Damping Rings Parameters

- 2 main rings for generating low emittance $e^+/e^-$
- 1 pre-ring for capturing $e^+$
- Similar to 3rd generation synchrotron light sources except
  - Injection and extraction at 120 Hz
  - Three bunch trains 95 bunches each

- 800 mA, $1.9 \times 10^{10}$ particles/bunch
- Typical beam size 60 x 6 µm (x,y)
- Bunch length $\approx 4$ mm
- Vacuum chamber radius $\approx 1.6$ cm

- Collective effects less severe for pre-damping ring
  - Larger beampipe, larger emittance, longer bunch, larger momentum compaction
Damping Rings

- Must provide stable injection into linac
  - Similar to 3rd generation light sources

<table>
<thead>
<tr>
<th></th>
<th>Pre-damping ring</th>
<th>Main damping rings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy (GeV)</td>
<td>1.9 – 2.1</td>
<td>1.9 – 2.1</td>
</tr>
<tr>
<td>Circumference (cm)</td>
<td>214</td>
<td>297</td>
</tr>
<tr>
<td>Bunch spacing (ns)</td>
<td>2.8</td>
<td>2.8</td>
</tr>
<tr>
<td>Fill pattern</td>
<td>2 trains 95 bunches</td>
<td>3 trains 95 bunches</td>
</tr>
<tr>
<td>Damping time (ms)</td>
<td>&lt; 5.2</td>
<td>&lt; 5.2</td>
</tr>
<tr>
<td>N_{max/bunch}</td>
<td>1.9\times10^{10}</td>
<td>1.6\times10^{10}</td>
</tr>
<tr>
<td>Current (mA)</td>
<td>800</td>
<td>750</td>
</tr>
<tr>
<td>Injected emittance X/Y (m-rad)</td>
<td>&lt; 9\times10^{-2} (edge)</td>
<td>&lt; 150\times10^{6} (rms)</td>
</tr>
<tr>
<td>Extracted emittance X/Y (m-rad)</td>
<td>&lt; 1\times10^{-4}</td>
<td>&lt; 3\times10^{-8}/0.03\times10^{-6}</td>
</tr>
<tr>
<td>RF voltage (MV)</td>
<td>2</td>
<td>1.5</td>
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<tr>
<td>Momentum compaction</td>
<td>0.0051</td>
<td>0.0066</td>
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<tr>
<td>Energy spread (%)</td>
<td>0.09</td>
<td>0.09</td>
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<tr>
<td>Bunch length (mm)</td>
<td>8.4</td>
<td>3.8</td>
</tr>
<tr>
<td>Vacuum pressure (torr)</td>
<td>1\times10^{-9}</td>
<td>1\times10^{-9}</td>
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<tr>
<td>Maximum rep. rate (Hz)</td>
<td>120</td>
<td>120</td>
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</table>
CD-1 Model "CDR"

- Revisit
  - Broadband and narrowband impedances
    - Update with new components where applicable
      - MAFIA
      - ABCI
  - Single bunch and multibunch collective effects
    - Growth rates, thresholds
  - Transient beam loading effects
    - Analyze interaction between beam and RF system
    - Develop schemes to control phase shift along bunch train

- Changes (1998)
  - Longer bunch trains
  - Increased momentum compaction
  - Increased aperture

- ZDR (1996)
  - Developed impedance budget
  - Analyzed collective effects

- No show-stoppers

- Demonstrates feasibility

- Experiments at ATF, ALS

- Goal to improve assessment of, and reduce, technical risk
ZDR Impedance Model

- Longitudinal wake
  - Major vacuum chamber components
    - RF cavities
    - Resistive wall
    - Ante-chamber slots
    - Bellows shields
    - BPM’s
    - Injection and extraction magnets
      - $Z/n \approx 0.03 \ \Omega$

- Similar impedance model for transverse wake

- Single bunch thresholds > design currents
Longitudinal single-bunch

- Potential well distortion

- Microwave instabilities
  - \( Z/n \approx 0.03 \, \Omega \)
  - Strong threshold estimate
    \[
    I_p = \frac{2\pi |\eta| (E_0/\sigma_p)^2}{Z/m_{\text{eff}}}
    \]
    - Threshold \( \approx 2 \times \) operating current
  - Simulations
    - Threshold \( \approx 4 \times \) operating current
Transverse single-bunch

- Transverse mode coupling instability (TMCI)
  - Simulations

- Threshold ≈ 10 x operating current
Gap transient effects

- Bunch-to-bunch synchronous phase variation
  - Leads to energy variation after bunch compression
- Compensation techniques
  - Adaptive-inverse feedforward with broadband klystron

\[ \Delta \phi = \frac{2kI_o T_{gap}}{V_{cavity} \sin \phi_{synch}} \]

- Harmonic cavities
- High-stored-energy cavities
Coupled-bunch instabilities

- Excited by transients and noise
- Damped RF cavities

- Longitudinal

- Transverse

  - Control residual motion with broadband feedback systems
    - Extend and develop ALS and PEP-II B-factory designs
Fast ion instability

- Interaction between intense electron beam and ions gives rise to fast transverse instability
- Growth time $\approx 1$ ms
- Experimental evidence from ALS and PLS
  - Maintain average pressure $< 1$ nTorr
  - Bunch-by-bunch feedback system
  - Additional gaps in bunch trains
Electron cloud instability

• Intense positron beam produces cloud of photoelectrons and secondary electrons
• Experimental evidence at BEPC
• Desorbs gas from surfaces
• Interaction between positron beam and electron cloud gives rise to fast transverse instability
  – Low secondary emission coatings
  – Bunch-by-bunch feedback system
  – Solenoidal magnetic fields
Lifetime and intrabeam scattering

- Gas-scattering lifetime several hours

- Touschek lifetime few minutes
  - Increase bunch volume for commissioning studies

- Intra beam scattering (IBS)
  - Significant at lower energies
Effort and schedule

- Impedance budget review: June 2001
- Transient effects review: January 2002
- Collective effects review: June 2002

<table>
<thead>
<tr>
<th></th>
<th>FY 99</th>
<th>FY 00</th>
<th>FY 01</th>
<th>FY 02</th>
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<tr>
<td>FTE</td>
<td>0.5</td>
<td>1</td>
<td>1</td>
<td>1.5</td>
<td>4</td>
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</table>

Staff
- K. Bane
- J. Corlett
- D. Li
- C. Ng
- T. Raubenheimer
Summary

• The NLC accelerator physics team is prepared to develop the damping rings impedance budget, and assess collective effects and transient behavior

  – Program established
    – Build on existing ZDR work
    – Update impedance budget
    – Compute collective effects
      » Minimize impedance at design stage
    – Analyze transient behavior and corrective measures
  – Cost and schedule in place
  – Organizational structure in place

• Ready to start!