI: Anthony Slotwinski

Pyxisvision Incorporated, Bristow, VA

Identification and Significance of Innovation

A new type of laser radar metrology inspection system that incorporates a novel, dual laser coherent detection scheme capable of eliminating both environmental and scanner based Doppler ranging error has been shown to be feasible. Due to the non-contact, stand-off nature of this technology, this system can measure optics and provide nearly real-time feedback to figuring/polishing instruments and, for advanced levels of integration and test, would allow fast, non-contact measurement of mirror rigid body alignment and prescription (i.e., radius, conic, aperture), with no special targets or references on the optic.

Estimated TRL (1 – 9) at beginning and end of contract: Beginning: 4, End: 6



Technical Objectives and Work Plan

Develop and fabricate the components for a prototype measurement system with:

-An Instantaneous Doppler Correction (IDC) dual laser oven for up to 100x improved range accuracy

-A Post-scanner Lens for up to 10x increase in scanning angular accuracy

-Improved target detection algorithms

The work plan has the following tasks:

-Fabricate and test a prototype IDC dual laser ranging device

-Develop a post-scanner lens with a calibration model to increase scanning accuracy

-Develop the embedded, signal processing and Windows interface software to support edge and hole detection algorithms.

NASA and Non-NASA Applications

-Joint Dark Energy Mission (JDEM) telescope mirror fabrication and integration

-International X-ray Observatory (IXO) x-ray telescope mirror prescription and alignment measurement

-mm-wave antenna fabrication and assembly

-Aircraft and ship-building industry support

-Optical telescope assembly

-Optical instrument assembly

Firm Contacts:

Mr. Anthony Slotwinski, Pyxisvision Inc, 703-864-5901

Mr. Ghassan Chamsine, Pyxisvision Inc, 571-278-1997

Mr. Mina Rezk, Pyxisvision Inc, 703-371-3643

NASA SBIR/STTR Technologies

S2.05-9386 - Removing mid-spatial frequency errors with VIBE

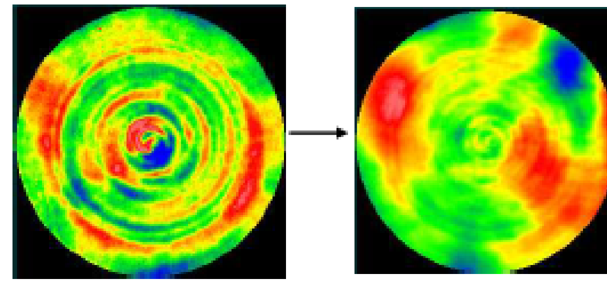
NNX10CF20P

PI: Jessica DeGroote Nelson
Optimax Systems, Inc. – Ontario, NY

Identification and Significance of Innovation

The Optimax VIBE process is a full-aperture, conformal polishing process incorporating high frequency and random motion to *eliminate mid-spatial frequency (MSF) errors* created by sub-aperture deterministic polishing in a VIBE finishing step while maintaining low spatial frequency form accuracy.

Expected TRL Range at the end of Phase II Contract (1-9): 4



Initial Sub-Aperture Polished Surface

Surface After 60-second VIBE Finishing

Sub-aperture polished surface before and after VIBE finishing

Technical Objectives and Work Plan

The Technical Objectives of the Phase II SBIR are to:

- Use VIBE to remove MSF errors from deterministically polished surfaces
- Expand VIBE finishing to remove MSF errors on
  - Spheres, Cylinders, Aspheres, Acylinders and Free-form surfaces
  - Optical materials other than glass (crystals and ceramics)
- Determine VIBE transfer function and compare to sub-aperture polishing techniques
- Potential deliverable (for discussion and determination by TPOC): VIBE polished optic of specific interest to NASA

Summary of Major Tasks in Work Plan:

- Design and build larger VIBE finishing platform
- VIBE finishing to remove MSF errors on curved surfaces
- Analyzing mid-spatial frequency errors
- Determine transfer function of VIBE finishing process

NASA and Non-NASA Applications

NASA:

X-Ray Telescopes: (IXO – slumping mandrels, produce surfaces less than 1.4nm rms between 2-20mm spatial frequency range.)

Exo-Planet Imaging Systems: (Minimize scatter on primary and secondary mirrors, specifically less than 1nm rms in 4-50 cycles/aperture range)

Non-NASA:

High Energy Laser Systems, EUV Optics (Lithography), Imaging Systems and X-Ray Synchrotron Optics

Firm Contacts

- Principal Investigator: Jessica Nelson
  - Phone: 585-217-0776
  - E-mail: jnelson@optimaxsi.com
- Corporate Controller: Tom Kelly
  - Phone: 585-217-0729
  - E-mail: tkelly@optimaxsi.com

2010 SBIR

Phase 1 10 Submitted 7 Funded

- **Innovative Deterministic Optical Surface Finishing,** Nanotrons
- **ELID Grinding of Large Aspheric Optics,** Flemming Tinker Inc.
- **Fabrication Technology for X-Ray Optics and Mandrels,** Flemming Tinker
- **Removing Mid-Spatial Frequency Errors on Curved Surfaces with VIBE,** Optimax Systems, Inc.
- **High-Resolution Detector for At-Wavelength Metrology of X-Ray Optics,** Radiation Monitoring Devices, Inc.
- **Cryogenic Optical Metrology Through a Chamber Window,** Flexure Engineering
- **In-Situ Extended Lateral Range Surface Metrology,** 4 D Technology Corporation

Phase II 2011

NASA SBIR/STTR Technologies

Innovative Deterministic Optical Surface Finishing

AGILTRON, Inc. - Woburn, MA

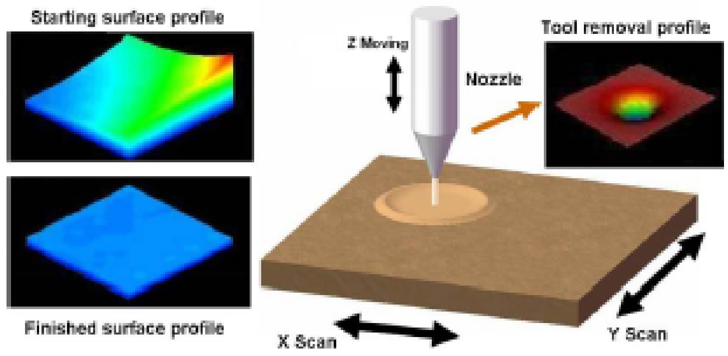
PI: Alexander Mazurenko

Proposal No.: S2.05-8362

Identification and Significance of Innovation

We will develop an computer-controlled deterministic optical surface finishing system with an innovate removal tool. An ultra high precision finishing capability, ~λ/100 surface figure, arbitrary shape generation and 5~10 times better surface smoothness is expected.

Estimated TRL (1 – 9) at beginning: 2;
and end of contract: 4



Technical Objectives and Work Plan

The overall objective of the proposal is to develop an innovative computer-controlled surface finishing system with ultra high surface figuring precision. The specific objectives of the tasks in Phase I are as follows:

1.Develop hardware and the tool system with design, assembly and installation.
2. Removal tool research and characterization.
3. Software development to implement the algorithm and control the system hardware.
4. Integrate the prototype system assembly and demonstrate system operation.
5. Prototype system debug and demonstration of flat optics fabrication

NASA and Non-NASA Applications

The proposed system will provide for extremely difficult ultra high precision optics fabrication. It will be able to handle Both flat and and arbitrary surface shape/pattern generation. This will greatly benefit NASA astronomy telescopes and the fabrication of other, previously difficult-to-fabricate optical parts.

Firm Contacts

Dr. Geoffrey Burnham
Agiltron, Inc.
15 Cabot Rd.
Woburn, MA 01801

P: 781-935-1200 x137
F: 781-935-2040
gburnham@agiltron.com
www.agiltron.com

NASA SBIR/STTR Technologies

SBIR
STTR

Proposal No. S2.05-8494 – ELID Grinding of Large Aspheres

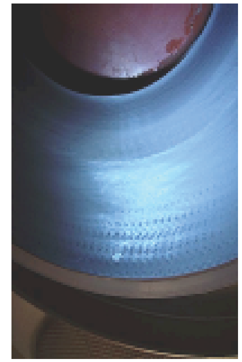
PI: Kai Xin PhD

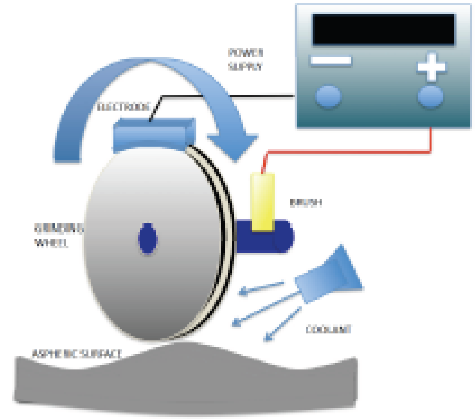
Flemming Tinker LLC / Aperture Optical Sciences Inc. – Higganum, CT

Identification and Significance of Innovation

Mid-spatial frequency (MSF) and High spatial frequency (HSF) surfaces errors in the grinding of fast aspheres are amplified in hard ceramics like SiC due to cyclic tool wear rates, vibration, and tool deformation. Flemming Tinker LLC – Aperture Optical Sciences Inc. will examine Electro-Lytic In-Process Dressing (ELID) as a solution to mitigate these phenomena and reduce the creation of MSF and HSF errors. Doing so will reduce the overall cost of making fast aspheres from hard ceramics by increasing removal efficiency while subsequently reducing the need for downstream MSF error correction through smoothing.

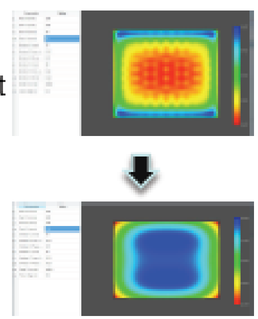
Expected TRL Range at the end of Contract (1-9): 3-4





Technical Objectives

1. Construct ELID grinding module on conventional surface grinder
2. Model the impact of cyclic wear conditions to predict results
3. Demonstrate reduction in MSF/HSF surface errors with ELID Grinding on glass and SiC test samples
4. Determine plan for implementing on conventional large-format grinding machines for fabricating 1-3 meter size aspheric mirrors



Work Plan

1. Analytical model development
2. Preparation of experimental ELID grinder
3. Experiments on glass & SiC samples
4. Analyze results and determine plan for full-scale demonstration

NASA and Non-NASA Applications

IXO Replication Mandrels
GenX mandrels and optics
Precision Cylindrical Optics
Large Format Aspheres
Low Mid-Spatial Period Optical Surfaces
Deterministic Low Cost Fabrication

Firm Contacts

Mr. Flemming Tinker, Aperture Optical Sciences Inc. (860) 316-2589

Dr. Kai Xin, PI, Aperture Optical Sciences Inc. (860) 316-2589

NASA SBIR/STTR Technologies

Proposal No. S2.05-8599 – Fabrication Technology for X-Ray Optics and Mandrels

PI: Kai Xin PhD

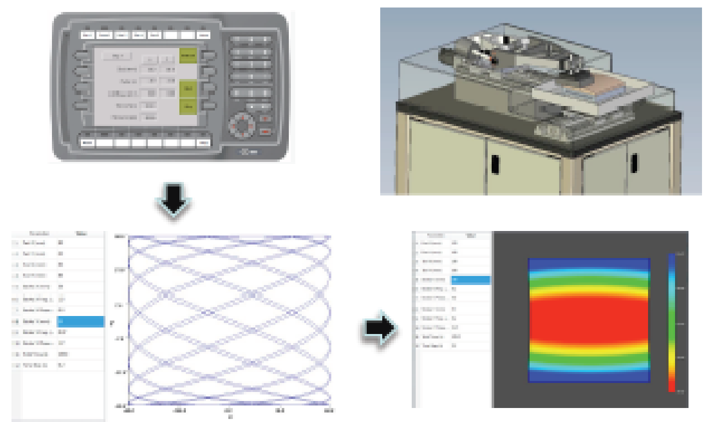
Flemming Tinker LLC Aperture Optical Sciences Inc. – Higganum, CT

Identification and Significance of Innovation

Aperture Optical Sciences Inc. has built and commissioned a low-cost deterministic grinding and polishing machine for cylindrical optics. This machine may be modified for full scale production of X-Ray mandrels which exhibit the following benefits:

-Scalable to 1-meter scale optics
-Material independent (glass or SiC mandrels)
-Unlimited range of CX or CC radius of curvature
-Automated, programmable, with predictive control software
-Can be modified for flats and general aspheres

Expected TRL Range at the end of Contract (1-9): 2-3



Technical Objectives

1. Scale up existing design for full-scale mandrel production
2. Demonstrate algorithmic predictor model to produce aspheric shapes
3. Optimization of control system for low Mid-Spatial Frequency surfaces
4. Demonstrate the principal of sequential and superimposed removal patterning
5. Determine tolerance analysis for expected machine performance

Work Plan

1. Identify candidate upgrades necessary for existing machine
2. Develop and test the new model
3. Prepare feasibility study to demonstrate mandrel fabrication
4. Complete conceptual design review

NASA and Non-NASA Applications

IXO Replication Mandrels
GenX mandrels and optics
Precision Cylindrical Optics
Large Format Aspheres
Low Mid-Spatial Period Optical Surfaces
Deterministic Low Cost Fabrication

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Mr. Flemming Tinker, Aperture Optical Sciences Inc. (860) 316-2589

Dr. Kai Xin, PI, Aperture Optical Sciences Inc. (860) 316-2589

NASA SBIR/STTR Technologies

Removing mid-spatial frequency errors on curved surfaces with VIBE

Optimax Systems, Inc. – Ontario, NY

PI: Jessica DeGroote Nelson

Proposal No.: S2.05 - 8826

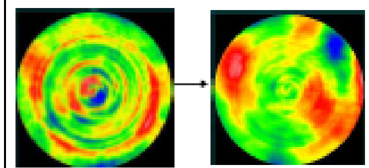
Identification and Significance of Innovation

The Optimax VIBE process is a full-aperture, conformal polishing process incorporating high frequency and random motion to *eliminate mid-spatial frequency (MSF) errors* created by deterministic polishing in a VIBE finishing step while maintaining low spatial frequency form accuracy.

MSF errors are formed during deterministic sub-aperture polishing processes. MSF errors cause small angle scatter and flare in optical systems.

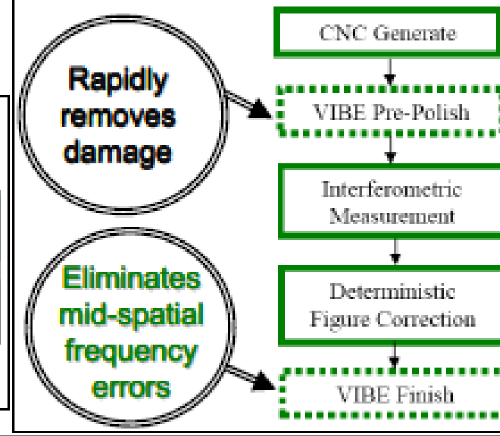
Estimated TRL at Beginning of Phase I: 2
Estimated TRL at End of Phase I: 3

VIBE Finishing results on a flat surface



Initial Sub-Aperture Polished Surface — Surface After 60-second VIBE Finishing

Introduction of VIBE into today's optical manufacturing process



Technical Objectives and Work Plan

The technical objectives of this Phase I SBIR are to:

- Prove feasibility that VIBE will remove sub-aperture polishing marks (or mid-spatial frequencies, MSF errors) from curved deterministically polished surfaces
- Examine the "transfer function" of VIBE finishing and compare to sub-aperture polishing techniques
- Quantify MSF errors using standard interferometry

The work plan is divided into 4 major tasks:

1. Induce mid-spatial frequency errors on spherical surfaces
2. Quantify errors with current metrology techniques
3. Implement VIBE finishing to reduce/remove MSF errors
4. Determine transfer function of VIBE finishing process

NASA and Non-NASA Applications

NASA:
X-Ray Telescopes: (IXO – slumping mandrels, produce surfaces less than 1.4nm rms between 2-20mm spatial frequency range.)
Exo-Planet Imaging Systems: (Minimize scatter on primary and secondary mirrors, specifically less than 1nm rms in 4-50 cycles/aperture range)

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High Energy Laser Systems, EUV Optics (Lithography), Imaging Systems and X-Ray Synchrotron Optics

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NASA SBIR/STTR Technologies

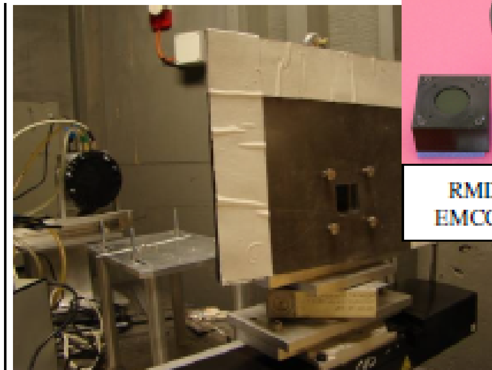
High-resolution detector for at-wavelength metrology of X-ray optics

Radiation Monitoring Devices, Inc. - 44 Hunt Street, Watertown, MA 02472

Proposal No.: S2.05-8926

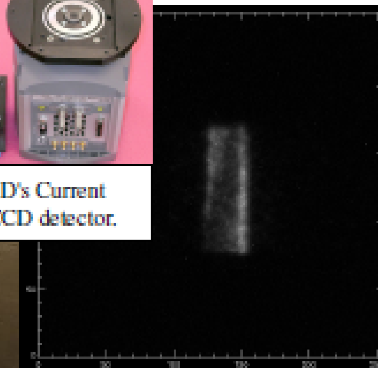
Identification and Significance of Innovation: The August, 2010 Decadal Survey highlights the important contribution that X-ray astronomy can make to address some of the most pressing scientific questions about black holes, cosmology and the ebb and flow of energy and matter in the evolving universe. It also emphasizes that while missions like the International X-ray Observatory (IXO) can address these issues, much research must be conducted to mature the key enabling technology, X-ray optics. The proposed development directly addresses this need by providing a unique detector designed specifically to support the development of the next generation of X-ray telescopes, which will allow researchers and engineers to characterize such X-ray telescopes with high accuracy, and thereby optimize their performance and best utilize the data they gather.

Estimated TRLs at start and end of Phase I contract: 4 and 5.



RMD's EMCCD, located in the detector room at the Nevis RMCF. The camera (at the left) is behind the coarse lead collimation. Not visible in this view is the final slit assembly.

RMD's Current EMCCD detector.



First light for the RMD EMCCD at the Nevis RMCF. A high resolution image of the slit assembly used for multi-layer reflectivity measurements.

Technical Objectives: Design and fabricate a dedicated 2D X-ray camera with high spatial and spectral resolution to test, characterize and calibrate the next generation of all NASA X-ray telescopes that operate in the energy range from a few keV up to nearly 100 keV. Fully test and qualify the device at Nevis and on site at NASA.

Work Plan: The Work Plan has three distinct primary areas:

- Develop protocols to deposit high resolution microcolumnar scintillator films directly onto coherent fiberoptic conduits for direct coupling to a special electron multiplying CCD (EMCCD).
- Develop ML-EM algorithms and software to achieve sub-pixel spatial resolution with moderate energy resolution.
- Integrate new components and software with our existing EMCCD camera and perform feasibility tests at Columbia University's Nevis Laboratory for testing NuSTAR mission optics.

NASA Applications: X-ray optics development support for specific missions and mission areas, including the International X-ray Observatory (IXO), the Nuclear Spectroscopic Telescope Array (NuSTAR), hard X-ray solar astronomy (e.g., the Focusing Optics X-ray Solar Imager, FOXSI), and X-ray detectors that can be used for characterizing any X-ray telescope at NASA MSFC.

Non-NASA Applications: High resolution X-ray/γ-ray detection, small animal single photon emission computed tomography (SPECT), time-resolved X-ray diffraction studies at synchrotron sources, dynamic X-ray imaging of hypervelocity projectiles, X-ray microscopy, and low-light optical tomography.

Firm Contacts:

Vivek V. Nagarkar – VNagarkar@rmdinc.com, 617-668-6937

Gerald Entine – GEntine@rmdinc.com, 617-668-6806

Michael Squillante – MSquillante@rmdinc.com, 617-668-6808

NASA SBIR/STTR Technologies

Cryogenic Optical Metrology Through a Chamber Window

Flexure Engineering, Greenbelt, MD

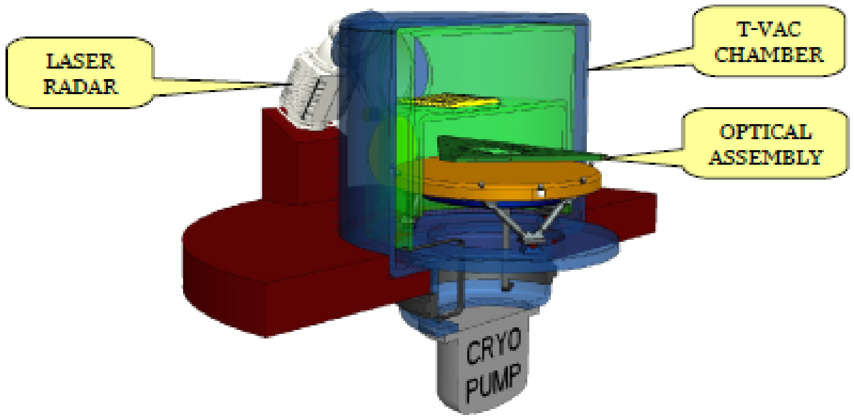
PI: Gregory Scharfstein

Proposal No. S2.05-9211

Identification and Significance of Innovation

Flexure's innovation marries the technologies of Thermal Vacuum Chambers and Non-Contact Metrology Systems providing NASA with sub-micron, three sigma uncertainties on Flight Hardware while at temperature (typically cryogenic, down to 30K) and in high vacuum (>10E-6 torr).

This innovation provides NASA and the Aerospace Community increased capabilities for the alignment and performance verification of telescope optical surfaces and telescope optical assemblies.



Expected TRL Range at the end of Contract (1-9): TRL 5

Technical Objectives and Work Plan

Develop specifications for a Vibration Control System to allow for sub-micron stability while pumping vacuum and flowing cryogen.

Develop specifications for a Thermal Control System to allow for 30K-hardware inside the chamber to be viewable through windows.

Develop specifications to enhance the Metrology System for modularity, ease of use and lower uncertainties. One example of each topic mentioned in this objective:

1. Modularity: a scalable system that can accommodate different size payloads
2. Ease of Use: Touchscreen GUI to control/monitor chamber/payload and obtain/analyze metrology data.
3. Lower Uncertainties: Integrating ESPI and PG to the system so that other metrology devices can be used to cross-reference measurements and bring down uncertainties.

NASA and Non-NASA Applications

NASA:

Next-generation Cryogenic Space Telescopes (JWST, WFIRST)

Lander, Rover and Manned Lunar Missions to explore ices at the Poles

Non-NASA:

Advancement of High Temperature Superconductor Technologies

Metrology Methods for Harsh Environment Manufacturing & other Enviromentally-controlled Processes

Firm Contacts

Gregory Scharfstein, Principal Investigator
Gregory.Scharfstein@FlexureEngineering.com

Russell Cox, Business Official
Russell.Cox@FlexureEngineering.com

NON-PROPRIETARY DATA

NASA SBIR/STTR Technologies

10-1 S2.05-9256 *In-Situ Extended Lateral Range Surface Metrology*

PI: Katherine Creath, PhD
4D Technology Corporation, Tucson, AZ

Identification of Innovation

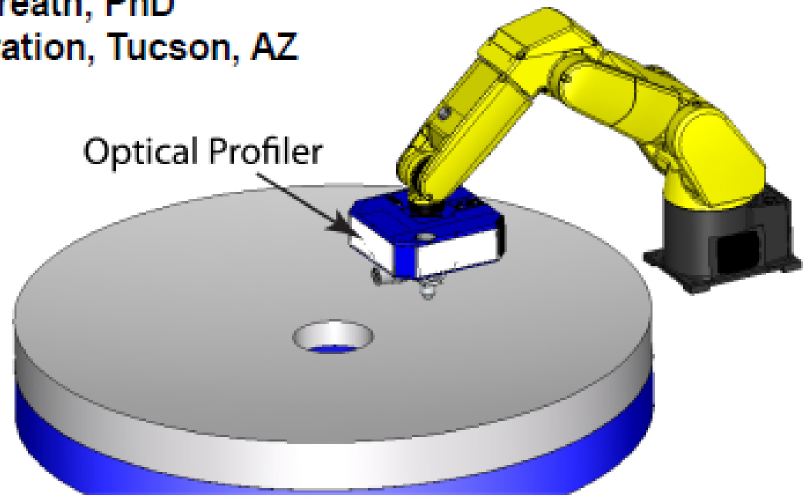
Dynamic, 4D optical profiler

- non-contact, sub-angstrom, surface roughness measurement
- vibration immune, patented phase sensor
- mounted in situ on polishing machine/robot
- rapid scanning over a wide area (free form shape)
- >3 decades of spatial frequency response

Significance

- Enabling for next generation meter-class and aspheric optics
- Significant cost savings in mfg of optics (reduced process time)
- lower surface scattering = improved background suppression
- unequalled by any existing commercial instruments

Est. TRL at beginning and end of contract (1-9): 2-3; 3-4



Technical Objectives:

1) Demonstrate in situ surface roughness measurement
2) Demonstrate extended lateral range concept
3) Demonstrate >3 decades of spatial frequency response

Work Plan:

1) Develop novel automated alignment system for on-tool measurement
2) Develop extended lateral range algorithm
3) Design target for lateral calibration
4) Develop calibration procedures and methods
5) Procure parts
6) Build breadboard to demonstrate technical objectives
7) Test and evaluate technical objectives
8) Prepare Reports

NASA and Non-NASA Applications

In-situ, on-tool, surface roughness measurement for:

- Super-smooth optics for LIGO, NIF, WFIRST, LISA
- Large optics such as LSST, GMT, TMT, ELT, JDEM, & ICEsat
- X-ray, synchrotron, DUV and EUV optics such as IXO
- Precision machined surfaces (medical, automotive)
- Engineered surfaces (flat panel and flexible displays, MEMS, Semiconductor wafers, etc.).

Firm Contacts

Dr. Katherine Creath, PI, 4D Technology Corp, 520-294-5600
Mr. Neal Brock, Dir New Tech Dev, 4D Technology, 520-294-5600
Dr. James Millerd, President, 4D Technology, 520-294-5600

Any Questions?