Hall C Moeller Polarimeter Upgrade

June 9, 2003

1. Operational limit of Basel Moeller polarimeter

   - Beam energy range 0.5 – 7.0 GeV/c
   - Steady beam current 2 μA
   - Rastered beam current 10 μA (?)
   - Hodoscope counting rate ~ 1 MHz (single arm)
   - Radiation background of downstream beamline and hall
   - Curie point = 770 ^{0}C (1043 ^{0}K)

2. Constraints for upgrade consideration

   - Maximum applied beam current 200 μA with dynamic range 10 – 200 μA
   - Keep presently operated Moeller system hardware unchanged
   - Keep present counting rate unchanged
   - Use 0.5 m space on 3C07 granite table for beam kicker magnet

3. Pure Iron Wire Target

Polarization of target electrons is determined by

$$P_T = M/(n_e \mu_B) \times (g' - 1)/g' \times g_e/(g_e - 1)$$

M – the bulk magnetization of target
n_e – electron density ($\rho N_A Z/A$)
g_e – 2.002319 free electron factor
μ_B – 9.273 $\times 10^{-21}$ G cm^3 Bohr magneton
g' – correction of orbit contribution to magnetization

Magnetization of Pure Iron Wire

2D magnetostatic simulation (a finite element analysis code) shows the internal flux lines are exactly parallel. The internal fluctuation of field amplitude is less than 3%.

Verification of boundary condition – under 5000 magnification (ESM) the surface property of Goodfellow 25 μ pure iron wire (as drawn) approaches mathematical shape without macrostructure.

Orientation character – symmetry about vertical rotation

4. Wire Heating Up Calculation

Condition: $t_{exp} = 0.1\ \mu s$
$t_{kick} = 1\ \mu s$
$t_{cool} = 100\ \mu s$
$d_{wire} = 10\ \mu$
$L_{wire} = 1$ cm
$I_{beam} = 200\ \mu A$
$D_{beam} = 200\ \mu$

Beam deposit power:

P_1 [W] = I [μA] $\times$ ΔE [MeV]

Cooling power through heat transfer:

P_2 [W] = -k [W/(cm ^{o}C)] A [cm^2] dT/dx [^{o}C/cm]

k = 0.73 W/(cm^{o}C) pure iron
A = 1.57×10^{-6} cm^2 for two ends

At equilibrium $P_1\ t_{exp} = P_2\ t_{cool}$, $T_{center} = 122\ ^oC$

Estimation of depolarization (Figure 5.10):

$M(122)/M(0) \approx 0.97$

$M(122)/M(25) \approx 0.99$

5. Kicker Magnet & Driver

- Bedstead shape coil
- L_{eff} = 24 cm
- Winding turns = 2
- Max. bending power = 800 Gauss cm
- Max. driving current ~ 240 A
- Max. kick angle ~ 40 μr at 11 GeV/c
- Switch time ~ 100 ns
- Inductance ~ 1.5 μH (including parasitic)
- Half H-bridge switch with I_{max} = 240 A
- $I(t) \propto (1 - e^{-t/\tau})$ $\tau = L/R = 18.75\ \mu s$
- T = 2 μs, Linearity ~ 95%
- V_{HVps} = 400 V
- Complementary gate signals are available from driver trigger electronics to strobe data stream

6. Estimation of Counting Rate

- For 4 μm Fe foil target at 2 μA, singles rate ≈ 100 ~ 200 kHz (2 ns bunch, 5×10^8 bunches/s)

- For single wire target at 2 μA beam, 4×10^5 bunches/s (size, thickness)

- $dn/dt\,(_{\text{foil, 2}\mu\text{A}}) : dn/dt\,(_{\text{wire, 2}\mu\text{A}}) = 1250$

- $dn/dt\,(_{\text{foil, 2}\mu\text{A}}) : dn/dt\,(_{\text{wire, 200}\mu\text{A}}) = 12.5$

- $dn/dt\,(_{\text{foil, 2}\mu\text{A}}) : dn/dt\,(_{\text{10 wires, 200}\mu\text{A}}) = 1.25$

- Flexible adjustability based on:
  $I_{beam} \times f_{trigger} / N\,(\text{wire}) = \text{Constant}$

7. Kicker & Downstream Optics

- Kicker provides vertical bending, no effect on achromatic performance of Hall C line

- Regional $M_y \sim 0.3$, $M_y' \sim 1$ (3C07 to target)
- beam displacement ~ 1 mm on Moeller target and Hall C target

- Present arc tuning (feedback optics) is ok.

- Complimentary strobe signal outputs gating Moeller measurement and experimental data acquisition alternatively.

- Potential capability running Hall C experiment together with Moeller measurement in a time share scale 100 : 1.

- Budget estimation: conventional Hall C account

8. Mesh target and cavity wiggler

- Nickel mesh sample (max. transmission ~ 80 %) from InterNet Inc.

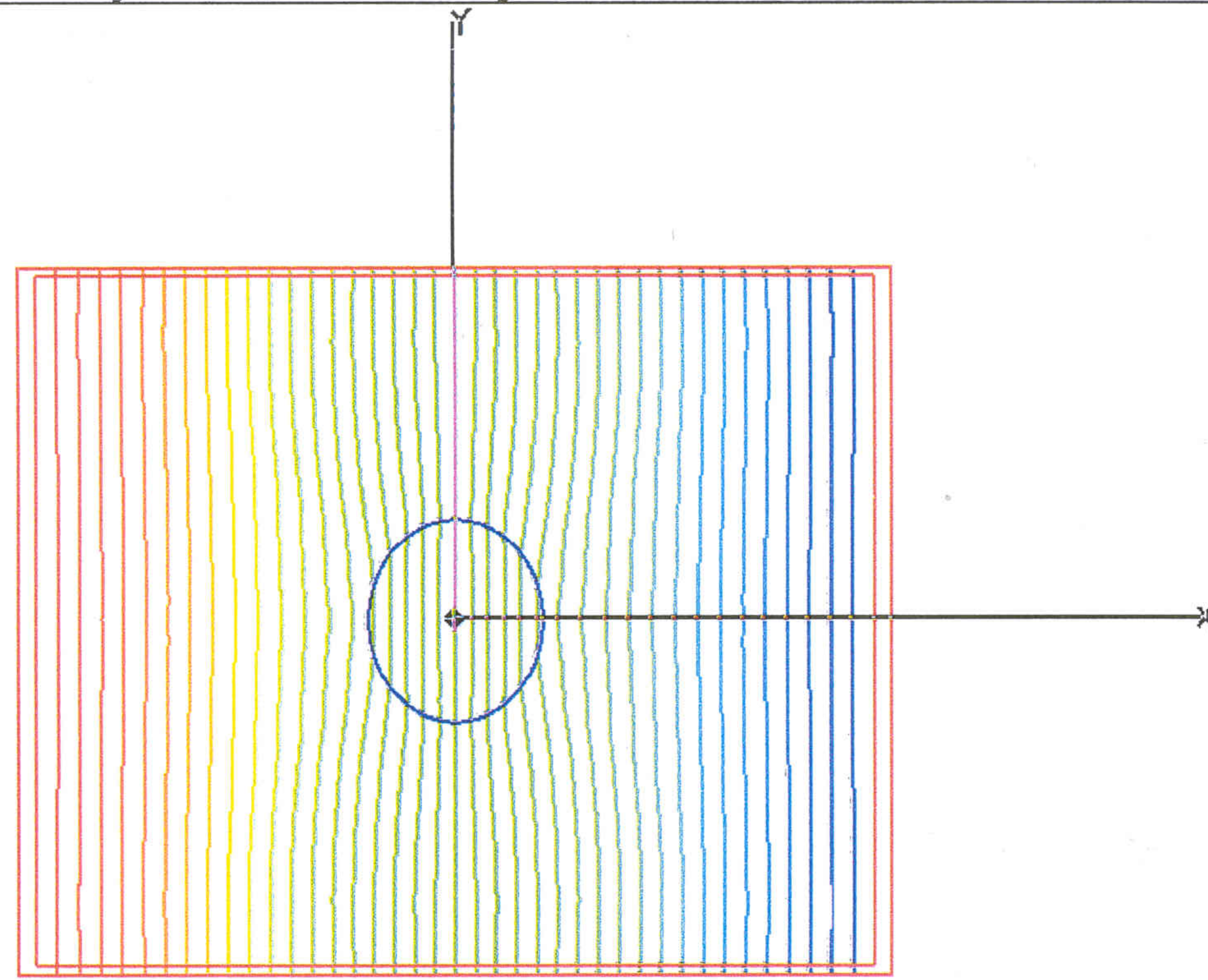
  Surface qualification
  Low saturation field

- Cavity available in lab

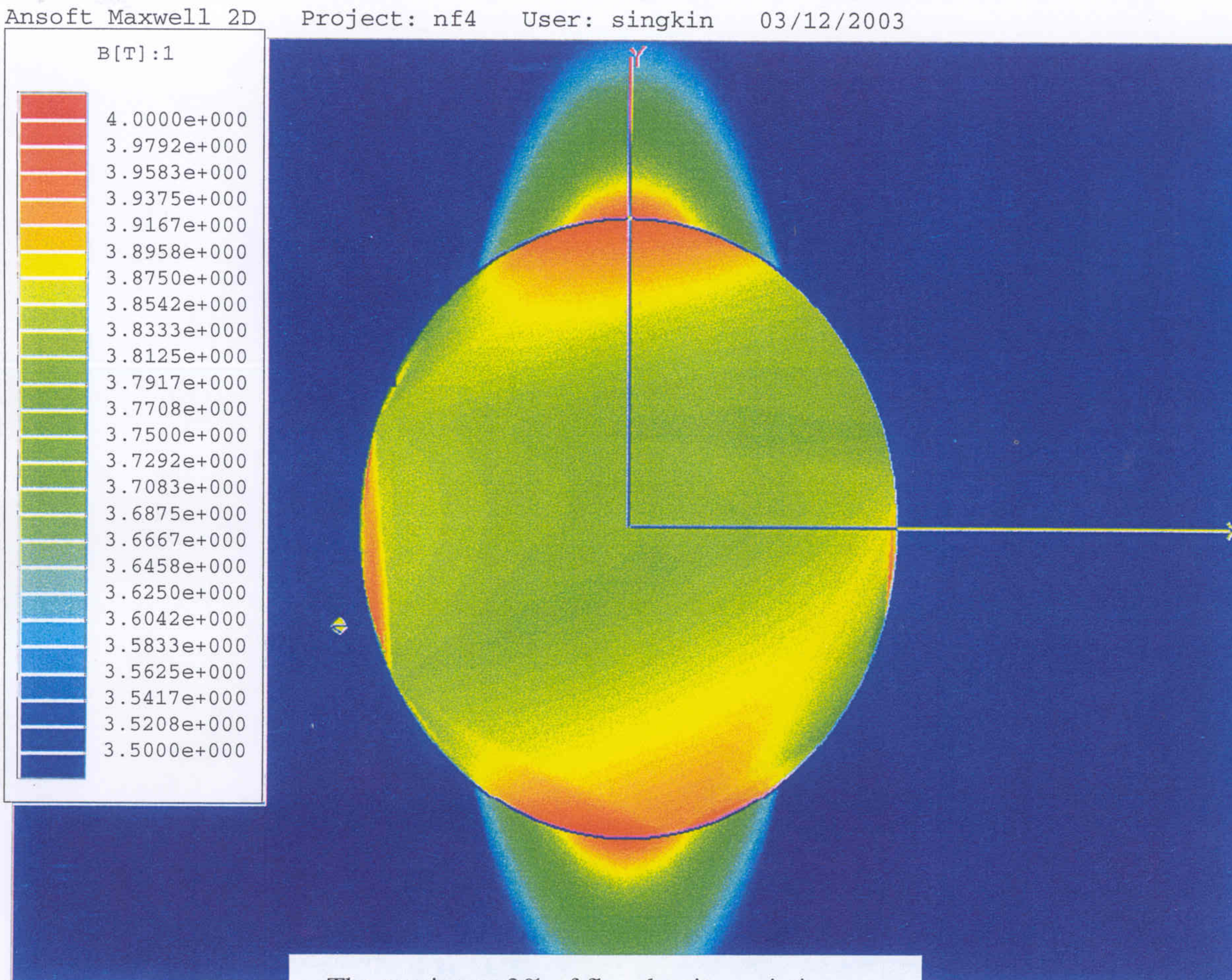
	Separation	Beam Position
Θ_{max}	0.5 mr/6 GeV	0.5 mr/6 GeV
$f_{operation}$	500 MHz	1.5 GHz
Q_{loaded}	2500	500/1500
$t_{relaxation}$	~ 1 ms	~ 1 ms
$\$_{fabrication}$	20k each	20k each
$\$_{amplifier}$	50k/kW	50k/kW

- Target heating up by cavity

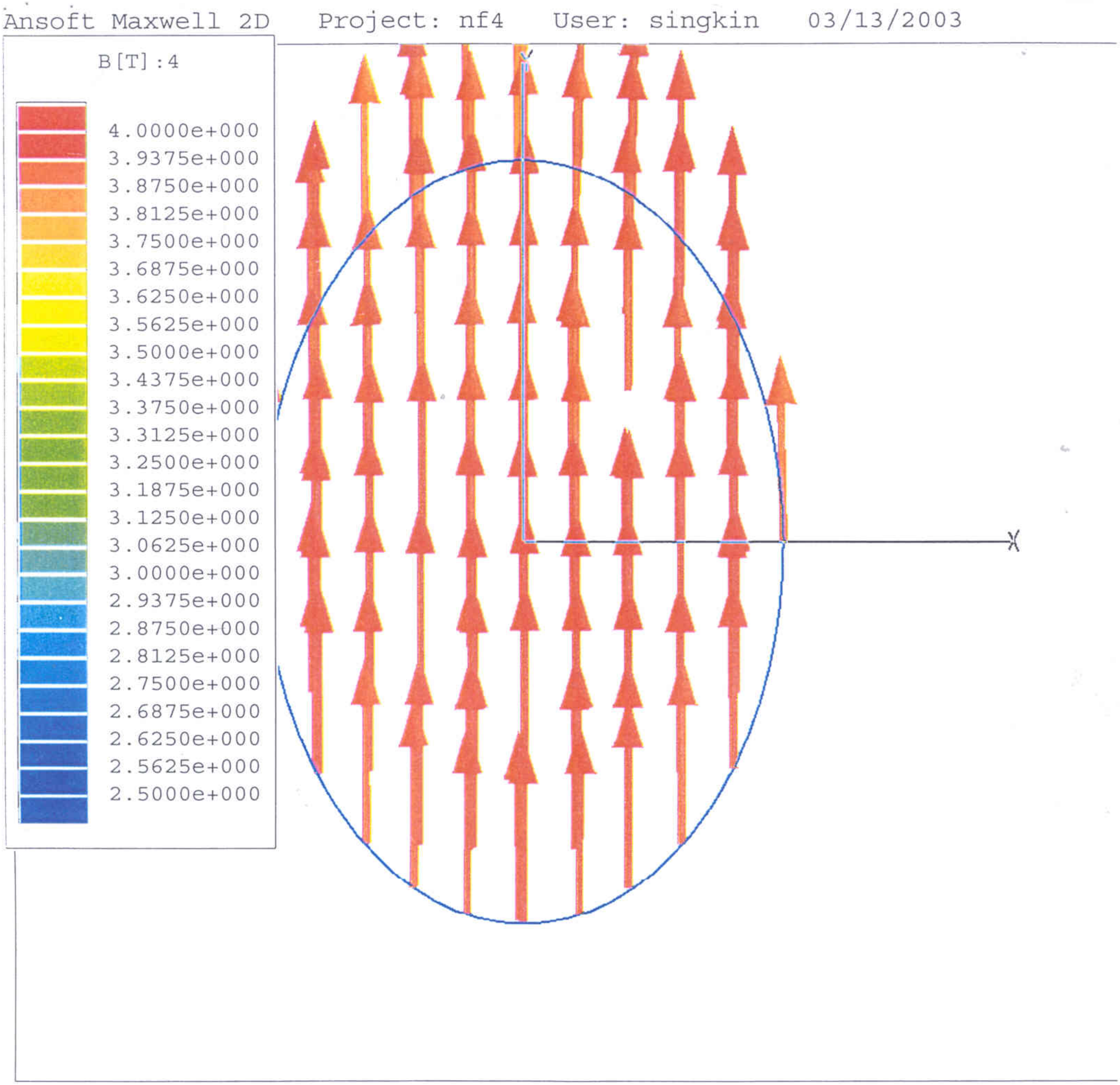
Mode	Target	T_{rise} (^{o}C)
Wiggler	10 μ Fe foil	6250
Raster (circle)	Nickel mesh	1250



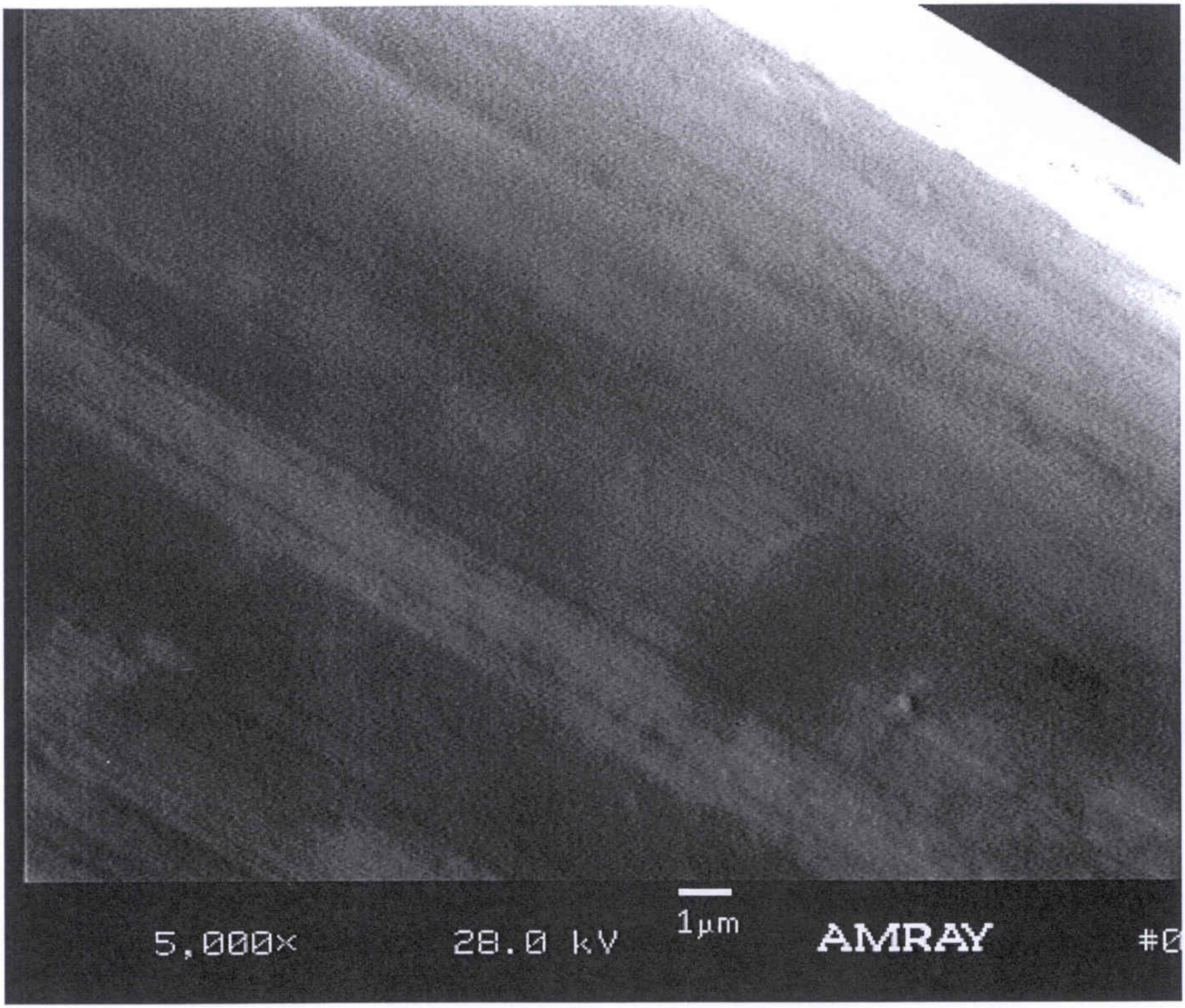
Global behavior of the flux line after inserting
a 10 μm pure iron wire



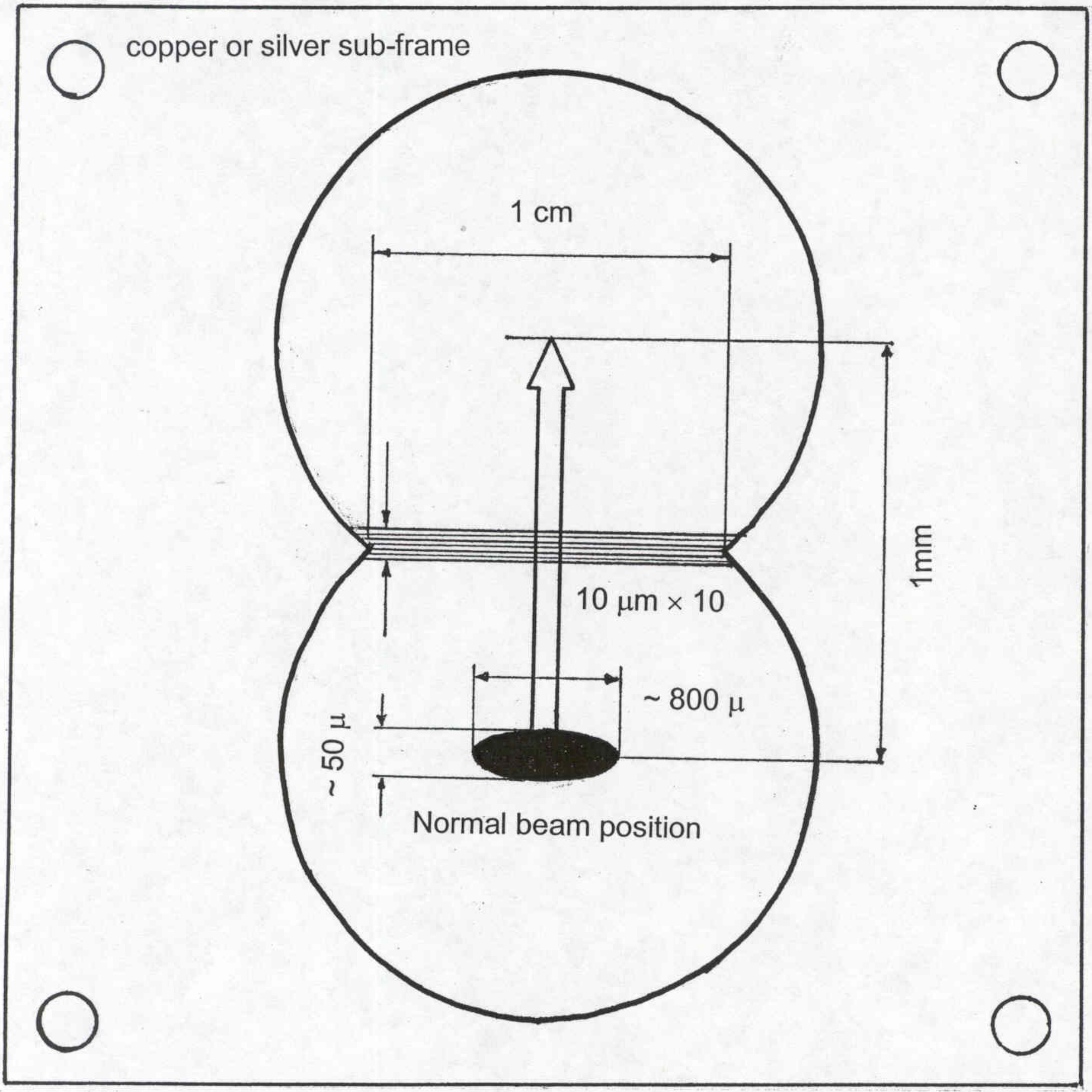
The maximum 3% of flux density variation distributes inside entire area of 10 μm iron wire cross section in 3 tesla field.



Detailed structure of B-vector orientation and amplitude inside the boundary of 10 μm iron wire cross section in 3 tesla field



Goodfellow 25 μ pure iron wire (as drawn, no anneal) under Scanning Electron Microscope with 5,000 magnification. No macro-structure can be seen.



Target Configuration

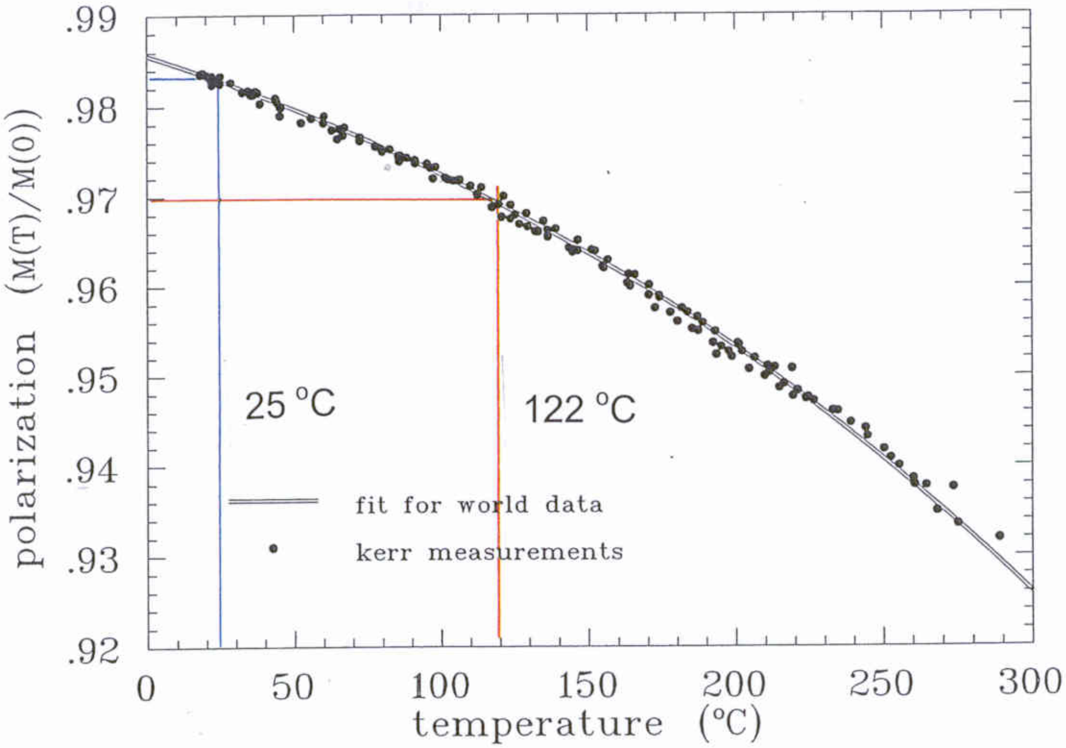
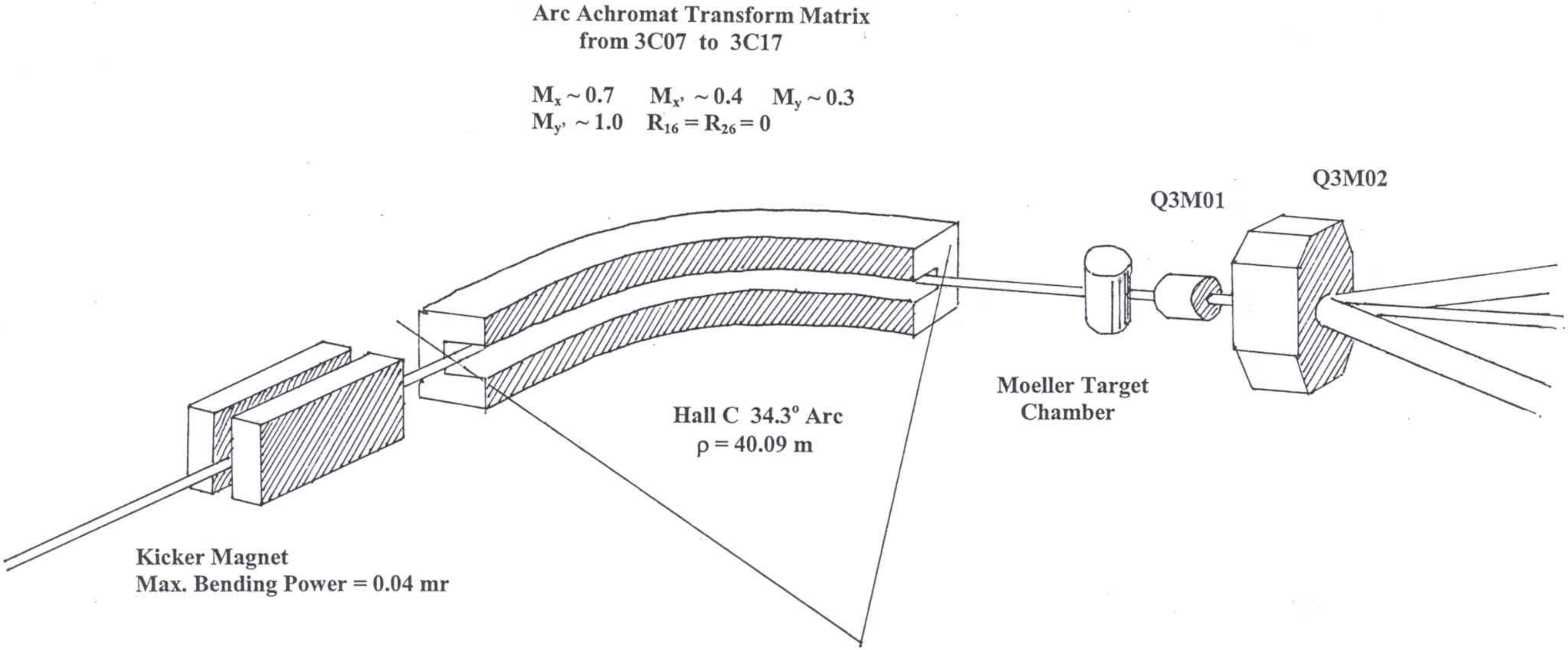
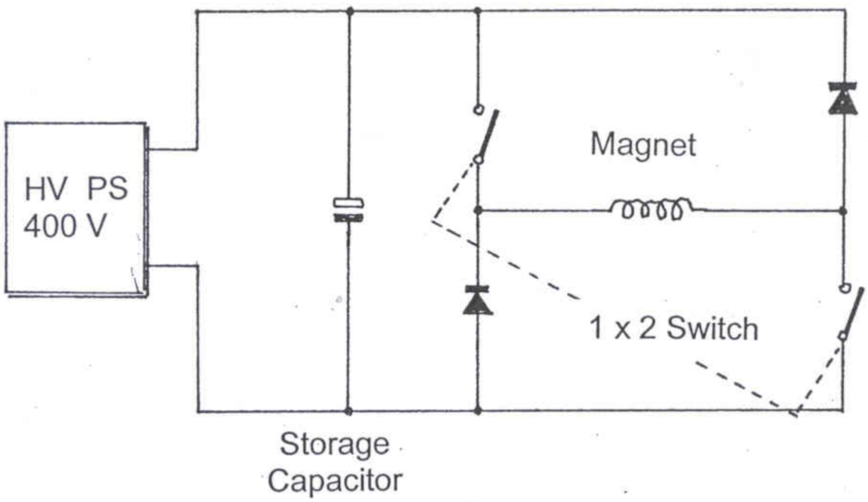


Figure 4.9: Depolarization measurements with the Kerr apparatus show that the measured depolarizations agree with known saturation data. The error up to 250^{0}C is better than 0.25% . For higher temperatures the thermal expansion of the iron foil is too large and produces a strong warp which causes problems with the reflection of the laser beam.

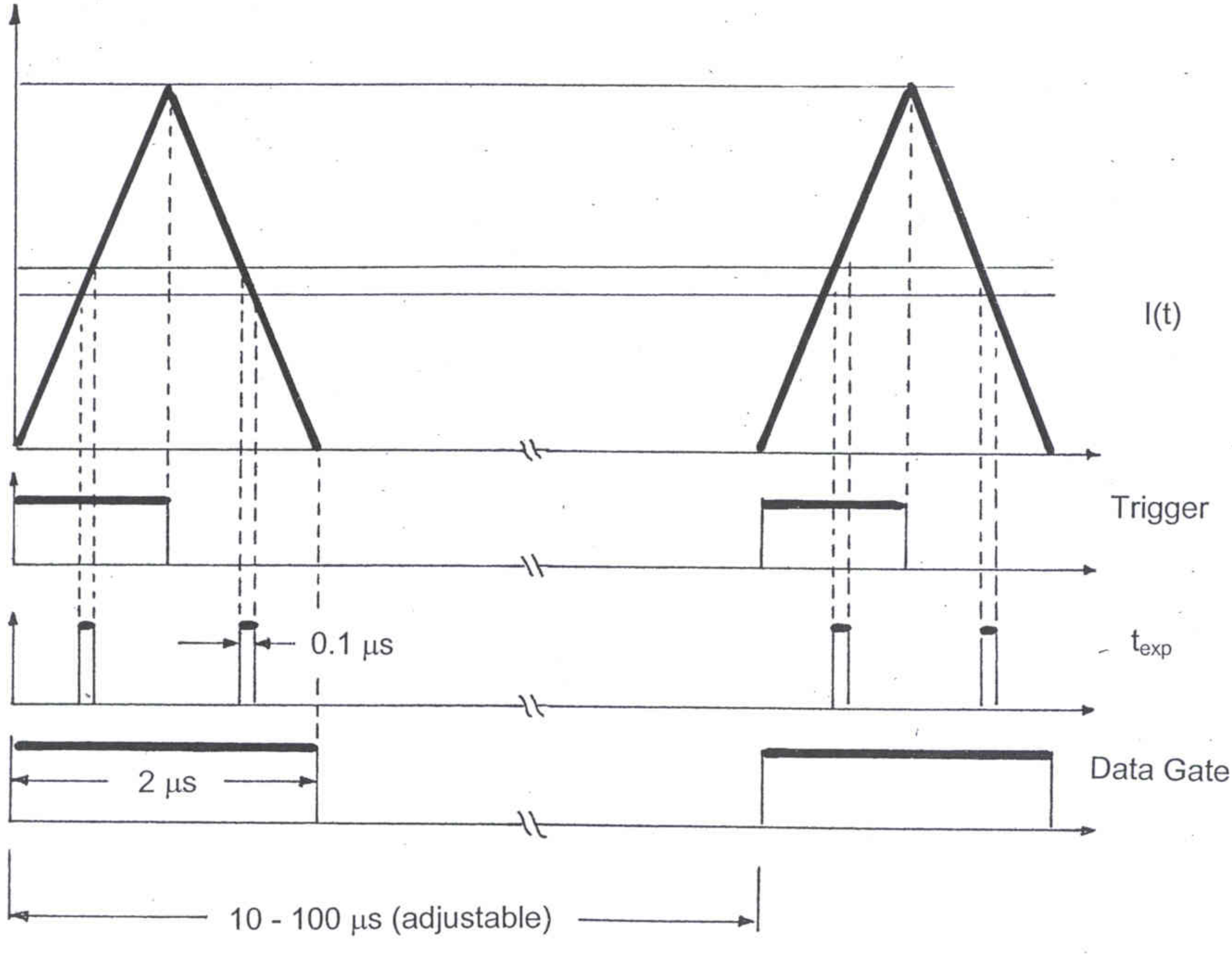


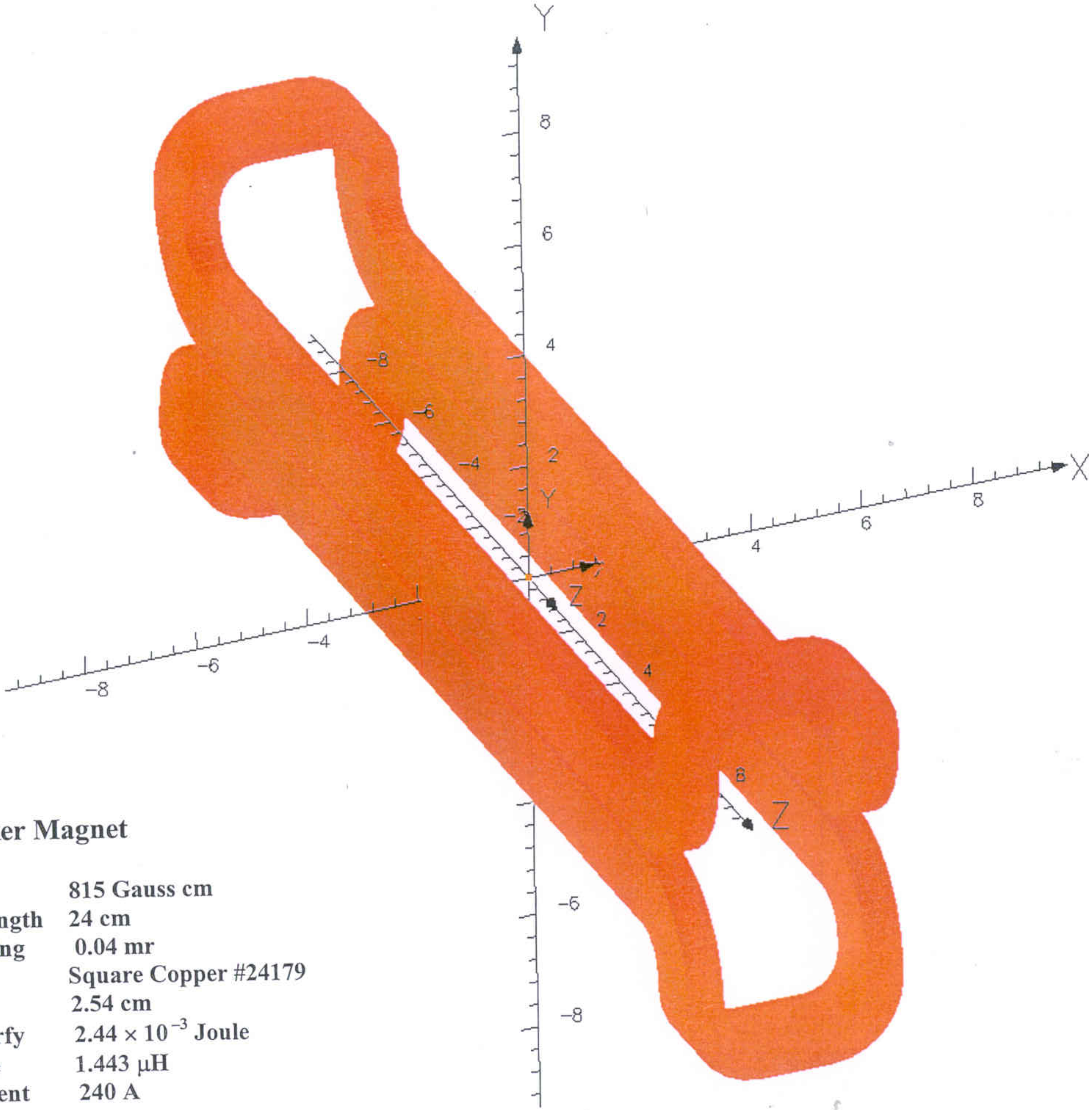
Sketch Layout of Hall C Moeller System Upgrade 2003

Conceptual Diagram of Kicker Driver



Kicker Control Waveforms

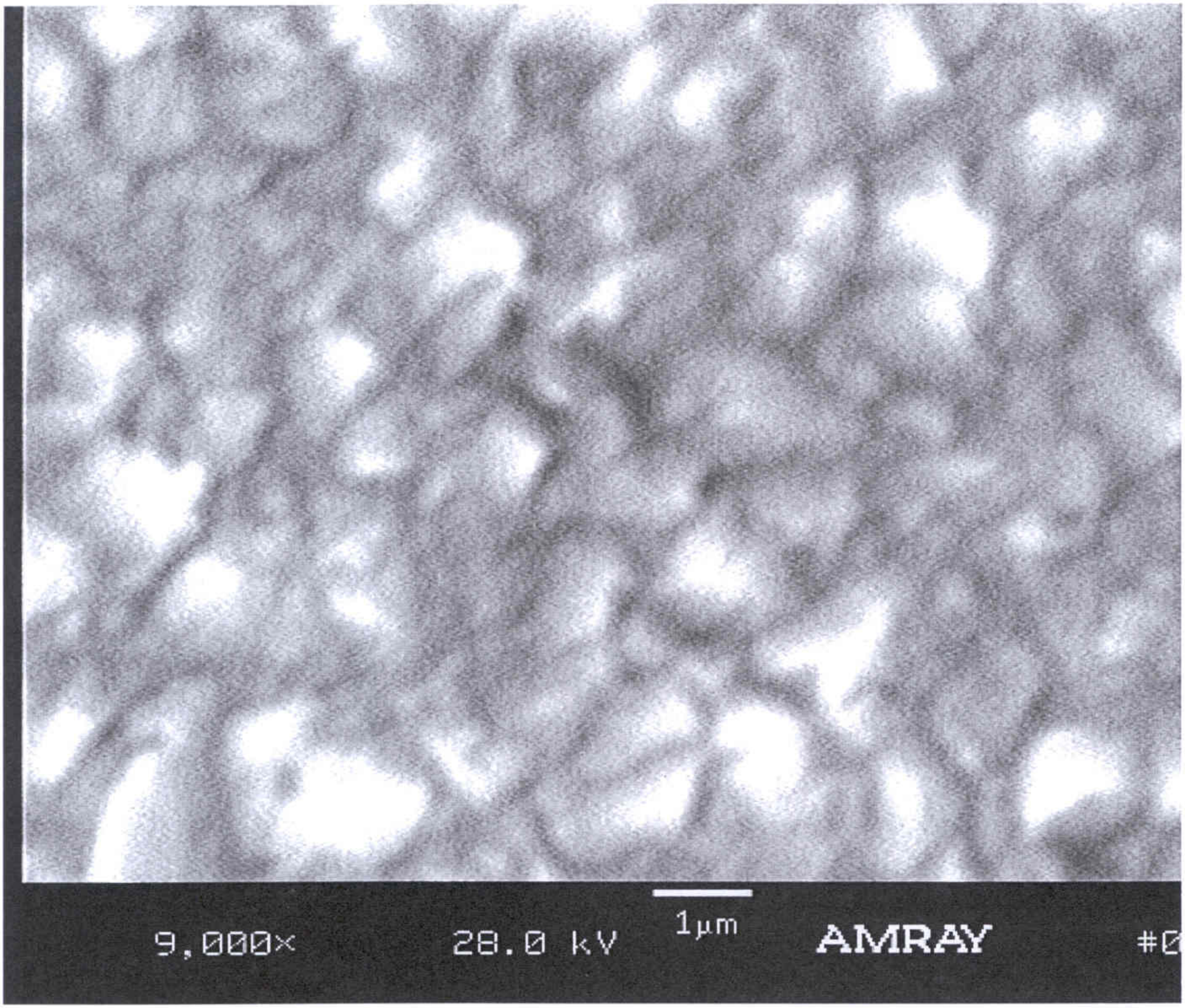




Kicker Magnet

Max. ∫ Bdl	815 Gauss cm
Effective length	24 cm
Max. bending	0.04 mr
Conductor	Square Copper #24179
Core dia.	2.54 cm
Stored enerfy	2.44×10^{-3} Joule
Inductance	1.443 μH
Max. Current	240 A

Model of a two turn kicker magnet



InterNet Inc. Nickel mesh under Scanning Electron Microscope with 9,000 magnification, on the surface micron size fish scales structure can be seen.