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Recent Work

Title
CRADA Final Report: Thermal Design and Analysis Tools forDense-Wavelength-Division-Multiplexed (DWDM) Optical Networks

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Author
Hopkins, Deborah

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CRADA Final Report
CRADA No. LBL-MY-01-10

1. Parties: Lawrence Berkeley National Laboratory and Fiber Net Engineering
Informal Partner: Agilent Technologies

2. Title of the Project: Thermal Design and Analysis Tools for Dense-Wavelength-Division-Multiplexed (DWDM) Optical Networks

3. Summary of the specific research and project accomplishments:

The goals of the CRADA were achieved through characterization of the heat dissipation and temperature sensitivity of specific components, and research and development of a unique high-precision thermal testing device that allows measurements to be made under tightly controlled conditions. The device can be used to evaluate prototype cooling devices, and to provide data that can be used to calibrate and validate modeling and design tools. Project accomplishments include:

- Thermal imaging was used to characterize the heat dissipation of a small form-factor gigabit-ethernet integrated circuit, and to evaluate the effectiveness of heat sinks.
- An exhaustive review of available thermal analysis software and simulation tools was conducted and results were summarized for industry partners.
- Laboratory experiments were conducted to measure the temperature sensitivity of laser diodes used for DWDM networks. The experiments carefully controlled the case temperature of the laser diode, as well as the input current, and measured the output spectrum of the laser. Two lasers were tested, one with a nominal central wavelength specified at 1530 nm, and the second at 1550 nm. The following relationships are documented: (1) the necessary power input to achieve lasing increases exponentially with temperature; (2) laser wavelength increases with temperature, at a constant rate of about 0.1 nm/°C; (3) laser wavelength increases with input power, at a constant rate of about 8 nm/W; (4) laser optical power output and efficiency decrease with temperature.
- Existing and potential strategies for heat dissipation were evaluated and discussed with industry partners including forced convection, heat sinks, conduction to a liquid-cooled back plane, heat pipes, micro-fluidic channels, and microjets. The techniques researched were summarized in a report to industry partners.
- Research was conducted to design a test station that would allow controlled testing and highly accurate local measurements that could be used to evaluate cooling devices, provide data for calibration and validation of models, and verify designs of new components.
- Modeling and engineering work were conducted to specify the requirements and design of the "guarded" hot plate that is the central component of the test station. A parametric thermal model was developed that included all relevant design variables and that made it possible to optimize the design for thermal performance. The model was used to determine the optimal geometry and material properties for the guarded hot plate.
- Four platinum heating and sensing elements were fabricated for the guarded hot plate. The delicate mask was fabricated out of a Beryllium copper alloy using an optical etching process. Several deposition runs were made to optimize the process. Once the elements were laminated to a base

plate, infrared thermography was used to investigate the uniformity of heat dissipation and to evaluate variations in electrical resistance. Thermography revealed undesirable hot spots, and the measured electrical resistivity was judged to be too high because it would have required excessively high voltages to obtain the maximum desired power density of 5 W/cm^2. Therefore, the heater traces were redesigned. To decrease the electrical resistance, the total path length was shortened, and the trace width was increased to maintain good thermal coupling to the underlying copper block. A slightly increased spacing between the traces improved the dimensional accuracy of the mask. Three sets of 15 heater elements each were deposited on a 1-mil-thick kapton sheet using the new design. All the sheets now meet the targeted electrical resistance of 17 Ohms, and the electrical resistance after lamination is low enough to provide the full range of power densities required to meet the performance targets for the device.

- Progress reports detailing technical developments were written and discussed with industry partners during periodic project reviews.

4. Deliverables:

Deliverable Achieved	Party (LBNL, Participant, Both)	Delivered to Other Parties?
Characterization of the heat dissipation and temperature sensitivity of specific components	All parties	Report delivered to partners
Design of a high-precision thermal measurement device allowing controlled experiments	All parties	Report delivered to partners
Fabrication and testing of the high-precision thermal measurement device	LBNL	Report delivered to partners
Report summarizing research, development and results	LBNL	Report delivered to partners

5. Identify publications or presentations at conferences directly related to the CRADA?

A paper summarizing the work performed under the CRADA will be published and presented at the Semiconductor Thermal Measurement, Modeling, and Management Symposium (Semi-Therm 22).

6. List of Subject Inventions and software developed under the CRADA:

An invention disclosure for the thermal measurement device is being prepared for submission to LBNL.

7. A final abstract suitable for public release:

The current project originated from discussions with designers and engineers in the opto-electronics industry who sought help from LBNL in identifying effective thermal-management strategies for optical-network components and systems. Miniaturization of opto-electronic components exacerbates the thermal management problem because it allows a greater number of temperature-sensitive components to be fit into less space. Measurement techniques are required to evaluate emerging technologies, test prototype designs, and provide data that can be used to calibrate and validate models.

To address these needs, LBNL and project partners developed a test station that allows experiments to be performed under tightly controlled conditions. The central component of the testing device is a "guarded" hot plate that enables high-precision temperature measurements, allowing forced-convection cooling devices to be evaluated. The device is so named because guard plates are used to eliminate heat flow and ensure that heat is not dissipated through the cooling device under investigation. This tool not only allows characterization of emerging technologies and materials, but also allows collection of high-resolution data that can be used to validate and improve simulation tools used to develop next-generation cooling devices for telecommunication systems. The ability to measure and analyze thermal performance benefits the photonics and optical-network industry by reducing development costs and time to market.

8. Benefits to DOE, LBNL, Participant and/or the U.S. economy.

The project supports the Department of Energy's mission to "promote scientific technological innovation" in support of their "overarching mission to advance the national economic and energy security of the United States." Telecommunication systems are recognized as being vital to national security. In recognition of this fact, the President's National Security Telecommunications Advisory Committee was formed in 1982, citing "increased Government reliance on commercial communications, and the growing importance of command, control, and communications to military and disaster response." The project benefits our industry partners and contributes to economic security by helping the domestic telecommunications industry to maintain a competitive advantage by reducing the time and cost of bringing new technology to market. The current project benefits LBNL by further developing the Laboratory's capabilities in infrared thermography, thermal analysis and modeling, as well as high-precision thermal measurements. These capabilities are used to support both LBNL's DOE projects and projects in collaboration with universities and industry.

9. Financial Contributions to the CRADA:

DOE Funding to LBNL	$ 339K
Participant Funding to LBNL	$ 0K
Participant In-Kind Contribution Value	$ 300K
Total of all Contributions	$ 639K

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