NOTES ON CEA

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Cambridge Electron Accelerator

General Parameters of CEA

Bending Radius: 26 meters
Average Radius: 36 meters
Orbital Frequency: 1.32 MHz
Repetition Rate: 60 Hz
Magnet Type: Alternating Gradient
Straight Section Length: 4 feet; 2 feet is useful
Magnetic Field: 7.6 kG at 6 GeV
Momentum Compaction: \( \alpha = 0.03 \)
Betatron Frequency: \( \nu = 6.4 \)
Amplitude Function: 100 in. < \( \beta < 600 \) in.
Harmonic Number: 360

1 mA peak current = \( 1.4 \times 10^7 \) e\(^-\)/bunch
1 mA average current = \( 1.4 \times 360 \times 10^7 = 5 \times 10^9 \) e\(^-\)

Cycling Mode Capability: \( E_{pk} = 5.5 \) GeV
\( I_{av} = 20-30 \) mA
Extraction efficiency = 60%

Storage Mode Parameters

Energy: 1.0 to 3.5** GeV
Current: rf limit \( < 300 \) mA
Instability limit \( > 100 \) mA
Achieved 55 mA

Lifetime: \( > 1 \) hour

Storage Mode

The CEA has a unique system of beam storage.

While the ring magnets cycle at 60 Hz between field values corresponding to 240 MeV and 2.1 GeV, 260-MeV electrons are injected at the appropriate times. Radiation damping at the top of the cycle reduces the phase space of the radial betatron motion and permits off-axis injection of additional current at the next minimum. The electrons originate in a 5-stage Varian linac. When the desired circulating beam intensity is reached (the maximum value is determined by single-bunch phase instability), after some 30 seconds, the ac component of the magnetic field

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**Can go to 5.0 GeV with additional damping magnets. RF limit at 5.0 GeV is \( -30 \) mA with present rf system.
is turned off slowly (~20 sec) in such a way that the peak energy remains at approximately 2.1 GeV. The dc field is then slowly raised (or lowered) to the desired final value. During this whole cycle, currents in the damping magnets and sextupole coils are programmed to insure stability of the electron current. The entire process of filling and changing the magnet excitation from ac to dc at the desired level takes ~1 minute. The multicycle injection scheme, by adding up many linac pulses, results in a uniform, reliable filling of the ring, largely independent of the linac output pulse amplitude.

Beam Size at 3.5 GeV* (full width at 1/e height)

<table>
<thead>
<tr>
<th>Location</th>
<th>Vertical</th>
<th>Radial</th>
</tr>
</thead>
<tbody>
<tr>
<td>Straight Section</td>
<td>0.10 mm</td>
<td>3.5 mm</td>
</tr>
<tr>
<td>Horizontal ( \theta ) max</td>
<td>0.06</td>
<td>5.0</td>
</tr>
<tr>
<td>Vertical ( \phi ) max</td>
<td>0.14</td>
<td>2.1</td>
</tr>
</tbody>
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Linac Characteristics

- **Energy**: 270 MeV
- **Current**: 100 mA
- **\( \Delta E/E \)**: ±0.5%
- **Pulse Length**: 1 usec
- **Emittance**: \(-0.25 \times \) mm-mrad
- **Peak Klystron Power**: 25 MW
- **Repetition Rate**: 60 Hz
- **Frequency**: 2855 MHz
- **Chopper**: 475.7 MHz

RF System

- **Frequency**: 475.7 MHz
- **Power**: 200 kW
- **Harmonic No.**: 360
- **Max. Volts/Turn**: 6 MeV for 16 cavities
- **Shunt Impedance**: \( 7 \times 10^6 \) \( \Omega \) per cavity
- **Q of Cavity**: 25,000
- **Cavity Tuning Range**: 1.3 MHz
- **Synchrotron Radiation Power**: 50 kW
  (Varies as \( E^{4/3} \) /p)

CEA Ring Vacuum System

- **Average Ring Pressure**:
  - no beam
  - 50 mA at 2.5 GeV
  - \( \leq 5 \times 10^{-9} \) torr
  - \( 2 \times 10^{-8} \) torr
- **Pumps**: 48 Triode ion pumps (400 l/sec)

*Beam size measured at low current. Radial size includes synchrotron width.
Vacuum Chambers: Ceramic. Conductance 5 1/sec
Bakeout: Almost all components bakeable to 150°-250° C
Materials: Stainless, ceramic, copper, ferrite, etc. No organics except 5 Viton "0" rings on ring segmenting valves.
Forepumps: Four 260 1/sec Turbo-molecular pumps manifolded to cover the entire ring.

Single Beam Instabilities

They Limit Accumulated Current By:
1. Sudden loss of current in some parts of fill
2. Increased beam size → shorter lifetime.

Technique of Observation of Onset of Instability
Frequency analyze displacement monitor signal.
Observe harmonics of orbital frequency and sidebands displaced by betatron or synchrotron oscillation frequency. Very sensitive.

Betatron Oscillation Instabilities—Possible Cures
1. Octupole: Increases Landau damping
2. RF Quadrupole: Gives each bunch a different value. Δv = 0.011 at 120 MeV
3. Make $\xi = \frac{\Delta v}{\Delta p/p} > 0$. This Works. A distributed sextupole system keeps $\xi > 0$ and raises limits for betatron instabilities to values above those for synchrotron instabilities.

Synchrotron Oscillations—Present Limit
Begin to observe at 5 mA peak current.
Reduces lifetime at 25 mA peak current.
Effects are the same with 1 rf bunch or many.

Possible Cures
1. Operate at low rf voltage \{ Increases Landau Damping
2. Use high harmonic cavity
3. Use 36th harmonic cavity

For More Information See:
2. CEAL-1000, CEA-81
   General reports on original synchrotron.