Plan for Truelight VCSEL Lifetime Study

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Outline

- Introduction
- Optical spectrum of aged VCSEL channels
- Plan on VCSEL lifetime study with opto-boards
- Plan on VCSEL lifetime study with opto-packs
- Candidate VCSELs for new opto-boards
- Industry standard for lifetime/burn-in procedures
- Summary

Transmission on Skinny Wires

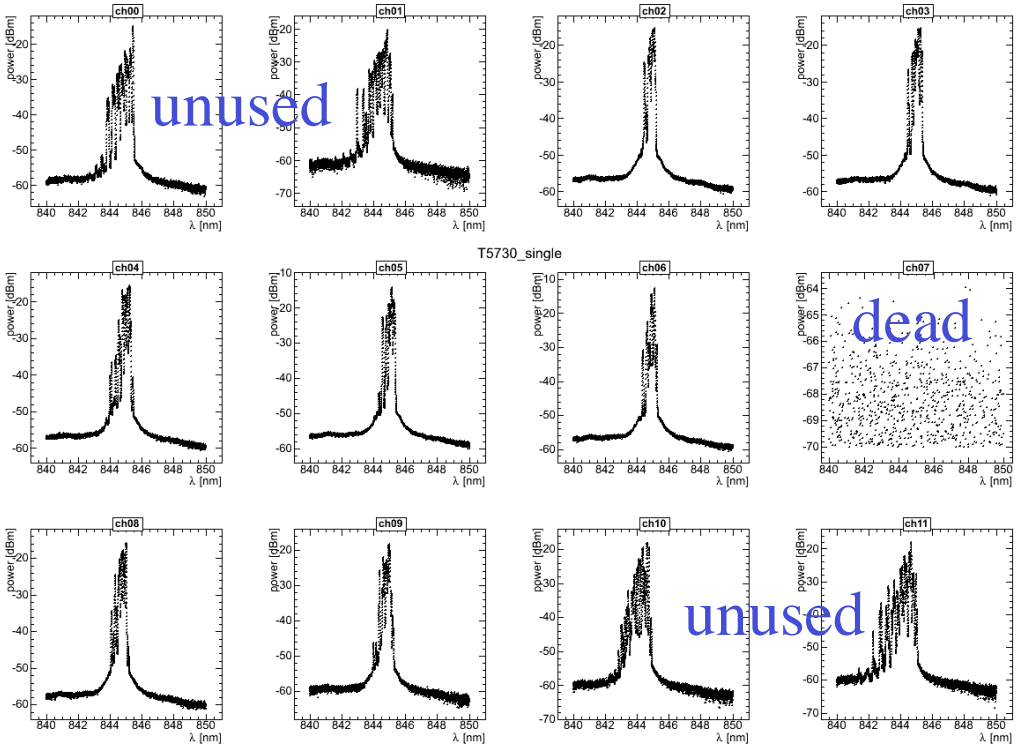
- IBL R&D shows 6 m electrical transmission is adequate for:
  - 40 MHz TTC signal in 36 AWG twisted pairs
  - 160 Mb/s data signal in 28 AWG twisted pairs
- current Type-0 cables use up to 1.4 m of 38 AWG twisted pairs
  - Ohio State can do a verification of transmission with 1.4 m of Type-0 cable plus 4 m of thicker wires
  - recommend SLAC takes the lead in the test

AWG	ID (μm)
28	321
36	127
38	100

Cause of TX VCSEL Failure

- reliability of supplied VCSELs?
  - sold millions of single-channel VCSEL in TO cans
    - very low numbers for field returns
    - VCSEL in LAr calorimeter also die
    - LHCb out straw tracker has ~1% failure (ULM (Philips))
  - ⇨ mishandled arrays somehow?
    - thermal stress because array is mounted on FR-4?
    - mechanical stress from optical epoxy covering VCSEL?
    - mechanical stress from Infineon spring connector?
    - chemical reaction between epoxy and VCSEL?
    - damage due to light reflected by epoxy into laser cavity?
    - damage due to humidity?

Optical Spectra of VCSEL



- used channels have narrower spectra
  - similar problem in LAr calorimeter
    - channel with narrower spectrum most likely to die
  - cause of spectrum narrowing not understood
  - very powerful tool for monitoring degradation

Implication for Opto-board

- VCSEL arrays on opto-boards of current pixel detector were fabricated using the process as the TX arrays
  - current accumulated live time ~ 0.05 months
  - TXs start to fail after 6 months of live time
    - ⇨ expect failure on opto-board VCSEL arrays starting in ~2015

Investigation of TX VCSEL Failure

- Taiwan: lifetime tests for 3 types of arrays
  - test at both room temperature and 70 C
  - with optical epoxy and Infineon connector
  - with optical epoxy but not using the Infineon connector
  - without optical epoxy (using LAPD for readout)
  - perform OSA measurements monthly
    to look for evidence of spectral narrowing
  - test will start in a week
  - will know in few months on whether epoxy or connector
    is the cause of the failure
    - if epoxy is the problem ⇨ opto-board VCSEL will die
    - if connector is the problem ⇨ opto-board VCSEL will be OK

Lifetime Test of Truelight VCSEL

- Siegen is performing test of four opto-boards
  - transmitting clock (50% duty cycle) at room temperature
    - Wuppertal will measure optical spectrum monthly
- similar study of 7-10 boards planned on test system at CERN
  - transmitting clock at all times
  - expect to be ready in ~2 weeks

Lifetime Test of Truelight VCSEL

- Ohio State has found ~50 VCSEL array from original production
  - 400 channels will be monitored
    - represent a significant fraction of final system: 1,788 channels
    - no need to use thermal acceleration
  - ~50% have improperly cured epoxy
  - will mount VCSEL on BeO board to emulate detector environment
  - will transmit clock at all times
  - will keep chamber at ~20^0 C flushed with N_2
  - requested funds from US management to acquire optical spectrum analyzer (OSA) to monitor degradation of spectrum with time
    - ULM (Philips) measure optical spectrum as part of QA
  - if some VCSELs in opto-boards/opto-packs fail in 6 months
    - ⇨ need to extract pixel detector to replace opto-boards

VCSEL Array Vendor

- AOC (formerly Honeywell)
  - large collection of VCSEL publications online
  - most experience in VCSEL reliability studies
  - have access to engineers
- ULM (Philips)
  - visited the company last Monday
  - provide VCSEL for mouse
  - least radiation hard
- Optowell (Korea)
  - no communication with the company!

New VCSELs for Opto-Boards

- IBL R&D resulted in the proposal to use AOC 10 Gb/s arrays for IBL opto-boards
  - chosen to gain experience with 10 Gb/s arrays for SLHC
    - 5 Gb/s array could also be used
      - 11 arrays packaged at Ohio State for lifetime study at Oxford
        - 10 arrays operating DC 10 mA @ 70 C
          - no failures in ~ 2 months
      - will package some arrays for OSA measurement at Wuppertal
  - ~25 10 Gb/s arrays have been packaged for next week irradiation
    - sample can be used to verify reliability for opto-boards of present pixel detector

Accelerated Aging Methods

- Accelerated aging of Truelight VCSEL array conducted at too low temperature
  - opto-board QA:
    - Burn-in at 50 C for three days
    - 10 thermal cycles between -25 and 50 C
- Example of tests by ULM (Philips)
  - 15 samples tested at 85% humidity/85 C test for 1000 hours
  - accelerated lifetime test at 170 C
  - recommended burn-in: 100 C for 24 hour
    - need to ensure all epoxies/encapsulant used can withstand 100 C
- AOC has most experience in VCSEL reliability studies
  - should compare ULM/AOC reliability studies for adaptation for VCSEL arrays on opto-board

Fabrication of New Opto-Boards

- Some conceptual design for opto-board has been done for IBL
  - new opto-pack design based on BeO instead of FR-4
    - has fabricated ~200 opto-packs
    - use wire bonding instead of challenging macro soldering
      - cold solder is a major cause of failures in current opto-links
    - use commercial instead of custom connector
  - ⇨ much simpler opto-board fabrication procedure
- Achieved the goal of 10 opto-boards/week in previous production
  - should not have problem achieving this rate in new design
  - opto-board design can't start unless we know the space constrain
- Would love to replace ceramic pins by stainless steel pins
  - how to obtain waiver for using magnetic material?

Summary

- recommend asking SLAC to do a study of long electrical transmission
- Accelerated lifetime test of 4 opto-boards at Siegen
  and 7-10 opto-boards at SR1
- Propose lifetime of 50 VCSEL arrays at Ohio State
  - ⇨ should know if VCSEL on opto-boards will fail in 6 months
- AOC 5 or 10 Gb/s arrays are candidates for new opto-boards
- opto-board lifetime test should be conducted at higher temperature