16th European Synchrotron Light Source
Radio-Frequency Meeting

ALBA, October 9th - 10th, 2012

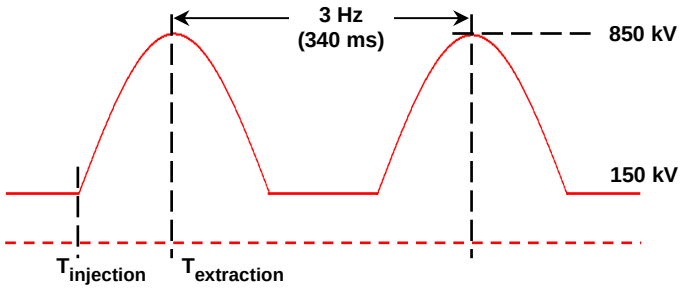
M. DIOP

OUTLINE

- **Operation**
  - Cavities
  - SSA
- **SOLEIL SSA**
  - State of the art @ 352 MHz
  - 500 MHz R&D
- **New projects**
  - ThomX
  - SESAME
  - LUNEX5
  - MYRRHA

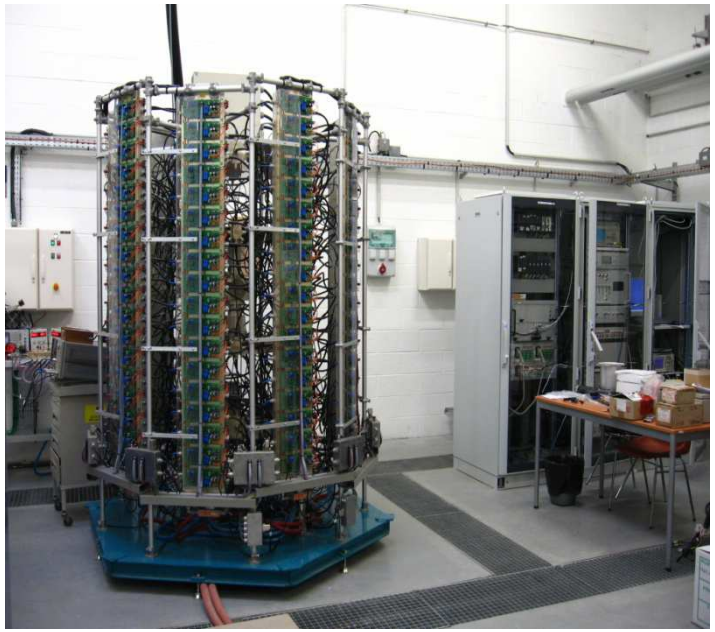
❖ BOOSTER

- 3 Hz RF ramping

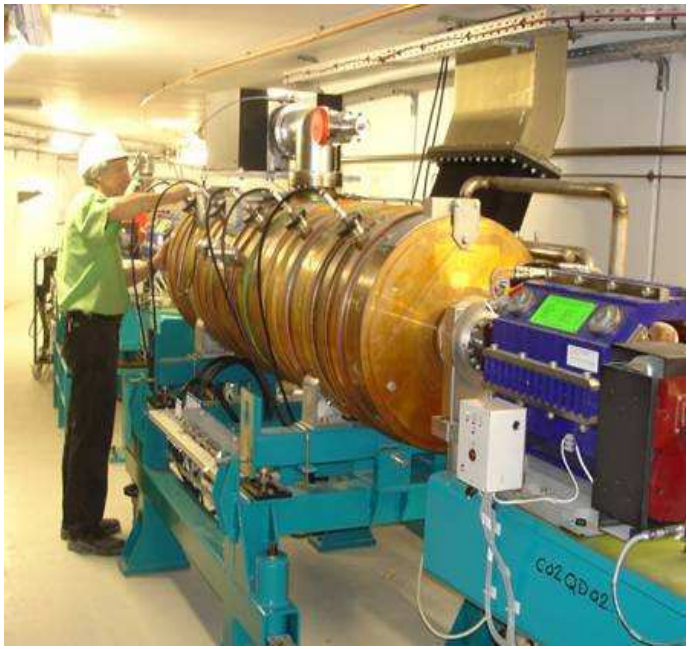


Power balance

- $P_{dissipated}$: 15 kW
- P_{beam} : 5 kW
- P_{total} : 20 kW



35 kW solid state amplifier & LLRF



5-cell LEP type cavity

❖ STORAGE RING

- 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 (SSA)
- Both CM supplied with LHe (4.5 K) from a single cryo-plant

Operating Modes

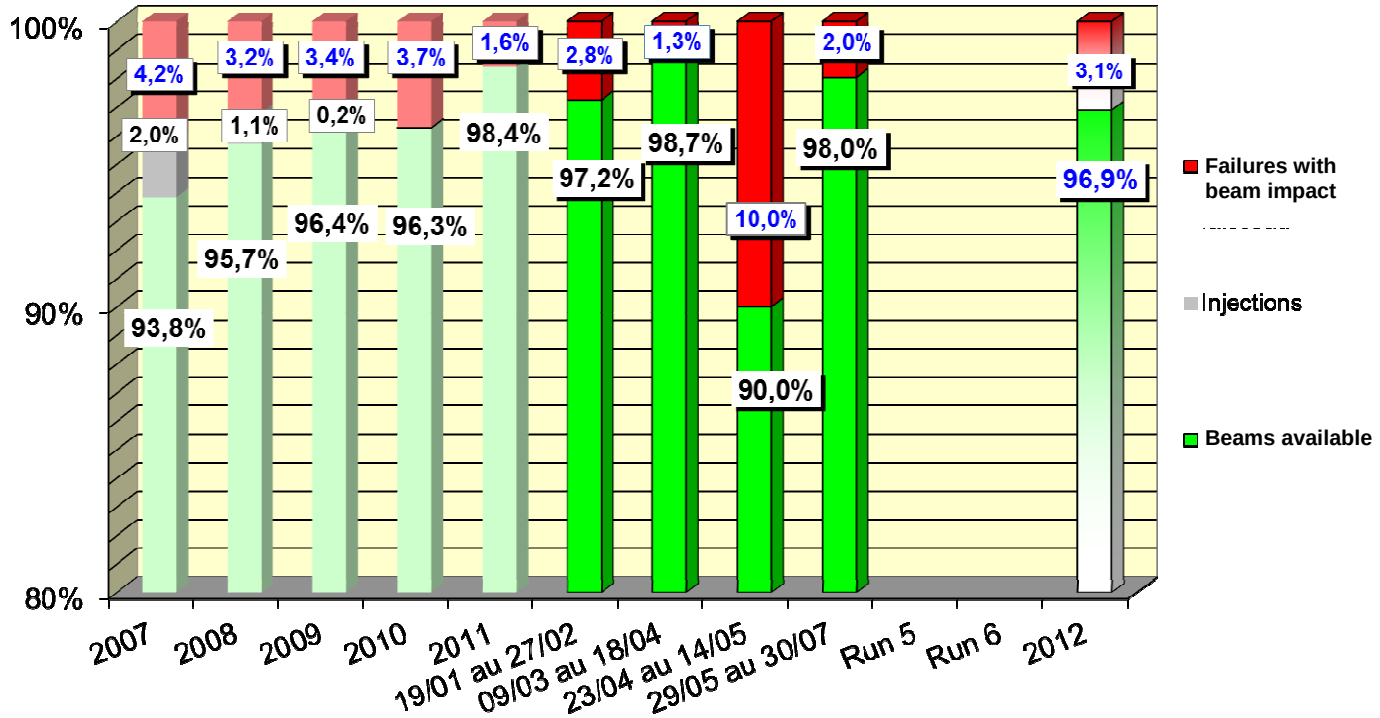
Mode of operation	User Operation	Ultimate performance achieved
Multibunch	430 mA *since September*	500 mA
Hybrid	425 mA + 5 mA *since September*	490 mA + 10 mA
8 bunch	100 mA	100 mA
1 bunch	11 mA	20 mA

+ Low α mode

α value	$\alpha_{nominal}/25 = 1.8\ 10^{-5}$ ($\alpha_{nominal}/100$)
Total current, current per bunch	20 mA, 70 µA
Bunch length	4.7 ps – RMS (instead of 15ps in hybrid mode)
Horizontal emittance, coupling	8 nm, 4 %
Lifetime	20 hours
RF voltage	3.2 MV

OPERATION

Historic of Beam time availibility



- Beam time availability of ~97% since September 2011 (>98% in 2011)
- 3 important beam downtime failures due to utilities:
  - 2 fluid failures ~ 14 hours of beam downtime
  - 1 compressed air failure ~ 10 hours of beam downtime

→ Impact on cryogenic system which need ~ 3 hours to restart

CAVITY OPERATION

- **18.6% of beam downtime due to RF**
- **100% operational availibility for the booster**

- Operation problem while doing amplifier's maintenance

  wh ⇒ using 3 cavities out of 4 to reach 400 mA

- 2 different RF interlock causes:
  - Discharges on cavity 1 pick-up ⇒ Vcav transient which drops very quickly and amplifier increases its power to compensate leading to interlock

    solved with ⇒ integrator on Pr interlock (capacitor added not to take into account events less than 5us)

    Discharges always present, typically 7 events per day

  - Suspicion of discharges on cavity 2 FPC? (no consistent data on vacuum to conclude)

    Same phenomena when operating with 1 CM @ 300mA

    When used for long time over 110kW, Pref interlocks appear on cavity 2 and it degrades over the time

    Solution ⇒ : lower the input power on cavity 2

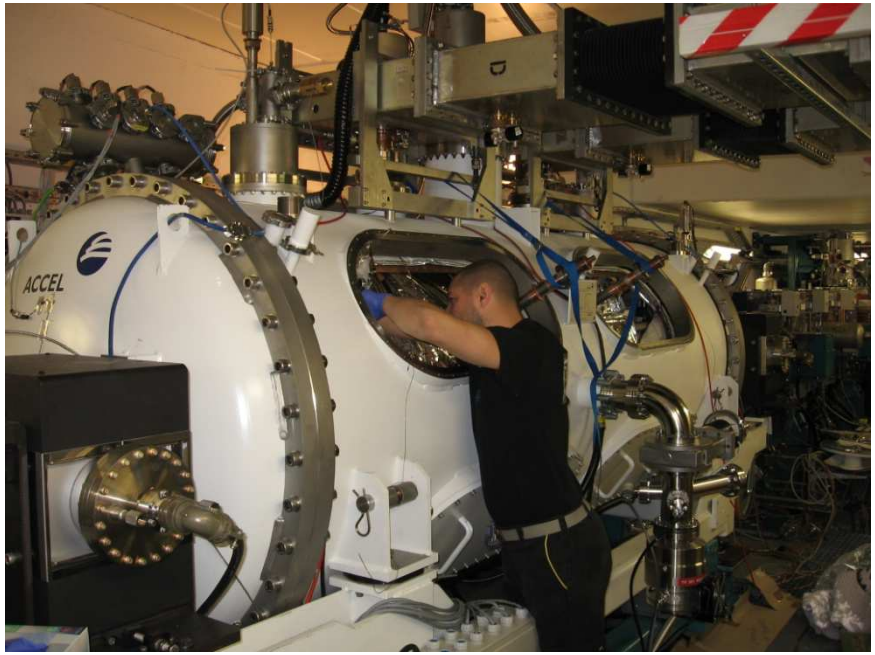
- Cavity vacuum gages replacement on CM2 during summer shut down ⇒ **CONDITIONING**
  Gage malfunction present from on-site installation and degrading over the time

TUNERS

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

1.

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



No more tuning problems since 29 months

CRYOGENIC SYSTEM OPERATION

- ≈ **42,000 hours running**
- **No beam downtime due to cryogenic system for the last 2 years**

- **Second compressor station operational since June 2010:**
  - Redundancy in operation in case of losses of utilities (electric, water) → few hours restart
  - Maintenance transparency (done in January 2011 on compressor 1)

- **Upgrade:**

  Increase capacity of liquid Helium Dewar : **2,000L actually** ➡ **5,000L**

  to minimize the impact of short liquefier interruptions on the machine operation

FPC R&D

- **300kW coupler**: collaboration with CERN and ESRF
  - 1st prototype for ESRF tested in Dec 2011
  - 2 couplers for SOLEIL to be tested at ESRF in february 2013

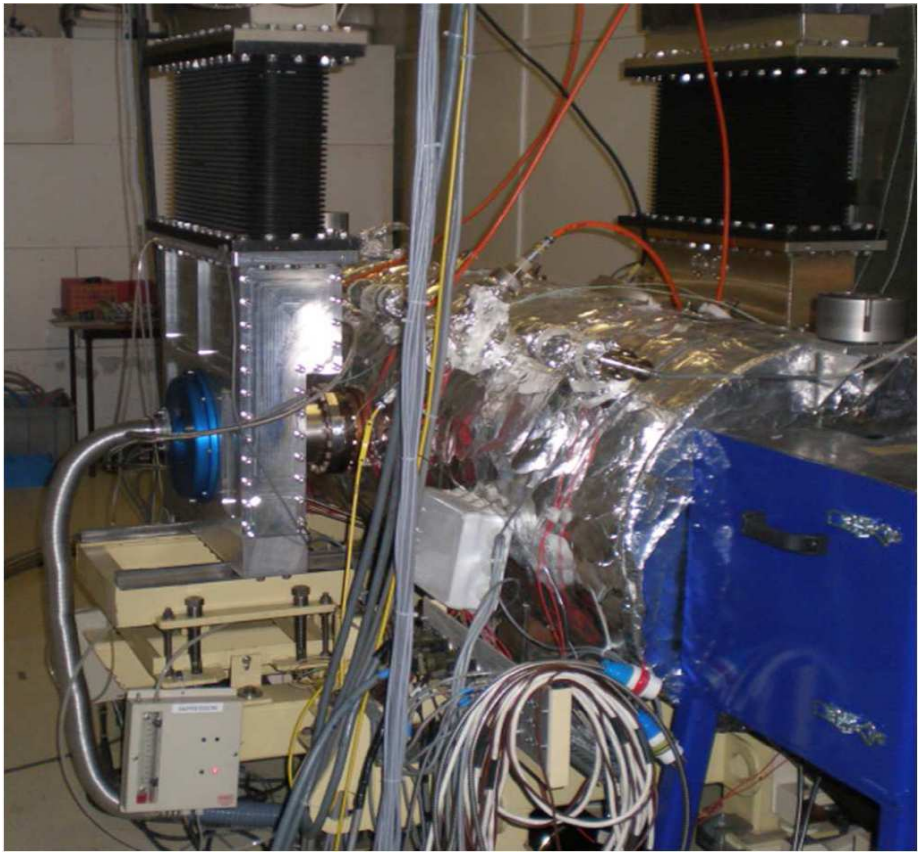
- FPC substitution on CM 1 planned for summer 2013 on-site (solve problems on cavity 2 FPC?)

  Cleanness constraints

- 2x180 kW amplifier combination study

  300 kW/cavity

  → Store 500 mA using a single cryomodule



300 kW FPC test bench at ESRF

SSA OPERATION

- ≈ **33,000 hours running**
- Module failure rate ~ 2% per year

Repair of faulty modules :
- transistor substitution (0.6%)
- re-soldering (1.4 %)

None of these failures has impacted the operation (modularity & redundancy) → **100% operational availability**

- **Upgrade**

- **BLF574XR (NXP)** tested and validated in 2011-2012 (~2,000 hours)
- From 2013 : Substitution of LR301 transistor to BLF574XR
  - Replacement of all LR301 modules
  - 1-2 tower per year

SOLEIL 352 MHz SSA State Of The Art

	Transistor type	Power supply per module	Module Parameters at nominal conditions	Amplifier design & nominal power	VSWR limitation *	Comments
SOLEIL Booster	D1029UK05 ◊ SEMELAB	1 x 600 W 280/28 Vdc	P_{1dB} = 330 W, G = 11 dB η = 60 % , T_{max} = 130°C	1 tower of 8 dis P_{nom} = 35 kW modulated	No limit with SOLEIL Booster duty cycle	1 trip over 7 years due to a human mistake
SOLEIL SR (actual)	LR301 Polyfet	1 x 600 W 280/28 Vdc	P_{1dB} = 315 W, G = 13 dB η = 62 % , T_{max} = 130°C	4 towers of 10 dis P_{nom} = 180 kW cw	70 kW full reflection Pr = 35 kW @ 180 kW	MTBF > 1 year
SOLEIL SR (upgrade)	BLF574XR NXP	1 x 600 W ♯ 280/48 Vdc	P_{1dB} = 350 W, G = 22 dB η = 69 % , T_{max} = 90°C	4 towers of 10 dis P_{nom} = 200 kW cw	70 kW full reflection Pr = 32 kW @ 200 kW	Much more robust than LR301
ESRF Booster (800W load)	BLF578 NXP	2 x 600 W 280/48 Vdc	P_{1dB} = 650 W, G = 20 dB η = 71 % , T_{max} << 75°C	2 towers of 8 dis P_{nom} =150 kW modulated	No limit with ESRF Booster duty cycle	In CW Pr limited at 5 kW for Pi = 150 kW
ESRF SR V2 (1.2kW load)	=	=	=	2 towers of 8 dis P_{nom} = 150 kW cw	85 kW full reflection Pr = 50 kW @ 150 kW	→ modified combination → + 1.2 kW load
ESRF SR V3 (power circul)	=	=	=	→ P_{nom} = 140 kW	140 kW CW full reflection	+ 5% power loss - 3% on efficiency Extra costs

- * VSWR limitation: when operating the amplifier at high CW incident power, Pi, with a high VSWR and the worst phase condition, **an unpowered module** (ie, both of its power supplies, or both sides of its push-pull broken) can see a power on its circulator load, Pload > Pi
- ***Rem***: full reflection for a short time (~10 ms) is not a problem (→ Pr interlock)
- ♯ 2 PS in series on 2 modules in //
- ◊ VDMOS ; all the other cases are LDMOS

SOLEIL R&D ON SSA

- After 6 years of operation, SSA innovative design has proved itself and demonstrated that it is an **attractive alternative to the vacuum tube amplifiers**, featuring an outstanding reliability and a MTBF > 1 year.

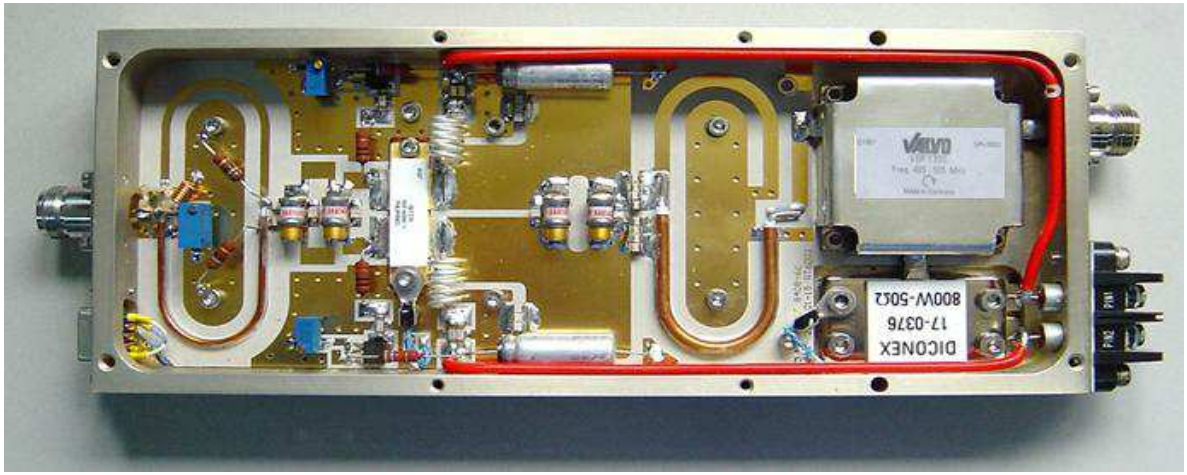
- Thanks to the acquired expertise and the arrival of the 6th generation LDMOS, SOLEIL has carried out developments which led to doubling the power of the elementary module (650 W) while improving the performance in terms of gain, linearity, efficiency and thermal stress.

- **Advantages of SOLEIL SSA:** low phase noise, good linearity, high reliability, long life time, easy maintenance, simple spare parts, no HV, no X ray.

- **New projects:**
  - Now 500 MHz amplifier based on this technology are being built for **ThomX** (50 kW) and **SESAME** (140 kW) projects.
  - *Study for new frequencies:* 1.3 GHz for **LUNEX5** (20kW) and 176 MHz for **MYRRHA** (180 kW)

500 MHz R&D ON SSA

6th generation LDMOS → BLF578 : 650 W modules

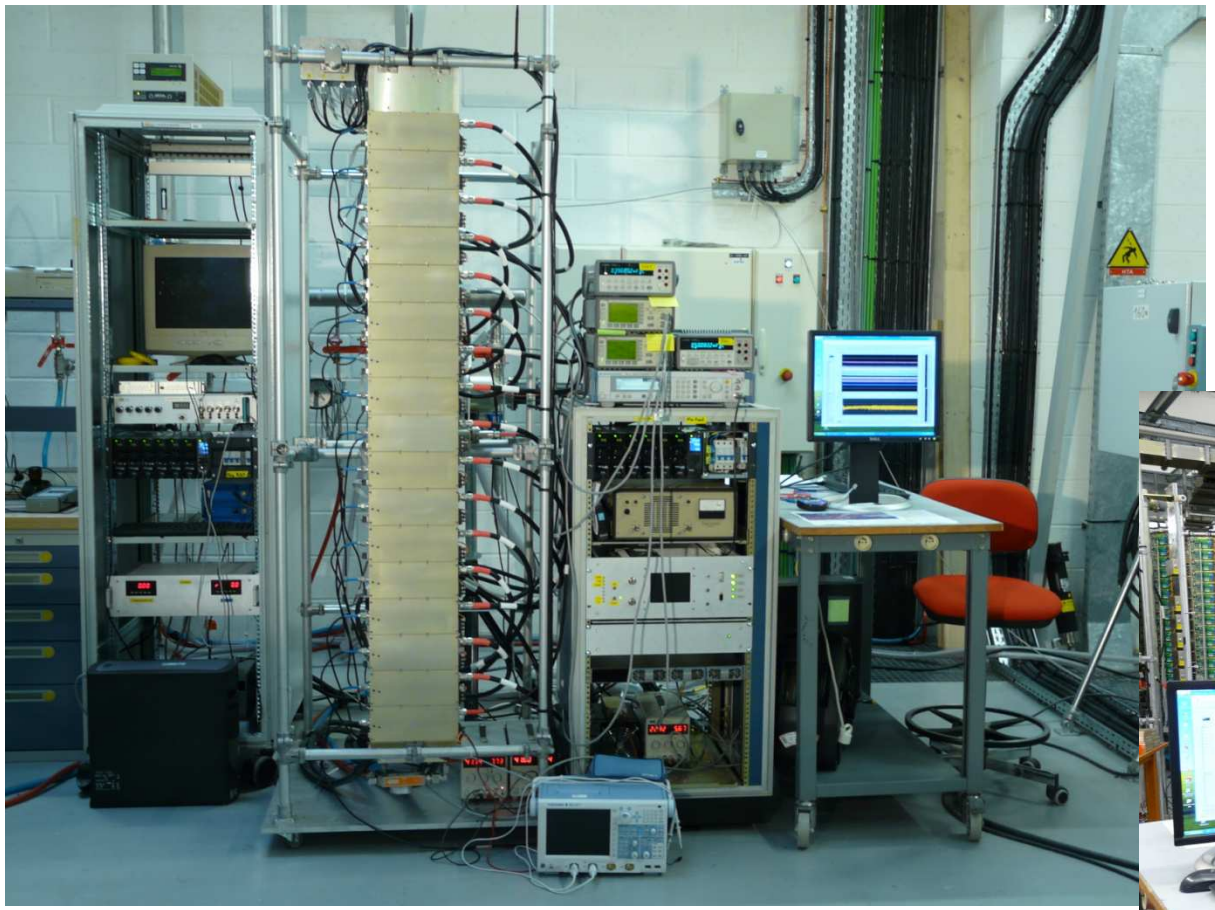


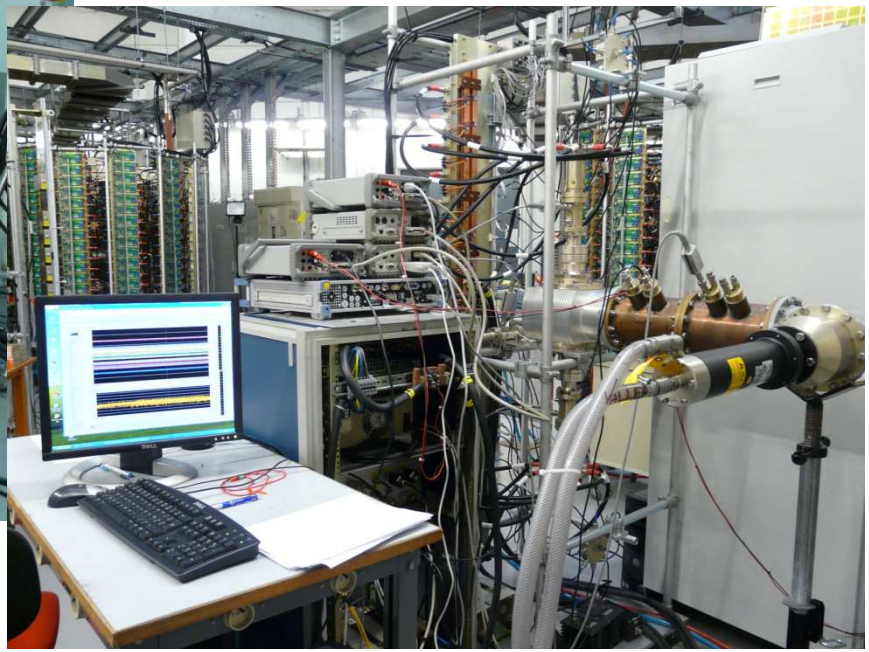
650W CW - 500 MHz amplifier module

High efficiency (96%) 220 V_ac / 50 V_dc power converters

500 MHz R&D ON SSA

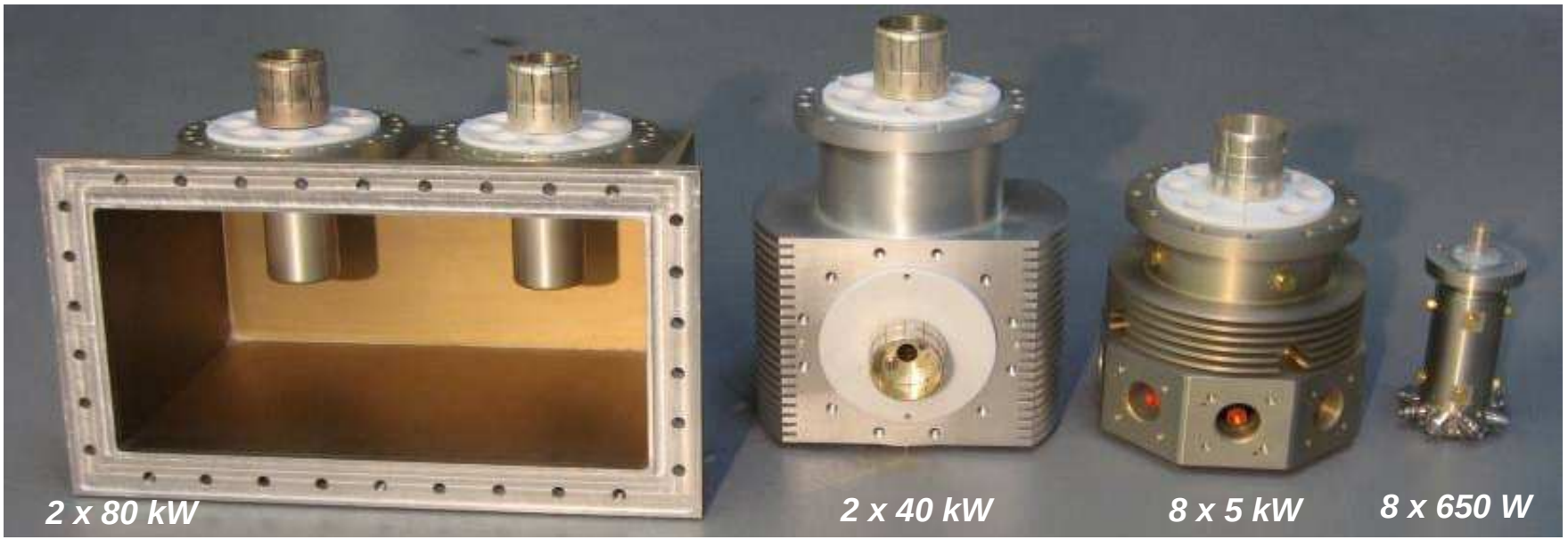
10 kW unit prototype for long term test (~ 500 hours until now)

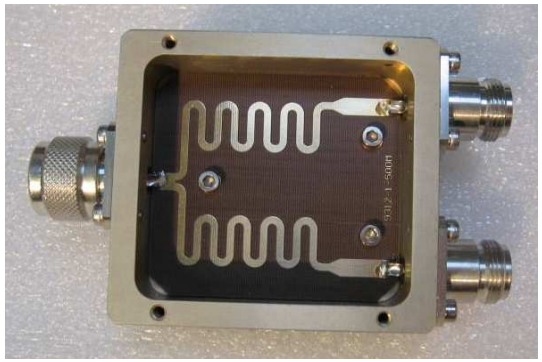




500 MHz R&D ON SSA

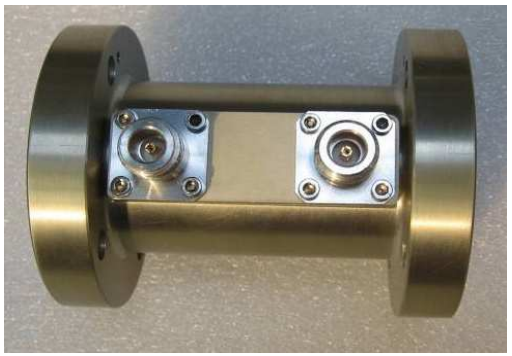
Power combination components





2-way splitter

8-way splitter



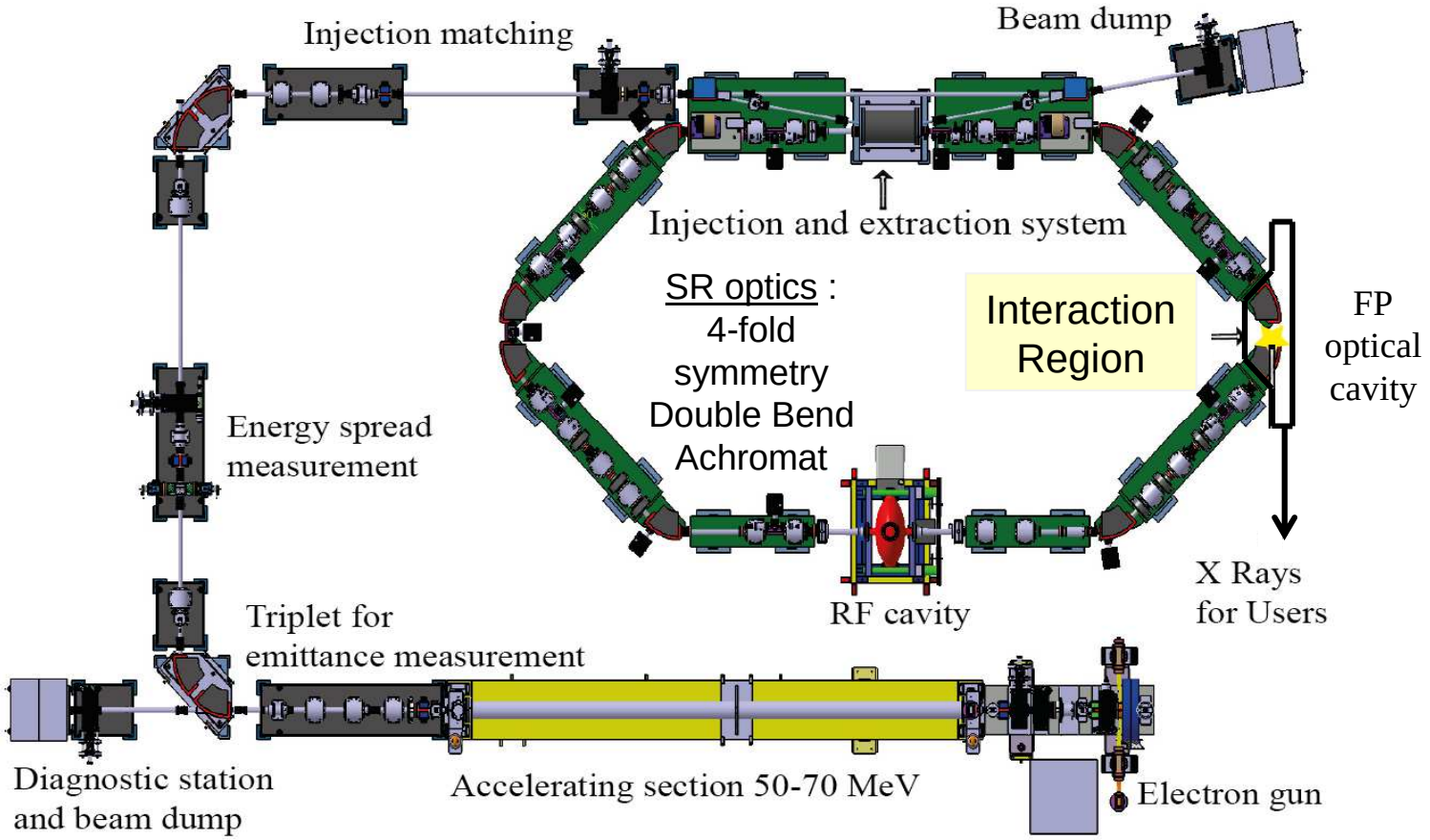
P_i - P_r monitoring coupler

ThomX

- **Compact source of hard X-rays (40 – 90 keV)**

Flux of up 10^{13} photons / sec, generated by Compton Back Scattering

- **Contributions:** LAL-Orsay CNRS-IN2P3, **SOLEIL**, CELIA Bordeaux, **ESRF**, C2RMF-CNRS, UDIL CNRS, INSERM Grenoble, Thales TED, Institute Neel Grenoble



Injection of a single e^- bunch (20 mA), which collides at each turn with laser pulses at the IP, inside the FP optical resonator → X rays from CBS

ThomX

- LAL-Orsay & SOLEIL in charge of the accelerator complex, housed inside the former DCI building on the university site in Orsay (~ 5 km from SOLEIL)

- **SOLEIL RF group mission**
  - **LINAC**
    - Photocathode RF gun
    - 3 GHz power source (modulator + klystron) and waveguide distribution
    - One accelerating structure (SOLEIL LINAC spare)
  - **STORAGE RING RF Systems**
    - Accelerating cavity (ELETTRA type, dedicated to SESAME but made available for ThomX)
    - 50 kW SOLEIL SSA @ 500 MHz
    - LLRF (+ longitudinal feedback) & control system
    - Transverse feedback

- **Milestone**
  - Conditioning of cavity+SSA by the end of 2013
  - On-site installation planned for mid 2014

RF systems for ThomX by P. Marchand at ESLS-RF 2011

SESAME

- New synchrotron light source under construction in Allan (Jordan)
- **SOLEIL contribution**:
  - 140 kW SOLEIL SSA @ 500 MHz (2 x 70 kW towers)
  - Training and support for the realization of 3 other SSA
  - Refurbishment of 2 ELLETRA cavities
- **Status** :
  - Order all components for the 70 kW tower by the end of 2012
  - Test and validation of the 70 kW tower by the end of 2013
  - 70 kW tower shipment to SESAME beginning of 2014

  } **SSA**

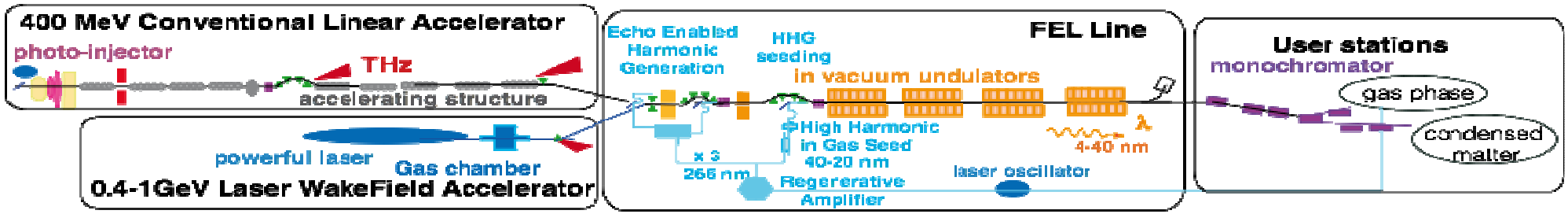
  - Reception of 2 ELLETRA cavities in December 2011
  - Conditioning of one of them by the end of 2013 then used for ThomX commisioning and returned back to SESAME in 2016
  - Shipment of the other one to SESAME beginning 2014

  } **CAVITIES**

LUNEX 5

Contributions: **SOLEIL**, LAL-Orsay CNRS-IN2P3, PhLAM/ CERLA, LOA, CEA, CEA-DAM-DIF, LCPMR, **ESRF**, CEA/DSM/IRFU/SACM, CEA/DSM/IRAMIS/SPAM

General layout



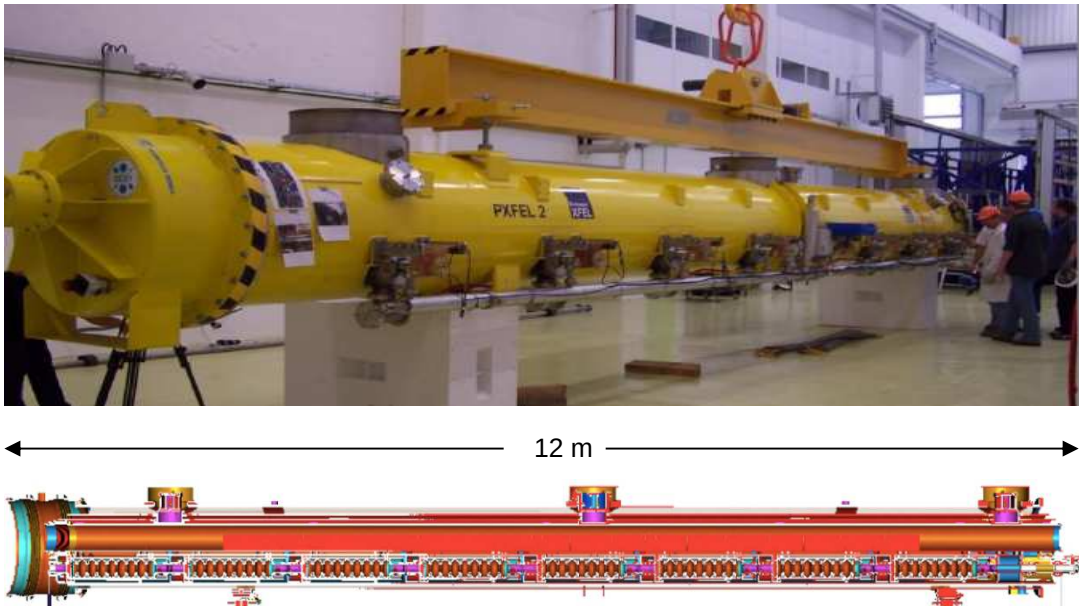
- **Phase 1:** Advanced fourth generation (4G+) light sources via the latest free electron laser seeding schemes and electron photon interaction
- **Phase 2**: Fifth generation (5G) light source => Conventional Linac replaced by a Laser WakeField Accelerator, FEL being viewed as a qualifying LWFA application

- **Collaboration between SOLEIL and CEA-SACM for the 400 MeV conventional LINAC (phase 1)**
  - *2 x 200 MeV XFEL cryomodules of 12 m (2 x 100 kW CW)*
  - *One RF power amplifier for each cavity → 16 x 16 kW @ 1.3 GHz (not the most economical but the best way for achieving the required cavity field stability)*
    - *LLRF system (0.01° in phase and 10^{-4} in amplitude) with its associated synchronization part*

- Green light after the PDR to proceed with the R&D in view of the TDR
- **R&D for the TDR**

Design, build and validate by cold tests in CryHolab at CEA an elementary RF assembly including :

- a 9-cell cavity (XFEL type), modified for CW operation at 1.8 and 2K
- a solid state RF amplifier, designed in house
- a LLRF system with its associated synchronization part

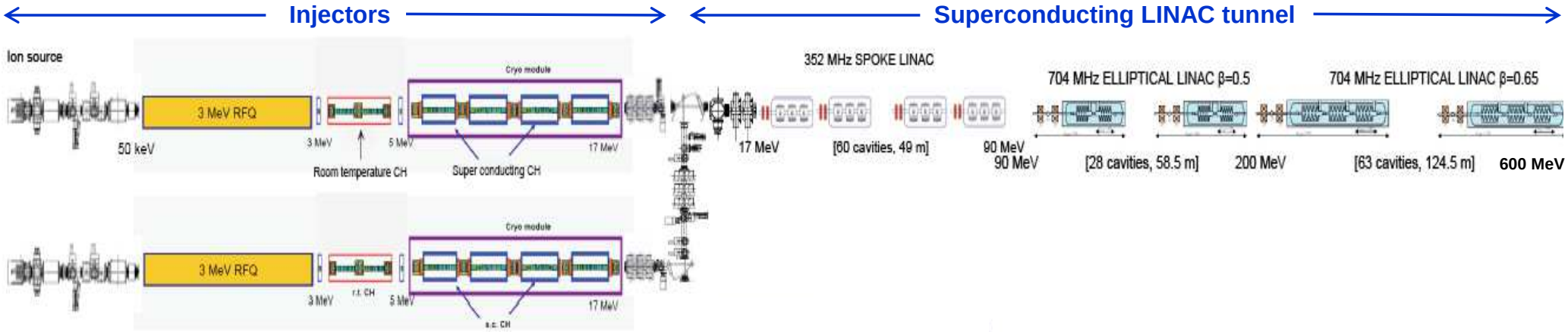


XFEL CM : 8 cavities, thermal shields (4-8 K & 50-80 K), He tranfer lines + Q-pole

MYRRHA

- Multipurpose hYbrid Research Reactor for High-tech Applications
- Project led by the Belgium Nuclear Research Center for radioactive waste treatment thanks to nuclear fission

Accelerator layout



- **1 SSA 180 kW (2 x 90 kW towers) at 176 MHz to drive the RFQ for the first injector**

Project to be discussed => SSA delivery for mid 2014?

- **200 MHz and 176 MHz module prototypes under fabrication**

- Preliminary phase ➡ more SSAs needed in the future?

Another one at 176 MHz and mass at 352 MHz and 704 MHz

SUMMARY & CONCLUSIONS

Operation and upgrade

- Use of 3 cavities out of 4 ⇒ impact on RF performances this year
- CM1 FPC substitution in summer 2013 ⇒ 300 kW per cavity
- Cryogenic system upgrade completed in 2014
  ⇒ dewar capacity increase: 2,000L to 5,000L
- LR301 to BLF574XR subtitution: 1-2 towers per year

500 MHz R&D

- BLF578
- Converters
- Power combination components

160 kW SSA @ 500 MHz
(2 x 80 kW towers)

New projects

- ThomX, SESAME @ 500 MHz
- LUNEX5 @ 1.3 GHz
- Myrrha @ 176 MHz

SOLEIL RF & LINAC GROUP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Thank you for your attention