Optocouplers and Phototransistors

ECI presentation days

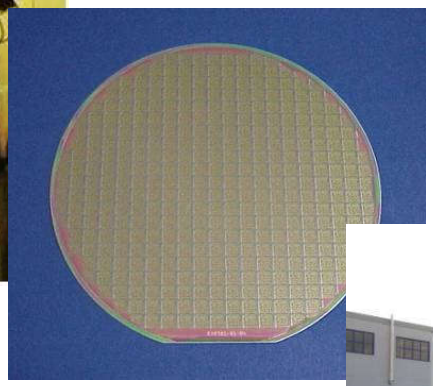
ASI, 29th Sept. 2016

Matteo Bregoli

OPTOI MICROELECTRONICS

Optoelettronica Italia Srl

Fondazione Bruno Kessler (FBK)



Optoi plant, ***Trento***

- **1995** – Foundation, **spin-off** company from FBK activity and small production start-up
- **2000** – Industrial projects and production, international trade mark **OPTOI Microelectronics**
- **2004** – **Quality System Certification** ISO 9001:2008 international customers
- **2005** – **New production plant**
- **2006** – First 10 years, Trentino **Green Consortium Habitec**, increased Optoi staff and partnership with FBK
- **2011** – Evolution of **Optoi Group as network of high-tech companies** Innovasens: Optoi, Advansid, Eoptis
- **2012** – **Clean room upgrade**: packaging line for space and medical devices
- **2013** – Growth in marketing network: **Brazil**, first overseas unit
- **2015** – Partnership agreement with **First Sensor** (Germany)

Microsystem Packaging

Technology

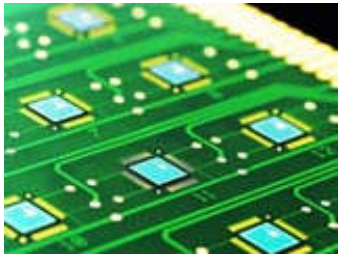
- COB (Chip On Board)
- CSP (Chip Scale Package)
- MCM (Multi Chip Module)
- Stack 3D
- SiP (System in Package)
- SMT (Surface Mount Technology)

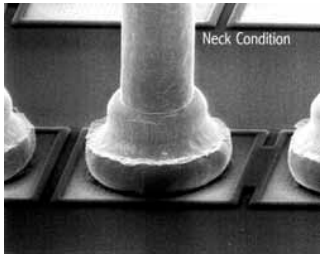
Materials

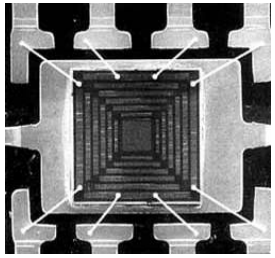
- Polimers: G200, Kapton, Teflon, FR4
- Ceramics: Alumina, LTCC, Glass
- Metals: Kovar, Al-clad, Inox

Capability

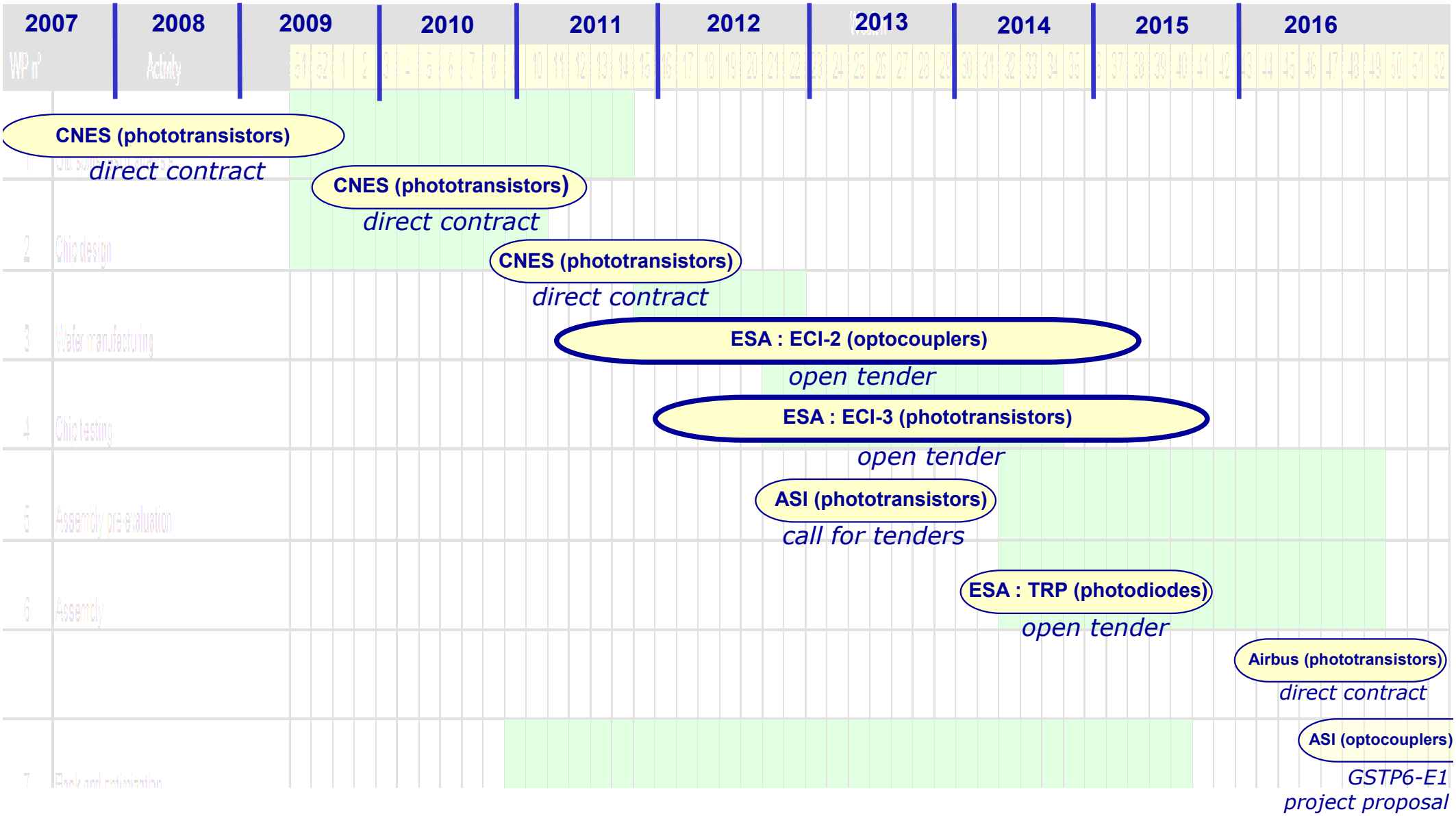
- direct die bonding
- wire bonding
- hermetic welding
- encapsulation
- oven curing
- sensing layer printer
- substrate dicing
- microsystem dicing
- thick film deposition
- SMD assembly line
- die shear test
- wire pull up test
- functional test
- temp. & hum. test







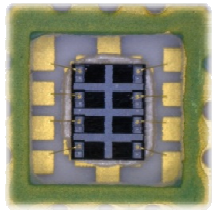
Optoelectronic activity-line: space component funded projects



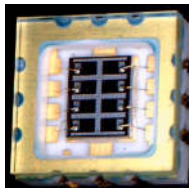
Optoi coordination
Projects funded by Space Agencies

- ESA **ECI-2**: Development, ESCC evaluation and qualification of a European radiation tolerant **optocoupler**
  Duration: 2011-2015
  Funded budget: 390kEuro

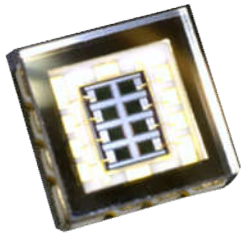
- ESA **ECI-3**: ESCC approval of a European source of 8-ch Si **phototransistors**
  Duration: 2011-2015
  Funded budget: 350kEuro



- ASI SME: Radhard **phototransistors** for space applications
  Duration 2012-2014
  Funded budget: 120kEuro

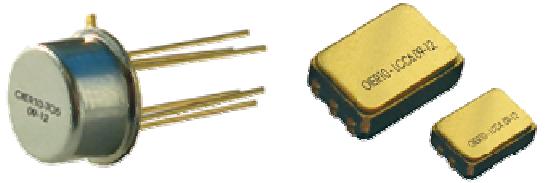


- ESA TRP: Manufacturing and preliminary space assessment of a new multi-channel silicon **photodiode** for optical encoders
  Duration: 2014-2015
  Funded budget: 210kEuro



ESCC eval and qualification of a European rad tolerant optocoupler

- Ref. AO/1-6300/09/NL/EM – ESA **ECI phase 2**
- Project duration: between Jan 2011 and March 2015
- Project effort: more than 2500 working hours (engineering)



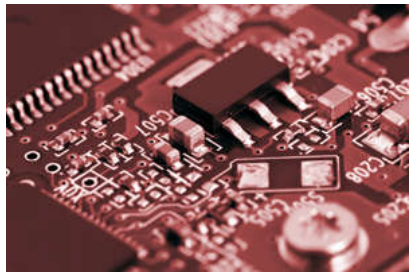
TO-5 *LCC6 and LCC4*

Microelectronic technologies *fully automatic assembly line for devices assembled in LCC and TO-5 packages*

Assembly **process flow**, compliant with *MIL-STD-883 , 750* and *ESA/SCC Basic Spec no. 2049000*

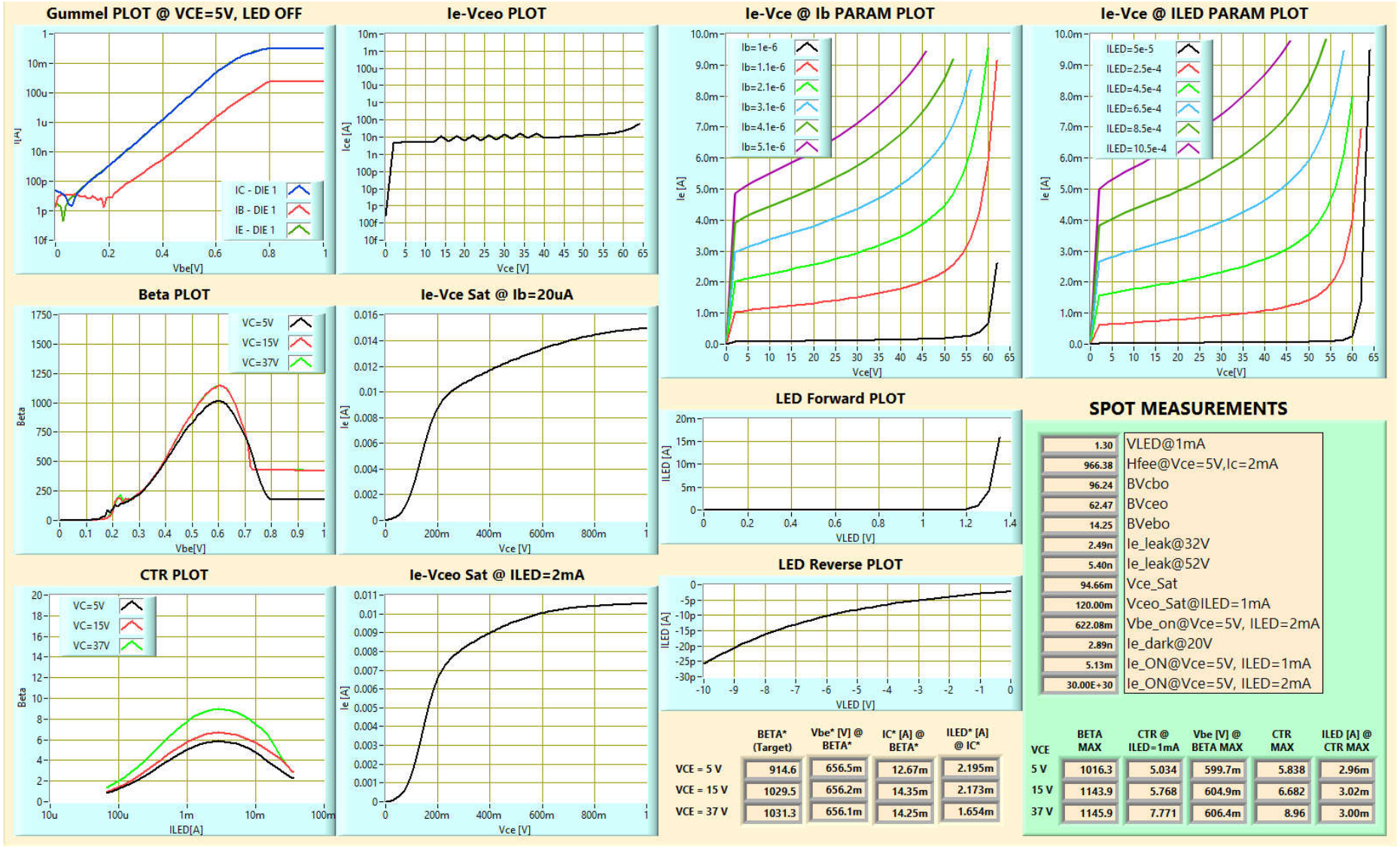
Typical applications

- electrical circuits, where one section has to be isolated from another in terms of current / voltage signals (galvanic isolation)
- electrical circuits, where signal noise has to be minimized or voltage transients have to be prevented, so that there is no interference between circuit sections sharing the same circuit reference



Typical device characteristics

LCC6 package



Radiation tests on optocouplers

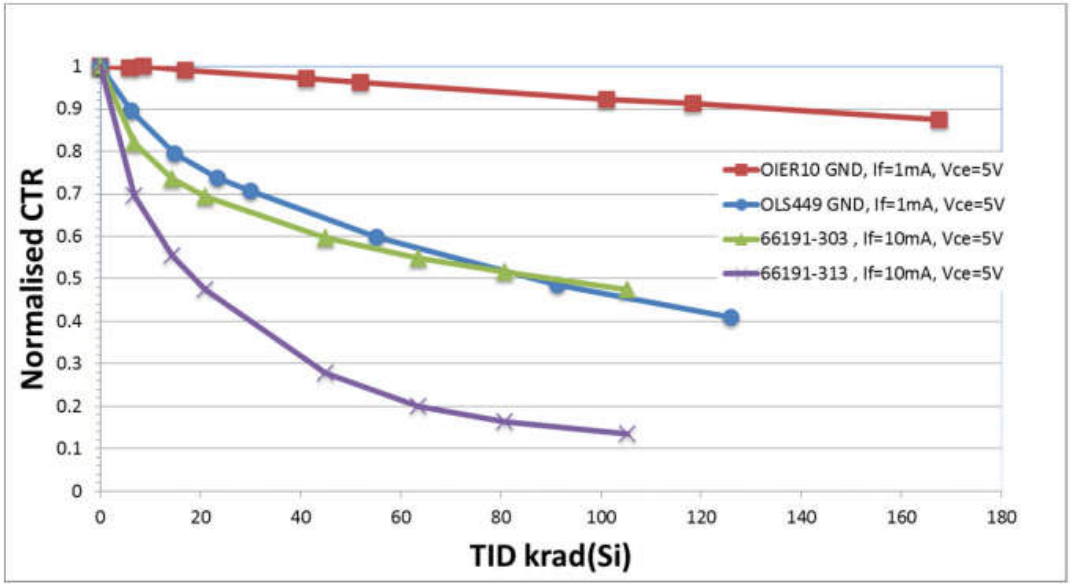
Gamma (ESTEC, Mar - Jun 2013)

36 - 360rad(Si)/h, up to 170krad(Si)
6 and 7 intermediate steps

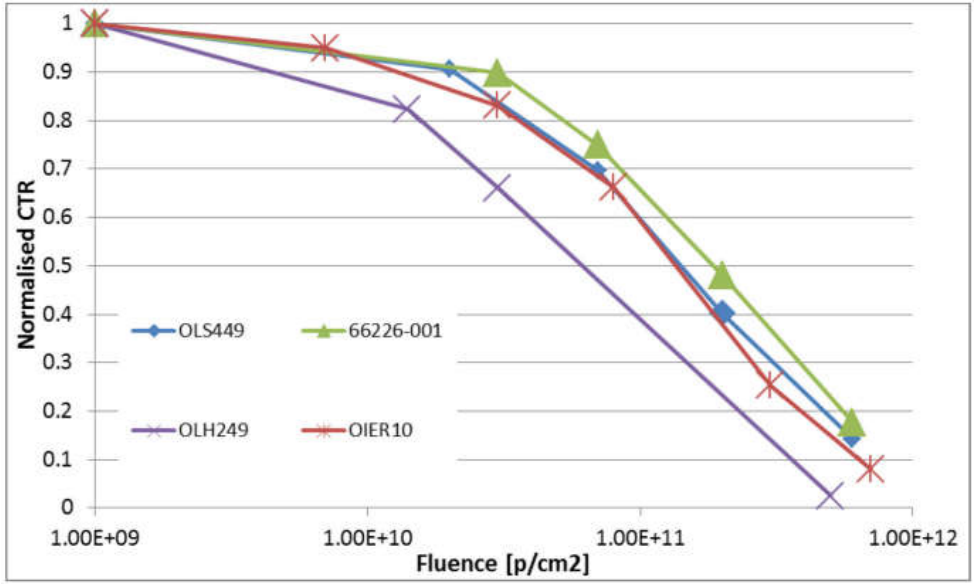
Protons (KVI, April 2013)

25 – 60 - 185MeV, five fluences for each

~150 tested devices



Normalized CTR degradation as a function of total ionizing dose



Normalized CTR degradation under 60MeV proton radiation as a function of fluence

Ref. RADECS publication, 2013
"Recent Proton and Co60 Radiation Test Data from a newly developed European Optocoupler source for space application", M. Bregoli et al.

Radiation report available on Escies

Evaluation Test Plan

Based on ESCC 2265000 methodology
Period : Sept 2013 – Feb 2014

Legend
T5 : TO5 package
L6 : LCC6 package
L4 : LCC4 package

ETP main outcomes

- Safe Operating Area identified
  (electrical - temperature - power step stresses)
- HTRB tests up to 40V, 125degC/48h
  (→ power dissipation properties)
- ESDS: device robust up to 4kV

No relevant drift or critical aspect detected after various tests
(maximum drift value allowed on CTR: +/- 20%)

• random vibration	28.4 and 44.8g rms
• mechanical shock	up to 1500g/0.5ms
• high temperature storage test	150degC / 1000hours
• lifetest	100degC / 1000hours then 125degC/1000 hours, continuous monitoring
• temp shock	five times from -65degC to +125degC, 1 minute transfer time, 30 minute dwell time
• temp cycling	500 times -55 / 125degC, 5degC/minute, 10 minute dwell time
• humidity	damp heat 85degC / 85% RH for 240 hours, followed by temperature cycling -5 / +50degC under humidity

ETP findings and perspectives

- LCC variants proved particularly robust
- LCC4 type revealed beneficial
- DPAs and FAs carried out
- Specific investigations were necessary

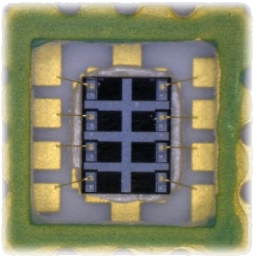
Marketing

- Procurement methodology
  - ✓ PID
  - ✓ Detailed specifications
  - ✓ Screening and Lot Validation Testing plans
- Customer interests
- Discussion of application-related requirements

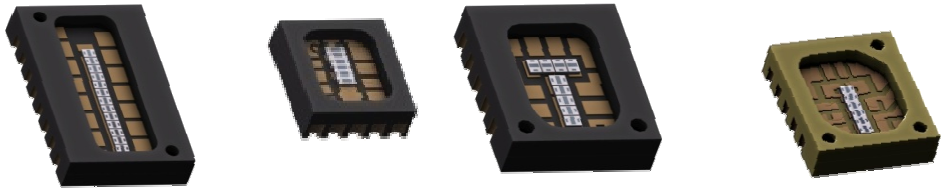
ESA ESCC **audit** held in September 2014

ESCC approval of a European source of 8-ch Si phototransistors

- Ref. ITT/AO/1-6836/11/NL/RA - **ECI phase 3**
- Project started in Nov 2011, about 47 months of overall activity
- Project effort - more than 4000 design & engineering hours by Optoi
- Optoi's expertise and know-how were beneficial



8ch pht array

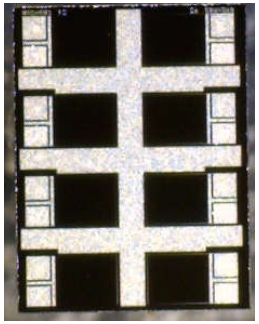


Typical applications

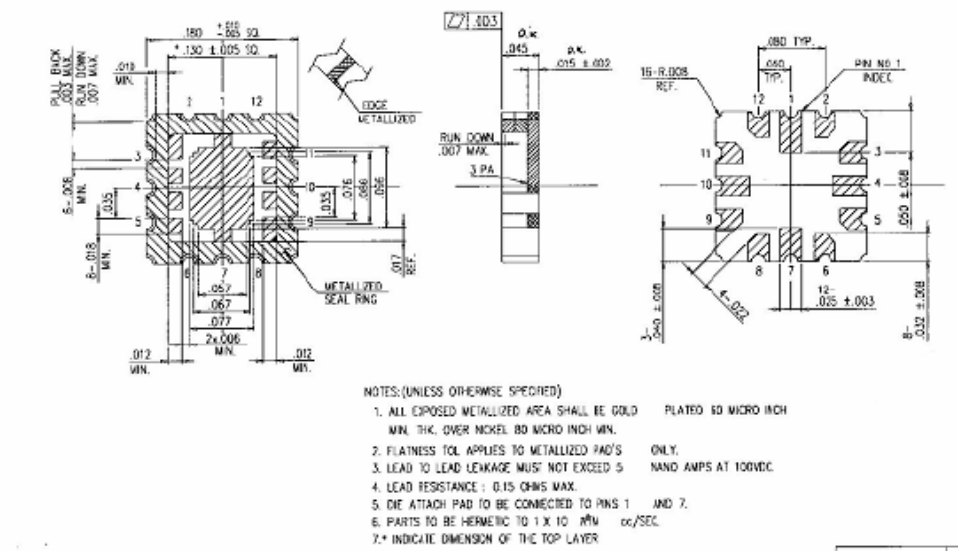
- angular optical encoders (rotational speed, angular position, acceleration and number of cycles)
- actuators of control moment gyros, part of motorized gimbals of last-generation satellites
- optocouplers
- optical switches

Tech requirements

Fourth progressive manufacturing run



- *Silicon-based npn vertical phototransistor*
- *Eight independent channels*
- *Reduced cross talk – light shield*
- *Common collector on the back*
- *Device thickness is critical*



Specific ceramic package

Parameter	Symbol	MIN	MAX	Unit	Condition
Collector-emitter voltage	V_{BCEO}	30		V	I_C = 100µA, H=0
Emitter-collector voltage	V_{BECO}	7		V	I_E = 100µA, H=0
Dark current	I_d		10*	nA	V_{CE}=5V, H=0
Collector-emitter saturation voltage	V_{CESAT}		250	mV	I_C = 1mA, H=20mW/cm2
Gain	h_{FE}	510	1790		V_{CE} = 5V, I_C=2mA, driving current on the base, H=0
Photocurrent	I_{L1}	85		µA	V_{CE}=5V, H=0.5mW/cm2 @ λ=865±30nm
Inter-channel variation	ΔIc		10	%	V_{CE}=5V, H=0.5mW/cm2 @ λ=865±30nm
Cross talk	CT		10	%	V_{CE}=5V, Ib=0.16uA Measured on two adjacent cells
Absorption peak	λ_P	800	920	nm	
Rise time	T_R		300	µs	V_C=5V, I_C=20µA, R_L=10KΩ
Fall time	T_F		300	µs	V_C=5V, I_C=20µA, R_L=10KΩ

*2.5µA@100°C

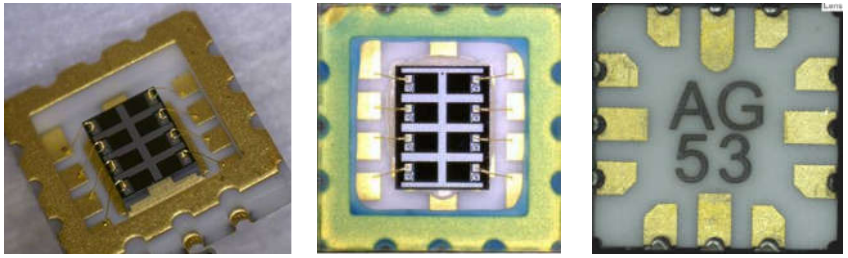
Set of requirements

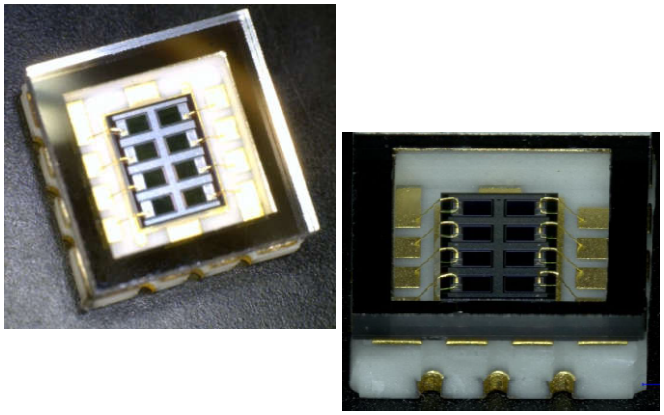
Parameter	Symbol	MAX	Units	Notes
Rise time	*Tr*	300	µs	Vc=5V, Ic=20µA, R=10kOhm
Fall time	*Tf*	300	µs	Vc=5V, Ic=20µA, R=10kOhm
Half-step rise time	*Tr50%*	150	µs	Vc=5V, Ic=20µA, R=10kOhm
Half-step fall time	*Tf50%*	100	µs	Vc=5V, Ic=20µA, R=10kOhm

New definition of absolute requirements in dynamics

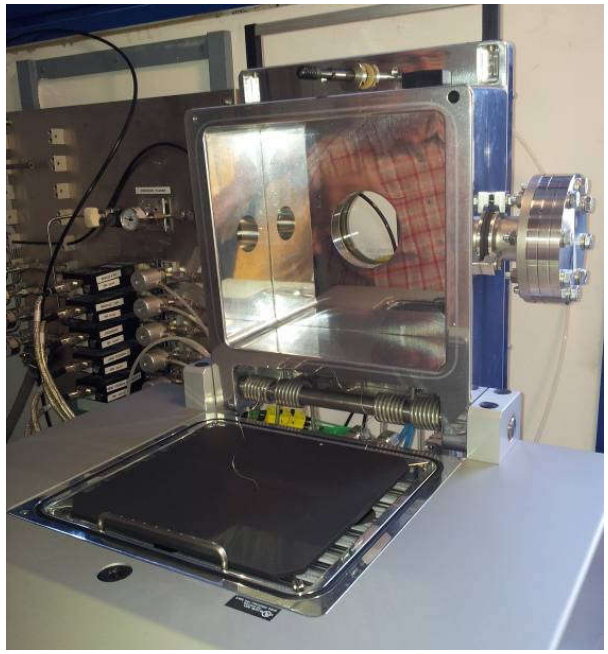
Device assembly: back-end

- MIL-STD-750 and 883
- ESCC Basic Spec 2045000 and 2049000
- CNES visual inspection criteria
- Application-related requirements
  - bonding loop and pull-up
  - glass lid attach
  - outgassing of resins
  - thermal stresses





Soldered glass lid - variant



Reflow oven

Radiation tests

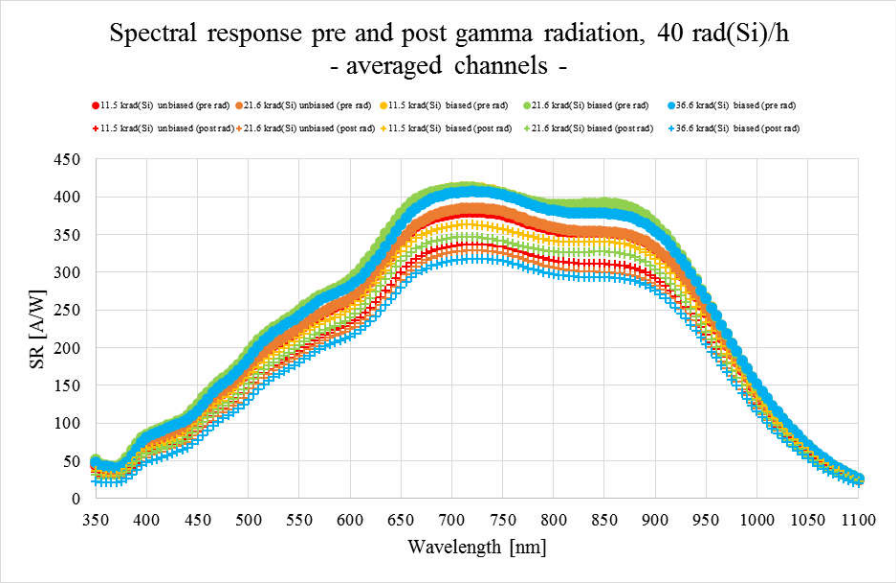
Gamma (ESTEC, Jan - Apr 2014)

400 - 40rad(Si)/h, up to 102.0 and 36.6krad(Si), 4 and 3 intermediate steps

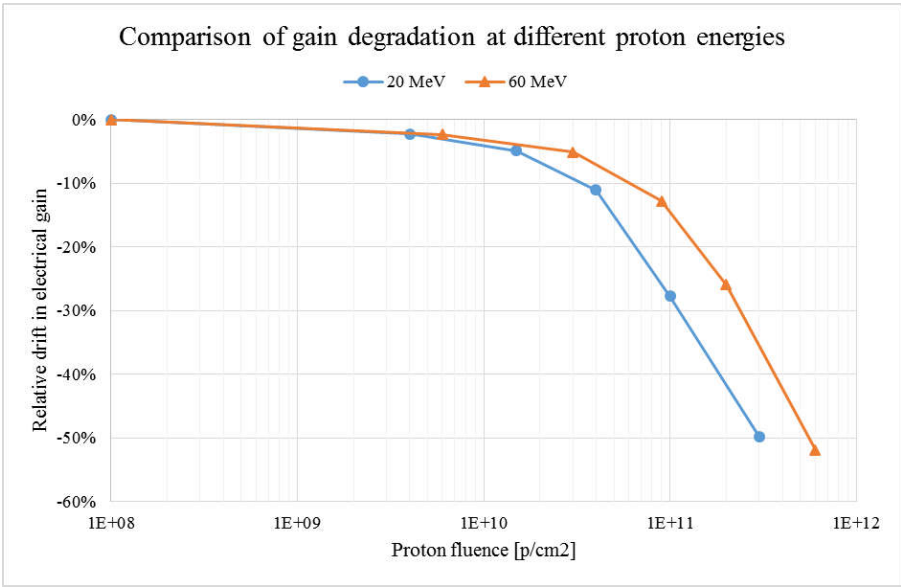
Protons (UCL, March 2014)

60 - 20MeV, five fluences for each

~130 tested devices → more than 700 channels investigated



device degradation spectral response after exposure to gamma radiation

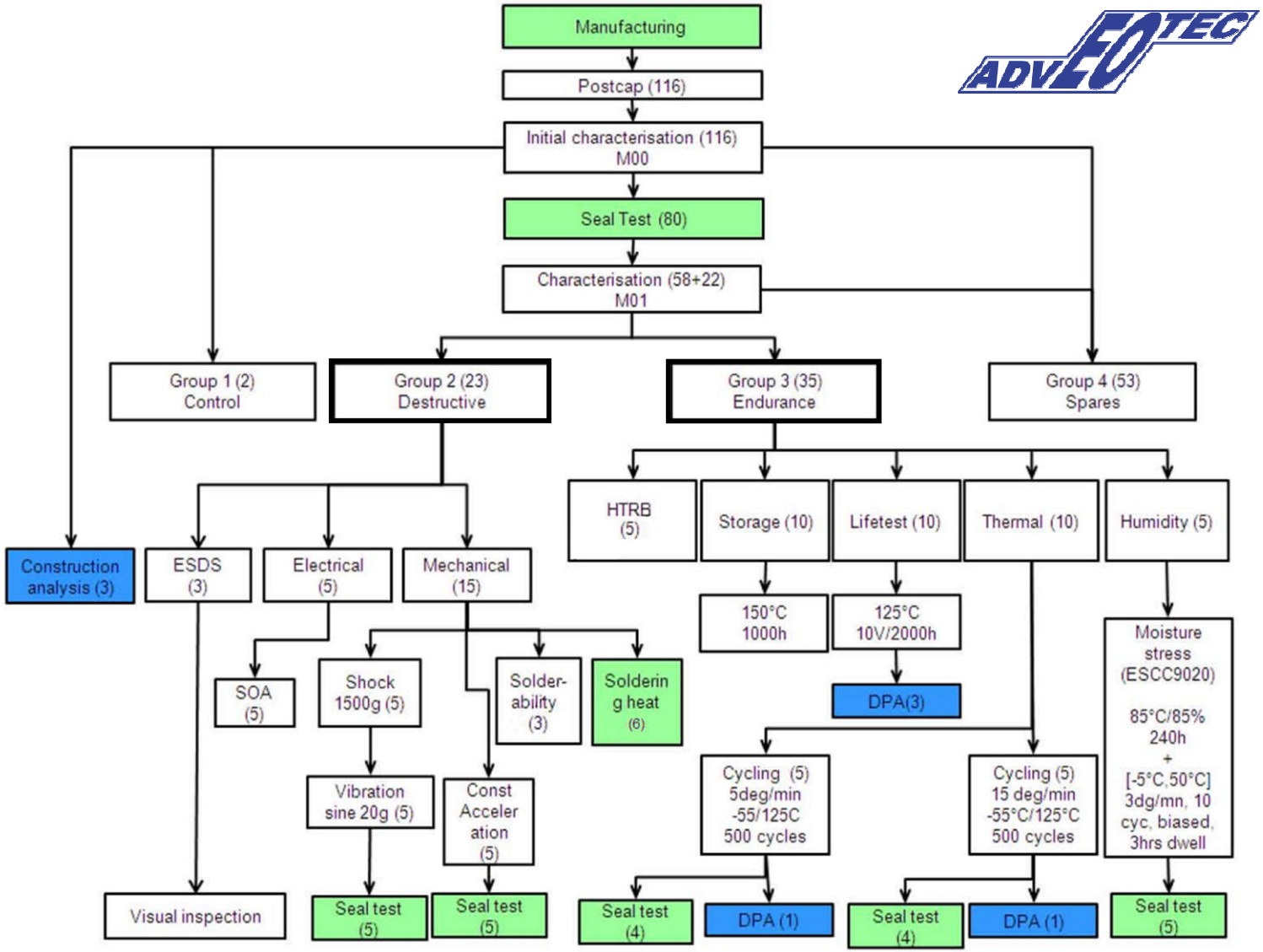


effects of proton energy radiation on the device gain: comparison between 20 and 60MeV

Ref. ICSO publication, 2014
"Development and ESCC evaluation of a monolithic silicon phototransistor array for optical encoders", M. Bregoli et al.

ESCC ETP

Based on ESCC 2265000 methodology
Period : Sept 2014 – Feb 2015



Activity conclusion

Full understanding of the device characteristics through a complete ESCC evaluation, radiation included.

First chance to evaluate mechanical aspects.

→ Release of Detailed Specifications, plan for Screening and LVT with AdvEOTec

Revision and **improvement** of internal manufacturing methodologies

→ Definition of device PID

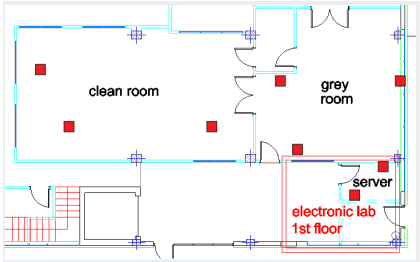
Financial closure of the project reached in early September 2015.

Acquisitions, upgrades and outlook

Optoi

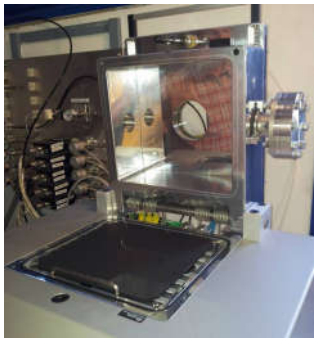
- Clean room upgraded
- Long-term storage
- Extended storage temperature
- Shipment
- Monitoring system



Collaboration with FBK

- Reflow oven for eutectic process
- Fine / gross leak tests capability, as per MIL-STD-883 TM 1014.13, cond. A1 and C1

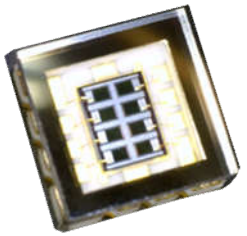


Local area strategy push

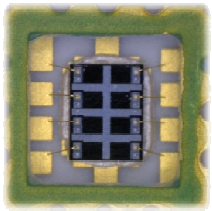
- Closer connection with Italian Space Agency
- New proton beam facility “AtreP” in Trento
- INFN TIFPA


Current status and perspectives

- 2014-16: **Photodiodes** developed, EMs manufactured (outcome of TRP activity)



- 2016: New activity on **phototransistors** with Airbus



- 2016-2017: ASI / ESA activity on **optocouplers**

- Investigation of **new opportunities:** new developments, assembly service, technological exploitation of previous activities

Conclusion

- Niche and limited business
- Strong effort needed
- ECI fund beneficial

- Increase of visibility
- Increase of respectability

Target

successful qualification of **optocouplers** and **phototransistors**

Ambition

European company for **space optoelectronic components**

Thank you for your attention

Matteo Bregoli
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