LASER DIODE INITIATED SYSTEMS FOR SPACE APPLICATIONS

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CNES RESEARCH STEPS IN OPTO-PYROTECHNICS

•**R&T ACTIVITIES SINCE 1995 WITH ISL** (French German Research Institute of Saint Louis)

▪Initiation of explosive materials : pyrotechnic compositions; double base powders ; secondary explosive with laser diodes and Nd-YAG laser :
Determination of key parameters of initiation / design of a miniaturised Nd/Yag laser source : 1995/1998

- ▪Design of an Opto Pyro Initiator : 1998/2000
- ▪Design of an all secondary explosive Opto Pyro Detonator based on DDT (Deflagration to Detonation Transition) : 1998/1999
- ▪Design of an all secondary explosive Opto Pyro Detonator based on SDT (Shock to Detonation Transition) – 2000/2001

▪Satellites system analyses for optopyrotechnics applications with ALCATEL SPACE Space and EADS ASTRIUM - 1999/2000

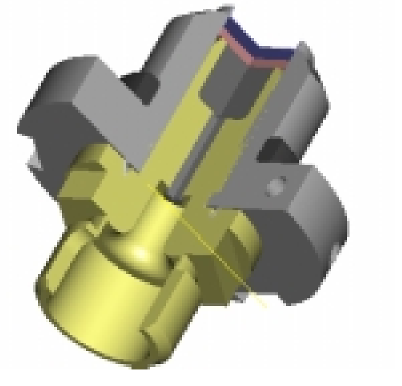
▪Development and Pre-Qualification tests of OptoPyro Initiator & Detonator -2001/2005

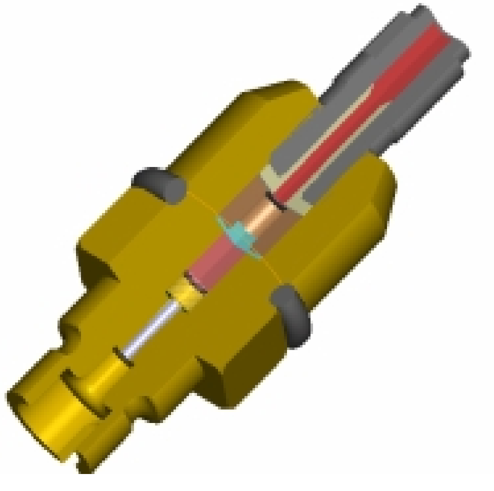
•In flight validation of an optopyrotechnic system on DEMETER µSat (2000/2004)

OPTO PYROTECHNIC DEVICES : INITIATOR & DETONATOR

Opto-Pyro Initiator (IOP) equivalent to NSI (NASA Standard Initiator)

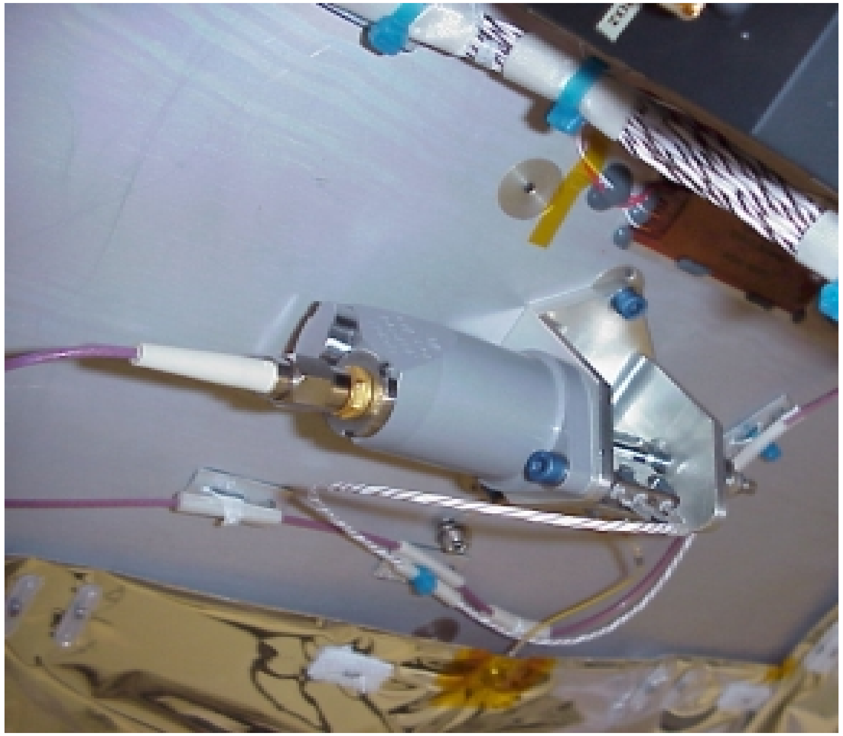
All secondary explosive Opto-Pyro Detonator Initiator (DOP) equivalent to ARIANE detonating transmission line tip





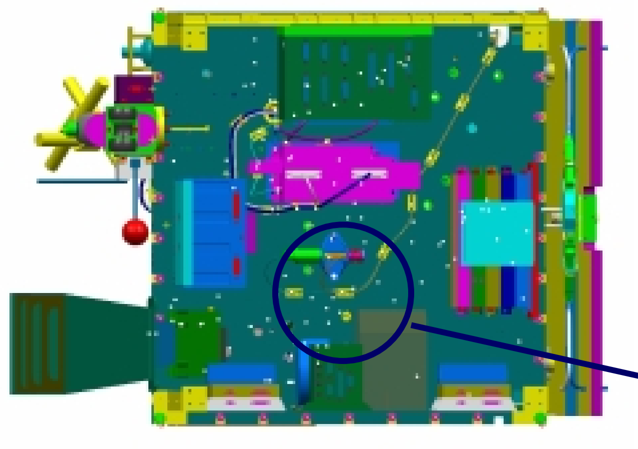
EXPERIMENT "PYROLASER" ON DEMETER

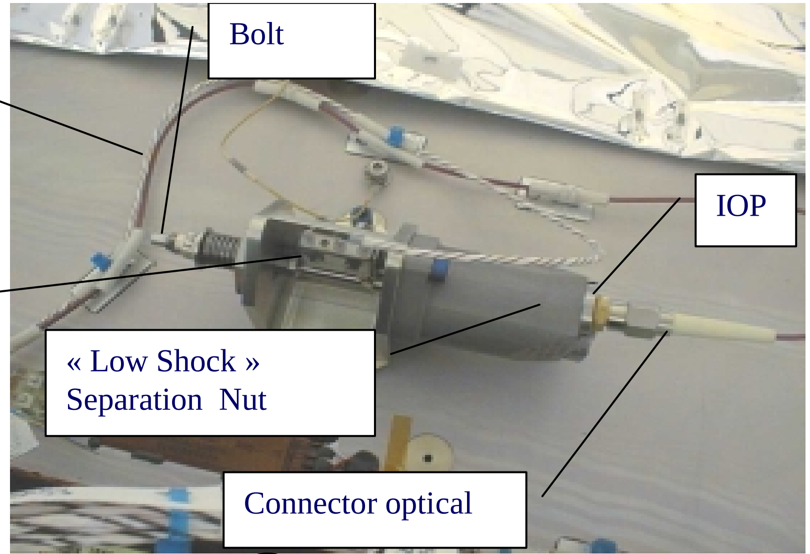
IN FLIGHT VALIDATION OF AN OPTO- PYRO SYSTEM

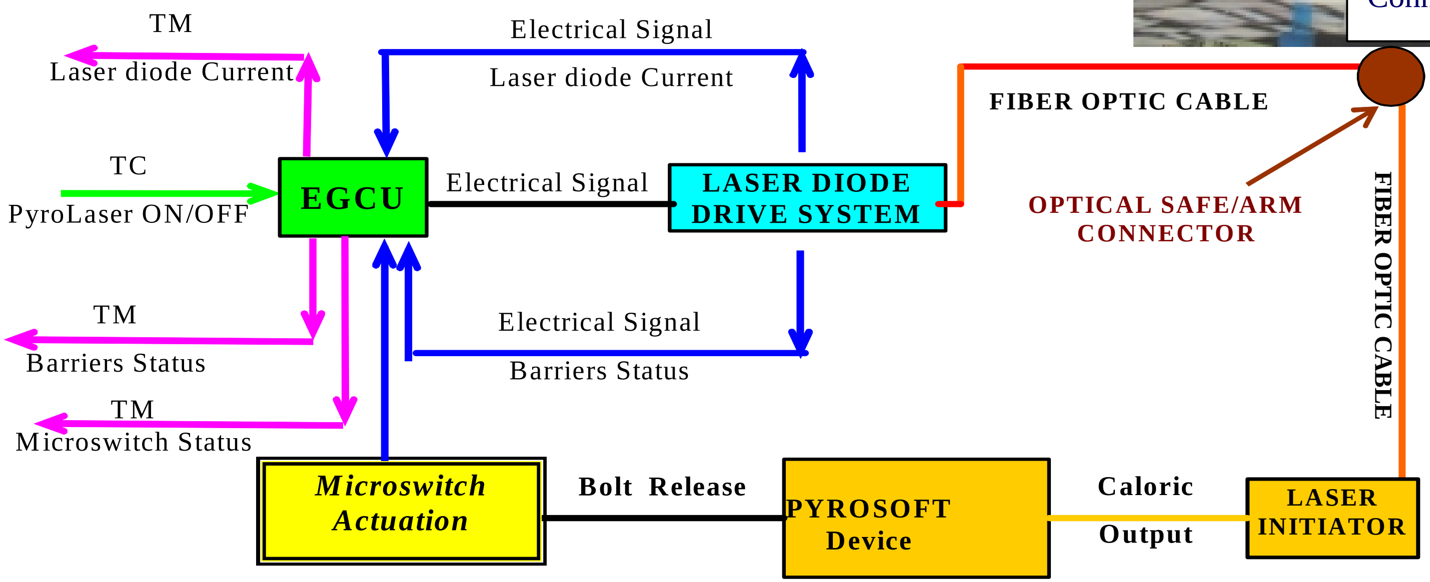


EXPERIMENT "PYROLASER" ON DEMETER

EXPERIMENT LAY OUT







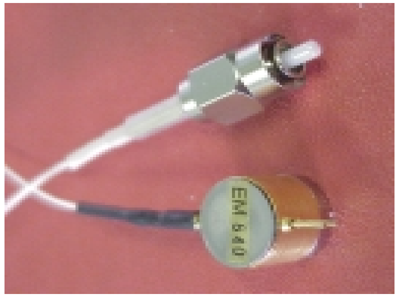
EXPERIMENT "PYROLASER" ON DEMETER

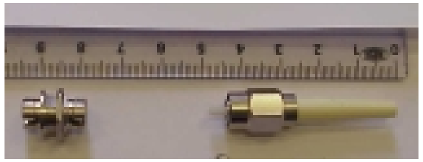
DEVELOPMENT and VALIDATION on 4 CHAINS

An OPTO-LASER CHAIN on DEMETER :

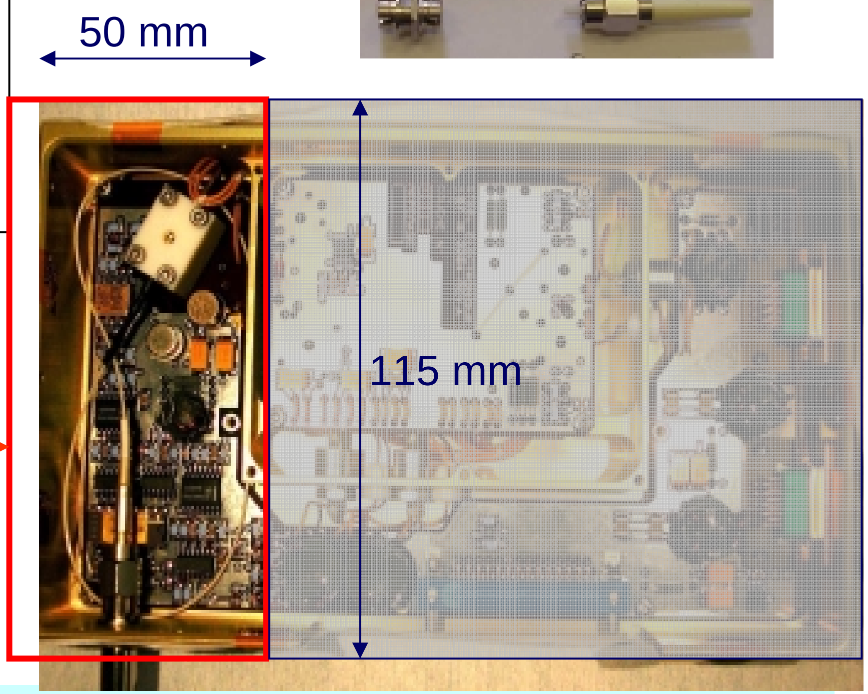
- **1 laser diode with fiber pigtail**
  - **+ 2 optical cables**
  - **+ 2 adapters**

Tests Performed : RADIATIONS - VIBRATIONS – SHOCKS - THERMAL VACUUM TESTS





DEVELOPMENT and VALIDATION of the LASER DRIVE UNIT

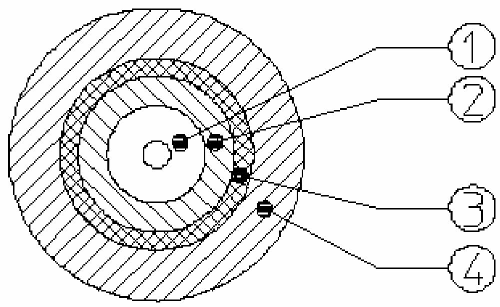


EXPERIMENT "PYROLASER" ON DEMETER

MULTIMODE FIBER OPTICAL CABLE 62.5 /125
NEXANS : Reference 132126

Main data

Operating temperature :	long term :	-55 to +125°C
	peak :	-65 to +150°C
Maximum pulling force :	long term :	10 daN
	short term :	25 daN
Tensile strength :		> 100 daN
Nominal weight :		4 Kg/Km
Minimum bending radius :	long term :	20 mm
	short term (installation) : 12 mm	
Maximum attenuation at 20°C	at 850 nm :	4 dB/Km
	at 1310 nm :2 dB/Km	
Effective index of refraction	at 850 nm :	1.4970
	at 1300nm	1.4919
Numerical aperture :		0.275 ± 0.015
Cable Bandwidth (MHz.km)	at 850 nm	>400
	at 1310 nm	>1000



① OPTIC FIBER
Core + cladding + coating
Silice/Silice/Acrylate
Type 62.5/125/400 µm

② PRIMARY JACKET
Copolymer O HAL High
Temperature
∅ 0.90 ± 0.05 mm

③ MECANICAL STRENGTH
Polymer aromatic fiber braid

④ OUTER JACKET
Copolymer O HAL High
Temperature ∅ nom.
1.5 mm
E.T.F.E.
∅ 1.8 ± 0.05 mm

- **Outgassing Tests : CVCM<1%**
- **Mechanical strength >20 N without optical degradation**

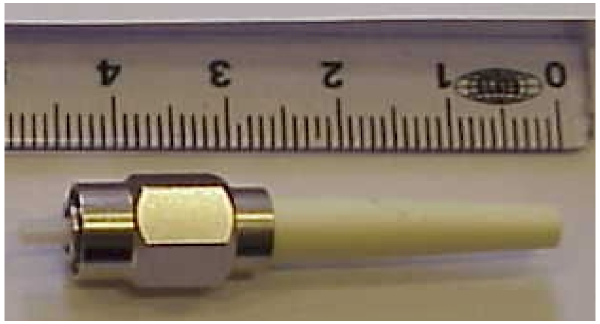
EXPERIMENT "PYROLASER" ON DEMETER

OPTICAL CONNECTION : JOHANSON NASA/GSFC qualified

FC: High Reliability Adapter P/N 2525-4

- Durability: >500 cycles
- Storage Temp: -55° to 150° C
- Operating Temp. -45° C to 110° C
- Vibration: 20g's rms, 20-2000Hz, IL 0.1 dB max. change, RL 0.5 dB max. change

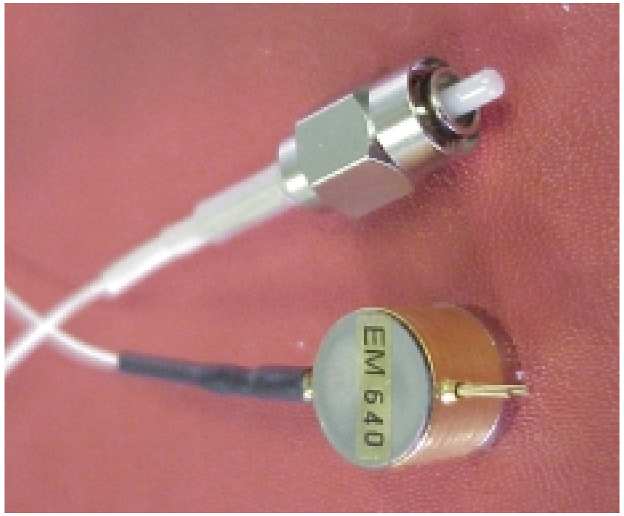
FC/PC : High Reliability, Sprung Connector P/N 2547-3



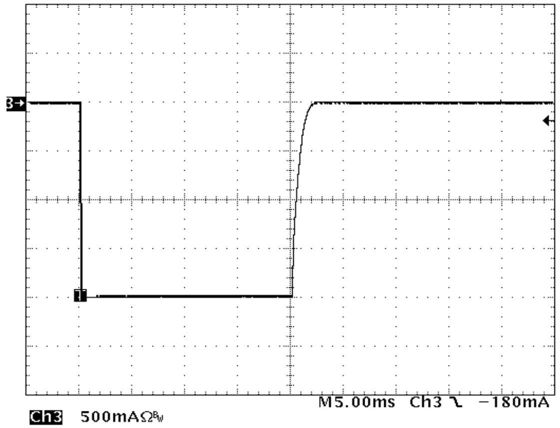
- Insertion Loss: 0.15dB typ. for single-mode
- Return Loss: < -45dB typ. for PC polish
- Tensile Loading: >20lb
- Durability: > 500 cycles
- Boot Out-Gassing: Avg. value TML < 1%, avg. value CVCM < 0.1%, per ASTM E-595-90
- Vibration: 20g's rms, 20-2000Hz, IL 0.1 dB max.change, RL 0.5 dB max. change *
- Storage temp: -55° to 150° C
- Operating temp: -45° to 110° C

EXPERIMENT "PYROLASER" ON DEMETER

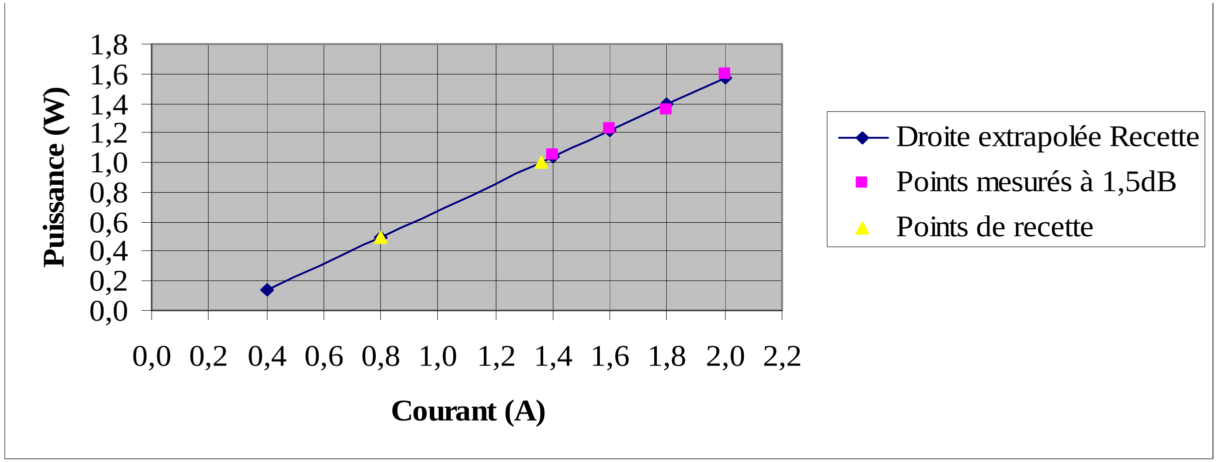
LASER DIODES JDS 2364L2 CHARACTERISTICS



LASER DRIVE UNIT
Current impulse : 2A / 20 ms



Laser diode response : Power = F(current)



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EXPERIMENT "PYROLASER" ON DEMETER

RADIATIONS TESTS

Test Sequence	Energy (MeV)	Fluence (p/cm²)	Equivalent Dose (krad)
Chain 1+2+3	50	$10^{E}10$	1
Chain 2+3	50	$5.10^{E}10$	5
Chain 3	50	$10^{E}11$	10

Equipment	Reference (mJ)	Test 1 (mJ)	Test 2 (mJ)	Test 3 (mJ)
Diode SN636	35.27	34.78		
Diode SN637	32.13		31.98	
Diode SN638	31.55			30.81
Cable 1	*30.22*	*30.54*		
Cable 2	*29.87*	*26.80*	*27.89*	
Cable 3	*28.25*	*27.09*	*27.67*	*27.58*

EXPERIMENT "PYROLASER" ON DEMETER

MECHANICAL TESTS

Sine Vibrations

5 Hz à 14 Hz	19 mm (0 - pic)
14 Hz à 100 Hz	15 g

Speed 4 octaves / mn.
1 sweep /axis_3 axis

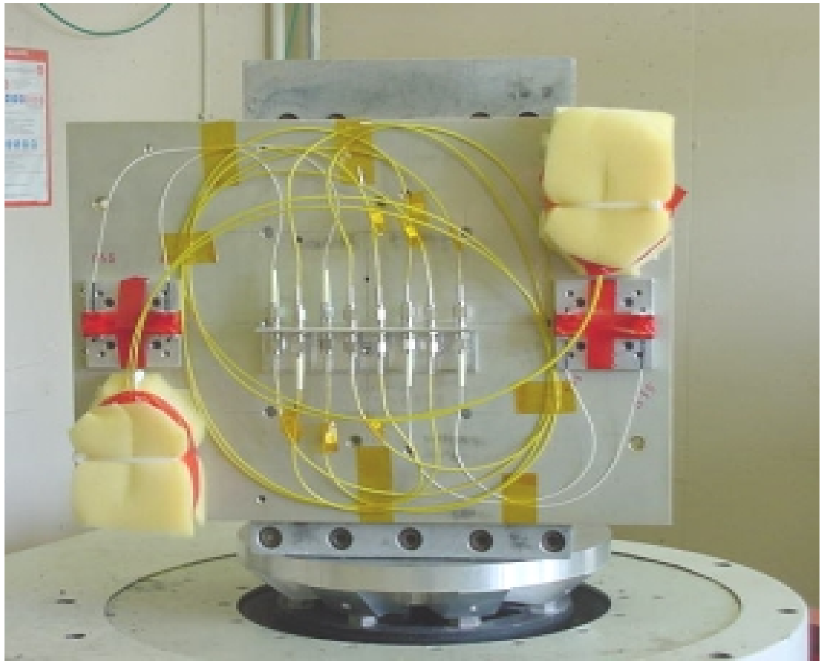
Random Vibrations

20 Hz à 100 Hz	+3 dB / octave
100 Hz à 400 Hz	0,7 g2 / Hz
400 Hz à 2000 Hz	-4 dB / octave

Duration : 1 minute / axe _ 3 axis
equivalent level : 25grms

Shocks through EGCU qualification (Electronique de gestion de la Charge Utile)

100 Hz	20 g
1 000 Hz	1000 g
1 000 Hz à 10 000 Hz	Palier à 1000 g

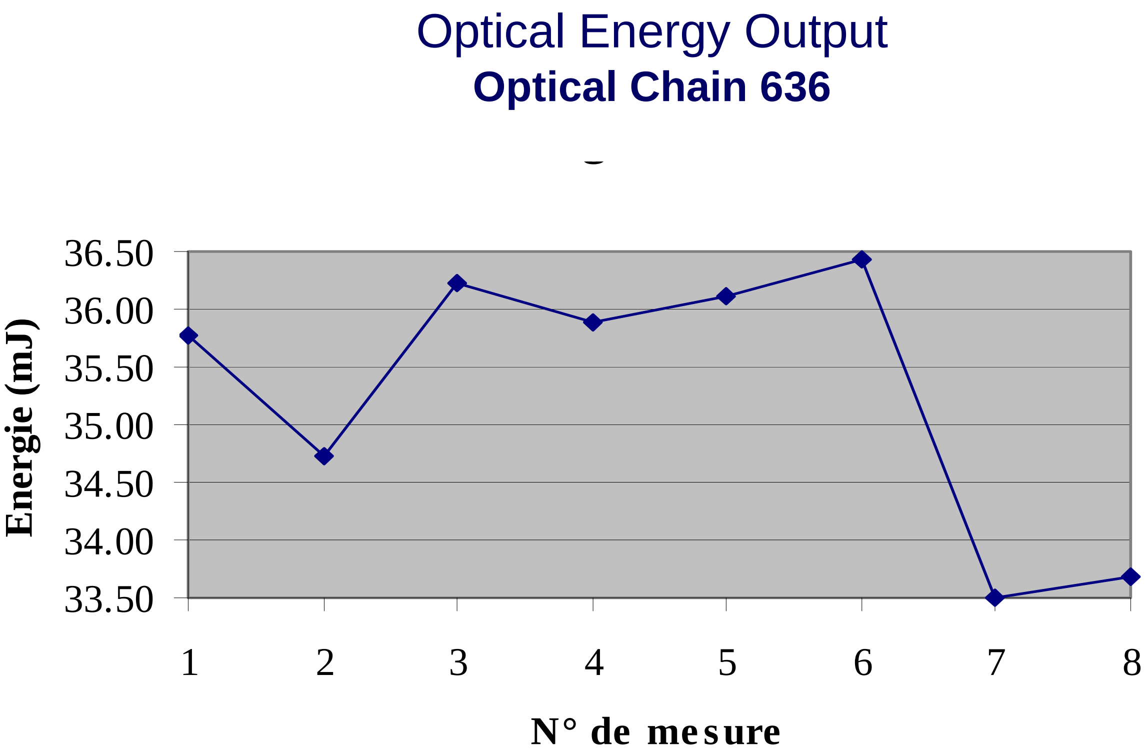


EXPERIMENT "PYROLASER" ON DEMETER

TESTS RESULTS AFTER MECHANICAL ENVIRONMENTS

Characterisation of the optical energy output after each step for the opto chain :

1 : reference
2 : axis 1 sine & random 50%
3 : axis 1 random 100%
4 : axis 2 sine & random 50%
5 : axis 2 random 100%
6 : axis 3 random 50%
7 : axis 3 random 100%
8 : axis 3 sine



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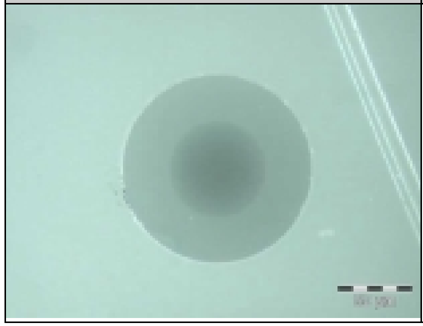
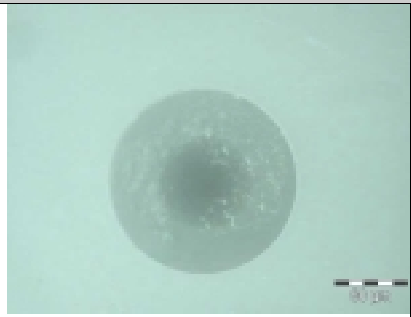
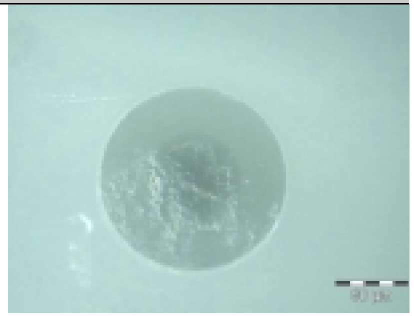
EXPERIMENT “PYROLASER” ON DEMETER

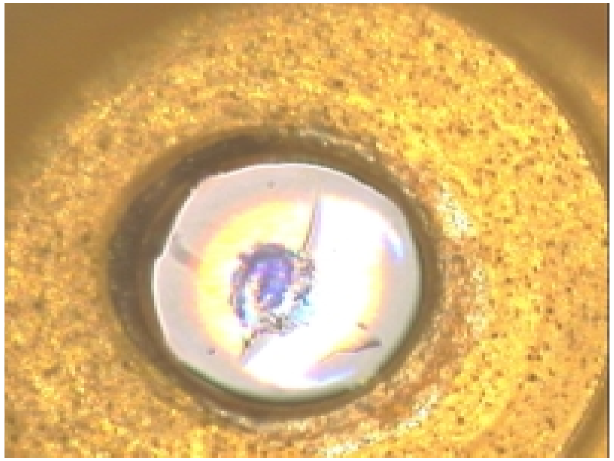
MAIN RESULTS

■ CONNECTOR END FACES DAMAGING

FC/PC connector before vibrations	FC/PC connectors after vibrations	
		

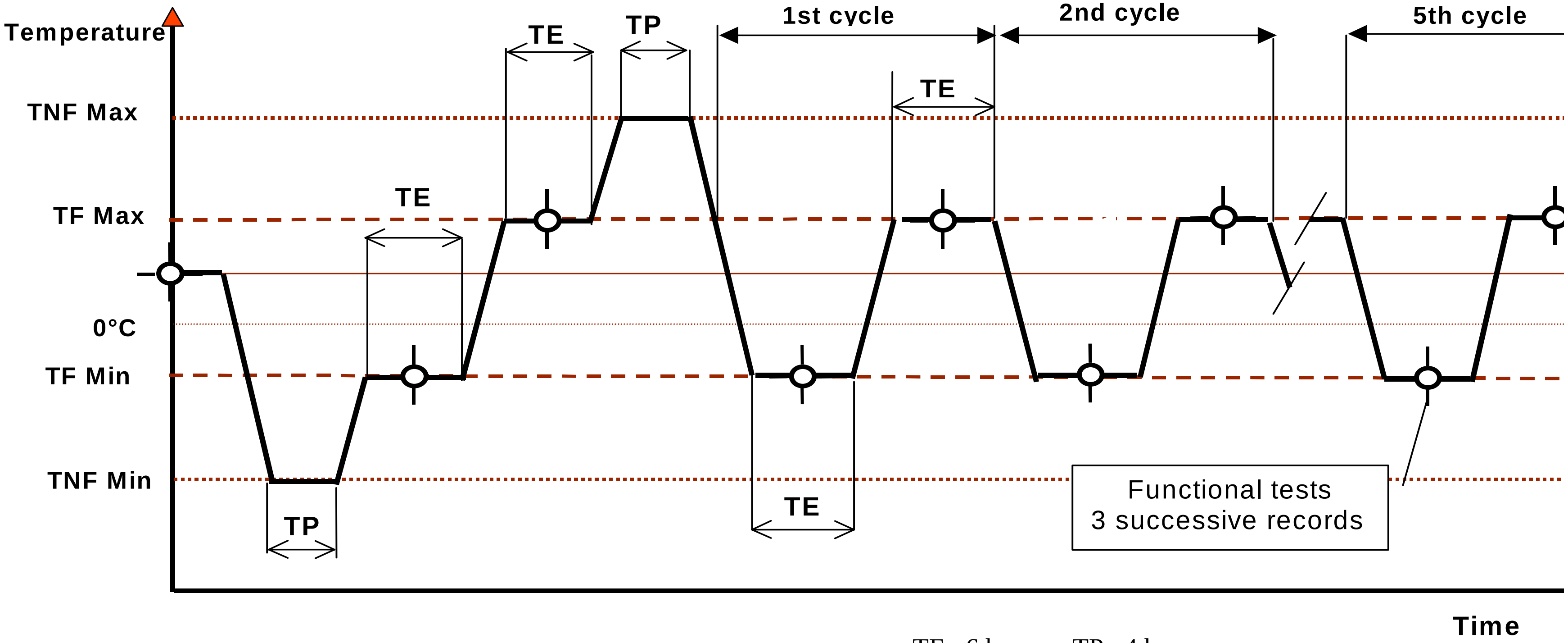
Optical losses : 0.3 dB (7%) for random vibrations with 25 grms level

■ INITIATOR OPTICAL INTERFACE DAMAGING



EXPERIMENT "PYROLASER" ON DEMETER

■ THERMAL VACUUM CYCLING

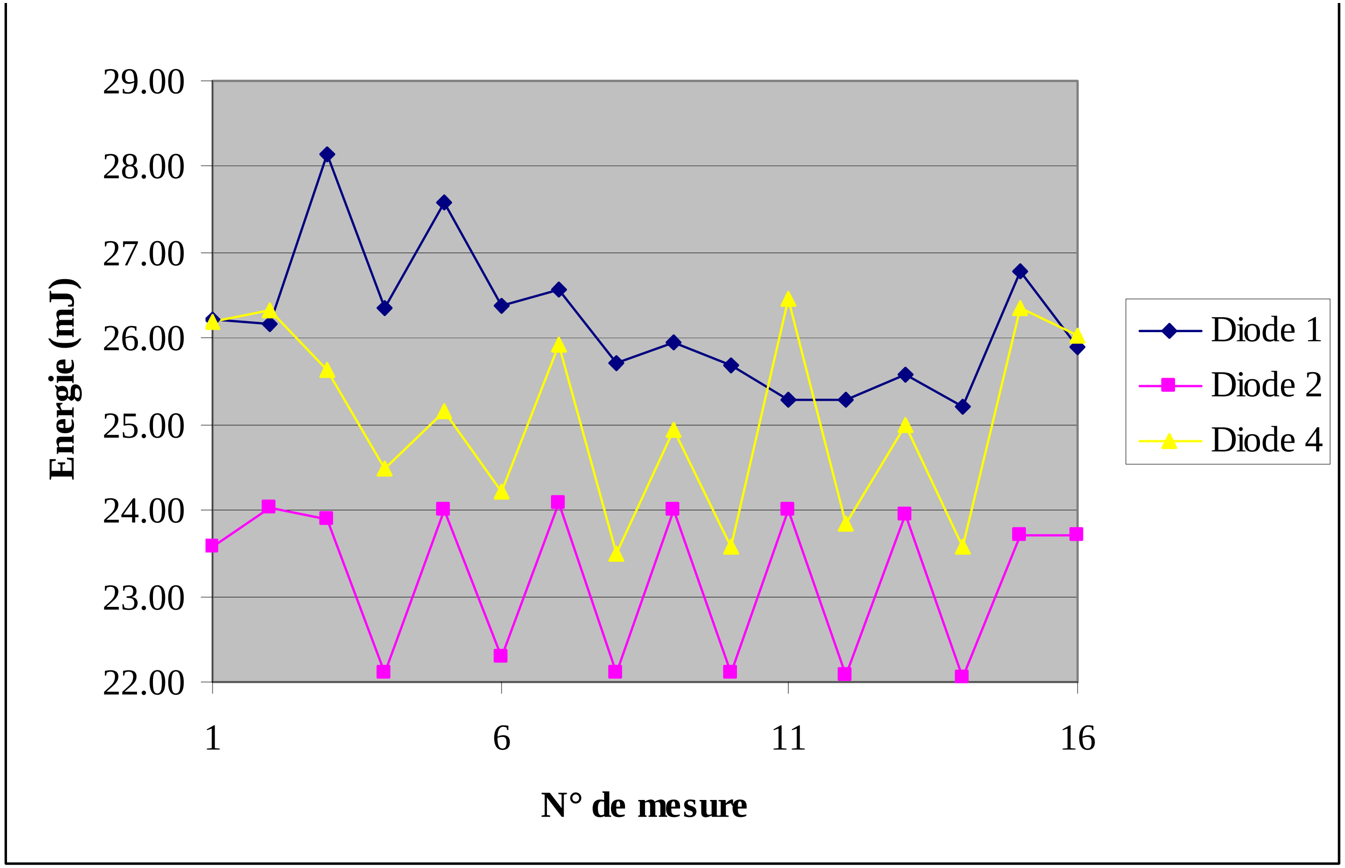


- TE : 6 hours - TP : 4 hours
- TFire Min : -25°C - TFire Max : + 55 °C
- TNoFire Min :- 40 °C - TNoFire Max : +60 °C

Vacuum : 1E-5 et 3E-6 mbar

EXPERIMENT "PYROLASER" ON DEMETER

■ THERMAL VACUUM CYCLING : LASER DIODE POWER OUTPUT DECREASE

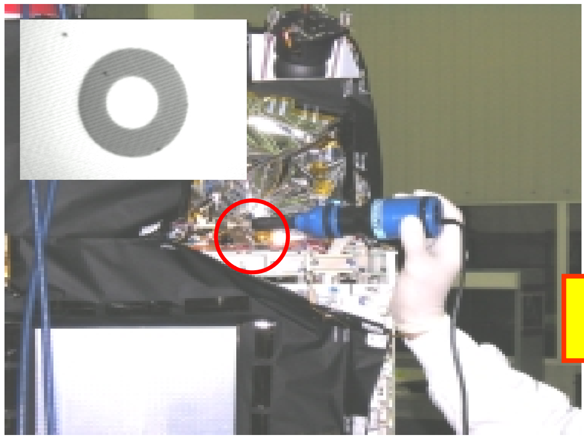


Power output decrease : 0.3 dB at +55°C

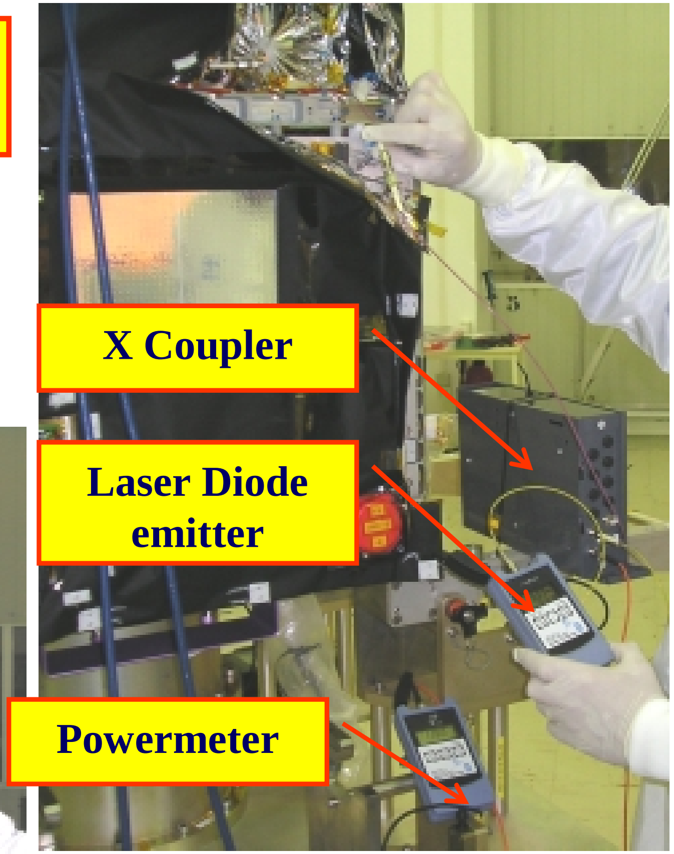
EXPERIMENT "PYROLASER" ON DEMETER

Assembly - Integration – Verification of the optical chain

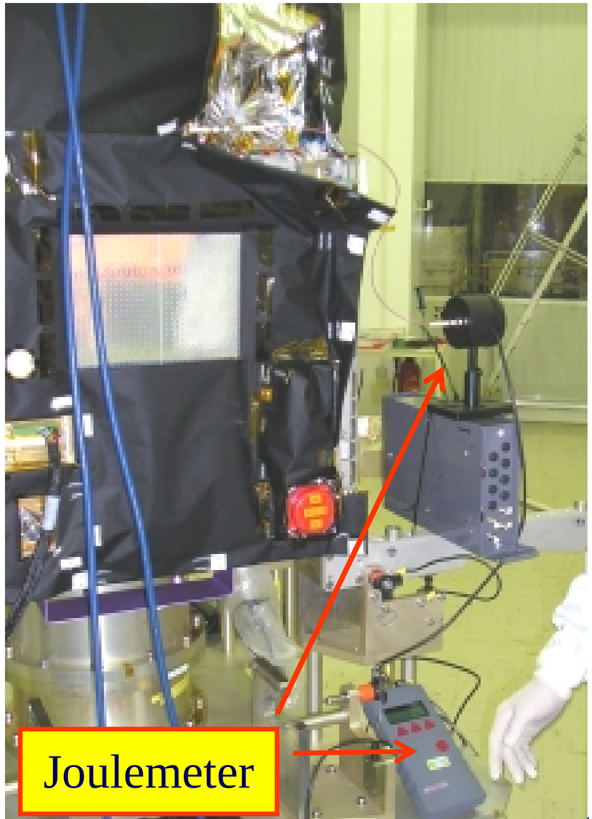
Cleanliness optical I/F



Optical Transmission S&A /IOP



Power & Optical transmission : Diode / S&A



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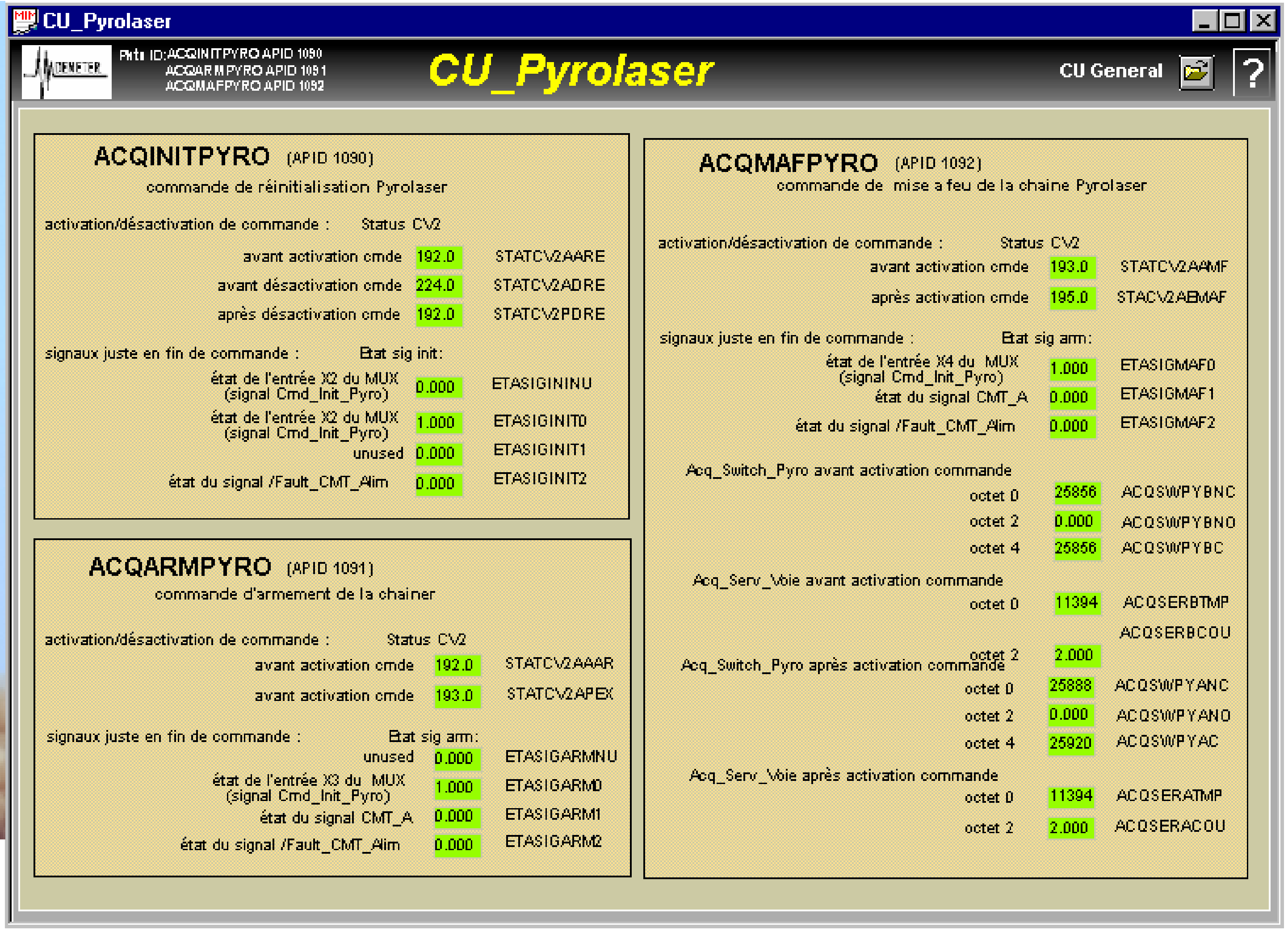

BAIKONOUR, June 29,2004 **CNES Toulouse Satellites Control Center - July 9,2004**

CONCLUSIONS

THANKS TO OPTROELECTRONICS :

- Satellite Pyro Harness : mass saving >50% with conservative design :
  - => significant mass saving when lines are numerous and long (3.5 kg typical and even 5kg, depending on the architecture optimisations)
  - => Mission Extension ≈ 10 days / Kg for a TELECOM S/C
  - => Eventually launch costs decrease (15 k€/ kilogram)
- Lower electrical budget : 2 A instead of 5 A / smaller batteries _ converters & relays
- Opto-pyro system is valuable for TELECOM S/C or PROBES (Mars Missions, etc)
- AIV constraints mainly on cleanliness of optical interfaces and ESD sensivity of laser diodes exist but are easy to manage (earth telecom and aeronautic experiences),
- Follow on activities are planned for future launchers developments