Accelerated Aging and Reliability Studies of Multisection Tunable GCSR Lasers for Dense WDM Applications

Olga A. Lavrova and Daniel J. Blumenthal
Optical Communications and Photonic Network Group,
Department of Electrical and Computer Engineering
University of California at Santa Barbara, Santa Barbara, CA 93106
Phone: (805) 893-5616 Fax: (805) 893-5705
e-mail: olavrova@engineering.ucsb.edu

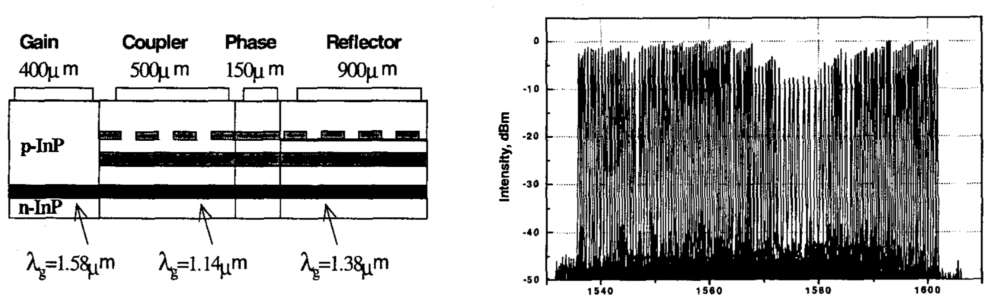
1. Introduction:

Widely tunable semiconductor lasers are promising light sources for future high-capicity Dense Wavelength Division Multiplexing (DWDM) and photonic switching systems [1,2]. The Grating Coupler Sampled Reflector (GCSR) laser [3] and Sampled Grating DBR (SG-DBR) laser [4,5] are the leading candidates for these applications due to their extremely wide continuous tuning range (60-114 nm reported [3,4]), high output power, large SideMode Suppression Ratio (SMSR), compactness and relatively low production cost. However, for system applications, requirements on the reliability of the device are very stringent. Lasing wavelength, power and corresponding currents of the device should operate in a "set-and-forget" mode i.e. a specific wavelength should be accessible with the same values of injected currents during the operating lifetime of the device (over 10-20 years). Furthermore, different channels should not exhibit frequency fluctuations or overlap with each other. Reliability and aging studies are necessary to define stability of these lasers and their expected lifetime in the network. Similar studies have been conducted on tunable DBR lasers ([6,7]), but have not been reported for GCSR or SG-DBR lasers so far.

2. Experiment:

In this paper we report on the accelerated aging studies of standard butterfly packaged GCSR tunable lasers. The schematic structure and overlapped lasing spectra at different ITU grid channels are shown in Figure 1. Device fabrication and tuning mechnism of these lasers has been described elsewhere [1,2,3]. GCSR lasers can be made to operate at any of the desired channels with ±10MHz accuracy by proper setting of the coupler, reflector and phase sections currents. During the reported accelerated aging test, the lasing frequency, power and SMSR ratio for a large number of channels within each device were systematically measured and recorded after a given period of time. A preliminary 37 hour burn-in at 85^{o}C eliminated all infant defect devices, and no failures were observed during the performed test.

Table 1 summarizes the conditions of the accelerated aging measurements. The first short (600 hour long) test was intended to study the changes in early device operation. Major changes happened within the first few hundred hours following burn-in, with only much smaller changes occuring during further operation of the device. Similar changes were observed previously [8]. This behavior suggests that a second longer



(a) (b)

Fig. 1: (a) Schematic structure of the Grated Coupler Sampled Reflector (GCSR) laser
(b) Superimposed optical spectra of a large number of ITU channels spaced 50 GHz apart

Table 1. Conditions of the performed accelerated aging tests.

Test number	Number of devices	Number of ITU channels	Aging Currents, mA (Gain, Coupler, Reflector, Phase)	Aging Temperature, ^{o}C	Duration, hours	Test objective
1	1	96	(150,15,15,5)	50, 60	600	Study early changes; define appropriate burn-in time
2	4	168	(150,15,15,5)	50	3000	Wavelength, power, SMSR and current stability; device operation lifetime
3	4	322	(150,15,15,5)	60	3000	

burn-in of the devices that have passed the infant death and defects screening should be employed to ensure stability before they go into the network. This will be discussed in more detail later.

Further, eight randomly selected devices were operated continuously at 50 and $60^{o}C$ for 3000 hours (see Table 1) and their characteristics were recorded at set intervals of time. Aging currents of the Gain, Coupler, Reflector and Phase sections were set to 150, 15, 15 and 5 mA correspondingly which are the maximum currents normally needed to obtain the full tuning range of the laser.

3. Results and Discussion:

Figure 2(a) shows measured frequencies of channels within one device as a function of aging time. It can be seen that that some channels are stable and remain at their orginal frequencies even after a long operation time at elevated temperature, but there are a number of channels that experience spontaneous mode hopping to a new frequency location. For clarity, figure 2(b) shows only the stable channels (one channel moves).

Under closer inspection it turns out that it is not only mode hopping that channels can experince, but also a gradual frequency shift as operation time increases. Figure 3(a) shows normalized frequency shifts for the stable channels shown in Fig.2(b). It can be seen that most of the changes take place during first 50-200 hours of device operation. There is a significant spread in the amount of the final shift - between 20 and 50 GHz. However, a major improvement in the frequency stability may be obtained if a device is given an additional burn-in prior to the actual operation time. Figure 3(b) shows normalized frequency shift for a similar device that had a 600 hour burn-in (as in test 1, Table 1) prior to the aging test. Frequency shifts for this device are significantly smaller – between 2 and 20 GHz. It is important to notice that the channels exhibiting larger frequency shifts correspond to the shorter wavelengths, obtained with higher tuning currents. This means that frequency drift is non-uniform over the spectral range.

While gradual frequency shifts are most likely due to heterointerface degradation and increasing leakage currents, the origin of the large jumps in frequency (as in Fig. 2(a)) can be understood if we analyze the changes of tuning properties of the device with operation time. Figure 4 shows wavelength tuning curves as a function of coupler current (coarse tuning). It can be seen that as operation time increases, constant wavelength plateaus are shifting to smaller current values. This means that given the same value of injected current, the lasing wavelength will hop to the wavelength of the next platau with increasing time. Since

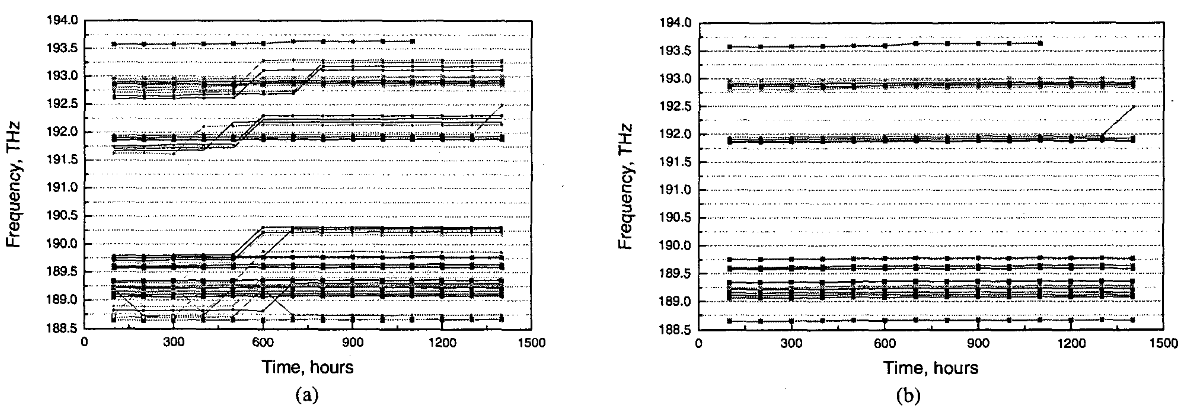
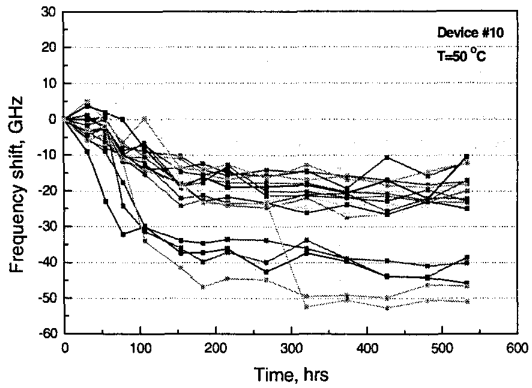
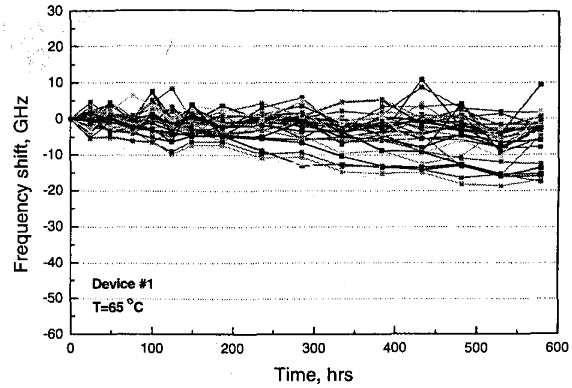


Fig. 2. (a) Frequencies of a large number of channels within one device as a function of aging time
(b) same as Fig. 2(a), only stable channels shown



(a)



(b)

Fig. 3. Normalized frequency shifts as a function of aging time for :
(a) device with only 37 hours burn-in; (b) device with a 37 and 600 hours burn-ins

tuning requires three variable currents to obtain lasing at a given ITU frequency, the probability of a wavelength jump increases proportionally. Power and SMSR were almost constant throughout the operation time and are not shown here.

The effective lifetime of the device amy be estimates based on the "10 GHz frequency shift" criteria. Using Arrhenius plot the median lifetime of the devices at room temperature is estimated to be 11.4 years (assuming activation energy value of 0.62 eV).

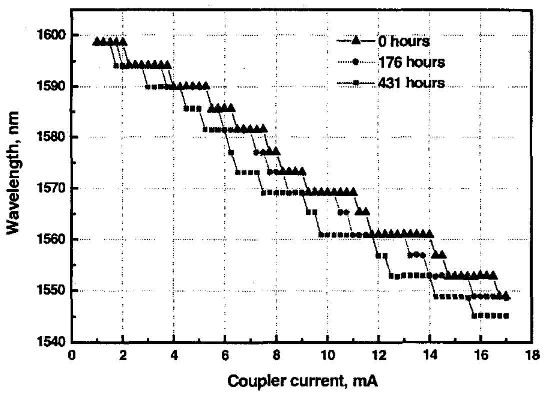


Fig. 4. Wavelength tuning curves for different moments of operation time.

4. Conclusions:

We have performed a 3000 hour long accelerated aging and reliability study of widely-tunable GCSR lasers. Very stable power and SMSR's were measured, however, lasing frequency drifts were as high as 20-50 GHz. A strong correlation between magnitude of injection current and frequency drift were observed. This can be significantly reduced by an additional burn-in prior to the aging study or application of the device in a real-life system. Equivalent room-temperature lifetime of the device was estimated to be 11.4 years. Statistical analysis of the observed changes as well as equivalent room temperature operation lifetime, based on the "10 GHz frequency shift" end-of-life criteria, will also be presented.

5. References:

[1] P.-J. Rigole et al. "State-of-the art: widely tunable lasers", SPIE Vol. 3001, p.382

[2] P.-J. Rigole et al. "Wavelength coverage over 67 nm with a GCSR laser. Tuning characteristics and switching speed", 15th IEEE Int. Semiconductor Laser Conference, paper W1.1, Haifa, Israel, October 1996

[3] P.-J. Rigole et al. "114-nm wavelength tuning range of a vertical grating assisted codirectional coupler laser with a super structure grating distributed Bragg reflector", IEEE Photonics Technology Letters, vol. 7, July 1995

[4] H. Ishii et al. "Broad-range wavelength coverage (62.4 nm) with superstructure-grating DBR laser", Electronics Letters, vol.32, Feb. 1996

[5] B. Mason. et al. "Directly modulated sampled grating DBR lasers for long-haul WDM communication systems", IEEE Photonics Technology Letters, vol. 9, March 1997

[6] H. Mawatari, M. Fukuda, F. Kano, Y. Tohmori, Y. Yoshikini, H. Toba, "Lasing Wavelength Changes Due to Degradation in Buried Heterostructure DBR Lasers", J. of Lightwave Technology, vol. 17, No. 5, p. 918

[7] F. Delorme, B.Pierre, H. de Bailliencourt, G. Terol, P. Devoldere, "Wavelength Aging Analysis of DBR Lasers Using Tuning Section IM Frequency Response Measurements", IEEE Photonics Technology Letters, vol. 11, No. 3, p.310.

[8] S. Lindgren, personal communication