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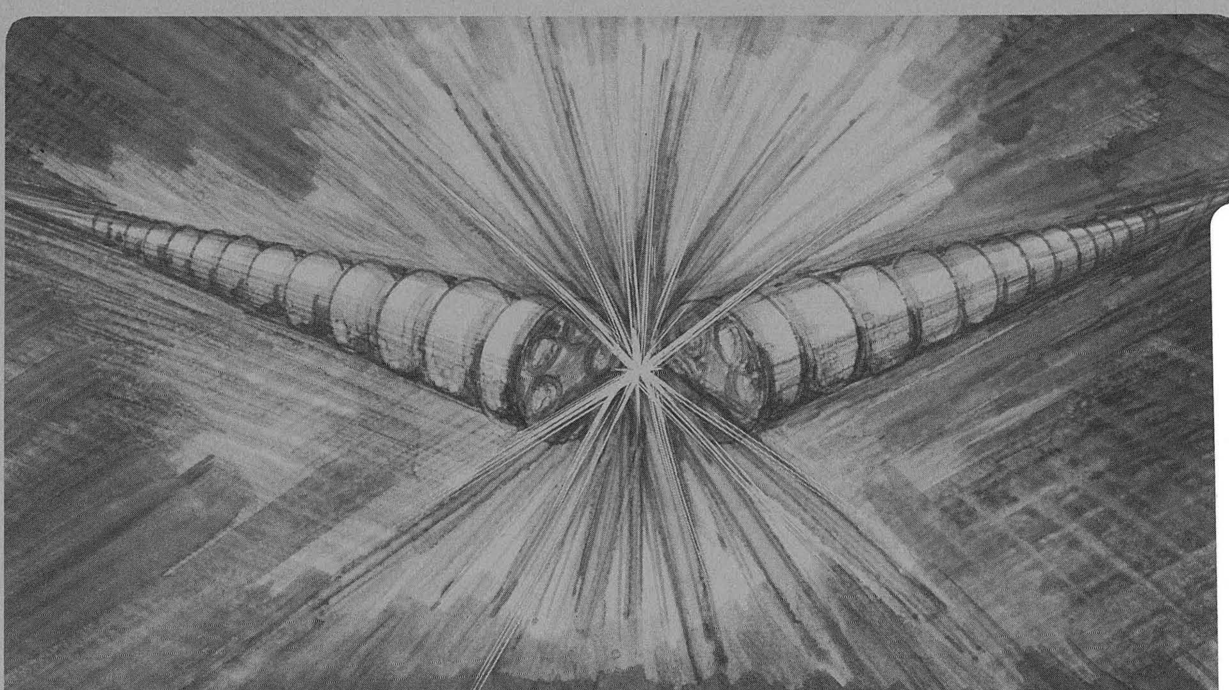

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ABSTRACT

PEP-II, a 9 GeV × 3.1 GeV e^+e^- collider with a design luminosity of 3×10^{33} $cm^{-2}s^{-1}$, was proposed jointly by SLAC, LBL, and LLNL. Recent efforts have continued towards an optimized design. In addition, an aggressive R&D program is under way to validate our design choices. Fabrication of a low-power prototype RF cavity is complete, and impedance measurements are beginning. A 500-kW, 476-MHz klystron has been completed; it will be used for testing both high-power RF windows and a prototype high-power cavity (now under design in collaboration with Chalk River Laboratory). Vacuum studies have demonstrated that chambers with suitable photodesorption properties can be fabricated. A mock-up of the two-ring arc area has been completed and used to investigate alignment and stability issues. The PEP-II project is ready to begin construction as soon as funds become available.

1. INTRODUCTION

In early 1991 a conceptual design [1] for the PEP-II collider was submitted to the U.S. Department of Energy. Since then, R&D activities aimed at optimizing the design and confirming design choices have been carried out. PEP-II will be housed in the PEP tunnel and will make use of the existing PEP magnets and infrastructure; no conventional construction is required to build the facility. The collider comprises two rings, a high-energy ring (HER) for 9-GeV electrons and a low-energy ring (LER) for 3.1-GeV positrons. To achieve the design luminosity, high beam currents (1–2 A) are used. Our design approach maintains single-bunch parameters at values typical of today's colliders but uses a substantially larger number of bunches (1658 per ring). Due to the large bend radius of the PEP magnets (165 m), synchrotron radiation losses are moderate. This permits the design to make use of relatively standard vacuum chamber approaches and well-understood room-temperature RF cavity technology. A list of the main collider parameters appears in Table 1.

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Table 1. Main PEP-II parameters.

	LER	HER
Energy, E [GeV]	3.1	9
Circumference, C [m]	2200	2200
$\varepsilon_y/\varepsilon_x$ [nm·rad]	3.9/97	1.9/48
β_y^*/β_x^* [cm]	1.5/37.5	3.0/75.0
$\xi_{0x,0y}$	0.03	0.03
f_{RF} [MHz]	476	476
V_{RF} [MV]	9.5	18.5
Bunch length, σ_ℓ [mm]	10	10
Number of bunches, k_B	1658[a]	1658[a]
Damping time, $\tau_{x,y}$ [ms]	36.4	37.2
Total current, I [A]	2.14	1.48
U_0 [MeV/turn]	1.2	3.6
Luminosity [$cm^{-2}s^{-1}$]	3×10^{33}	

[a]Includes gap of ≈5% for ion clearing.

2. RF SYSTEM

The high circulating beam currents in the PEP-II rings excite strong wakefields at the parasitic higher-order modes (HOMs) of the RF cavities. These wakefields couple the motion of the many bunches in each ring, thus leading to very strong instabilities. Two complementary approaches are used in PEP-II to deal with this effect. The first is to reduce the amount of HOM impedance by minimizing the number of RF cavities and the second is to damp the unwanted HOMs by means of broadband loads [2].

In the HER, we provide 18.5 MV with 20 RF cavities, leading to a wall power (per cell) of 130 kW. We are collaborating with Chalk River Laboratory (CRL) on the design of a high-power test cavity to demonstrate satisfactory cooling properties. To assess thermal behavior, a three-dimensional computer model was generated. Preliminary results show that the thermal loads are not excessive and can be handled with straightforward cooling techniques. The model high-power cavity will be available for testing in about one year. Loads capable of dissipating about 10 kW per waveguide are also being developed jointly with CRL.

A high-power test stand that will serve to test both the cavity and the RF window (which must operate reliably at a 500-kW power level) is under construction. For this purpose, a 500-kW klystron operating at 476 MHz is needed. The klystron has been fabricated at SLAC (see Fig. 1) and is now available. It is based on a modified 353-MHz PEP klystron; the gun structure, beam tunnel and collector of the original PEP klystron are retained but the accelerating structures are redesigned to reflect the higher frequency needed for the PEP-II device. Multipactoring in the first gain cavity (affecting broadband operation) was found in earlier tests on an unmodified PEP klystron but was successfully eliminated in the PEP-II klystron by TiN coating. Achieved performance parameters are summarized in Table 2. The ultimate goal of this aspect of the R&D effort is to produce a 1.2-MW klystron that will power two RF cavities in PEP-II. Design of a 1.2-MW klystron is well along and discussions with potential industrial partners are ongoing.

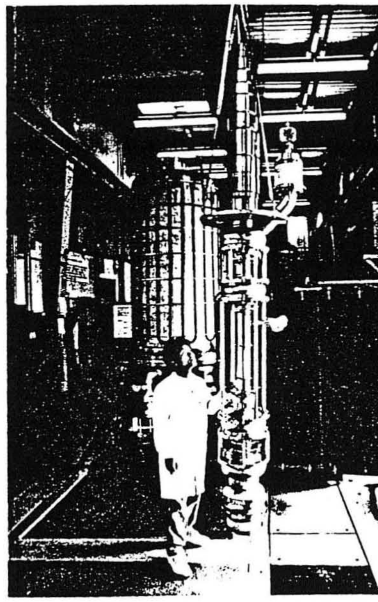

Fig. 1. Prototype 500-kW, 476-MHz klystron.

Table 2. PEP-II klystron performance.

Frequency [MHz]	476
Max. output power [kW]	517
Beam voltage [kV]	67
Efficiency [%]	61.6
Gain [dB]	41
Bandwidth at 1 dB [MHz]	1.7
Tuned circuit delay [ns]	300

The PEP-II klystron will also be used in a hardware simulation of the RF feedback loop (needed to reduce the cavity impedance near the fundamental mode). Performance aspects of the fast RF feedback will be tested by injecting a portion of the klystron output and a simulated beam signal into the low-power cavity model and closing the loop through appropriate feedback electronics. Because the PEP-II klystron serves in a fast RF feedback loop, bandwidth and delay are important parameters. Both were improved on this klystron over the original PEP design, and further improvement is anticipated for the 1.2-MW klystron.

Even with only 20 RF cavities, the HOM impedance would give unmanageable instability growth rates in the PEP-II HER if nothing were done to reduce it. Therefore, we use a broadband damping technique whereby the cavity body is penetrated by three waveguides to which damping loads are attached. This technique has already been demonstrated successfully at LBL with a pill-box geometry. Damping waveguide dimensions are selected such that the waveguides are beyond cutoff for the fundamental RF mode but allow the HOM fields to propagate. Our estimates [1] indicate that the Q of the fundamental is reduced by only about 5% when the strong TM011 mode is damped by a factor of 1000. Based on ARGUS and MAFIA calculations, a waveguide location on the cavity body has been selected that couples well to the expected HOM fields. A low-power prototype cavity, shown in Fig. 2, has just completed fabrication. Measurements of the device are beginning at LBL to ensure that no HOMs escape damping. For these tests, simple low-power damping loads will suffice.

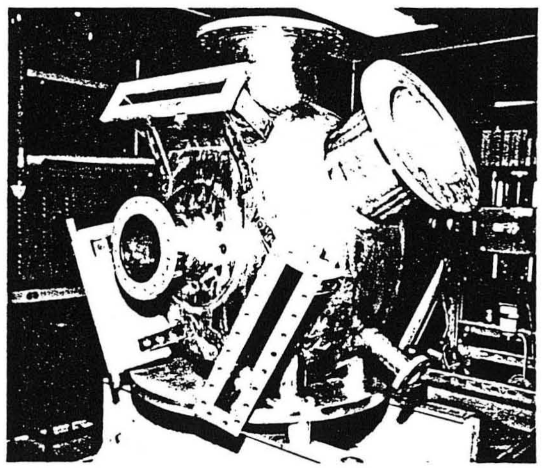

Fig. 2. PEP-II low-power cavity prototype.

3. FEEDBACK

Even after damping the cavity HOMs, feedback systems are required. The PEP-II longitudinal system is based on digital signal processing [3]. A down-sampling approach makes our system applicable to many projects, including the ALS at LBL and DAΦNE at Frascati, both of which are collaborating on the feedback R&D program. We have reached agreement with the ALS to provide them with our DSP hardware for their longitudinal feedback system, with delivery expected in 12–15 months.

A prototype PEP-II longitudinal kicker (see Fig. 3) is undergoing wire measurements at LBL to examine its frequency response; its behavior is consistent with expectations. This kicker is essentially identical to that required for the ALS.

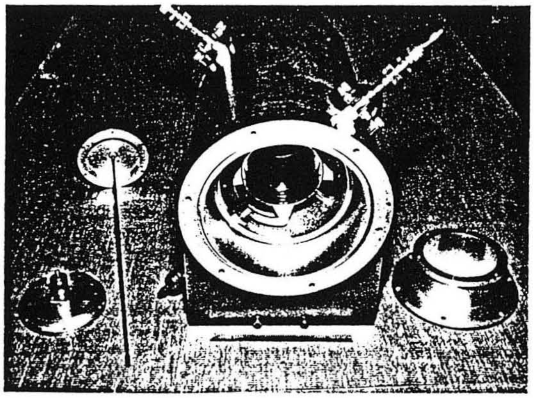

Fig. 3. Prototype longitudinal kicker with measurement wire.

In the transverse case, the instability is driven by the resistive-wall impedance rather than that of the cavity HOMs. A down-sampling technique is not applicable (the system is inherently undersampled in betatron frequency) and we plan on a simpler analog approach with two pickups, located 90° apart in betatron phase, and a stripline kicker.

4. VACUUM SYSTEM

Synchrotron radiation levels at PEP-II will be ten times that of PEP. To reduce the gas load and to provide a self-shielded beam environment, the PEP-II vacuum chambers will be made from copper, which desorbs gas molecules ten times less copiously than aluminum. As the chamber design relies crucially on the assumption of low desorption, a collaboration of LLNL and BNL scientists and engineers has begun a program of desorption measurements at BNL using photon beams from the NSLS.

Measurements [4] on a cylindrical chamber fabricated with electron-beam welding techniques (similar to those envisioned for the actual PEP-II chambers) demonstrate that adequately low photodesorption yields (taken here to mean $\eta \leq 2 \times 10^{-6}$) can be obtained for a copper chamber in a modest amount of running time. We have also demonstrated the beneficial effects of argon glow discharge cleaning (GDC). To simulate a realistic installation process, after the glow discharge process the chamber was baked, cooled, and vented to air for two days. The improvement due to GDC was found to survive the venting process, and we confirmed with a residual gas analyzer that the Ar gas is completely removed in the bakeout step.

5. SUPPORT SYSTEM MOCK-UP

A mock-up of the PEP-II two-ring support system, as currently conceived, has been set up in IR8 at PEP (see Fig. 4). A short section of PEP was demounted and the magnets refurbished in the manner planned for PEP-II. These magnets, which will be used for the HER, were incorporated into the mock-up. In addition, dummy magnets for the LER and dummy vacuum chambers were fabricated to simulate the proper space requirements and provide a realistic weight distribution. The mock-up, which spans three standard PEP-II half-cells serves to: validate the structural integrity and ease of fabrication; establish the level of refurbishment required for

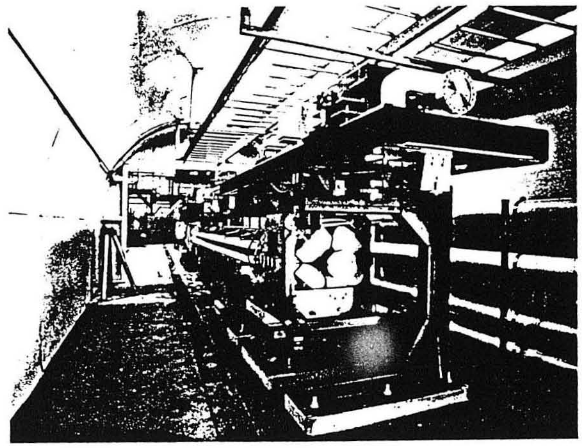

Fig. 4. Mock-up of PEP-II support system.

existing PEP components; establish optimal alignment procedures; avoid and arbitrate space conflicts; and optimize installation procedures. This study has resulted in a decrease in the estimated time for the magnet removal process, with a concomitant cost savings. It has also become clear that the support of the LER magnets from below is inconvenient in terms of alignment stay-clear requirements, and this aspect will be changed for the actual PEP-II system.

6. SUMMARY

Great progress has been made in the past year towards optimizing the design of PEP-II. We have shown that the vacuum performance can be achieved with realistic chamber fabrication procedures and we have begun construction of a prototype longitudinal feedback system that will be tested under "combat" conditions at the ALS storage ring. A 500-kW, 476-MHz klystron has been built and plans for a 1.2-MW version are well along. A low-power prototype RF cavity is complete and is now undergoing impedance measurements.

We hope for funds in FY 1993 to begin a final engineering design of the facility, and we are optimistically preparing for a possible construction start the following year.

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