An Optical Magnetometer – Recent Work

International Magnetic Measurements Workshop

August - 2007

Company Overview

- Tai-Yang Research Co. - Knoxville, Tennessee - Founded in 2001
- Number of Employees: 4 (3 Full-time, 1 Part-time)
- Core Capabilities: HTS, LTS Magnets & current leads, cryogenic systems, CVD thin films - Design, analysis, fabrication, test

- Number of Phase I contracts: 8
- Number of Phase II contracts: 5

Optical Magnetometer Project Overview:

1) Background.
2) Concept / Method.
3) Results.
4) Future Development.

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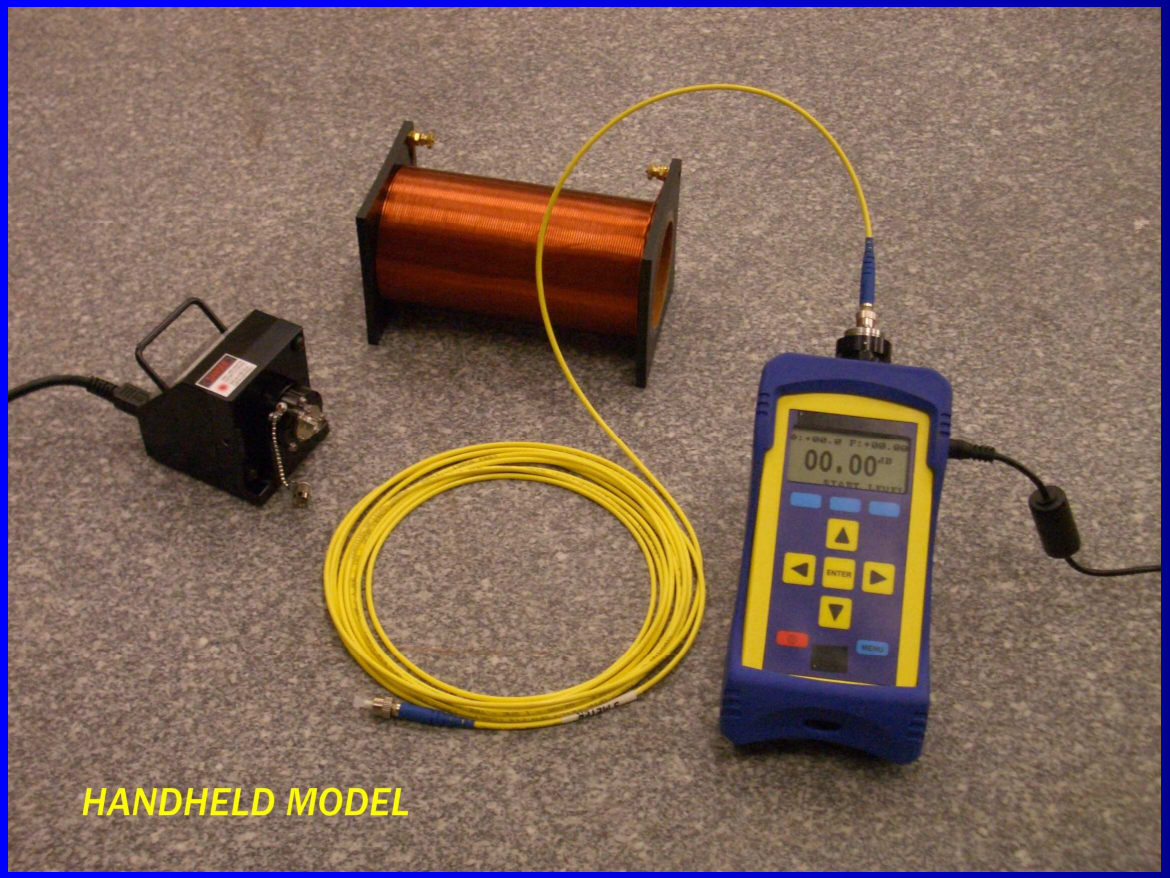
Background

- U.S. Department of Energy SBIR
  Phase I – 2003
  Phase II – 2004

- Research Completed at:
  (with assistance from)
  FNAL , LBL, NHMFL

- Measurement of:
  Solenoids, Dipoles, Quads, Current Carrying Conductors

The Optical Magnetometer



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Concept

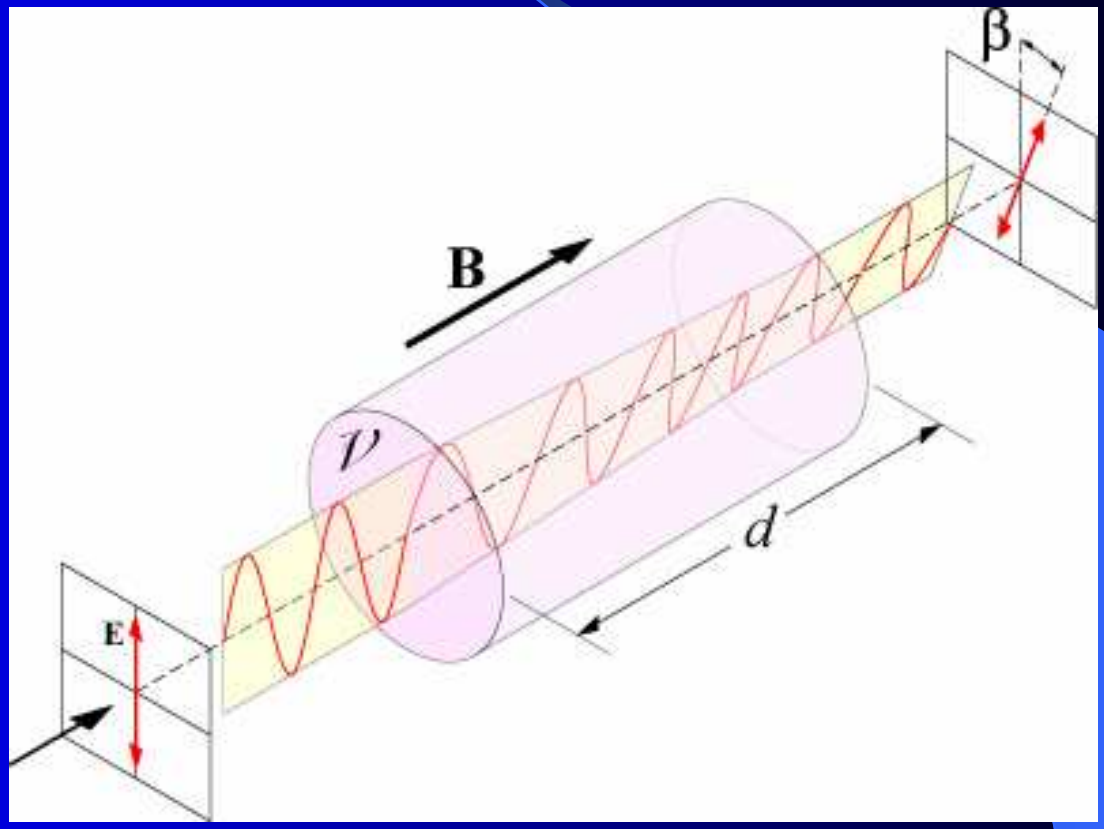
- Faraday Rotation

  $\beta = \nu * d * B$

  ν = "Verdet Constant"
  $\nu = f(\text{Material}, \lambda, T)$

$$\int B \cdot dl$$

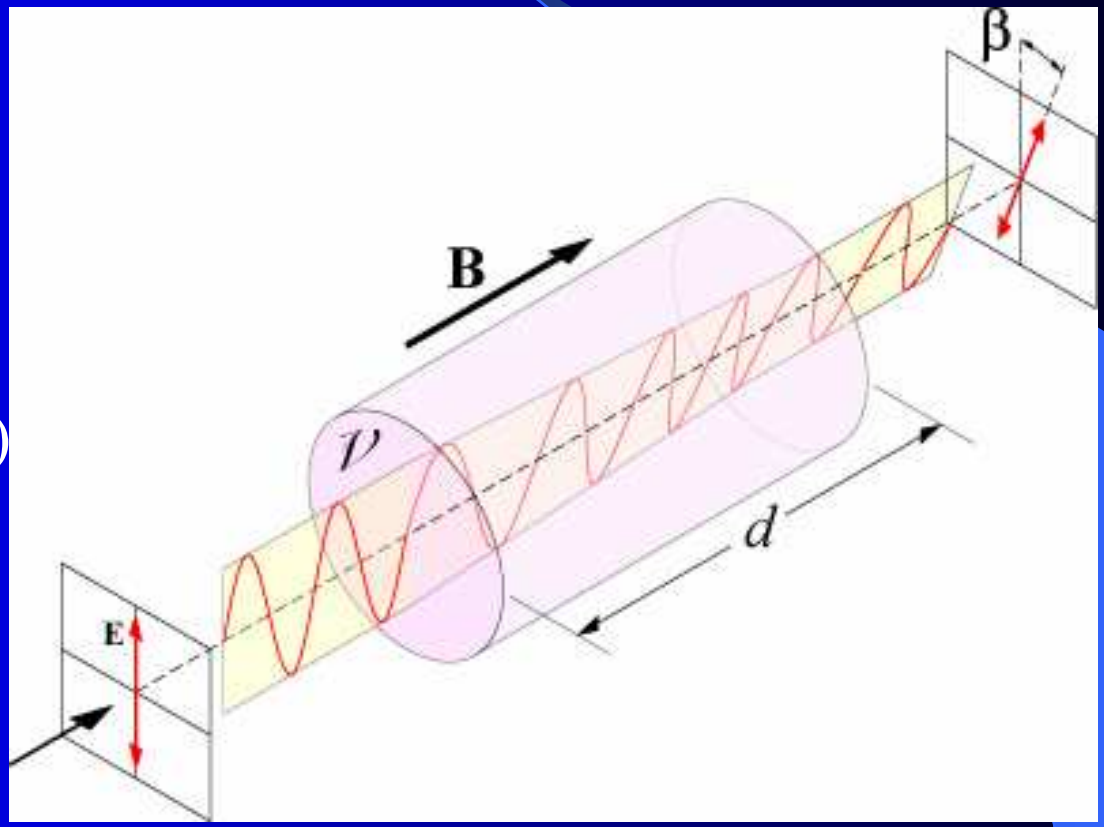
(Not a 'point' measurement)



Concept

- Originally meant for Quadrupole magnets
- Faraday Effect weaker for perpendicular fields than for parallel(~100x)

$$\int B \cdot dl$$

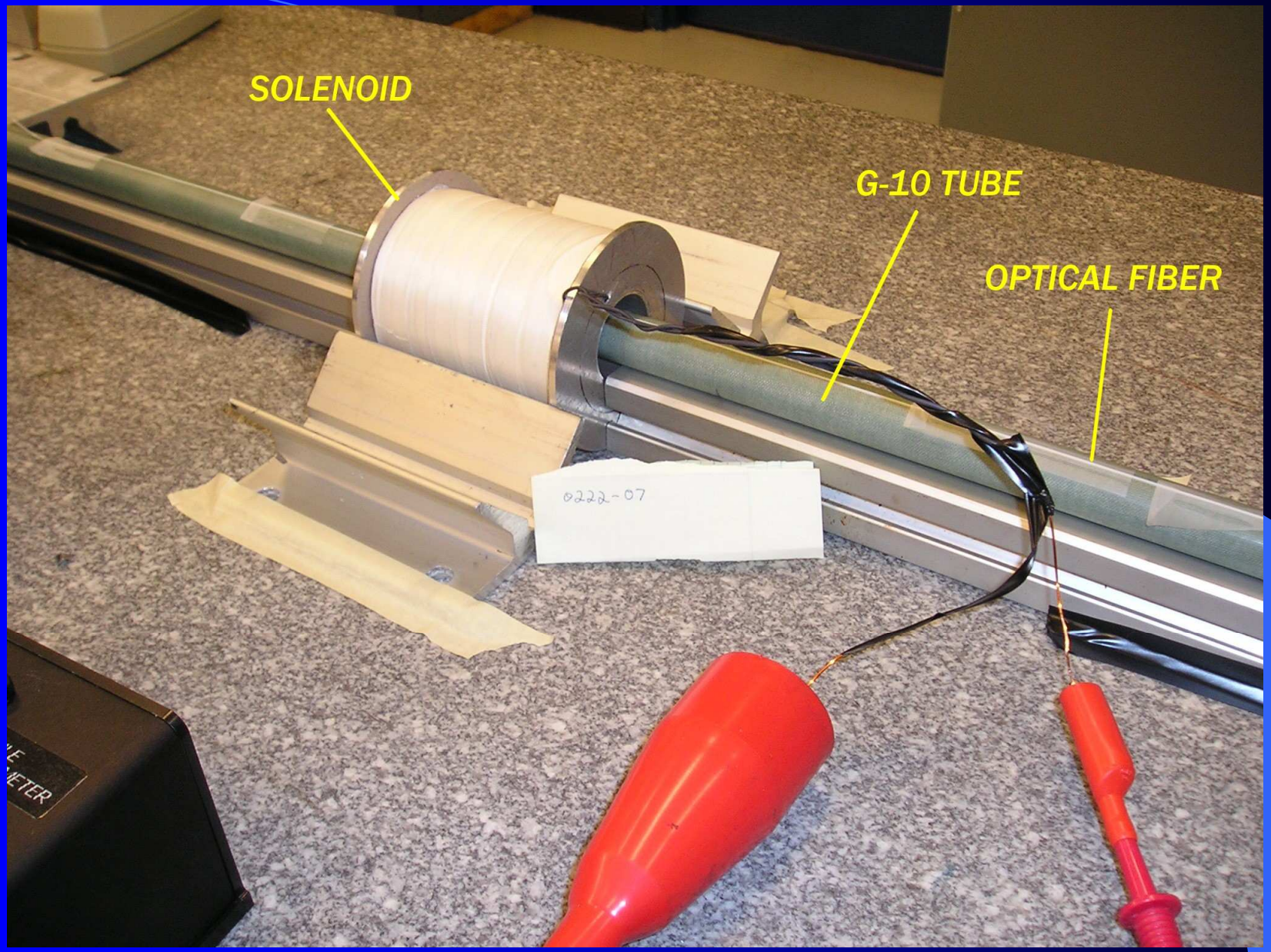


Method

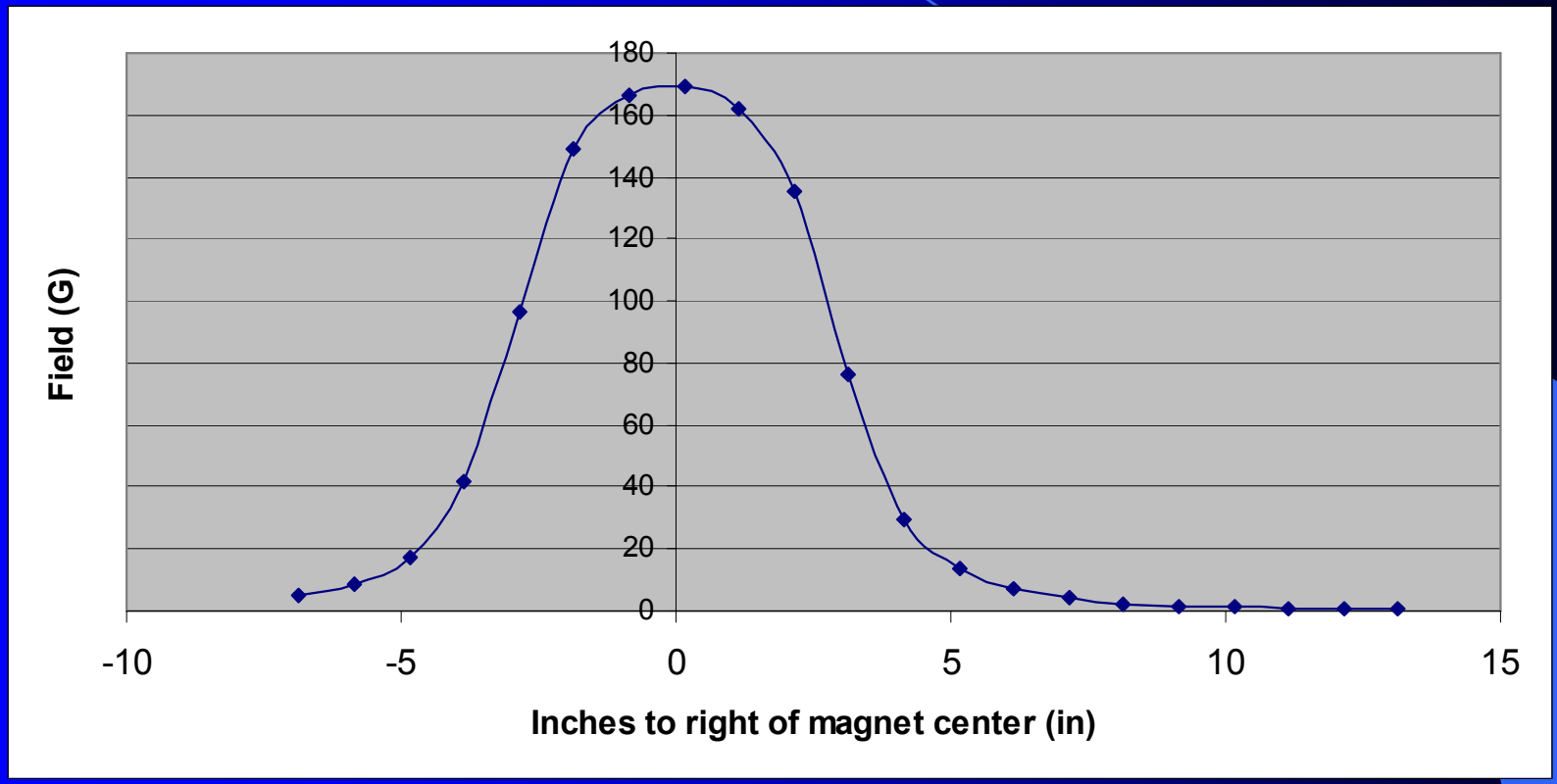
- General Setup
  -Light Source, ”Sense” Fiber, Patch Cords, Sensor
- Solenoid
  -Axial placement, compare with Hall Probe
- Quadrupole
  -Bore center, Radial Movement
- Metrics:
  -Polarization Angle (Delta Theta) – Desktop Unit
  -Extinction Ratio (ER) – Handheld Unit

Results

- FNAL
  Small Solenoid, Dipole, Quadrupole
- LBL & NHMFL
  High Current Measurement


SOLENOID
G-10 TUBE
OPTICAL FIBER
0222-07

Calibration



Hall Probe Measurement 1,085 G*in

Calibration

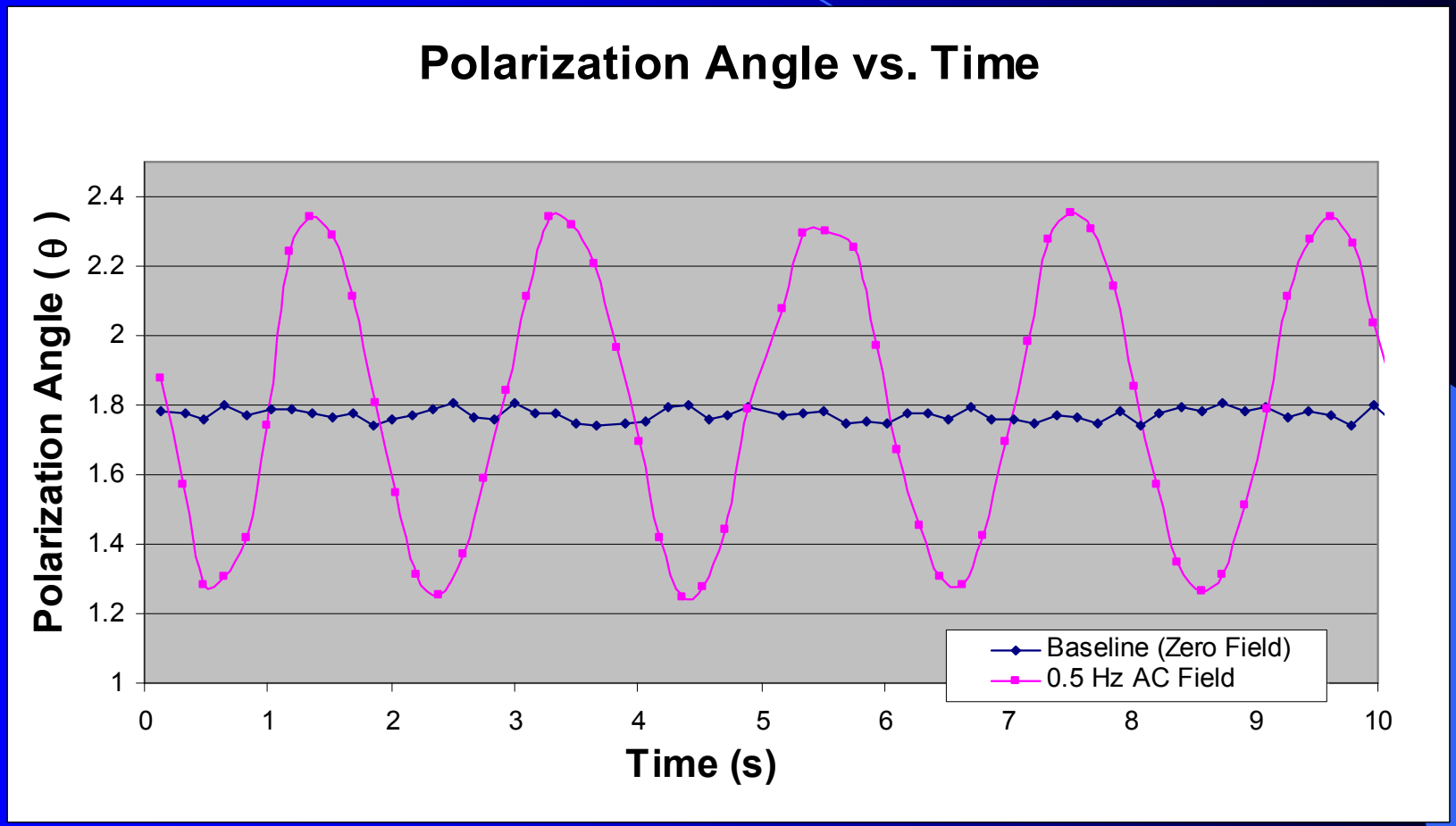
θ = vBL BL = 1085 G*in

θ = 0.505 deg BL = 0.276 T*cm

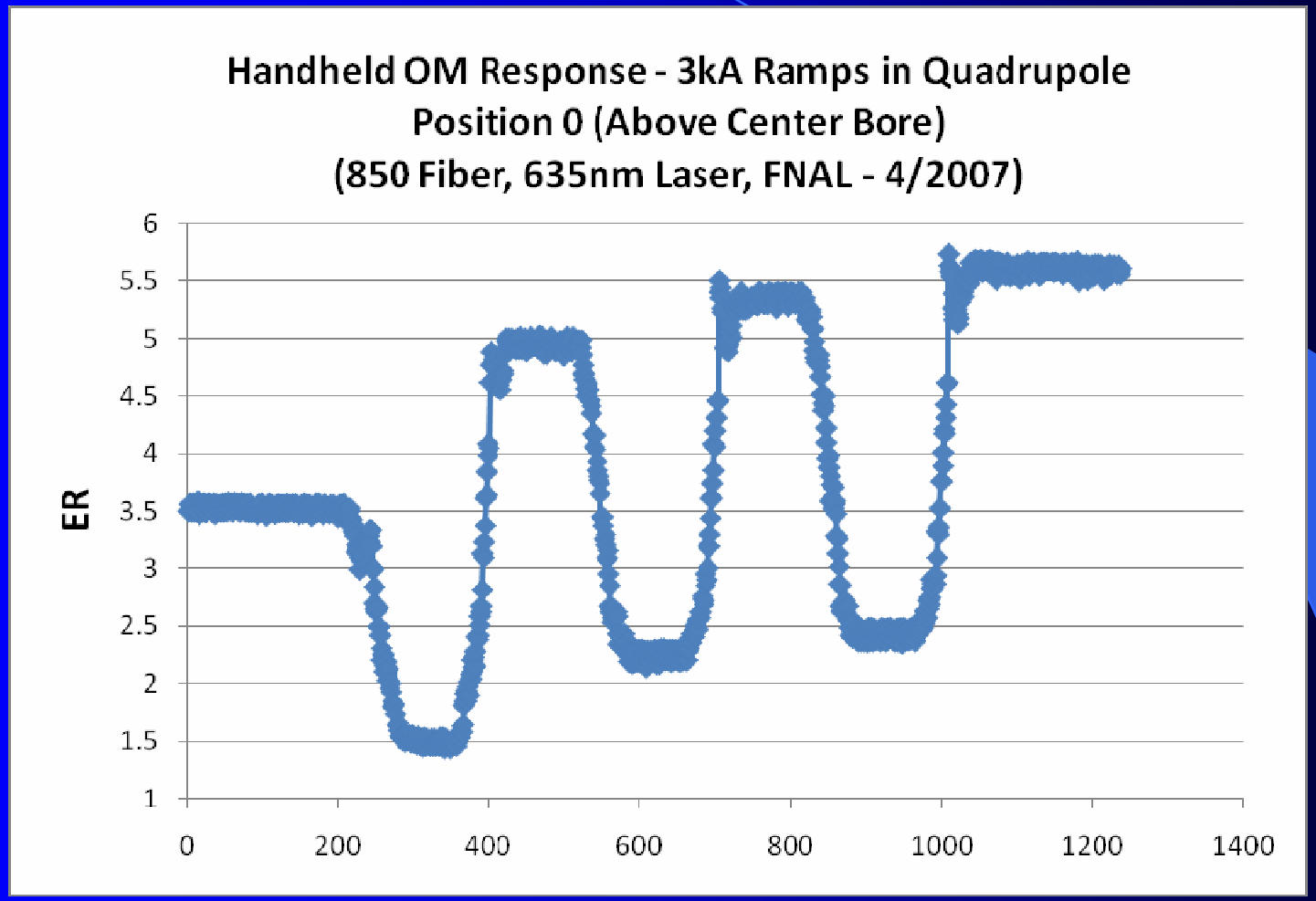
v = 1.83 deg/(T*cm)

This is close to published values of Flint glass.

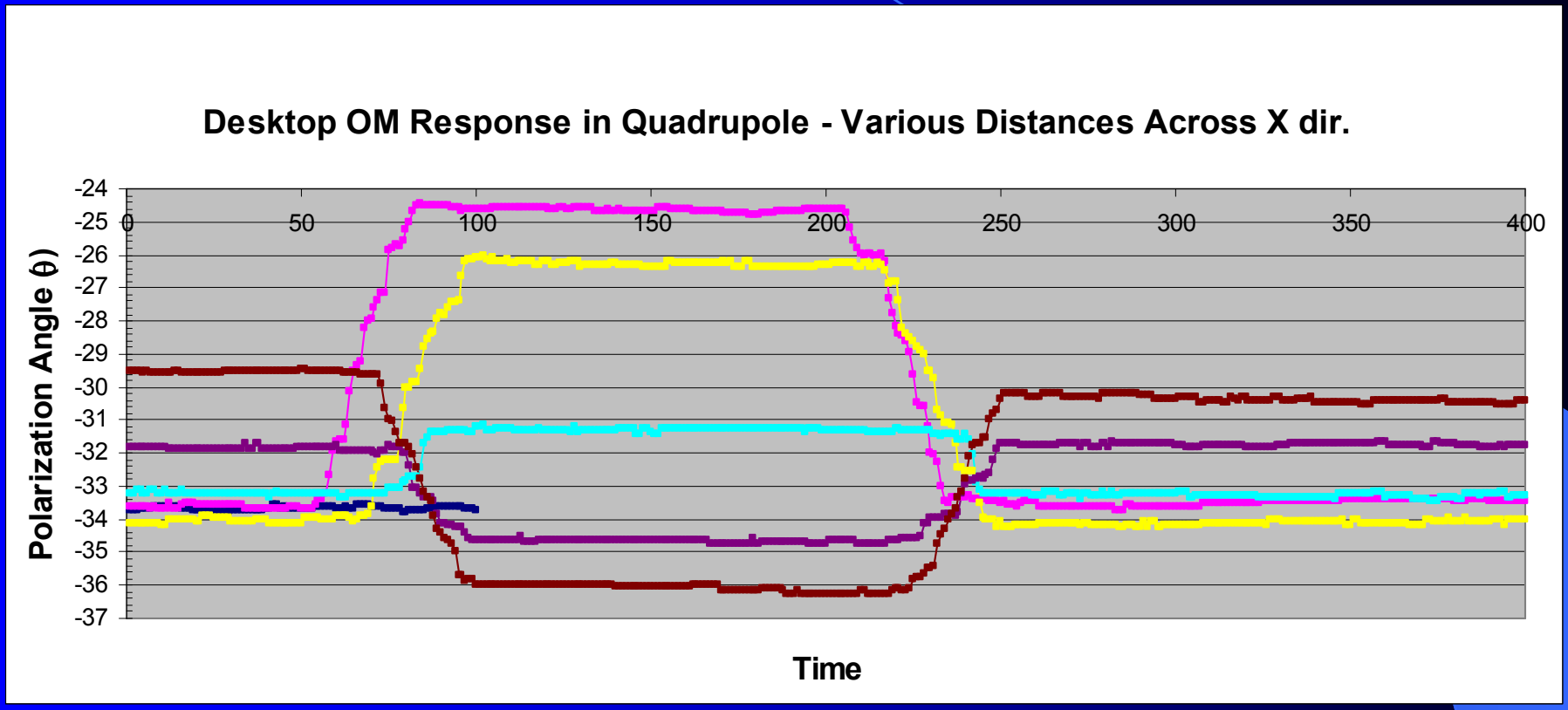
Results-Solenoid



Results-Quadrupole



Results-Quadrupole



- Desktop OM Sensitivity in parallel fields: ~1 degree / inch

Calculation of Ultimate Resolution based on best data seen from OM

5A Current	produces	2756.6	G*cm
1A Current*	produces	551.3	G*cm

	Data Points		
	(1-37)	(39-107)	(110-200)
Angle AVG	-62.011	-62.134	-62.015
Angle STDV	.004	.004	.003
shift (off to on)	-0.12		
shift (on to off)		-0.12	

So there was a shift of 0.12 degrees in polarization angle for 551.3 G*cm of B*dl.

If we also assume that we need three (3) standard deviations for a single unit of resolution, then we have:
3 x (.004) = .012

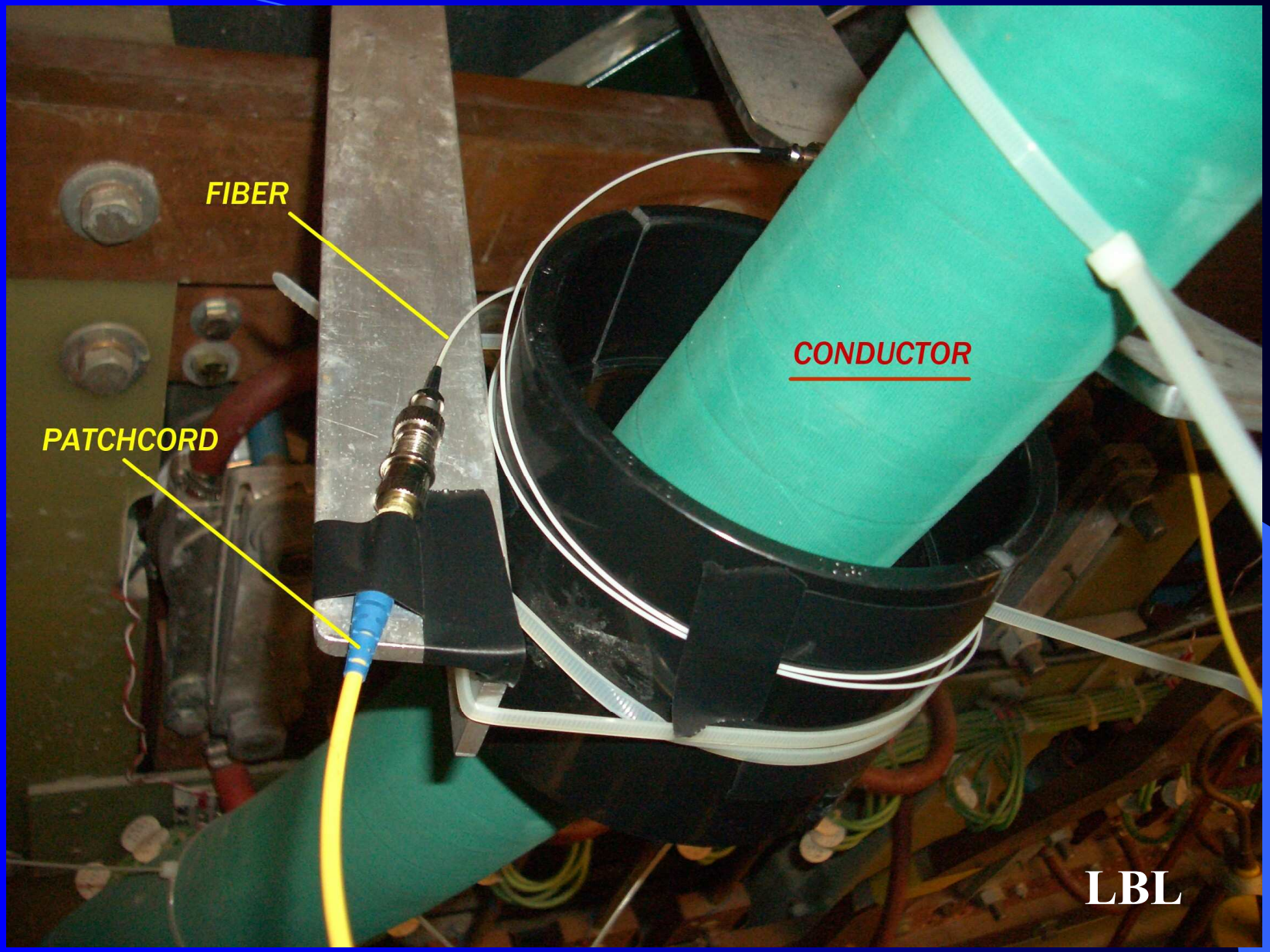
The angle shift here was almost exactly ten times this, so our resolution is 1/10th the B*dl of 551.3 G*cm, which is 55.1 G*cm

Hence, our calculated ultimate (Best) reolution for the current OM setup is: ~ 55 G*cm

Note that these calculations apply only to parallel fields (not dipoles).

Indirect Current Measurement

- Measure B-Field around single conductor.
  (Wrapped optical fiber)
- Resolution : ~100 Amps
  Maximum Field : (tested to 18kA)
- Safe method
  (Electrically isolated from current source)


FIBER
PATCHCORD
CONDUCTOR
LBL

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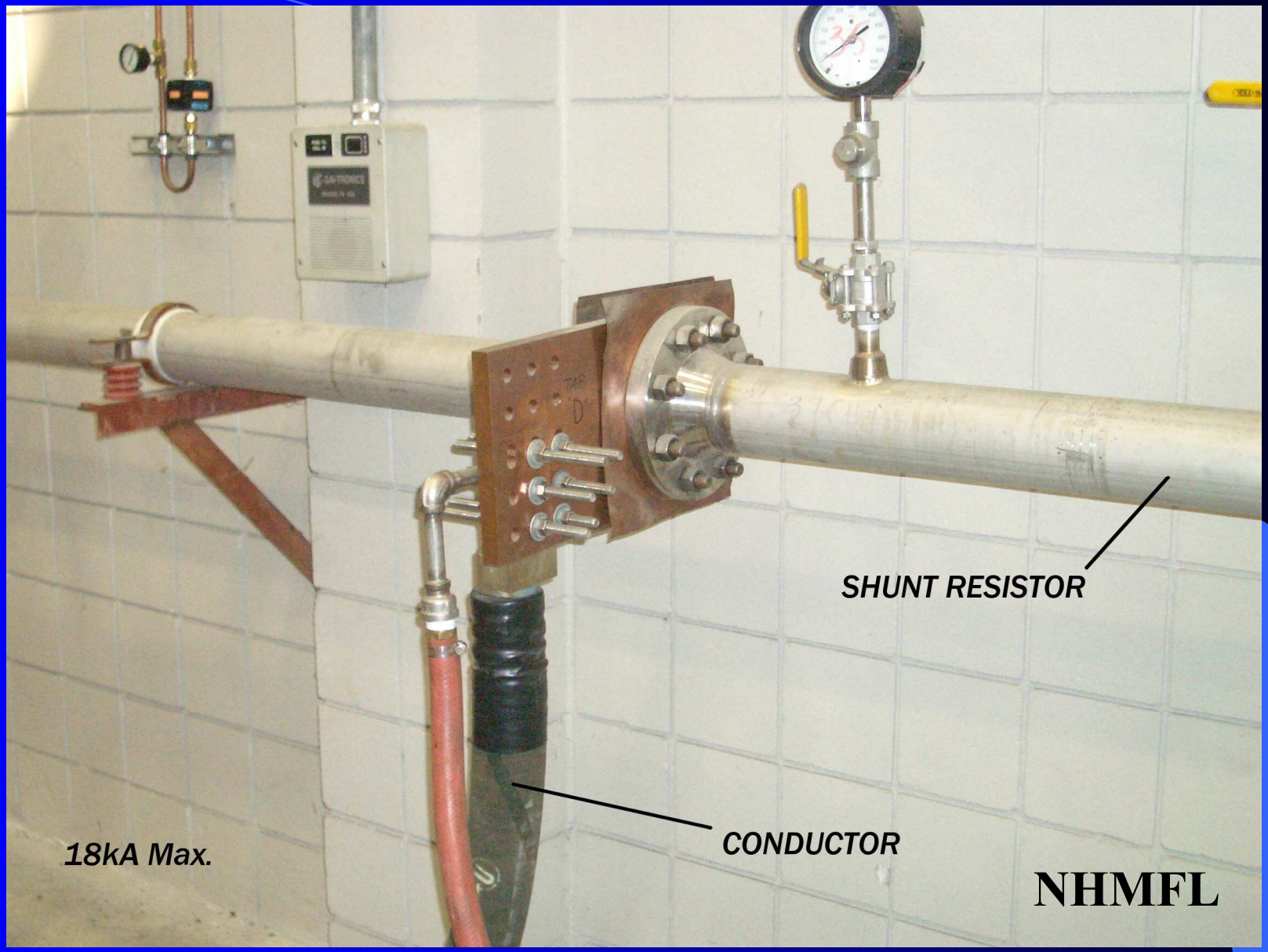
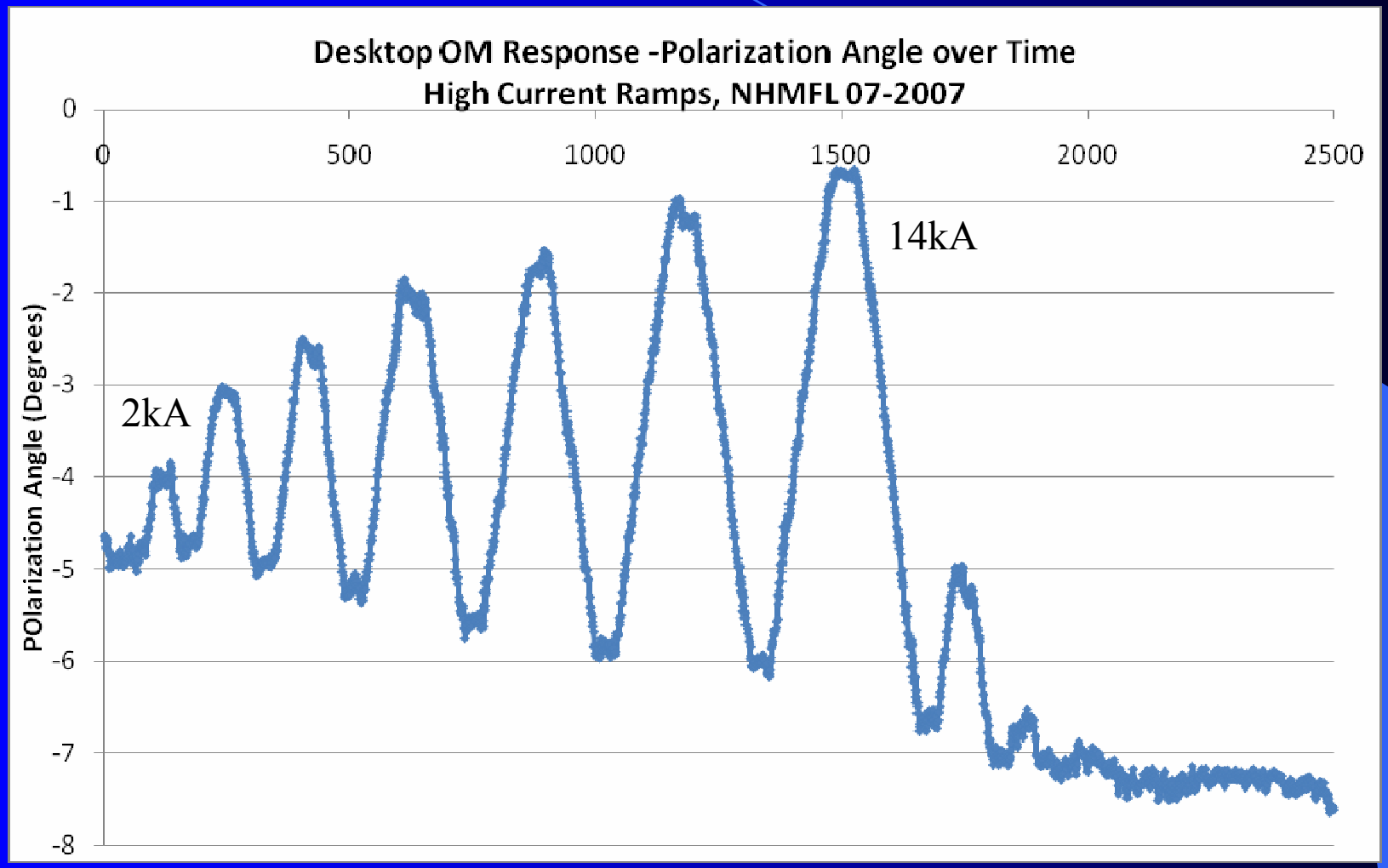
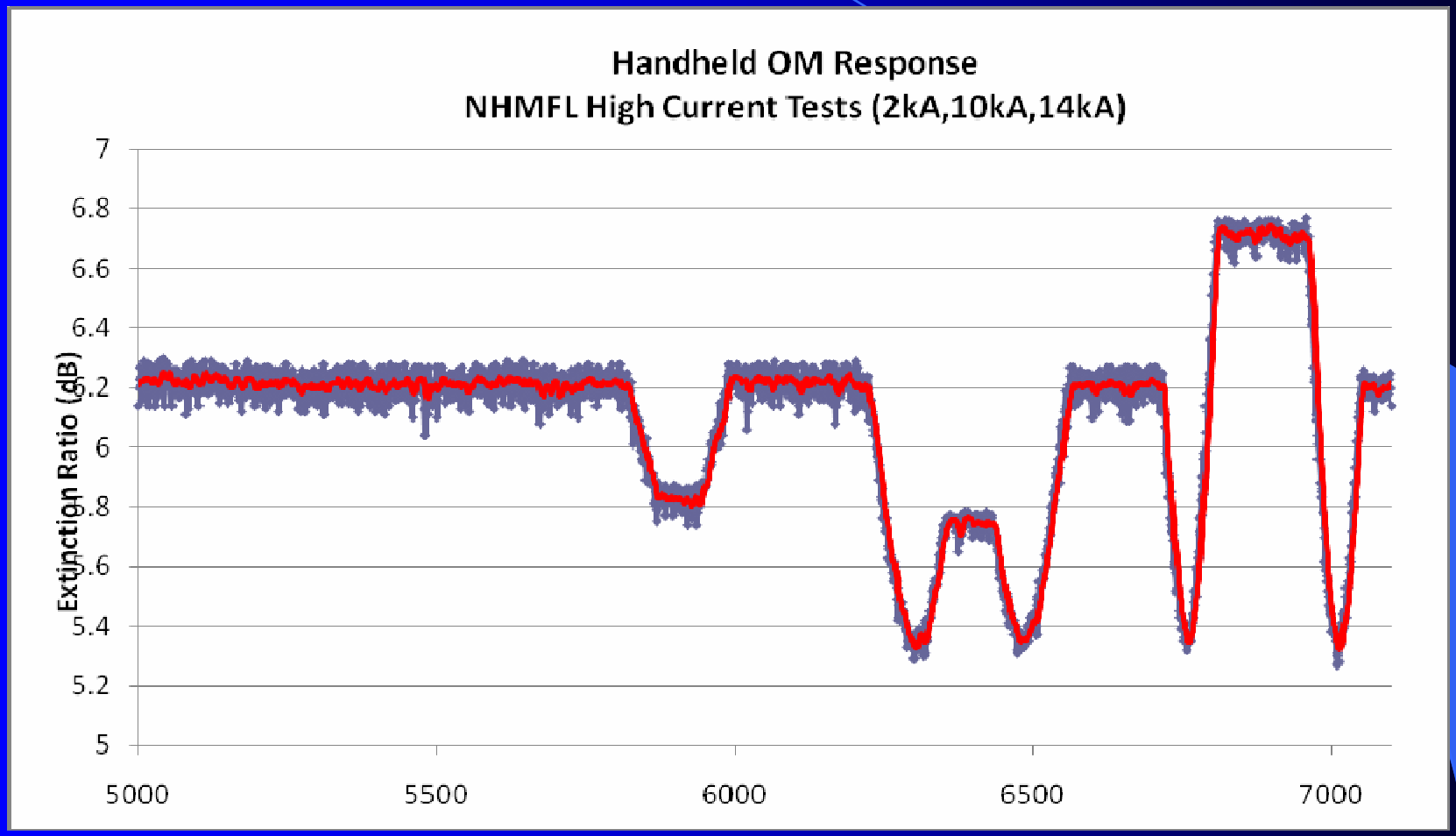

SHUNT RESISTOR
CONDUCTOR
18kA Max.
NHMFL

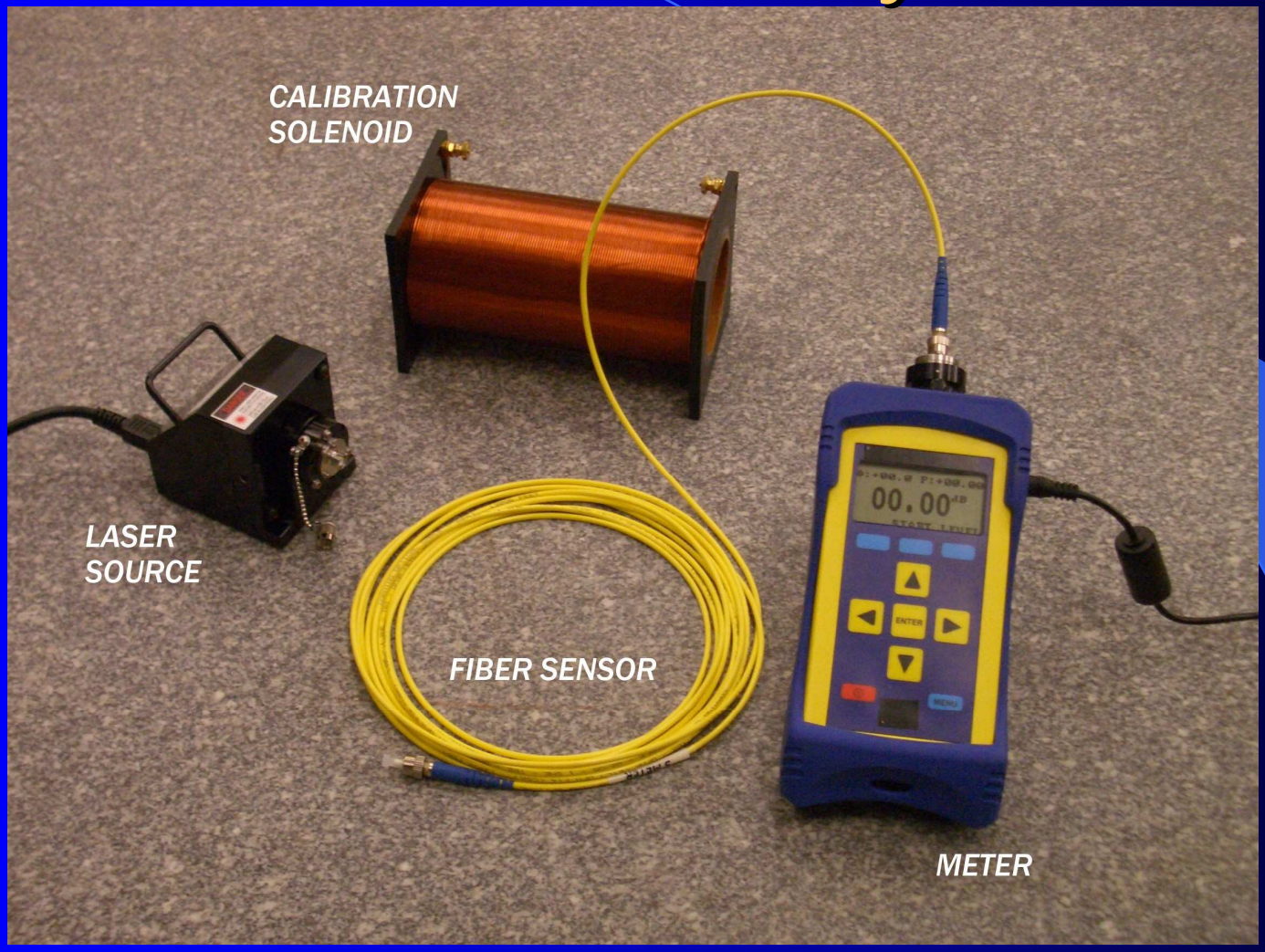
Results-NHMFL



Results-NHMFL



Handheld OM System



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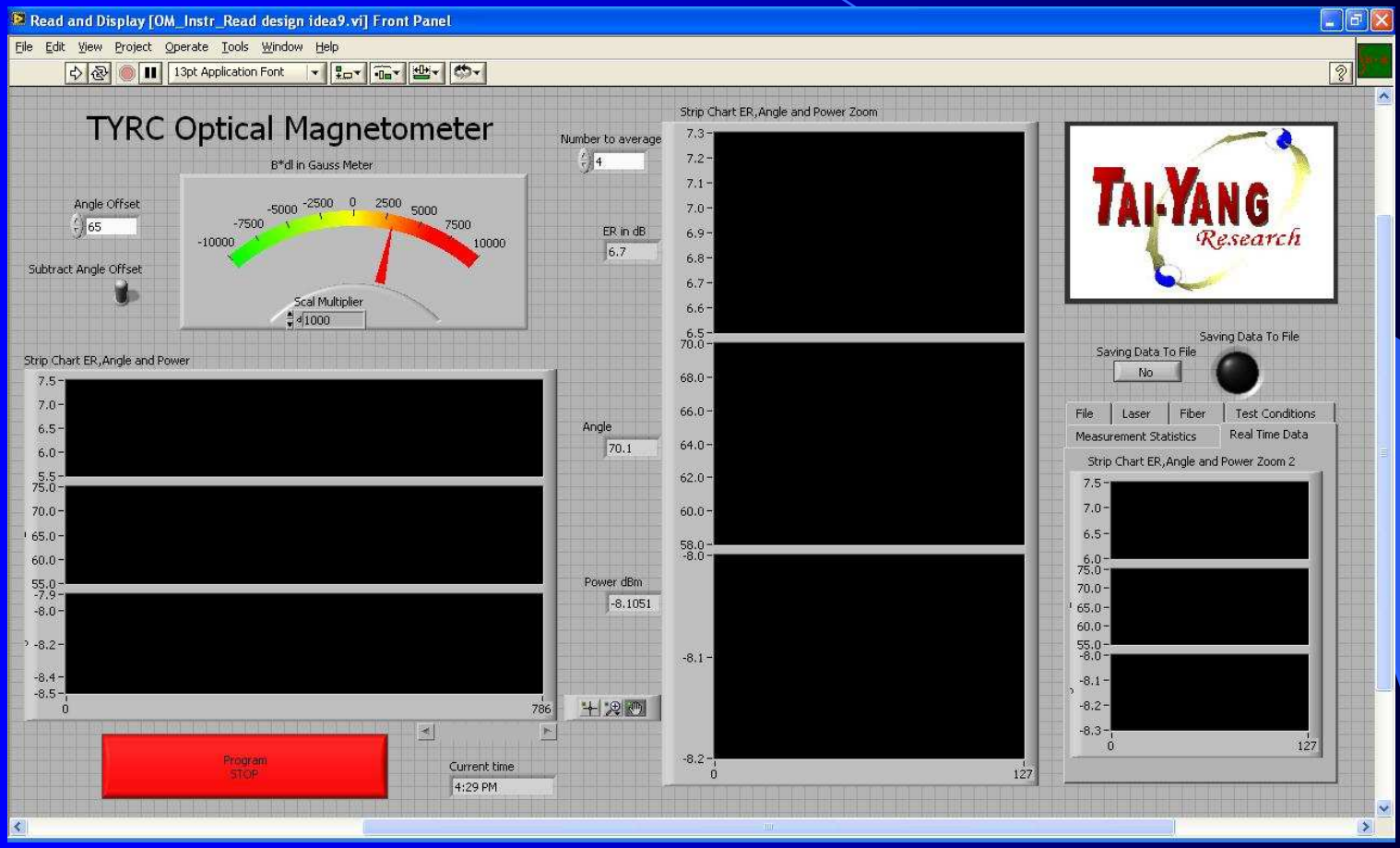
Handheld OM GUI

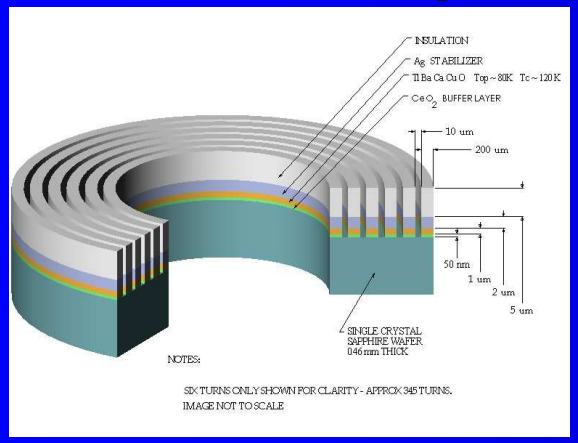


Future

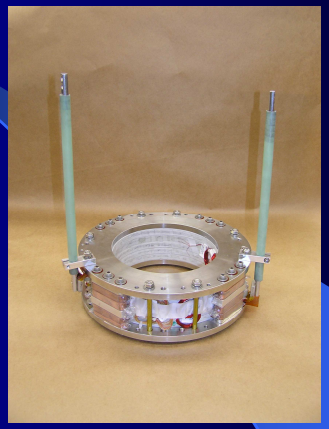
- Permanent Placement
  (Potting alongside SC Coil Fabrication)
- New Fiber – Cryogenic Sensitivity
  (Electro-Optic Glass)
- New Interrogation Equipment – Increase Frequency
  (Interferometer)
- Foundation for Related Projects…
  (New SBIR Proposals)

Other Tai-Yang Projects...

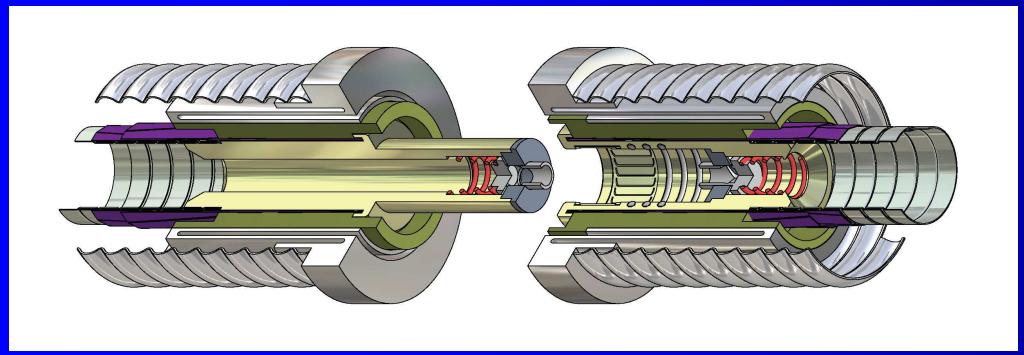
Thin Film Magnets



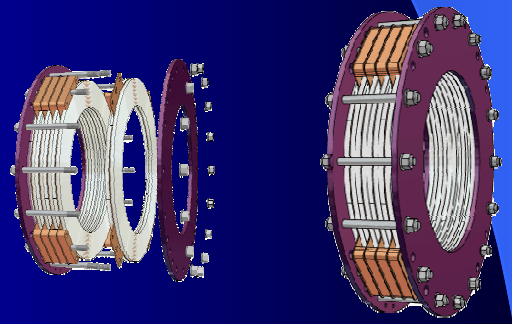
2G HTS Current Leads



Navy Cryogenic Quick-Connect



NASA VASIMIR Coils



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