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RF SYSTEM FOR SLAC STORAGE RING*

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Introduction

With the guide field parameters of the SLAC storage ring (SPEAR), a 2.5 GeV electron will radiate 272 keV of energy each revolution. A peak RF voltage of 350 kV will restore this radiated energy with an adequate lifetime for quantum fluctuations. This energy will be supplied from an RF system operating at 51.22 MHz, which is the 40th harmonic of the rotation frequency. For initial operation, the RF power will be obtained from eight Collins 205G-1 transmitters (obtained from U. S. Government surplus) which are rated to deliver 20 kW cw power in the frequency range 20 to 60 MHz. Also, two cavities with a total shunt impedance of about 1.7 MΩ will be used. Thus, the RF power limitations at 2.5 GeV will result in somewhat less than one-half amp total current. To proceed to higher energies, additional cavities and RF power sources will be required. Additional power of about 200 kW will be provided from surplus RF equipment presently being refurbished.

Cavity

The straight sections of SPEAR have an available free space of about 3 meters. The center of these straight sections are an integral number of half-wavelengths from the interaction regions and this is where the cavity gaps will be located. The cavity at 51.22 MHz was designed to fit in the straight section along with the vacuum pumping and necessary flanging. An all-vacuum cavity of aluminum construction is used. Good structural strength can be obtained relatively inexpensively using aluminum with welded joints. A schematic of the cavity is shown in Fig. 1. This cavity has a design Q of 13,000 and shunt resistance of about 0.85 MΩ and consists of two quarterwave capacitively loaded coaxial cavities with a common high voltage gap. All connections to the outside are by means of stainless steel ultra-high-vacuum flanges which are explosively bonded to aluminum.[1] The coaxial vacuum window is based on a design for high power klystrons. The coupling loop, the center conductor and the capacitive loading plates are water cooled. The large amount of cavity detuning necessary for the storage of high currents is provided by means of a capacitive tuner moved in the region of high electric fields as shown in Fig. 1. An experimental model of this cavity has been successfully tested and was found to be well within the design specifications. Also, it is planned to install in the center of a straight section an insulated gap. Across this gap will be applied an RF voltage at a harmonic number different from that of the main RF system, to split the synchrotron frequencies of the bunches.[2]

RF Power Generation

A voltage-tunable crystal oscillator at 1.280 MHz is the starting point of the RF system. The 1.280 MHz signal is multiplied to the 40th harmonic, and after passing through an electronic variable attenuator is amplified to a level of 5 W for division and distribution to the high power amplifiers.

The eight 20 kW amplifiers provide the high power radio-frequency energy to the accelerating cavities. Four of these amplifiers will drive one cavity and four the other. The amplifiers are combined in pairs using coaxial branch-line couplers. Phasing for proper combining is accomplished by phase shifters at the input of each amplifier. A simplified block diagram is given in Fig. 2.

The synchrotron frequency splitting cavity will be driven from a separate amplifier of about 10 kW at about 200 MHz.

Cavity Matching

Because of beam-loading, the cavity input impedance varies during filling. With the beam current expected in the initial operation of SPEAR, the range of variation will be about 4:1. It is proposed to couple the H field of the cavity with a large loop terminating the coaxial line from the RF power sources. This loop will be sized to produce an impedance match at full beam current, while at zero beam a 4:1 mismatch will exist. Since at zero beam the RF power requirements are low, it is not anticipated that there will be any serious adverse effects on the RF amplifiers.

Cavity Tuning

To maintain stability in the cavity-beam system and to compensate for beam-loading effects, it is necessary to adjust the tuning of the cavity during filling. At a given beam energy, the amount of tuning is a linear function of beam current. In SPEAR, the maximum tuning is on the order of 80 kHz, at an energy of 1 GeV and beam currents of 0.5 A (per beam, dc). It is also necessary to compensate for thermal detuning effects of the order of several hundred kHz.

A mechanical tuner has been incorporated in the cavity, and operates upon the fringing fields of the two loading plates on either side of the gap. The tuner is driven by a stepping motor through a gear train. Negator springs have been installed on the drive mechanism to counter-balance the forces of atmospheric pressure upon the bellows, thus reducing the torque demands on the stepping motor. The rate of linear motion of the tuner is approximately 1/2 in per second, so that under most conditions of beam loading all the required tuning can be accomplished in about 2 s.

Feedback Systems

Because of beam-loading effects and stability requirements, it is necessary to provide feedback control of cavity tuning and gap voltage.

A small coupling loop on the cavity, sensitive to transmitted signal, provides input for both of these systems. For gap voltage control, the signal from the loop is detected and compared with a dc reference voltage. The error signal is amplified and sent to the electronic attenuator in the low power drive system, which in turn controls the amount of RF power delivered to the cavity.

For the tuning system, the signal from the small coupling loop is compared in phase to the signal incident upon the cavity input. A voltage proportional to phase is derived from the comparison, and after amplification, is used to drive the mechanical tuner on the cavity.

Block diagrams of both feedback systems are given in Figs. 3 and 4.

References

1. U. Cummings, N. Dean, F. Johnson, J. Jurow, J. Voss, J. Vac. Sci. and Tech. 8, 348-351 (1971).

2. M. A. Allen, M. J. Lee, P. L. Morton, "Synchrotron frequency splitting in the SLAC storage ring," paper in these transactions.

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Acknowledgements

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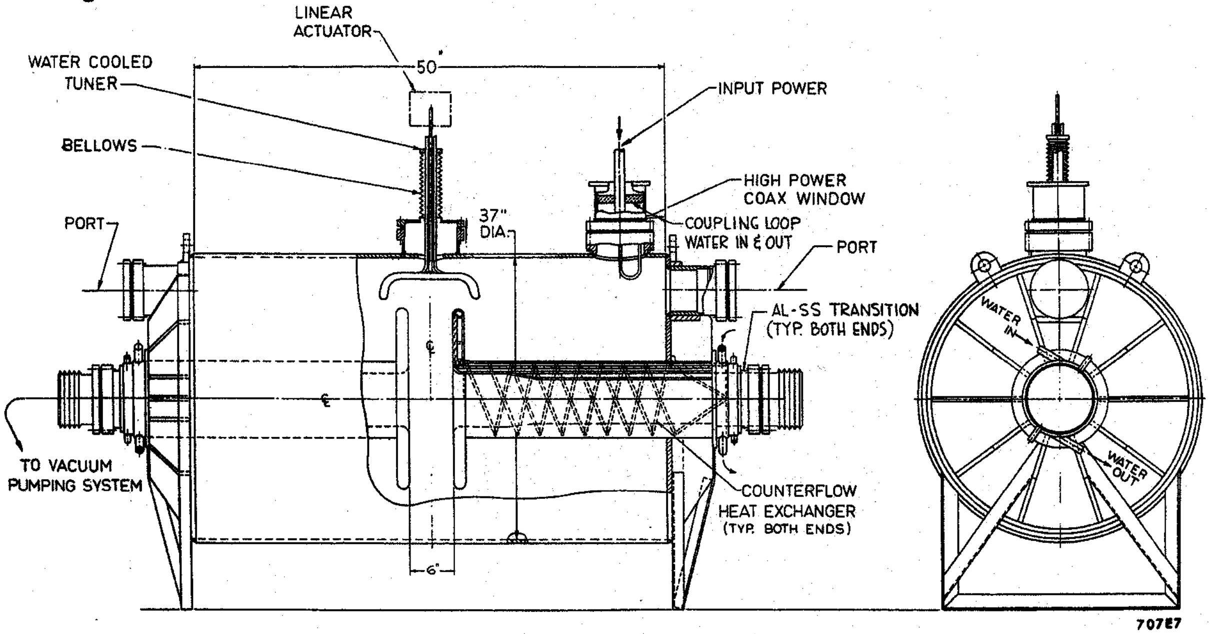

FIG. 1--RF cavity.

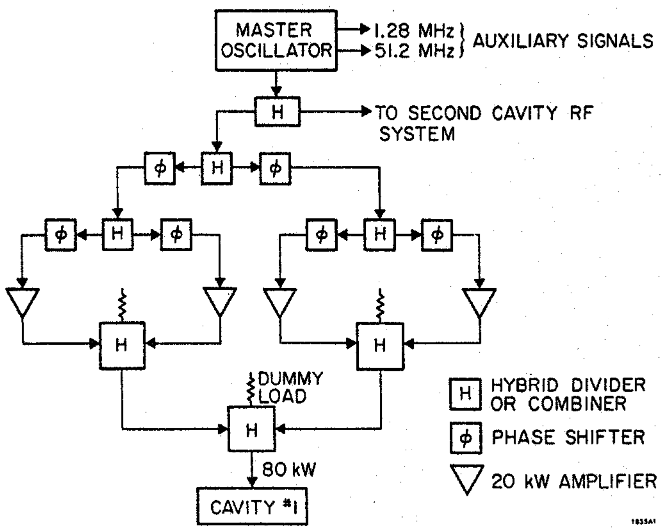

FIG. 2--RF power distribution to the cavities.

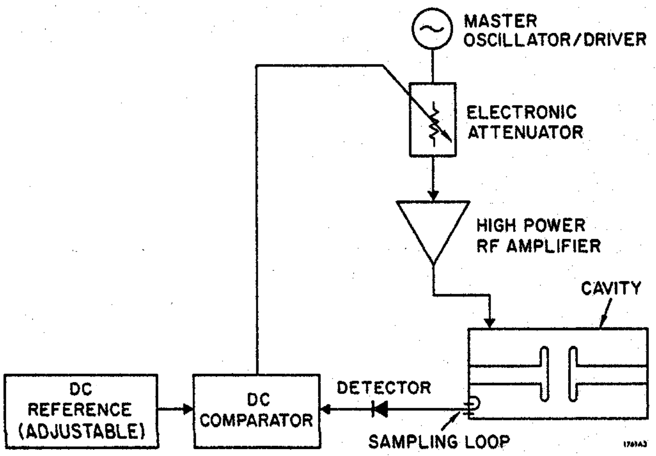

FIG. 3--Gap-voltage control system.

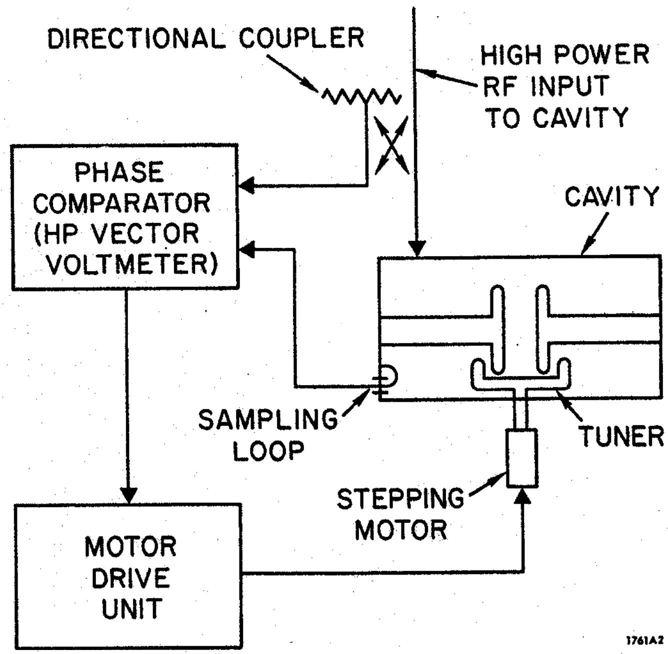

FIG. 4--Cavity tuning control system.