NASA SBIR Subtopic:

S2.03 “Advanced Optical Systems”
S2.04 “Optical Manufacturing and Metrology”
E3.02 ”Adv Tech Telescope for Balloon Mission”

H. Philip Stahl, Ph.D.
Sub-Topic Manager

2012 SBIR ‘Optical Technology’ Summary

S2.03 (which is managed by MSFC) has 3 awards out of 10 proposals

JPL	1
GSFC	1
MSFC	1

S2.04 (which is managed by GSFC) has 3 awards out of 15 proposals

GSFC	1
MSFC	2

E3.02 (which is managed by MSFC) has 2 awards out of 4 proposals

MSFC	2

NASA ‘Optics’ 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)	11% (1/9)
2011	28% (7/25)	20% (1/5)
2012	28% (8/29)	
Total	35% (65/187)	45% (22/49)

“Advanced Optical Systems” 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)	00% (0/3)
2011	33% (4/12)	00% (0/3)
2012	30% (3/10)	
Total	33% (25/74)	42% (8/19)

“Optical Manufacturing & Metrology” 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)	17% (1/6)
2011	23% (3/13)	50% (1/2)
2012	20% (3/15)	
Total	34% (37/109)	45% (14/31)

“Adv Tech Telescope for Balloon Mission” Statistics

	Phase 1	Phase 2
2012	50% (2/4)	
Total	50% (2/4)	

2012 SBIR S2.03

Phase I 10 Submitted 3 Funded

Low-Stress Silicon Cladding for Surface Finishing Large UVOIR Mirrors, ZeCoat Corp

Broad-Band EUV Multilayer Coatings for Solar Physics, Reflective X-ray Optics, LLC

Composite Single Crystal Silicon Scan Mirror Substrates, Onyx Optics, Inc

Phase II TBD Submitted TBD Funded

NASA SBIR/STTR Technologies

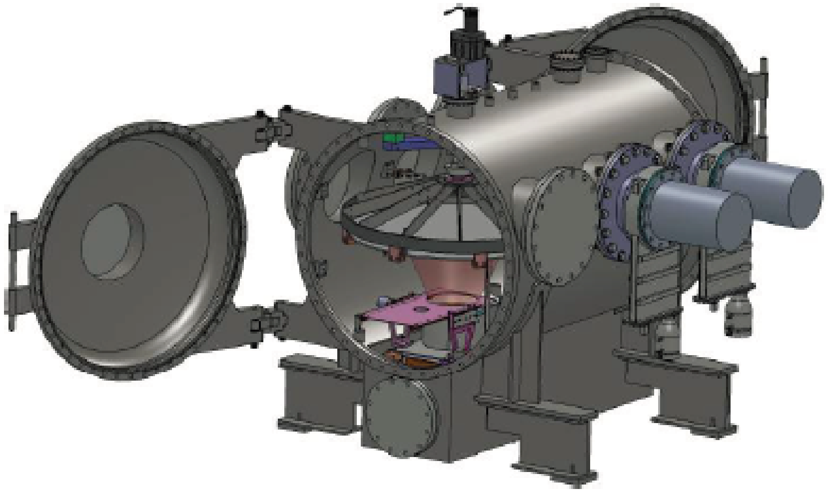
S2.03-8249 - Environmentally Stable UVOIR Reflective Coating for Large Mirrors

PI: David Sheikh
ZeCoat Corporation - Encinitas, CA

Identification and Significance of Innovation

ZeCoat Corporation will develop an affordable, environmentally stable, broadband UVOIR reflective coating (100-nm to 2500-nm) for large mirrors. A chamber integrated, FUV reflectance monitoring system (100-nm to 200-nm), will be used to optimize the coating process. By maintaining a constant coating geometry, ZeCoat's motion-controlled evaporation process is directly scaleable to mirrors 4-meters in diameter.
ZeCoat proposes three process innovations; (1) application of a positive pressure of pure nitrogen gas outside the coating the chamber to reduce oxidation of the aluminum reflector while under vacuum; (2) the use of a pulsed DC ion assist process to create a dense metal-fluoride protective layer, (3) removal of aluminum oxide contamination by ion etching, just prior to applying a protective metal-fluoride over-coat.
Normal incidence 4-meter class UVOIR telescopes have been cited as a high NASA priority by multiple government review panels.

Estimated TRL at beginning and end of contract: (Begin: 2 End: 3)



Technical Objectives and Work Plan

Objectives
Metric Goal
Technical Objectives:
1. Reflectance (100-nm to 200-nm)>83%
2. Reflectance (200-nm to 1500-nm)> 89%
3. Reflectance (1500-nm ? 2500-nm)> 95%
4. Surface Roughness After Coating<5 A RMS
5. Coating Stress< 85 MPa
6. Humidity 80C/80 RH, 24 hour
7. Thermal Cycling -80 + 150 C (ten cycles)
8. Adhesion ASTM Tape Test

Work Plan (Tasks)
1. Effect of neutralization filament contamination
2. Reflectance degradation of Al coating under vacuum
3. Degradation of Al coating with 5-nm of LiF substrate roughness
4. Surface roughness of 1-micron LiF
5. Scatter of Al (300-nm to 400-nm)
6. Environmental testing of Al/LiF coatings
7. Deliverables

NASA Applications

The ultimate goal of this research is to apply a UVOIR coating developed by ZeCoat, to a future NASA space-based observatory.

Non-NASA Applications

ZeCoat plans to offer through its website, a standard line of environmentally stable mirror products for microlithographic applications (157-nm and 193-nm).

Firm Contacts

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NASA SBIR/STTR Technologies

S2.03-8635 - Broad-Band EUV Multilayer Coatings For Solar Physics

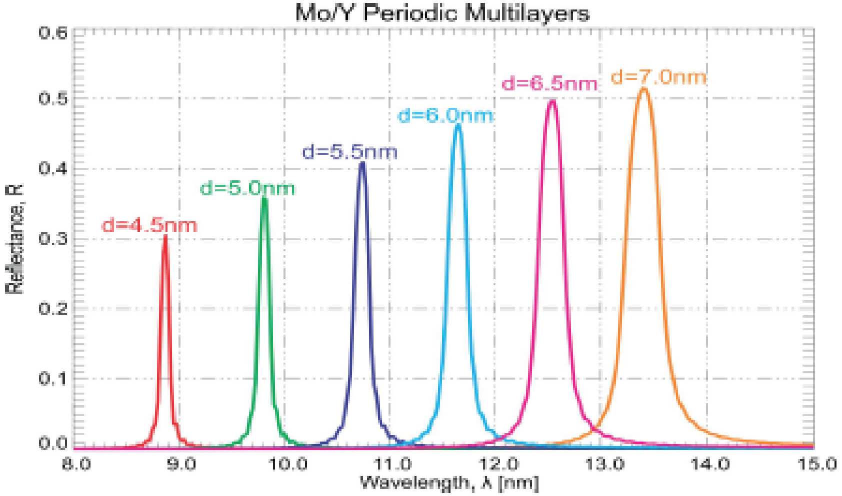
PI: David Windt

Reflective X-ray Optics, LLC - New York, NY

Identification and Significance of Innovation

We propose to develop a new class of aperiodic multilayer coating that is designed to provide high normal-incidence reflectance over a wide spectral band-pass in the extreme ultraviolet region from 9 to 14 nm. A broad-band reflective coating working at these wavelengths will enable, for the first time, the construction of high-resolution imaging spectrometers for solar physics utilizing diffraction gratings operating near normal incidence in this range, akin to previous instruments utilizing normal-incidence optics working at longer EUV wavelengths (> 17 nm) such as the Hinode/EIS satellite instrument and the EUNIS sounding rocket instrument. The development of high-resolution, normal-incidence grating spectrometers operating in the 9-14 nm range will in turn allow for detailed investigations of important solar emission lines, such as those from Fe XVIII - XXIII, that can provide unique diagnostics of high temperature plasma associated with solar flares and active regions.

Estimated TRL at beginning and end of contract: (Begin: 2 End: 4)



Technical Objectives and Work Plan

We propose to design, fabricate, and test a prototype aperiodic multilayer comprising Mo/Y bilayers that operates at normal incidence over the 9-14 nm range. Periodic Mo/Y multilayers have good performance at these wavelengths, and have been used already for the 9.4 nm imaging channels of the SDO/AIA and GOES-R/SUVI instruments. However, we have also identified several other candidate material combinations - i.e., Pd or Ru combined with B_4C or Y - that show promising performance over this range as well, and may prove to be superior to Mo/Y for use in aperiodic coatings. We therefore plan to experimentally investigate the performance of these other material systems in comparison to Mo/Y as part of our proposed Phase I research. We anticipate that our Phase II program will focus on the optimization and comprehensive testing of broad-band multilayers based on the results of our Phase I effort, so as to increase the TRL of these new coatings to a level high enough (i.e., TRL=4 or 5) for use in future NASA missions without further significant development.

NASA Applications

The successful development of efficient, broad-band EUV multilayers for the 9-14 nm region will enable future flights of the EUNIS rocket to target this band, and will also enable the development of high resolution spectrometers that can meet the science requirements of future NASA satellite missions, such as RAM, Solar-C and others that are currently being contemplated.

Non-NASA Applications

The new broad-band coatings we plan to develop may find application in a variety of research areas, including plasma diagnostics, synchrotron radiation instrumentation, ultra-fast physics experiments, and free-electron laser experiments.

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2012 SBIR S2.04

Phase I 15 Submitted 3 Funded

Advanced Optical Metrology for XRAY Replication Mandrels and Mirrors, Aperture Optical Sciences Inc

Light Weight, Scalable Manufacturing of Telescope Optics, ReliaCoat Technologies, LLC

Low Cost Method of Manufacturing Space Optics, ORMOND, LLC

Phase II TBD Submitted TBD Funded

NASA SBIR/STTR Technologies

S2.04-9140 - Low Cost Replication Mandrels for XRAY Astronomy

PI: Kai Xin

Aperture Optical Sciences Inc - Durham, CT

Identification and Significance of Innovation

Advanced x-ray observatories such as IXO and GenX will require thousands of thin shell mirror segments produced by replication using convex mandrels. The replication method has been succesfully demonstrated however is limited by the cost and precision of useable mandrels. The proposed development effort will address these two points by producing one or more mandrels having accuracy < 5 arc-seconds, and describing a pathway to achieving results for less than $25,000 per unit.

Estimated TRL at beginning and end of contract: (Begin: 3 End: 4)

NASA SBIR/STTR Technologies

Proposal No. S2.04-9140 – Low Cost Replication Mandrels for XRAY Astronomy

PI: Kai Xin PhD

Aperture Optical Sciences Inc. – Durham, CT

Identification and Significance of Innovation

Advanced x-ray observatories such as IXO and GenX will require thousands of thin shell mirror segments produced by replication using convex mandrels. The replication method has been succesfully demonstrated however is limited by the cost and precision of useable mandrels. The proposed development effort will address these two points by producing one or more mandrels having accuracy < 5 arc-seconds, and describing a pathway to achieving results for less than $25,000 per unit.

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

Technical Objectives

1. Demonstrate mandrel fabrication having axial slope error < 5 arc-second and describe a path to achieving sub-arcsecond performance
2. Produce sample components as deliverable items to validate results.
3. Based on results and previous analysis describe a path toward reaching budgetary goals of cost per unit effective area
4. Prepare a cellular, optimized, production workcell to produce compliant mandrels for NASA.

Work Plan

1. Prepare design for mandrels to be fabricated
2. Acquire Raw Materials and Plan Fabrication Work
3. Rough Generating of Mandrel Shape
4. Pre-polishing with Zeeko Robotic Platform
5. Polish to Best Figure

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.

Dr. Kai Xin, PI, Aperture Optical Sciences Inc.

NON-PROPRIETARY DATA

Technical Objectives and Work Plan

OBJECTIVES

Demonstrate mandrel fabrication having axial slope error < 5 arc-second and describe a path to achieving sub-arcsecond performance

Produce sample components as deliverable items to validate results.

Based on results and previous analysis describe a path toward reaching budgetary goals of cost per unit effective area

Prepare a cellular, optimized, production workcell to produce compliant mandrels for NASA.

WORK PLAN

1. Prepare design for mandrels to be fabricated
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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

Non-NASA Applications

Precision Cylindrical Optics
Large Format Aspheres
Low Mid-Spatial Period Optical Surfaces
Deterministic Low Cost Fabrication

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NON-PROPRIETARY DATA

NASA SBIR/STTR Technologies

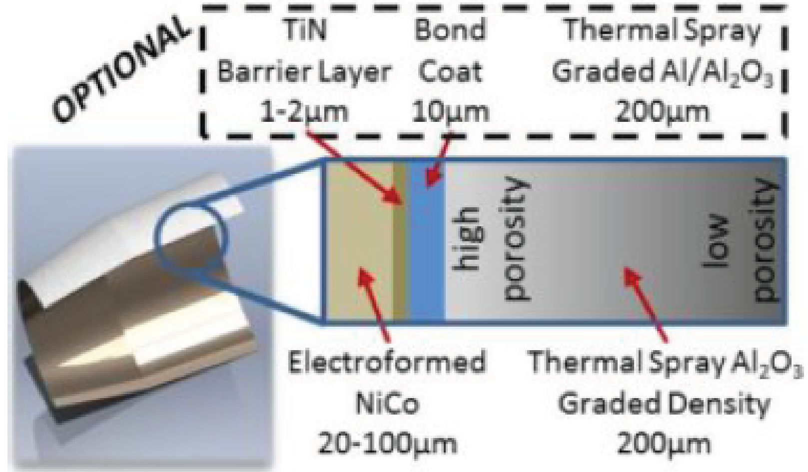
S2.04-9446 - Light Weight, Scalable Manufacturing of Telescope Optics

PI: Christopher Jensen
ReliaCoat Technologies, LLC - Stony Brook, NY

Identification and Significance of Innovation

X-ray telescopes use large nested mirrors to facilitate the collection of X-rays. Traditionally these reflectors are made from zerodur which are 20mm thick. The thickness of these optics is a limiting factor for the number of shells implemented in a telescope. State of the art observatories utilize nickel/cobalt reflectors manufactured through an electroforming process which are on the order of 1mm thick. While the number of shells can be greatly increased due to the reduced thickness, there still exists the need to reduce telescope mass. The proposed innovation seeks to replace much of the NiCo with a stiff, lightweight ceramic material. Instead of a 1mm thick NiCo layer a sub-100um layer can be stiffened by depositing a 200um ceramic coating on the rear of the optic. This process can result in an order of magnitude reduction in telescope weight and thus a cost savings in terms of launch vehicle requirements.

Estimated TRL at beginning and end of contract: (Begin: 1 End: 3)



Technical Objectives and Work Plan

The focus of this program will be to develop a lightweight density graded ceramic coating to be used as a support structure for a thin nickel/cobalt electroformed optic. The ceramic layer will be deposited with minimal residual stress as to not affect the figure accuracy of the optic. Additionally the porosity grading will be used to optimize the stiffness of the optic while allowing matching the CTE of the ceramic to the NiCo.
Through interaction with program partners specifications will be developed for each coating layer of the optic. A detailed design plan will be formulated and reflector coating development will address issues such as print through and adhesion while simultaneously determining the minimum NiCo layer thickness. The density graded multilayer laminate will then be optimized for stiffness and matching the CTE with the NiCo shell. Material properties of the coating system will be measured as well as characterization of X-ray performance and surface microroughness. This will all be performed with the vision of scale-up and manufacturing in mind with the goal to produce a three shell nested optic in Phase II.

NASA Applications

The development we are proposing includes fabrication and manufacturing techniques that can benefit X-ray telescope technology by fabricating and testing new lighter weight, stronger material optics that will allow high throughput X-ray telescopes to be substantially lighter weight, with improved angular resolution. This endeavor would lead to the design and development of X-ray optics for future NASA missions, including Explorer missions.

Non-NASA Applications

Significant possibilities exist for multi-spectral systems in areas of defense telescopes, commercial space exploration and medical imaging. Proposed innovation is also applicable for membrane-type solid oxide fuel cell fabrication from dense electrolyte layers to porous electrode layers for graded microstructure and residual stress management.

Firm Contacts

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NASA SBIR/STTR Technologies

S2.04-9968 - Low Cost Method of Manufacturing Space Optics

PI: Dan Alberts
ORMOND, LLC - Auburn, WA

Identification and Significance of Innovation

As ground and space based astronomical optics systems become larger and the use of difficult to machine materials becomes more desired, cost, risk and schedule are setting limits to the feasibility of many projects. Proposed is the development of a manufacturing technology that will increase feasible large optics design options and significantly reduce the manufacturing time, cost and risk involved in producing large optics components. Specifically addressed are cutting, near net shaping and light weighting of glass and ceramic optical components.

Estimated TRL at beginning and end of contract: (Begin: 4 End: 7)

Technical Objectives and Work Plan

The primary goal of this SBIR is to make available a new technology that will provide significant manufacturing cost and time savings and will increase feasible design options in space optics.

The technical objectives of the Phase I program include:

-Demonstrate feasibility of a low risk glass and ceramic optics cutting process and determine required support tooling

-Demonstrate feasibility of a low cost milling for near net shaping and light weighting of ceramic optics structures

-Demonstrate the initial technical performance of the technology in terms of machining process time, cut quality, residual stress development, and sub-surface damage.

NASA Applications

Management at the Raytheon Space and Airborne Systems group have stated that the developments made under this SBIR will directly support NASA programs including JDEM, IXO, LISA, ICESAT, ATLAST, CLARREO and ACE.

Non-NASA Applications

The developments made under the proposed SBIR will support any application where brittle materials are machined, especially applications where challenging ceramics such as SiC must be machined in bulk.

Another large market area is the ceramic armor industry. Manufacturers are searching for reduced cost methods of shaping armor plates; an excellent

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2012 SBIR E3.02

Phase I 4 Submitted 2 Funded

Low Cost, Cosmic Microwave Background Telescope, Vanguard

Affordable, Ultra-stable CVC SiC UVOIR Telescope for BENI Mission, TREX

Phase II TBD Submitted TBD Funded

NASA SBIR/STTR Technologies

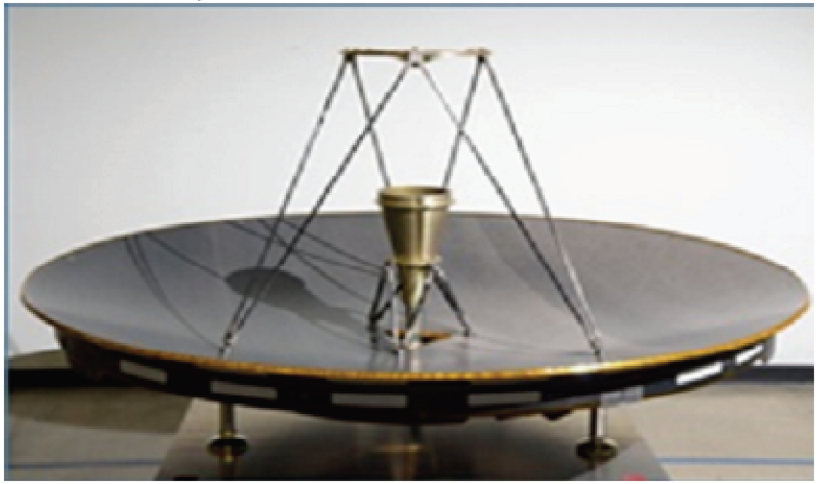
E3.02-8944 - Low Cost, Cosmic Microwave Background Telescopes (P-NASA12-003)

PI: Mark Schlocker
Vanguard Space Technologies, Inc. - San Diego, CA

Identification and Significance of Innovation

Cosmic Microwave Background (CMB) polarization measurements on large angular scales can probe the Universe's post-birth state. Small angular scale measurements probe the Universe's structure evolution over cosmic time. EBEX is the largest CMB telescope with an aperture of 1.5 meters, limited by mission size and weight constraints. Future CMB missions require high-quality lightweight reflectors as an enabling technology. Vanguard Space Technologies proposes building upon the success and leveraging the lessons learned from BLAST. A technology demonstration program is recommended leading to a successful PDR that includes a preliminary design with budgeted errors, a detailed manufacturing plan, and a recurring cost model and estimate. A CDR package and two telescope systems will be provided during Phase II. The system will feature 2X lower areal cost and 2X lower areal mass than BLAST. VST proposes to meet TRL requirements by incorporating carbon fiber composite component technologies.

Estimated TRL at beginning and end of contract: (Begin: 4 End: 6)



Technical Objectives and Work Plan

The Phase I objective is to develop a preliminary design and manufacturing plan for carbon fiber composite reflectors and/or a carbon fiber telescope that are traceable to the requirements of current and future CMB missions. The Phase II objectives are to complete the design and manufacturing planning, fabricate necessary tooling, manufacture hardware components that include two reflector support structures, integrate and align the reflectors into the support structure, and confirm telescope optical performance via analysis of as-built mechanical alignment and surface accuracy data. To prepare for and conduct the PDR within six months, the proposed Phase I tasks will include: 1) Develop telescope requirements in conjunction with CMB researchers and/or NASA with the goal of resolving sufficient detail to evaluate CFRP technology for CMB missions, 2) Compare the requirements to CFRP heritage, as-built results, and experience, 3) Develop a concept based upon high (currently 4-9) TRL CFRP component technologies, 4) Predict the performance, 5) Develop a pricing model to predict recurring cost, 6) Define a preliminary manufacturing plan that includes predicted versus budgeted errors, 7) Develop a summary technical/cost compliance matrix that summarizes predictions versus requirements, 8) Summarize all engineering, manufacturing, and cost information in preparation for PDR including the envisioned path to telescope TRL6 during Phase II, and 9) Conduct a PDR.

NASA Applications

The capabilities proposed are relevant to Space/Earth science missions with immediate technology insertion for CMB. Potential applications include balloon, space, and ground-based astronomy and remote sensing missions, e.g. High Altitude Scientific Balloon Flight Program, SMLS, and CCAT. Reflectors (mirror facets) for large concentrators are required to develop solar devices for sustainable energy and lunar oxygen generation devices and studies at JPL, Cornell, GSFC, UPENN and LaRC.

Non-NASA Applications

Renewable energy interests have indicated a desire to field an ever-growing number of large solar concentrators. The maturing of system competencies could benefit DOE and DoD. Large, accurate, thermally stable telescopes are needed for broadband spacecraft. The need to provide Internet service in remote locations has providers and manufacturers considering constellations of spacecraft.

Firm Contacts

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NASA SBIR/STTR Technologies

E3.02-9771 - Affordable, Ultra-stable CVC SiC UVOIR Telescope for BENI Mission

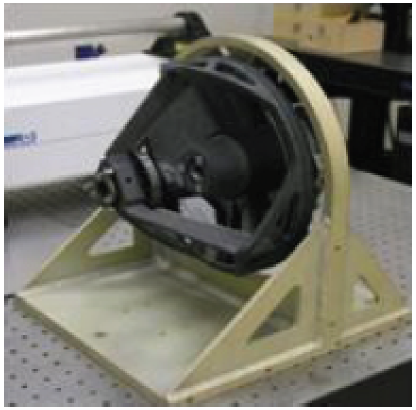
PI: Dr. Goodman
Trex Enterprises Corporation - San Diego, CA

Identification and Significance of Innovation

TEAM: Trex, ITT-Exelis (System Integrator partner), Richard Lyon (NASA/GSFC Principal Investigator Compact Achromatic Visible Nulling Coronagraph Technology Maturation), Lee Feinberg (telescope expert)
Preliminary Design for 1-meter aperture, ultrastable, UVOIR telescope made with highly athermal Trex Chemical Vapor Composite Silicon Carbide (CVC SiC).
Provides affordable solution for the Balloon Exoplanet Nulling Interferometer (BENI) Mission to qualify the VNC, with traceability to the requirements of the ATLAST observatory.

Demonstrate replicated, powered CVC SiC substrates using a new, polishable graphite mandrel material.
New process eliminates rough and fine grinding of the optical surface. Factor of 2X reduction in the areal cost, reduction in schedule ~6-months. Meniscus mirror designs also reduces cost & schedule for CVC SiC mirrors.

Estimated TRL at beginning and end of contract: (Begin: 4 End: 6)



Technical Objectives and Work Plan

Project Objectives:
1) To conceptualize, design and analyze a 1-meter aperture, ultra-stable, CVC SiC UVOIR telescope tailored to the specific mission requirements of BENI, with the quality of the mirrors being traceable to the goals of future UVOIR observatories such as ATLAST. Wavelength: 300-2200 nm. Transmitted WFE < 36 nm (diffraction limited @ 500 nm). FOR: 20 to 70 degrees Elevation. FOV: > 10 arcsec;
2) To demonstrate a new replication process for rapidly and inexpensively producing large, high quality, lightweight silicon carbide mirrors by eliminating the long lead, high cost rough and fine grinding procedures prior to polishing the mirror surface;
3) To demonstrate by design and analysis a meniscus primary mirror mounted using a tangent flange approach. This approach obviates the need for a mirror mount hub (mushroom) on the back side of the mirror, lessens the overall thickness of the CVC SiC substrate deposit, and eliminates the long lead time and expensive isogrid lightweighting.

Work Plan:
1) Requirements Definition with NASA and ITT-Exelis.
2) Weekly TIMs
3) CVC SiC Replication Experiments
4) BENI TELESCOPE DESIGN AND ANALYSIS

NASA Applications

First Foremost is a telescope for the BENI mission to qualify Visible Nulling Coronagraph to TRL 6. Furthermore, the common need cited in Astro 2010 and 2012 National Research Council report "NASA Space Technology Roadmaps and Priorities etc." is a mirror technology that is lightweight, dimensionally stable, high performance, and above all else, cost effective. One potential future observatory mission is the Advanced Technology Large-Aperture Space Telescope (ATLAST).

Non-NASA Applications

Low cost, lightweight, dimensionally stable SiC mirrors have use in complex telescopes/optical instruments for Astronomy, Imaging/ Remote Sensing apps, imaging, surveillance, and reconnaissance missions for police, paramilitary units and national defense, fire fighters, power/pipeline monitoring, search/rescue, atmospheric/ocean monitoring, imagery/mapping for resource mgt, and disaster relief.

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2011 SBIR S2.04

Phase I	12 Submitted	4 Funded

Diamond Turned Super Alloy Mandrel for X-Ray Mirrors; Dallas Optical Systems

Lightweight Composite Mirrors for Telescopes; Materials Modification

Carbon Nanotube and Carbon Fiber Reinforced SiC Optical Components; M Cubed

Dual Band EUV Multilayer Coatings for Solar Physics; Reflective X-Ray Optics

Phase II	3 Submitted	0 Funded

2011 SBIR S2.05

Phase 1 13 Submitted 3 Funded

Cryogenic & Vacuum Compatible Metrology Systems; Flexure Engineering

Optical Fabrication & Metrology of Aspheric & Free Form Mirrors; OptiPro

Very Large Computer Generated Holograms for Precision Metrology of Aspheric Optical Surfaces; Arizona Optical Metrology

Phase II 2 Submitted 1 Funded

Optical Fabrication & Metrology of Aspheric & Free Form Mirrors; OptiPro

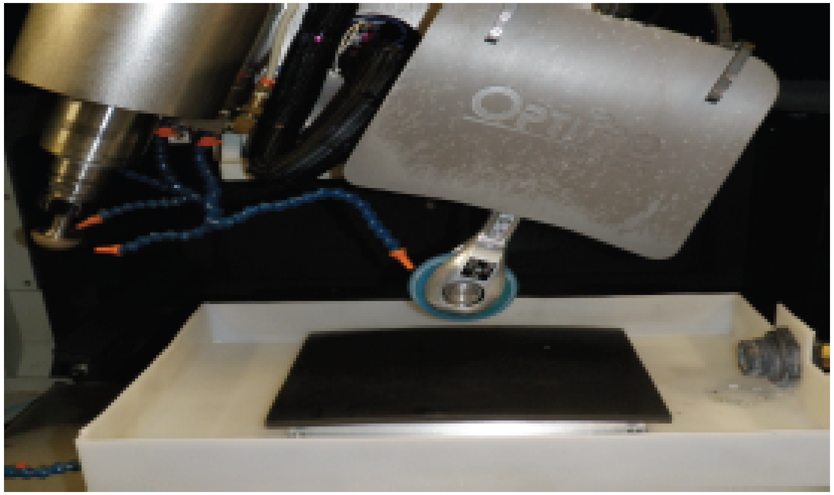
NASA SBIR/STTR Technologies

S2.05-8333 - Optical Fabrication and Metrology of Aspheric and Freeform Mirrors

PI: David Mohring
OptiPro Systems LLC - Ontario, NY

Identification and Significance of Innovation

OptiPro's UltraForm Finishing (UFF) is a sub-aperture compliant wheel and belt type grinding and polishing process for rapid material removal from the ground state to a finished optic. The UFF removes residual grinding sub-surface damage, mid spatial frequency errors, and provides the mechanism required for surface corrections. The UFF, with its 5 axis of motion provides a platform to polish traditional flats and spheres as well as aspheres and freeform shapes. The UFF was designed for deep concave shapes and it is suitable for finishing conformal optics. Large optics and mirrors require cost effective fabrication and in-situ metrology solutions. Currently the UFF and UltraSurf platforms have addressed the fabrication requirements for small aspheric and freeform optics. This proposal implements new tool designs on these platforms required for the fabrication of large mirrors with stringent mid spatial waviness error requirements.



Estimated TRL at beginning and end of contract: (Begin: 2 End: 4)

Technical Objectives and Work Plan

The main objectives of this phase I is to develop and demonstrate new tooling and metrology techniques for the fabrication of precision optical mirrors, utilizing the UltraForm Finishing (UFF) platform and UltraSurf techniques. The UFF platform is commercially available and cost effectively manufactures aspheres up to 300mm diameter. The scaling up of the UFF UltraWheel and process for large work piece grinding and polishing will require the analysis and optimization of the forces using finite element analysis (FEA) techniques. OptiPro Systems will test and analyze the machine, tooling and process requirements for large optical mirror and mandrel fabrication. The developed tooling and process parameters required for cost effective fabrication will drive the design of a new large mirror fabrication platform. A key component to this cost effective platform and process, is the in-situ metrology. New technologies and sensors will be tested and analyzed on existing equipment for scalability to large optics and integration into the fabrication platform. The above testing will provide the steps required for a robust process, special attention will be made to overall cycle time improvements with the large UltraWheel and belt design. With our MasterCAM and UFF toolpath generation software we will analyze various process scenarios to optimize the process parameters and reduce the cycle times while maintaining the required surface accuracy.

NASA Applications

Beneficiary NASA applications include the fabrication of forming mandrels used to produce multiple segmented shell mirrors for the International X-Ray Observatory (IXO) as well as aspheric and off axis parabolic or freeform optical surfaces required by LISA and WFIRST. These programs require cost effective solutions for the fabrication of large optics and mirrors.

Non-NASA Applications

The DOD and commercial applications for this technology is for 10mm to 300mm diameter optics and windows. The scaling up of this technology to larger optics, windows and mirrors will enable cost effective fabrication and metrology of military vehicle windows, satellite optics and telescope components.

Firm Contacts

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Any Questions?

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 specifically identifies optical components and coatings as key technologies:

- **Light-weight x-ray imaging mirrors for future large advanced x-ray observatories**
- **Large aperture, light-weight mirrors for future UV/Optical telescopes**
- **Broadband high reflectance coatings for future UV/Optical telescopes**

National Academy "NASA Space Technology Roadmaps and Priorities" states that one of NASA's top challenges should be to develop a new generation of larger aperture, lower-cost telescopes:

- **Active align/control of < 1 arc-second angular resolution x-ray imaging**
- **Active align/control of 500 nm diffraction limit imaging systems**
- **Normal incidence 4-meter (or larger) diameter 5 nm rms WFE mirrors**

Desired Technologies

This subtopic solicits solutions in the following areas:

- Optical Components, Coatings and Systems for potential x-ray missions
- Optical Components, Coatings and Systems for potential UV/Optical missions

Proposals should show an understanding of one or more relevant science needs, and present a feasible plan to fully develop a technology and infuse it into a NASA program.

The primary emphasis of this subtopic is to mature technologies needed to manufacture, test or operate complete mirror systems or telescope assemblies.

Technical Callenges

In all cases, the most important metric for an advanced optical system is affordability or areal cost (cost per square meter of collecting aperture). Currently both x-ray and normal incidence space mirrors cost \$4 million to \$6 million per square meter of optical surface area. This research effort seeks a cost reduction for precision optical components by 5 to 50 times, to less than \$1M to \$100K/m2.

Successful proposals shall provide a scale-up roadmap (including processing and infrastructure issues) for full scale space qualifiable flight optics systems. Material behavior, process control, active and/or passive optical performance, and mounting/deploying issues should be resolved and demonstrated.

X-Ray Technologies

Potential x-ray missions require

- X-ray imaging telescopes with <1 arc-sec angular resolution and > 1 to 5 m^2 collecting area;
- Multilayer high-reflectance coatings for hard x-ray mirrors (NuSTAR)
- X-ray transmission and/or reflection gratings

Multiple technologies are needed to enable < 1 arc-sec x-ray telescopes.

- new mirror materials such as silicon carbide, porous silicon, beryllium;
- improved techniques to manufacture (such as direct precision machining, rapid optical fabrication, slumping or replication technologies) 0.3 to 2 meter mirror shells or segments;
- improved testing techniques;
- active alignment of mirrors in a telescope assembly; and
- active control of mirror shape.

X-Ray Desired Outcomes

Successful proposals will demonstrate ability to:

manufacture, test & control 0.25 to 0.5 m prototype x-ray mirror assembly; or coat a 0.25 to 0.5 m representative optical component.

Ideal Phase 1 delivers 0.25 m x-ray mirror.

Ideal Phase 2 advances technology to produce TRL 4/5 0.5 m mirror.

Deliverables include all necessary documentation, including optical performance assessment and all data on processing and properties of its substrate materials.

Phase 2 also includes a mechanical and thermal stability analysis.

UVOIR Technologies

Potential UV/Optical missions require:

Large aperture, light-weight mirrors
Broadband high reflectance coatings

Successful proposals will demonstrate an ability to:

manufacture, test &control ultra-low-cost precision 0.25 to 0.5 m optical systems; or coat a 0.25 to 0.5 meter representative optical component.

Ideal Phase 1 deliverable would be a precision mirror of at least 0.25 meters; or a coated mirror of at least 0.25 meters.

Ideal Phase 2 advances technology to produce TRL 4/5 mirror > 0.5 m.

Deliverables include all necessary documentation, including optical performance assessment and all data on processing and properties of its substrate materials.

Phase 2 also includes a mechanical and thermal stability analysis.

Large UVOIR Mirror Technology

Future UVOIR missions require 4 to 8 or 16 meter monolithic or segmented primary mirrors with < 10 nm rms surface figures.

Mirror areal density depends upon available launch vehicle capacities to Sun-Earth L2 (i.e. 15 kg/m2 for a 5 m fairing EELV vs. 60 kg/m2 for a 10 m fairing SLS).

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 mirrors or lens segments.
- reflective, transmissive, diffractive or high order diffractive blazed lens optical components for assembly of large (16 to 32 meter) optical quality primary elements.

Large Area UVOIR coatings

Large telescopes require broadband (from 100 nm to 2500 nm) high-reflectivity mirror coating with extremely uniform amplitude and polarization properties.

Proposals include, but are not limited to:

- investigations of new coating materials with promising UV performance;
- new deposition processes; and
- examination of handling processes, contamination control, and safety procedures related to depositing coatings, storing coated optics, and integrating coated optics into flight hardware.

An ability to demonstrate optical performance on 2 to 3 meter class optical surfaces is important.

Any Questions?