Multibunch Workshop

PEP-II
Tune Monitor
and
Synchrotron-Light Monitor

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17 September 1997
Tune Monitor

Requirements
Dedicated system for on-line tune measurements
Wide dynamic range
  • Single small bunch \((5 \times 10^8)\) in ring
  • Full ring: 1658 large bunches \((8 \times 10^{10}\) for 3-A fill) every 4.2 ns
Measure tune with transverse and longitudinal feedback running
Measure tune of individual bunch or group of bunches in a full ring

Basic Tune Measurement
Excite beam (if needed) with a swept-frequency sinusoid or white noise.
Sum with transverse or longitudinal feedback signals.
  • Share the power amplifiers and striplines
  • Reduces impedance and cost
Send signals from dedicated set of 4 BPM-type buttons to spectrum analyzer
Spectrum Analyzer for Dedicated Tune Measurements

Two-channel, 0–10 MHz, all-digital spectrum analyzer: Hewlett-Packard 89410A
Includes excitation source with sines and random noise
Built-in and user programmable functions
  - Automatically follows peaks: tune tracking
  - Feedback to get tune peak with minimum excitation
Analyzer interfaces to control system with both ethernet and GPIB
  - Data transfer, remote control, and display on an X terminal
PEP-II Tune Monitor

\[ \Delta x = (B + Y) - (R + G) \]

\[ \Delta y = (B + R) - (G + Y) \]

\[ \Sigma = B + R + G + Y \]
## PEP-II Tune-Monitor: Components, Gain, and Noise

<table>
<thead>
<tr>
<th>Component Path:</th>
<th>Power Rating (dBm)</th>
<th>Gain (dB)</th>
<th>Noise Figure Gain (dB)</th>
<th>Cascaded Gain forward (dB)</th>
<th>Cascaded N.Figure forward (dBm/Hz)</th>
<th>Noise Level (dBm/Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attenuator</td>
<td>Narda 766, 3 dB, 20 W</td>
<td>43</td>
<td>-3.0</td>
<td>3.0</td>
<td>0.50</td>
<td>0.50</td>
</tr>
<tr>
<td>Long-haul cable</td>
<td>LDF4-50A, 0.5&quot; Heliax, 0.0751 dB/m</td>
<td>-4.7</td>
<td>4.7</td>
<td>0.34</td>
<td>0.17</td>
<td>7.7</td>
</tr>
<tr>
<td>Attenuator</td>
<td>Narda 4780, 6 db, 0–6 GHz, 2 W</td>
<td>33</td>
<td>-6.0</td>
<td>6.0</td>
<td>0.25</td>
<td>0.04</td>
</tr>
<tr>
<td>180° hybrid</td>
<td>Anzac H-183-4</td>
<td>37</td>
<td>-3.7</td>
<td>3.7</td>
<td>0.43</td>
<td>0.02</td>
</tr>
<tr>
<td>180° hybrid</td>
<td>Anzac II-183-4</td>
<td>37</td>
<td>-3.7</td>
<td>3.7</td>
<td>0.43</td>
<td>0.01</td>
</tr>
<tr>
<td>Step attenuator</td>
<td>HP8495G (0–70 dB), loss at 0-dB setting</td>
<td>30</td>
<td>-0.5</td>
<td>0.5</td>
<td>0.90</td>
<td>0.01</td>
</tr>
<tr>
<td>Amplifier</td>
<td>Mini-Circuits ZHL-1042J</td>
<td>20</td>
<td>25.0</td>
<td>4.5</td>
<td>316.23</td>
<td>2.19</td>
</tr>
<tr>
<td>Gate</td>
<td>Mini-Circuits ZYSWA-2-50DR</td>
<td>22</td>
<td>-1.1</td>
<td>-1.1</td>
<td>1.1</td>
<td>0.78</td>
</tr>
<tr>
<td>Band-pass filter</td>
<td>RLC Electronics BPF-750-952-19-4-R</td>
<td>47</td>
<td>-2.5</td>
<td>-2.5</td>
<td>2.5</td>
<td>0.56</td>
</tr>
<tr>
<td>Attenuator</td>
<td>Narda 4780, 3 dB, 0–6 GHz, 2 W</td>
<td>33</td>
<td>-3.0</td>
<td>3.0</td>
<td>0.50</td>
<td>0.04</td>
</tr>
<tr>
<td>Amplifier</td>
<td>Mini-Circuits ZFL-1000H</td>
<td>20</td>
<td>28.0</td>
<td>5.0</td>
<td>630.96</td>
<td>299.57</td>
</tr>
<tr>
<td>Attenuator</td>
<td>Narda 4780, 3 dB, 0–6 GHz, 2 W</td>
<td>33</td>
<td>-3.0</td>
<td>3.0</td>
<td>0.50</td>
<td>150.14</td>
</tr>
<tr>
<td>Mixer</td>
<td>Anzac MDC-149</td>
<td>25</td>
<td>-6.3</td>
<td>7.3</td>
<td>0.23</td>
<td>35.20</td>
</tr>
<tr>
<td>Attenuator</td>
<td>Narda 4780, 6 db, 0–6 GHz, 2 W</td>
<td>33</td>
<td>-6.0</td>
<td>6.0</td>
<td>0.25</td>
<td>8.84</td>
</tr>
<tr>
<td>Low-pass filter</td>
<td>Mini-Circuits SLP-10.7</td>
<td>27</td>
<td>-1.0</td>
<td>1.0</td>
<td>0.79</td>
<td>7.02</td>
</tr>
<tr>
<td><strong>System Gain</strong> <strong>G</strong> and Noise Figure <strong>F</strong>:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Local-Oscillator Path:

<table>
<thead>
<tr>
<th>Component</th>
<th>Make &amp; Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase shifter</td>
<td>SLAC</td>
</tr>
<tr>
<td>Doubler</td>
<td>Techtrol Cyclonetics FXA897A</td>
</tr>
<tr>
<td>Splitter</td>
<td>Mini-Circuits ZFSC-2-5</td>
</tr>
<tr>
<td>Attenuator</td>
<td>Narda 4780, 3 dB, 0–6 GHz, 2 W</td>
</tr>
</tbody>
</table>
Other views of the Beam Response

FFT of a 1024-turn BPM record

Follow oscillations of a bunch around one turn using all BPMs

Second dedicated set of 4 buttons (both rings) for direct input to a high-frequency spectrum analyzer: bunch dynamics

Provide additional button pickups and cables for study of bunch spectra
  • Use with a high-frequency spectrum analyzer
  • No extensive remote control

Extensive diagnostics incorporated in the feedback systems
High Energy Ring Synchrotron Light
(low beam current)
**Synchrotron-Light Profile Monitor**

**Configuration**

Measure HER, and in future LER too, at the middle of Arc 7  
Collect light emitted near QDs: large vertical beam size  

**HER**  
- Water-cooled, grazing-incidence mirror in wall of dipole chamber  
  - Light directed horizontally back across chamber  
  - Periscope at downstream end of chamber sends light down to optics table  

**LER**  
- Slit in middle of photon stop passes some of light  
  - Water-cooled, grazing-incidence mirror reflects horizontally outward  
  - Two more mirrors reflect horizontally, then downward to optics table  

Fused-silica windows after mirrors to exit beamline vacuum  
Below HER dipole, optics table has HER & LER optics in N$_2$-filled enclosure  
  - Remote adjustment of steering, focus, intensity  
  - Beam is imaged onto CCDs on this table, for better stability and resolution  
  - A path also planned to a lab 10 m above for streak camera and fast gated camera
Synchrotron Light Monitor Installation
Schematic of HER Synchrotron-Light Optics

HeNe laser

Shaft

λ/4 plate

Filters and polarizers

M1

Movable

f1

e⁻ beam

Images of e⁻ beam

Images of M1 and slot

f2

f3

f4

f5

Streak camera

Image of e⁻ beam

TV
Arrangement of HER Optics

Note: The LER optics will be mounted on the same table, above the HER optics.
Vertical Resolution and Diffraction

Vertical angle of horizontally polarized synchrotron light: almost Gaussian with size

$$\sigma_{l_y} = \frac{0.6}{\gamma} \left( \frac{\lambda}{\lambda_c} \right)^{1/3}$$

Product of rms size and angle for a Gaussian light beam

$$\sigma_{l_y} \sigma_{l_y} = \frac{\lambda}{4\pi}$$

Image size

$$\sigma_{\text{image}}^2 = \sigma_y^2 + \sigma_d^2$$

where

$$\sigma_y = \sqrt{\varepsilon_y \beta_y}$$
electron/positron beam size

and

$$\sigma_d = \sigma_{l_y} - A(\rho \lambda^2)^{1/3}$$
diffraction spot size

Substituting for the critical wavelength $\lambda_c$ gives $A = 0.21$

LEP's experimental resolution corresponds to $A = 0.26$, which we will use below.
For measurements at a 300-nm wavelength (near ultraviolet):

<table>
<thead>
<tr>
<th>Parameter</th>
<th>HER Mid-Arc</th>
<th>HER Start of Arc</th>
<th>LER Mid-Arc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radius of curvature in dipole [m]</td>
<td>165</td>
<td>165</td>
<td>13.75</td>
</tr>
<tr>
<td>Diffraction spot size $\sigma_d$ [\mu m]</td>
<td>64</td>
<td>64</td>
<td>28</td>
</tr>
<tr>
<td>Dispersion function $\eta$ [m]</td>
<td>1.14</td>
<td>0.29</td>
<td>0.33</td>
</tr>
<tr>
<td>Horizontal beta function $\beta_x$ [m]</td>
<td>10.85</td>
<td>8.01</td>
<td>4.92</td>
</tr>
<tr>
<td>Vertical beta function $\beta_y$ [m]</td>
<td>21.57</td>
<td>26.70</td>
<td>23.68</td>
</tr>
<tr>
<td>Electron/positron beam size $\sigma_x$ [\mu m]</td>
<td>1000</td>
<td>645</td>
<td>622</td>
</tr>
<tr>
<td>Electron/positron beam size $\sigma_y$ [\mu m]</td>
<td>176</td>
<td>196</td>
<td>216</td>
</tr>
<tr>
<td>$\sigma_y / \sigma_d$</td>
<td>2.8</td>
<td>3.1</td>
<td>7.7</td>
</tr>
<tr>
<td>Image size $\sigma_{\text{image}}$ [\mu m]</td>
<td>187</td>
<td>206</td>
<td>218</td>
</tr>
<tr>
<td>$\sigma_{\text{image}} / \sigma_y$</td>
<td>1.06</td>
<td>1.05</td>
<td>1.01</td>
</tr>
</tbody>
</table>
\[ C(x) = a_6 + a_1 \cdot \exp[-6.6 \cdot ((x-x_0)/\sigma_1)^2] \]

where:

- \( a_6 = 1.3535 \pm 0.0362 \) E-1
- \( a_1 = 3.6283 \pm 0.0362 \) E-1
- \( x_0 = 2.617 \pm 0.002 \) E-1

Estimated Chi squared = 163.9668

PROF, P111, 04/26
16-SEP-57 07:52:58

Mean 2.65562594
Std dev 0.86172671
Skew 0.1439166
Kurtosis 0.853706
Width 1.52716403

Mean 5.41679689
Std dev 2.56591269
Skew 0.75162636
Kurtosis 7.7316289
Width 6.6179664

\[ C(x) = a_6 + a_1 \cdot \exp[-6.6 \cdot ((x-x_0)/\sigma_1)^2] \]

where:

- \( a_6 = -4.82 \pm 0.16 \) E-3
- \( a_1 = 4.286 \pm 0.14 \) E-1
- \( x_0 = 5.432 \pm 0.192 \) E-1

Estimated Chi squared = 56.02E2

PROF, P111, 04/26
16-SEP-57 07:52:58

314
Mean 2.77846371
Std dev .751695295
Skew .163846786
Kurtosis -.688686819
Width .265 .8684126
Width@60% 1.78888198

PROF,FL11,6426
16-SEP-67 07:11:25

Mean 5.46677977
Std dev 1.732666544
Skew -6.99515172
Kurtosis -.65064566
Width@25% 7.43668788
Width@60% 4.54392741

PROF,FL11,6426
16-SEP-67 07:11:49