CEA-SACLAY LABORATORY REPORT

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Abstract

The CEA Saclay in France is involved in many different superconducting radiofrequency related activities ranging from basic R and D to support for present or future accelerator projects. A brief overview of the present going on work will be presented, including:

- surface morphology (cf. poster[1]),
- resistivity measurements (cf. poster[2]),
- hydrogen contamination (cf. poster[3]),
- Q-slope, baking (cf. invited paper[4] and poster [5]),
- Super3HC (cf invited paper[6] and [7]),
- CryHoLab, 700 MHz cavities (cf. poster [8]),
- SOLEIL (cf. poster [9]),
- SPIRAL 2 (cf. poster [10]),

NEW ORGANIZATION AT SACLAYS

Recently accelerators issued techniques have been regrouped in a new department gathering accelerators, cryogenics and superconducting magnets (SACM). Two groups over four are now dealing with RF activities: the LEDA and the LESAR. The first group (LEDA), is dedicated to accelerators developments, mainly general design, beam dynamics, injectors, sources, optical devices, while the LESAR is involved more specifically in the R&D concerning accelerating structures and RF: development: cryomodules including cavities, RF systems, couplers, beam diagnostics, tuning devices…

Both groups work on several project including common ones. The main developments are:

- Beam dynamics (from modelling to operation)
- RF structures: cavity and couplers design
- RF instrumentation (cold tuning system, coupler, BPM...)
- RF superconductivity

While the main applications are

- High intensity beams (protons and ions)
- Synchrotron light sources
- High energy physics

HIGH INTENSITY BEAMS

We are involved in two main projects: IPHI a high intensity proton injector that includes an ECR source (SILHI), and an RFQ, and SPIRAL2 a linac dedicated to ion acceleration for nuclear physics. We are also developing 700MHz proton cavities and their associated Cryomodule for the high energy part of a proton accelerator.

IPHI

SIHLI

- ECR source
- 100 mA protons (100% duty cycle)
- 95 keV
- Emitance: 0.2π mm.mrad (normalized RMS)
- accelerates H^+, D^+ [11]

The realization of SIHLI has included EM modelling, beam dynamics for trajectories of proton and their extraction from the source, construction of a prototype and its optimization. A lot of work has been done to improve the reliability (in view to ADS) and the electromagnetic compatibility. The development of beam diagnostics without interaction with the beam (collab^n IN2P3 [12, 13]) is still going on and is now applicable to other sources.

RFQ

- 100mA
- frequency: 352 MHz
- 3 MeV
- 100% CW

The realization of the RFQ has also included EM modelling and beam dynamics. In addition an extended thermo-mechanical study of the structure has been conducted. We have also developed several codes to model the behaviour of the beam in high intensity ions linacs (collective effects, space charge, image effect…) [14, 15]. The experience gained on IPHI allowed us to participate to the RIA project with ANL, NSCL [16].

Studies around IPHI include also the development of an H^- ECR sources, that has produced 900µA at 950 W, and which is aimed to reach some 10 mA, and of a short hot model of DTL (4 gaps) which has been successfully tested at CERN at 45 kW [17].

TDR Spiral2:

We have launched in collaboration with IN2P3 a two years detailed study on a ISOL-type facility for the production of high intensity exotic beams. The rare isotope beams are produced via the fission process, with the aim of 1013 fissions/s, induced either by fast neutrons from a C converter in a UCx target or by direct bombardment of fissile material. The driver, with an acceleration potential of 40 MV, has to be upgradeable and versatile: it will accelerate deuterons (5 mA) and q/A=1/3 ions (1 mA) and even heavier ions in a later stage. It consists in high-performance ECR sources, an RFQ cavity and lydindependent phase superconducting resonators (100% duty cycle).

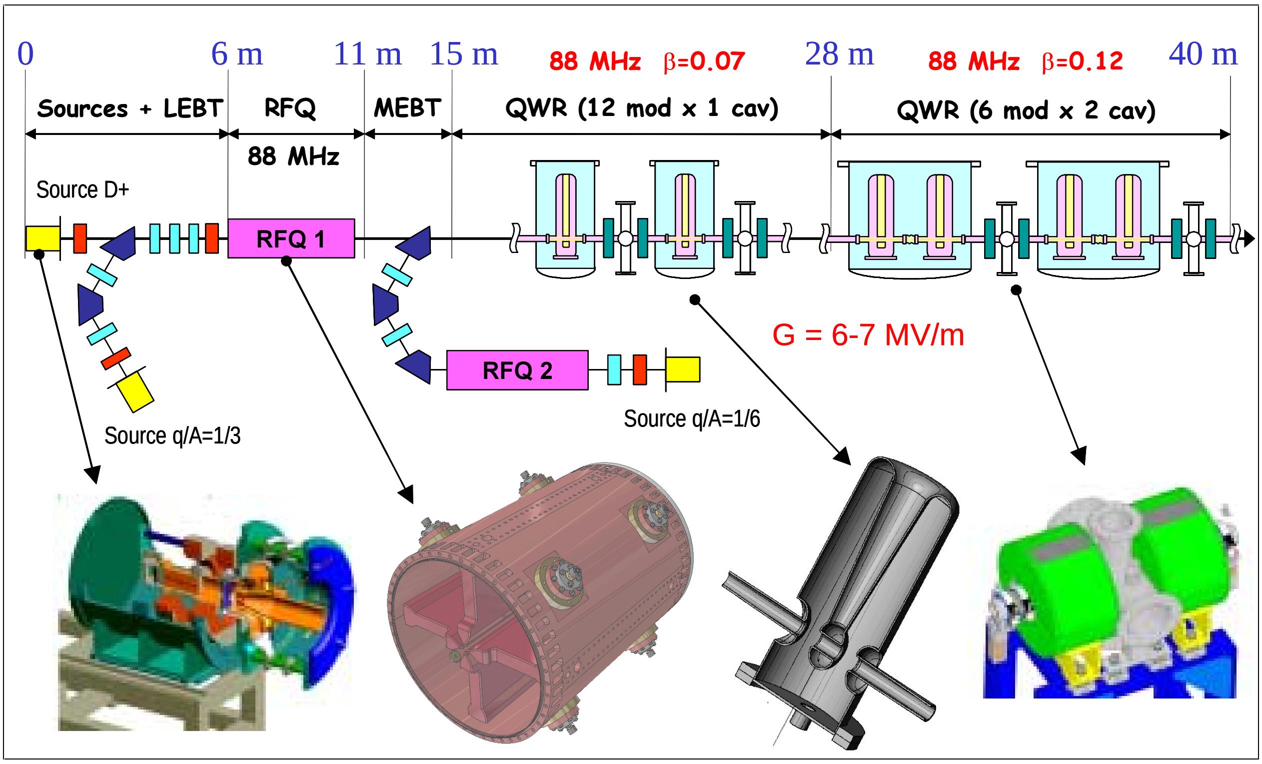

Figure 1: Architecture of the SPIRAL 2 Linac

The lab is implied in various activities:

- RF electronics: design of amplitude and phase feedback loops for the control of the final accelerating field (analogical and digital), power sources.
- Mechanical design: coupled RF/Mechanical calculations needed for frequency stability evaluation.
- Tuning sensitivity: specifications for cold tuning systems

Cavity shape optimization: RF parameters optimization: E_{peak}/E_{acc}, B_{peak}/E_{acc}, r/Q, calculations of: RF losses, coupling, ...

(See [18-20] for more details)

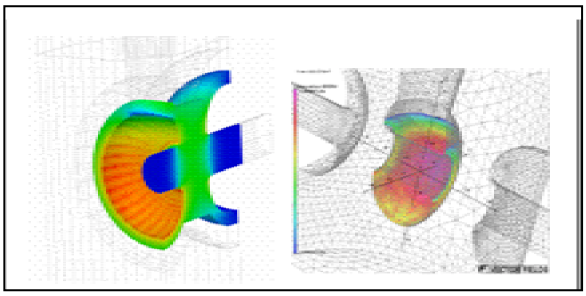

Figure 2: optimization of the SPIRAL2 λ/4 cavity: reduction of Epeak [10]

700 MHz cryomodule

The aim of this project (collab^{n} with IN2P3) is to demonstrate the feasibility of a complete Cryomodule with 5-cell cavities. It includes the design of several monocells and 5-cells cavities and their test with Helium tank in CRYHOLAB [21], the realization of a cold tuning system, the adaptation of the design for the power coupler, the installation of a coupler bench test.

More technological developments are also under study like optimization of the flanges, or protection of brazing against chemicals.

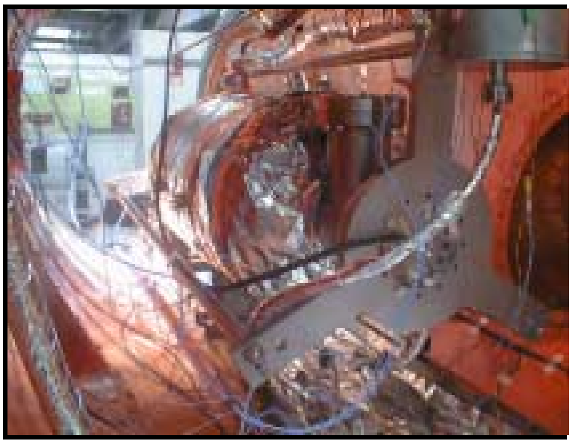

Figure 3: Test in CryHoLab: 700 MHz 5-cell cavity for proton Linac

SYNCHROTRON LIGHT SOURCES

Saclay is now well involved into 3rd generation light sources. In the SOLEIL project, a new concept with two heavily coupled cavities has shown to be very beneficial to the beam life time by lengthening of bunches and also reduction of the beam instabilities due to HOM.

SOLEIL

Saclay was involved in the design of a whole Cryomodule. Fabrication of the 352 MHz cavities, assembly and first tests without beam were done at CERN [22]. In 2002, the cryomodule has been installed on the ESRF ring and four tests at cold, with RF power and beam, have been performed. The cryomodule equipped with LEP2 couplers can accelerate a 170 mA electron beam corresponding to an input power of 190kW per cavity [23]. Thus this cryomodule will be used for the commissioning of the SOLEIL ring (2005), after some improvement of the static losses (shield) and the cooling of the couplers (cryogenic tubing), and the improvement of the notch filter. This final design will be duplicated with a second cryomodule in order to give the needed RF voltage on the fully equipped ring [9].

Magnetostatic and thermomechanical calculation has also been done for lattice dipoles and quadripoles (influence of real geometry, tuning of magnetic length, multipoles coefficients).

Super 3HC

The efficiency of the "SOLEIL" design has conducted to the development of two other Cryomodules, based on the same principle, and dedicated to two presently working synchrotron sources: Elettra at Synchrotron Trieste and Swiss Light Source at PSI. Each cryomodule contains a third harmonic superconducting RF system consisting of two passive 1500 MHz Nb/Cu single-cell cavities (designed at Saclay and fabricated at CERN). Operation of the rings (warm and cold) has been successfully driven, firstly with cavities at room temperature and detuned, and then at 4K with cavities tuned close to the 3rd harmonic. In this bunch lengthening mode, the measurement made at SLS shows a lifetime increase greater than a factor 2 at the design current of 400 mA [6]. At ELETTRA, activation of the 3rd harmonic cavity allows to stabilize longitudinally the beam at 2.0 GeV, 300 mA, due to the Landau damping induced by the cavity. At the same time the beam lifetime is increased by about a factor 2 [7]. See [5] for more details.

4th generation light sources

We have recently started to work in collaboration with IN2P3 on the conception of a future French source (Arc-en-ciel project) based on a 700 MeV SC linac. Different options (SASE/FEL/ERL) are under discussion [24].

TTF-TESLA

TTF

These 2 last years, we were involved in three main actions:

- Collaboration to the measurement of HOM[25], especially in superstructures [26].
- Design of a beam position monitor adapted to cryogenic environment. It will be soon tested on TTF (cryomodule 1) and could be used either in TESLA or X-FEL.
- A new conception for the accelerator protection in case of beam losses, based on differential measurement at the beginning and the end of the machine.

TESLA

We have been involved in the design of most parts of the beam delivery system:

- Beam swith yard : we have adopted a double band achromat arrangement for minimizing the emittancy enhancement by synchrotron radiation
- Fast emergency line.
- We are presently working on the collimation system of the whole line, taking into account all the momentum order effects [27].

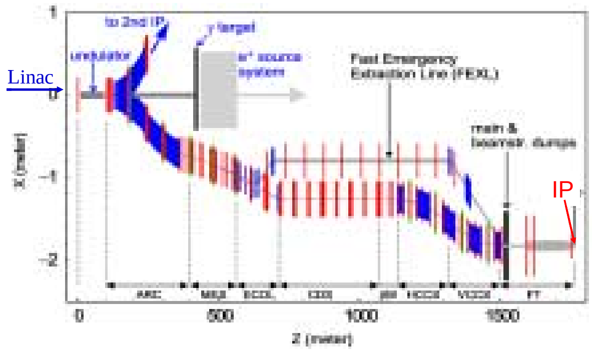

Figure 4: overall optics design of the beam delivery system

BEAM DYNAMICS

Beam dynamics calculation is involved in many different projects. We have been involved in the conception of storage rings (SOLEIL), high energy beam delivery (TESLA, IFMIF), high intensity proton linacs (CONCERT, ESS, SPIRAL 2, IFMIF), electron injectors (TTF) and general conception on projects like ν-factories or hadrontherapy.

R&D IN RF SUPERCONDUCTIVITY

The understanding of the physical origin of limitation is helping us in our race toward high Q_0 and high accelerating gradients. Comparison of cavity tests and sample analysis should give us indication about the origin of thermal dissipations that limit cavities performances.

We are exploring three different approaches:

- Surface morphology: roughness measurements on samples are far from being accurate to measure the morphology of the surface inside the cavity. Moreover the eight of the "steps" is not relevant to explain for instance local field enhancement. By the mean of a replica, non destructive technique, we are now able to explore the morphology of the inner surface of the cavity. Coupled with a temperature map this technique allows to search for specific features in the vicinity of the quench. Moreover, specific topologic analysis permit to make more relevant comparison between surfaces states (cavities as well as samples). See [1]

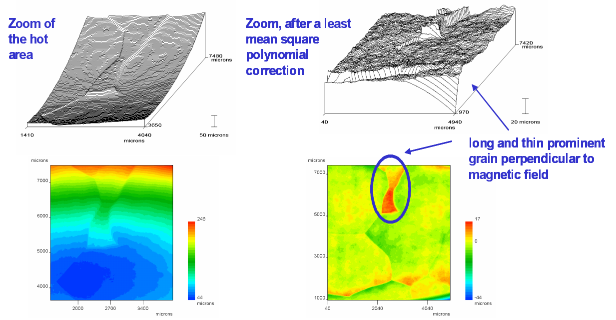

Figure 5: example of a morphological defect found in the vicinity of the quench (localized by a temperature map)

- Surface analysis to study the repartition of contaminants near and under the interface between the oxide and the superconducting matrix. In this conference we present a paper on hydrogen contamination brought by various electrochemical treatments.
- Grain boundaries behavior. In addition to surface analysis, we have some indication that the repartition of impurities inside bulk niobium is far from homogeneous. Surface and grain boundaries segregation

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