ILC-LNF TECHNICAL NOTE

Divisione Acceleratori

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UPDATED RF SYSTEM FOR THE ILC DAMPING RINGS

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Introduction

For the ILC damping rings, a frequency of 650 MHz has been selected because of the simple relationship with the main linac RF, 1300 MHz. Table 1 lists the DR parameters of importance for the RF system design. Currently, high power 650 MHz RF sources are not commercially available. However, several major klystron manufacturers can develop these by modifying 500 MHz klystrons of equivalent power level. Similarly, the RF cavity units can be designed by scaling from existing 500 MHz superconducting module designs. These SC modules, comprising 500 MHz single-cell Nb cavities housed in a fully equipped cryostat, have been developed and currently are in successful operation at CESR, KEK, and elsewhere. A number of cryo-modules, with well-defined operating parameters, have also been produced "turn-key" by industry upon technology transfer agreements with Cornell University and KEK. The outline dimensions of an RF cryo-module are about 3 m in length and 1.5 m in diameter. For either the electron or positron rings, the beam power and the total RF voltage will be shared among 18 superconducting cavities (either KEK- or CESR-like). In the present version, the damping rings design includes two RF straight sections. Since the total length of each cryo-module is 3 m, to accommodate up to 10 SC cavities in one straight section requires that the length of each RF section be roughly 40 m. Operating 18 SC cavity modules per ring ensures adequate energy and beam power margin in case of an RF station fault, and permits continued operation with 14 cavity modules at full performance by increasing the RF field in the remaining units.

Table 1: : Damping rings RF system parameters

	e^- and e^+
Energy (GeV)	5
Number of bunches per train	2767
Number of particles per bunch	2.0×10^{10}
Average current (amps)	0.40
Energy loss per turn (MeV)	8.7
Beam power (MW)	3.5
Bunch current (mA)	0.14
Total RF voltage (MV)	24
Circumference (km)	6.695

Table 2 summarizes the RF system main features and compares the parameters for the nominal case with that when one RF station is off. Parameters are scaled from the 500 MHz units developed by industry and being operated in various laboratories.

Table 2: Estimated 650 MHz SC cavity parameters (scaled from 500 MHz model) for both EDR and PDR

	e^- and e^+ rings	
Frequency [MHz]	650	
Active cavity length [m]	0.23	
R/Q [Ω]	89	
Operating temperature [K]	4.5	
Stand by losses at 4.5 K [W]	30	
Number of operating SC modfules per ring	18	14[a)]
Accelerating gradient [MV/m]	5.8	7.5
Accelerating voltage [MV]	1.33	1.72
Q_o ($x10^9$) at operating gradient	0.6	0.6
Cryo-RF-losses per cavity [W]	33	50
Total cryo-losses [W] per straight[b)]	1130	1120
Beam power per cavity [kW]	194	250
Number of klystrons per ring	5	4
Klystron output RF power [kW]	780	1000

[a)] with one station off; [b)] including stand by losses.

System Description

RF System Layout

Two or three RF stations will be housed in a 40 m long region of each RF-wiggler straight section, as indicated schematically in Fig. 1.

Each klystron can feed 4 SC cavities by means of a distribution system having magic-tees for power splitting and 3-port isolators for protecting the klystron. To guarantee sufficient power margin in case of a klystron fault 1.2-MW CW power sources will be utilized. One “hot-spare” station in each ring will be operated with only two cavities, rather than four. In order to place the stations in each ring upstream of the wiggler in that ring, the RF systems will be located at opposite ends of the straight section tunnel, with waveguides connecting them to the klystrons housed in centrally located alcoves having access shafts to the surface.

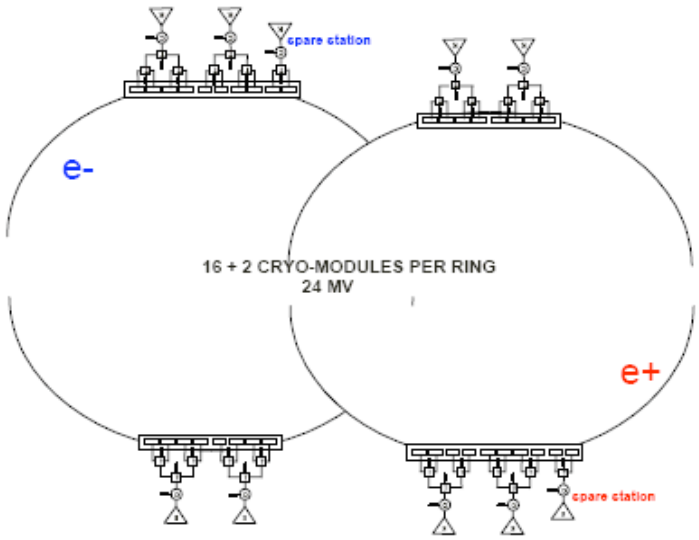

Figure 1: Schematic layout of DR RF systems. Each of the two RF-wiggler sections will accommodate three stations from one ring, and two from the other. All stations will be situated upstream of the wiggler in that ring.

RF Units

The selection of 650 MHz requires a redesign of an existing 500-MHz cryo-module. Not only must the cavity shape be scaled from 500 MHz, the input coupler and the HOM dampers must be redesigned. The input coupler is the most critical element in a new 650 MHz structure, mainly because the power handling capability, about 260 kW CW in presently operating 500 MHz systems, must be kept at a comparable level in the 650 MHz design. Scaling the HOM dampers wrapped around the beam pipe appears to be straightforward. Finally, the cryostat mechanical details must be considerably revised, especially the cavity LHe reservoir, to account for the smaller cavity dimensions and the warm-to-cold transitions. The number of cryo-modules needed justifies the effort of developing a new unit.

RF Sources

The RF stations comprise a 650 MHz CW klystron supplied by a DC high-voltage power supply. As noted, new RF power sources are necessary but should be easily obtained. Klystrons having a power rating and frequency close to our requirements are commercially available, and can be modified by a manufacturer with a modest R&D effort. Ferrite circulators for klystron protection can also be developed or obtained commercially. HV power supplies for this type of klystron are in operation at DESY. Products with similar specifications are being operated in various laboratories. The RF system includes the rectangular waveguide network (WR1500 standard) and magic-tees for splitting the power among the SC cavities. Other components, like directional couplers, RF loads and solid-state drivers, are all available commercially.

Cryogenic Plants

The total RF cryo-losses per straight section are about 1130 W either with 18 and 14 modules in operation. One cryogenic plant in each RF straight section is envisioned. With this choice, the He transfer lines to the RF will not be very long and will have modest impact on the cryogenic plant cost. Therefore, with some margin, the cryogenic plants must be designed to provide the RF cavities with 1200 W of cooling at 4.5 K. 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 400 kW. Table 3 summarizes the specifications of the cryogenic system.

Table 3: Main specifications of the cryogenic system

	18 modules/ring
Normal cryo-losses per straight section [W]	130
Design cryo-losses per straight section [W]	1200
Wall plug power per cryo-plant [kW]	400
Total number of cryo-plants	2