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Optical Mode Converters Final Report CRADA No. TC-0838-94

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Disclaimer

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Optical Mode Converters

Final Report
CRADA No. TC-0838-94
Date Technical Work Ended: January 1998

Date: March 21, 2001 Revision: 3

A. Parties

This project was a relationship between Lawrence Livermore National Laboratory (LLNL) and Hewlett-Packard Company. Hewlett-Packard reorganized in the fall of 1999, and the division that participated in this CRADA became a separate company called Agilent Technologies.

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B. Project Scope

The information age was maturing, and photonics was emerging as a significant technology with important national security and commercial implications at the time of the CRADA. This was largely due to the vast information carrying capacity of optical beams and the availability of cheap and effective optical fiber waveguides to guide the light. However, a major limitation to the widespread deployment of photonic systems was the high-cost (in an economic and performance sense) associated with coupling optical power between optoelectronic waveguide devices or between a device and an optical fiber. The problem was critical in the case of single-mode waveguide devices. Mitigating these costs would be a significant and pervasive enabler of the technology for a wide variety of applications that would have crucial defense and economic impact.

The partners worked together to develop optical mode size converters on silicon substrates. Silicon was chosen because of its compatibility with the required photolithographic and micromachining techniques. By choosing silicon, these techniques could enable the close coupling of high-speed, high density silicon electronic circuitry to efficient low-cost photonics. The efficient coupling of electronics and photonics technologies would be important for many information age technologies.

The joint nature of this project was intended to allow HP to benefit from some unique LLNL capabilities, and LLNL would be in a position to learn from HP and enhance its value to fundamental DP missions.

Although the CRADA began as a hardware development project to develop the mode converter, it evolved into a software development venture. LLNL and HP researchers examined literature, performed some preliminary calculations, and evaluated production trade-offs of several known techniques to determine the best candidates for an integrated system.

Deliverables

- Optical mode conversion devices integrated with optical waveguides and waveguide devices on silicon substrates
- Low-cost techniques for the manufacturing of integrated optical waveguide devices
- Advanced codes for simulation of Photonic devices

C. Technical Accomplishments

There were five (5) phases to this three-year project:

1. Evaluation
2. Theoretical design
3. Modeling
4. Process development
5. Fabrication of LLNL test structure

Optical mode conversion devices were developed. Specifically glass ball lenses were applied to silicon substrates. LLNL assisted HP in the development of low-cost techniques for the manufacturing of these integrated optical waveguide devices. LLNL wrote and applied a code (MELD) for simulating and studying the behavior of photonic devices of interest to HP. Version 1 of MELD was a uni-directional simulation. Version 2 simulated two directions of wave propagation.

D. Expected Economic Impact

D.1 Specific Benefits:

Hewlett-Packard/Agilent is a leading U.S. supplier of computers, peripherals, measurement instruments and optical link technology. LLNL established a working partnership with a leading manufacturing company. The goodwill generated by a successful collaboration could lead to additional collaborations with H-P as well as with other companies who would see the benefit of working with a National Laboratory. The experience gained by the team in performing this work would be applicable to other optical waveguide device projects in both the respective organizations.

Benefits to Industry

Hewlett- Packard/Agilent is expected to use these mode converters in instrumentation produced by their Optical Communications Division based in San Jose, CA. They were primarily looking for reductions in manufacturing costs of optical transmitters and lightwave instruments.

Benefits to DOE Program

The experience gained by LLNL on the design and fabrication of these optical mode converters would benefit Defense Programs.

Photonics has been recognized as a critical technology for both DOE/DP and DOD missions for several years.

Although there were many reasons for the importance of this technology, primarily it provided the ability to communicate large amounts of information over relatively long distances very quickly. For instance, the weapons program at LLNL has relied on the development and application of this technology to the remote instrumentation of nuclear weapons tests with great success. In 1992, a group at LLNL was awarded the DOE Weapons Excellence Award for its efforts in developing and fielding state-of-the-art high bandwidth (80 Gigabit/Sec) photonic instrumentation for weapons diagnostics. (This group at LLNL executed the LLNL side of the joint work.) This instrumentation system has yielded important weapons physics information unattainable by any other means, by virtue of its excellent temporal resolution (or high bandwidth).

In considering the benefit to Defense Programs, LLNL referenced a draft version of the Department of Energy National Security Strategic Plan dated November 1993, as a guide. This strategic plan was assembled at the direction of Vic Reis and Jack Keliher. This project had a significant impact on Focus Areas I, Ill, and V of the plan.

This specific project impacted DP missions in several areas, including

- A new generation of high-speed diagnostics for above ground weapons physics experiments for stock-pile stewardship
- Maintenance of "core competencies" for weapons experiments
- Improving the power of computing resources for weapons simulations for stock-pile stewardship
- Technology development for nonproliferation surveillance

E. Partner Contribution

LLNL Responsibilities and Tasks

1. Evaluated various approaches in collaboration with HP and settled on small set of potential designs
2. Theoretical calculations evaluated trade-offs and designed one or two test structures for proof of principle.
3. Provided modeling support to both HP's and LLNL's design efforts
4. Developed materials and process
5. Fabricated test structures
6. Decided what approach to use
7. Demonstrated practical application
8. Optimized of design and processing to minimize cost in collaboration with HP

Partner Responsibilities and Tasks:

1. Evaluated various approaches in collaboration with LLNL and settled on small set of potential designs
2. Reviewed design calculations and helped LLNL determine best/most useful structure for second mode converter design
3. Fabricated initial mode converter design and assisted LLNL with development of film growth and etching techniques by providing technical guidance and some of the necessary processing
4. Optimized design and processing to minimize cost in collaboration with LLNL

F. Documents/Reference List

Reports

1. M. D. Pocha, O. T. Strand, J. A. Kerns, "Thermal Study of Silicon Optical Microbenches With on Board Heaters for Soldering," Technical Digest, OSA Topical Meeting on Integrated Photonics Research, 358-361, 1996, UCRL-JC-123202

2. M. D. Pocha, O. T. Strand, J. A. Kerns, "A Silicon Microbench Concept for Optoelectronic Packaging," Proceedings, Surface Mount International Conference, 377-382, Sept. 1996.

3. Ratowsky, R P;Yang, L;Deri, R J;Chang, K W;Kallman, J S;Trott, G, "Accurate calculation of ball lens coupling efficiency," UCRL-JC-122169

4. Ratowsky, R P;Yank, L;Deri, R J;Kallman, J S;Trott, G, " Ball lens reflection by direct solution of Maxwell's equations," UCRL-JC-119957

5. Ratowsky, R P;Kallman, J S;Deri, R J;Pocha, M D, " Multi-scale electrodynamics (MELD): a CAD tool for photonics analysis and design," UCRL-ID-129668

Patent/Copyright Activity

MELD - Multiscale Electrodynamics code (Rick Ratowsky Jeff Kallman approx 1998) may be copyrighted, but was never officially released. Copyright was not asserted on either version 1 or version 2.

Subject Inventions

None

Background Intellectual Property

None

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.
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.

Kent W Carey 4/3/01

Kent Carey Date
Hewlett Packard (now Agilent Technologies)

M. D. Pocha 4/11/01

Michael Pocha , Principal Investigator Date
Lawrence Livermore National Laboratory

Attachment I – Final Abstract

Optical Mode Converters

Abstract (Attachment I)
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E. Project Dates

January 1995 - January 1998