Magnetic Performance of the Advanced Light Source EPU5.0 Elliptically Polarizing Wiggler

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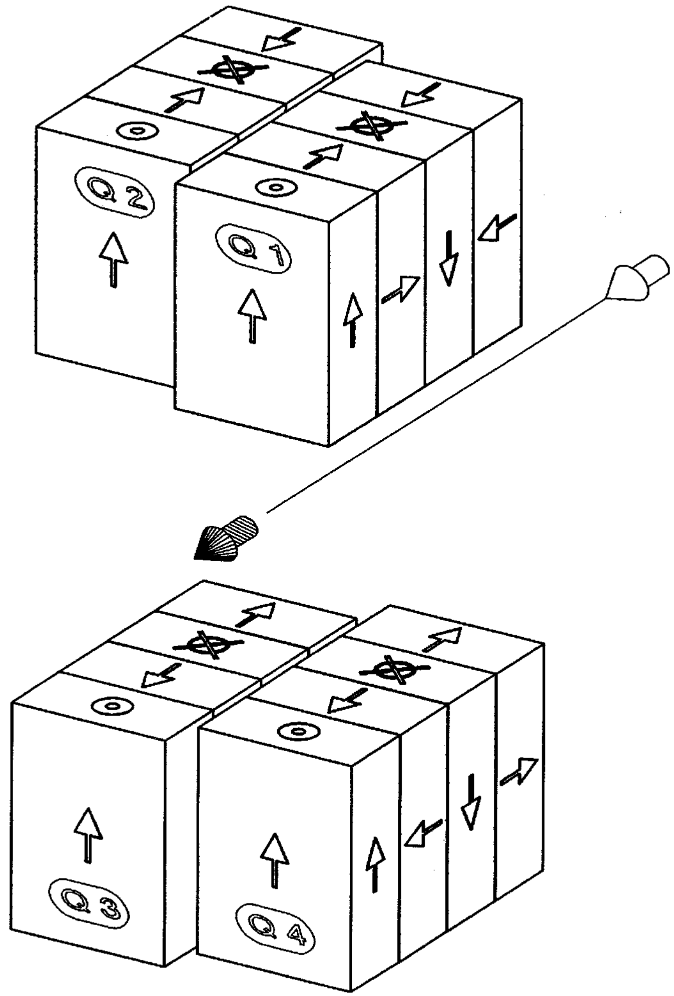
EPU Principal of Operation



EPU Principal of Operation

- **Four Identical Quadrants**
- **Polarization Changes by Moving Q1/Q3 Relative to Q2/Q4**

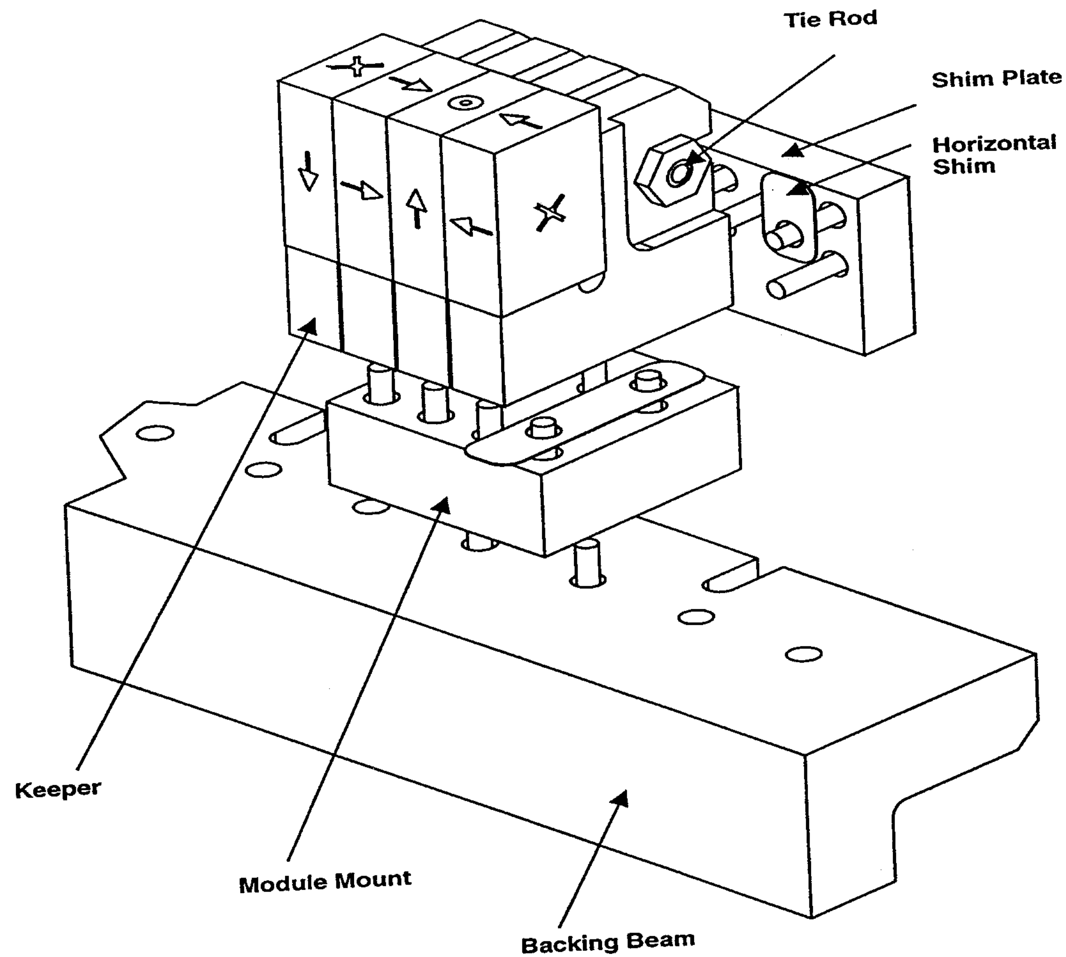
$$B_x = B_{x0}\sin(\varphi/2);\quad B_y = B_{y0}\cos(\varphi/2)\ ;\ \varphi = 2\pi dz/\lambda$$

- **Polarization Modes**
  - **horizontal:** $dz = 0$, $B_{x0} = 0$
  - **vertical:** $dz = \lambda/2$, $B_{y0} = 0$
  - **circular:** $B_x = B_y$, **fundamental only**
  - **elliptical:** $B_x \neq B_y$, **harmonics**

Magnetic Design

- 5.0 cm Period Length
- Standard Sasaki Configuration
- 13.8 mm Minimum Gap
- 37.5 Full Strength Periods
- Magnetic Modules Consist of 4 Keepers
- Each Keeper is Adjustable $\pm$0.25 mm in x and y
- Ends Designed to be Steering & Deflection Free

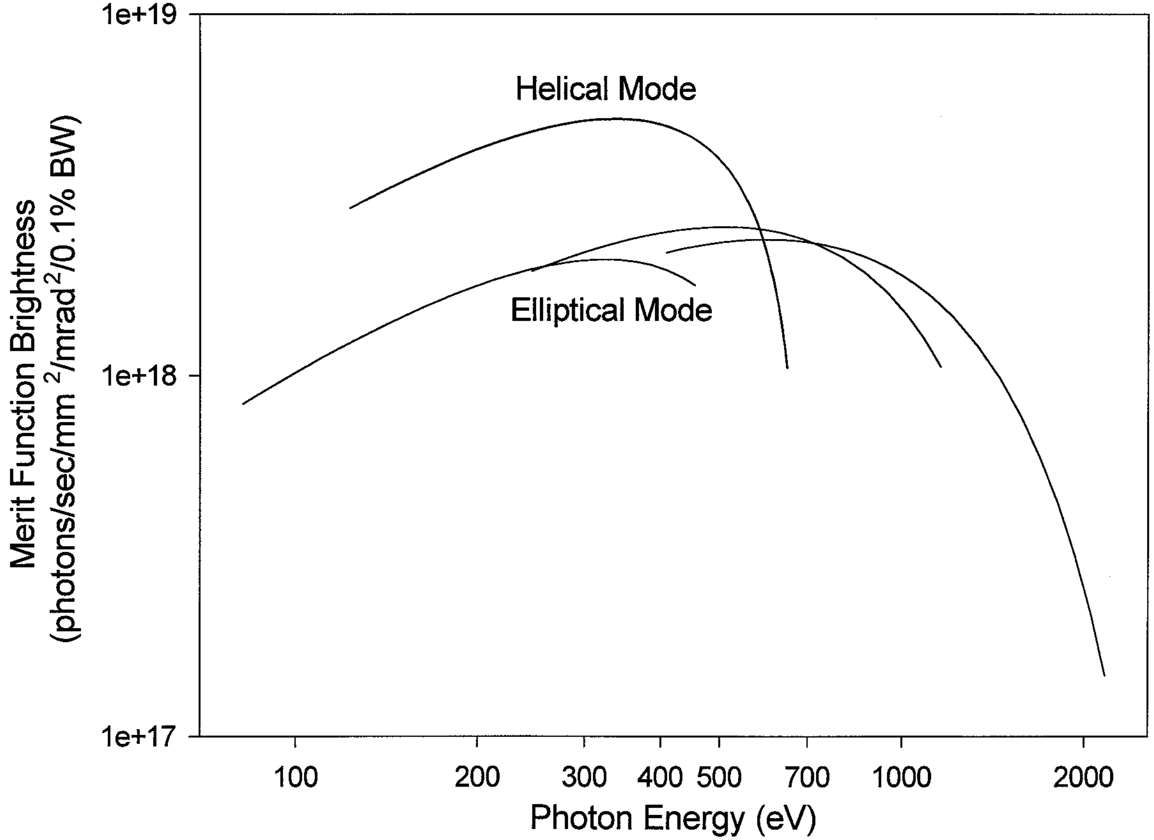
EPU Magnetic Module



EPU5.0 Design Spectrum

B_r = 1.2 T
G_{min} = 14.5 mm
$B_y = 3B_x$ (elliptical)
P_c > 0.75

Elliptical:
100eV - 1500eV
Helical:
130eV - 500eV



Magnetic Shimming

- Approaches for conventional undulators:
  — Limit RMS field errors: tolerances, shimming
  — Apply iron shims to cancel accumulated errors, determined from field measurements

- Approach for EPU5.0:
  — Measure fields and determine errors for dz = 0 and dz = $\lambda/2$
  — Minimize local phase errors, local field integrals with dx, dy for Q1/Q3 and Q2/Q4
  — Minimize lateral integral nonumiformities
  — Check spectrum for other φ

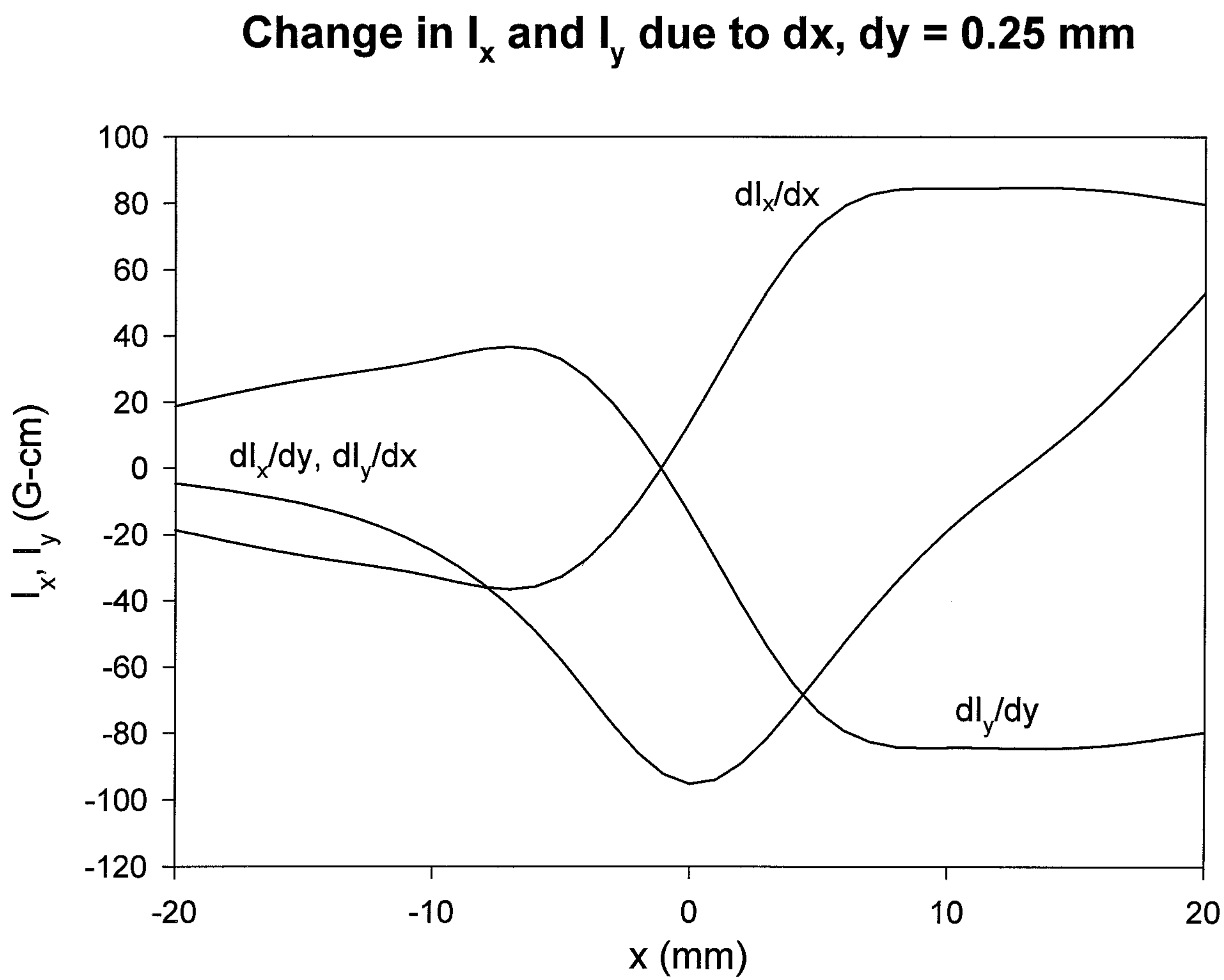
Optical Phase Error

$$
\begin{aligned}
\Delta s(z) = {} & x_0(z)\Delta x'(z) + y_0(z)\Delta y'(z) \\
& - \int_{-\infty}^{z} \left[x_0(\xi)\Delta x''(\xi) + y_0(\xi)\Delta y''(\xi) \right] d\xi \\
& + \frac{1}{2} \int_{-\infty}^{z} \left[\Delta x'^2(\xi) + \Delta y'^2(\xi) \right] d\xi
\end{aligned}
$$

Results of Shimming

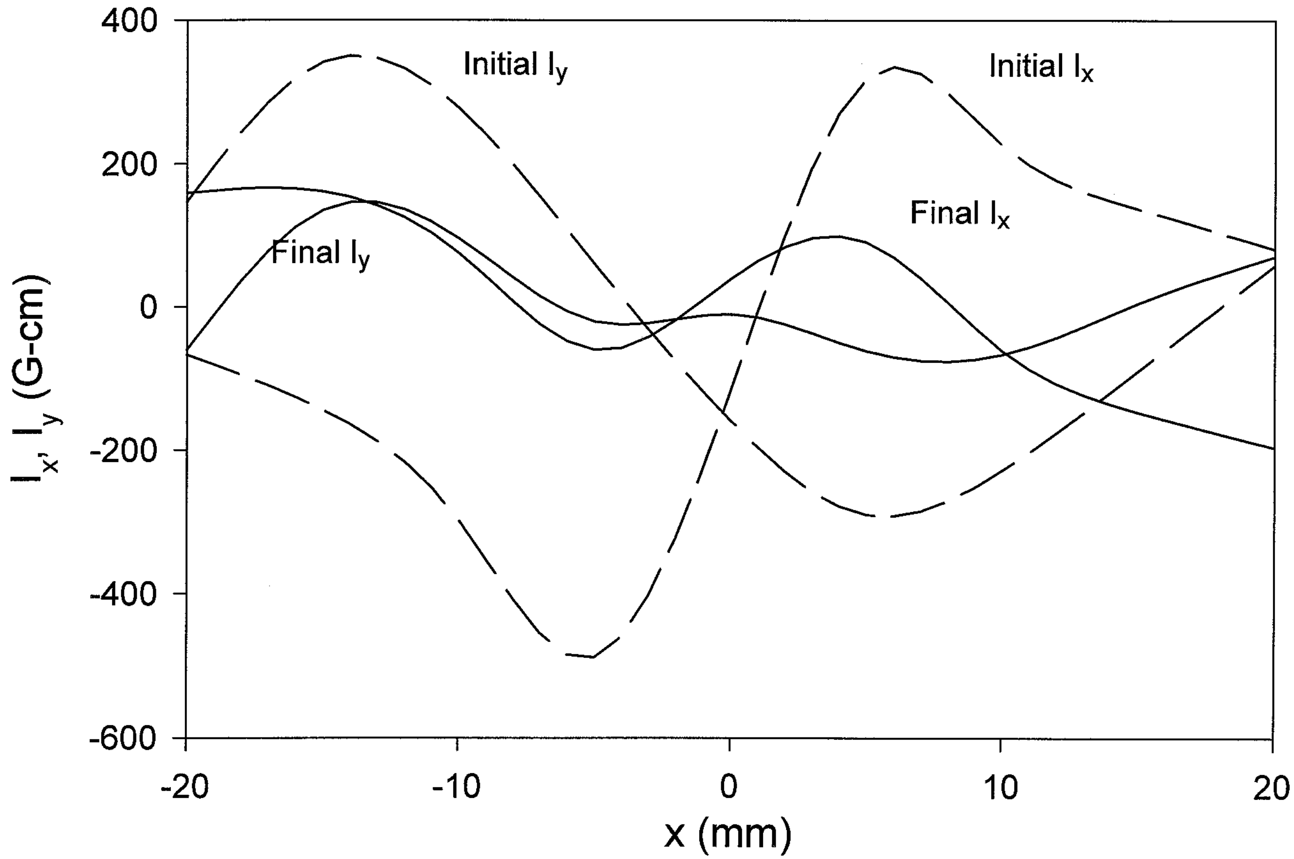
- Three Shimming Iterations
- dz = 0:
  - RMS Phase error: 10º $\Rightarrow$ 9º
  - RMS I_x: 147 G-cm $\Rightarrow$ 59 G-cm
  - RMS I_y: 95 G-cm $\Rightarrow$ 76 G-cm
- dz = $\lambda/2$:
  - RMS Phase error: 32º $\Rightarrow$ 12º
  - RMS I_x: 218 G-cm $\Rightarrow$ 56 G-cm
  - RMS I_y: 165 G-cm $\Rightarrow$ 64 G-cm

Integral Distribution Shimming

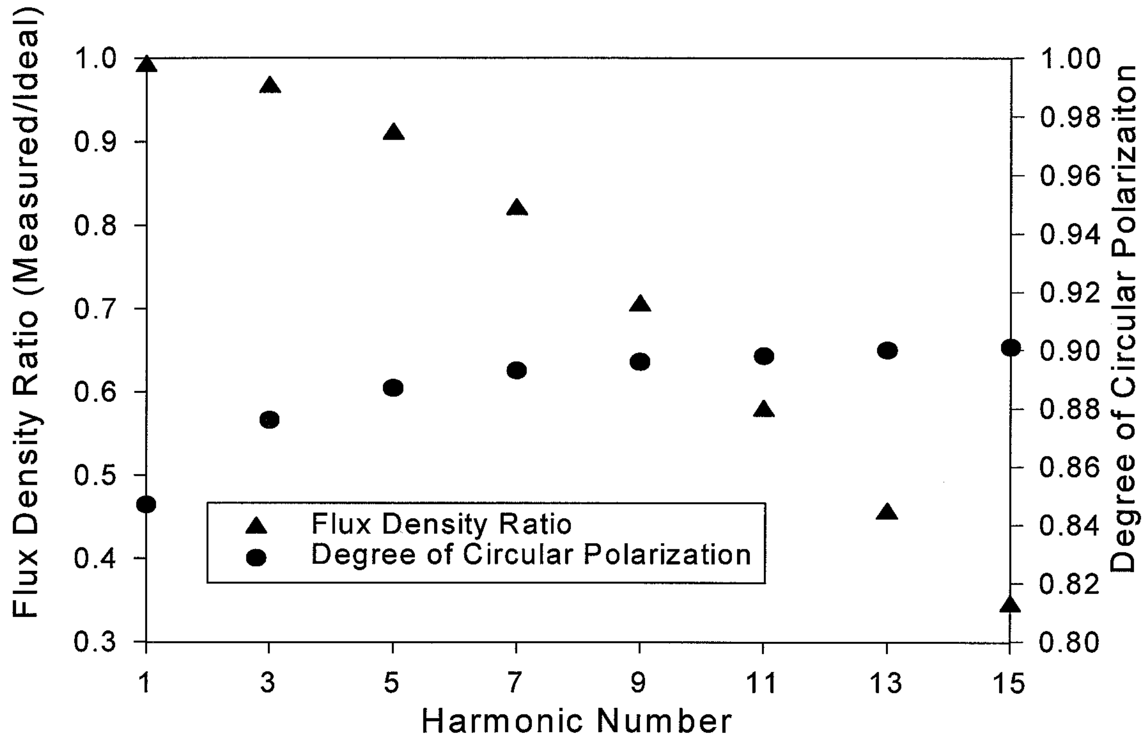


Results of Integral Shimming

I_x and I_y at 14 mm gap, dz = 0



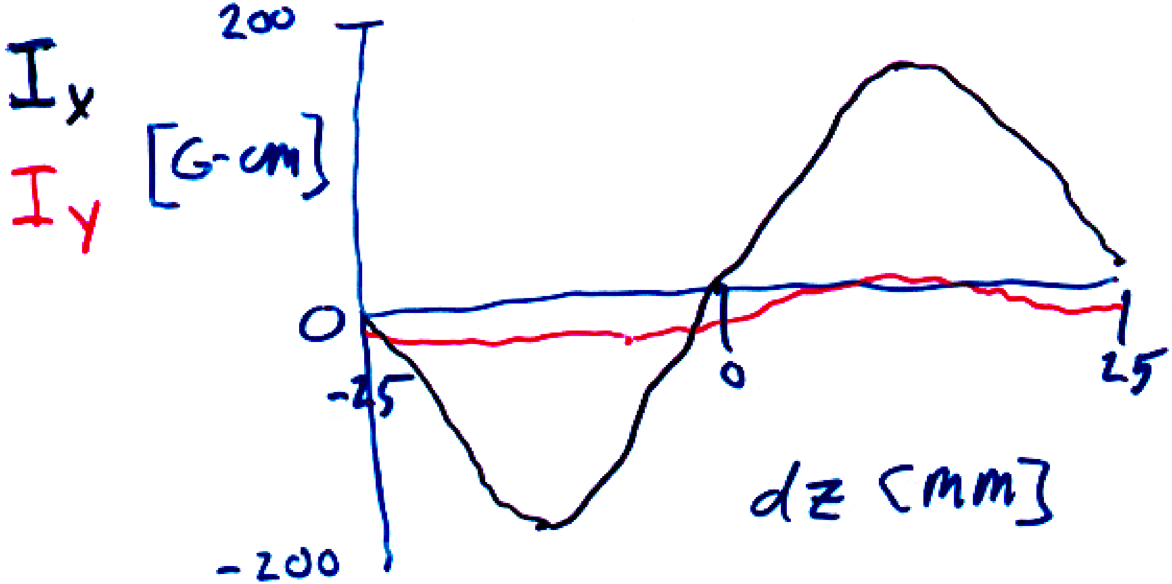
Spectral Quality



- 23 mm gap, dz = 9 mm
- E_1 = 220 eV, E_3 = 660 eV
- Field errors do not degrade polarization

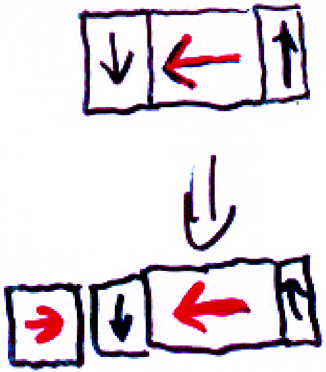
On-axis I_x, I_y @ 14 mm gap

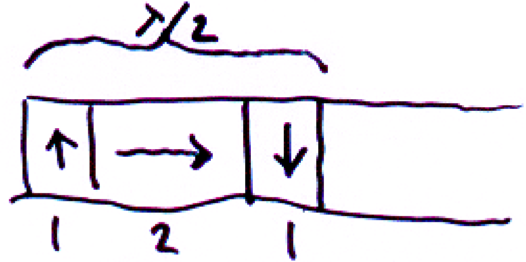
for axial Q1/Q3 shift $-\lambda/2 \le dz \le \lambda/2$



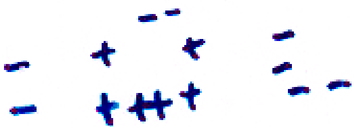
$\lambda = 50$

kf/df end



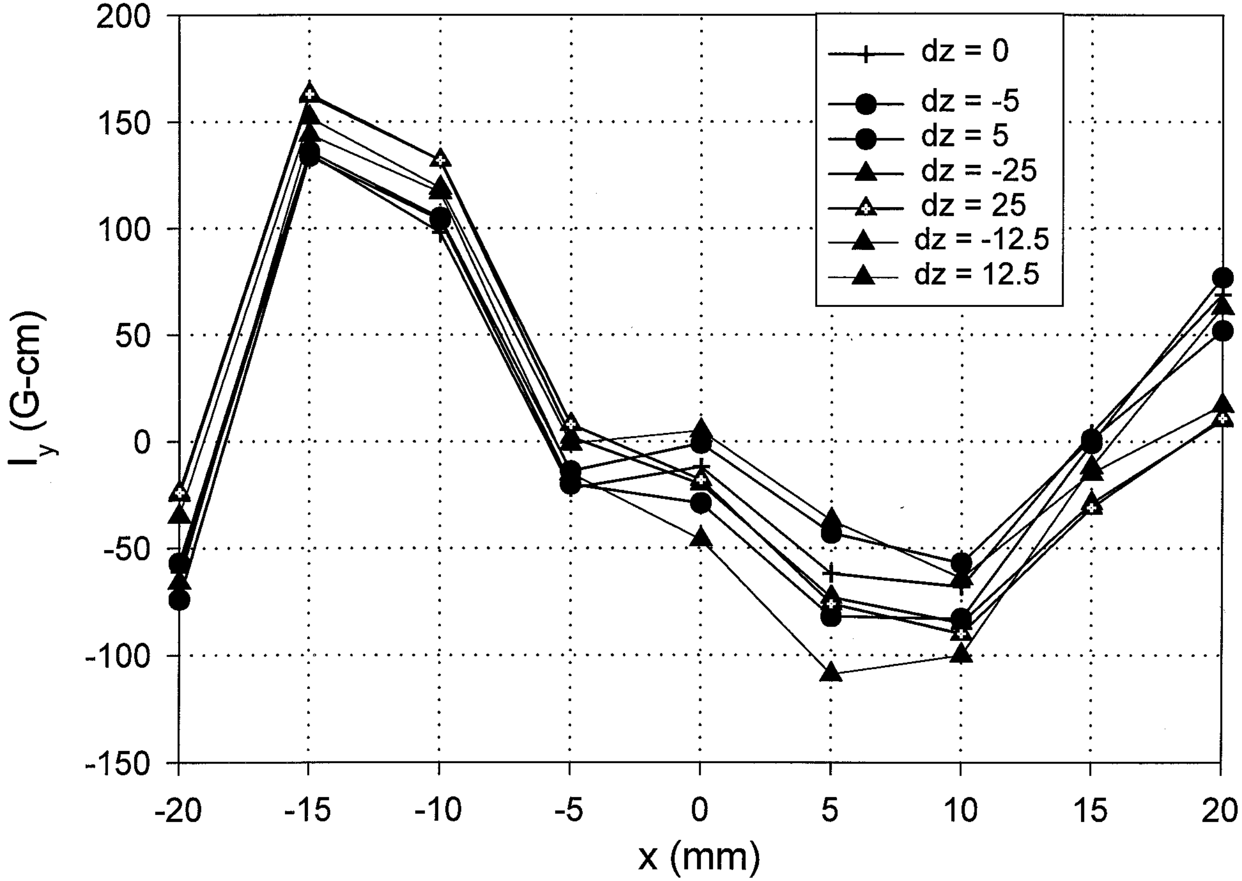


this variation ramps up to full field most quickly

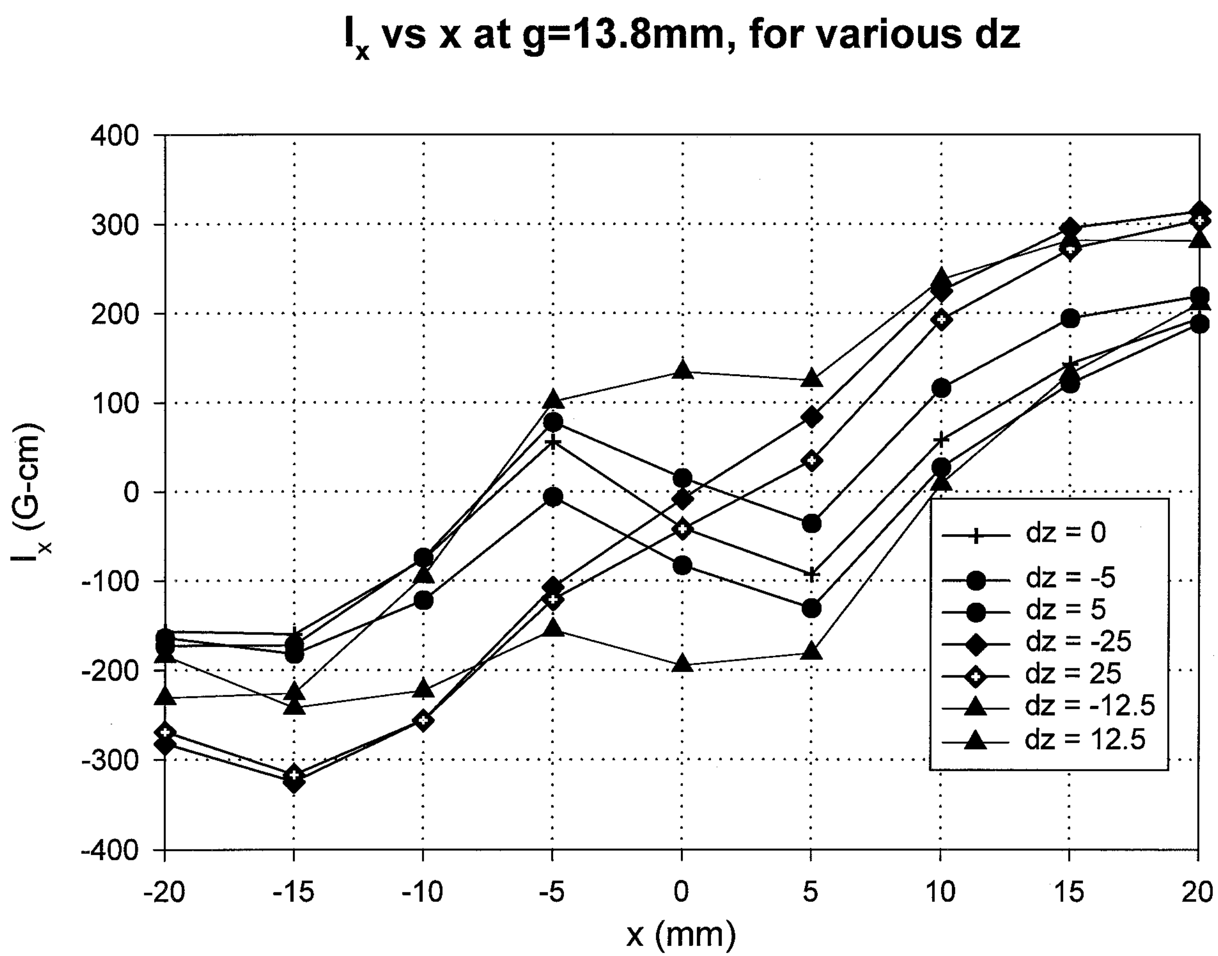


Integral Quality

I_y vs x at g=13.8mm, for various dz

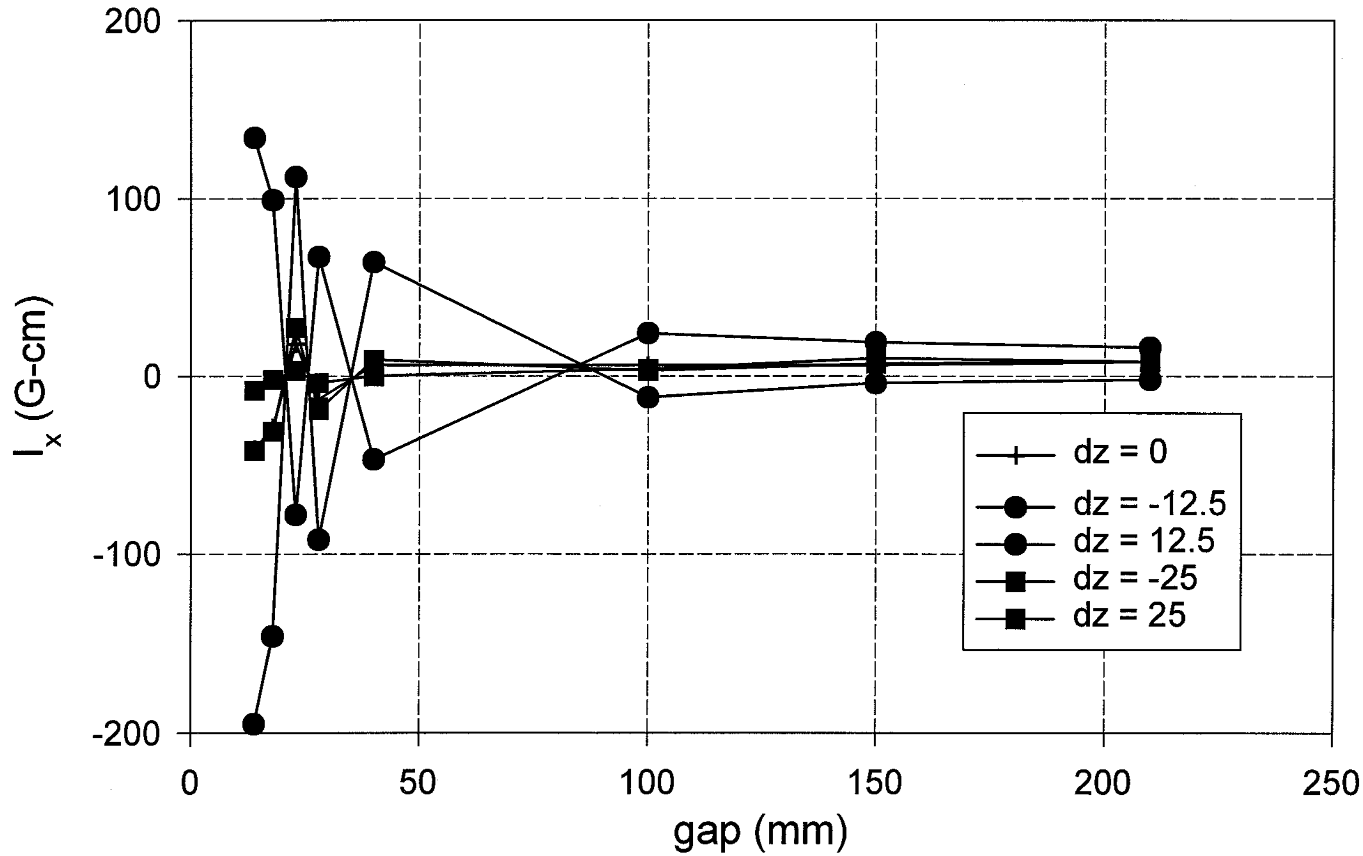


Integral Quality



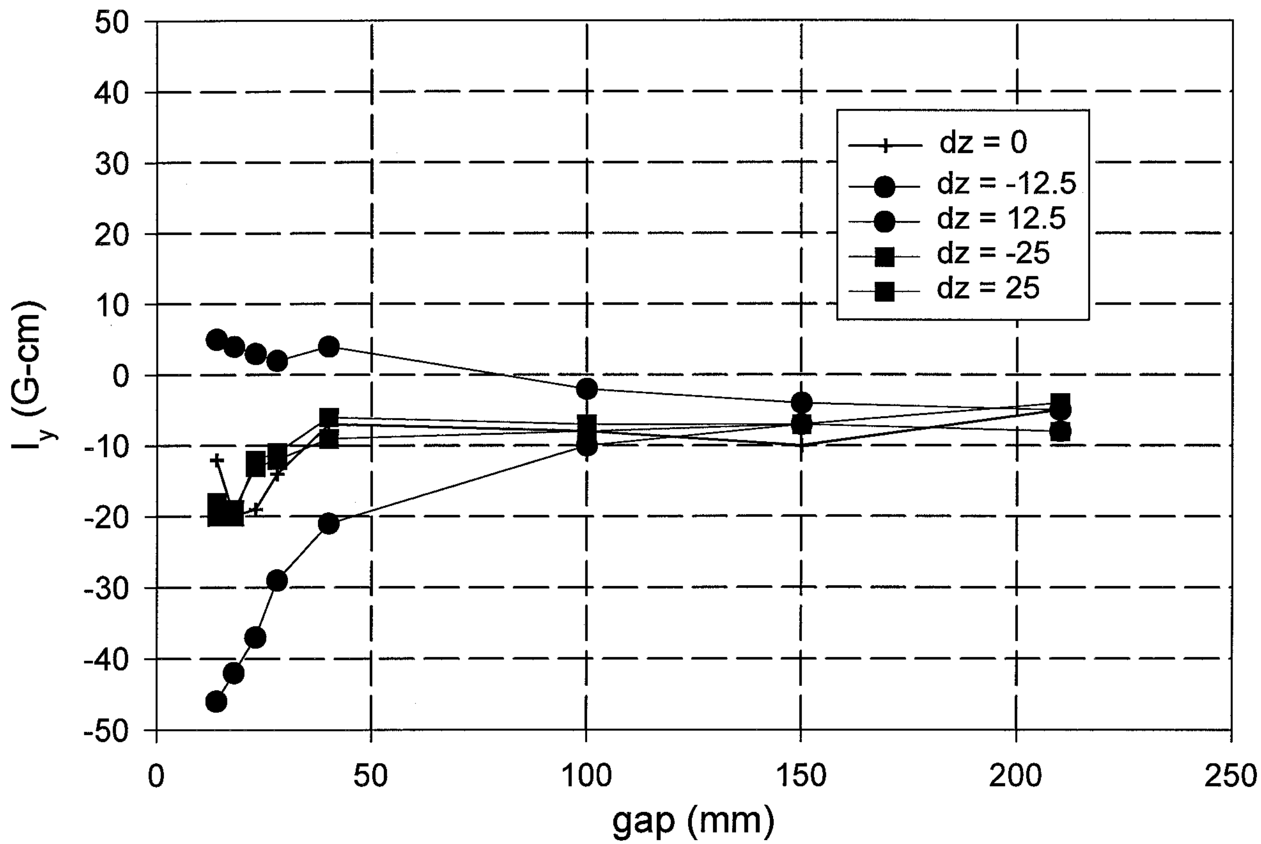
Integral Quality

I_x vs. gap at dz = 0



Integral Quality

I_y vs. gap at dz = 0



Position Control

- **Requirements:**
  - **Gap repeatability: ± 5 μm**
  - **Quadrant offset repeatability: ± 1 μm**
  - **Forces change/reverse over range of dz**
    - F_x: +5262 lbs to -9528 lbs
    - F_y: -2982 lbs to +1728 lbs
- **Position repeatability limited by encoder resolution:**
  - **Gap: ±1 μm**
  - **Quadrant: ±0.25 μm**
  - **Settling time < 1.5 sec.**