LASER DIODE INITIATED SYSTEMS FOR SPACE APPLICATIONS

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ESA/ESTEC – October 6 , 2005

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

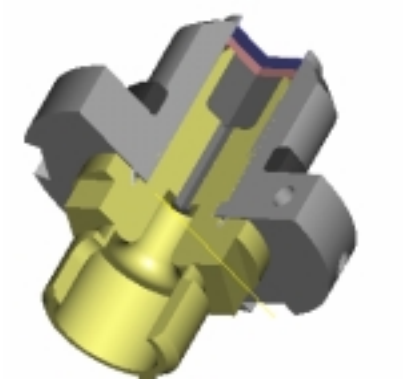
- Development and Pre-Qualification tests of OptoPyro Initiator & Detonator -2001/2005

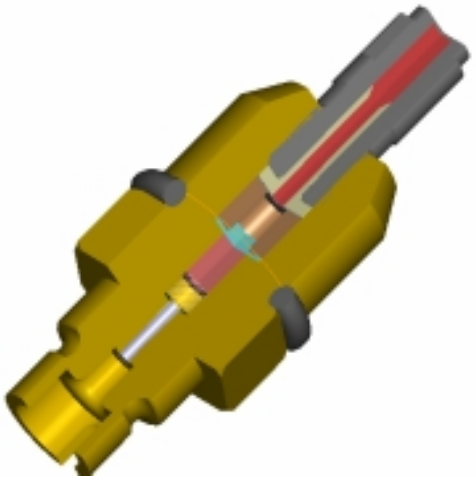
•In flight validation of an optopyrotechnic system on DEMETER µSat (2000/2004)

OPTO PYROTECHNIC DEVICES : INITIATOR & DETONATOR

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

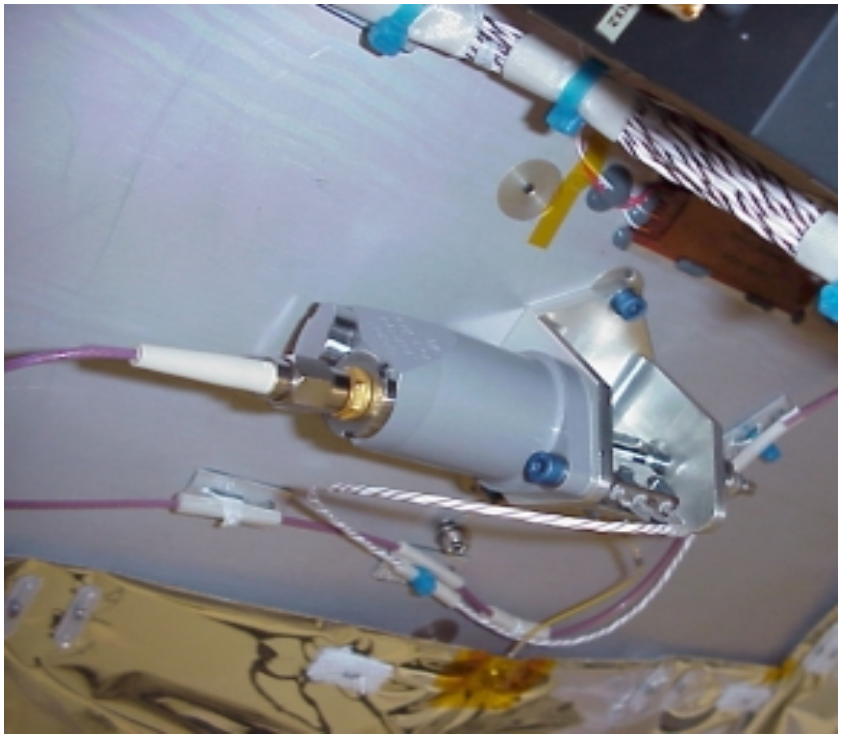
All secondary explosive Opto-Pyro Detonator Initiator (DOP) equivalent to ARIANE detonating transmission line tip





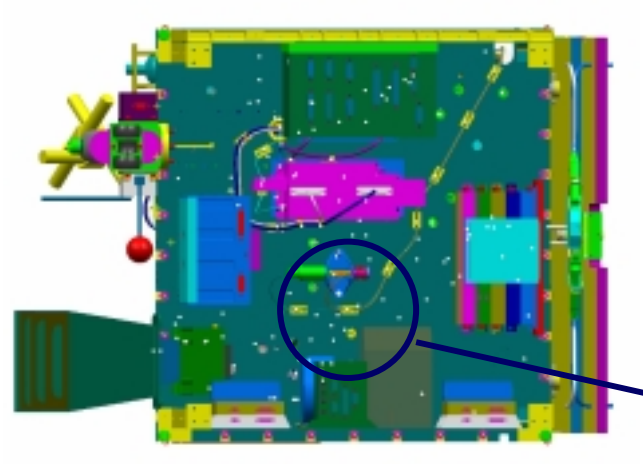
EXPERIMENT “PYROLASER” ON DEMETER

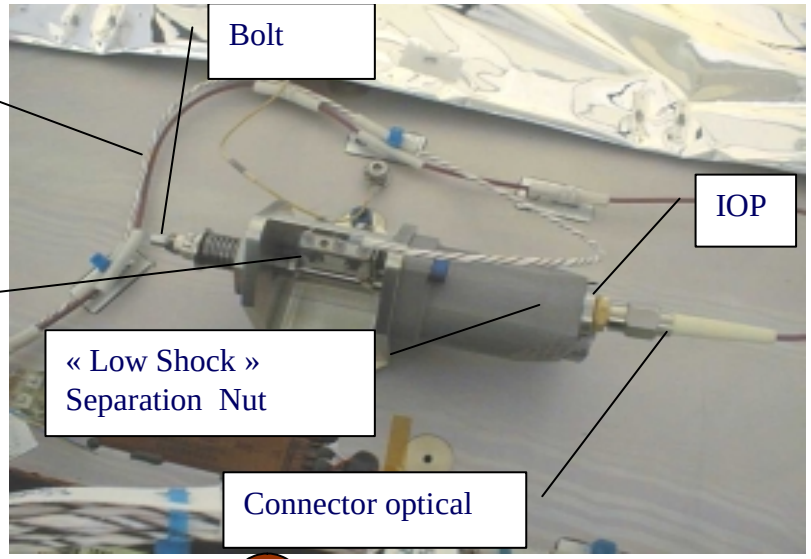
IN FLIGHT VALIDATION OF AN OPTO- PYRO SYSTEM

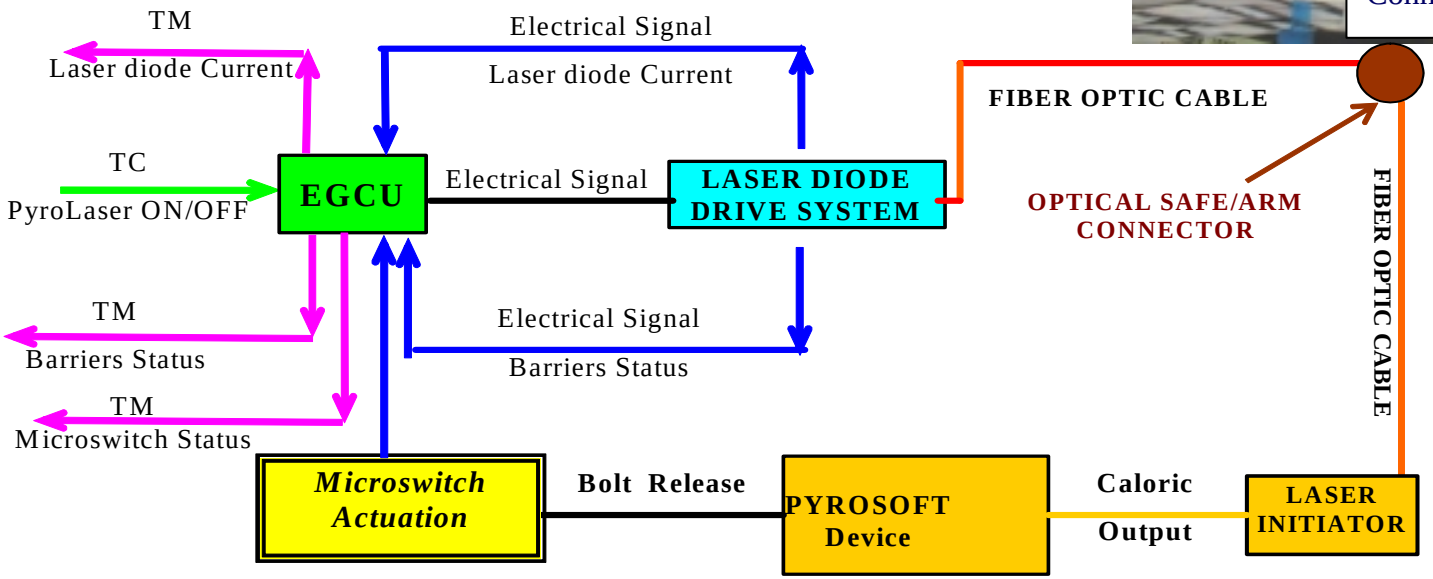


EXPERIMENT "PYROLASER" ON DEMETER

EXPERIMENT LAY OUT







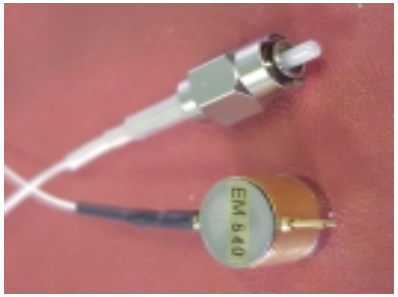
EXPERIMENT "PYROLASER" ON DEMETER

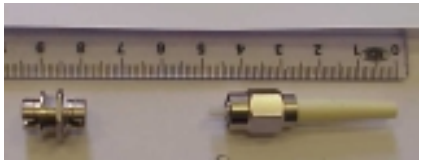
DEVELOPMENT and VALIDATION on 4 CHAINS

An OPTO-LASER CHAIN on DEMETER :

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

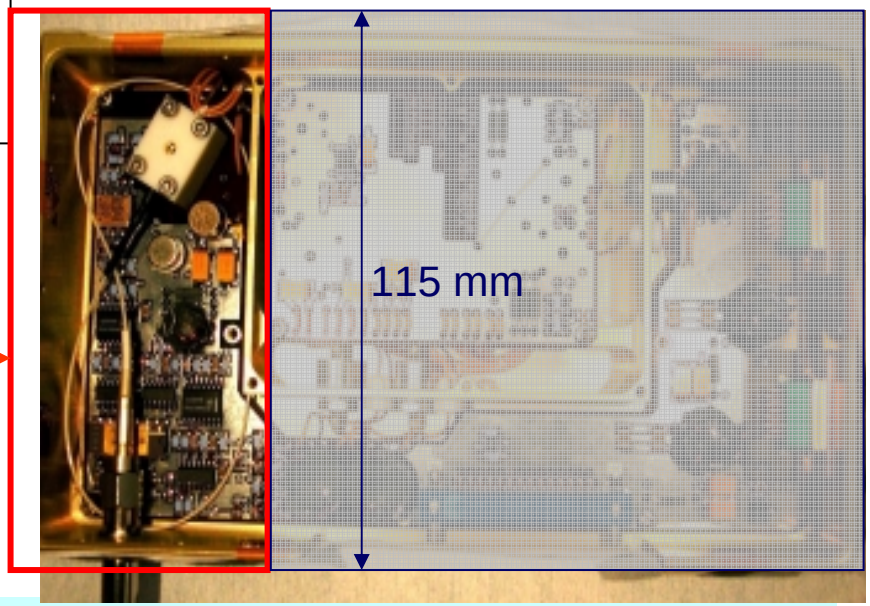
Tests Performed : RADIATIONS - VIBRATIONS – SHOCKS - THERMAL VACUUM TESTS





50 mm

DEVELOPMENT and VALIDATION of the LASER DRIVE UNIT →

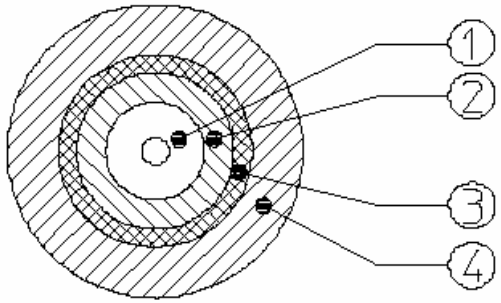


EXPERIMENT "PYROLASER" ON DEMETER

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**

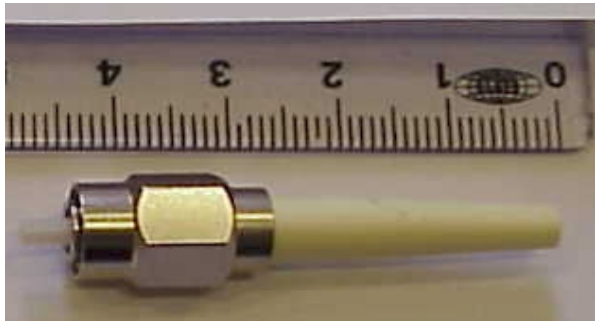
EXPERIMENT "PYROLASER" ON DEMETER

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

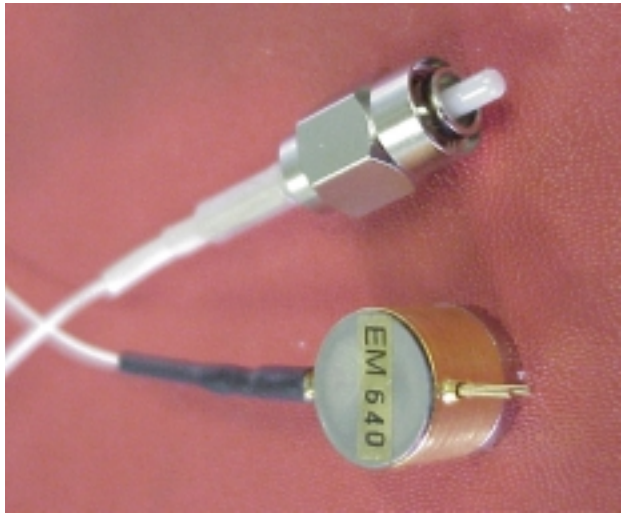
FC/PC : High Reliability, Sprung Connector P/N 2547-3



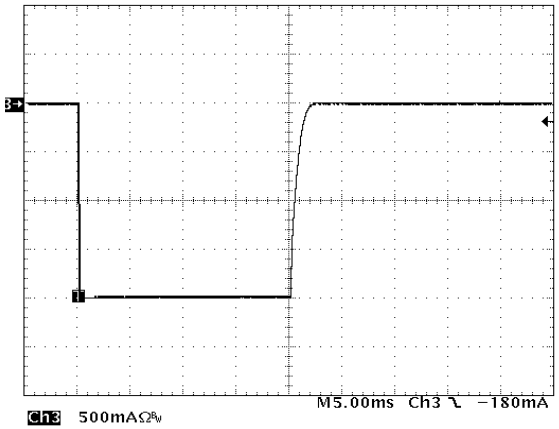
- Insertion Loss: 0.15dB typ. for single-mode
- Return Loss: < -45dB typ. for PC polish
- Tensile Loading: >20lb
- Durability: > 500 cycles
- Boot Out-Gassing: Avg. value TML < 1%, avg. value CVCM < 0.1%, per ASTM E-595-90
- Vibration: 20g's rms, 20-2000Hz, IL 0.1 dB max.change, RL 0.5 dB max. change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

EXPERIMENT “PYROLASER” ON DEMETER

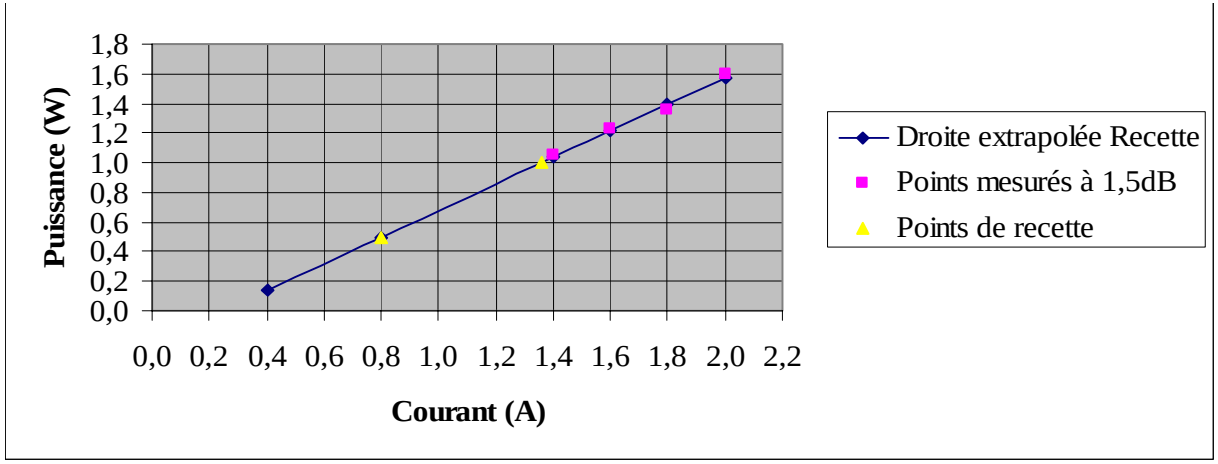
LASER DIODES JDS 2364L2 CHARACTERISTICS



LASER DRIVE UNIT
Current impulse : 2A / 20 ms



Laser diode response : Power = F(current)



EXPERIMENT "PYROLASER" ON DEMETER

RADIATIONS TESTS

Test Sequence	Energy (MeV)	Fluence (p/cm^2)	Equivalent Dose (krad)
Chain 1+2+3	50	10^E10	1
Chain 2+3	50	5.10^E10	5
Chain 3	50	10^E11	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

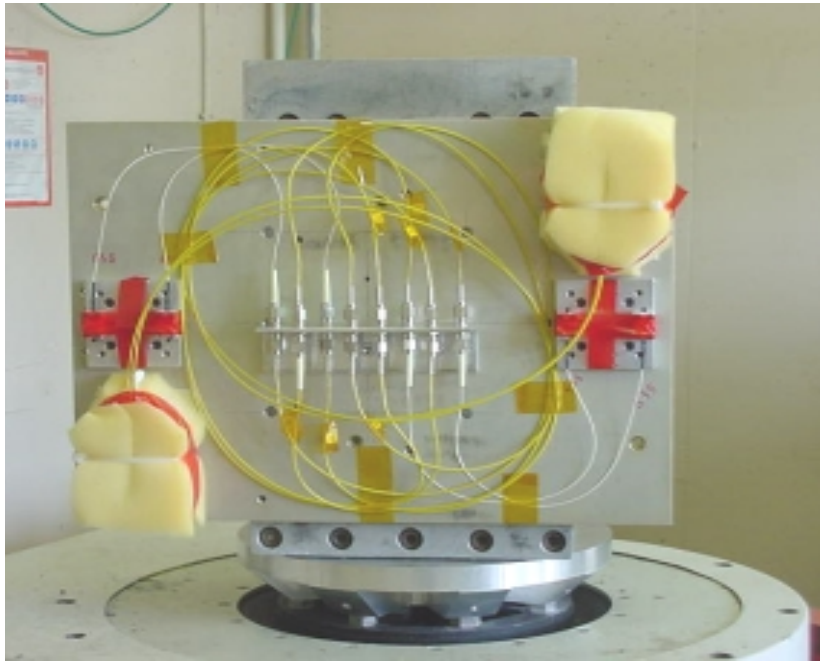
Random Vibrations

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



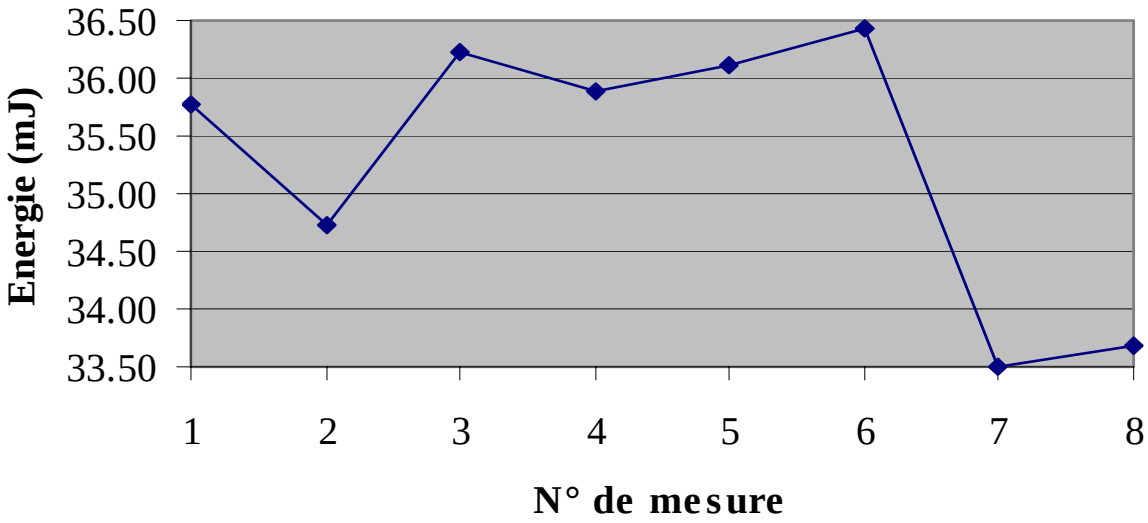
EXPERIMENT “PYROLASER” ON DEMETER

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

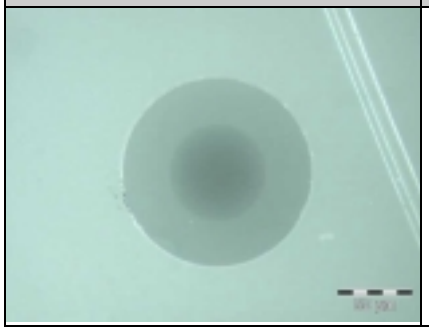
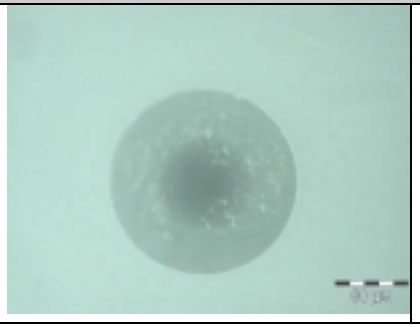
Optical Energy Output
Optical Chain 636



EXPERIMENT "PYROLASER" ON DEMETER

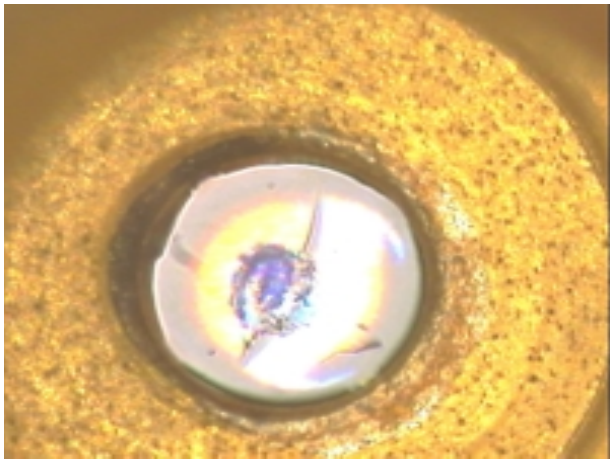
MAIN RESULTS

- **CONNECTOR END FACES DAMAGING**

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

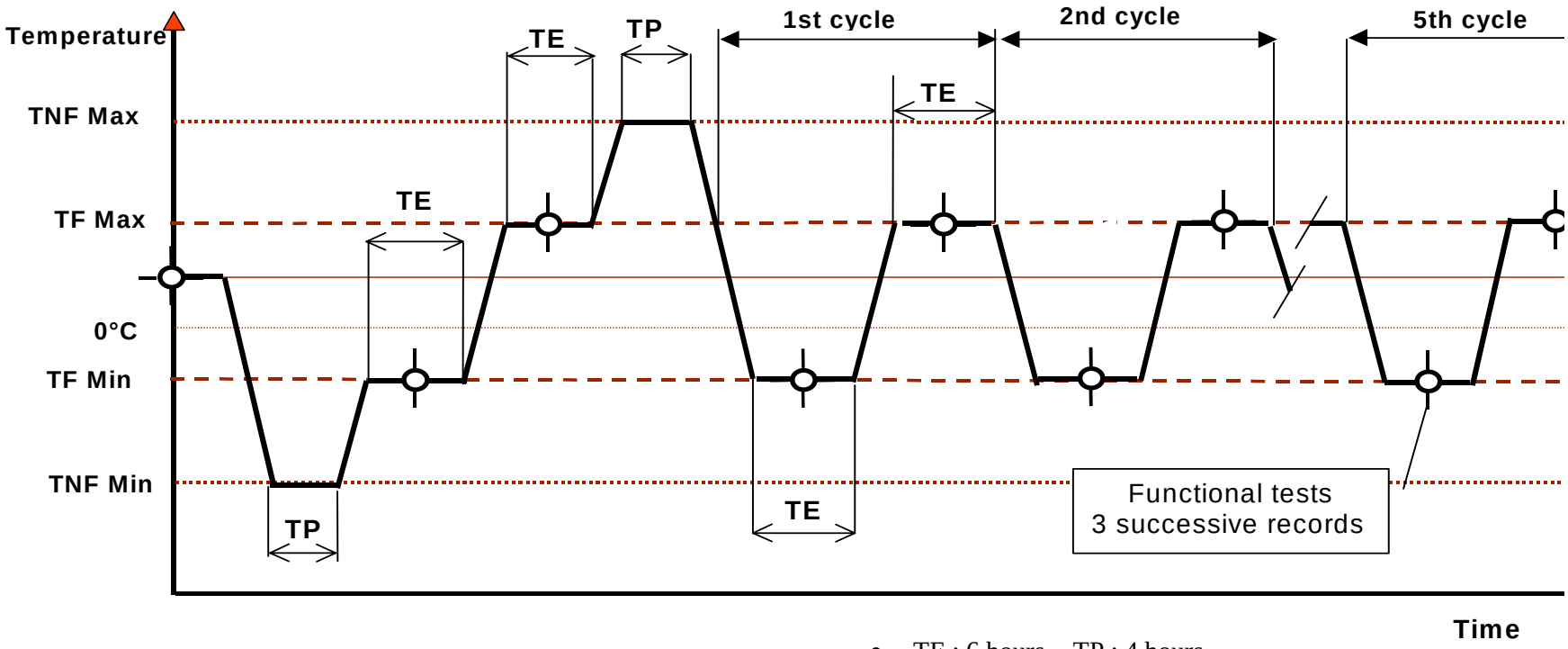
Optical losses : 0.3 dB (7%) for random vibrations with 25 grms level

- **INITIATOR OPTICAL INTERFACE DAMAGING**



EXPERIMENT “PYROLASER” ON DEMETER

■ THERMAL VACUUM CYCLING

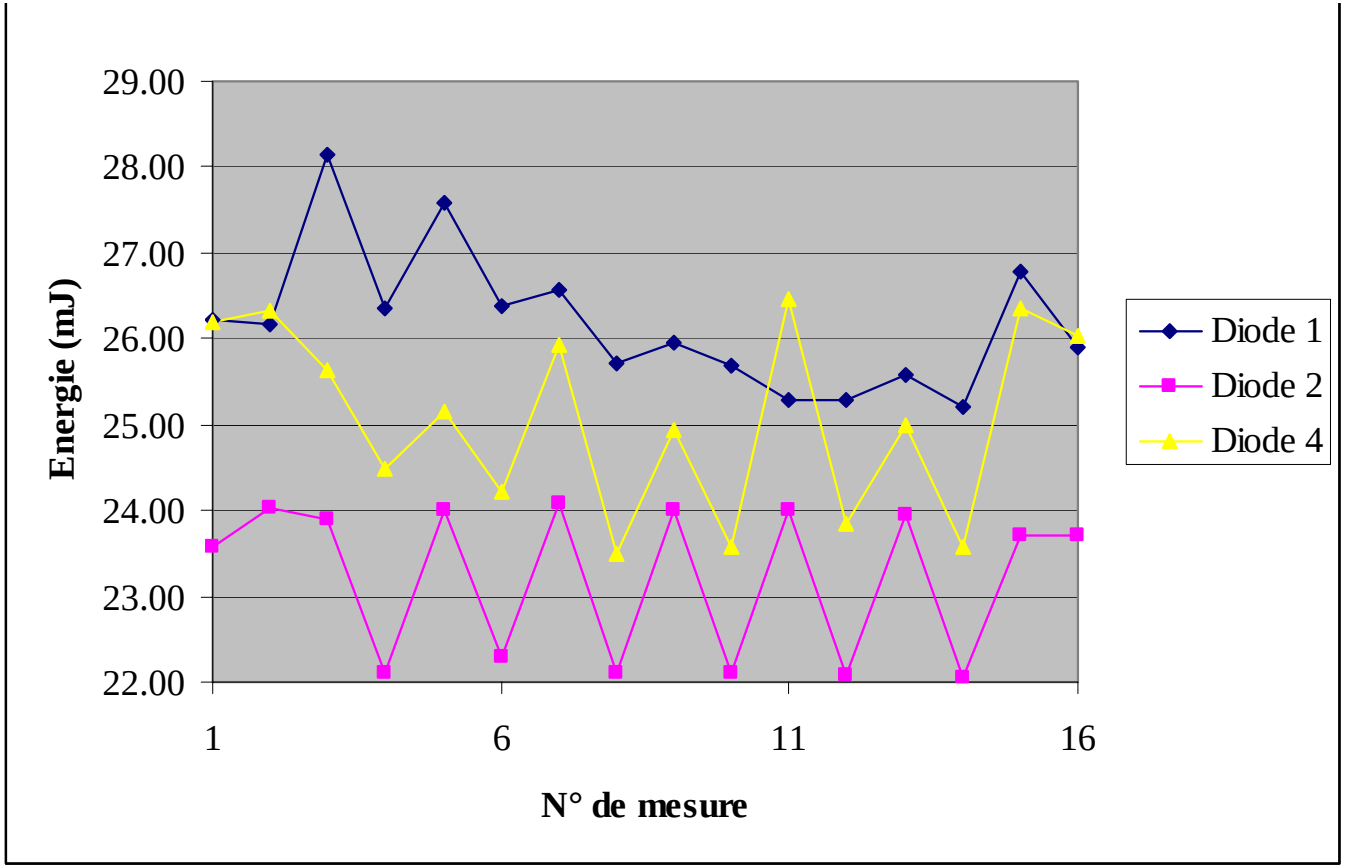


- TE : 6 hours - TP : 4 hours
- TFire Min : -25°C - TFire Max : + 55 °C
- TNoFire Min :- 40 °C - TNoFire Max : +60 °C

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

EXPERIMENT “PYROLASER” ON DEMETER

■ THERMAL VACUUM CYCLING : LASER DIODE POWER OUTPUT DECREASE

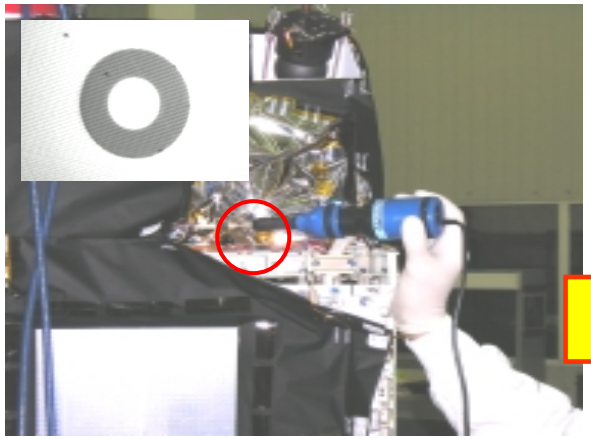


Power output decrease : 0.3 dB at +55°C

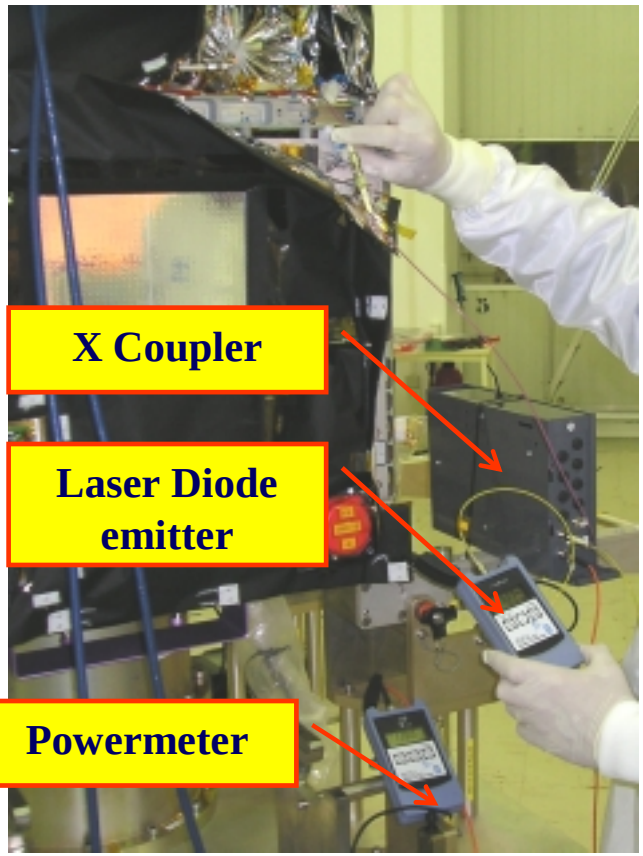
EXPERIMENT "PYROLASER" ON DEMETER

Assembly - Integration – Verification of the optical chain

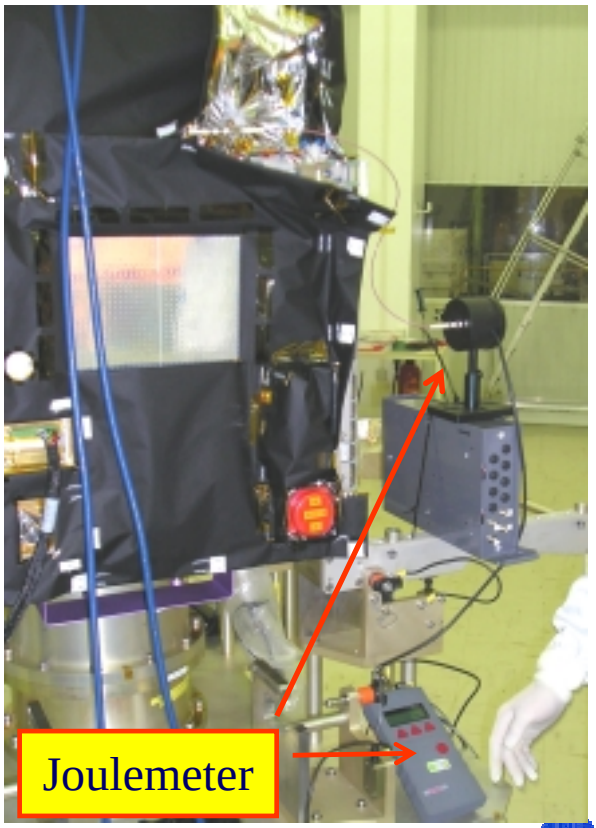
Cleanliness optical I/F



Optical Transmission S&A /IOP



Power & Optical transmission : Diode / S&A



EXPERIMENT “PYROLASER” ON DEMETER

CU_Pyrolaser

Pkts ID:ACQINITPYRO APID 1090
ACQARMPYRO APID 1091
ACQMAFPYRO APID 1092

CU_Pyrolaser — CU General

ACQINITPYRO (APID 1090)
commande de réinitialisation Pyrolaser

activation/désactivation de commande : Status CV2		
avant activation cmde	192.0	STATCV2AARE
avant désactivation cmde	224.0	STATCV2ADRE
après désactivation cmde	192.0	STATCV2PDRE
signaux juste en fin de commande : Etat sig init:		
état de l'entrée X2 du MUX (signal Cmd_Init_Pyro)	0.000	ETASIGININU
état de l'entrée X2 du MUX (signal Cmd_Init_Pyro)	1.000	ETASIGINIT0
unused	0.000	ETASIGINIT1
état du signal /Fault_CMT_Alim	0.000	ETASIGINIT2

ACQARMPYRO (APID 1091)
commande d'armement de la chainer

activation/désactivation de commande : Status CV2		
avant activation cmde	192.0	STATCV2AAAR
avant activation cmde	193.0	STATCV2APEX
signaux juste en fin de commande : Etat sig arm:		
unused	0.000	ETASIGARMNU
état de l'entrée X3 du MUX (signal Cmd_Init_Pyro)	1.000	ETASIGARM0
état du signal CMT_A	0.000	ETASIGARM1
état du signal /Fault_CMT_Alim	0.000	ETASIGARM2

ACQMAFPYRO (APID 1092)
commande de mise a feu de la chaine Pyrolaser

activation/désactivation de commande : Status CV2		
avant activation cmde	193.0	STATCV2AAMF
après activation cmde	195.0	STACV2ABMAF
signaux juste en fin de commande : Etat sig arm:		
état de l'entrée X4 du MUX (signal Cmd_Init_Pyro)	1.000	ETASIGMAF0
état du signal CMT_A	0.000	ETASIGMAF1
état du signal /Fault_CMT_Alim	0.000	ETASIGMAF2
Acq_Switch_Pyro avant activation commande		
octet 0	25856	ACQSWPYBNC
octet 2	0.000	ACQSWPYBNO
octet 4	25856	ACQSWPYBC
Acq_Serv_Voie avant activation commande		
octet 0	11394	ACQSERBTMP
octet 2	2.000	ACQSERBCOU
Acq_Switch_Pyro après activation commande		
octet 0	25888	ACQSWPYANC
octet 2	0.000	ACQSWPYANO
octet 4	25920	ACQSWPYAC
Acq_Serv_Voie après activation commande		
octet 0	11394	ACQSERATMP
octet 2	2.000	ACQSERACOU

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