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LLNL-TR-737545

Improved Advanced Actuated Hybrid Mirrors Final Report CRADA No. TC02130.0

T. W. Barbee, M. A. Ealey

August 28, 2017

Disclaimer

This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

Improved Advanced Actuated Hybrid Mirrors

Final Report
CRADA No. TC02130.0
Date Technical Work Ended: August 19, 2009

Date: July 17, 2010 Revision: 3

A. Parties

This project was a relationship between Lawrence Livermore National Laboratory (LLNL) and Northrop Grumman Xinetics (NG Xinetics).

Lawrence Livermore National Security, LLC
Lawrence Livermore National Laboratory
7000 East Avenue
Livermore, CA 94550
Troy W. Barbee, Jr.
Tel: (925) 423-7796
Fax: (925) 422-6892

Northrop Grumman Xinetics
115 Jackson Road
Devens, MA 01434
Mark A. Ealey
Tel: (978) 772-0352, ext. 109
Fax: (978) 772-2814

B. Project Scope

This was a collaborative effort to develop and demonstrate an improved Advanced Actuated Hybrid Mirrors (AAHM) for commercial or Government purposes. The AAHM consists of a nanolaminate film replicating a precision optical surface bonded to a Silicon Carbide (SiC) substrate with active figure control capability.

The goal of this project was to further the development of specific AAHM technologies. The intent of the CRADA was to combine the expertise of LLNL and NG Xinetics in the manufacture and test of a very high quality AAHM, incorporating lessons learned from earlier joint efforts.

The project consisted of seven major tasks and the following major deliverables:

NG Xinetics Deliverables:

NG Xinetics agreed to provide the following to LLNL

1. a final report regarding optical performance of the advanced actuated hybrid mirror. This report is CRADA proprietary information. Deliverable Due: Month 4
2. mandrels on or before week 1 of the CRADA.
3. draft results of Task 5 and Task 6 on or before November 10, 2008. Task 5: integrate actuators and bipods for mounting over a 6 week period. Task 6: conduct optical test of the completed mirror segment.

LLNL Deliverables:

LLNL agreed to provide the following to NG Xinetics:

1. nanolaminate calibration run data reporting residual stress, residual stress profile, thickness profile, and nanolaminate thermal expansion coefficient. Deliverable Due: Month 2
2. report documenting the stress distribution and the film thickness measurements of the nanolaminate film as delivered to NG Xinetics. Deliverable Due: Month 2
3. witness samples providing traceability to the previous calibration nanolaminate deposition as described in Deliverable 2. Deliverable Due: Month 2
4. one nanolaminate on the NG Xinetics mandrel. Deliverable Due: Month 2
5. draft and final versions of Final Month 5

During manufacture, LLNL sent data almost daily to Xinetics regarding status of nanolaminate processing. Deliverables 1 and 2 were satisfied in a report entitled "Lumens Mandrel Nano-Laminate Fabrication: Mandrel Preparation and Inspection Reports, June 10 2009 – June 17, 2009". Witness samples (Deliverable 3) were delivered to NG Xinetics in July of 2009. One nanolaminate on the NG Xinetics mandrel was delivered to NG Xinetics on June 19, 2009.

This CRADA was originally designated as a nine (9) month project. A no-cost time extension request was executed in February 2009, extending the project for an additional six months (to August 19, 2009) to allow enough time for LLNL to receive the mandrel from NG Xinetics in order to complete the tasks and deliverables. Although there was a further delay in receiving the last deliverables from NG Xinetics, all of the task and deliverables were successfully completed.

C. Technical Accomplishments

The specific technical accomplishments of this project were the manufacture and test of a very high quality Advanced Actuated Hybrid Mirrors (AAHM) incorporating lessons learned from earlier joint efforts

D. Expected Economic Impact

The result of this cooperative may yield optical mirrors of exceptional quality. Success of this technology demonstrates a new paradigm for the production of actuated hybrid optical mirrors that can be rapidly manufactured at relatively low cost, and will provide extremely lightweight, precision controlled optical surfaces for the future generations of space and ground based optical instruments.

D.1 Specific Benefits

Benefits to DOE
This CRADA was part of a large ongoing government sponsored project, supporting the continued development of a new generation of Advanced Actuated Hybrid Mirrors (AAHM) and optical components. The CRADA benefits DOE through a technology that will provide low cost, rapidly manufactured precision reflective optical surfaces. The AAHMs employing the nanolaminate replicated optical films can be manufactured in a variety of sizes and configurations for both U.S. Government and commercial customers. These AAHMs will provide the customers with very lightweight, lower cost, rapid delivery, precision mirrors and optical components for use in space based astronomy and earth observation optical systems as well as ground and airborne optical sensors. This technology also supports programmatic goals of primary importance to DOE's nonproliferation responsibilities.

Benefits to Industry
This CRADA benefits NG Xinetics and industry through the production of actuated hybrid optical mirrors that can be rapidly manufactured at relatively low cost, and will provide extremely lightweight, precision controlled optical surfaces for the future generations of space and ground based optical instruments. The results of this CRADA also benefit the manufacture of consumer telephone and optical switching components.

E. Partner Contribution

NG Xinetics provided the mandrel and used existing proprietary SiC technology for the manufacture of the advanced actuated hybrid mirror. They also should be able to provide data regarding integration of actuators and bipods for mounting and resulting optical performance of the advanced actuated hybrid mirror segment.

F. Documents/Reference List

*Protected CRADA Information

Reports

*Proprietary Project Report entitled "Lumens Mandrel Nano-Laminate Fabrication: Mandrel Preparation and Inspection Reports, June 10 2009 – June 17, 2009".

*Proprietary Project Report entitled "Lumens – End Item Data Package EIDP", January 15, 2010.

Copyright Activity

All drawings and data are based on prior art.

Subject Inventions

No Subject Inventions were disclosed by either Party.

Background Intellectual Property

LLNS/LLNL disclosed the following Background Intellectual Property for this project:

U.S. Patent No. 5,742,471 (LLNL IL-9901A), *Nanostructure Multilayer Dielectric Materials for Capacitors and Insulators*; Inventors: Troy W. Barbee Jr., Gary W. Johnson; Issued 4/21/98

U.S. Patent No. 6,278,764 (LLNL IL-10484A), *High Efficiency Replicated X-ray Optics and Fabrication Method*; Inventors: Troy W. Barbee Jr., Stephen M. Lane, Donald E. Hoffman; Issued: 8/21/01

U.S. Patent No. 6,396,900 (LLNL IL-10838A), *Multilayer Films with Sharp, Stable Interfaces for Use in EUV and Soft X-ray Applications*; Inventors: Troy W. Barbee Jr., Sasa Bajt; Issued: 5/28/02

NG Xinetics licensed the above Background Intellectual Property under LLNL License Agreement No. TL02067-0.0, executed on May 19, 2006.

LLNL IL-11969A, Patent Pending

NG Xinetics has not expressed an interest in licensing the LLNS/LLNL Background Intellectual Property listed above, IL11969A.

NG Xinetics disclosed the following Background Intellectual Property for this project:

U.S. Patent No. 7,195,361, *Active Hybrid Optical Component*; Inventor: Mark A. Ealey

U.S. Patent Application No. 11/123,473, *High Authority Deformable Optical System;* Inventor: Mark A. Ealey

U.S. Patent Application No. 10/730,412, *Integrated Actuator Meniscus Mirror;* Inventor: Mark A. Ealey

U.S. Patent No. 7,125,128, *Adaptive-Optics Actuator Arrays and Methods for Using such Arrays*; Inventor: Mark A. Ealey

G. Acknowledgement

Industrial Participant's signature of the final report indicates the following:

1) The Participant has reviewed the final report and concurs with the statements made therein.
2) The Participant agrees that any modifications or changes from the initial proposal were discussed and agreed to during the term of the project.
3) The Participant certifies that all reports either completed or in process are listed and all subject inventions and the associated intellectual property protection measures generated by his/her respective company and attributable to the project have been disclosed and included in Section E or are included on a list attached to this report.
4) The Participant certifies that if tangible personal property was exchanged during the agreement, all has either been returned to the initial custodian or transferred permanently.
5) The Participant certifies that proprietary information has been returned or destroyed by LLNL.

Mark A. Ealey, President
Northrop Grumman Xinetics

Date

Troy W. Barbee Jr., LLNL Principal Investigator
Lawrence Livermore National Laboratory

October 27, 2010
Date

for Veronica Fazio

Erik J. Stenehjem, Industrial Partnerships Director
Lawrence Livermore National Laboratory

November 17, 2010
Date

Attachment I – Final Abstract

G. Acknowledgement

Industrial Participant's signature of the final report indicates the following:

1) The Participant has reviewed the final report and concurs with the statements made therein.
2) The Participant agrees that any modifications or changes from the initial proposal were discussed and agreed to during the term of the project.
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4) The Participant certifies that if tangible personal property was exchanged during the agreement, all has either been returned to the initial custodian or transferred permanently.
5) The Participant certifies that proprietary information has been returned or destroyed by LLNL.

Mark A. Ealey, President
Northrop Grumman Xinetics — Date: 10/29/10

Troy W. Barbee Jr., LLNL Principal Investigator
Lawrence Livermore National Laboratory — Date

Erik J. Stenehjem, Industrial Partnerships Director
Lawrence Livermore National Laboratory — Date

Attachment I – Final Abstract

Improved Advanced Actuated Hybrid Mirrors

Final Abstract (Attachment I)
CRADA No. TC02130.0
Date Technical Work Ended: August 19, 2009

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A. Parties

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B. Purpose and Description

This is a collaborative effort between Lawrence Livermore National Security, LLC as manager and operator of Lawrence Livermore National Laboratory (LLNL) and Northrop Grumman Xinetics (NG Xinetics), to develop and demonstrate an improved Advanced Actuated Hybrid Mirrors (AAHM) for commercial or Government purposes. The goal of this project was to further the development of specific AAHM technologies. The intent of the CRADA was to combine the expertise of LLNL and NG Xinetics in the manufacture and test of a very high quality AAHM, incorporating lessons learned from earlier joint efforts.

The AAHM consists of a nanolaminate film replicating a precision optical surface bonded to a Silicon Carbide (SiC) substrate with active figure control capability. This optic structure consisting of a LLNS fabricated Nano-lamiante coupled with a Northrup-Grumman Xinetics silicon carbide actuated Facesheet will demonstrate an advanced cost-effective approach to the manufacture of precision off-axis aspheric mirror segments.

C. Benefit to Industry

This CRADA benefits NG Xinetics and industry through the production of actuated hybrid optical mirrors that can be rapidly manufactured at relatively low cost, and will provide extremely lightweight, precision controlled optical surfaces for the future generations of space and ground based optical instruments. The results of this CRADA also benefit the manufacture of consumer telephone and optical switching components.

D. Benefit to DOE/LLNL

This CRADA was part of a large ongoing government sponsored project, supporting the continued development of a new generation of Advanced Actuated Hybrid Mirrors (AAHM) and optical components. The CRADA benefits DOE through a technology that will provide low cost, rapidly manufactured precision reflective optical surfaces. The AAHMs employing the nanolaminate replicated optical films can be manufactured in a variety of sizes and configurations for both U.S. Government and commercial customers. These AAHMs will provide the customers with very lightweight, lower cost, rapid delivery, precision mirrors and optical components for use in space based astronomy and earth observation optical systems as well as ground and airborne optical sensors. This technology also supports programmatic goals of primary importance to DOE's nonproliferation responsibilities.

E. Project Dates

September 19, 2008 through August 19, 2009.