Gaussian Beam Optics

Dathon Golish
OPTI 521 Tutorial

December 5th, 2006
I. Theory

Why work with Gaussian beams?

- Geometric vs. Diffraction-limited regimes
- System Scale vs. Wavelength
- Detector Technology
I. Theory

\[
\left( \nabla^2 + k^2 \right) \Psi = \frac{\delta^2 E}{\delta x^2} + \frac{\delta^2 E}{\delta y^2} + \frac{\delta^2 E}{\delta z^2} + k^2 E = 0
\]

\[
E(x, y, z) = u(x, y, z)e^{-j kz}
\]

\[
R = z + \frac{1}{z} \left( \frac{\pi w_0^2}{\lambda} \right)^2
\]

\[
w = w_0 \sqrt{1 + \left( \frac{\lambda z}{\pi w_0^2} \right)^2}
\]
II. Beam Sizes – PoleSTAR LO

- PoleSTAR: 4-pixel 810 GHz Array
- LO 4-way Splitter

Figure 2: PoleSTAR on AST/RO
III. Tolerancing – SuperCam

- SuperCam: 64-pixel 345 GHz Array
- Typical tolerances are on the order of microns & milliradians.
- With wavelengths ~1000 times larger, tolerances are much more lenient.
### III. Tolerancing – SuperCam

#### Shift (along axis) (mm)

<table>
<thead>
<tr>
<th>Optic</th>
<th>-X</th>
<th>+X</th>
<th>-Y</th>
<th>+Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flat Tertiary</td>
<td>†</td>
<td>†</td>
<td>†</td>
<td>†</td>
</tr>
<tr>
<td>Hyperbola</td>
<td>-15.8</td>
<td>15.8</td>
<td>-21.5</td>
<td>17.4</td>
</tr>
<tr>
<td>Flat Fold</td>
<td>†</td>
<td>†</td>
<td>†</td>
<td>†</td>
</tr>
<tr>
<td>Ellipse</td>
<td>-16</td>
<td>16</td>
<td>-18.3</td>
<td>14.4</td>
</tr>
</tbody>
</table>

†Shift has no effect.

#### Rotation (around axis) (deg)

<table>
<thead>
<tr>
<th>Optic</th>
<th>-X</th>
<th>+X</th>
<th>-Y</th>
<th>+Y</th>
<th>-Z</th>
<th>+Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flat Tertiary</td>
<td>-.72</td>
<td>3.2</td>
<td>-1.5</td>
<td>1.5</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Hyperbola</td>
<td>-1.7</td>
<td>1.3</td>
<td>-1.7</td>
<td>1.7</td>
<td>-21.5</td>
<td>21.5</td>
</tr>
<tr>
<td>Flat Fold</td>
<td>-2.6</td>
<td>3.0</td>
<td>-3.1</td>
<td>3.1</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Ellipse</td>
<td>-1.4</td>
<td>1.3</td>
<td>-1.3</td>
<td>1.3</td>
<td>-21.5</td>
<td>21.5</td>
</tr>
</tbody>
</table>

*Shift has no effect.
IV. Optical Manufacturing – SuperCam

<table>
<thead>
<tr>
<th>Optic</th>
<th>Surface Quality Quantity</th>
<th>Value</th>
</tr>
</thead>
</table>
| Flat Tertiary      | Curvature Error in Fringes                          | -.43  
|                    | Irregularity in Fringes                             | -.28  
| Hyperbola          | Radius of Curvature (1692 mm Nominal)               | -54   
| Hyperbola          | Irregularity in Fringes                             | -1.67 |
| Flat Fold          | Curvature Error in Fringes                          | -3.2  
| Flat Fold          | Irregularity in Fringes                             | -2.1  
| Ellipse            | Radius of Curvature (772 mm Nominal)                | -16.7 |
| Ellipse            | Irregularity in Fringes                             | -4.6  |

- Wavelength = 870 μm
- Fringe = 0.435 mm, flatness easy to achieve
- Radii ~3%, easy to manufacture
V. Vibration & Stability – TREND

- TeraHertz REceiver with a NbN Device (TREND)
- FIR Laser LO Source
- Long lever arm
- LO Instability
VI. Cryogenics – SuperCam

- **Superconductor-Insulator-Superconductor Detectors**
- **Require LHe temperatures (4K) or lower**
- **Mixer plane is kept at 4K**
- **Differential contraction becomes a significant factor**
VI. Conclusions

- Just a sampling of the various issues working in this regime can introduce.

- As the FIR technology and radio technology approach each other, these differences must be recognized and reconciled.

- Terahertz technology in particular is growing quickly and will require knowledge of both regimes.