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THE SLAC STORAGE-RING PROJECT — SPEAR*

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Abstract

The SLAC positron-electron storage ring SPEAR is a single ring comprising two superperiods and having two interaction regions. It will operate initially at energies up to 2.5 GeV and at luminosities up to about 10^{32} $\mathrm{cm}^{-2}\ \mathrm{sec}^{-1}$. The main features of the design, including the magnet system, the vacuum system, the radiofrequency system, the injection system, and the computer-based instrumentation and control system, are described. Initial operation of SPEAR is scheduled for April 1972. Options for future improvement of the storage ring, which include raising the beam energy as high as 4.5 GeV and adding a second intersecting storage ring are also discussed.

Construction of the SLAC positron-electron storage ring SPEAR began in August 1970. Completion is expected in April 1972. As finally designed, SPEAR is a single ring comprising two superperiods and having two interaction regions. See Fig. 1. The interaction regions are served by pits to contain experimental apparatus. Quadrupole doublets (Q2, Q3) are used to focus the beams to values of the vertical betatron function as small as 5 cm there. As installed, the ring will operate with beam energies up to 2.5 GeV. Table I gives selected parameters and typical performance.

The bending magnets and quadrupoles are constructed with solid iron cores and aluminum coil conductors. The magnets are supported on concrete girders

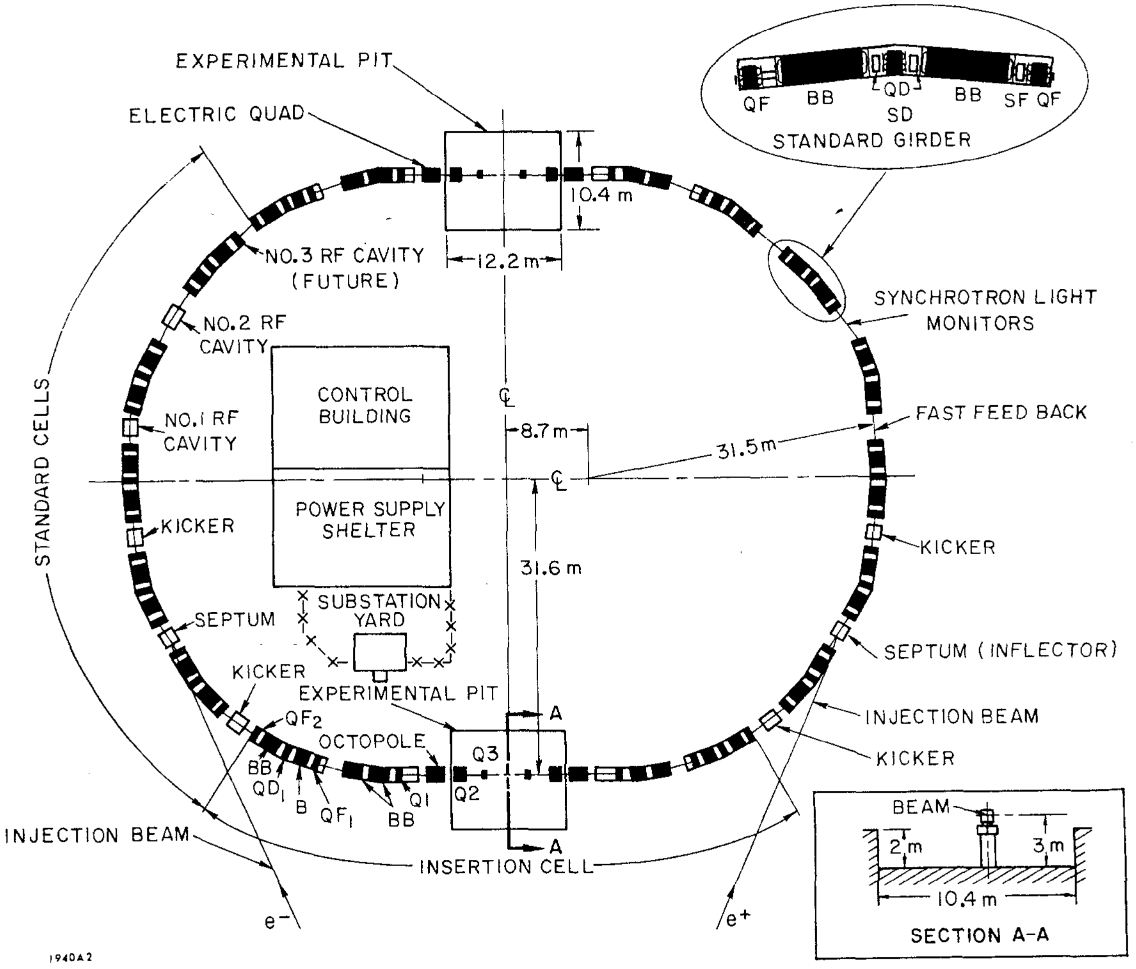

FIG. 1--Layout of SPEAR showing selected details including uses of standard straight sections.

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TABLE I

SELECTED PARAMETERS

Geometric	
Gross Radius (circumference/2π)	37.3 m
Number of Superperiods	2
Number of Interaction Regions Served at Same Time	2
Focusing Structure	10 standard cells + 2 insertions
Orbit Frequency	1.28 MHz
Bending Radius	12.7 m
Standard Straight-Section Length	3.0 m
Interaction Region (Experimental) Straight-Section Length	5.0 m
Injection System	
Injection Energy	1.5 GeV
Radiation Damping Times: Transverse	67 ms
Longitudinal	33 ms
Number e per Injected Pulse	5×10^8
Pulse Repetition Rate	20 Hz
RF System	
Radiofrequency	51.2 MHz
Harmonic Order	40
Number of Cavities	2
Shunt Impedance per Cavity	1.0 MΩ
Maximum Accelerating Voltage per Cavity	300 kV
RF Power Available	160 kW
Vacuum System	
Useful Aperture at Cell Straight Section	12 cm × 2.9 cm
Materials	aluminum and stainless steel
Bakeout Temperature	200° C
Vacuum Pumps (sputter-ion)	36 × 600 L/s + 20 × 140 L/s
Magnet System	
Bending Magnet Type	rectangular pole, $n = 0$
Number of Bending Magnets (BB, B)	36
Number of Standard Quadrupoles (QF, QF1, QF2, QD, QD1, Q1)	46
Number of Special (figure-eight) Quadrupoles (Q2, Q3)	8
Number of Independently Adjustable Quadrupole Circuits	8
Number of Sextupole Magnets	52
Total Iron Weight	220 tons
Total Aluminum Weight	10 tons

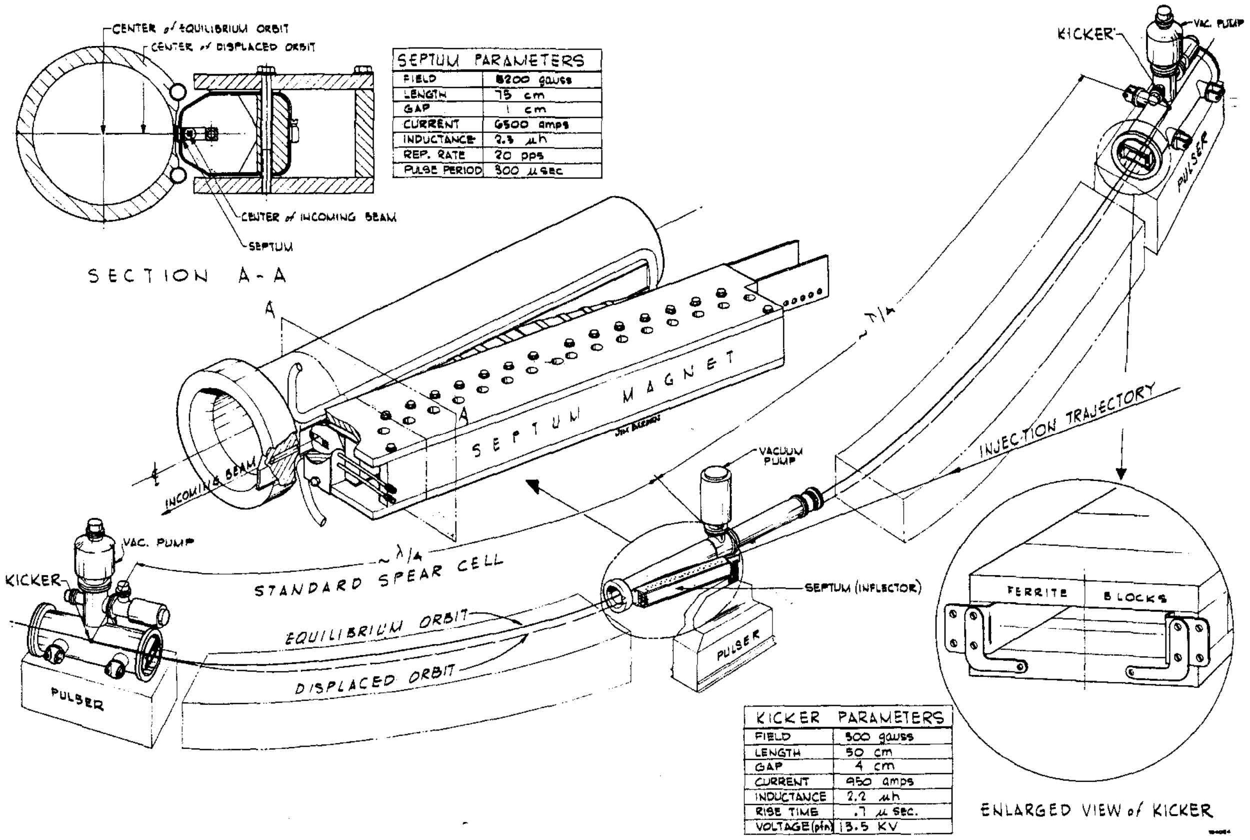
Adjustable Beam Dynamical Parameters	
Betatron Wave Numbers (ν_x and ν_y)	5.00 to 5.25
Interaction-Region Functions:	
Horizontal β-function (β_x)	1 to 5 m
Vertical β-function (β_y)	0.05 to 1 m
Local Dispersion (η)	0 to 5 m
Betatron Wave-Number Shift Between e^+ and e^- by Electric Quadrupole	0.1
Chromaticity Controlled by Sextupole System	
Landau Damping by Octopole System	
Typical Performance at 2 GeV (low-dispersion mode)	
Bending Field	0.525 Tesla
Radiation Loss per Turn	111 keV
Radiation Damping Times: Transverse	28 ms
Longitudinal	14 ms
Betatron Wave Numbers: Horizontal	5.25
Vertical	5.15
Interaction-Region Functions: β_x	1.9 m
β_y	0.05 m
η	0
Standard-Cell Functions: $\beta_{x\,max}$	14 m
$\beta_{y\,max}$	22 m
η max	2.6 m
Momentum Compaction Coefficient	0.038
Natural rms Energy Spread	0.96 MeV
Natural rms Bunch Length (V_{RF} = 500 kV)	8.8 cm
Natural rms Beam Width:	
At Standard Straight Section	0.2 cm
At Interaction Region	0.07 cm
Conditions for Maximum Luminosity:	
rms Beam Dimensions (width × height):	
At Standard Straight Section	0.8 cm × 0.07 cm
At Interaction Region	0.3 cm × 0.007 cm
Stored Current (each beam) ($N = 10^{12}$)	0.2 A
Luminosity/Interaction Region	0.5×10^{32} cm^{-2} s^{-1}
Expected Beam Lifetime	1 to 2 hours

which are in turn supported on concrete piles in the underlying sandstone. The magnets are capable of operation up to 4.5 GeV but are powered for only 3 GeV operation.

Injection of electrons and positrons from the SLAC linac takes place at an energy of 1.5 GeV. Figure 2 shows details of the injection system. Ferrite kicker magnets located about one-quarter betatron wavelength upstream and downstream from the septum inflector magnet distort the equilibrium orbits of the stored particles to bring the stored beam near the inflector. New particles are injected then with oscillation amplitudes smaller than the half-aperture. The horizontal betatron tune at injection is very near 5.25, so the new injected particles would not return to the septum until the fourth turn, 3.2 microseconds later, by which time the kickers have been switched off and the particles are captured. The septum inflector is pulsed only to keep down the power dissipation in it. Filling times of a few minutes are expected.

The RF accelerating structure consists of two cavities. For each cavity, 80 kW of RF power at 51.2 MHz is available. The cavities are made of aluminum. They are entirely evacuated and they have mechanical tuning to compensate for beam loading. The two cavities together will provide a sufficient voltage to store beams up to 2.5 GeV. The addition of another cavity at a later time would allow storage to 3.0 GeV.

The vacuum system is constructed largely of extruded aluminum tubing. Figure 3 shows a vacuum chamber for a SPEAR module. The module chamber



SEPTUM PARAMETERS	
FIELD	8200 gauss
LENGTH	75 cm
GAP	1 cm
CURRENT	6500 amps
INDUCTANCE	2.3 μh
REP. RATE	20 pps
PULSE PERIOD	300 μsec

KICKER PARAMETERS	
FIELD	300 gauss
LENGTH	50 cm
GAP	4 cm
CURRENT	950 amps
INDUCTANCE	2.2 μh
RISE TIME	.7 μ sec.
VOLTAGE (pfn)	13.5 KV

FIG. 2--Schematic drawing of injection system showing details of the injector (septum) magnet and the ferrite kicker magnets.

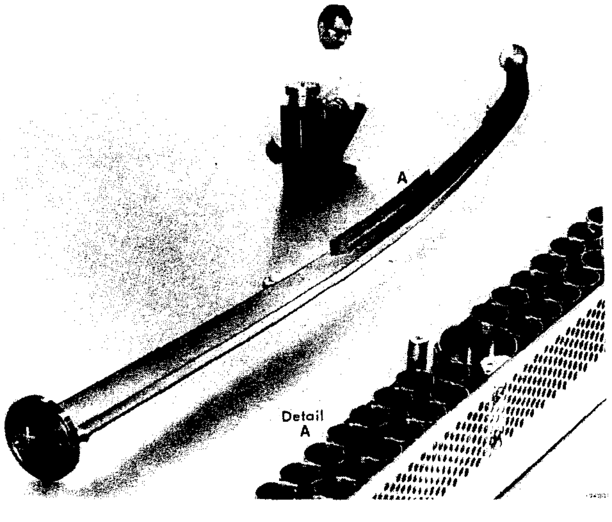


FIG. 3--The thirty-foot-long girder vacuum chamber. The 600 liter-per-second distributed sputter-ion pumps have been removed from the chamber and set on top, and a detail of the pumping structure with the top titanium gettering plate removed is shown.

threads through two bending magnets, three quadrupoles and three sextupoles. Within the chamber, in the fields of bending magnets, are located two distributed sputter-ion pumps of SLAC manufacture, which provide approximately 600 liters per second pumping speed each. The inset in Fig. 3 shows a detail of the distributed pump with one of the titanium gettering surfaces removed.

The SPEAR lattice has been designed to provide a high degree of flexibility as indicated by the Adjustable Beam Dynamical Parameters in Table I. In addition to the adjustability of tune and interaction-region beta-functions, we have arranged to vary the local dispersion at the interaction region from zero to an anomalously high value. We refer to these two extreme configurations as the low-eta mode and the high-eta mode, respectively. Plots of the characteristic functions are given in Fig. 4 for typical cases. The reason for including the feature of adjustable dispersion is the following: In order to achieve the design luminosity in SPEAR, it is necessary to produce an effective interaction area much larger than that obtained when the beams collide head-on at natural size. It is our plan to increase the effective area by artificially inducing betatron oscillations; however, this may prove difficult, and if it does, we can still achieve the desired area by using dispersion to widen the beam and a crossing angle to increase its height.

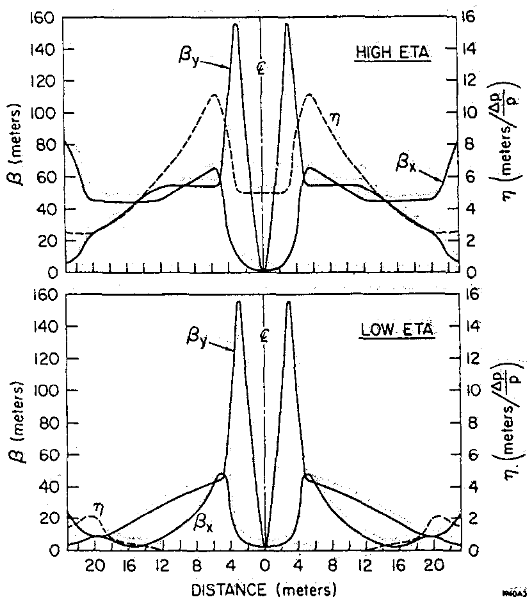


FIG. 4--Beta-functions and local dispersion function (η) in the insertion cell in typical high-eta and low-eta modes.

For beam position information, 20 electrostatic beam position monitors are provided. An XDS Sigma 5 time-shared computer is the crux of the Instrumentation and Control System; it will also be used for experimental data acquisition. Wideband feedback systems with risetimes of 10 nanoseconds are provided for control of coherent transverse bunch motion. In addition a d.c. current transformer will provide a total current signal accurate to 0.1% and two monitors utilizing photoemission from the center conductor of a coaxial line will measure the time structure of the beams with a risetime of 10^{-10} second. Optical monitors will be used to measure the beam size.

There are two main directions along which future improvements may proceed. One is an increase in beam energy to 4 or 4.5 GeV which would be accomplished by augmenting the magnet power supply and replacing the RF system with a high-voltage, higher-power system probably at a higher frequency. The other is a conversion to a double-intersecting-ring system like that described by Richter in the Seventh International Conference on High Energy Accelerators in 1969. The conversion would be accomplished by the additions to the existing equipment and would provide increased luminosity at energies below 2 GeV.