

# Recent achievements from a new European space optoelectronic component supplier

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## Abstract

*Optoi's involvement in R&D activities under ESA funds has progressively grown in the last few years, leading to the creation of a company unit for space business. A first activity centred on the development and ESCC evaluation of an European radiation tolerant optocoupler is now reaching its conclusion; the encouraging radiation results collected throughout 2013 led to a ESCC ETP being initiated in September 2013 and concluded in February 2014. The collected results are currently under elaboration and the ESCC procedures are being followed, with a view of reaching the EPPL inclusion.*

*In parallel, another has started focusing on the development of an 8-channel phototransistor array for optical angular encoders, whose early developments for CNES have been presented in the three previous editions of ISROS. The current project state is presented in this paper, focusing on two key aspects related to this device, i.e. its strategic importance within the European market and the current development of an hermetic assembly version, as long as the back-end packaging technology is concerned.*

*Finally, Optoi has recently started a third activity for the manufacturing and preliminary space assessment of a new multi-channel silicon photodiode, representing a complementary solution addressing different requirements for future optical encoders.*

*All the abovementioned developments are based on the internal manufacturing of devices; the microelectronic front-end process is managed by FBK's MNF, in close collaboration with Optoi which on the other hand is mainly involved in the coordination of all these projects as well as the design of the assembled components and in particular the accomplishment of the back-end manufacturing.*

*The company current aim is to lead these activities to a stage where the robustness achieved on the developed devices, the proven maturity of the technology and also the visibility gained especially within the European market, will enable the start of the production on business-to-business based procurements.*

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## I. INTRODUCTION

Optoelettronica Italia Srl, also known as Optoi Microelectronics, is an Italian company that has been involved for more than 15 years in the development and marketing of optical sensors for industrial applications, in particular for optical encoders [1]. The company's main activity has always been centred on customized solutions for industrial applications, often based on a collaboration with Fondazione Bruno Kessler (FBK), this last being the silicon technology expertise developer. Recently, an increase involvement in the development of optoelectronic devices for space use has been achieved. The collaborations established with CNES, ESA and ASI in the last few years represent Optoi's most relevant involvement in a field where reliability, long-term durability and robustness of devices are key factors [2]. In the next sections, the most representative running projects are presented and for each of them the related component under development is described.

## II. OPTOCOUPERS

The development centred on a radiation tolerant optocoupler started in 2011 [3], among the growing activities involving the company's aerospace unit. This project has been funded by the European Space Agency, in the framework of the European Component Initiative (Phase 2). The ECI programme [4] comes from an Electrical-Electronic-Electromechanical (EEE) Parts European Action Plan, formulated by ESA and supported by several National Space Agencies, which aims at the development of components in Europe that are currently only available from the US and may fall under export restrictions.

Optoi's project was focused on the development and European-Space-Component-Coordination (ESCC) evaluation of an European Optocoupler for space applications, keeping the performances of the non-European counterparts as reference.

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A. Technology

The optocoupler developed by Optoi is composed by a phototransistor and a LED. The first component has been simulated, designed and manufactured by FBK’s MNF. Specifically, the device is fabricated on a 10- $\mu$ m thick, n-type epitaxial layer. This layer is the collector of the phototransistor, and the thick, highly doped n substrate guarantees a good ohmic contact. The active area of the device is the phototransistor base, which is made by a  $p+$  implant on a large area, in order to optimize the light reception and generation of current. A dielectric stack is deposited over the active area, in order to enhance the spectral responsivity and tune the absorption peak as a function of the LED emission wavelength.

The fabrication of the device in FBK’s class-10 clean room requires 6 photolithographic masks. The process features an in-line quality control according to the ISO-9001 certification.

The device assembly is managed directly by Optoi, on fully automated back-end machines, following MIL-STD-883 and ESA/SCC internal visual inspection specifications n. 2049000.

Figure 1 shows the LCC6 type of device, which represents the specific variant over which most of the analyses were carried out, due to its market potential.



Figure 1: optocoupler assembled in LCC6 package

B. Results achieved

The most recent results were presented at RADECS conference in 2013 [5] and they were mainly related to the radiation study, where the device proved robust especially against gamma radiation, and comparable to other brands against proton irradiation.

In the meantime, the device has been subject to a complete ESCC ETP as in Figure 2, with the support of AdvEOTec both for the ETP definition and for the accomplishment of the tests, with related result elaboration.

Three device variants have been included in the ETP, i.e. in LCC6, LCC4 and TO-5 microelectronic packages.

C. Current development status

Currently Optoi is working on the last result elaborations, with a view to submitting the components to the EPPL inclusion by the end of the year.

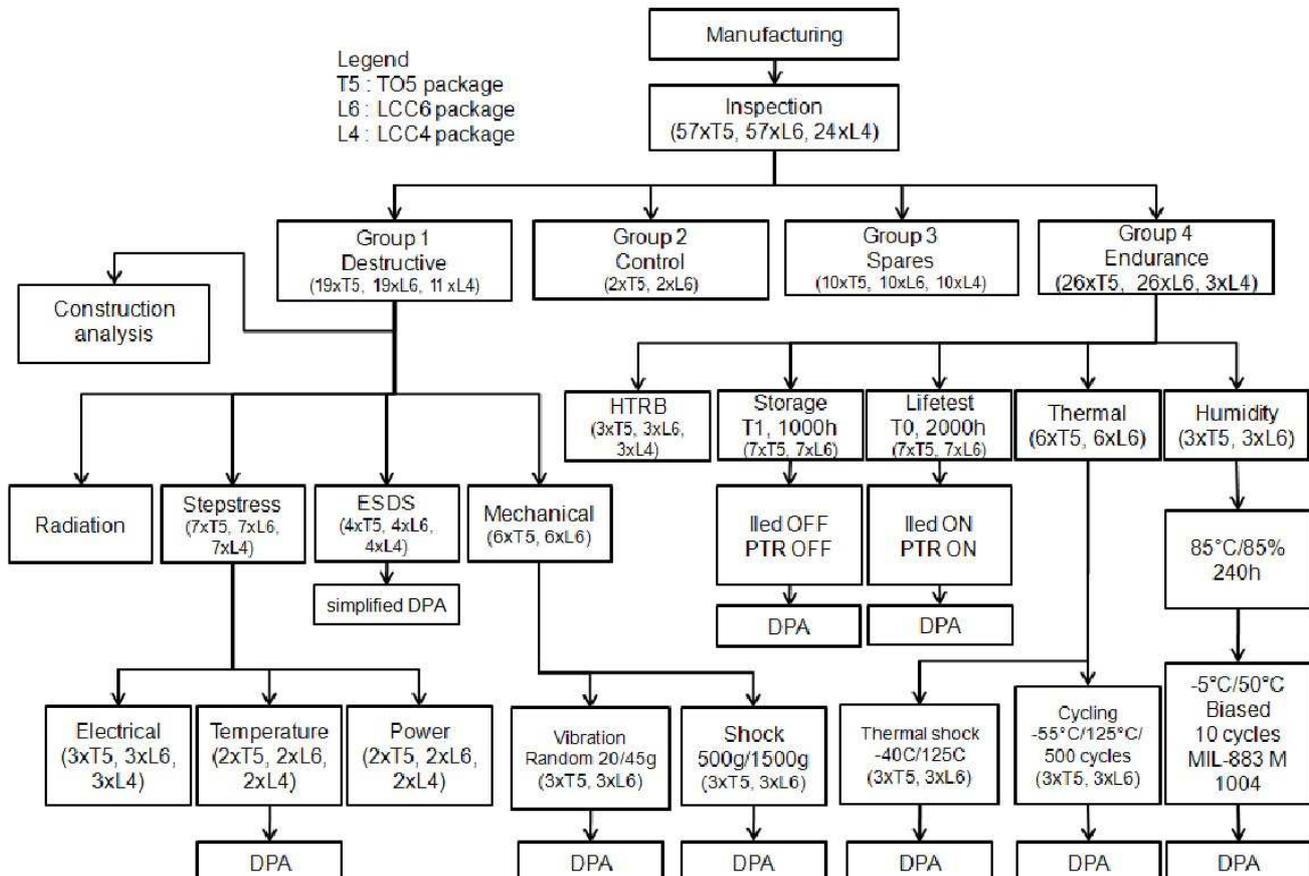


Figure 2: ETP carried out on the optocouplers

### III. EIGHT-CHANNEL PHOTOTRANSISTOR ARRAYS

The development presented in this section relates to an ECI-3 project for ESA and the current maturity of the described technology was possible through three past R&D activities for CNES, between 2007 and 2012.

The eight channel phototransistor array as in Figure 3 represents a typical component for the current encoder generation for space use. Each channel is actually a silicon-based npn vertical phototransistor with floating base and emitter termination, the collector on the back of the die being common to the whole device. The transistor base corresponds to the photosensitive area.

The die dimensions are  $2.25 \times 1.70 \times 0.30\text{mm}^3$  (LxWxT). The package is a ceramic LCC (*Leadless Chip Carrier*) with gold plated terminations, measuring  $4.57 \times 4.57 \times 1.14\text{mm}^3$ . The microelectronic assembled package is closed with an optical borosilicate glass lid measuring  $4.50 \times 4.50 \times 0.55\text{mm}^3$ .

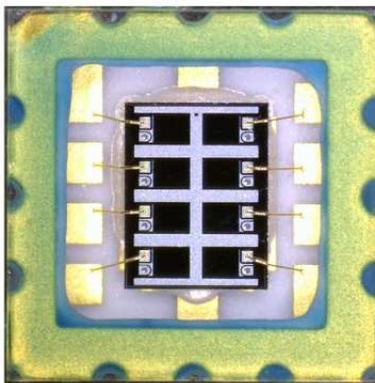


Figure 3: 8-channel phototransistor array

#### A. Technology

Also this device is fabricated by FBK, on epitaxial layer with the same characteristics and similar process flow as the optocoupler.

The vertical pitch between channels measures  $550\mu\text{m}$ , while the centers of the active areas are  $650\mu\text{m}$  apart. Each active area measures  $435 \times 335 \mu\text{m}^2$ . Outside of the single devices, most of the surface is covered by metal.

The back-end assembly process covered by Optoi follow similar methods as described in the previous section on optocouplers, but this time the device closure is made by means of a transparent glass lid and no encapsulant is used for protecting the bare die.

Apart from the device version as shown in Figure 3, where the glass lid is attached by means of a microelectronic adhesive (which anyway ensures the required degree of reliability), Optoi is currently involved on an R&D activity in order to develop an equivalent device version, where the lid is sealed to the package by means of eutectic process and brazing technique (Figure 5). In this context, the major difficulty is represented by the fact that two types of material need to be sealed together and their intrinsic properties are very different (glass vs. alumina).

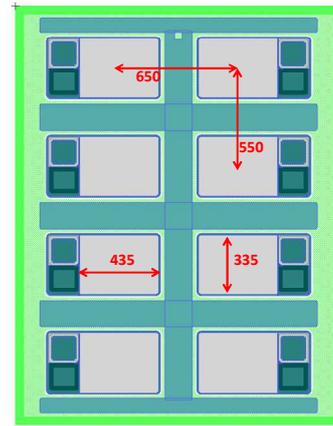


Figure 4: 8-channel phototransistor array (device layout). The reported measured are in microns

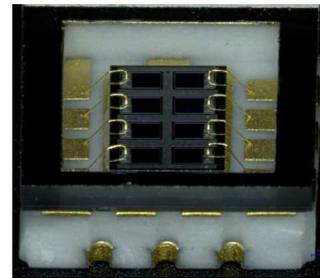


Figure 5: fully-hermetic device variant

#### B. Results achieved

The progressive development achievements have been presented in the past editions of ISROS [6, 7, 8].

Recently, a full radiation study has been conducted, for evaluating the device robustness both under gamma and protons. As usual, application-related requirements have been taken into account for defining the radiation plan and properly elaborate the gathered results.

TID irradiations were carried out in ESTEC using a Co-60 source at the two comparative dose rates of 400 and  $40\text{rad}(\text{Si})/\text{h}$ , reaching 102 and  $36\text{krad}(\text{Si})$  respectively.

Proton irradiations were carried out in UCL with the two energies of 60 and 20MeV, considering 5 different fluences for each energy.

The scope of the radiation study was to determine the complete degradation trend of the developed technology. Since independent groups of devices have been reserved for each of the radiation conditions mentioned above, such activities involved about 130 parts, each of them presenting either 8 or 4 connected channels, thus leading to a considerable amount of results which guarantees the statistical representativeness of the analysis.

The obtained results confirmed the device robustness and were in line with the previous manufacturing run [8], leading Optoi's development to complete positively this important project step.

#### C. Current status

An ETP derived from the ESCC 2265000 has been proposed with the support of AdvEOTec, similarly to the case of the optocouplers described above.

The ETP is expected to start before summer 2014, in order to reach its conclusion by the end of the year.

#### IV. EIGHT-CHANNEL PHOTODIODE ARRAYS

In the framework of a Technology Research Programme (TRP) project for ESA, Optoi is currently developing photodiode arrays, representing a complementary solution with respect to the phototransistor technology as in Figure 3, i.e. addressing different requirements for future optical encoders.

This technology is intrinsically more robust and stable in harsh environment, and offers faster response time, although it needs to be coupled to an ASIC.

##### A. Technology

The device shares a similar layout of the 8-channel phototransistor array, but this time obviously the emitter is not present. The metal pad of the base, then, fills the room left by the emitter.

The microelectronic package used for this device is the same as the phototransistor array as shown in Figure 3.

##### B. Current status

Optoi and FBK are currently working on the device design and this phase will be concluded in the next few months. Shortly after, the parts will be manufactured and submitted to a preliminary reliability evaluation, including irradiations. In case of positive achievements, this development might approach to a more complete ESCC evaluation, like for the optocouplers and phototransistors as described in the previous sections.

#### CONCLUSION

Optoi's involvement in the development of optoelectronic devices for the space sector has rapidly grown in the past few years, and the first activities are now approaching successful conclusion.

This demonstrates that progressive improvements were introduced within the manufacturing procedures and design rules, both in Optoi's back-end but also in FBK's front-end processes, enabling to fulfil application-related requirements beyond the most traditional ones relating the industrial field.

Now that the developed technology has proved suitable for space applications, Optoi's capability is extended to all those domains where robustness, long term durability and mostly reliability are needed, such as defence, avionics and high-rel automation.

#### REFERENCES

- [1] Dalla Betta G. F., Pignatelli G. U., Verzellesi G., Bellutti P., Boscardin M., Ferrario L., Maglione A., Zorzi N., "Design and optimization of an npn silicon bipolar phototransistor for optical position encoders". *Microelectronics Journal*, 1998, v. 28, n. 1, p. 45 – 54
- [2] M. Bregoli, Attività e componenti optoelettronici per applicazioni spaziali, in Proc. V LNL National Course, 2013.
- [3] M. Bregoli et al., "Development and ESCC evaluation of an European Optocoupler for Space Applications", in Proc. ICSO Conf., 2012
- [4] <https://spacecomponents.org/webdocument/showArticle?id=899&groupid=7>
- [5] M. Bregoli et al., "Recent Proton and Co60 Radiation Test Data from a newly developed European Optocoupler source for space application", in Proc. RADECS Conf., 2013
- [6] M. Bregoli, A. Maglione, M. Franceschi, A. Collini, P. Bellutti, P. Spezzigu, L. Bechou, "Customized and highly reliable 8-channel phototransistor array for aerospace optical encoders", presented at the first edition of ISROS in May 2009
- [7] M. Bregoli, P. Bouvier, A. Maglione, "Microelectronic packaging assembly and qualification process flows of a customized phototransistor array for aerospace optical encoders", presented at the second edition of ISROS in April 2010
- [8] M. Bregoli, C. Ress, L. S. How, A. Collini, "Space assessment program on a customized and highly reliable 8-channel phototransistor array for aerospace optical encoders", presented at the third edition of ISROS in October 2012