Ultra high power, Ultra low RIN up to 20 GHz 1.55 µm DFB AlGaInAsP Laser for analog applications.

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ABSTRACT

Low levels of intensity noise in semiconductor lasers is a key feature for numerous applications such as high resolution spectroscopy, fiber-optic sensors, signal distribution in broadband analog communications as CATV, and more generally for microwave photonics systems. In particular, a DFB laser with very low relative intensity noise (RIN) levels from 0.1 to 20 GHz is a key component as it correspond to the whole frequency bandwidth of interest for radars. Several approaches have been reported but most suffer from the compromise between RIN level and power out level and stability, with RIN level in the range –150 dB.Hz^{-1} to –155 dB.Hz^{-1} in this frequency range [1,2]. We report here results from a new AlGaInAs DFB laser developed at 3S PHOTONICS. Excellent device performance is observed across an operating range from the laser threshold up to the thermal roll-over. Pure longitudinal single mode at 1545 nm is obtained over the whole current operating range with side mode suppression ratio higher than 50dB. The maximum output power reaches up to 130 mW. In these conditions, RIN levels below –160 dB.Hz^{-1} is obtained in up to 20 GHz. These are the best results to our knowledge combining such high single mode output power with such low RIN level in the frequency range 0.4-20 GHz.

Keywords: Semiconductor, laser diode, high-power, low RIN, single-mode, 1550 nm.

1. INTRODUCTION

Analog microwave optical links for CATV or radar and electronic warfare exhibit a number of design challenges that are not met in numerical optical transmission solutions. They require wide bandwidth, high efficiency and low noise emitters as well as high bandwidth & high saturation power receptor together with drastic linear properties. In particular, a DFB laser with very low relative intensity noise (RIN) levels from 0.1 to 20 GHz is a key component as it correspond to the whole frequency bandwidth of interest for radars. In particular, it has been shown that decreasing the RIN level below –165 dB.Hz^{-1} allows to have radar systems with noise figure limited by shot noise [3]. While low RIN values are reported for frequencies below 2 GHz, lasers with high output power suffers from RIN levels in the –150-160 dB.Hz^{-1} range for higher frequencies due to the laser resonant frequency which often occurs between 5 to 10 GHz [1,2]. By optimizing the design of the laser cavity, RIN levels below –165 dB.Hz^{-1} from 0.1 to 20 GHz at output power up to 130 mW were achieved.

2. DEVICE DESIGN

Two laser designs were defined in this study. The lasers are based on an AlGaInAs MQW structure grown by MOVPE. The grating has been realized by holographic inscription, followed by an MOVPE epitaxial step for confinement and contact layers deposition. Then ridge technology was realized. The final steps consist in bars cleaving, HR and AR coating and mounting p side up on AlN submount.

The vertical structures have been optimized for the first one (design 1) to obtain above 150 mW at the chip level, and the second (design 2) to have RIN levels below –165 dB.Hz^{-1}. The results are presented in the following sections.

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3. CHIP ON SUBMONT RESULTS

3.1 Power and spectrum of CoS.

Figure 1 below presents the typical L(I) curves obtained at 25°C with the two designs. The chip length for the design 1 is 1.2 mm, and the chip length for the design 2 is 1.5 mm. As expected, the design 1 reaches optical power above 170 mW. With the design 2, power above 130 mW are obtained. No kinks are observed from threshold up to the saturation power for both designs. These output power values show a drastic increase compared to previous results obtained on 1.55µm DFB realized with AlGaInAs material [4].

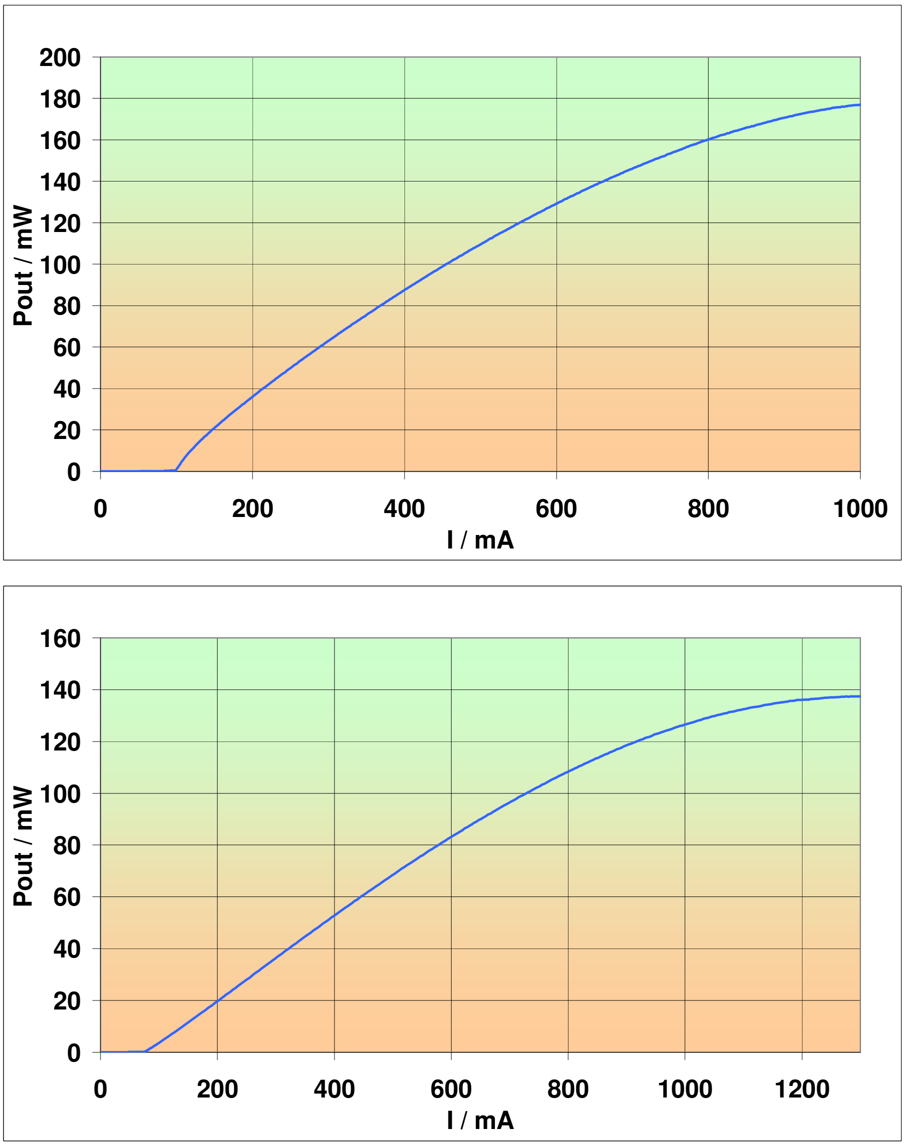
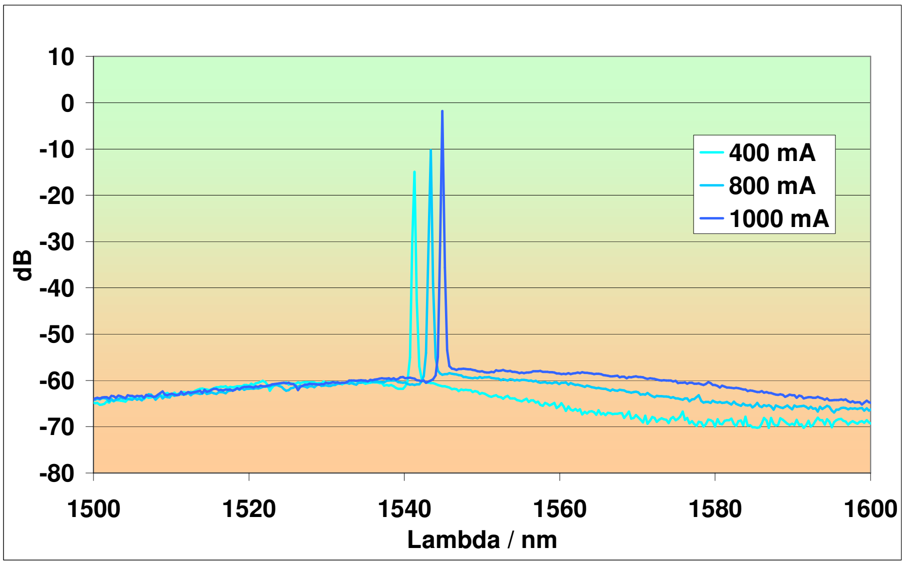


Figure 1: L(I) curves at 25°C for both designs. Top: design 1. Bottom: design 2.

The spectra for the two designs at several current values are presented in figure 2. Pure DFB spectra are maintained on the complete current swing for the two designs. Similarly, SMSR are better than 50 dB for the two designs. These results show the robustness of the designs to the current induced variation such as index changes, carrier density changes and thermal effects.



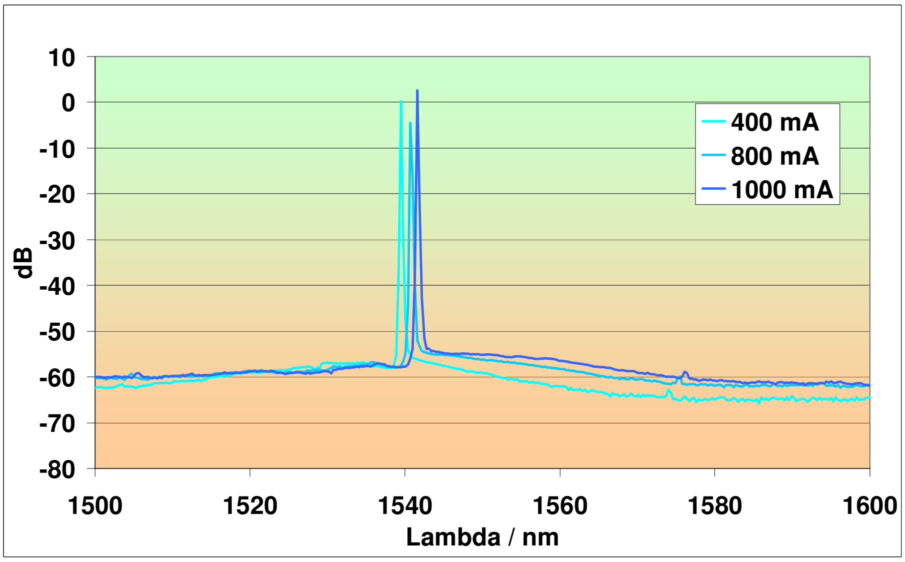


Figure 2: Spectra at 25°C for both designs at 400mA, 800mA, and 1A. Top: design 1. Bottom: design 2.

Following the good results of the chip on submount, modules were realized with both designs. The results are presented below.

4. MODULE DESIGN

A specific module was designed for these lasers. The conception rules were those used for 980 nm pump products. The module was specifically optimized in order to improve the thermal behavior so as to allow a temperature module of 75°C (T_{case}). The module has an optical isolator and a Polarization Maintaining fiber so as to be compatible with external modulators. A photograph of the module is presented in figure 3.

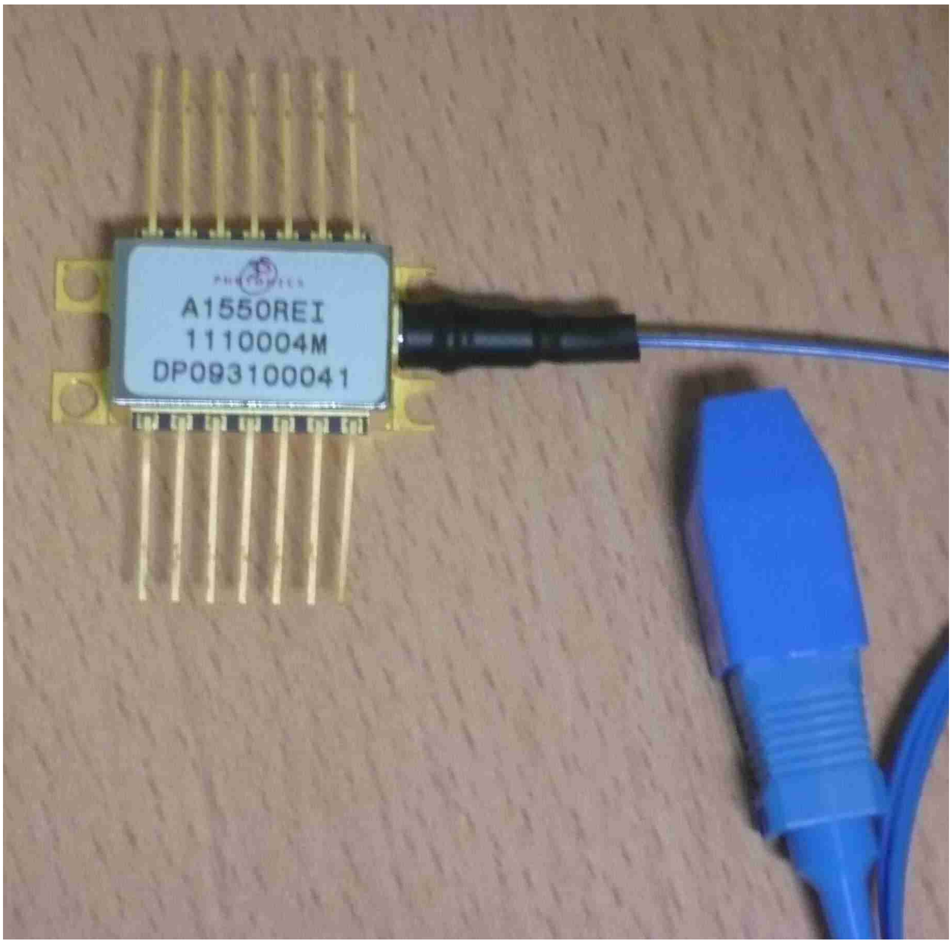


Figure 3: photograph of the DFB module.

5. MODULE RESULTS

5.1 Output power, spectrum and consumption of the module.

The output power for the modules realized with design 1 and design 2 laser chips are presented in figure 4. The laser temperature (T_{wave}) is set to 25°C. The external temperature of the module (T_{case}) was set to 25°C or 75°C. The corresponding spectra at a current of 1A are presented in figure 5. It can be seen that the L(I) curves still present no kinks and the spectra are similar to chip on carrier spectra, which indicates that the module does not affect the chip properties. When the external temperature of the module is varied from 25°C to 75°C, only minor changes are seen. This validates the thermal conception of the module. For both designs, optical power above 100 mW are obtained, which places these modules at the state of the art level for these kind of applications.

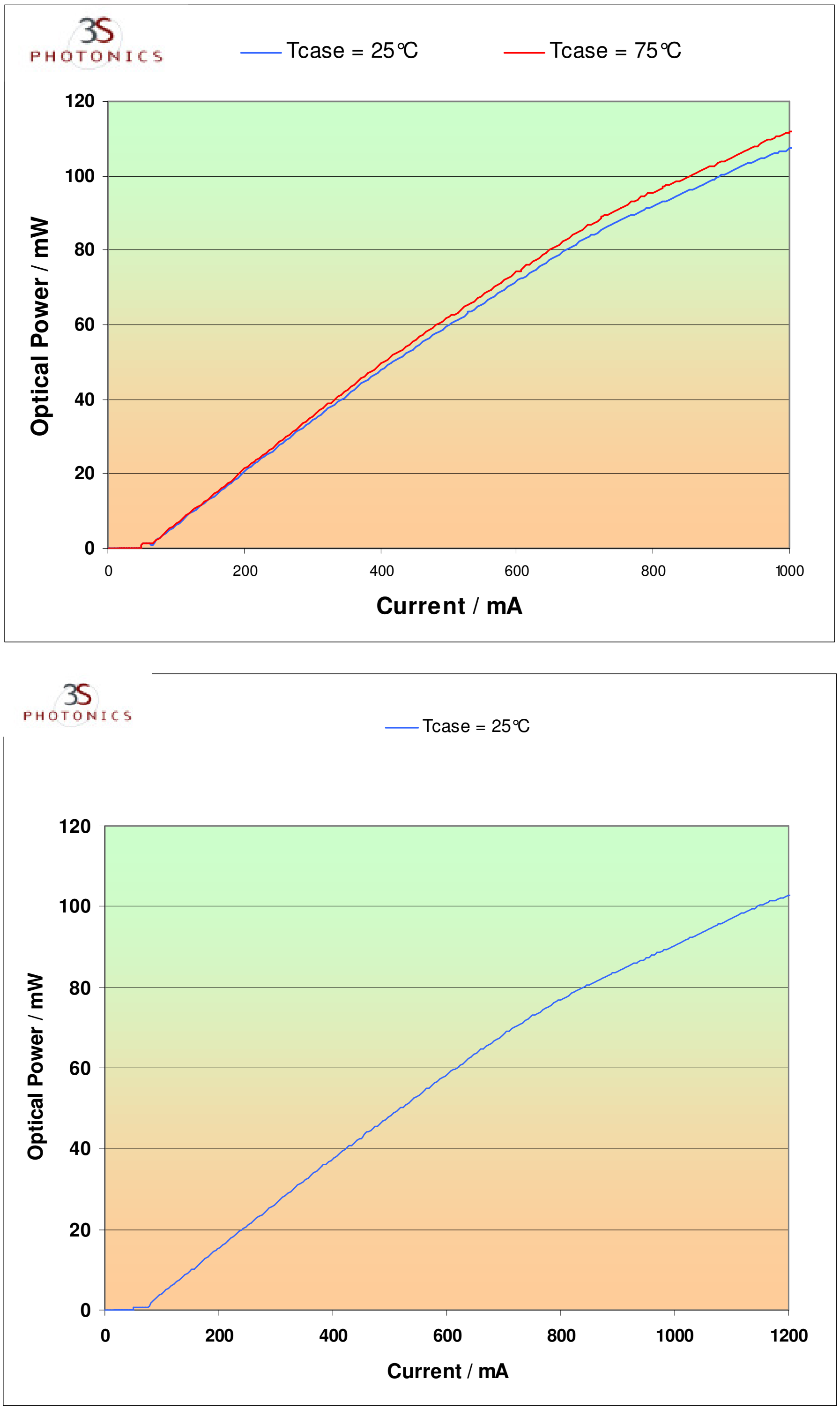


Figure 4: L(I) curves at T_{wave} 25°C for both designs. Top: design 1 with T_{case} = 25°C and 75°C. Bottom: design 2.

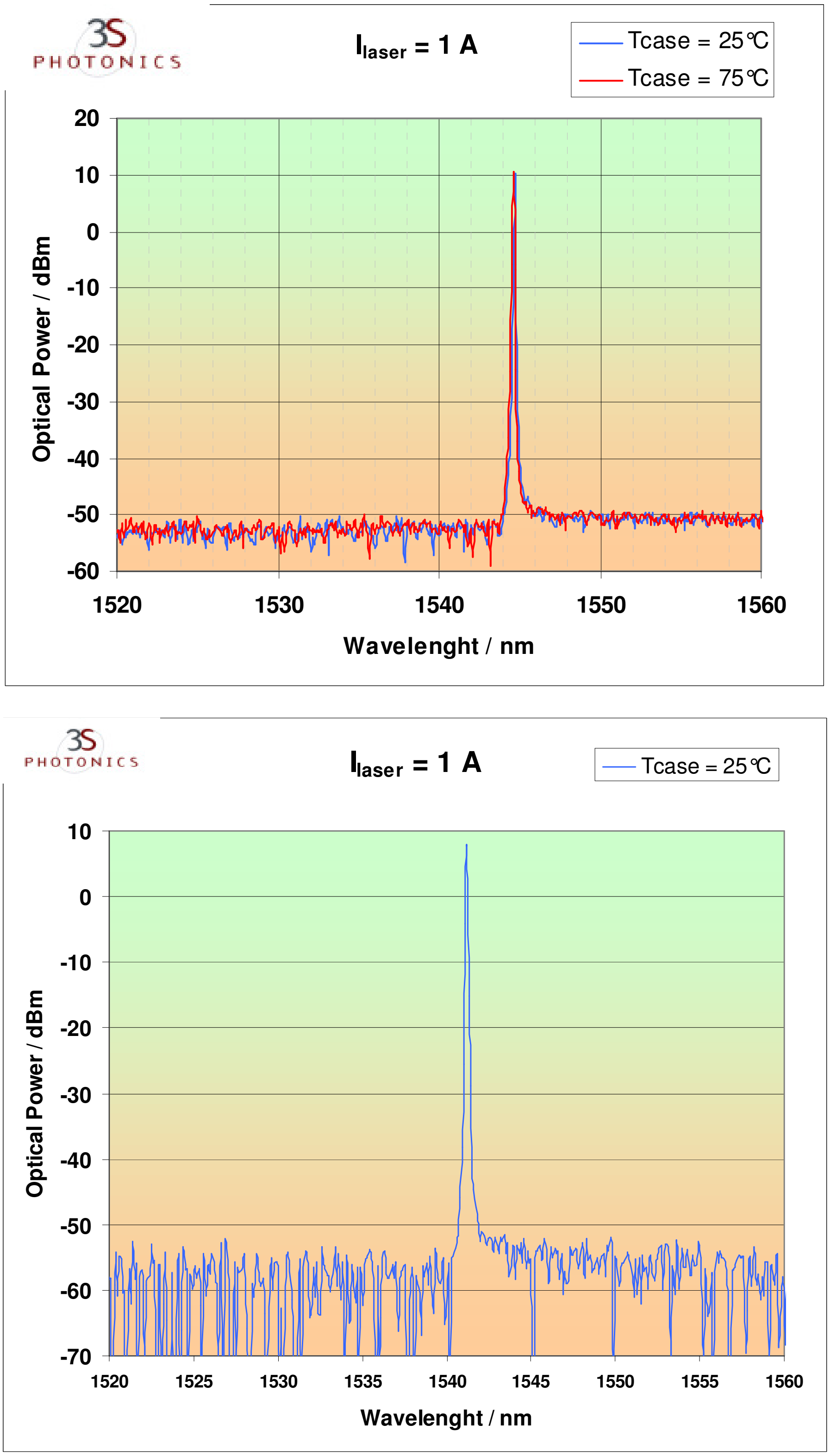


Figure 5: spectra at T_{wave} 25°C and 1A for both designs. Top: design 1 with T_{case} = 25°C and 75°C. Bottom: design 2.

A critical aspect for the module is the overall consumption. Figure 6 presents the Peltier cooler consumption as a function of the thermal load. In the worse case which is for Tcase = 75°C, the Peltier cooler consumption remains below 6 W. This makes an overall consumption inferior to 8.5 W.

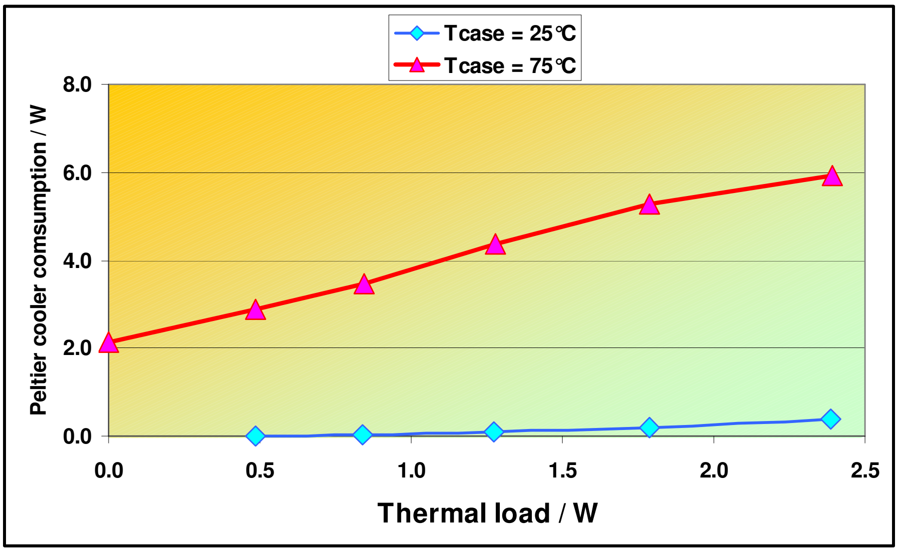


Figure 6: Peltier cooler consumption as a function of the thermal load at T_{case} = 25°C and 75°C.

Finally, the Relative Intensity Noise (RIN), which is a critical point for analog application, were measured. The results are presented below.

5.2 RIN measurements

For analog applications, the RIN level should be as low as possible, considered in the frequency range of the application. We have thus considered the RIN in the frequency range up to 20 GHz, which covers in particular the Ku band for radar applications. The results for the two designs as a function of the current are presented in figure 7. As expected, the RIN level diminish as the current is increased to attain a minimum value. Figure 8 shows the resonance frequency for both design as a function of the laser current. It presents also the RIN measured at this frequency. For design 1, the minimum value obtained is below –160 dB.Hz^{-1}. For design 2, the RIN level at the resonance frequency decreases below –165 dB.Hz^{-1}.

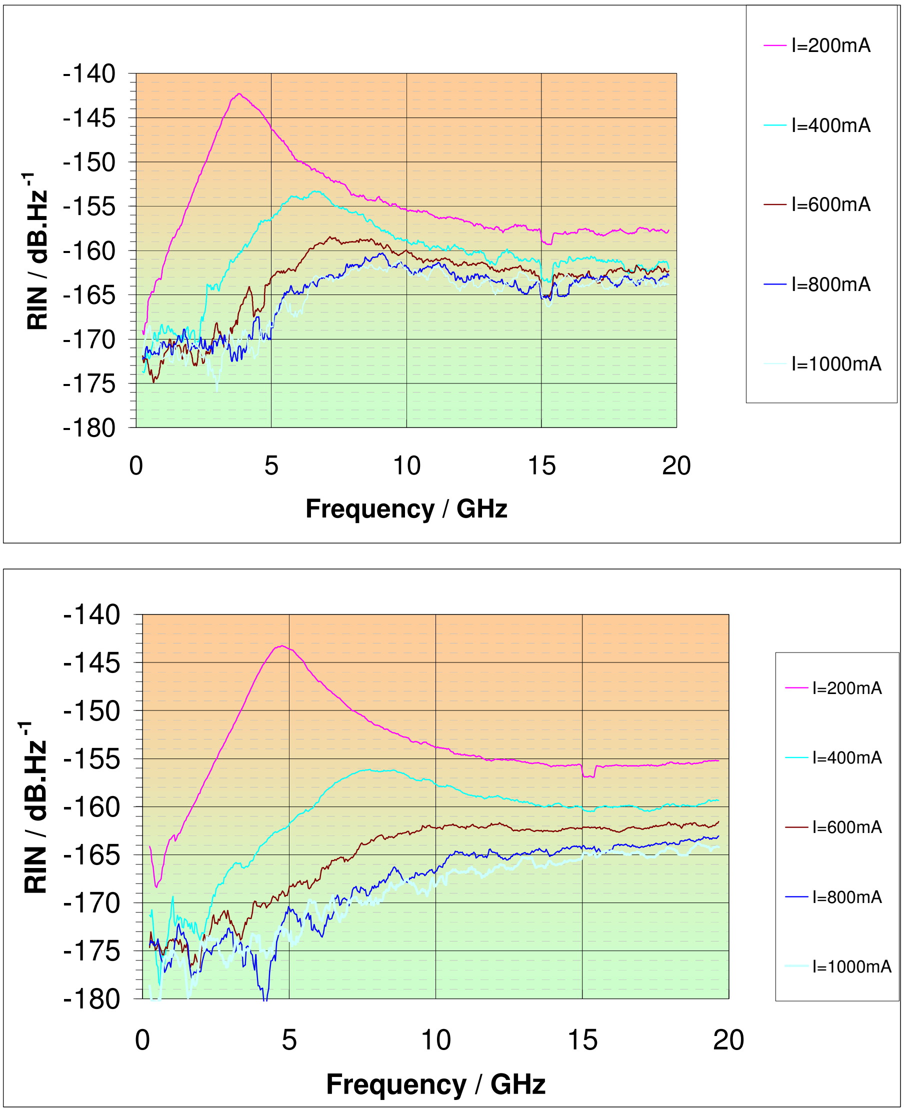


Figure 7: RIN measurements at T_{wave} 25°C and T_{case}=25°C for both designs.

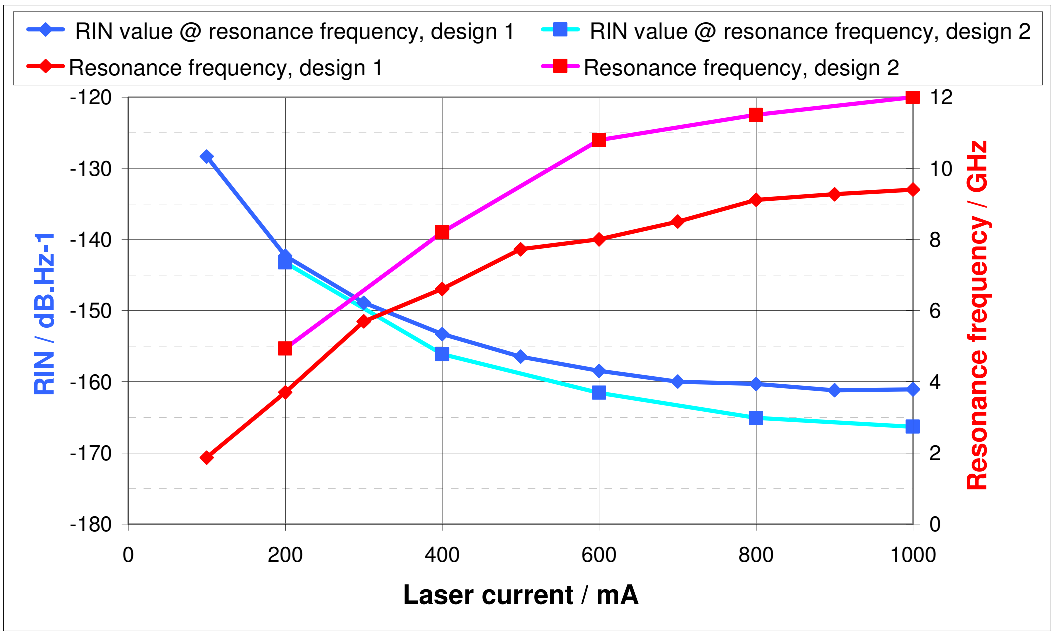


Figure 8 : evolution of the RIN value at the resonance frequency and the resonance frequency value versus laser current value.

Figure 9 presents the RIN spectra at 1A for both designs. For design 2, the whole spectrum is below –165 dB.Hz^{-1}, which is, to our knowledge, the lowest RIN value obtained on such type of laser on the frequency range.

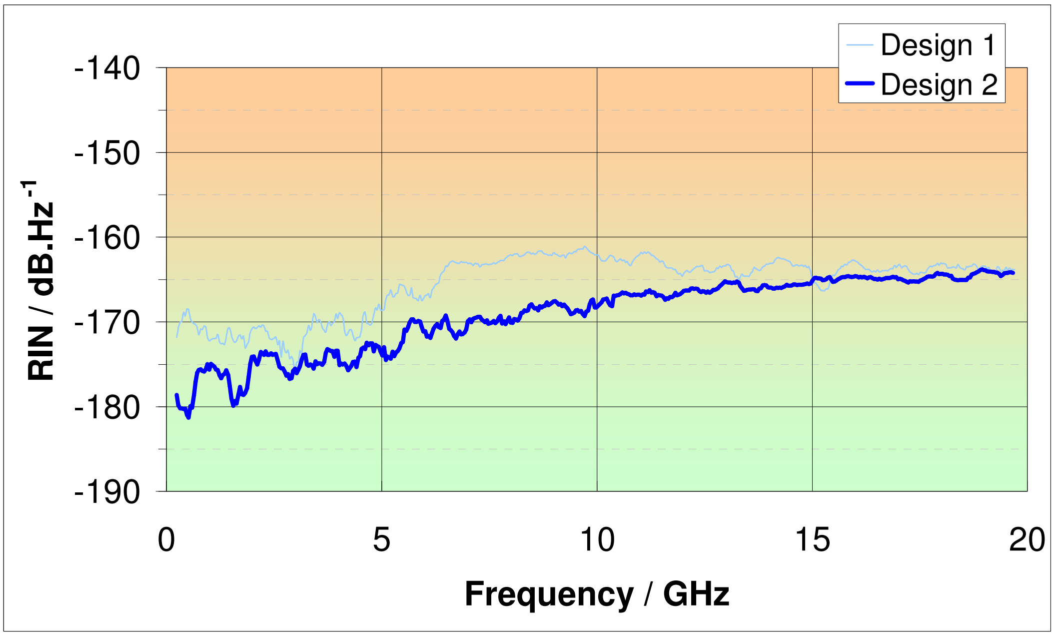


Figure 9 : comparison of minimum RIN for the two designs.

6. ACKNOWLEDGEMENTS

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7. CONCLUSION

Two DFB lasers at 1550nm were designed in order to get high optical output and low RIN values. A module has also been designed for these lasers. Output power above 130 mW at the chip level, leading to over 100 mW output power from the module for both laser designs were obtained. The lasers have high spectral purity with SMSR better than 50 dB from threshold up to saturation of the laser. Stable function of the laser is maintained with external temperature of the module up to 75°C. The RIN measurement show extremely low values for both designs, with a maximum value of –165 dB.Hz^{-1} over the complete frequency range from 0.1 GHz up to 20 GHz. With this results, these modules are at the state of the art for the output power with the lowest RIN values reported to our knowledge. This makes these modules perfectly suitable for analog applications, especially for CATV and radar applications.

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