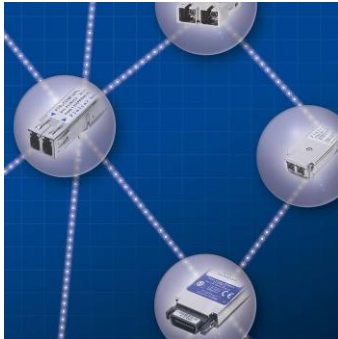


Finisar

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Optical Components for 100Gbps

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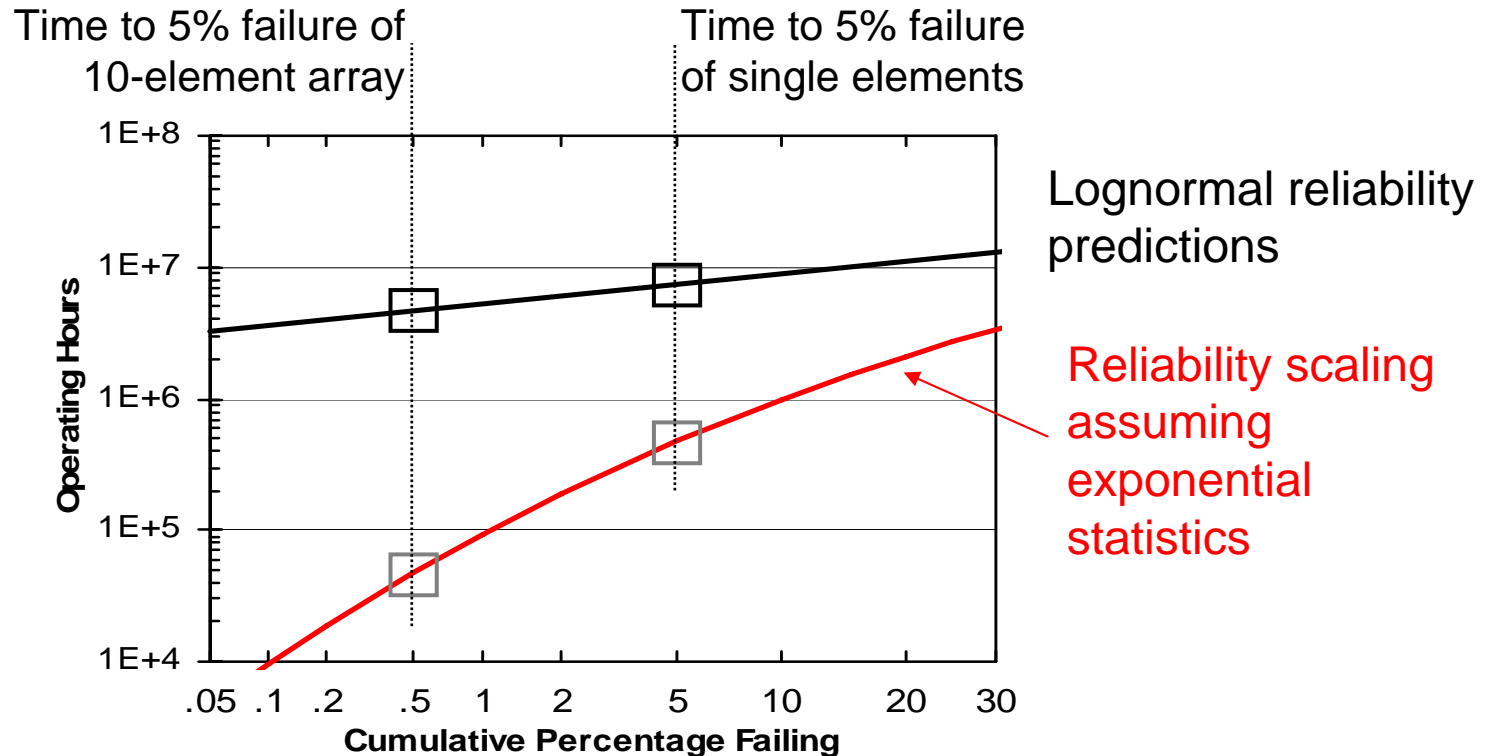
Laser Technology Choices

- ▶ Serial is not really an option with current devices that are directly modulated (lowest cost option)
- ▶ Some form of multiplexing is required
 - Spatial (arrays and ribbon fibers)
 - Wavelength
 - Others?
- ▶ Each form of multiplexing requires multiple laser and detector sources
 - Question is how the reliability of single components scale to multiple components, particularly in VCSEL arrays
 - Little question about the reliability of detectors

Spatial versus Spectral Multiplexing

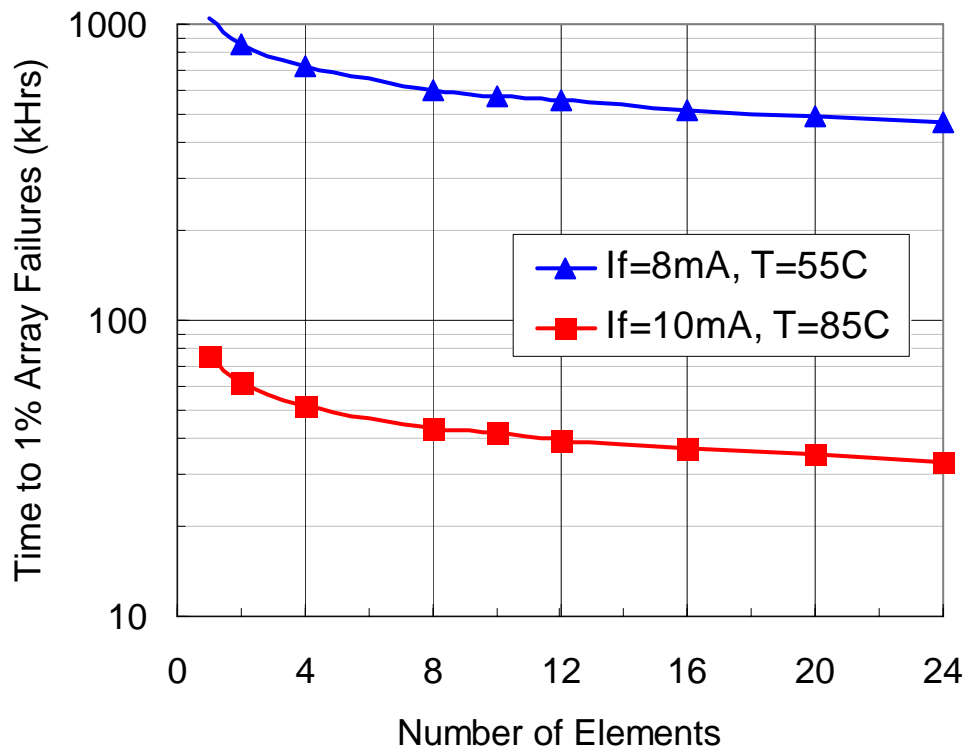
- ▶ From a VCSEL and Detector standpoint, each of the components are *independent*
- ▶ Scaling of reliability should be done using lognormal scaling rules, not exponential rules (i.e. you cannot just divide the time to failure by the number of elements)
- ▶ If the wavelength gets very short (less than 800nm) there are some potential limitations that are imposed on reliability due to the higher photon energy and higher Al content mirrors

850nm 10GB VCSEL Arrays



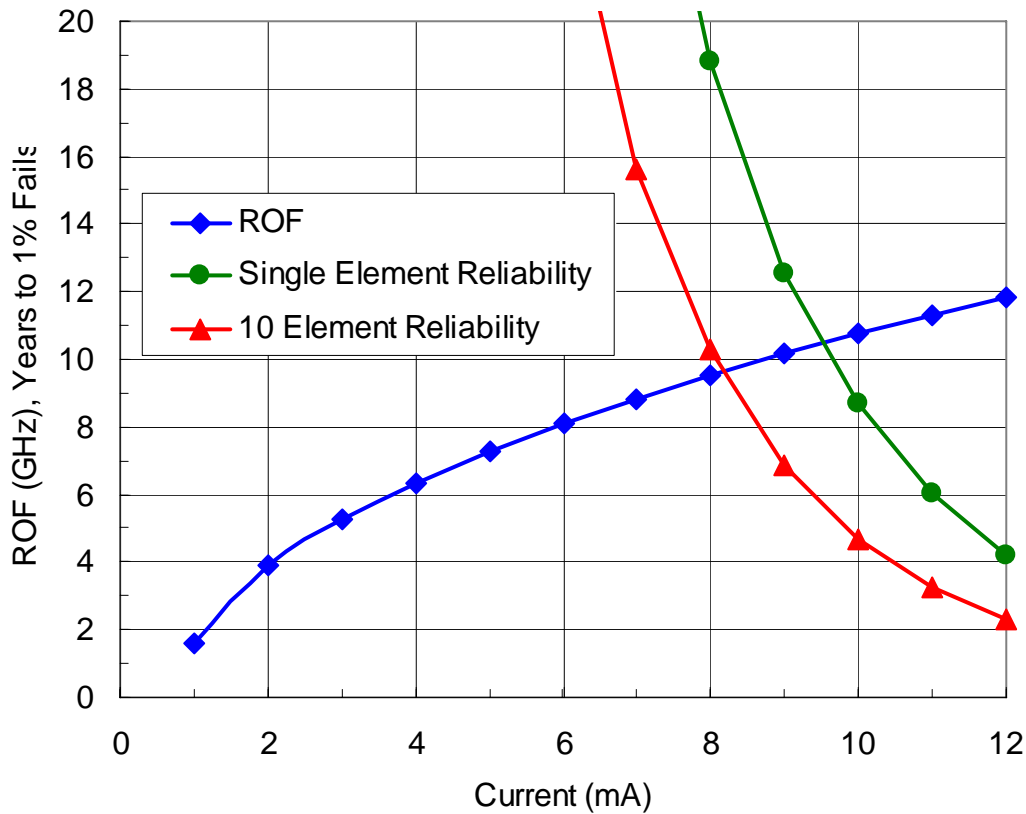
- ▶ VCSEL failure distribution is actually *lognormal*
- ▶ Exponential failure distribution with same MTTF is assumed in many system reliability calculations
- ▶ In example, 10-element array has >50% of single element life for lognormal, <10% of single element life for exponential (non-rigorous statistics)

VCSEL Reliability



- ▶ 5 year continuous operation of a 10 element VCSEL array at 85C ambient is possible, with further improvements to 10 years in the near future

VCSEL Design Tradeoffs



▶ The desire to increase the operating current to increase the speed must be balanced by the reduction in reliability. Data shown for 85C ambient operation

Other failure modes

- ▶ Shipping statistics from more than 50M VCSELs deployed in data communications, random failure rates are well under 10ppm
 - Handling (ESD) is still the number one issue
- ▶ VCSEL and detector arrays have been shipping for more than 5 years, and show the same failure statistics as singlet devices
- ▶ In 3 years of shipping 10G devices, there are ZERO reliability returns

Conclusions

- ▶ Properly manufactured and handled 10G 850nm VCSELs and PINs are highly reliable.
- ▶ Operating 850nm VCSELs above 10G has reliability implications.
- ▶ Extending 850nm VCSELs to WDM has reliability implications.
 - Coarse WDM has fiber bandwidth issues
 - Manufacture of VCSEL arrays at multiple frequencies adds a series of complex process steps.