

THE SLAC STORAGE-RING PROJECT — SPEAR\*

SLAC Storage Ring Group\*\* (Presented by J. Rees)

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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  $10^{32}$   $\text{cm}^{-2} \text{sec}^{-1}$ . 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

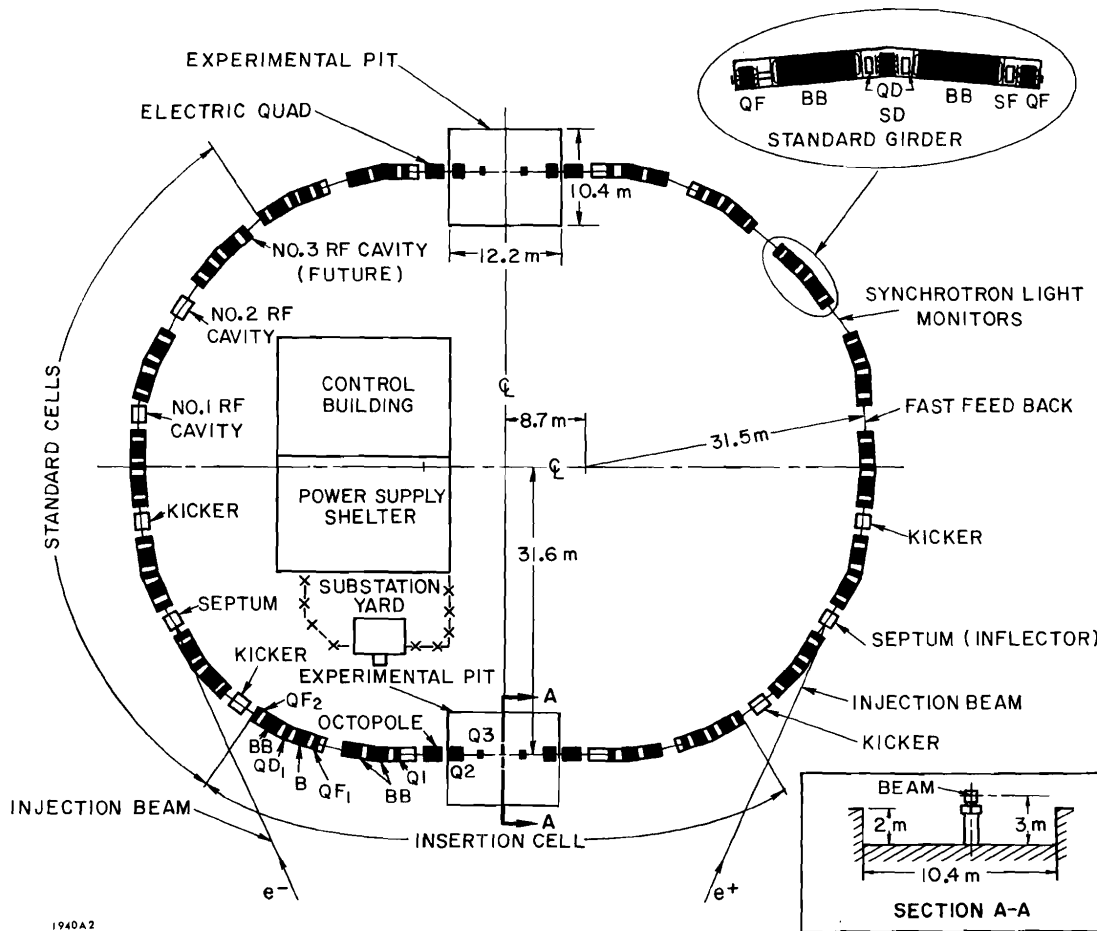


FIG. 1--Layout of SPEAR showing selected details including uses of standard straight sections.

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TABLE I  
SELECTED PARAMETERS

<u>Geometric</u>		<u>Adjustable Beam Dynamical Parameters</u>	
Gross Radius (circumference/2 $\pi$ )	37.3 m	Betatron Wave Numbers ( $\nu_x$ and $\nu_y$ )	5.00 to 5.25
Number of Superperiods	2	Interaction-Region Functions :	
Number of Interaction Regions Served at Same Time	2	Horizontal $\beta$ -function ( $\beta_x$ )	1 to 5 m
Focusing Structure	10 standard cells + 2 insertions	Vertical $\beta$ -function ( $\beta_y$ )	0.05 to 1 m
Orbit Frequency	1.28 MHz	Local Dispersion ( $\eta$ )	0 to 5 m
Bending Radius	12.7 m	Betatron Wave-Number Shift Between $e^+$ and $e^-$ by Electric Quadrupole	0.1
Standard Straight-Section Length	3.0 m	Chromaticity Controlled by Sextupole System	
Interaction Region (Experimental) Straight-Section Length	5.0 m	Landau Damping by Octupole System	
<u>Injection System</u>		<u>Typical Performance at 2 GeV (low-dispersion mode)</u>	
Injection Energy	1.5 GeV	Bending Field	0.525 Tesla
Radiation Damping Times : Transverse	67 ms	Radiation Loss per Turn	111 keV
: Longitudinal	33 ms	Radiation Damping Times : Transverse	28 ms
Number e per Injected Pulse	$5 \times 10^8$	: Longitudinal	14 ms
Pulse Repetition Rate	20 Hz	Betatron Wave Numbers : Horizontal	5.25
		Vertical	5.15
<u>RF System</u>		Interaction Region Functions : $\beta_x$	1.9 m
Radiofrequency	51.2 MHz	$\beta_y$	0.05 m
Harmonic Order	40	$\eta$	0
Number of Cavities	2	Standard-Cell Functions : $\beta_x$ max	14 m
Shunt Impedance per Cavity	1.0 M $\Omega$	$\beta_y$ max	22 m
Maximum Accelerating Voltage per Cavity	300 kV	$\eta_{max}$	2.6 m
RF Power Available	160 kW	Momentum Compaction Coefficient	0.038
<u>Vacuum System</u>		Natural rms Energy Spread	0.96 MeV
Useful Aperture at Cell Straight-Section	12 cm x 2.9 cm	Natural rms Bunch Length ( $V_{RF} = 500$ kV)	8.8 cm
Materials	aluminum and stainless steel	Natural rms Beam Width :	
Bakeout Temperature	200 $^{\circ}$ C	At Standard Straight Section	0.2 cm
Vacuum Pumps (sputter-ion)	36 x 600 L/s + 20 x 140 L/s	At Interaction Region	0.07 cm
<u>Magnet System</u>		Conditions for Maximum Luminosity :	
Bending Magnet Type	rectangular pole, n=0	rms Beam Dimensions (width x height) :	
Number of Bending Magnets (BB,B)	36	At Standard Straight Section	0.8 cm x 0.07 cm
Number of Standard Quadrupoles (QF, QF1, QF2, QD, QD1, Q1)	46	At Interaction Region	0.3 cm x 0.007 cm
Number of Special (figure-eight) Quadrupoles (Q2, Q3)	8	Stored Current (each beam) ( $N = 10^{12}$ )	0.2 A
Number of Independently Adjustable Quadrupole Circuits	8	Luminosity/Interaction Region	$0.5 \times 10^{32} \text{cm}^{-2} \text{s}^{-1}$
Number of Sextupole Magnets	52	Expected Beam Lifetime	1 to 2 hours
Total Iron Weight	220 tons		
Total Aluminum Weight	10 tons		

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

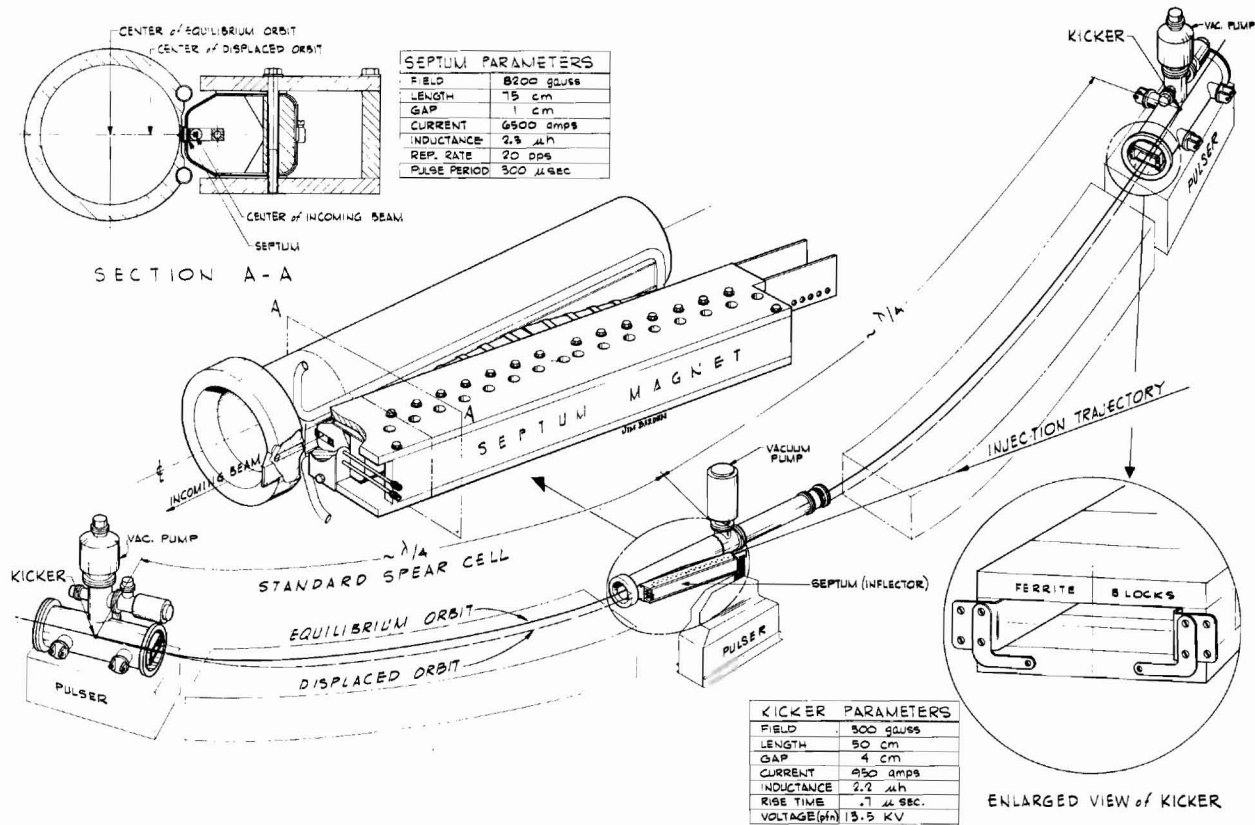


FIG. 2--Schematic drawing of injection system showing details of the injector (septum) magnet and the ferrite kicker magnets.

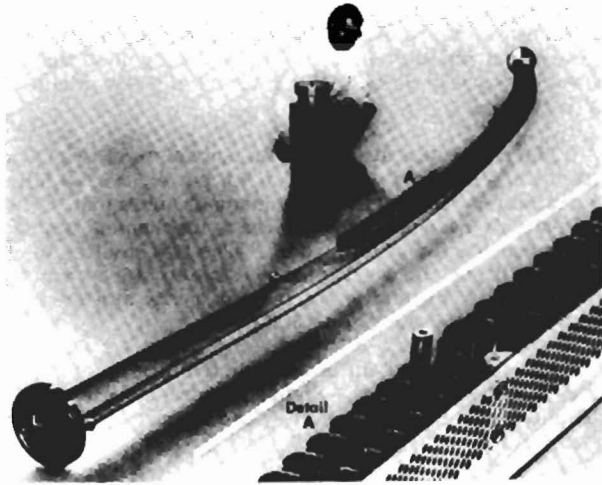


FIG. 3--The thirty-foot-long girder vacuum chamber. The 600 liter-per-second distributed sputter-ion pumps have been removed from the chamber and set on top, and a detail of the pumping structure with the top titanium gettering plate removed is shown.

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.

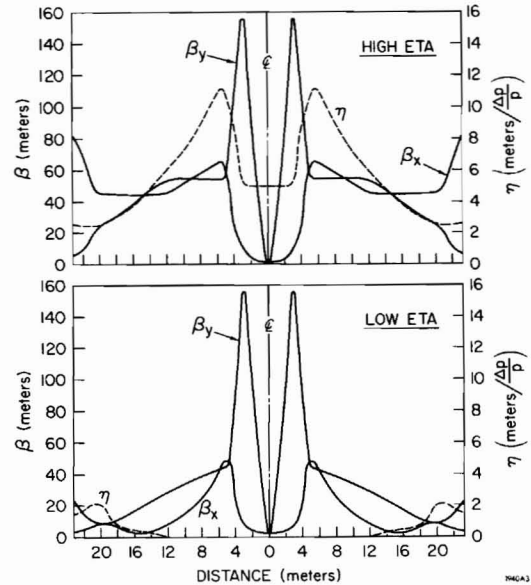


FIG. 4--Beta-functions and local dispersion function ( $\eta$ ) in the insertion cell in typical high-eta and low-eta modes.

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.

DISCUSSION

C. PELLEGRINI : What is the field tolerance in the high-beta quadrupole ?

G. FISCHER : P. Morton and M. Lee have calculated the tolerances so that each individual higher-order-pole term in these magnets and also in the standard quads produces no larger tune shift than 0.01 vertical and horizontal on particles whose orbits are averaged over the injection aperture. This aperture also corresponds roughly to plus or minus six standard deviations of the beam size after damping. Rotating coil measurements on the prototype interaction region quads and the others show that after single corrections to the ends of the iron, the

integrated 12 and 20 pole harmonic contents are smaller than the calculated tolerances by a factor of between five and ten. Generally this corresponds to a total field deviation from linearity of less than 0.1 % over 90 % of the quad diameter.

H. BRUCK : Could you give some figures concerning schedule dates ?

J. REES : We expect to close the vacuum chamber and begin shake-down in January 1972 (in about three months) and to begin injection in April (three months later).