

- Title

Permanent Magnet Quadrupole Lens with Variable Strength

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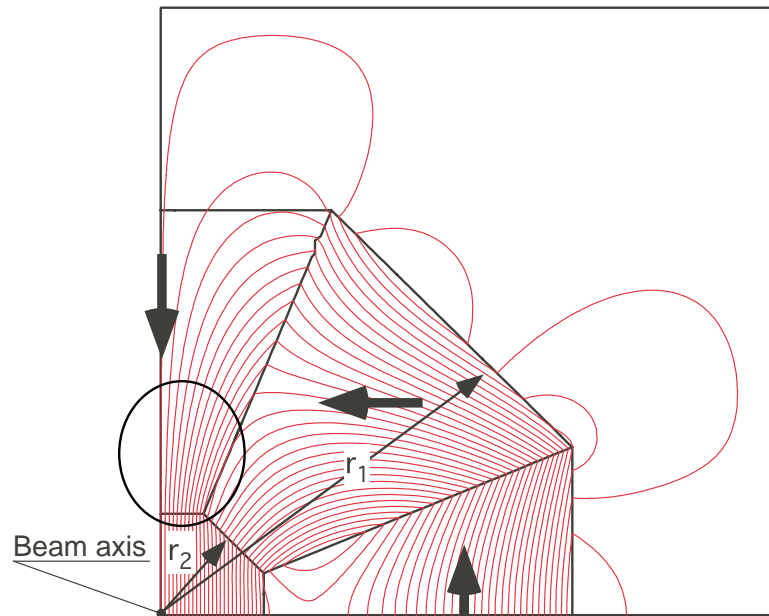
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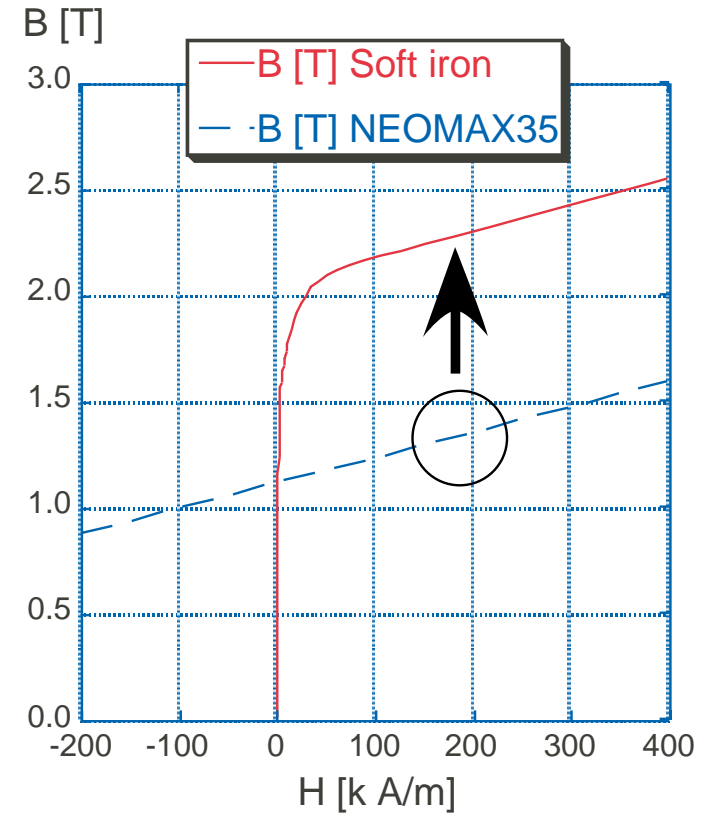
- Introduction - Superstrong PMD
- PMQ, iPMQ (saturated iron PMQ)
- Variable
- XPMQ
- Sketch
- NanoControl

- PMD & B-H curve

Halbach's dipole REC magnet.



1.37 T @ $r_1, r_2=1\text{cm}, 4\text{cm}$

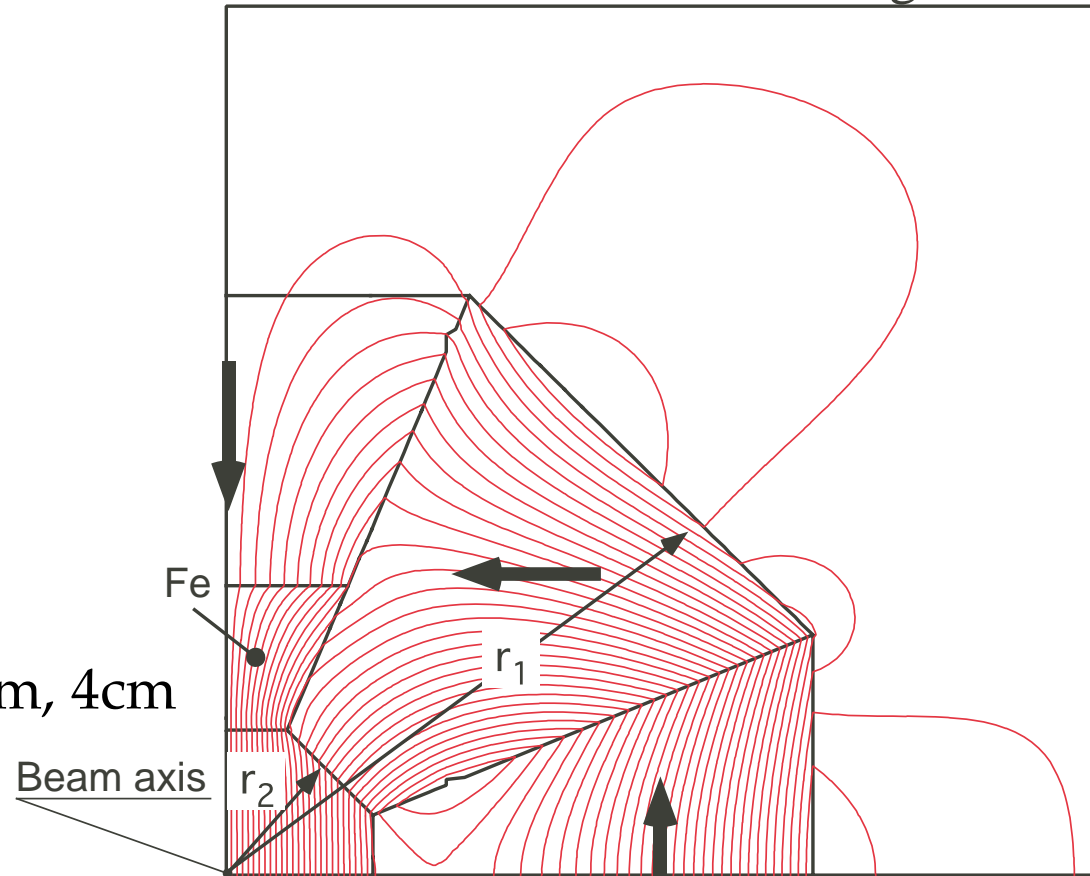


$$B=B_r \ln(r_1 / r_2) \cos(\pi / M) \sin(\pi / M) / \pi$$

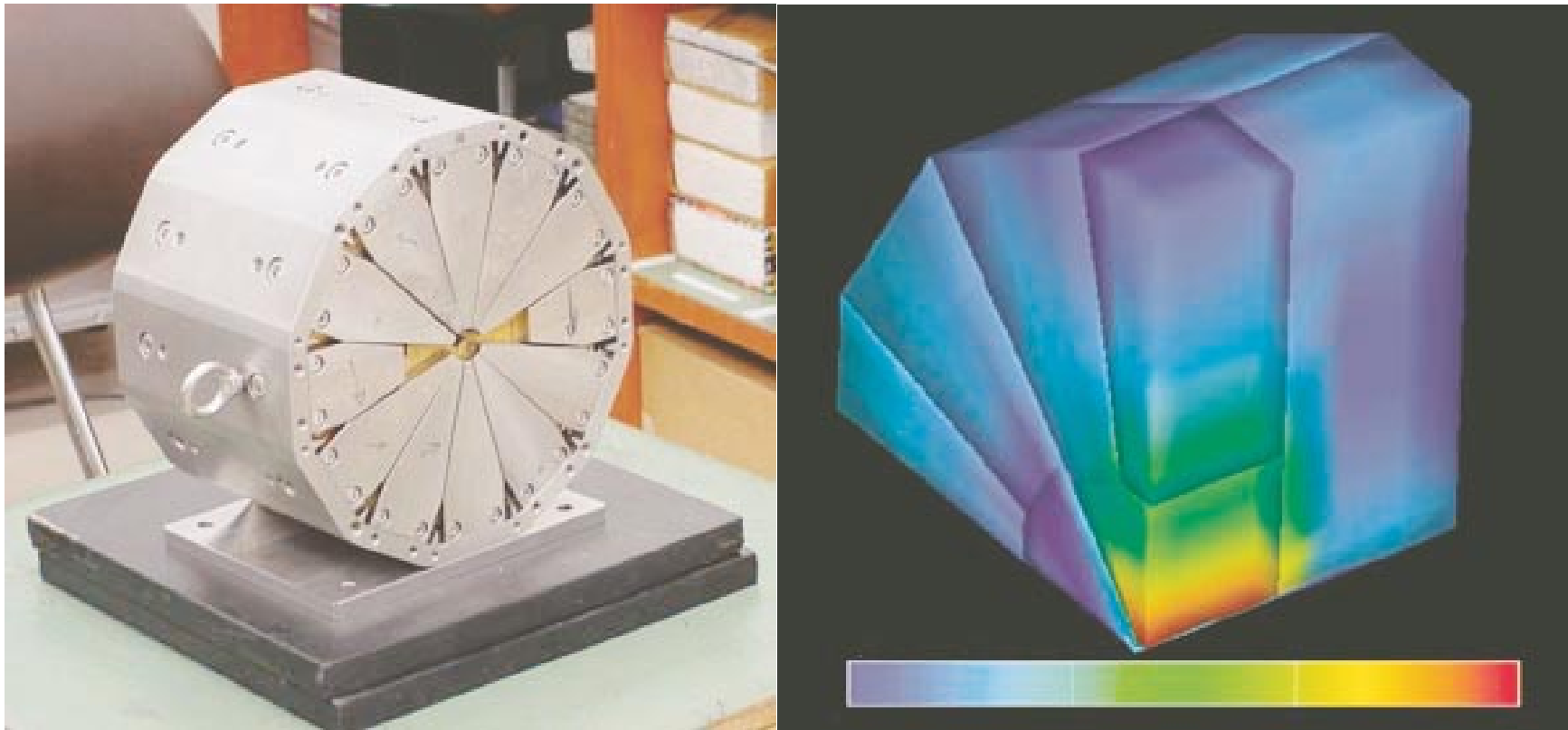
- SuperPMD

Modified Halbach's magnet.

1.64 T @ r_1 , $r_2=1\text{cm}, 4\text{cm}$
(was 1.37T)



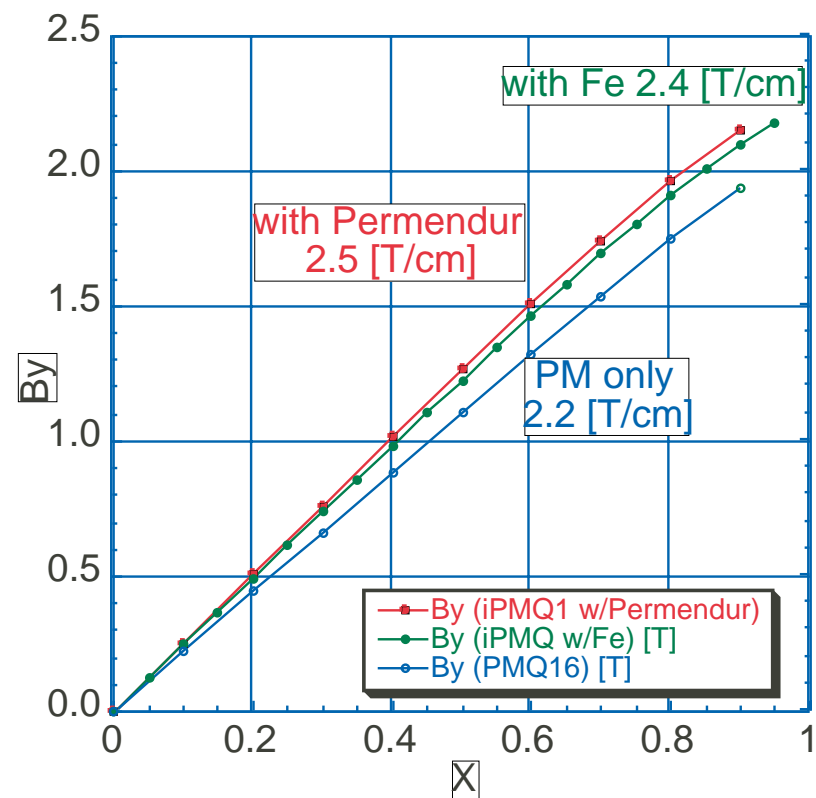
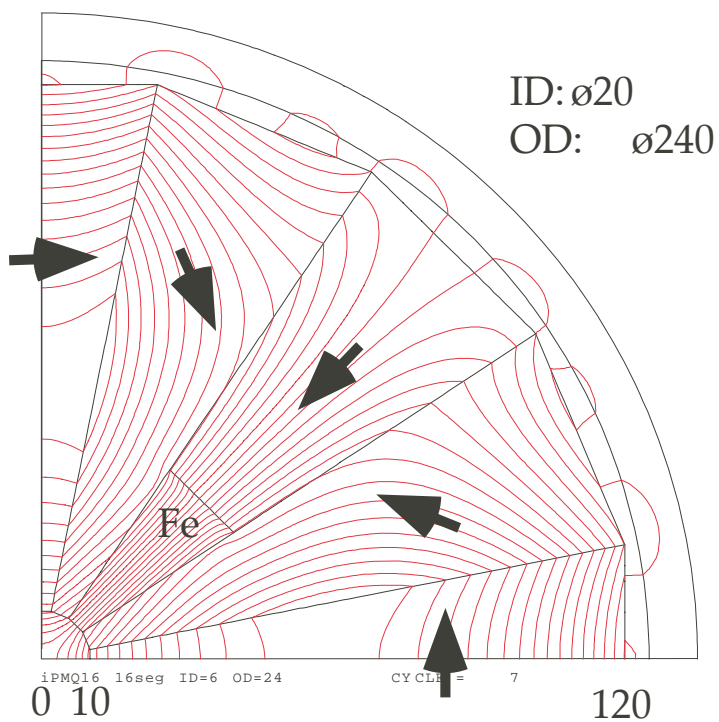
- 4.45T Dipole



Achieved 4.45T @-29°C (3.9T @room temperature)

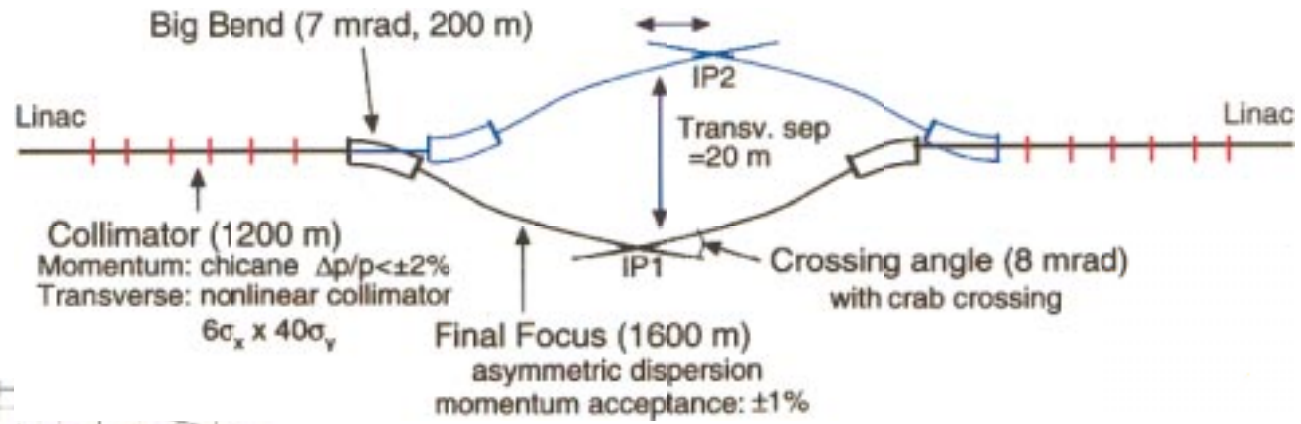
M. Kumada et al., CERN Courier, vol. 41, no.7, Sep. 2001, p. 9

- PMQ & iPMQ – Gradient (Field plot)

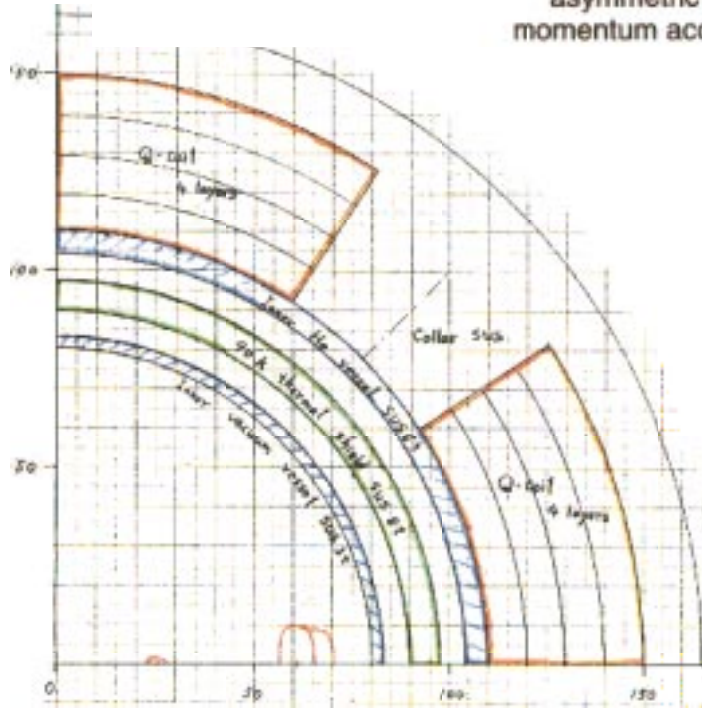


$$B = 2B_r (1 - r_1 / r_2) \cos^2(\pi / M) \sin(2\pi / M) / (2\pi / M)$$

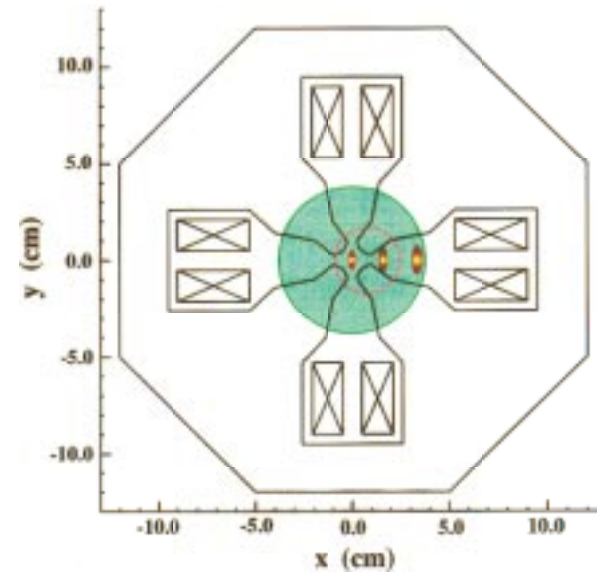
- IP



note: 9cm aperture for super conducting QC1, Jan.2000
note: 4cm beam pipe just in front of QC1

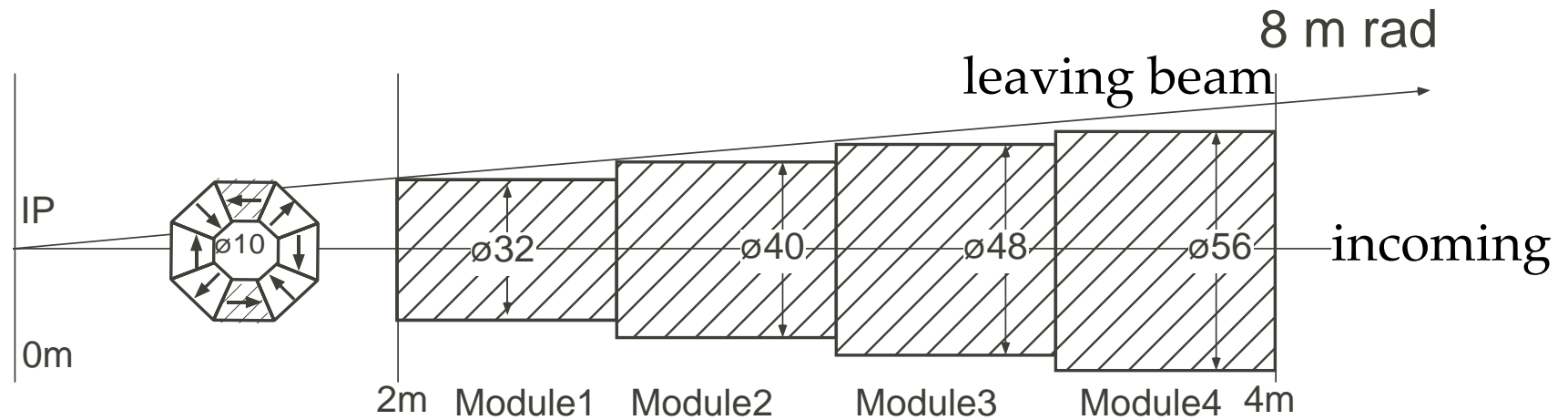


Superconducting Q



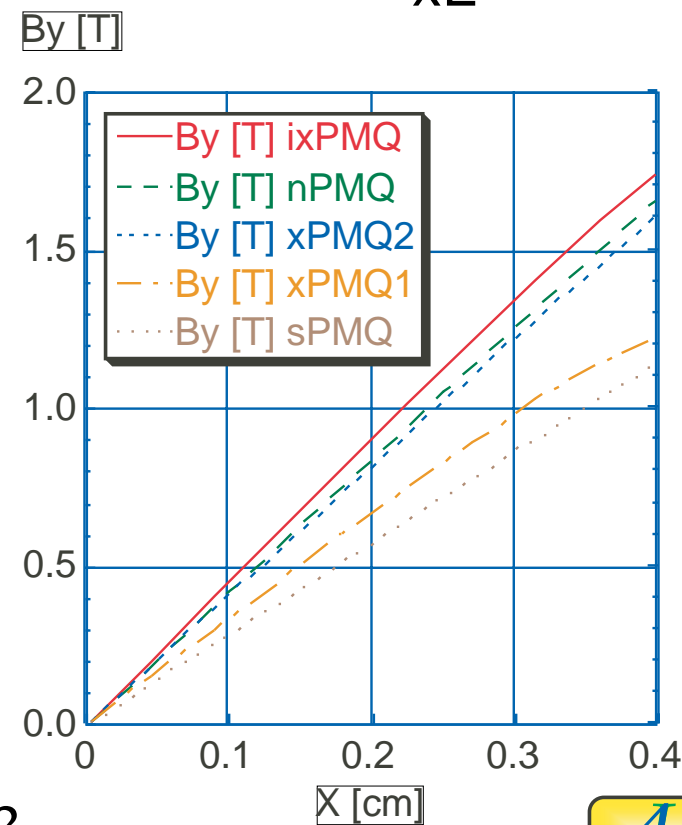
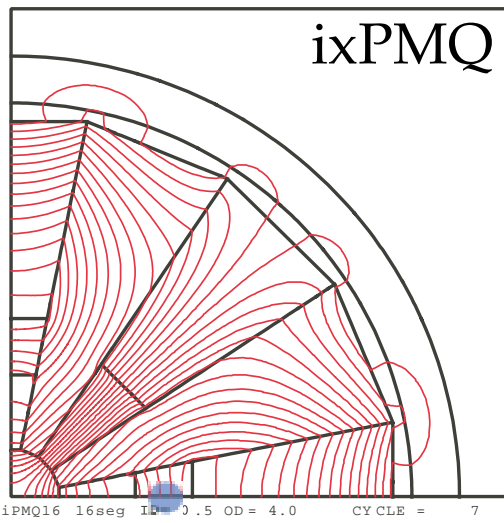
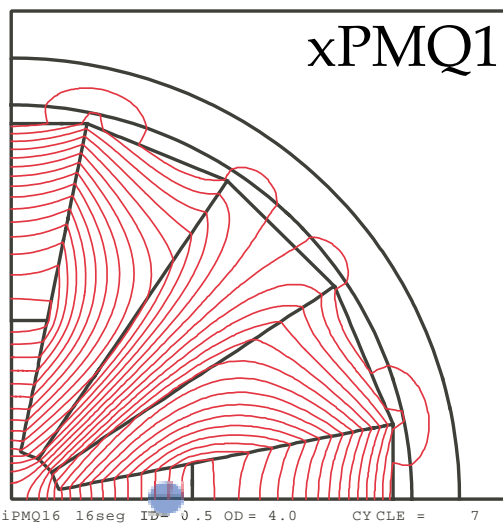
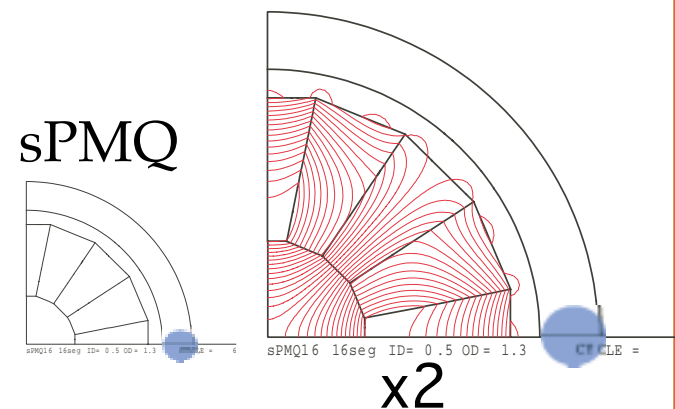
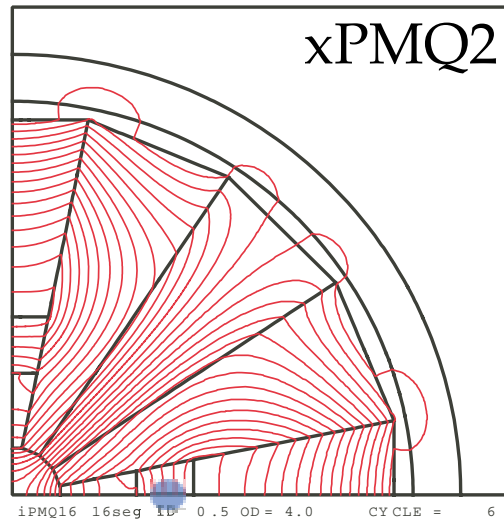
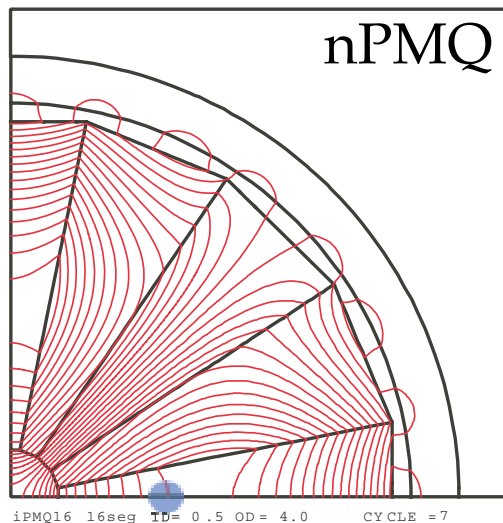
Room temp. Q

- Final Focus PMQ



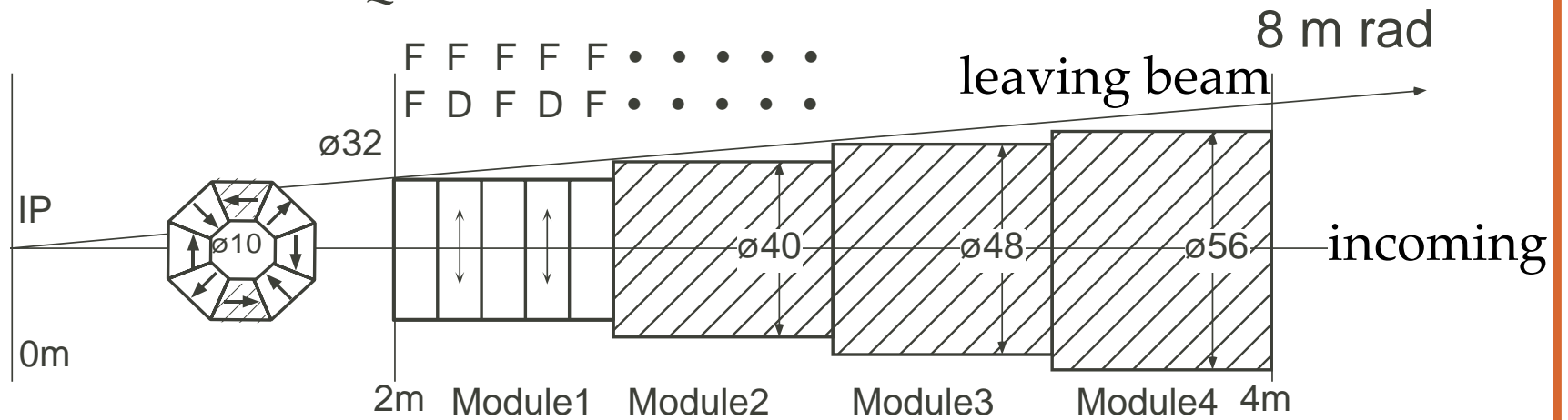
need some margin for leaving beam

- Let the beam go through



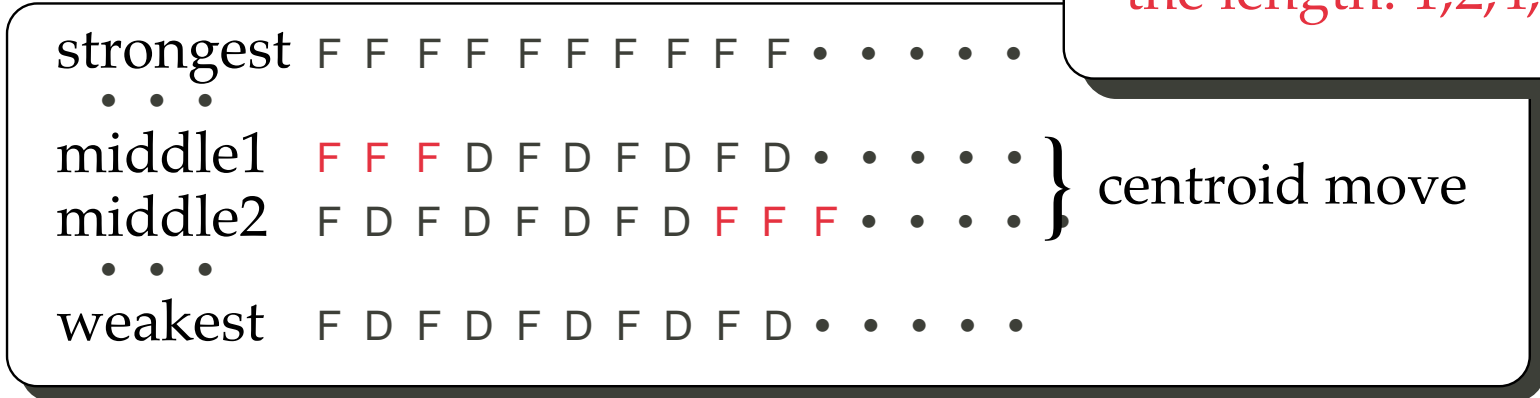
Beam pipe for leaving beam?

• Final Focus vPMQ

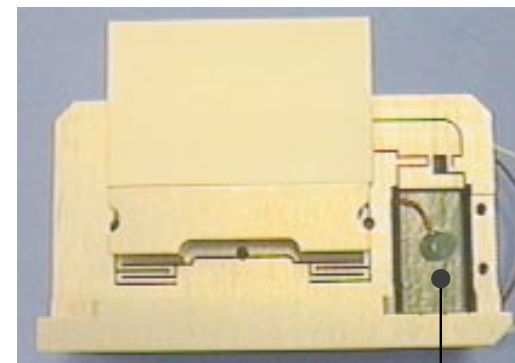
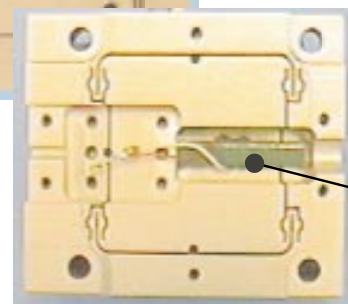
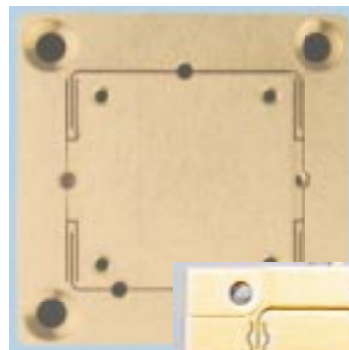
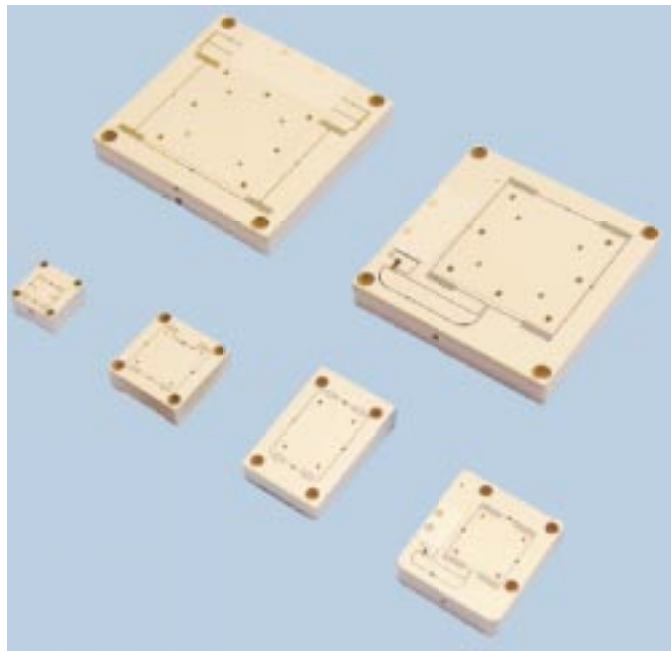


5~10cm/unit → 20~40units/2m
 ... some units may be fixed

Stepwise variable
 Higher resolution by
 binary increment of
 the length: 1,2,4,... cm

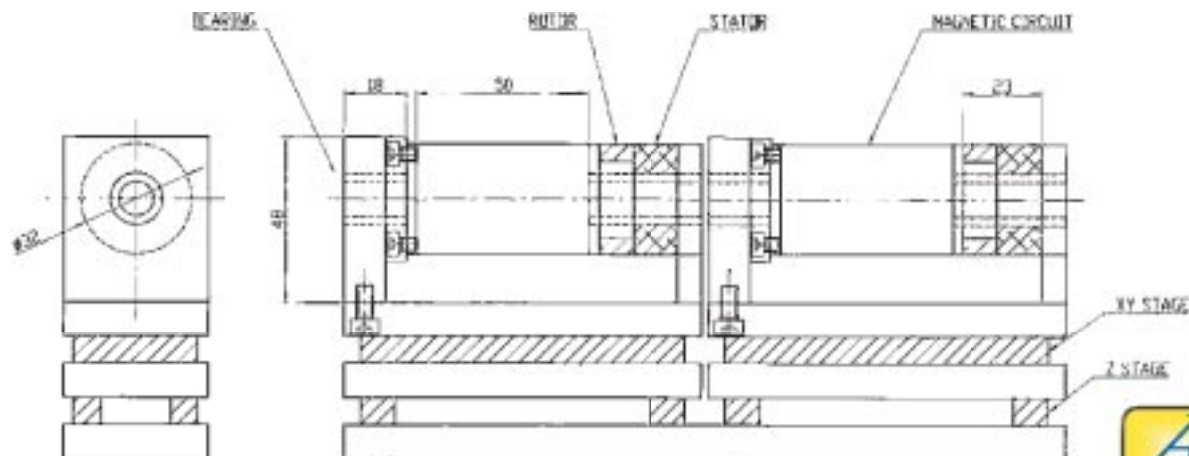
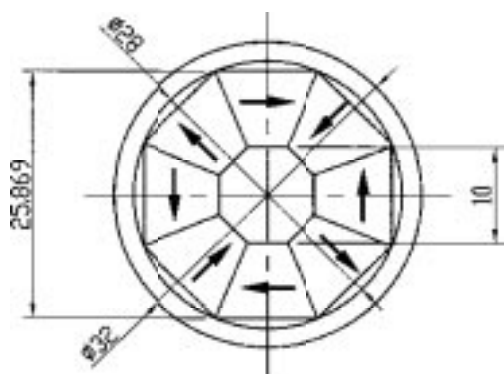


- X-Y stage supplied by NanoControl Co.Ltd.



Piezo Actuator
stroke: $15\mu\text{m} / 2\text{cm}$

Supersonic Motor or Pneumatic system



- Some issues

- 🍏 Strength 10^{-5} ?
- 🍏 Displacement 0.2 nm ?
- 🍏 Rotation (skew) $3\mu \text{ rad}$?

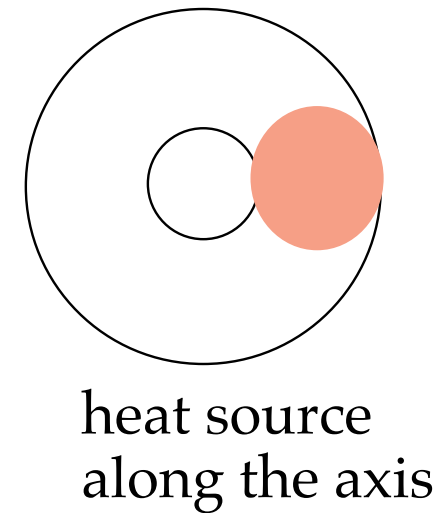
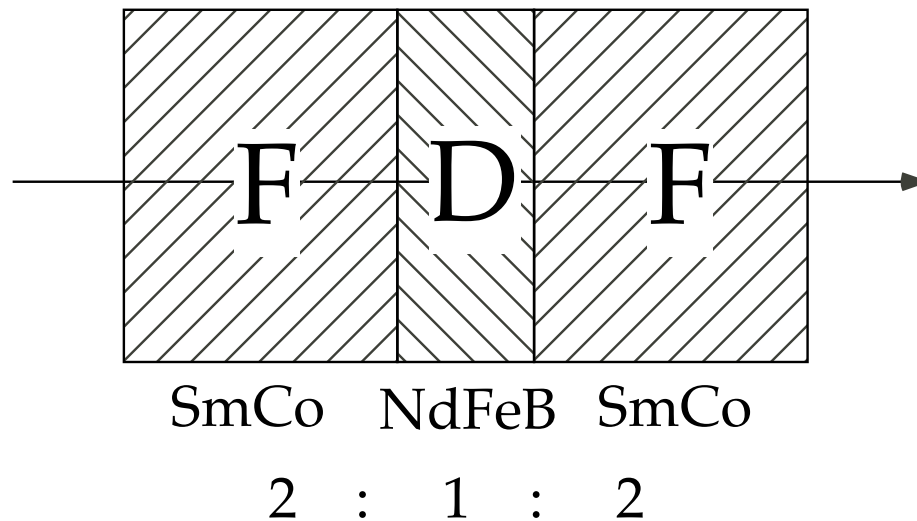
above three needs temperature compensation

- 🍏 Step size?
- 🍏 Multipole component?
(dodecapole)
- 🍏 Radiation damage?
- 🍏 temperature coefficient?
- 🍏 Helical Quadrupole(round beam)?

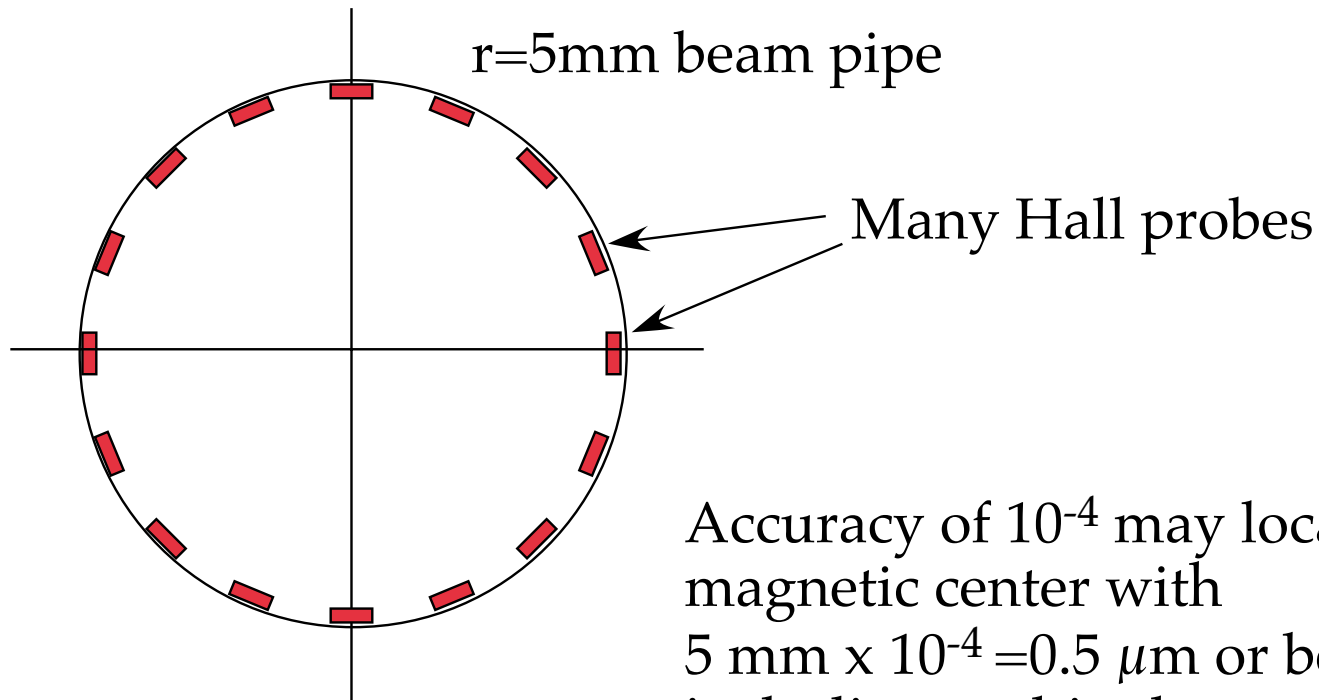
- Temperature Coefficient Compensation

Basic idea from E.Antokin

NdFeB: $-0.11\%/^{\circ}\text{C}$
SmCo: $-0.03\sim 0.04\%/^{\circ}\text{C}$ } x4 difference



- Quad center monitor



Accuracy of 10^{-4} may locate the magnetic center with $5\text{ mm} \times 10^{-4} = 0.5\ \mu\text{m}$ or better including multipoles.

Radiation damage?
Dirfts?