VCSEL Lifetime Studies

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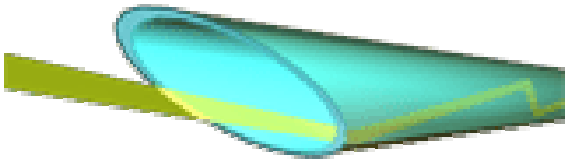
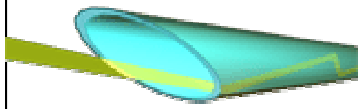


SCT links meeting
February 2000



Arrhenius Equation

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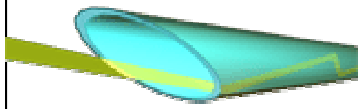
$$AF = \frac{TTF_2}{TTF_1} = \left(\frac{I_{F1}}{I_{F2}}\right)^2 \exp\left[\frac{E_a}{k_B}\left(\frac{1}{T_{J2}} - \frac{1}{T_{J1}}\right)\right]$$

- TTF: time to failure
- I_{Fx}: bias current during tests: I_1=20mA, I_2=10mA
- k_B : Boltzmann´s constant
- T_J : junction temp. : T_1= 40°, T2= -5°
- E_a: activation energy (1.0 eV)



Arrhenius Equation

- Additional accelerating factor of 12 is applied: LHC is only operating a third of a year, link occupancy is about 50% and an equal population of 0´s and 1´s

Acceleration factor vs. temperature

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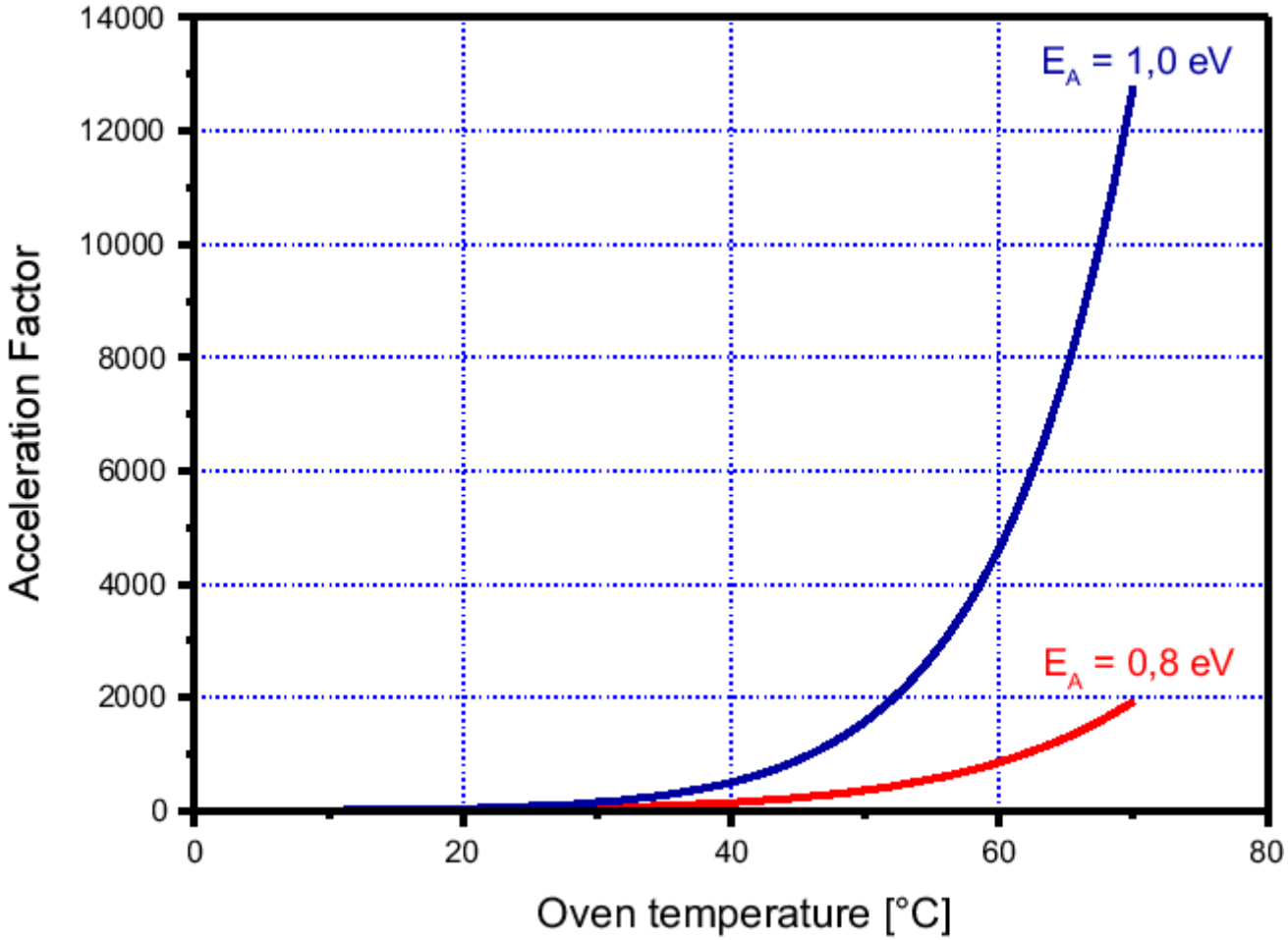
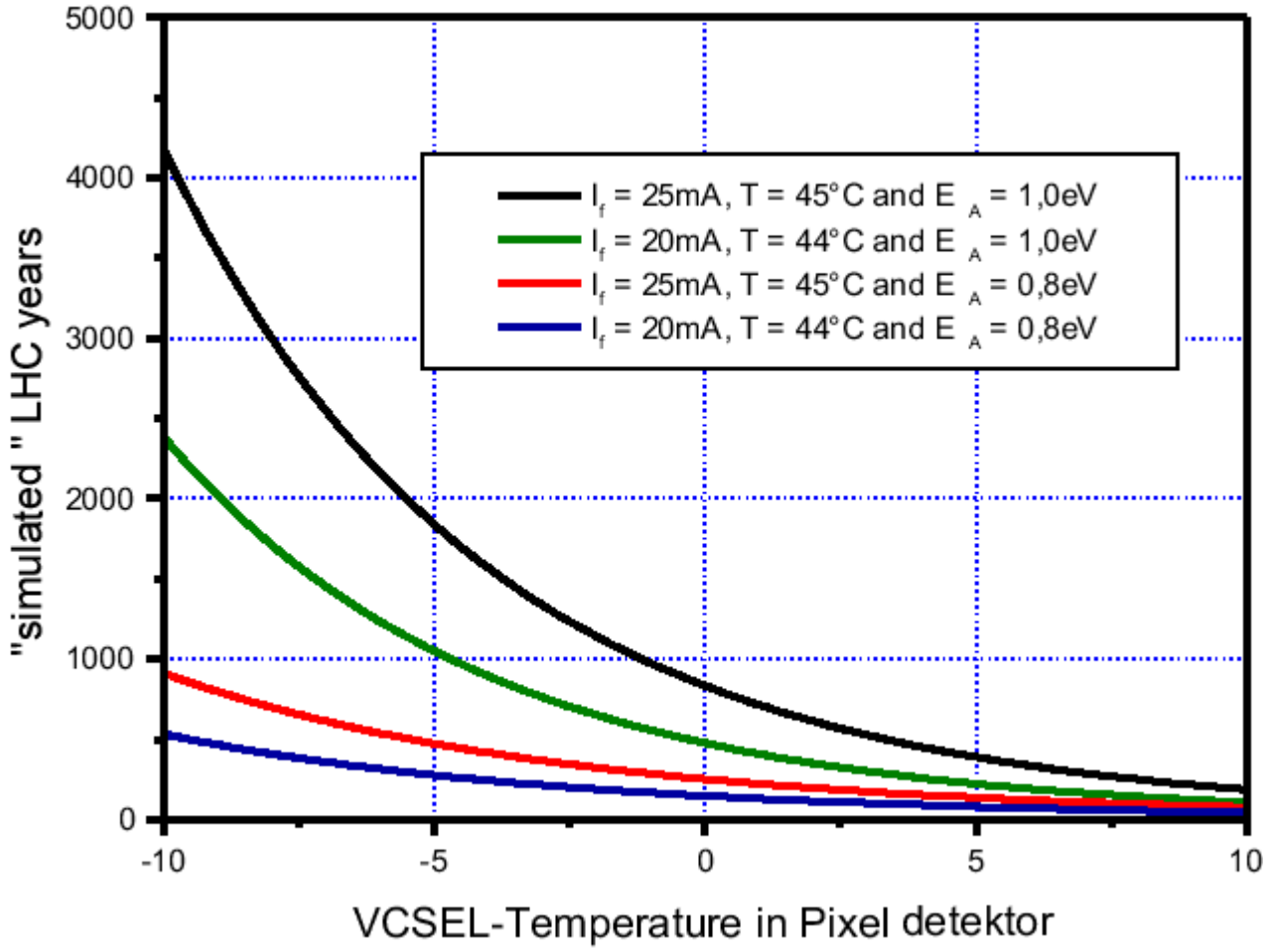
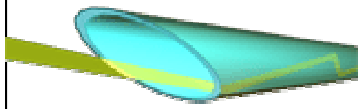


Number of LHC-Jahre





Irradiation

Irradiation	Energy level	Group A (VCSEL A1-A20) [Neutrons /cm^2]	Group B (VCSEL B1-B8) [Neutrons /cm^2]
Nr.1	≤ 10keV > 10keV	$5{,}16 \times 10^{15}$ $(4{,}10 \pm 1{,}39) \times 10^{14}$	--- ---
Nr.2	 ≤ 10keV >10keV ≤ 10keV > 10keV	<u>VCSEL A1-A10:</u> $(2{,}48 \pm 0{,}05) \times 10^{15}$ $(3{,}22 \pm 0{,}93) \times 10^{14}$ <u>VCSEL A11-A20:</u> $(2{,}89 \pm 0{,}05) \times 10^{15}$ $(4{,}08 \pm 1{,}12) \times 10^{14}$	 $(2{,}85 \pm 0{,}05) \times 10^{15}$ $(5{,}20 \pm 0{,}96) \times 10^{14}$

Annealing Studies

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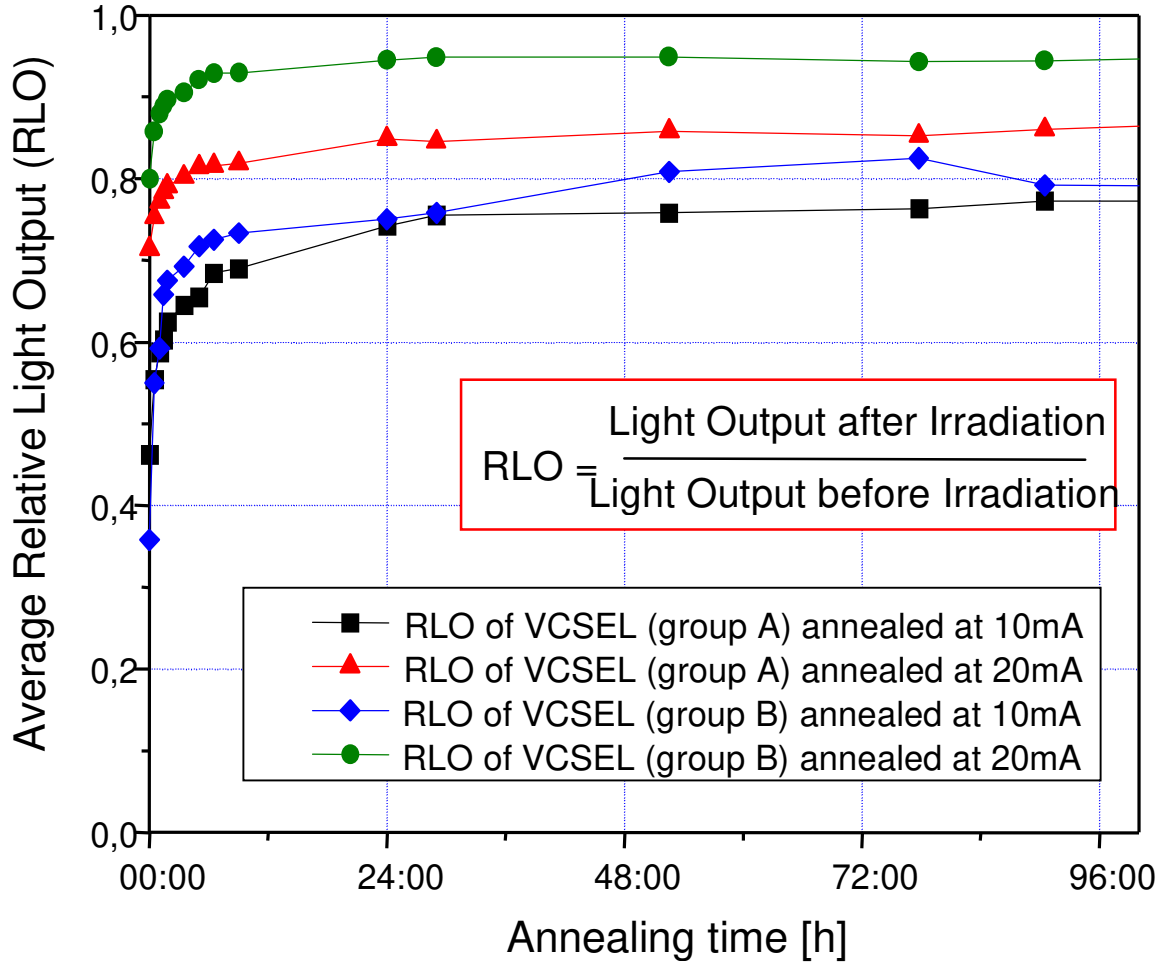
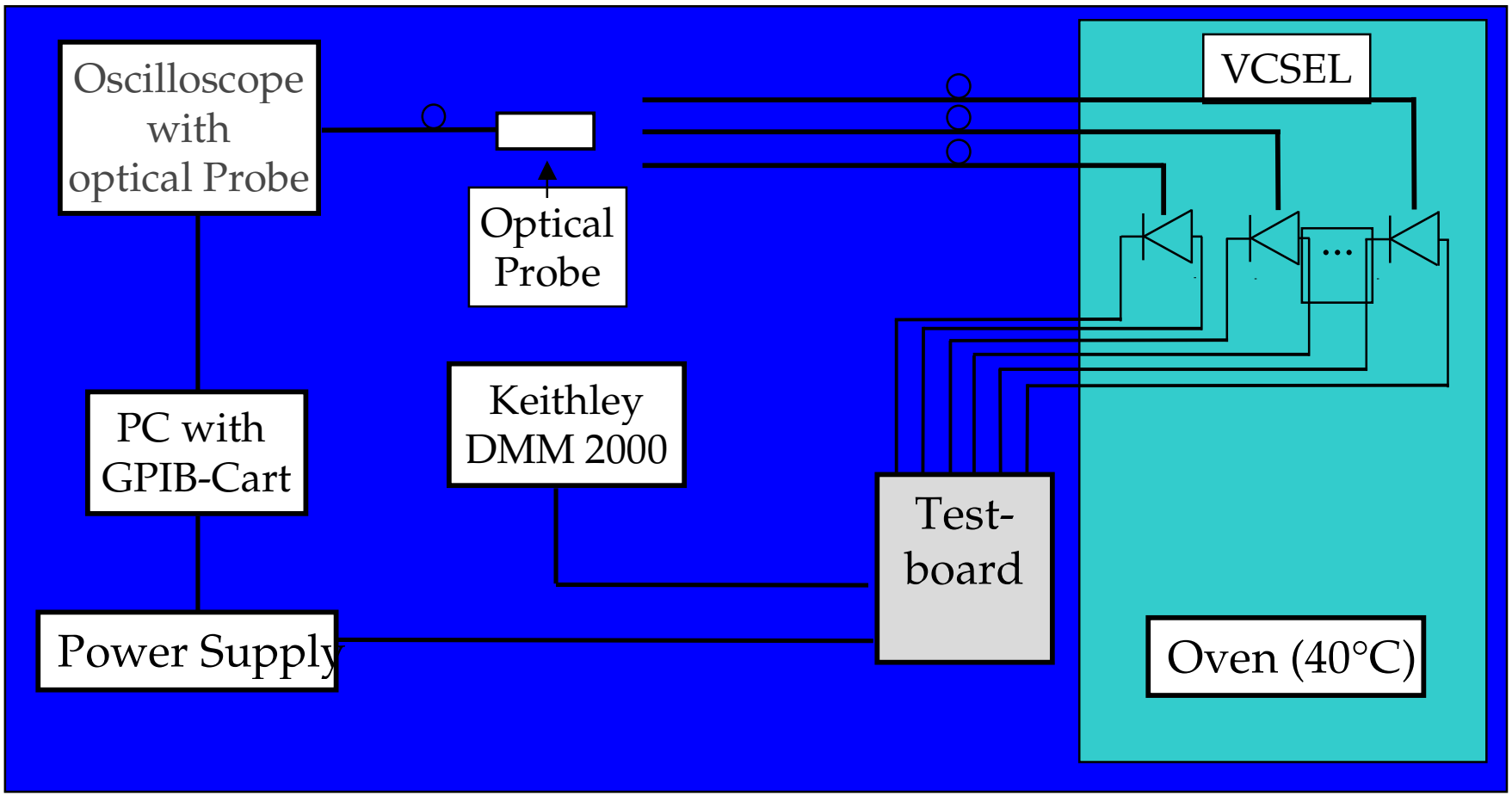


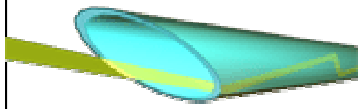
Radiation levels:

$A = 8 * 10^{14}\ n/cm^2$

$B = 5 * 10^{14}\ n/cm^2$

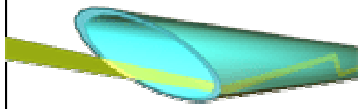
Test Setup


Oscilloscope with optical Probe
Optical Probe
VCSEL
PC with GPIB-Cart
Keithley DMM 2000
Test-board
Power Supply
Oven (40°C)



Expected Lifetimes

Activation Energy	0,8 eV		1,0 eV	
Current	20mA	25mA	20mA	25mA
-5°C	504 y	779 y	2100 y	3278 y
0°C	257 y	399 y	941 y	1482 y
+5°C	25 y	38 y	437 y	684 y



Maximal error rate

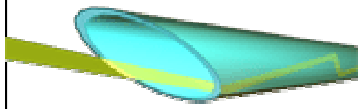
- Max. Error rate with no dead VCSELs

$$p = \left(\frac{1}{n}\right) \ln\left[\frac{1}{1 - C(0)}\right]$$

  - n : number of tested devices
  - C(0): confidence level

- max. failing VCSEL:

$$A = 10 \times 4456\, VCSEL \times \frac{p}{a} \approx 10$$



Results

- No failures (failure = -3dB drop in output power)
- a maximum of **0.2%** (90% confidence level) will fail during the 10 year lifetime of ATLAS
- results are compatible with standard aging tests with non-irradiated VCSELs
- further irradiation test with photons are planned