DESIGN OF COMPACT PULSED 4 MIRROR LASER WIRE SYSTEM FOR QUICK MEASUREMENT OF ELECTRON BEAM PROFILE

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1. Concept of Aspect ratio

2. Selection of design values

3. Scheme to obtain small beam size

4. Results of compact resonator

5. Mirror alignment scheme in Vacuum


Thursday, May 10, 2012

Mode Locked fiber laser and high power optical cavity R & D Meeting
Aim: To obtain, minimum beam waist in one plane (sagittal plane)
\[ \sigma \leq 6 \mu m \] (using green Laser oscillator, 532 nm)

In present optical bench set up, we use IR (1064 nm) Laser oscillator

We define term, Aspect ratio as ratio of mirror separation between adjacent plane and concave mirror to length of resonator

\[
R \ (Sagittal) = R / \cos \alpha / 2 \\
R \ (Tangential) = R \times \cos \alpha / 2 \\
\text{Aspect ratio} \\
\alpha = \tan^{-1} \frac{d}{L}
\]

Present Laser Wire System in ATF damping ring is 2 mirror CW green laser wire system
### ASPECT RATIO AND MINIMUM BEAM WAIST

<table>
<thead>
<tr>
<th>Length L (mm)</th>
<th>412</th>
<th>206</th>
<th>103</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance d (mm)</td>
<td>116</td>
<td>58</td>
<td>29</td>
</tr>
<tr>
<td>Curvature ρ (mm)</td>
<td>408</td>
<td>204</td>
<td>102</td>
</tr>
<tr>
<td>Total path length (Lcav.) mm</td>
<td>1680</td>
<td>840</td>
<td>420</td>
</tr>
<tr>
<td>Aspect ratio (α) rad</td>
<td>0.2745</td>
<td>0.2745</td>
<td>0.2745</td>
</tr>
<tr>
<td>Min. beam waist (ω&lt;sub&gt;s&lt;/sub&gt;, ω&lt;sub&gt;T&lt;/sub&gt;)</td>
<td>(30,80)um</td>
<td>(21,57)um</td>
<td>(14,40)um</td>
</tr>
</tbody>
</table>

If we fix aspect ratio of resonator, and scale down the long length resonator, we approach towards smaller minimum beam waist.
### Selection of Curvature

**Beam Size in mm**

**Radius of Curvature of Concave Mirror**

- **Tangential**
- **Sagittal**

<table>
<thead>
<tr>
<th>R (mm)</th>
<th>(2σ), IR Laser</th>
</tr>
</thead>
<tbody>
<tr>
<td>102</td>
<td>(12.8, 40) μm</td>
</tr>
<tr>
<td>102.01</td>
<td>(10.6, 39.9) μm</td>
</tr>
</tbody>
</table>

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BEAM SIZE VARIATION w.r.t. “d"

<table>
<thead>
<tr>
<th>“d” mm</th>
<th>(σ_S, σ_T) value, IR Laser</th>
</tr>
</thead>
<tbody>
<tr>
<td>29</td>
<td>(7.3, 20) um</td>
</tr>
<tr>
<td>29.1</td>
<td>(6.91, 20) um</td>
</tr>
<tr>
<td>29.2</td>
<td>(6.43, 20) um</td>
</tr>
<tr>
<td>29.3</td>
<td>(5.81, 20) um</td>
</tr>
</tbody>
</table>

Curvature “R” mm | (σ_S, σ_T) value, IR Laser |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>102</td>
<td>(6.43, 20) um</td>
</tr>
<tr>
<td>102.01</td>
<td>(5.33, 20) um</td>
</tr>
<tr>
<td>101.9</td>
<td>(10.15, 20.2) um</td>
</tr>
<tr>
<td>101.5</td>
<td>(14.4, 21) um</td>
</tr>
</tbody>
</table>
**Beam Evolution Inside Resonator**

**Sagittal Plane**

**Tangential Plane**

**Longitudinal Distance in mm**

**Beam waist (2\(\sigma\)) value in mm**

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**PULSED MODE-LOCKED LASER OSCILLATOR**

- **Crystal**: Nd:VAN
- **Wavelength**: 1064 nm
- **Repetition rate**: 714.037 MHz
- **Pulse width**: 7.5 ps (FWHM)
- **O/P Power @ \( I_{2.25} \) A**: 520 mW

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**Graph**: Output power vs. pump diode current.

- **Output Power (mW)**: 0 to 700
- **Pump Diode Current (A)**: 1 to 2.5

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OPTICAL BENCH SETUP

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**NEED FOR CYLINDRICAL LENS SYSTEM**

At injection Mirror
Sagittal beam size is **larger**
Tangential beam size is **smaller**

\[ \frac{\sigma_T}{\sigma_S} \approx 3 \]

At Minimum beam waist position
Sagittal beam size is **smaller**
Tangential beam size is **larger**
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Cavity length is varied by PZT.

Piezo actuator is driven by triangular wave through a HV amplifier.
DIVERGENCE METHOD FOR BEAM WAIST MEASUREMENT

\[ W_0 = \lambda \frac{\pi}{\theta} \]

Laser beam at output mirror need to be scanned both in horizontal and vertical direction.

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SAGITTAL PLANE AND TANGENTIAL PLANE SCAN

Sagittal Plane Scan

\[ \sigma = 12.31 \pm 0.62 \text{ um} \]

Legend
\[ A = 0.1687 \times 10^{-1}; B = 0.1125 \times 10^{+1} \]

Tangential Plane Scan

\[ \sigma = 24.9 \pm 1.5 \text{ um} \]

Legend
\[ A = 0.8318 \times 10^{-2}; B = 0.1892 \times 10^{+0} \]
**Beam Size Analysis Using Guoy Phase Study**

- **Mirror Separation $\delta$ in mm**:
  - **Sagittal Plane**
    - Beam Size ($\sigma$ value)
      - Divergence Method: $12.31 \pm 0.62$ um
      - Guoy Phase Method: $14.5 \pm 0.5$ um
  - **Tangential Plane**
    - Beam Size ($\sigma$ value)
      - Divergence Method: $24.9 \pm 1.5$ um
      - Guoy Phase Method: $25.9 \pm 0.7$ um

**Graphs**

- **Guoy Phase in Radians** vs. **Mirror Separation $\delta$ in mm**
  - **Tangential Plane**
  - **Sagittal Plane**

**Additional Information**

- **Thursday, May 10, 2012**
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 FINESSE OF COMPACT RESONATOR 

$r_1 = 99.75$
$r_2 = 99.985$
$r_3 = 99.985$
$r_4 = 99.985$

Theoretical Finesse = 1547.5

Measured Finesse = $\frac{FSR}{FWHM}$

1325 $\mp$ 40

Enhancement Factor = 710
DESIGN OF COMPACT RESONATOR

All Mirrors are tilted at 8 degrees.

L = 103 mm

29.2 mm

 Longer PZT Case

Shorter PZT Case

Mirror Holder

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d = 29.2 mm

L = 103 mm

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Injection

Concave Mirror

Plane Mirror with shorter PZT

Plane Mirror with Longer PZT

Min. Beam waist

Beam Pipe

Cutting of beam pipe

between Plane mirror

between Concave mirror

Transmitted light

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### COMPACT CAVITY USING GREEN PULSED OSCILLATOR

<p>| | |</p>
<table>
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</thead>
<tbody>
<tr>
<td>L</td>
<td>103 mm</td>
</tr>
<tr>
<td>d</td>
<td>29.2 mm</td>
</tr>
<tr>
<td>(\alpha)</td>
<td>0.1381 rad</td>
</tr>
<tr>
<td>(\rho) (Curvature)</td>
<td>102 mm</td>
</tr>
<tr>
<td>Beam size (IR) (\omega_S, \omega_T) ((\sigma))</td>
<td>(7, 20) um</td>
</tr>
<tr>
<td>Beam Size (Green Laser) (\omega_S, \omega_T) ((\sigma))</td>
<td>(3.75, 14.1) um</td>
</tr>
</tbody>
</table>

Green Laser Oscillator with Repetition rate 714 MHz, will give beam size less than 5 um in sagittal plane
MERITS

1. Four mirror resonator reduces the sensitivity to the misalignment of mirror compared to two mirror resonator, thus more stable.

2. At present, CW Laser Wire has been used to measure the small emittance beam. If we replace it to pulsed laser wire, more efficient laser-beam collision can be realized.

3. CW laser wire system takes more time in scanning of electron beam compare to Pulsed laser.

4. With green laser oscillator, beam waist less than 5 um can be obtained in one plane.
ANALYSIS

Compact Cavity is very sensitive to mm accuracy.

Scheme to obtain very small beam size requires proper mirror alignment scheme for fixing of mirrors.

Green laser oscillator will give smaller beam size compare to IR oscillator.