# Present design of ELIOS electron linac injector of SOLEIL SR ring

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*Abstract*

This conventional 100 MeV S-band linac, feeding a synchrotron booster, was designed keeping in mind the excellent reliability required. This led us to take two klystrons and two accelerating structures. The goal was to be able at any time to yield an useful beam of 65 MeV in case of one klystron failure. The study aim was to keep a good beam behaviour and a small emittance into both SR ring filling modes: short few pulses for temporal struture operation called single bunch mode and long pulse for multibunch operation. Linac conceptual design and beam simulation results are presented.

## 1 . INTRODUCTION

The SOLEIL project is a 2.5 GeV storage ring with a circumference of 337 m [1]. It is filled at the operating energy using a synchrotron booster and an RF linac. Since the first linac study started in mid 1995 [2] when the $e^+$ $e^-$ options were still conceivables, several new electron Storage Ring light sources were successfull commissioned. Then the SOLEIL Project Group decided to inject the Storage Ring with electron only. The linac and the booster will be located inside the S.R..

This S-band RF linac system (see fig.1) utilizes two 35 MW klystrons and two 3 m accelerating structures to achieve the required performances and ensure a great reliability.

Table 1: linac parameters

General

| | |
|---|---|
| RF frequency | 2998.55 MHz |
| Klystron power | 35 MW |
| No of Klystrons | 2 |
| No of section | 2 + buncher |
| repetiton rate | 12 Hz |

Beam parameters

| | |
|---|---|
| Gun current | 30 or 300 mA |
| Output current | 5.5 or 100 mA |
| Beam pulse width | 2 ns or 300 ns |
| Output charge | 0.2 or 1.6 nC |
| Output energy | 100 MeV |
| Energy spread | < ± 1.5% |
| Output emittance (geometric) | < 1π mm mrad |

## 2 . LINAC DESCRIPTION

### 2.1 Injector

The injector consists of a thermionic gun, a prebuncher cavity, and a standing wave buncher. The 90 keV triode gun produces short single pulse 2 ns FWHM, 300 mA or a pulse train at 352.2 MHz, 30 mA during 300 ns, at the repetition rate of 12 Hz. A single prebuncher cavity in TM010 (3GHz) produces a velocity modulation with ± 9 kV. Finally a 1 meter long standing wave buncher

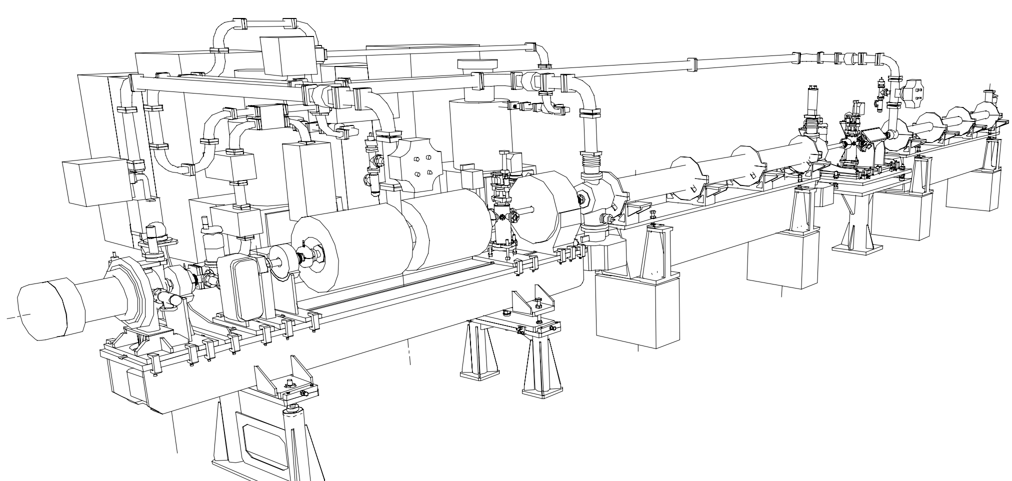

Figure 1. Layout of the linac and RF network, without shielding walls

compresses the bunch into 15 ps and increases the energy up to 15 MeV. The choice of this high energy buncher avoids the use of solenoids on the first accelerating section.

Three small shielded lenses between the gun and buncher ensure the beam focusing at low energy. They are followed by a shielded solenoid over the buncher and a shielded lens after the buncher output. The beam radius is contained into 5 mm.

### *2.2 Accelerator*

The accelerator part consists of two identical Traveling wave sections of 3 m long, working in $2\pi/3$ mode with constant gradient of 16 MV/m for 17 MW RF power input. This RF structure has been studied by Thomson -CSF, and the proposed technology is a cell sealing by a high temperature brazing making the RF structure itself without vacuum leak. In the middle of section a residual pressure of $10^{-8}$ mbar is guaranteed by two 40 l/s ion pumps on input and output wave guides. Between the sections a triplet of quadrupoles ensures the beam transport.

### *2.3 Klystron and modulator*

They are two klystron TH 2100 (Thomson) 35 MW. The first one is feeding the buncher (5 MW) and the first section (17MW), it is running at about 25 MW. The second one feeding only the second section (17 MW) runs at 20 MW. As we see each klystron is underemployed and this is an aspect of reliability. But in case of klystron or modulator failure, the RF network can switch the remaining RF source on the linac front end. The remaining klystron will have then to supply its maximum power (35 MW) and the modulator also (80 MW). Finally the linac is always capable of supplying a 65 MeV electron beam, reasonnably good for the booster.

### *2.4 Power RF network*

An originality of the power RF network is to be able to commute any klystron on the linac front end. But the use of power RF switches constrains us to fill the waveguide by $SF_6$ gaz. The RF network input and output are isolated by RF windows. This arrangement allows to replace a faulty klystron while the linac is running.

### *2.5 Beam Diagnostics*

To verify the good beam transmission along the linac, five fast current transformers (FCT) are used from the gun to the linac output. They must be able to monitor short single pulse of 2 ns FWHM and 300 ns long pulse.

The transverse profile of the beam will be monitored by retractable aluminium-oxide screens. Two charge monitors (integrating current transformer) at the output of linac and transfer line give a right measurement of the total beam charge per macropulse. This allows to measure the transfer line transmission ratio which depends on energy dipersion and beam emittance.

After the first bending magnet of the transfer line, an energy analysing slit limits the beam energy dispersion supplied to the booster to ± 1.5%. Followed by a FCT the slit is also used to measure the beam energy spectrum.

The beam emittance is measured, using the 3 gradients method, in the straight line where a one jaw collimator and a FCT are used to measure the horizontal beam profile.

### *2.6 Vacuum System*

In order to get the lower pressure, especially in the gun and RF structures, 7 ion pumps of 40 l/s are used along the 13 m linac. As the gun vacuum is particularly important for the cathode lifetime, a 50 l/s ion pump keeps the pressure at $10^{-9}$ torr, so we can expect several years of lifetime. Each 3m long accelerating section is pumped out by 40 l/s ion pumps on input and output waveguides. Pressure calculations give $10^{-8}$ torr in the middle of structure where the electric field on the iris is 33 MV/m. Along the 16 m tranfer line 7 ion pumps of 40 l/s keep the pressure at $10^{-6}$ torr. All the elements (ion pump, gauge, valve...) are controled by an automat linked to the main controller.

## 3.THE TRANSFER LINE

Along this 16 m transfer line (see fig.2), 7 Quadrupoles match the beam emittance ellipse from the linac output to the booster entrance acceptance. The booster is injected on-axis, with an energy acceptance of ±1.5 %. After the first bending magnet an analysing slit limits the beam energy spread at the desired value. The straight line is used to measure the beam emittance and allows a fine tuning of quadrupole strengths. See the detailed study in ref [3]

## 4 . INJECTION PARAMETERS

### *4.1 Storage Ring and Booster*

The storage ring may be filled in two modes : (i) multibunch mode (MB mode) that consists of 500 mA in 396 bunches, 2.8 ns apart .The SR is filled 3 or 4 times by quarter or third of circumference by 125 mA in 15 seconds (ii) single bunch mode (SB mode) the SR is filled from 2 to 12 bunches of 40 mA in 40 seconds. The 112 m
circumference booster (Tr = 360 ns) achieves injection and ejection in 300 ns in a single turn mode at the frequency of 12 Hz. Its longitudinal acceptance is 2.8 ns, and its injection energy acceptance is ±1.5 %.

### *4.2 Linac*

In the MB mode, the beam current is chopped at 352.2 MHz in order to decrease the RF structure beam loading, to increase the booster injection efficiency and reduce the radiation production. The linac fills the booster with a pulse train of 300 ns, 1.6 nC at 12 Hz.

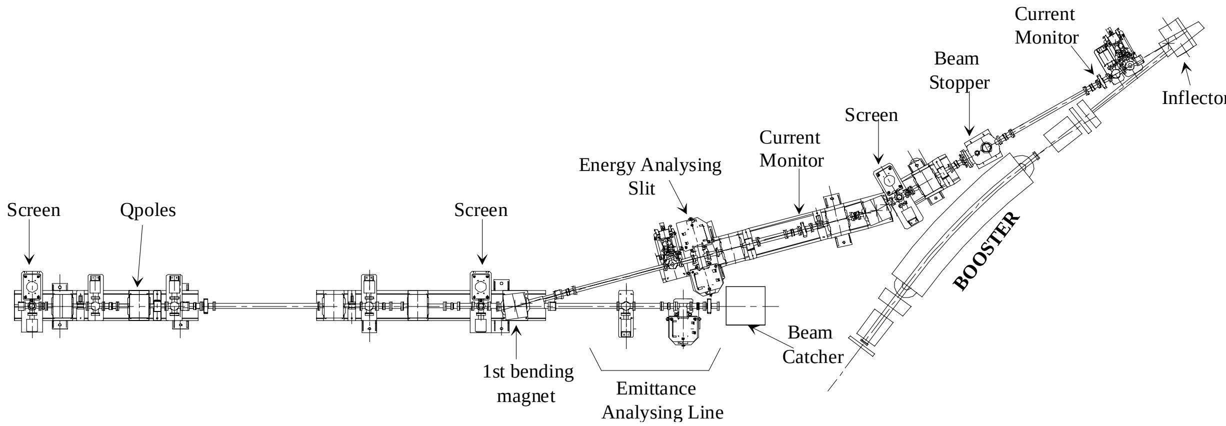


Figure 2. Layout of the Transfer line.

In the SB mode, there are several combinations to fill the SR, but the linac always inject the booster with 2, 3, or 4 pulses of 2 ns, 0.2 nC each at 12 Hz. Table 2 summarizes the injection parameters.

Table 2: Injections parameters

| Mode | ¼ SR filling | Booster current | Output Linac | | | Gun |
|---|---|---|---|---|---|---|
| MB | 125ma in 15 s | 180ma | 11ma | 281ns | 1.6nC | 25ma at 352Mc |
| SB | 2x40ma | 2x60ma | 100ma | 2x2ns | 0.4nC | 250ma |
| | 3x40ma | 3x60ma | 100ma | 3x2ns | 0.6nC | 250ma |
| | 4x40ma | 4x60ma | 100ma | 4x2ns | 0.8nC | 250ma |

## 5. BEAM DYNAMICS SIMULATION

As Thomson-CSF Airsys group studied the RF accelerating structure, they also undertook the beam dynamics study along the linac with the DYPAL code (C. Bourat Thomson). An interesting comparison with the PARMELA code, used by the SOLEIL team, has been performed. The two results are very similar (see the compagnon paper [3]). The simulation on beam dynamics were performed (i) with Egun code for optimize the gun emittance, (ii) with DYPAL and PARMELA codes for determine the bunching efficiency and the beam focusing parameters along the linac. The table 3 gives the simulation results for the hardest case (300 mA). Beam output emittance is $\varepsilon_n$: 155 $\pi$ mm mrad.

Table 3: Beam parameters simulation results

| | Energy MeV | X rad. mm 95% | Y rad . mm 95% | N/No versus phase | Trans. | Energy spread |
|---|---|---|---|---|---|---|
| gun output | 0.09 | 2.5 | 2.5 | 100% in 360° | 100% | |
| buncher input | 0.09 ±0.009 | 3 | 3 | 60% in 70° | 76% | 10% 360° |
| buncher output | 15.7 | 4 | 4 | 60% in 15° | | 1.3% for 60%$e^-$ |
| linac output | 110 | 1.5 | 1.5 | 59% in 15° | 74% | 1.2% for 56%$e^-$ |

## 6 . CONSTRUCTION AND SCHEDULE

Two approaches have been considered (i) turnkey system from only one manufacturer (ii) the SOLEIL team takes the responsability of the manufacturing, although some parts as klystrons, RF structures will be purchased from specialised manufacturers, and others ones as modulators, gun, magnets... would be made in collaboration with other laboratories and small manufacturers. The linac study always has been performed with the second way in mind, but as long as we are waiting for the building decision, the turnkey approach can not be out of question. From the starting signal it has been planned 2 ½ years to get an operational linac, including: orders, assembly and tests.

## 7 . ACKNOWLEDGEMENTS

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## 8 . REFERENCES

[1] M.-P. Level et al., *Status report of the SOLEIL project, PAC 97, Vancouver.*

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[3] M.-A. Tordeux et al.,*Theoretical study of the 100 MeV linac, injector of the SR ring SOLEIL, These proceedings*.