U.S. R&D on High Data Rate Optical Links

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Optoelectronics Working Group
Mini-Workshop
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U.S. R&D on High Data Rate Optical Links

Fermilab has initiated an U.S. effort on high data rate optical links with collaborators from national laboratories, universities, and private industry

Two separate efforts will be reported today:

Collider Detector Research and Development (DOE/CDRD)
"High Data Rate Links for Collider Experiments"

Collaborators: Argonne, UMinnesota, Ohio State, Southern Methodist
Funded by DOE for 3 years

University of Chicago Strategic Collaborative Initiative Seed Grants (UC/SCI)
"Optical Modulation with WDM For HEP Readout"

Collaborators: Argonne, UChicago
Application submitted for review

High Data Rate Links for Collider Experiments – DOE/CDRD
Development Projects

- Integrated Optical Modulators

  "to investigate and develop two alternative modulation methods that are based on indirect modulation of the optical signal and are applicable to longer wavelengths (Mach Zehnder and Electro Absorption Modulators"

- 120 Gbps Parallel Links

  "to develop a parallel optical transmitter to support the deployment of a low-mass 120 Gbps data links based on industry standards"

- Free Space Optical Links

  "to design and develop a free-space optical link for trigger and data extraction"

  (due to funding limits, this projects was dropped from the proposal)

High Data Rate Links for Collider Experiments – DOE/CDRD

Work Plan and Collaborators

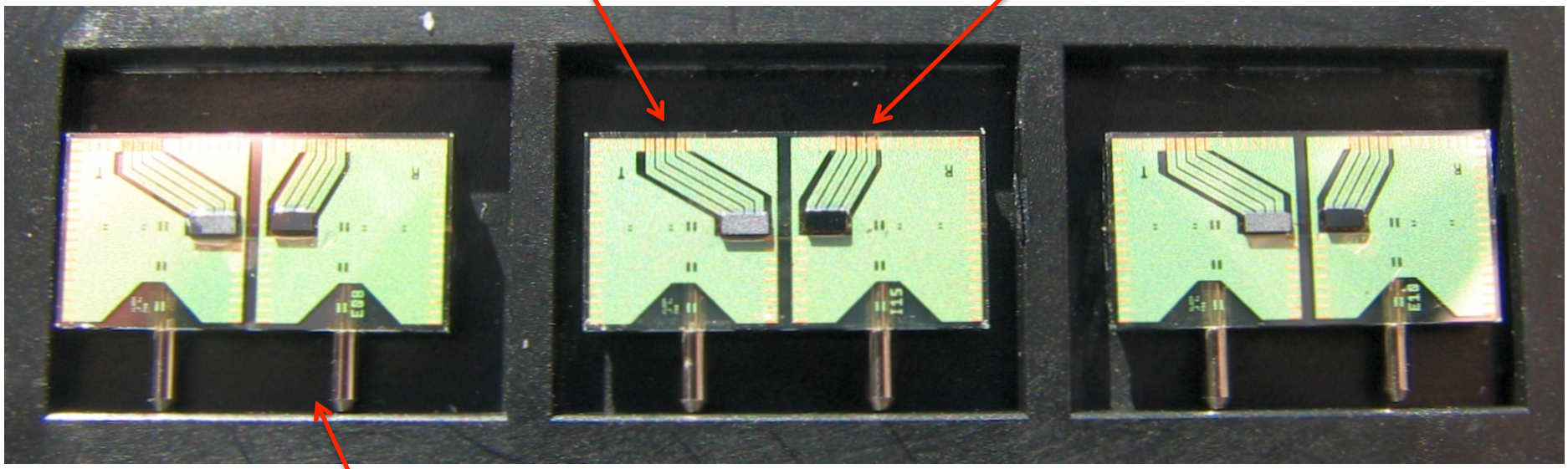
- University of Minnesota – Integrated Optical Modulators
  - Investigation of new material systems for use in HEP environments
- Argonne National Laboratory – Integrated Optical Modulators
  - Radiation tolerance and characterization of modulators
- Fermi National Accelerator Laboratory - 120 Gbps Parallel Links
  - Optical coupling investigation and component and link testing
- Ohio State University - 120 Gbps Parallel Links
  - Laser array driver development
- Southern Methodist University - 120 Gbps Parallel Links
  - Development of 12 channel transmitter for ATLAS Li Ar
  - Array serializer development

High Data Rate Links for Collider Experiments – DOE/CDRD

4 Channel Tx Devices (4x TRx)

VCSEL Electrical Interface (Tx)

P-I-N Diode Electrical Interface (RX)

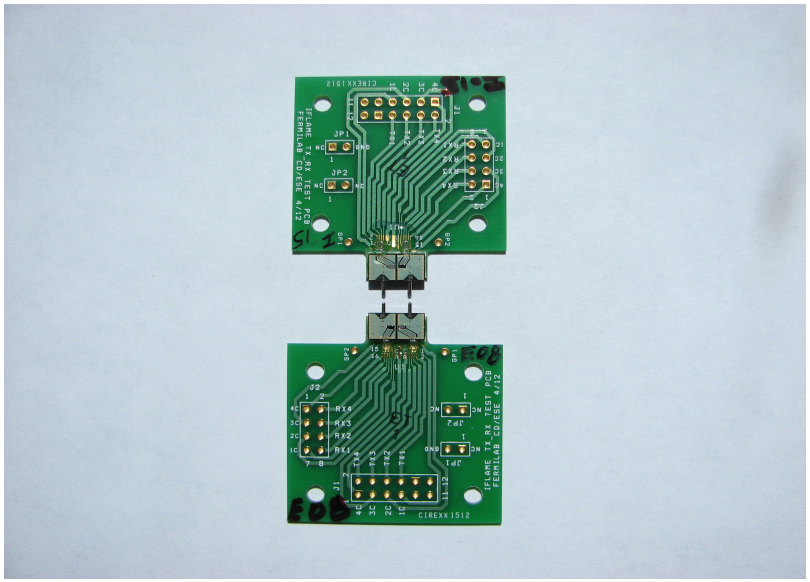


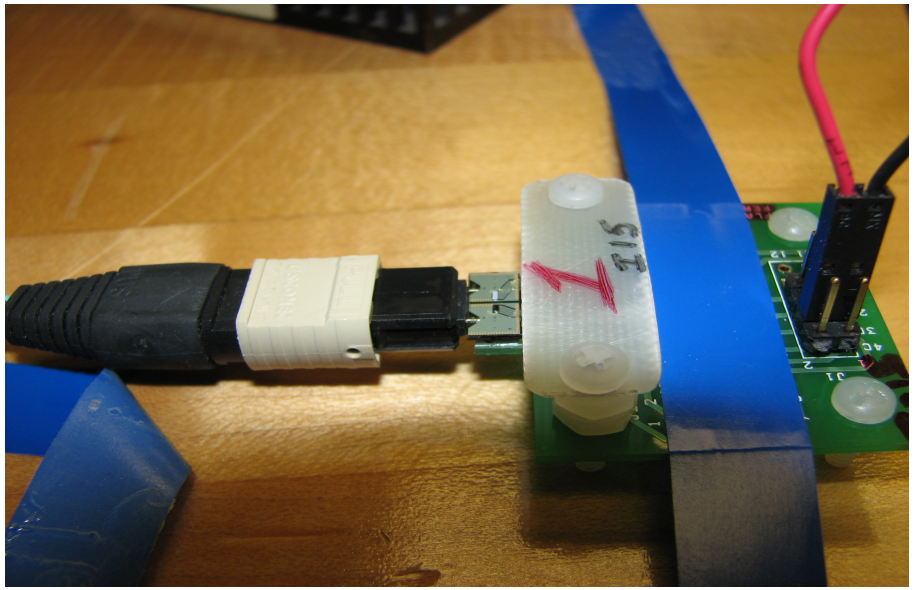
MT Optical Connection (4 Tx channels, 4 Rx channels)

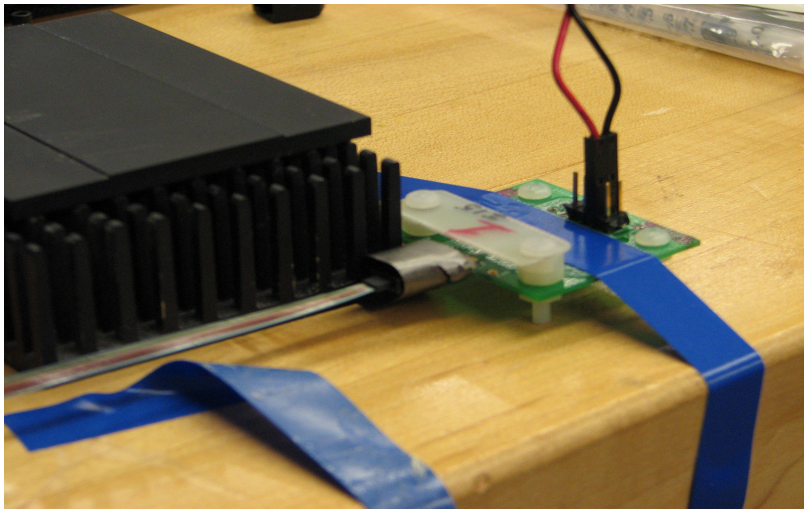
Tx channels only tested

High Data Rate Links for Collider Experiments – DEO/CDRD

4x Tx Test Boards

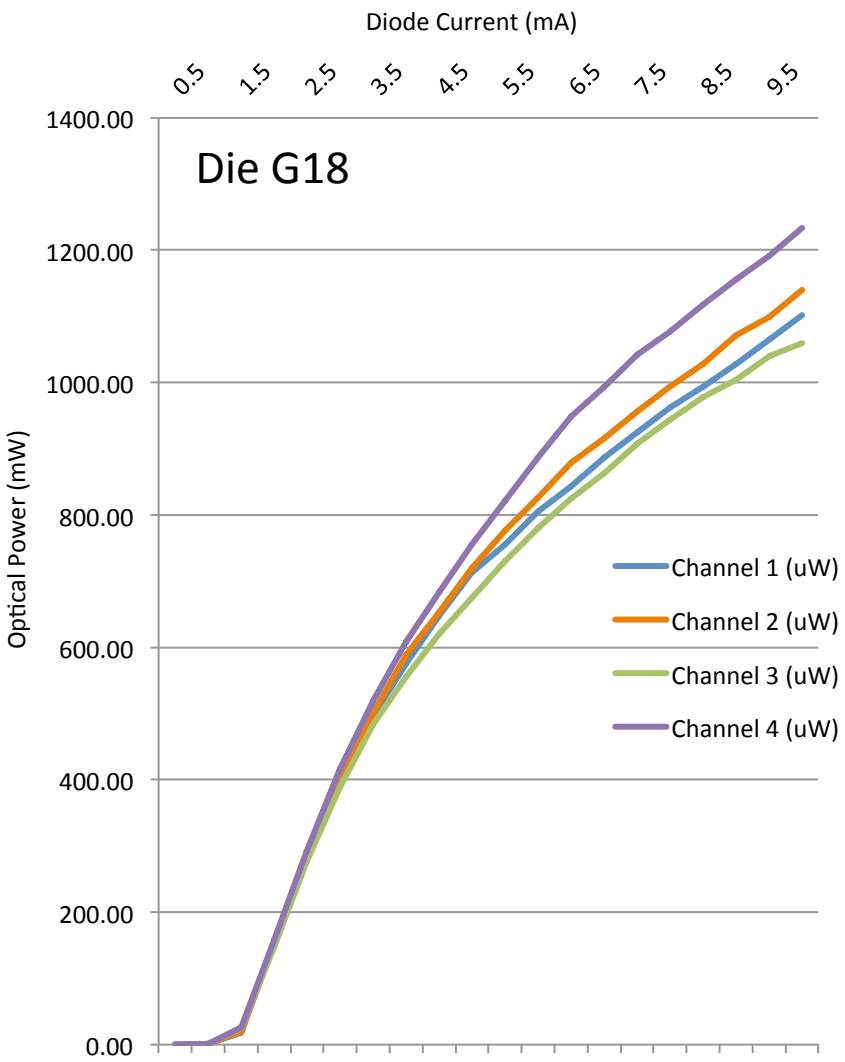


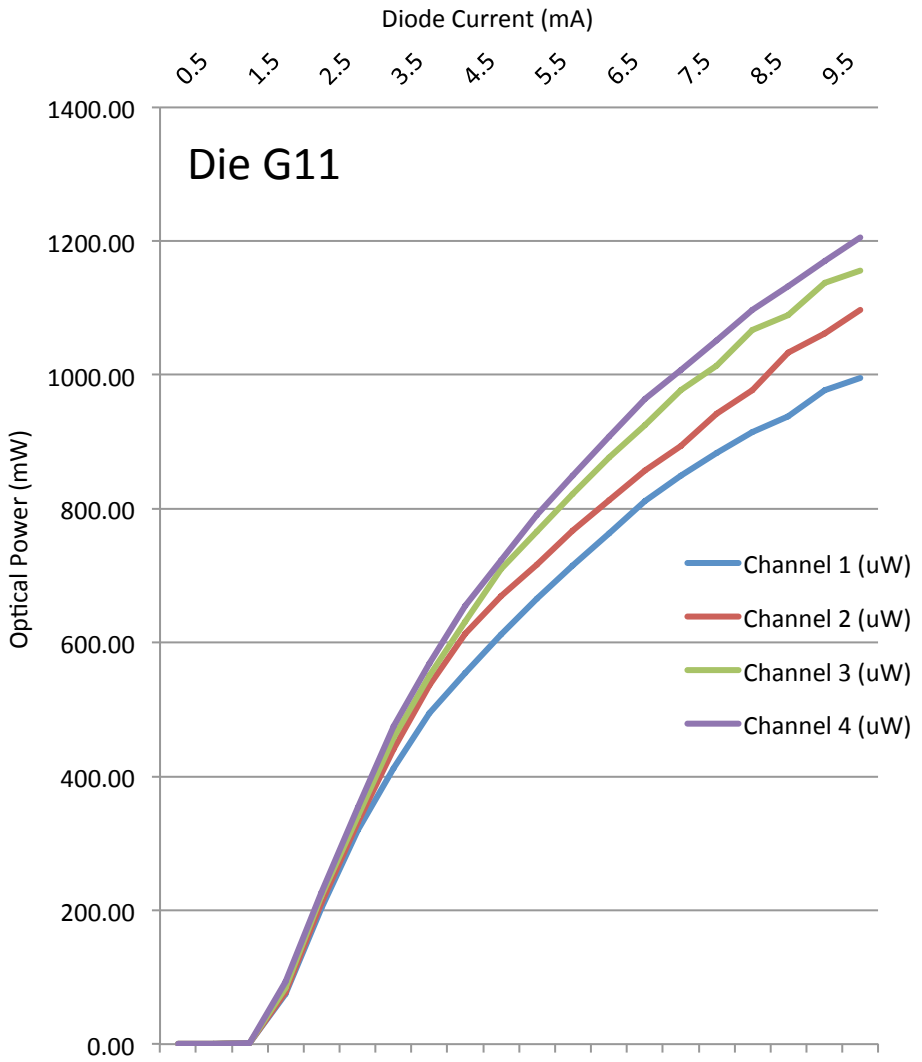




High Data Rate Links for Collider Experiments – DOE/CDRD

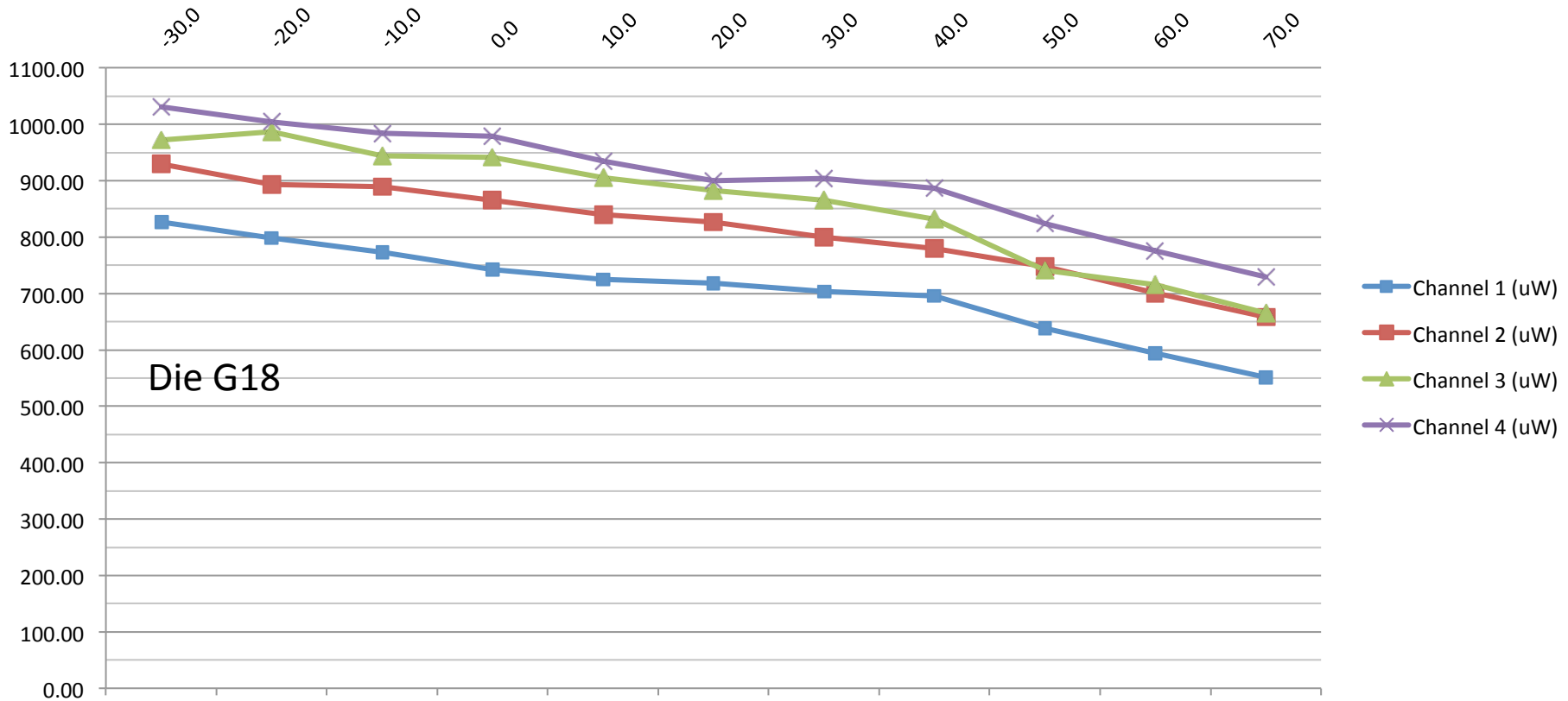
4x Tx DC L-I Curves





High Data Rate Links for Collider Experiments – DOE/CDRD

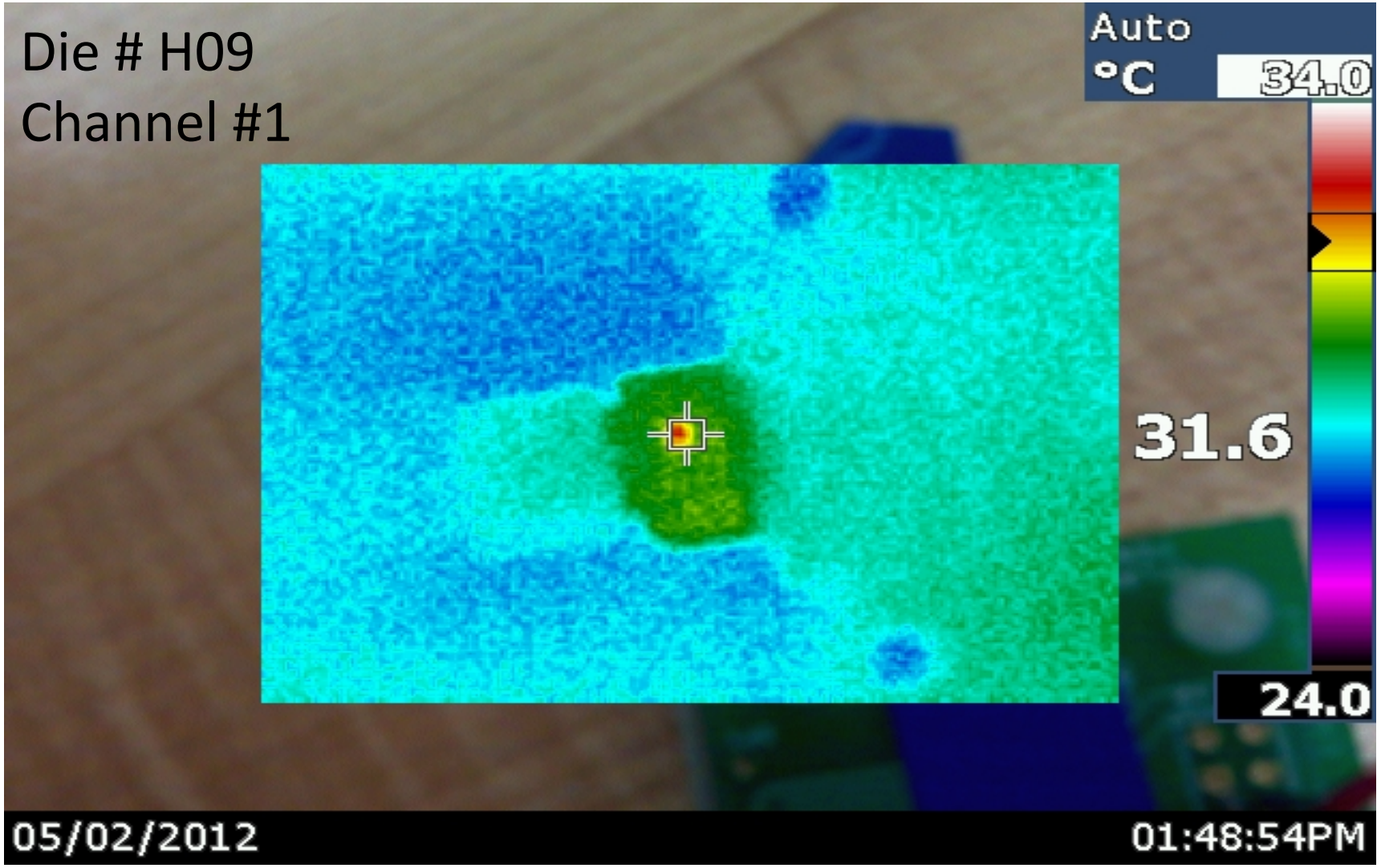
4x Tx DC Optical Power vs. Temperature Profile



Each channel passing 10 mA current at all temperatures

High Data Rate Links for Collider Experiments – DOE/CDRD

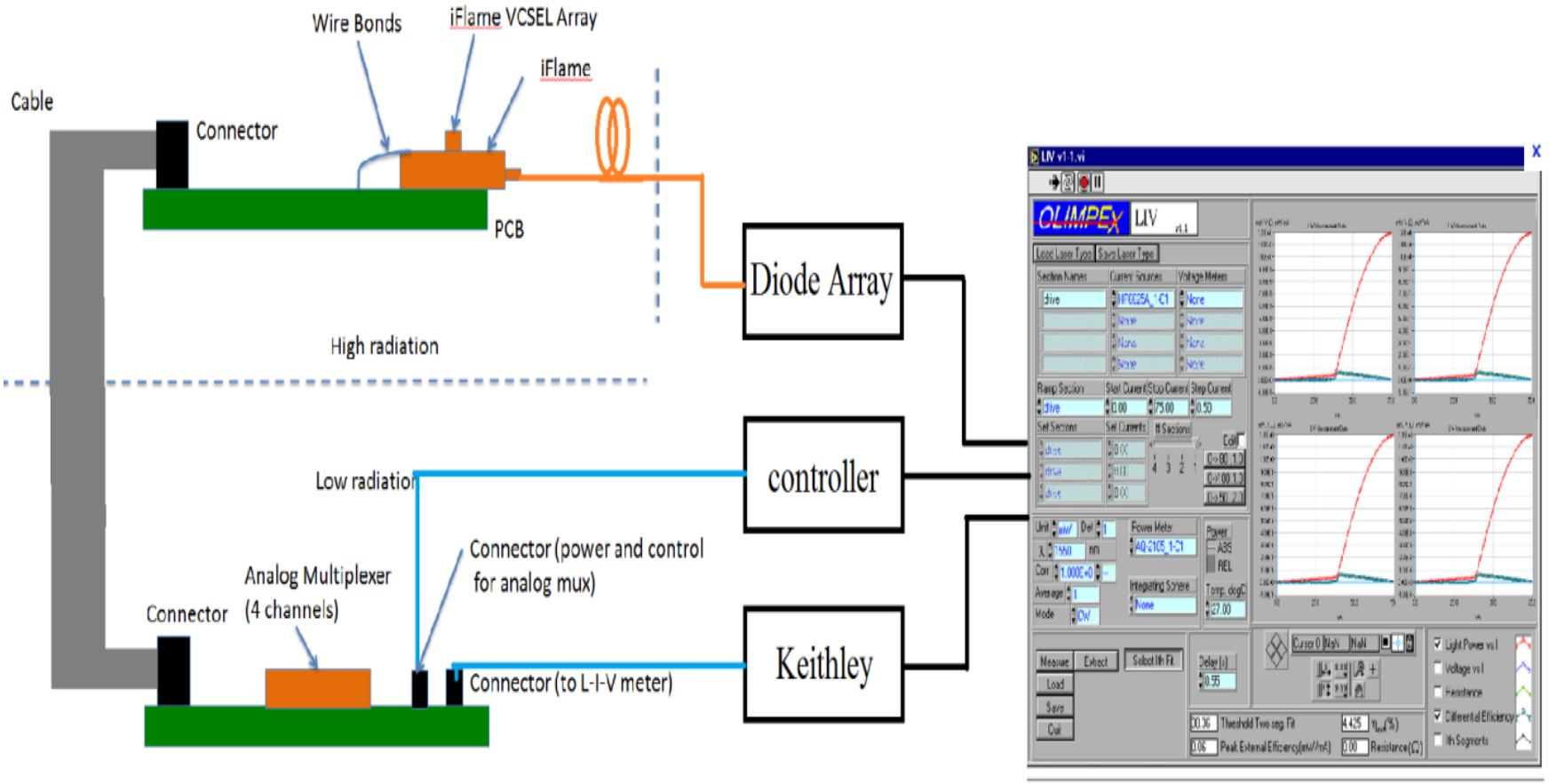
4x Tx Device Thermal Image



Bias Current of 10mA (1 channel only)
Light Output = 0.69dBm

High Data Rate Links for Collider Experiments – DOE/CDRD

4x Tx Device L-I Irradiation Testing



SMU (together with BNL) will carry out a proton beam test at MGH. A number of test DUTs will be cascaded along the beam.

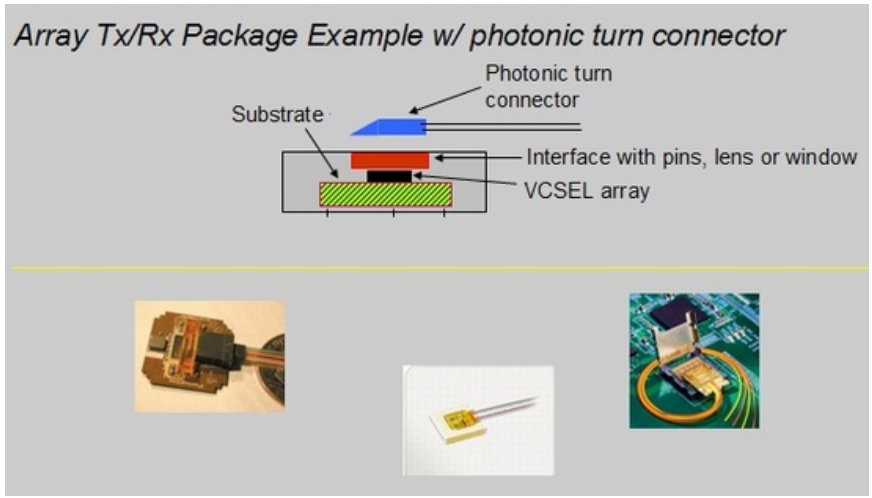
Only the assembly will be exposed. Instrumentations are placed closed by in a shielded area (~2m away). PC control will be in a remote room.

Target fluence is 5E15/cm^2 at flux up to 5E11/cm^2/s .

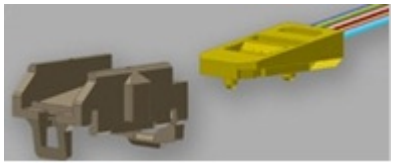
High Data Rate Links for Collider Experiments – DOE/CDRD

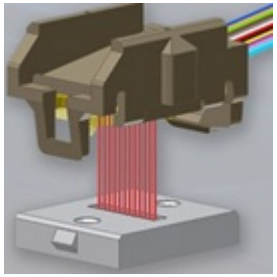
Pacakaging and Optical Coupling Options

120G-ATx module option one



Courtesy MENO CO. Ltd





Courtesy Usconec

- VCSEL array vendors
  - ULM, Finisar
- LDD array options
  - COTS - IPtronics, Gigoptix sampled. Ensphere waiting.
  - SMU SOS LOCld4
  - OSU SiGe, yr1 design, yr2 submission
- The optical interface adapts the Prizm connector (TIR lens with fiber ribbon pigtailed)
- The optical coupling is strengthened by lens array pedestal.
- Die placed on PCB for prototype
- Will likely need substrate for reliability, will consult and collaborate with industry partners

Optical Modulation with WDM For HEP Readout – UC/SCI

Motivation

Sub-Detectors for the HL-LHC will require more on-detector communications bandwidth than is available from current optical transceivers (including VCSEL arrays). Examples are:

- ATLAS/CMS Track Trigger
- ATLAS Calorimeter

Increase in on-detector bandwidth requirements must be provided within thermal (low power) and mass (small footprint) budgets with rad-hard components

The importance of component reliability is crucial

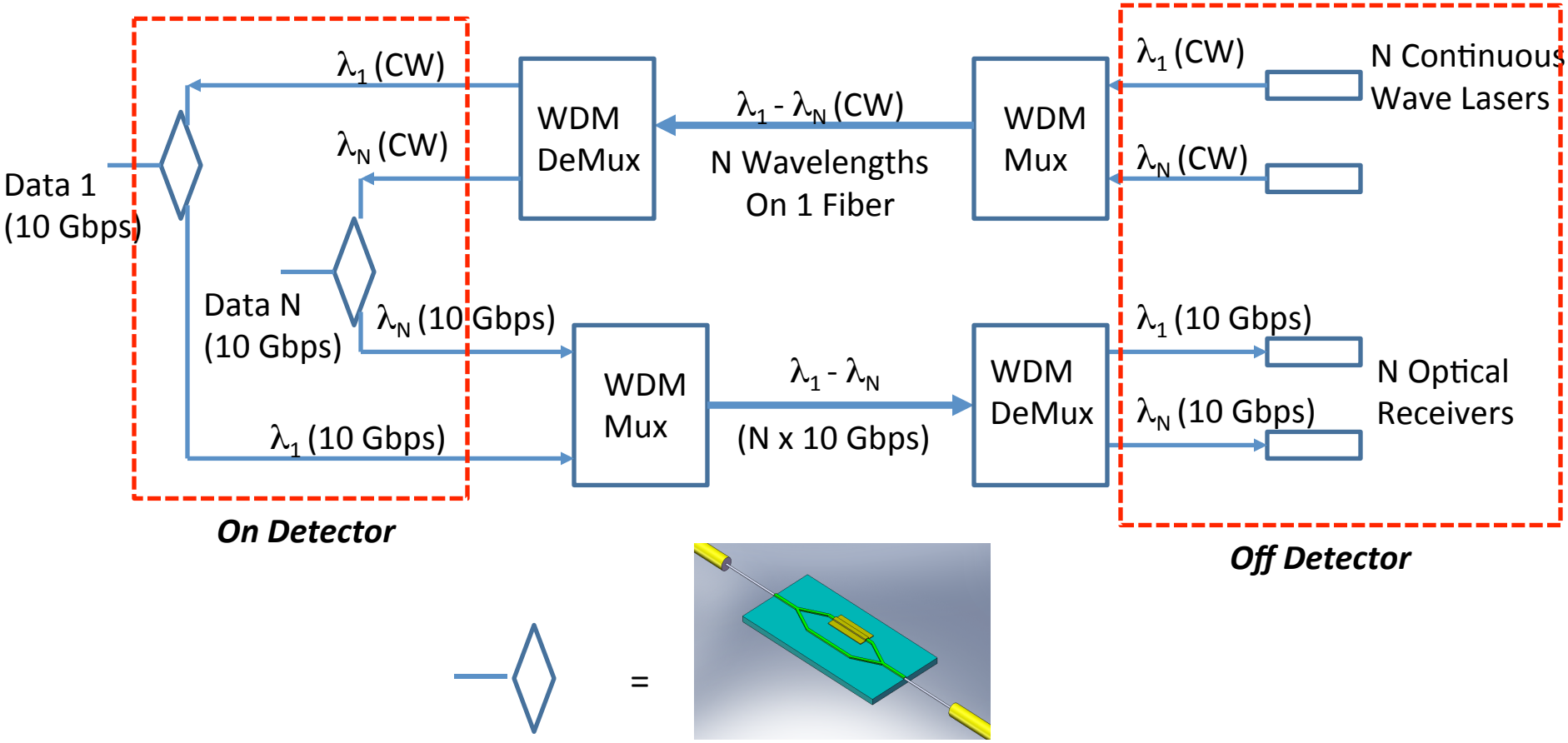
- Access to failed components is often restricted
- Failures degrade detector performance, reduce data collection efficiency, increase costs

Proposal: an approach based on externally modulated optical communications

1. Intrinsic radiation hardness (operation is based on bulk properties of the material)
2. Very low power consumption for improved thermal margins
3. High flexible data rates achievable (modular structure with each channel at operating at 10 Gbps) without the use of on-detector lasers (reduced thermal load)
4. Custom modulators can be developed in suitable materials (for rad-hardness) and small form factors (~ 1 cm^2)

Optical Modulation with WDM For HEP Readout – UC/SCI

System Concept



Mach-Zehnder Intensity Modulator

Wavelength Division Multiplexing (WDM) at 10Gbps/channel with external CW laser sources and modulators at the experiment . Total number of channels is scalable from 1 to 72 channels covering wavelengths from 1519.48 nm to1577.03 nm with spacing of 100 GHz between adjacent channels.

Optical Modulation with WDM For HEP Readout – UC/SCI
Collaborators

- Argonne National Laboratory
  - Test stand development for modulator radiation testing
    - Characterization and radiation testing of commercial modulators ,modulator drivers, and links
- Fermi National Laboratory
  - Multi-Gbps electronics design and test for optical communications
    - Develop PCBs and test stands for modulator and driver electronics
    - Complete characterization of electrical and optical channel performance
- University of Chicago
  - Infrastructure for irradiation studies
    - Establish HL-LHC environment in enclosure M3 near pinhole collimator in FNAL meson line
    - Fabrication of control electronics, radiation and SEU monitoring and loopback communications
  - Design studies for a driver ASIC
    - Feasibility studies and protocols including implementation in 90 nm technology
    - Layout of driver coupling to FPGA capable of achieving >15 Gbps
- Industrial Partner: Vega Wave Systems
  - Complete semiconductor fabrication facilities in West Chicago, IL
    - Design and characterization of compound semiconductor Mach-Zehnder Modulator
    - Selection of suitable COTS components for WDM system architecture