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LLNL-TR-740391

Miniature CCD X-Ray Imaging Camera Technology Final Report CRADA No. TC-773-94

A. Conder, F. J. Mummolo

October 20, 2017

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Miniature CCD X-Ray Imaging Camera Technology

Final Report

CRADA No. TC-773-94

Date Technical Work Ended: September 19, 1995

Date: July 23, 2001

Revision: 5

A. Parties

This project was a relationship between Lawrence Livermore National Laboratory and Princeton Instruments, Inc. Roper Scientific acquired Princeton Instruments in 1997.

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Lawrence Livermore National Laboratory
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Livermore, CA 94550
Alan Conder
Principal Investigator
Telephone: (925) 422-2032
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Princeton Instruments, Inc. (now Roper Scientific)
3660 Quakerbridge Road
Trenton, NJ 08619
Frank J. Mummolo
President
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B. Project Scope

The goal of the project was to develop a compact, large active area, high spatial resolution, high dynamic range, charge-coupled device (CCD) camera to replace film for digital imaging of visible light, ultraviolet radiation, and soft to penetrating X-rays. The camera head and controller needed to be capable of operation within a vacuum environment and small enough to be fielded within the small vacuum target chambers at LLNL.

There were three phases to the project:

1. Manufacture of a prototype CCD camera head with these specifications:
 - a. Small size 60mm x 60mm x 60mm
 - b. High resolution CCD using the TK1024 CCD or equivalent
 - c. Thermoelectric cooling of the CCD sensor to between -20° to -30°C for dynamic range of 14-16 bits
 - d. Electronics and packaging compatible with a vacuum environment
2. Design, development, and manufacture of prototype CCD camera controller with these specifications:
 - a. Small size approximately 130mm x 130mm x 180mm
 - b. Dual 100 kHz 16 bit video digitization capability
 - c. Serial communication data link
 - d. Electronics and packaging compatible with a vacuum environment

(CCD camera controller was not developed because it was impractical for the vacuum applications that we originally intended for its use. Princeton Instruments delivered a commercial CCD controller and worked with us to guarantee it would interface with our CCD camera head.)

3. Development and manufacture of computer interface hardware package that would have IBM 486 (or equivalent) compatibility and would be capable of interfacing with four camera controllers, and the development of the computer interface software for display and analysis of digital images.

(Princeton Instruments provided software support that insured the CCD camera we developed could be used on the IBM 486 and equivalent.)

There were five deliverables:

1. Miniaturized camera head prototype
2. Compact camera controller
3. Computer interface card
4. Computer software
5. Documentation

C. Technical Accomplishments

A compact CCD camera head capable of use in the laser vacuum target chamber was developed. Through the cooperation of Princeton Instruments, it was designed to be integrated into an ST-138 camera controller and WinView imaging software. This endeavor was completed on time and these systems are now in use at LLNL and the University of Rochester. There are no unresolved issues.

Our original technical objectives were to design, develop, and manufacture a compact, large active area, high spatial resolution, high dynamic range, charge-coupled device (CCD) camera to replace film for digital imaging of visible light, ultraviolet radiation, and soft to penetrating X-rays. The camera head and controller needed to be capable of operation within a vacuum environment and small enough to be fielded within the small vacuum target chambers at LLNL.

There were five milestones:

1. Miniaturized Camera Head Prototype

The miniaturized camera head prototype was completed, and evaluated by LLNL during May 1994. At that time, it was made available to Princeton Instruments for their own independent evaluation, which was completed in July 1994.

2. Compact Camera Controller

The compact camera controller prototype was completed, and evaluated by LLNL during August 1994.

3. Computer Interface Card

A computer interface card prototype was evaluated by LLNL.

4. Computer Software

The computer software was evaluated by LLNL.

5. Documentation

LLNL and Princeton Instruments completed final documentation, including a complete fabrication package, along with test and evaluation reports.

D. Expected Economic Impact

These compact CCD cameras have a broad spectrum of applications as optical and X-ray imaging devices for DoD, DOE, industrial, and medical applications.

This collaboration with Princeton Instruments, an established national leader in the manufacturing of CCD cameras, provided a direct relationship to a proven product line.

D.1 Specific Benefits

By jointly developing this new compact, large area CCD camera, LLNL had immediate access to Princeton Instruments' experienced digital device engineers, tested system operation procedures and software packages for integrated control and image processing. Having Princeton Instruments as an active participant in the development and evaluation of each stage of the project provided early user feedback and a focus on the utility, not just the capability, of the final product. Princeton Instruments provided future technical support for these CCD cameras. That was important since maintenance of these systems outside of the DOE Weapons Program was not a desirable task for LLNL.

Collaboration with Princeton Instruments gave the Weapons Program a direct line to a national technology leader and allowed future access to developing technologies in the area of digital imaging devices.

The development of this technology benefited DOE and other government agencies or universities involved in scientific research where the acquisition of very high quality two-dimensional (X-ray, ultraviolet, or visible light) images is required.

E. Partner Contribution

LLNL was responsible for the electrical and mechanical design of the miniature camera head. Princeton Instruments reviewed the camera head design prior to manufacture. LLNL and Princeton Instruments collaboratively designed and manufactured the miniature camera controller.

F. Documents/Reference List

Design schematics and prints of the CCD camera head developed at LLNL were turned over to Princeton Instruments. In turn, Princeton Instruments published advertising literature in their product catalog and took over commercial documentation and support as they would with any other product they sold.

Reports

None

Copyright Activity

No copyrighted software was developed.

See attached list of drawings to which LLNL has received permission to assert copyright from the DOE. (Attachment II)

Subject Inventions

IL-9458 A

Patent # 6,078,359

Title: Vacuum Compatible Miniature CCED Camera Head

Inventor: Alan Conder

Date issued: June 20, 2000

The assignee is the University of California.

IL-9458 B – Patent Pending

Title: Vacuum Compatible Miniature CCED Camera Head

Inventor: Alan Conder

Background Intellectual Property

LLNL

IL-9458

LLNL licensed the "Vacuum Compatible Camera Head" to Princeton Instruments in January 1995 as License Number TL-1078-94.

This license was terminated by the partner on March 25, 1999.

Princeton Instruments (now Roper Scientific)

DC131 system design and chip set

WinView Software

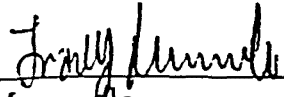
Princeton Instruments CCD circuitry and signal processing details

ST-133 Architecture

G. Acknowledgement

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. The personnel from Princeton Instruments who worked on this project are no longer with the company. To the best of our knowledge, Roper Scientific believes the statement to be true.
- 2) 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 F or are included on a list attached to this report. The personnel from Princeton Instruments who worked on this project are no longer with the company. To the best of our knowledge, Roper Scientific believes the statement to be true.
- 3) 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. The personnel from Princeton Instruments who worked on this project are no longer with the company. To the best of our knowledge, Roper Scientific believes the statement to be true.



Frank J. Mummolo
President
Roper Scientific (formerly Princeton Instruments)

8/2/01

Date



Alan Conder
Principal Investigator
Lawrence Livermore National Laboratory

8/16/01

Date

Attachment I - Final Abstract
Attachment II - Copyright Drawings

Miniature CCD X-Ray Imaging Camera Technology

Final Abstract (Attachment I)

CRADA No. TC-773-94

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Collaboration with Princeton Instruments gave the Weapons Program a direct line to a national technology leader and allowed future access to developing technologies in the area of digital imaging devices.

The development of this technology benefited DOE and other government agencies or universities involved in scientific research where the acquisition of very high quality two-dimensional (X-ray, ultraviolet, or visible light) images is required.

E. Project Dates

September 19, 1994 – September 19, 1995

Attachment II
CRADA TC-773-94
List of LLNL Copyrighted Drawings

Title	Drawing Number	Author
Schematic: X-Ray Mini-Camera: Pre-amp Board Camera Head	LEA93-1669-01 Rev A	Alan Conder, Jim Dunn, Bruce Young
Parts List: X-Ray Mini-Camera Pre-amp Board Camera Head	LEA93-1669-03 Rev A (7 pages)	Alan Conder
Assembly & Mechanical Fab: X-Ray Mini-Camera Pre-amp Board Camera Head	LEA93-1669-04-E Rev A (18 pages)	Alan Conder, Jim Dunn, Steve Shiromizu, Bruce Young
Schematic: X-Ray Mini-Camera: Driver Board Camera Head	LEA93-1669-11 Rev A	Alan Conder, Jim Dunn, Bruce Young
Parts List: X-Ray Mini-Camera: Driver Board Camera Head	LEA93-1669-13 Rev A	Alan Conder
Assembly & Mechanical Fab: X-Ray Mini-Camera: Driver Board Camera Head	LEA93-1669-14 Rev A	Alan Conder, Jim Dunn, Steve Shiromizu, Bruce Young
Schematic: X-Ray Mini-Camera: Digital Interface Board Camera Head	LEA93-1669-21 Rev A	Alan Conder, Jim Dunn, Bruce Young
Parts List: X-Ray Mini-Camera: Digital Interface Board Camera Head	LEA93-1669-23 Rev A	Alan Conder
Assembly & Mechanical Fab: X-Ray Mini-Camera: Digital Interface Board Camera Head	LEA93-1669-24 Rev A	Alan Conder, Jim Dunn, Steve Shiromizu, Bruce Young
Schematic: X-Ray Mini-Camera: Flexible Cable Camera Head To Camera Controller I/O	LEA93-1669-31 Rev 0	Alan Conder, Jim Dunn, Bruce Young
Parts List: X-Ray Mini-Camera: Flexible Cable Camera Head To Camera Controller I/O	LEA93-1669-33 Rev A (4 pages)	Alan Conder
Assembly & Mechanical Fab: X-Ray Mini-Camera: Flexible Cable Camera Head To Camera Controller I/O	LEA93-1669-34 Rev 0 (6 pages)	Alan Conder, Jim Dunn, Steve Shiromizu, Bruce Young
Schematic: X-Ray Mini-Camera: Bias Board Camera Head	LEA93-1669-41 Rev A	Alan Conder, Jim Dunn, Bruce Young
Parts List: X-Ray Mini-Camera: Bias Board Camera Head	LEA93-1669-43 Rev A (6 pages)	Alan Conder
Assembly & Mechanical Fab: X-Ray Mini-Camera: Bias Board Camera Head	LEA93-1669-44 Rev A (9 pages)	Alan Conder, Jim Dunn, Steve Shiromizu, Bruce Young
Schematic: X-Ray Mini-Camera: Tek-Array Board Camera Head	LEA93-1669-51 Rev A	Alan Conder, Jim Dunn, Bruce Young
Parts List: X-Ray Mini-Camera: Tek-Array Board Camera Head	LEA93-1669-53 Rev A (4 pages)	Alan Conder, Jim Dunn, Bruce Young

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Assembly & Mechanical Fab: X-Ray Mini-Camera: Tek-Array Board Camera Head	LEA93-1669-54 Rev A (10 pages)	Alan Conder, Jim Dunn, Steve Shiromizu, Bruce Young
Schematic: X-Ray Mini-Camera: EEV-Array Board Camera Head	LEA93-1669-61 Rev A	Alan Conder, Jim Dunn, Bruce Young
Parts List: X-Ray Mini-Camera: EEV-Array Board Camera Head	LEA93-1669-63 Rev A (4 pages)	Alan Conder, Jim Dunn, Bruce Young
Assembly & Mechanical Fab: X-Ray Mini-Camera: EEV-Array Board Camera Head	LEA93-1669-64 Rev A (10 pages)	Alan Conder, Jim Dunn, Steve Shiromizu, Bruce Young
X-Ray Mini-Camera Assembly	LEA93-1669-00 Rev 0 (2 pages)	Alan Conder, Jim Dunn, Steve Shiromizu, Bruce Young
Spacer - Donut 1 X-Ray Mini-Camera	LEA93-1669-05 Rev B	Alan Conder, Jim Dunn, Steve Shiromizu, Bruce Young
Spacer - Donut 2 X-Ray Mini-Camera	LEA93-1669-06 Rev B	Alan Conder, Jim Dunn, Steve Shiromizu, Bruce Young
Spacer - Donut 3 X-Ray Mini-Camera	LEA93-1669-07 Rev B	Alan Conder, Jim Dunn, Steve Shiromizu, Bruce Young
Back Cover X-Ray Mini-Camera	LEA93-1669-08 Rev B	Alan Conder, Jim Dunn, Steve Shiromizu, Bruce Young
Thermal Plate X-Ray Mini-Camera	LEA93-1669-09 Rev B	Alan Conder, Jim Dunn, Steve Shiromizu, Bruce Young
Gasket X-Ray Mini-Camera	LEA93-1669-15 Rev A	Alan Conder, Jim Dunn, Steve Shiromizu, Bruce Young
Glass Gasket X-Ray Mini-Camera	LEA93-1669-16 Rev A	Alan Conder, Jim Dunn, Steve Shiromizu, Bruce Young
Glass Holder X-Ray Mini-Camera	LEA93-1669-17 Rev A	Alan Conder, Jim Dunn, Steve Shiromizu, Bruce Young
Retaining Plate X-Ray Mini-Camera	LEA93-1669-18 Rev A	Alan Conder, Jim Dunn, Steve Shiromizu, Bruce Young
Interface X-Ray Mini-Camera	LEA93-1669-19 Rev 0	Alan Conder, Jim Dunn, Steve Shiromizu, Bruce Young
Internally Cooled Thermal Plate	LEA93-1669-25	Alan Conder, Jim Dunn, Steve Shiromizu, Bruce Young
Internally-Cooled Thermal Plate Cover	LEA93-1669-26	Alan Conder, Jim Dunn, Steve Shiromizu, Bruce Young
Strain Relief, Top	LEA93-1669-27	Alan Conder, Jim Dunn, Steve Shiromizu, Bruce Young
Strain Relief, Bottom	LEA93-1669-28	Alan Conder, Jim Dunn, Steve Shiromizu, Bruce Young
Manifold	LEA93-1669-29	Alan Conder, Jim Dunn, Steve Shiromizu, Bruce Young
Solid Thermal Plate - Top Assembly	LEA93-1669-35	Alan Conder, Jim Dunn, Steve Shiromizu, Bruce Young
Solid Thermal Plate - Sub Assembly	LEA93-1669-36	Alan Conder, Jim Dunn, Steve Shiromizu, Bruce Young

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Internally Cooled Thermal Plate - Top Assembly	LEA93-1669-37	Alan Conder, Jim Dunn, Steve Shiromizu, Bruce Young
Internally Cooled Thermal Plate - Sub-Assembly	LEA93-1669-38	Alan Conder, Jim Dunn, Steve Shiromizu, Bruce Young
Adapter- Pump Out	LEA93-1669-39	Alan Conder, Jim Dunn, Steve Shiromizu, Bruce Young

Solid thermal Plate Sub-Assembly X-Ray Mini Camera	LEA93-1669-36-B	Alan Conder
	LEA93-1669-64-E-A	
Bottom Assembly, Bottom View	LEA93-1669-44-E-	
	LEA93-1669-24-E-A	
	LEA93-1669-34-E-A	