Optical Link in the CDF Run II Silicon Tracking System

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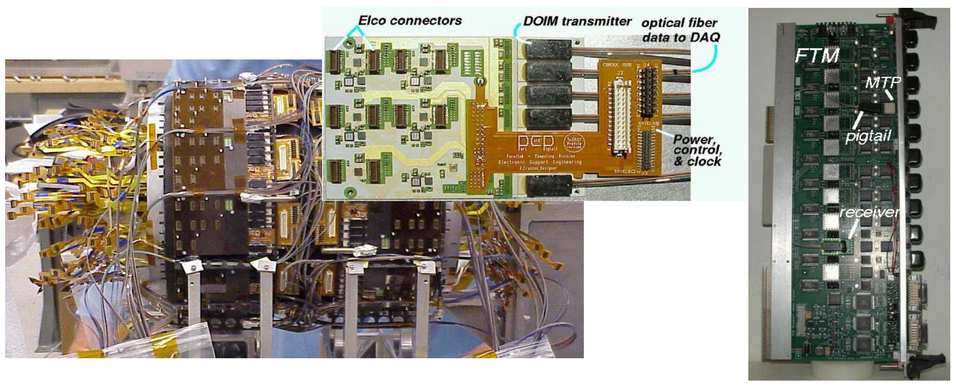
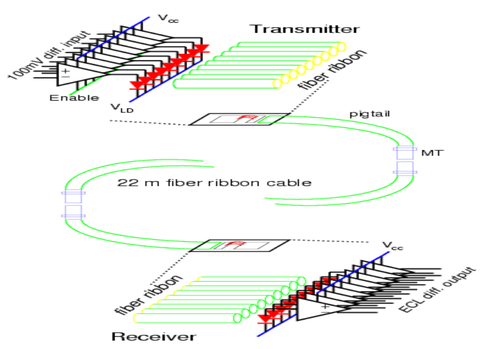
The byte-wide optical link in the CDF Run II silicon tracker consists of transmitters (TX) connected with 22 m fiber ribbon cables to receiver (RX) modules out of the detector. In total 556 transmitters on the Port Cards are located on the outer ring of the silicon detector. Five silicon ladders configured in layers in a wedge are connected to a Port Card and a transmitter is used to read the byte-wide data and a clock for a ladder.

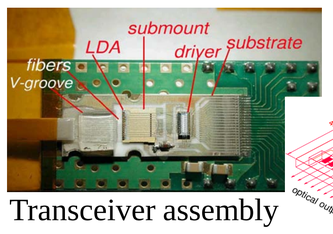


Optical Interface Modules on portcards surrounding the CDF Silicon Tracker

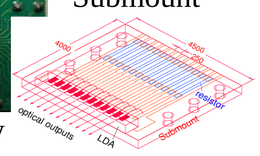
Fiber Transceiver Module outside detector.

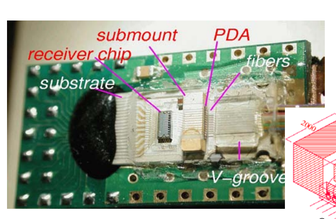
The transmitter module consists of a edge-emitting laser diode array of 1550 nm (12-ch. InGaAsP/InP, Telecom Lab Chunghwa Telecom) and a custom design driver chip (AMS 0.8 μm BiCMOS). The receiver has a matching PIN diode array and a receiver chip (same manufacturers) to convert optical inputs into differential ECL signals. Each transmitter and receiver pair has nine identical channels for externally defined 8-bit data and a clock signal operating at 53 MB/sec .



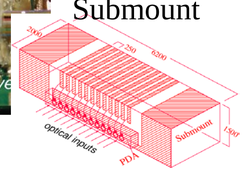


Transceiver assembly



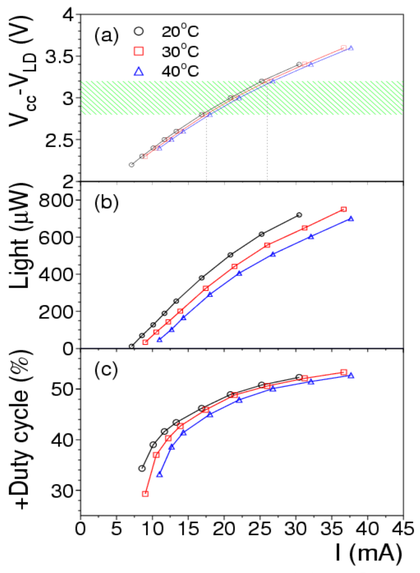


Receiver assembly

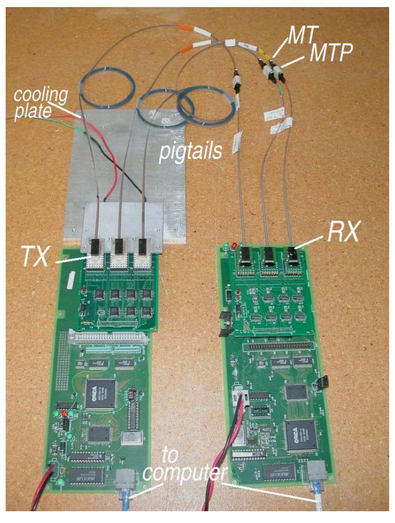


Components of the Dense Optical Interface Modules

The edge-emitting laser output is sensitive to operation temperature, the nominal operation current is 10 mA per channel at a tunable bias of 3 V. The laser light pulse received by a PIN diode is converted into a current pulse to the receiver. Signal processing is in NRZ (non-return-to-zero) format, with a tolerance of 40 - 60% width.



Laser response to current (a) voltage drop, (b) light output, and (c) light pulse width to a 50% duty cycle input.



Bit-Error rate test in burn-in setup using the Fermilab BERT circuits and program.

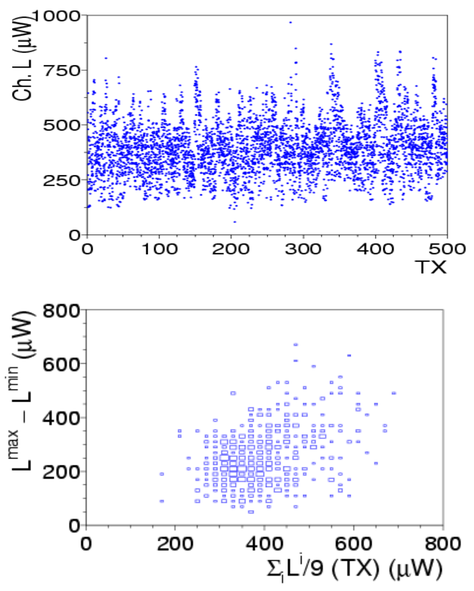
CDF optical link spec

designated data rate	53 Mbytes/sec
data format	NRZ (non-return to zero)
bit error rate	$< 10^{-12}$
temperature range	$-10°$ to 35°C

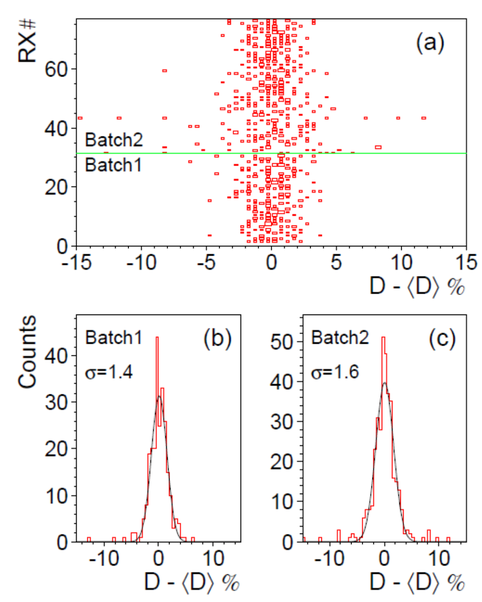
Transceiver		Receiver	
input protocal	diff. ECL or LVDS > 100 mV	input high threshold	50 ∼ 800 μW (1550 nm)
enable control	TTL	input low threshold	< 20 μW (1550 nm)
optical wavelength	1550 nm nominal	output protocol	differential ECL
optical output (on)	200 ∼ 800 μW/channel	power supply	5 V
optical output (off)	< 10 μW/channel	power dissipation	2 W/module
power supply	V_{cc} (5 V), and V_{cc}−3 V		
power dissipation	2 W/module		

Specification of CDF optical link modules and functions.

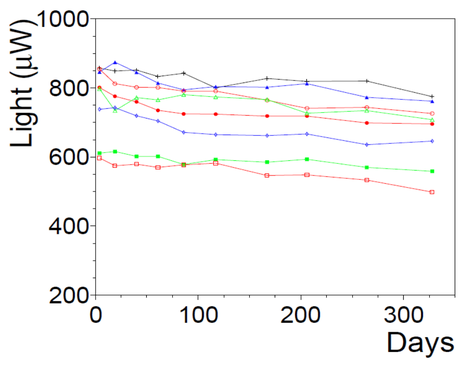
A laser-diode array, biased in common, to yield a uniform light output is highly desired. However, the TX modules have large deviation in light coupling to fiber, due to spread in far field angle of the elliptical light distribution from laser cleaved emission window.



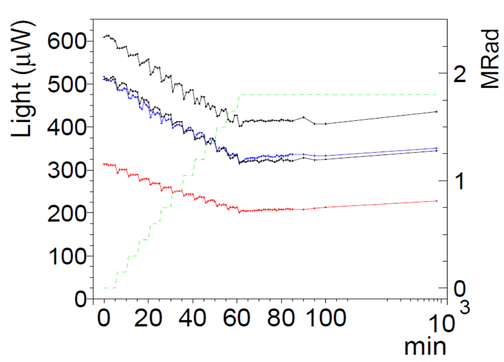
Distributions of transceivers: (a) each column has channel light outputs of a TX, (b) the span versus average of a TX.



Differences of ECL duty cycles (a) and projections (b,c) to the mean of a RX channels, tested with laser light input of 970 μW and pulse width of 45%.



The light outputs of a transceiver in ageing test at 60°C over a year.



Laser iight outputs in 30 MeV protons at INER, to 1.8 Mrad ($1x10^{13}$ p/cm^{2}s).

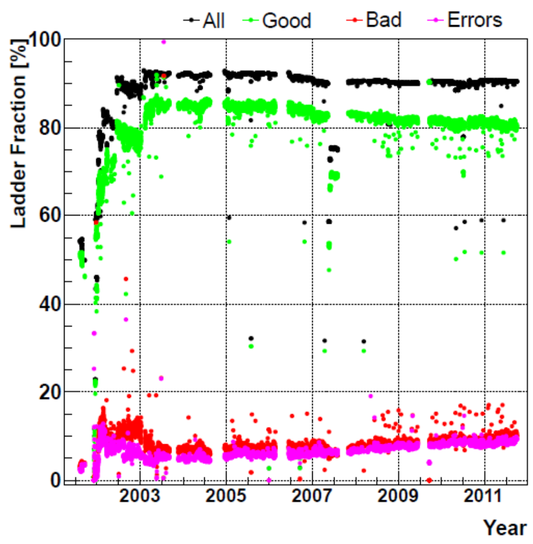
The potential failure of transceivers were evaluated in a accelerated aging test, biased and kept at 60°C over an one-year period. Light loss is indicated and is within 10% .

Radiation damage was investigated. The fiber (by FOP) in use has a germanium doped core, showing no attenuation after irradiation with 30 MeV protons to a few Mrad.

The transceiver module is required for radiation tolerance. Beam tests with protons of 30 MeV (INER), 63 MeV (Davis), and 200 MeV (IUCF) were conducted. The light degradation is approximately linear to the irradiation dose. The tests at INER with 30 MeV protons with online fiber readout degraded to 65% of the original, corresponding to 1.8 Mrad ($1x10^{13}$ p/cm^{2}s). The tests at IUCF with 200 MeV protons dropped to 30% of the original for 1.4 Mrad ($3x10^{13}$ p/cm^2).

Dose equivalent for GaAs: $1x10^9$ p/cm^2 =186, 37 rad, for 30, 200 MeV proton, respectively.

The fraction of integrated (black) ladders considered good (green) and bad (red) vs run number. The fraction of average digital error rate in pink. A ladder is considered good if it has a digital error rate <1%. Shown also is the average error rate (magenta). Over the past 8 years of operation, the good ladder fraction has reduced by 5%



The CDF silicon tracker was commissioning with 85% of ladders operated without errors. After 10 years, 80% of all ladders are still operating without digital errors. The loss is dominated by chip failures. The optical link has endured a decade of operation without any error, for an integrated luminosity of 12 fb^{-1}.

[1] Dense Optical Interface Modules for the CDF Run II Silicon Tracking System, CDF note 6497, Jun 6, 2003
[2] Experience with Parallel Optical ink for the CDF Silicon Detector, NIM A 511 (2003) 166
[3] Radiation hardness of the 1550 nm edge emitting laser for the optical links of the CDF silicon tracker, NIM A 541 (2005) 208