THE DIAMOND RF SYSTEM

D M Dykes, CLRC Daresbury Laboratory, Warrington, WA4 4AD UK

Abstract

The RF System for the proposed 3 GeV UK Light Source, DIAMOND needs to provide an accelerating voltage of 5.1 MV and sufficient RF power to make up synchrotron radiation losses of up to 2.5 MeV per turn for a beam current of 300 mA. The technical design and feasibility, as well as the economics of various accelerating structures, are discussed. Amplifier and feeder options are assessed, and possible system layouts are shown.

1 INTRODUCTION

The RF system for any particle accelerator has to provide the accelerating voltage and make up the power losses of the beam no matter the cause. This paper describes possible solutions for the RF system for the proposed UK Light Source DIAMOND [1].

Firstly the basic parameters that affect the RF systems for both the storage ring and the booster synchrotron are examined, and an RF specification derived. Possible system components are identified, and the important components such as the RF cavity are examined in some detail. Finally a complete alternative system is discussed.

2 STORAGE RING RF SYSTEM

Table 1 gives the basic parameters of DIAMOND which affect the RF system.

Table 1. DIAMOND Parameters affecting the Storage Ring RF system.

Energy	3 GeV
Current	300 mA
Magnet Bending Radius	7.128 m
No. Multipole Wigglers	9
No. S/C Dipoles	4
Radiation Loss/turn	2.24 MeV
Momentum Compaction	0.00086
RF Acceptance	3 %

The RF frequency has been chosen to be 500 MHz. Short bunch lengths are required by several of the potential users, many system components are available at 500 MHz, and the sizes of the components are easily handled and fitted into the storage ring.

To achieve the required energy acceptance, with the given radiation loss per turn, an overvoltage of 2.28 is necessary. This gives the required acceleration voltage of 5.1 MV. Assuming that a total of 21 MΩ RF impedance in the storage ring is easily achievable, and that a single cell cavity can hold off 0.85 MV, then the necessary RF parameters are given in Table 2.

Table 2. Basic Storage Ring RF System Parameters.

Cavity Voltage	5.1 MV
No. Cavities	6
Cavity Shunt Impedance	3.5 MΩ
Voltage/cavity	0.85 MV
Cavity Quality Factor (unloaded)	30000
RF Frequency	499.654 MHz
Overvoltage	2.28
Synchrotron Frequency	9.6 kHz
Quantum Lifetime	1E205 hrs
Radiation Damping Time	0.76 ms
Natural Bunch Length	13.7 ps
Total Beam Power	670 kW
Total Cavity Power	620 kW
Required Cavity Coupling	2.1
Window throughput Power	215 kW
Total Source Power	1420 kW

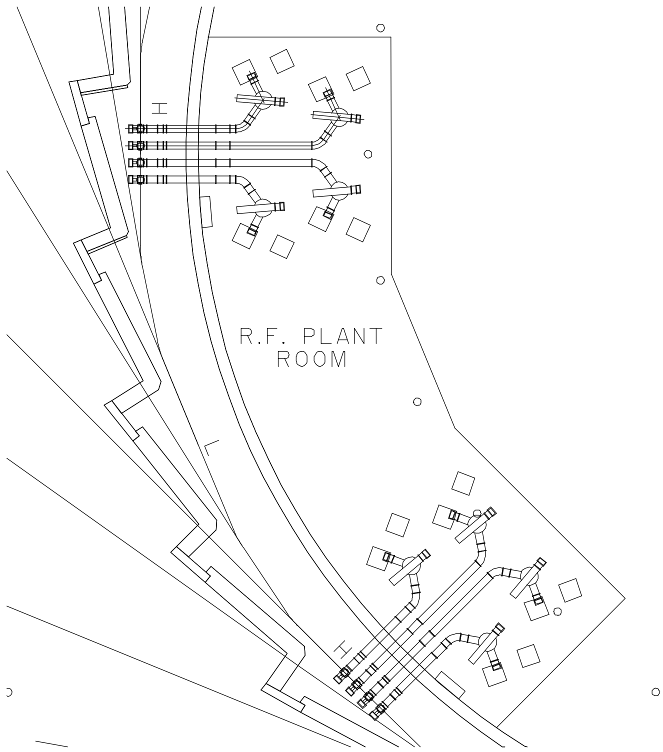

Figure 1. RF Layout.

The storage ring RF system will consist of 6 normal conducting cavities, each with an effective shunt impedance of 3.5 MΩ. Each cavity will be powered from a 250 kW klystron via a waveguide feeder system. A possible system layout is shown in Figure 1.

The figure shows 8 cavities, but 2 of the cavities will be installed later as an upgrade as and when more RF power is needed, for example when powerful insertion devices are installed in the two long straights.

It will be possible to operate any one cavity-klystron system at a frequency one orbit harmonic different from the fundamental RF frequency to provide a further tool to overcome possible HOM’s.

3 BOOSTER SYNCHROTRON RF SYSTEM

Table 3 gives the basic parameters of the DIAMOND booster synchrotron [2] which affect the RF system design

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Table 3. Booster Synchrotron Parameters affecting RF System.

Final Energy	3 GeV
Current	20 mA
Magnet Bending Radius	8.862 m
Radiation Loss/turn	808.5 keV
Momentum Compaction	0.025
Required Quantum Lifetime	1 s

From the above parameters, the RF system parameters are determined as in table 4.

Table 4. Basic Booster RF System Parameters.

Cavity Voltage	1.6 MV
No. Cavities	2
Cavity Shunt Impedance	3.5 MΩ
Voltage/cavity	0.8 MV
Cavity Quality Factor (unloaded)	30000
Overvoltage	2.0
Quantum Lifetime	160 s
Total Beam Power	16 kW
Total Cavity Power	183 kW
Total Source Power	202 kW

Two cavity-klystron systems of the same type as used in the storage ring will be used for the booster RF, but the klystrons will be operated at a lower HT voltage. Common low power systems, as used in the storage ring, will be utilised.

4 RF SYSTEM COMPONENTS

4.1 RF Cavity

A possible cavity shape to achieve the effective shunt impedance under the required operating conditions is described by McIntosh [3], including details of the higher order mode (HOM) spectrum.

However, the detailed engineering design needs further consideration, with particular attention to ;-

1. the tuning mechanism,
2. the cooling system, and
3. the power coupling system.

4.1.1 Cavity Tuning

The frequency tuning of the RF cavity can easily be made using a non contacting plunger as on the SRS cavities and elsewhere, however, recent experience at Daresbury [4] has shown that the normal plunger movement over a beam decay causes a beam movement of >20 μm horizontally and >10 μm vertically. This must be avoided in DIAMOND. Tuning by longitudinally squeezing the cavity, as at ELETTRA [5] is under active investigation. A non automatic plunger tuner is still an essential tool to combat HOM’s.

4.1.2 Cavity Cooling

Particular attention needs to be paid to the cooling of the cavity. As can be seen from table 1, the power dissipated in each cavity to provide the required acceleration voltage is >100 kW. If the cavity body temperature is kept constant by having a temperature probe at one point, with a water flow of 400 l/m there will be a temperature rise in the water between input and output of 4 °C. Clearly the water flow has to be directed carefully as non uniform temperature gradients can cause distortions in the cavity geometry and consequent changes in the frequency.

A powerful method to control the HOM spectra of a cavity is to change the temperature - giving a small change in the fundamental frequency, but moving the mode frequency by a large amount. So the cooling system has to operate over a range of at least 60 °C, and to be controlled to <0.1 °C.[6]

4.1.3 Power Coupling

The throughput power of the cavity coupler is high at >215 kW. No particular type of coupler has been chosen at present, but various schemes are under investigation. Both the window for the superconducting cavity at CESR [7] and for the cavity for the SLAC B-Factory [8] have operated at greater power levels than those required for DIAMOND.

Alternatively one of the klystron manufacturers could be commissioned to develop a cavity window based on the output coupling loop from a high power klystron.

4.2 Feeder System

The power feed from the RF power source to the cavity will be waveguide WR 1800. Commercially available circulators will be used to isolate the cavity, and provide a matched load for the klystron. Monitoring directional couplers will also be incorporated, but at present no special waveguide components, such as filters, are being considered

4.3 RF Power Source

The power sources will be 250 kW high power, high efficiency klystrons; these are available from a number of manufacturers. For the booster synchrotron, as the power requirement per tube is only 100 kW, the HT voltage will be turned down to increase the electrical efficiency.

The Daresbury designed crowbarless klystron power supply [9] will be used in all cases.

4.4 Low Power RF System

The low power RF system for DIAMOND is detailed elsewhere [10]. As one klystron feeds one cavity, the high power feeder system is relatively simple: phase and amplitude control will be achieved in the low power system. Provision will also be made for both plant and personnel safety.

5 ALTERNATIVE RF SYSTEM

Until recently superconducting RF systems for light sources have rarely been considered. They were regarded as too complex and costly:

1. The enormous beam power compared to the cavity power, results in the necessity to provide complex accurate feedback systems to prevent system instability; either sudden loss of beam or gross phase changes in the beam.

2. Development of superconducting RF systems for a relatively low number of cavities is expensive. However systems could be developed by a number of Laboratories in collaboration, reducing the development costs and sharing the tasks.

The main advantage of using a superconducting system over the warm system is the ability to damp all the monopole modes and the significant dipole modes [3] [7].

The shunt impedance of the superconducting cavity would be at least 10,000 greater than a normal conducting cavity. For DIAMOND this means that the total power needed would be halved. Therefore for the storage ring 3 cavities would be fed by 3 klystrons and only one cavity-klystron system would be needed for the booster. The capital cost of a complete superconducting RF system for DIAMOND would be comparable to a warm system, whereas the running costs would provide significant savings. Too little data is presently available to predict the operational efficiency of a superconducting system for a light source.

6 SUMMARY

At present it is assumed that the DIAMOND storage ring RF system will consist of six 250 kW klystrons feeding 6 normal conducting cavities, and the booster will have two cavity-klystron systems.

However, superconducting technology is not ruled out, and developments are being actively investigated.

REFERENCES

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