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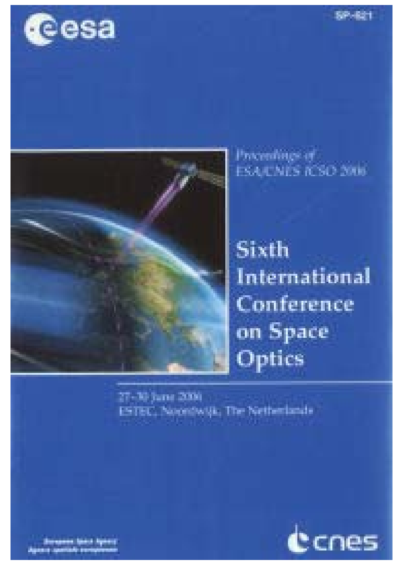

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EFFECTS OF GAMMA RADIATION ON SUPERLUMINESCENT LIGHT EMITTING DIODES (SLEDS) FOR FIBRE OPTIC GYROSCOPE APPLICATIONS

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ABSTRACT

In this work we present a study on the Super Luminescent Light Emitting Diodes (SLEDs) performance under high doses of gamma radiation. We investigate GaAs SLEDs with emission wavelengths around 830 nm. The devices were exposed to ionising radiation at a dose rate of about 4.7 Gy/s, up to a cumulated dose of 10.1 MGy in the CMF facility of the Belgian nuclear research centre SCK·CEN. We measured the device characteristics before and after irradiation. We show that the SLED performance is only marginally affected.

1. INTRODUCTION

Super Luminescent Light Emitting Diodes (SLEDs) are well-suited broadband optical sources for Fibre Optic Gyroscopes (FOGs) and other fibre optic based sensors used in navigation systems.
FOGs can be considered as a privileged technology for applications of inertial guidance and control. Their configuration brings crucial advantages over other approaches using spinning wheels or gas ring lasers. FOGs are based on the Sagnac effect, which produces a phase difference proportional to the rotation rate in a ring interferometer. To achieve optimal operation FOGs require optical sources with a high optical output power and a large optical bandwidth. The short coherence length related to the large bandwidth allows the realization of sensors with improved sensitivity. This strongly reduces the interference contrast of the various parasitic waves generated in the system by backreflection, backscattering, or polarization cross-coupling [1].

SLEDs available today meet the performance requirements to be used in FOGs, both in terms of output power and bandwidth. They are commercially available with hermetically sealed and ruggedized packages, a fibre pigtail, a Peltier element and a temperature sensor [2]. Moreover, SLED's are compact, cost effective and can be produced at different wavelengths. For certain applications, additional device aspects are of key importance. In space for instance the devices must also be resistant to both ionising radiation and energetic particle fluxes. To the best of the authors' knowledge, there are no published studies reporting on the SLED behaviour in radiation environments.

In this work we present a study on the SLED performance under high doses of gamma radiation. In the next sections we describe the investigated devices, the experiments and the results.

2. DEVICES

We investigated SLEDs with emission wavelengths around 830nm. These GaAs based chips were mounted into TO-56 packages. All the chips embedded into the package originate from the same production batch. We tested a total number of 10 devices in order to obtain statistically relevant information. More details on this device can be found in [2] under the product code EXS8310-B001. Fig. 1 displays such a device.

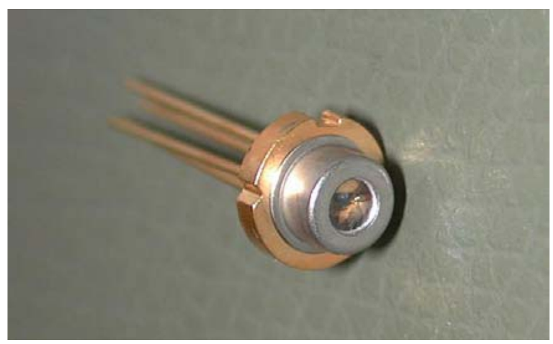

Fig. 1. SLED packaged into a TO-56 housing.

3. EXPERIMENT

The devices were exposed under ambient conditions, that is about 55°C within the irradiation container, to ionising radiation (^{60}Co sources) at a dose rate of about 4.7 Gy/s, up to a cumulated dose of 10.1 MGy in the CMF facility of the Belgian nuclear research centre SCK·CEN [3]. The experimental dose rate was estimated with an accuracy of ~10 %, using Red Perspex dosimeters.

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During irradiation, the devices were short-circuited. We measured both the current-power and current-voltage characteristic before and after irradiation at room temperature. To measure the power we placed a large area photodiode in front of the TO-56 package window. We recorded the output optical power and the forward voltage as a function of the current.

4. RESULTS AND DISCUSSION

Fig. 2 shows the characteristics obtained for the 10 devices under test (DUTs) before irradiation. All the investigated devices show a similar performance. The sharp step seen in the (I,V) curve for the lowest currents is due to the fact that the curves were taken with a 5 mA current step.

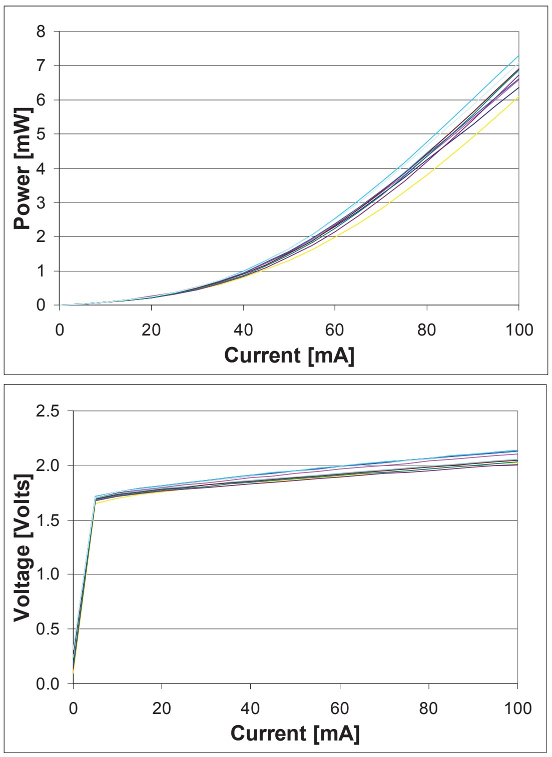

Fig. 2. SLEDs optical output power (upper figure) and forward voltage (lower figure) before irradiation for all the 10 investigated devices.

After irradiation we repeated the measurements using the same setup. We took particular care to perform the measurements under identical conditions, that is at the same environmental temperature and using the same heat sink, because this TO-56 package does not contain a thermo-electric cooler.

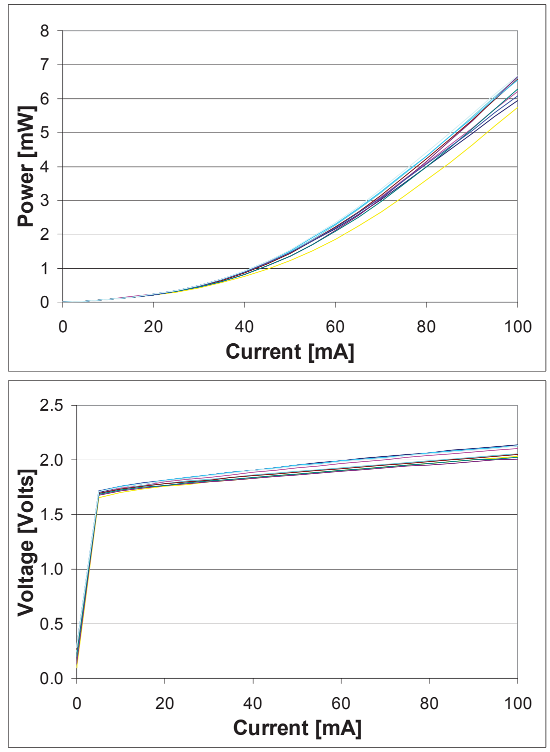

Fig. 3. SLEDs optical output power (upper figure) and forward voltage (lower figure) after irradiation up to 10.1 MGy for all the 10 investigated devices.

Fig. 3 depicts the results after irradiation obtained for the 10 DUTs. The results are very similar to those of Fig. 2 indicating that the gamma radiation did not degrade the device performance remarkably, merely affecting the optical output coupling efficiency through the generation of competing non-radiative recombination centres in the active region.

In order to better see the variation induced by the irradiation we plotted in Fig. 4 the relative output power and voltage variation. We observe that the output power varies less than 10 % for all the devices, while the forward voltage practically remains unchanged (variations < 10 mV). The limited output power degradation could be explained with the intrinsic short lifetime of the highly confined charge carriers, which is hardly affected by the radiation induced non-radiative recombination centres.

The relative insensitivity to gamma radiation was also observed in the past for LEDs and laser diodes [4,5] and this is consistent with our findings. However, generally speaking, care must be taken, if we want to compare our results with those from literature because of two reasons. First, to the best of the authors' knowledge, no results on the SLEDs behaviour in radioactive environments have been reported so far. Second, some typical parameters studied for LEDs or diode lasers, which are optoelectronic components similar to SLEDs, may not apply for SLEDs, such as the threshold current, which is a key parameter for laser diodes.

This first successful accelerated high total dose assessment supports the potential use of SLEDs for instrumentation applications in extremely harsh environments, such as those expected in the future International Thermonuclear Experimental fusion Reactor (ITER), or within large particle accelerators such as the future large hadron collider (LHC) at CERN.
Our SLEDs are also particularly interesting for applications in space missions, where the prescribed tolerance levels against total ionising doses are much smaller compared to the doses used in our study. We are further investigating the effects of gamma radiation on our devices. In particular we will look for potential changes of the output spectra and on the device lifetime changes after irradiation. In a next step towards their complete reliability assessment for space applications, their behaviour under energetic proton fluxes should however be verified as well, since we do expect a more severe degradation from the proton-induced displacement damage.

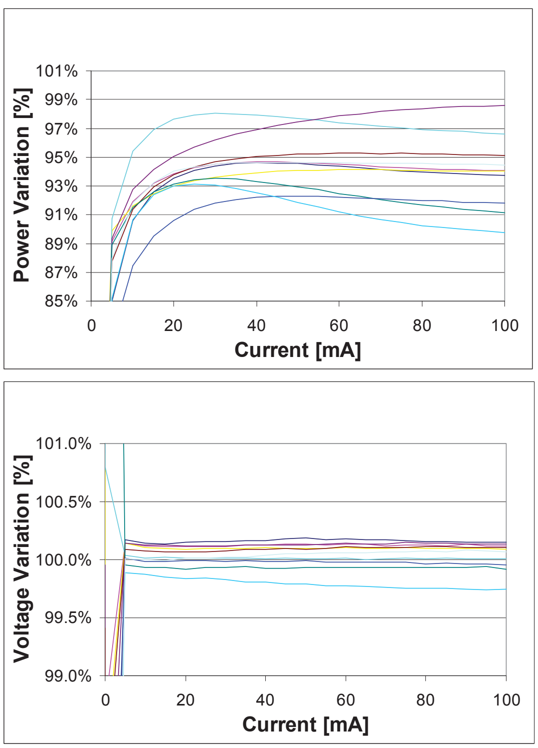

Fig. 4. SLEDs optical output power (upper figure) and forward voltage (lower figure) relative variation after irradiation for all the 10 investigated devices.

5. CONCLUSIONS

We presented a study of the Superluminescent Light Emitting Diodes performance under high doses of gamma radiation, up to 10.1 MGy. We showed that the output power of our GaAs based SLEDs at 830 nm degrades less then 10%, while the forward voltage does not show any significant variation. Our first results support the potential use of these SLEDs in radioactive environments, particularly for fiber optic based navigation or sensing systems. Space-born applications require however to further investigate their robustness under energetic proton fluxes.

6. REFERENCES

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