ILC-LNF TECHNICAL NOTE

Divisione Acceleratori

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Note: **ILC-LNF-001**

RF SYSTEM FOR THE ILC DAMPING RINGS

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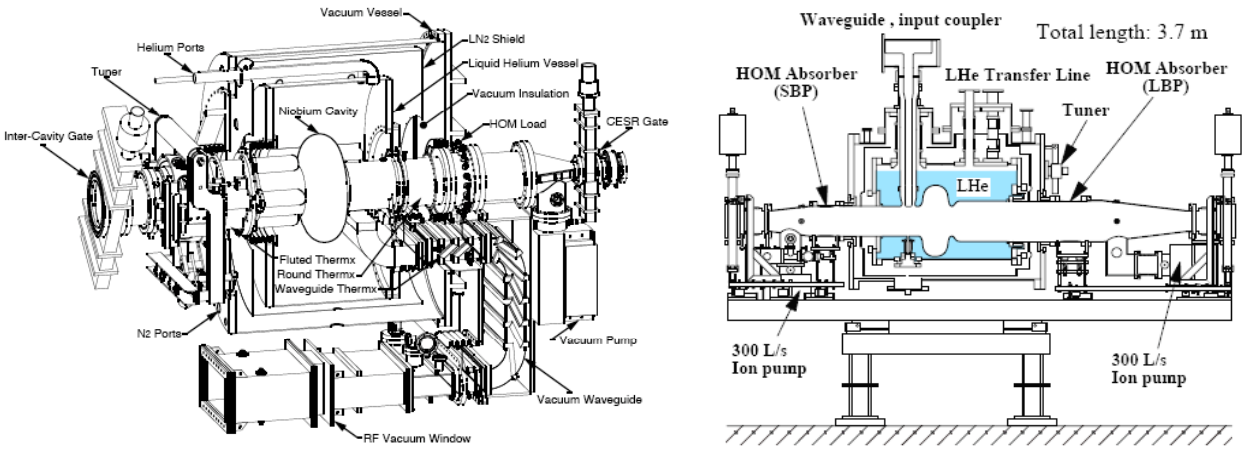
Introduction

For the ILC damping rings, the frequency of 650 MHz has been proposed because of the simple relationship with the main Linac radiofrequency, 1300 MHz. Table 1 reports the DR parameters that are significant to the RF system design.

Currently, high power 650 MHz RF sources are not commercially available. However, some major klystron manufacturers can develop them by modifying 500 MHz klystrons of equivalent power level. The RF accelerating units may be derived by modifying the 500 MHz single cell superconducting modules (see Fig. 1).

SC modules, consisting of 500 MHz Nb single cell, housed in a fully equipped cryostat, have been developed and currently are in operation successfully at CESR, KEK and elsewhere. A number of cryo-modules, with well defined operating parameters, are also produced turn-key by the industry upon technology transfer agreement with the Cornell University and KEK. The outline dimensions of a cryo-module are 3.5 m in length and 1.5 m in diameter.



CESR Cryo-Module KEK-B Cryo-Module

Figure 1: 500 MHz cryo-modules utilized in accelerator rings.

Table 1: Damping rings RF system parameters

	e-	**2 x e+**
Energy (GeV)	5	5
Number of bunches per train	2767	1384
Number of particles per bunch	2.0×10^{10}	2.0×10^{10}
Average current (amps)	0.40	0.20
Energy loss per turn (MeV)	8.7	8.7
Beam power (MW)	3.5	1.7
Bunch current (mA)	0.14	0.14
Total RF voltage (MV)	46.6	46.6
Circumference (km)	6.695	6.695

In the electron and positron rings, the beam power and the total RF voltage may be shared among 32 superconducting cavities (KEK or CESR-like). In the present version, the damping rings design includes 4 straight sections. Since the total length of each cryo-module is 3.5 m, to accommodate 8 SC cavities in each straight section the length of each RF section should be at least 30 m. Figure 2 depicts the layout of the RF distribution system.

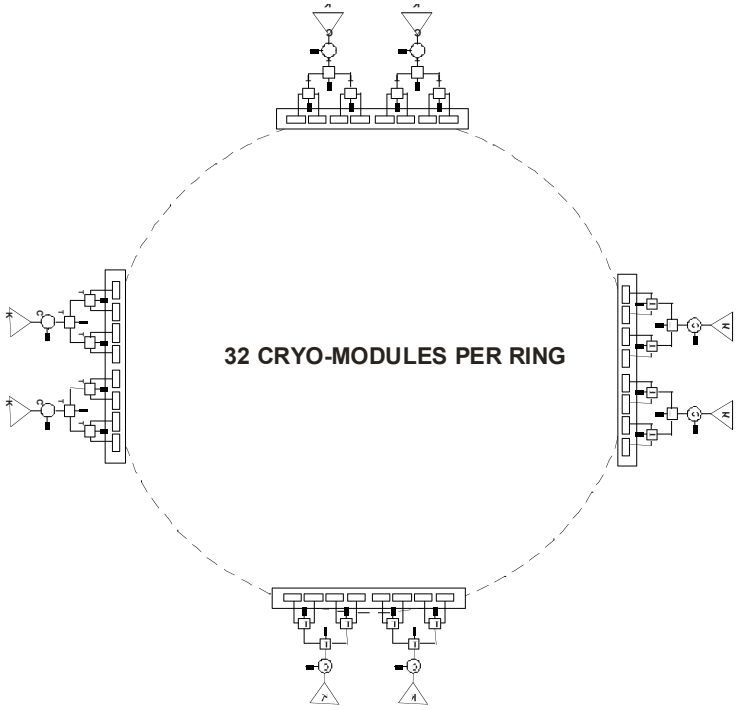


Figure 2: Damping Rings RF system layout.

The above scheme with 32 SC-modules ensures good energy and beam power margin in case of an RF station fault and permits to continue to operate with 28 modules at full performances by increasing the RF field in the remaining cavities. Table 2 reports the RF system main features and compares the parameters with the case when one RF station is off. They are scaled from the 500 MHz units developed by the industry and being operated in other laboratories.

Table 2: Estimated 650 MHz SC cavity parameters (scaled from 500 MHz model)

	Electron ring		**2 x Positron ring**	
Frequency [MHz]	650		650	
Active cavity length [m]	0.23		0.23	
R/Q [Ω]	89		89	
Operating temperature [K]	4.5		4.5	
Standby losses at 4.5 K [W]	30		30	
Number of cryo-modules in operation per ring	**32**	**28** (1 station OFF)	**32**	**28** (1 station OFF)
Accelerating gradient [MV/m]	6.33	7.2	6.33	7.2
Accelerating voltage [MV]	1.45	1.66	1.45	1.66
Qo (x10^9) at operating gradient	1	0.9	1	0.9
Cryo-RF-losses per cavity [W]	23.6	34.4	23.6	34.4
Total cryo-losses [W] per ring	1716	1803	1708	1803
Beam power per cavity [kW]	109	125	53	61
Q_{EXT} [**x**10^3]	215	248 (°)	445	507 (°)
Number of klystrons per ring	8	**7**	8	**7**
Klystron output power [kW]	436	500	212	243

(°) Q_{EXT} is a constant for a fixed coupler setting and is independent of Qo. Here, it is assumed that Q_{EXT} might be variable. In theory it would be possible, even though practically difficult. In alternative, Q_{EXT} could be fixed for one set of parameters or a mid value may be set.

RF System Layout

As reported in Fig. 2, two RF stations may be housed in a 30 m long straight section. Each klystron can feed 4 SC cavities through magic-tees and 3-port circulator. Figure 3 shows the schematic layout of the 650 MHz RF system for the ILC electron damping ring. To guarantee sufficient power margin in case of a klystron fault, it is opportune to choose a source of 800 kW CW output power.

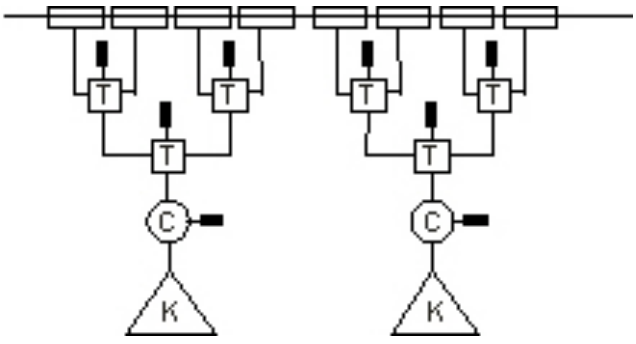


Figure 3: Layout of the straight section RF system.

An alternative layout consists in splitting the RF power with successive couplers as shown schematically in Fig. 4.

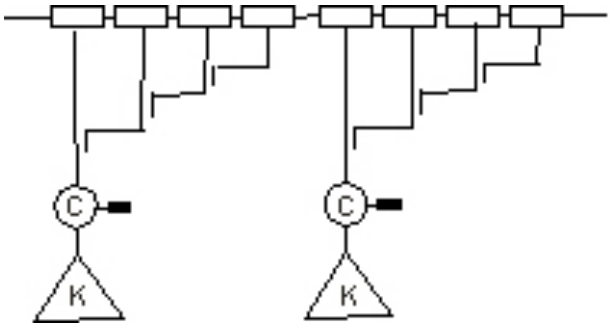


Figure 4: RF power feeding with consecutive couplers

RF Units

The modification of the frequency from 500 to 650 MHz requires to re-design the cryo-module. In fact, the cavity shape must be scaled from 500 MHz; the input coupler and the HOM dampers must be re-designed too. The input coupler is the most critical element in a new 650 MHz structure, mainly because the power handling capability, that is about 260 kW-CW in the 500 MHz system, must be of comparable level in the new design. Scaling the HOM dampers, wrapped around the beam pipe warm sides, does not appear a hard work. Finally, the cryostat must be considerably renewed, especially the cavity LHe tank, for the smaller cavity dimensions and the "warm-to-cold transitions". Anyhow, the large number of needed cryo-modules justifies the effort of developing a new unit.

RF Sources

The RF stations will consist of the CW 650 MHz klystron supplied by its CW Power Supply. New RF power sources are necessary. Klystrons of power and frequency close to the needed ones exist on the market and can be modified by the manufacturer, with a moderate R&D effort. The RF industry [1] is available to develop the new power source. HV power supplies for this type of klystrons are in operation at DESY. Ferrite circulators for the klystron protection can be developed too. Products with similar specifications are being operated in other laboratories.

The RF system includes the rectangular waveguide network (WR1500 standard) and the magic-tees for splitting the power among the SC cavities. Other components, like directional couplers, RF loads and solid state drivers are available on demand.

Cryogenic Plants

The cryogenics is a crucial system of the full complex. The total cryo-losses per ring are 1803 W when 28 modules are in operation in case of a klystron fault. Due to the distance between the straight sections, the use of individual cryo-plants per each section appears the best solution. In this way, the He transfer lines will be not excessively long and will have modest impact on the cryo-plant cost. The cryo-plant capability must be calculated taking into account that, in case of one klystron fault, the cryo-power on the associated straight section decreases to 260 W but that of other ones must increase to 520. Therefore, the cryo-plants must be designed to dissipate 520 W at 4.5K. With the standard refrigerator efficiency of 0.3% at 4.5 K, the total wall-plug power for each straight-section refrigerator will be about 175 KW.

Table 3 summarizes the specifications of the cryogenic system.

Table 3: Main specifications of the cryogenic system

	32modules/ring
Normal-rated cryo-losses per straight section [W]	430
Over-rated cryo-losses per straight section [W]	520
Wall plug power per cryo-plant [kW]	175
Total number of cryo-plants	12

References

[1] Thales Electron Devices, private communication, Febr, 13, 2006.