RF SYSTEM FOR THE ELETTRA NEW FULL ENERGY BOOSTER INJECTOR

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Abstract

The Elettra new full energy injector will be based on a 100 MeV linac and a 2.5 GeV booster synchrotron and it will replace the existing 1.2 linac injector. This paper presents the design, construction and the test results of the RF system for the booster synchrotron. The analysis of the foreseen operating scenario is also described. The system must be as simple and reliable as possible, taking into consideration the high availability required for the possible top–up mode of operation. It has also to be consistent with the other upgrades of the facility, as the upgrade of the storage ring RF system. The booster RF system will use a 500 MHz 5-cell copper cavity powered by a 60 kW klystron based power plant. The low level electronics has been in-house developed, starting from the system in operation in the storage ring, increasing the performances and developing the new features required by the use of a five-cell cavity, instead of a single cell one, and by the ramped operation. The commissioning of the new injector is scheduled to start in summer 2007, while the first Elettra operation for users with the new full energy injector is expected for the first quarter of 2008.

OVERVIEW

The construction of the new injector for Elettra is advancing. The new injector will be made of a 100 MeV linac and a 2.5 GeV booster synchrotron at 3.125 Hz repetition rate [1]. Top-up operation shall be possible.

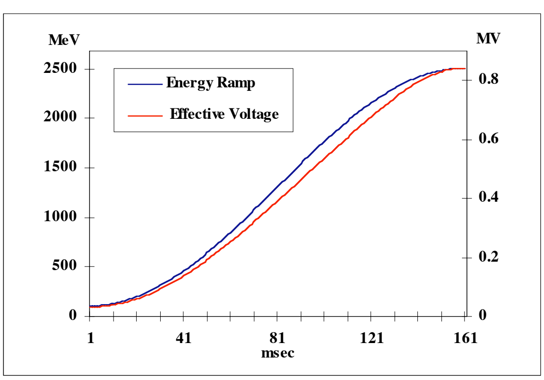

Figure 1: Voltage and beam energy ramps.

The RF system for the booster has to satisfy some basic requirements. The RF frequency is the same as the storage ring to assure the matching between the two machines. At extraction the RF system has to provide sufficient lifetime for the beam. The design quantum lifetime at 2.5 GeV is 1 second, a value sufficient for the extraction keeping the RF voltage requirements in a reasonable range. It must be noted that at the same voltage, quantum lifetime will be much higher at the usual operating energies of Elettra for users (2 and 2.4 GeV). At injection sufficient energy acceptance must be provided for the beam injected from the linac, but the RF voltage should be relatively smaller compared to the value at the extraction for longitudinal capture optimisation. Therefore the RF voltage has to be ramped as beam energy. Figure 1 shows the voltage ramp, calculated keeping the synchrotron frequency constant.

TECHNICAL DESCRIPTION

The design parameters of the system at the extraction energy are listed in table 1 for the nominal and the low emittance optics [2].

Table 1: RF system design parameters at 2.5 GeV

	Nominal	Low Emitt.	
Beam energy	2.5	2.5	GeV
Beam current	5	5	mA
Energy loss	388	388	keV
Harmonic number	198	198	
Revolution freq.	2.524	2.524	MHz
RF frequency	499.654	499.654	MHz
Mom. compaction	0.0433	0.0308	
Quantum lifetime	1	1	sec.
Overvoltage factor	2.16	1.58	
Total RF voltage	840	730	kV
Energy acceptance	3.07E-3	3.07E-3	
Cavity power	25.20	19.03	kW
Beam power	1.94	1.94	kW
Total RF power	27.14	20.97	kW

Cavity

Two options were considered for the cavity:

- Single cell cavity. In this case the adoption of Elettra type cavities was considered. These cavities were designed and built for Elettra and also provided to other light sources (such as Campinas, Anka, SLS and Indus II). In this case all the know-how for the construction and operation is well established in the lab.
- Multi-cell cavity. In this case the use of a 5-cell cavity was considered, since it can be acquired as a turnkey component from industry.

Due to the voltage required at the extraction in the first case two cavities are needed, while in the second case one is sufficient. Also lower RF power is needed in the 5-cell case and of course this has an important impact on costs. For a booster and for the design current, multibunch instabilities will not be an issue, so it was decided to buy a 5-cell PETRA type cavity from Accel GmbH.

The cavity has been installed and tested in the high RF power test stand of the laboratory. Following the low power characterization (measurements of frequency, Q, tuning range, etc.) and the bake out, the cavity was conditioned up to 54 kW cw, i.e. two times the foreseen operating power. There were some difficulties to complete the conditioning due to multipacting thresholds that were very hard to pass in the range below 8 kW. This could be partially related to the provisional vacuum equipment installed and to the low vacuum threshold interlock (1e-7 mbar) that was set during the conditioning. However finally this process could be completed and the cavity operation has been established, although a clear pressure bump is still evident while crossing this range.

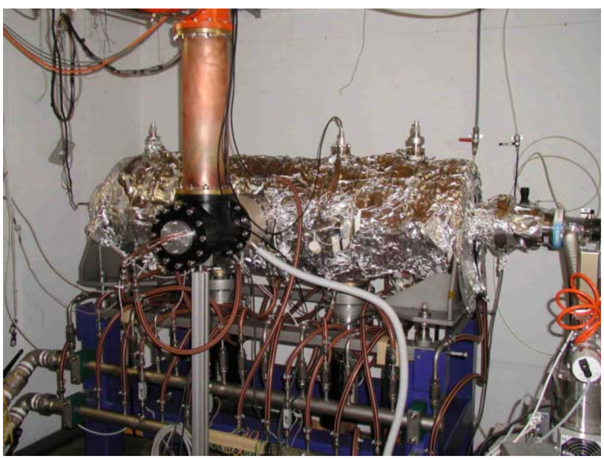

Figure 2: The 5-cell cavity in the lab test stand.

Power Plant

According to table 1 and considering some margins to take into account the losses in the transmission line, the power amplifier must be able to deliver 30 kW.

For the power amplifier it was possible to take profit of the ongoing upgrade of the storage ring RF plants, which has released one complete 500 MHz 60 kW plant [3]. The power amplifier uses a TV klystron from E2V as the final stage. A 75 kW circulator from AFT is used to decouple cavity and power amplifier. Power transmission is performed by means of rigid 6 1/8" coaxial lines.

Particular concern has been dedicated to availability issues, which are quite important since the system is expected to work continuously when top-up operation is established. For this reason till the beginning the possibility of installing a second amplifier in the future has been considered in the design of the system. This will be a similar 60 kW amplifier that will be released when the second phase of the upgrade project of the storage ring RF system is completed. A three ports high power coaxial switch will be used to connect the cavity to the amplifier in operation, without the need to dismount the transmission lines when switching from one amplifier to the other.

Figure 3. The power amplifier and the circulator.

Low Level System

The low level system has the task to control and regulate the driving signal to the power amplifier, keep the cavity tuned, regulate amplitude and phase of the cavity field. The system is based on the one designed for Elettra with the modifications adopted for the Diamond booster low level electronics built by Elettra [4].

A frequency and field flatness loop keeps the cavity tuned compensating for beam loading and temperature effects. It has also the task to correct excessive unbalance of the fields between the cells. For frequency tuning, a phase comparison is made between the sample of the field in the cavity's central cell and the input power to the cavity. For amplitude balance, the samples of the field in cells 2 and 4 are compared in amplitude. In both cases the error signals drive the plungers: either simultaneously for tuning or separately for balance [5]. Sensitivity of the frequency loop can be set at ± 100 Hz, ± 500 Hz or ± 1000 Hz, with an open loop bandwidth of 200 Hz. The balance between the voltages measured in the cells is kept in a ± 5% range by the field flatness loop. The system is synchronized to the booster ramp. This also avoids excessive operation of the plunger's motors.

Cavity gap voltage is regulated by an amplitude loop, which regulates the driving power to the amplifier by means of a voltage controlled phase-free attenuator. The loop compares the sample of the cavity field to the required value. The result of the comparison drives the variable attenuator. By means of the amplitude loop the cavity voltage will be set according to the desired 3.125 Hz waveform. Regulation of the loop will be better than ± 1% with open loop bandwidth variable up to 3 kHz.

Phase stability in a ± 0.5 degrees range at all operating levels of the cavity input power is assured by a phase loop. The phases of the plant driving signal and of the cavity input power are compared. The output of the phase detector drives an electronic phase shifter. Open loop bandwidth will be variable up to 2 kHz, therefore high enough to counteract the effects from the ripple of the klystron high voltage power supply at 600 Hz.

All the loops have a dynamic range higher than 20 dB and can be operated either in closed or open loop mode.

A remotely controlled 500 degrees mechanical phase shifter performs the phasing of the booster RF plant to the storage ring RF and linac pre-injector.

A fast pin diode switch will be used to apply/remove the RF drive. It will be driven either by the operator or interlocks. For personnel safety in addition to the fast pin diode there will be two coaxial relays.

RF Distribution

The RF distribution system provides the 500 MHz signals for storage ring and booster RF and for the linac pre-injector. In addition it provides the reference to different systems of the facility such as timing, bpm, feedbacks, etc. The construction of the new injector requires an upgrade of the existing system. Although in operation only one RF master oscillator will be used for all the machines, the possibility of driving each machine with its own oscillator is foreseen during the commissioning period. The distribution of the 500 MHz will be performed with low loss air dielectric coaxial cables.

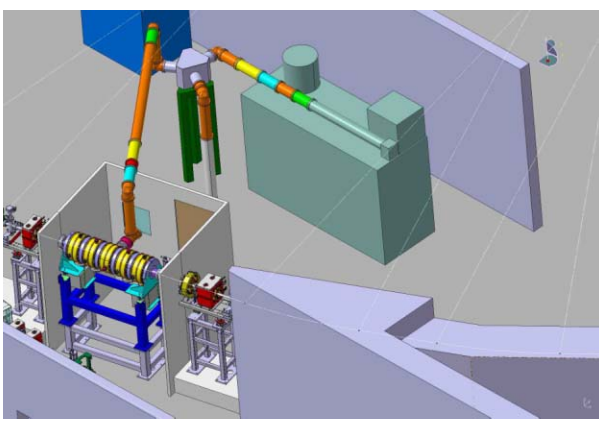

Figure 4: Layout.

Layout

All the components of the power plant will be installed in the booster service area. The layout of the system is very compact to minimise space requirements. The transmission line will run at 2.75 m. height in order to allow the passage of people and equipment. Since there is no wall to separate tunnel and service area, a dedicated shielding will be mounted to allow the setting into operation of the cavity. Figure 4 shows the foreseen layout.

The possibility of installing a second amplifier as a reserve system has been taken into consideration and space has been reserved for this purpose.

CONSTRUCTION STATUS AND INSTALLATIONS

The cavity is in the RF laboratory test stand, ready to be moved to the new booster service area. The power amplifier, circulator and dummy load have been dismounted and moved to the booster service area.

The low level system is under assembly. Amplitude and phase loops have been tested at low and high power on the five-cell cavity, therefore almost in the real situation. All the specifications have been met. The frequency and fields flatness loop and the remaining components of the low level system are under test in the second half of June 2007. It must be noted that the low level system is equal to the one built for the Diamond booster and now in operation from beginning of 2006.

Installation of the booster RF system will start at beginning of July 2007. A two months period is foreseen for installation, testing and commissioning of the RF system without beam.

CONCLUSIONS

The construction of the new Elettra booster RF system is well advanced. Cavity and power plant are ready for installation. The low level system is being tested.

The commissioning of the booster will start at end of August 2007 and in Fall 2007 the connection to the storage ring is planned. The operation of Elettra with the new injector is foreseen at the beginning of 2008.

The possibility to upgrade the booster RF system with a spare amplifier has been examined. This will increase the availability of the system, especially in view of the foreseen top-up operation.

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