RF SYSTEM FOR THE ANKA BOOSTER SYNCHROTRON

A. Fabris, C. Pasotti, M. Svandrlik, Sincrotrone Trieste, Trieste, Italy
D. Einfeld, F. Perez, S. Voigt, FZK, Karlsruhe, Germany

Abstract

The booster synchrotron of the 2.5 GeV synchrotron light source ANKA, under construction at FZK, Karlsruhe, will ramp the energy of a 10 mA beam from 50 MeV to 500 MeV (injection energy to the storage ring) with a repetition rate of 1 Hz. The RF system will use a simplified ELETTRA cavity powered by a 200 W cw RF plant. The operating frequency will be the same of the storage ring (499.652 MHz). In this way it will be ensured that the time structure of the bunch train at extraction from the booster will fit comfortably in the storage ring RF buckets. The low level electronics will include, apart from a phase shifter to adjust the phase between the booster and the storage ring RF systems, a frequency tuning loop for the cavity and an amplitude loop. The system has been designed in order to be as simple as possible while still satisfying the requirements for reliable and efficient operation. A general description of the system and the status of the design and construction is reported together with some considerations of the effects of beam cavity interaction on the whole RF system.

1 INTRODUCTION

The ANKA synchrotron light source, under construction at FZK, Karlsruhe, Germany, will be a 2.5 GeV 400 mA storage ring [1]. The injector will consist of a 50 MeV microtron followed by a 500 MeV booster synchrotron. The booster nominal electron beam current is 10 mA with the possibility to operate also at 15 mA. The repetition rate of the booster will be 1 Hz.

The design of the booster RF system is governed by the requirements that the system has to be as simple, conservative and efficient as possible, taking into account the high reliability required. It will consist of one RF cavity powered by a 200 W cw RF plant, together with the related low level electronics.

2 RF SYSTEM REQUIREMENTS

The main parameters of the booster RF system are listed in table 1. The booster will make use of a 499.652 MHz RF system as will the storage ring. The choice of the same frequency will assure that the time structure of the bunch train at the extraction from the booster will fit comfortably in the storage ring RF buckets. Notwithstanding the larger momentum compaction factor in the booster compared to the storage ring (0.27 compared to 8.1 10^{-3}), the rms bunch length in the booster will be only about 131 psec (39 mm) at 500 MeV, which can easily be accepted into the 250 psec storage ring energy acceptance.

At injection into the booster, the RF system has to provide sufficient energy acceptance for the injected beam. At the lower energies, the minimum required cavity voltage is determined by the electron energy increase due to the ring magnet field. At the higher energies, the dominant term will be the synchrotron radiation losses. The necessary RF voltage at the end of the cycle will be determined by the requirement of having a sufficient longitudinal quantum lifetime. Based on calculations performed, it is planned to maintain constant the RF voltage throughout the entire accelerating process. However, the architecture of the system allows to vary it by simply changing the reference level of the amplitude loop which could be easily achieved by an amplitude program generator. This could be used in case, although not expected, the bucket size at injection would produce too large a deviation leading to particle losses.

Table 1: Booster RF System Parameters

Energy	50 - 500	MeV
Beam current (nominal)	10	mA
Beam current (maximum)	15	mA
Energy loss per turn	3.3	keV
Harmonic number	44	
Revolution frequency	11.4	MHz
Momentum compaction factor	0.27	
Energy spread	3.3E-4	MeV
Longitudinal damping time	13.7	msec
RF frequency	499.652	MHz
Synchrotron frequency	110	kHz
Synchronous phase	7.6	degrees
Energy acceptance	0.15	%
Bunch length	39	mm
Overvoltage factor	7.5	
Number of cavities	1	
Effective cavity voltage	25	kV
Cavity wasted power	104.2	W
Beam power (10 mA)	33	W
Total RF power	137.2	W

3 DESCRIPTION OF THE SYSTEM

The RF system can be split into three subsystems: cavity, power plant and low level electronics.

A block diagram of the booster RF system is shown in figure 1.

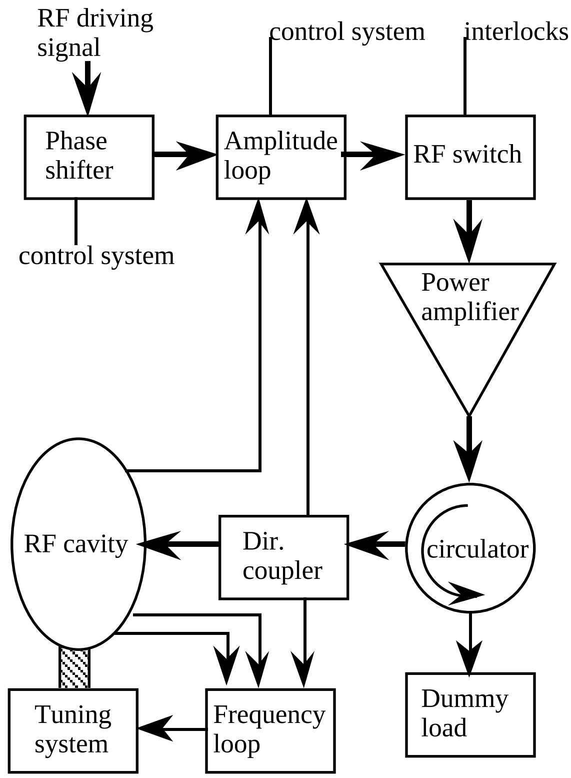

Figure 1: Block diagram of the booster RF system

3.1 RF Cavity

The RF cavity will be a single cell, bell-shape cavity resonating at 499.652 MHz. It will be a simplified version of the cavities mounted in the storage ring [2], i.e. it will have the same internal profile as an ELETTRA cavity but with a much simpler external profile. It will be made of normal conducting oxygen free copper designed to operate in an ultra high vacuum environment. The nominal axial length and the internal diameter will be respectively 480 and 526 mm. Quality factor will be higher than 38000 and the shunt impedance will be larger than 3 MΩ.

Tuning of the cavity will be performed by means of a plunger, the expected tuning range will be higher than 1 MHz and the speed will be between 1 and 10 kHz/sec. RF power is fed to the cavity by means of a coaxial vacuum feedthrough. Coupling to the cavity is obtained by means of a coupling loop. The vacuum to air transition is made with an alumina ceramic window. Besides the main coupler port, other five ports are installed on the equatorial surface for the measurement pick-ups and the connection to the vacuum devices (pump and measurement gauge). Cooling to the cavity is provided by copper pipes brazed on the cavity surface. Since the cavity has to handle a maximum power of 200 W the cooling is simplified compared to the storage ring cavities. Unlike the storage ring cavities there is also no need for a sophisticated cooling system to stabilise the cavity temperature.

3.2 Power Plant

The power plant is designed for 200 W cw RF power, which gives a safe margin compared to the power requirements (about 140 W) also taking care of the losses in the transmission line. The working frequency is well inside the UHF television band and the power required is as well inside common commercial values.

The solid state amplifier will be a 200 W cw solid state class AB amplifier, with a -1 dB bandwidth larger than ±2 MHz around the central working frequency (499.652 MHz). It will be derived from an UHF TV commercial transmitter. The RF input power will be a 10 mW signal provided by the low level electronics system. Power stability will be 1 % at each rated output and the phase stability ± 3 degrees. Cooling of the amplifier will be performed with forced air. All the setting and the main parameters of the amplifier are available for remote control. An adequate level of interlocks (overpower, overtemperature, VSWR protection) will protect the amplifier by automatically switching it off in case of malfunctioning.

Although these solid state amplifiers have a quite good capability to work also under high reflection conditions, nevertheless a circulator is used to decouple cavity and amplifier. Besides protecting the amplifier, this will assure that the possible reflected wave from the cavity always sees a matched load. In this way the beam will always see the parallel of the equivalent shunt impedance of the cavity with the constant transferred impedance of the amplifier. The circulator is a 500 W UHF circulator. The choice of higher power circulator has been required by the fact that normal TV circulator power specifications are defined as the maximum power the circulator can handle when one port is terminated with a VSWR equal to 2 and the following one is matched. Since the cavity could give a VSWR even higher than 2 in some particular cases (for example beam losses) and the cost difference was not high, it was decided to have this higher power circulator. Insertion loss of the equipment is below 0.1 dB and the isolation is better than 25 dB.

Other components of the power plant are a 250 W load and a 250 W directional coupler which will be placed between circulator and cavity to provide the necessary signal for the frequency loop. Power transmission will be performed by 7/8" flexible coaxial cables. As is well known, these cables have an air dielectric (the content of dielectric being limited to the support of the central conductor) and are rated for much higher power than 200 W at 500 MHz. For this reason they are not expected to give any effect on phase stability of the RF power.

3.3 Low Level Electronics System

The low level electronics system will include a frequency loop for the cavity, an amplitude loop, together with a mechanical phase shifter and an interlock switch.

The low level electronics system is basically equal to the one of the storage ring (for a detailed description see [3]). The main difference is that no phase loop is required for the booster RF plant, since it was not necessary due to the small phase variations expected in the power plant.

The frequency loop will keep the cavity tuned, compensating for beam loading and temperature effects. It will compare a reference signal (from the directional coupler before the cavity) to two other signals, opposite in phase, picked up from the cavity. The output of the frequency loop will drive the motor of the tuning plunger. Window detectors are used to inhibit the tuning if the error signal exceeds pre-set limits. Limiting blocks are also used in case the window detector fails. Sensitivity of the loop will be either 100 and 500 Hz. The open loop 3 dB bandwidth will be 200 Hz and the open loop dc gain will be 36 dB (100 Hz sensitivity) or 23 dB (500 Hz sensitivity). The tuning speed range will be from 1 kHz/sec to 10 kHz/sec. The only difference compared to the storage ring frequency loop will be that the motor driven by the frequency loop will drive a plunger instead of a tuning cage which compresses or stretches the axial length of the cavity.

The amplitude loop will keep the cavity gap voltage stable in a 1 % range counteracting the beam loading effect. The amplitude loop will control the driving signal to the amplifier. In this way the output power of the amplifier will be regulated so as to give the required beam power, while keeping constant the power wasted on the cavity walls. The loop will compare a sample of the cavity field picked-up in the cavity to the reference signal provided by the control system. The error signal will drive a voltage controlled variable attenuator which will regulate the amplifier drive power. The open loop 3 dB bandwidth will be selectable in eight steps between 30 Hz and 4 kHz. The open loop 3 dB gain will be 30 dB and the recovery time will be less than 6 msec. The main difference compared to the storage ring amplitude loop will be that the amplitude loop for the booster will obviously control one cavity instead of two as in the storage ring.

A coaxial RF switch will enable the application of the driving signal to the booster power amplifier. This will also react to interlocks signals for protection of the system. For example the signals from the cavity vacuum measurement or the end range switches of the tuning system will cut the RF power.

A 500 degrees at 500 MHz mechanical shifter will set the relative phase of the booster RF plant compared to the storage ring plants. This will allow to optimise the injection from the booster into the storage ring.

4 STATUS

The fabrication of the booster cavity and tuning system will start in the near future, following the construction of the first storage ring cavity. The power amplifier has been completely specified and the manufacturer has been chosen. It will be constructed by an Italian company. The other components of the power plant have been already acquired and tested, except the power transmission cables. The construction of the low level electronics system will be done in parallel with the fabrication of the low level electronics for the storage ring RF plants. The two racks that will host the low level system have been acquired and they are now being equipped.

The acceptance test of the booster RF system will be performed at Trieste at the beginning of March 1999. Afterwards it will be moved to Karlsruhe to be installed in the booster synchrotron, whose commissioning will start in September 1999.

5 CONCLUSIONS

The RF system for the ANKA booster synchrotron has been completely designed and its construction is advancing. Efficiency and reliability will be assured by the conservative choice of the parts of the system. The cavity is a simplified version of the ELETTRA cavities, which are well tested. The components of the power plant are equipment which are equal or derived with minor modifications to industrial ones, therefore having the advantage of being completely tested. Finally also the low level electronics system of the booster as well as the one of the storage ring is based on the ELETTRA one, which has been in operation for many years.

REFERENCES

[1] ANKA Team, "Status of the 2.5 GeV Light Source ANKA", this Conference.

[2] A. Fabris, C. Pasotti, P. Pittana, M. Svandrlik, D. Einfeld, F. Perez, S. Voigt, "The ANKA RF cavities", this Conference.

[3] A. Fabris, C. Pasotti, M. Svandrlik, D. Einfeld, F. Perez, S. Voigt, "Low Level RF System for the ANKA Storage Ring", this Conference.