13th European Synchrotron Light Source Radio-Frequency Meeting

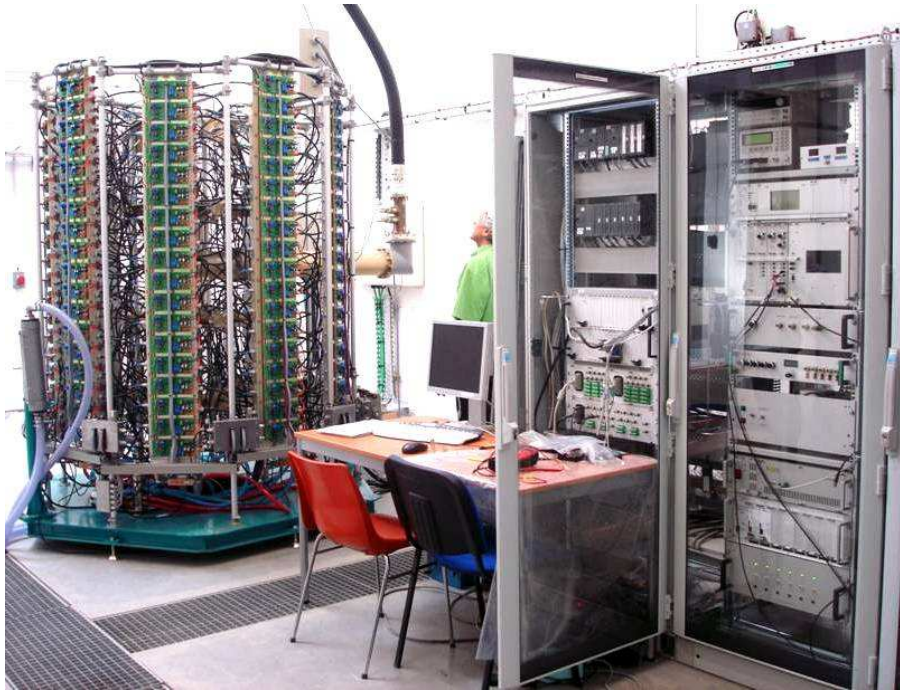
30 September – 1 October, 2009
DESY, Hamburg, Germany

OPERATIONAL EXPERIENCE WITH THE SOLEIL RF SYSTEMS

P. Marchand

Booster RF

5-cell LEP type cavity



35 kW solid state amplifier & LLRF

In operation since mid 2005 (~ 18 000 running hours)

Only a single trip in operation due to a human mistake (2006)

Since then, not the least dead time due to the RF !

Amplifier : 5 module repairs out of 147 (0 transistor failures !)

Storage ring RF

- 580 kW (500 mA) & 4 MV @ 352 MHz
- 2 cryomodules, each containing a pair of single-cell s.c. cavities
- Each cavity powered by a 180 kW solid state amplifier
- Both CM supplied with LHe (4.5 K) from a single cryo-plant

Phase 1 : Operation with a single CM

Operation with a single CM for about 2 years (mid 2006 – mid 2008)
→ 250 mA (users), 300 mA (machine R&D) and 8 x 10 mA

Beam time availability of ~ 95%

with only ~ 5% of the dead time attributed to the RF

Essentially due to interlocks, « Excess of cavity reflected power », erratic events at a mean rate of ~ 2 per week, which disappeared after operating with 2 CM (less power on CM1 cavities)

→ Discharges on coupler window → (500 mA with 2 CM) ?

Sparing use of the cav. freq. tuners (pb with similar tuners on S-3HC cav)

→ as much as possible, back-up mode at fixed tuning,

Tuned @ I_{bmax} (300 mA) → V_{cav} (I_{beam}) and Φ_{cav} (V_{cav})

→ No pb with tuners of CM1

No evidence of HOM excitation : no heating of the HOM loads
& residual beam phase oscillations < 0.1°

Arrival of cryomodule 2 (CM2) !

CM2 order placed with ACCEL; tests (individual cavity in vertical cryostat and complete CM with RF power) planned at CERN ; **but delays in succession**

→ Beg. 2008, change of strategy : cancel the power tests of the CM at CERN and installation in the SOLEIL SR during shutdown of May 19 – June 20

SD (20/05 – 20/06) **: CM2 installation & cool-down + start RF conditioning of cav3**

20/06 - 27/07 : CM1 active + CM2 passive (2 cavities detuned) → *No pb*

RF conditioning possible only during dedicated shifts & 2 days in SD of August

29/08 - 21/09 : Operation with 4 active cavities (P_{cav4} < 60 kW)

→ Pb cryo (re-optimization of parameters for operating with 2 CM)

→ Vacuum interlocks on cav4

SD (end of Sept.) : Sticking of cav4 tuner (Δf ~ 100 kHz)

03/10 … : Operation with 3 active cavities (cav4 passive) → *no pb*

Oct. 19 → 400 mA stored for + 1 hour (3 x 135 kW); not limited by RF

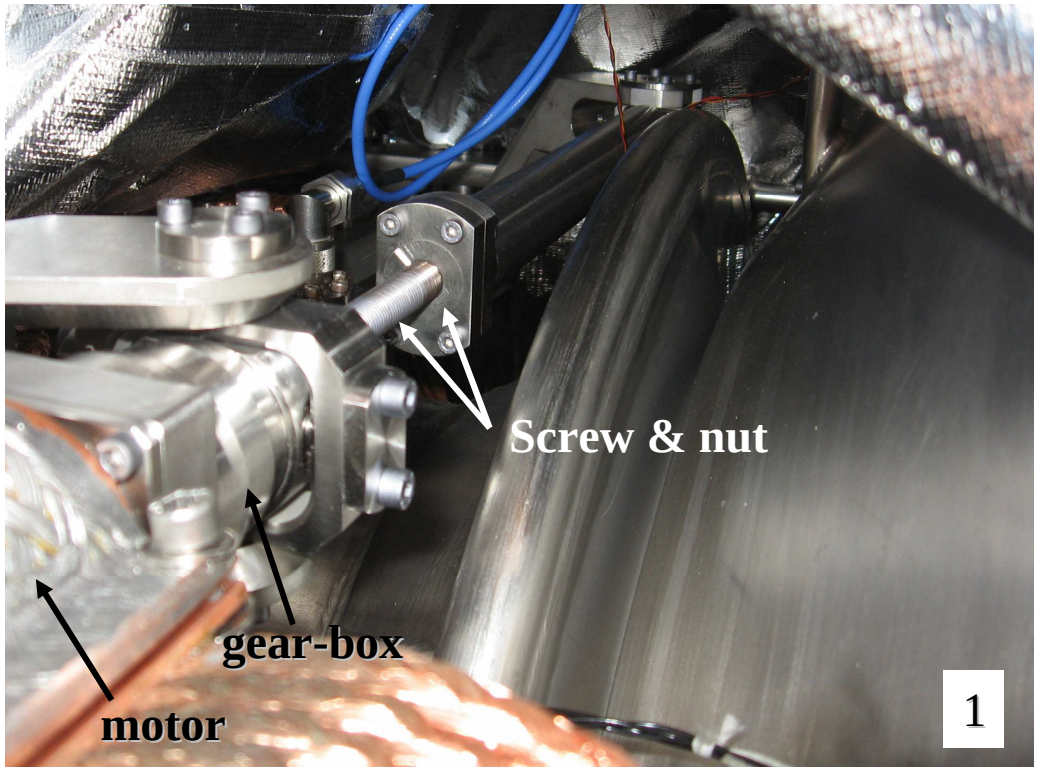
Nov. 16 → 455 mA stored for + 1 hour (3 x 150 kW, no pb)

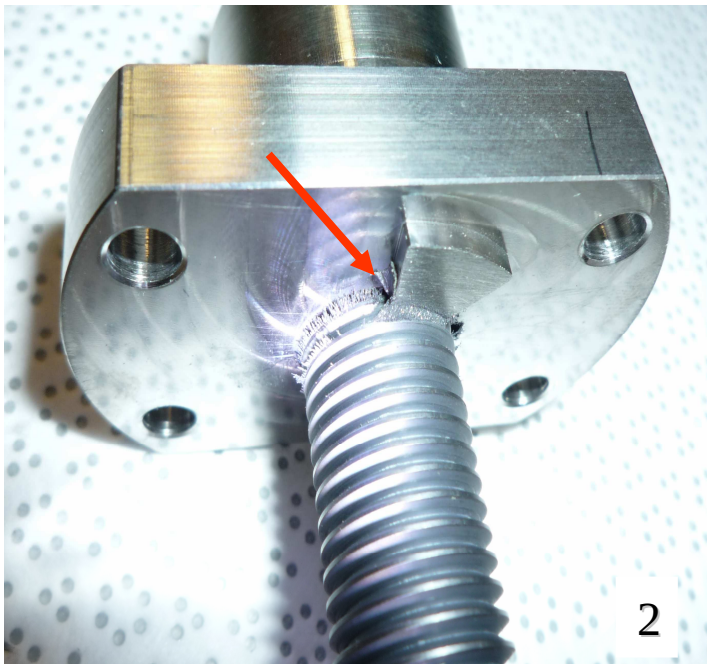
→ Sticking of cav3 tuner (Δf ~ 15 kHz)

→ 250 mA for users until Dec. SD (Pr/Pi - cav3 : 30/120 kW)

SD (end 2009) : CM2 warm up → Opening beg. of 2009

Tuner screw damages

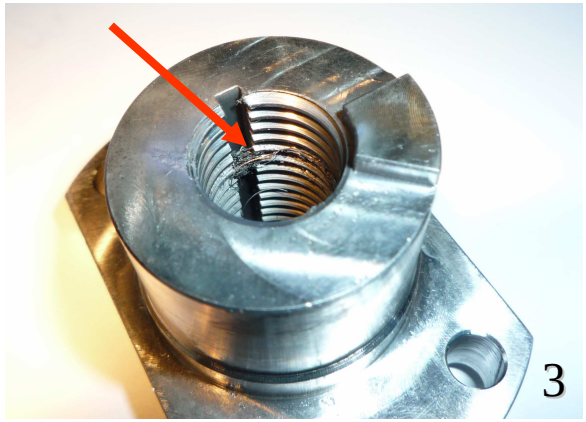


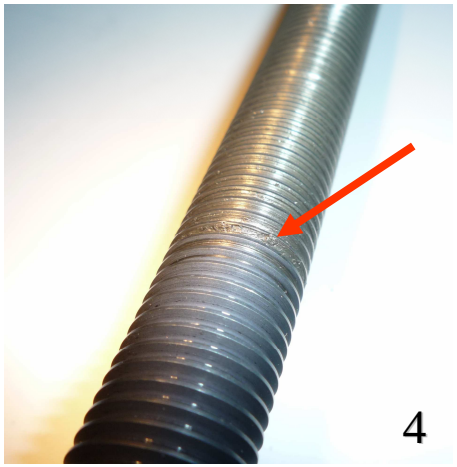


CM2 → stainless steel

CM1 → CuBe2

Both → same lubricant surface treatment for vacuum & cryogenics





2009 : CM2 tuner story, continuation !

Beg. 2009, new tuner design, under development but not yet validated
→ Try to get the existing one working

→ Replace stainless steel screws of CM2 by similar ones, but more mech. game

After a few days of operation, same issue : tuner screw of cav3 stuck again !

→ Replace stainless steel screws of CM2 with CuBe2 ones (like on CM1)

After a few weeks of operation, problem with the gear box !
(likely, a consequence of the preceding failures)

Rem : Each time, it was first working @ RT (observable) & failed @ cold (blind)

SD of Aug. 2009, new version mounted on CM2 ; in use since beg. of Sept.

Signs of wear on CM1 → fixed tuning on CM1 & variable tuning on CM2

→ Replacement of CM1 tuners scheduled for the SD, in January 2010

New tuner version

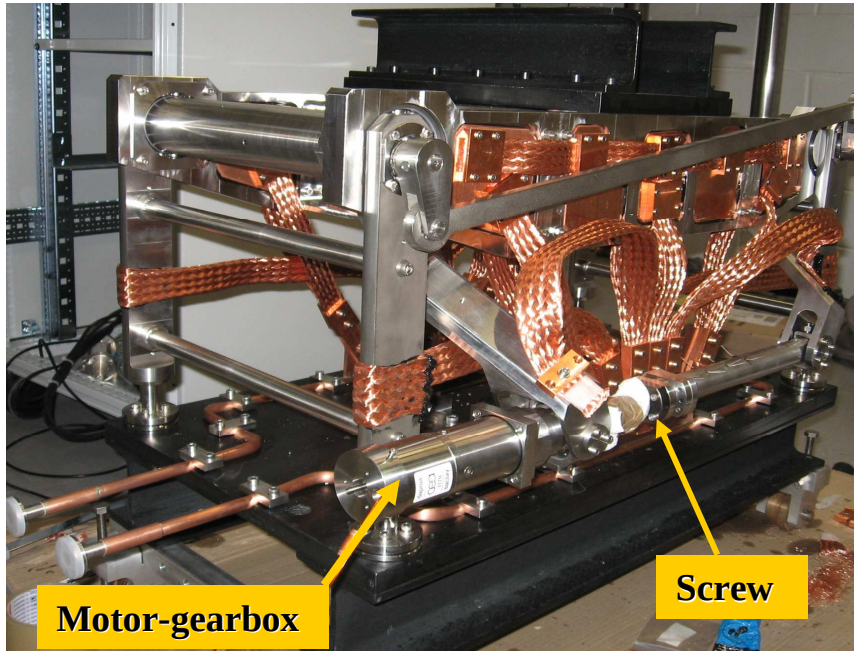
1) Standard screw-nut assembly replaced by *planetary roller screw*

2) Stepper motor + harmonic drive gear box → Stepper motor with planetary gear box

→ Less friction
→ More robust
} → Longer lifetime

Prototype successfully tested on a test bench @ cold in CryHolab at CEA

⟺ 20 years of SOLEIL operation



Operation in 2009

First half of 2009, most of the time, the tuners of CM2 were not operational
In spite of that, impact on the operation remained relatively weak
Variable tuning on CM1 & fixed on CM2 (tuned @ 500 mA → variable V_{cav} & Φ_{cav})

- **From mid of March → 300 mA top up (uniform filling) standard mode for users**
- **Hybrid (300 mA - ¾ ring + 6 mA) and 8 x 10 mA modes also available for users**
- **400 mA top up routinely for machine R&D → End 2009 for users (500 mA → 2010)**
- **500 mA for short times (R&D) → transv. instabilities → improve TMB feedback**

RF system related problems (other than tuners)

➢ *Cryogenics :* - malfunctionning of CM LHe level control loop
- ½ day of beam time lost due to a failing LHe level gauge on the Dewar
- losses of utilities (electr., water) → few hours restart → + autonomy
→ Spare compressor station with separarate utilities (beg. 2010)

➢ ***Instabilities @ high I_b*** → RF feedback gain reduction (compromise stabil. / µphonics)

➢ *Coupler discharges @ high power* → new design of ceramic window for P > 300 kW
(Project in collaboration with CERN & ESRF) → 500 mA with a single CM

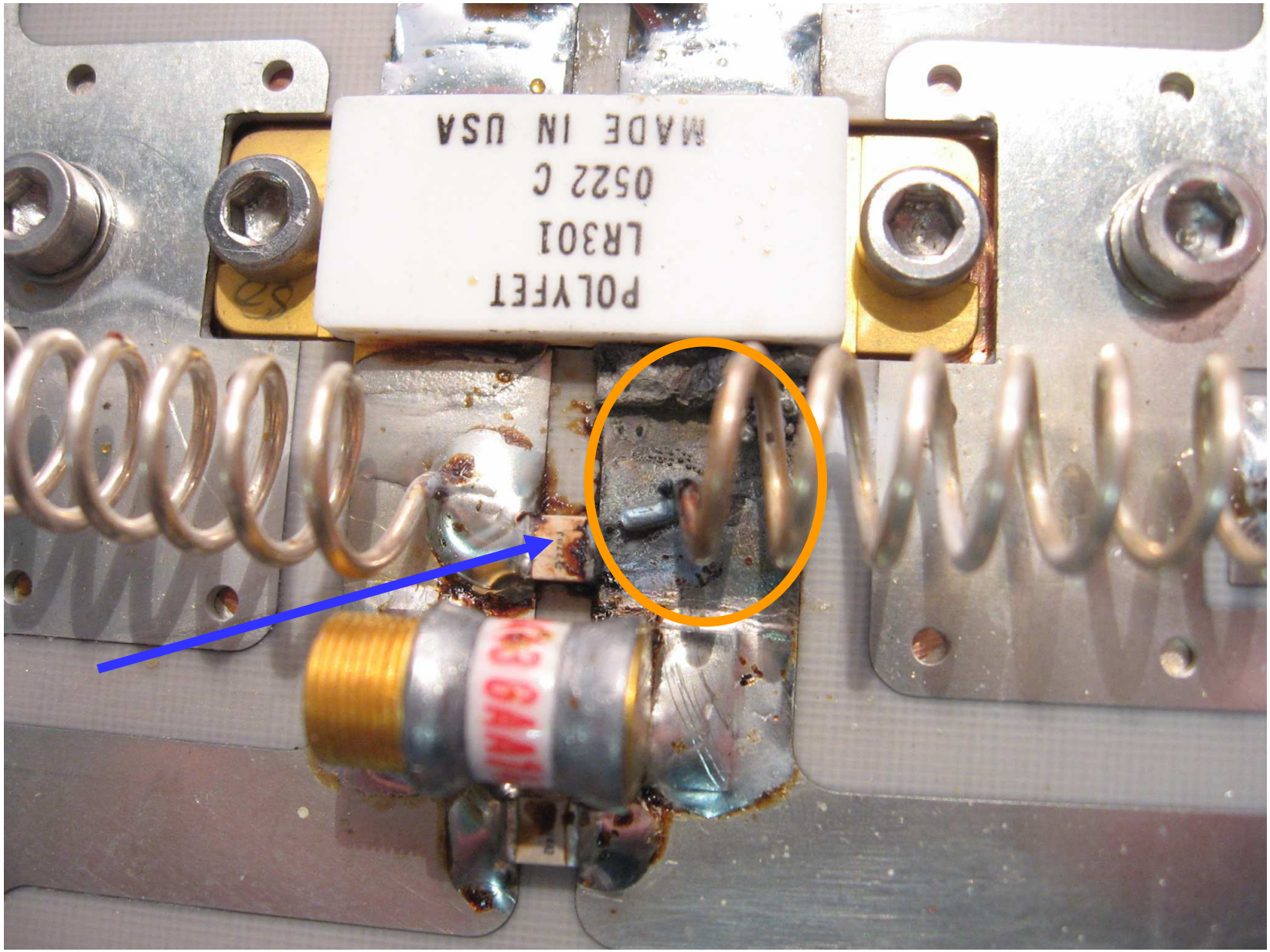
SR RF power amplifiers

Amplifiers 1 / 2 (CM1)				A 3 / 4 (CM2)
	2006 - 2007	2008	2009	2008 - 2009
Running hours	~ 6 000	~ 6 000	~ 4 000	~ 6 000
Trans. failure	4% (6.2 / 1.8)	3% (5 / 1)	0.9% (1 / 0.8)	1.7%
Solder pb	0.6%	2.2% (4 / 0.4)	2.9% (5.2 / 0.5)	0.6%

On A1, mistreatments due to lack of protection → higher failure rate

→ ~ 1% for all

Solder degradation



SR RF power amplifiers

Amplifiers 1 / 2 (CM1)				A 3 / 4 (CM2)
	2006 - 2007	2008	2009	2008 - 2009
Running hours	~ 6 000	~ 6 000	~ 4 000	~ 6 000
Trans. failure	4%	3% (5 / 1)	0.9% (1 / 0.8)	1.7%
Solder pb	0.6%	2.2% (4 / 0.4)	2.9% (5.2 / 0.5)	0.6%

On A1, « mistreatments » due to lack of protection → higher failure rate

→ High Q capacitors (T : 130 → 110 °C)
→ Soldering material for higher temp. (ΔT > 30 °C)

Failing components (other than modules)

1 DC/DC converter,
1 multiplexer
4 x 2.5 kW combiners

Above failures had ~ no impact on the operation (3 short dead times over 3 years)
→ ~ 100 % operational availability of the amplifiers
Mainly a matter of maintenance (rather light)

Solid state amplifier R & D

- Module 400 W - 476 MHz (Vdc : 50V) → collab. with LNLS : 2 x 40 kW (end 2009)
  f : 350 - 500 MHz, P ~ 400 W, G ~ 20 dB, η ~ 70%

- Higher power modules (Vdc : 50V) → P = 700 W, G > 20 dB, η > 70% @ 350 MHz
  Module validated → run test of a 350 MHz - 10 kW unit (16 mod.), beg. 2010
  [SOLEIL modules (Vdc = 28V) → P = 315 W, G = 13 dB, η = 62 % @ 350 MHz]
  ↳ Huge improvement (better performance and T_{max} : 130 °C → ~ 70 °C)
  If anyone's interested, we've achieved ~ the same performance at 500 MHz !

- *Other projects :*
  → 352 MHz - 20 kW pulsed for CERN LINAC4 bunchers
  → 352 MHz - 200 W CW for CERN LHC klystron drivers
  → 88 MHz (5, 10, 20 kW CW) for SPIRAL2 – GANIL
  → L band (1.3 – 1.5 GHz) for 4th generation LS
  → ESRF upgrade (replacement of the 352 MHz klystron amplifiers of BO & SR)

- In 2008, transfer of technology agreement concluded with ELTA-AREVA
  → ESRF contract for 7 amplifiers of 150 kW (2 towers of 75 kW)
  First tower to be delivered by the end of 2010

- SOLEIL: progressive replacement of the actual modules by the 700 W generation

Summary & conclusions

SOLEIL SYNCHROTRON

After more than 3 years of operation, result globally satisfying :

- **For the BO RF, no pb at all**
- **In SR, for the first 2 years, using a single CM, only 5 % of dead time due to RF**
- **The third year, with the commissioning of CM2, it has nearly tripled**
- **Significant improvements expected from the corrective actions :**
  - **→ Upgrade of the CM frequency tuners**
  - **→ Installation of a spare He compressor station**
- **In longer term → Upgrade of the power couplers (collab. with CERN & ESRF)**
  - **→ Replacement of the actual ampli modules by the new (700 W) generation, currently under development**

Concerning the SSA, R&Ds are going on : several projects are in progress.
For dealing with the production and marketing business, we have concluded a transfer of technology to the industry, namely ELTA, subsidiary of AREVA

Within this frame, a contract is about to be signed with the ESRF for the supply of 7 x 150 kW amplifiers, 1st stage of their upgrade

Acknowledgement

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