Lab 1. Measurement of Dipole Magnet

Laboratory Assignment #1

Measure magnetic fields of a dipole magnet with a Hall probe and characterize the properties of the bending magnet
$N = 237$ Turns
Lab 2. Measurement of Quadrupole Magnet

Laboratory Assignment #2

Measure magnetic fields of a quadrupole magnet with a Hall probe and characterize the properties of the focusing magnet
I (A)

B (Gs)

N = 96
Lab 3. Measurement of RF Cavity

Laboratory Assignment #4

Measure resonant frequencies and Q-factors of RF cavities with a vector network analyzer and measure different modes and harmonics.
Popcorn Can

$f \sim 900 \text{ MHz}, Q \sim 100 \text{ (TM010)}$

$df < 0$

Reduce E volume, $f$ decrease

Reduce B volume, $f$ increase

$df > 0$
f ~ 1 GHz (TM010), measured Q 1,000 ~10,000
Theory ~19,000. It need a narrow frequency span, no
more than a few MHz, to measure a high Q cavity
Measured quality factor lower than theory:

1) \[ \frac{1}{Q} = \frac{1}{Q_0} + \frac{1}{Q_P} + \frac{1}{Q_T} \]
Theory gives \( Q_0 \). What we measure is \( Q \), which also include \( Q_P \), power coupler, and \( Q_T \), transport pickup. \( Q \) can be increased by reducing RF coupling (increase both \( Q_P \) and \( Q_T \))

2) Theory use pure aluminum, we fabricate with aluminum alloy

3) Surface imperfections, welding, and leaks etc
\( \pi \)-mode
0-mode
In a M-cell cavity, there are M passband modes because of RF coupling in all the cells. For M passband modes of the TM010 mode,

Phase between each cell: \( \frac{n}{M} \cdot \pi \quad (n = 1, 2, \ldots, M) \)

In particle accelerator world, you will learn that there are many different personal preferences, such as, beam emittance, index of magnet
Quarter Wave Resonator (coaxial cavity)

TEM mode, $f \sim 350$ MHz. Low frequency structure usually for heavy ion (low beta) acceleration

Harmonics: 1f, 3f, 5f, …
What’s the difference between harmonics and modes?

Modes TEM\_r1\_a1\_z1, and TEM\_r2\_a2\_z2:

If, \( r1 = r2 \), and \( a1 = a2 \), but \( z1 \neq z2 \) \( \Rightarrow \) harmonics
If, \( r1 \neq r2 \), or \( a1 \neq a2 \) \( \Rightarrow \) modes

For harmonics, the same field pattern exactly repeat along z axis, but modes are different
Lab 4. Measurement of BCM and BPM

Laboratory Assignment #5

Measure and calibrate Beam Current Monitor (BCM) and Beam Position Monitor (BPM) using function generator and oscilloscope
Your instructor can be wrong!
Square wave, BCM calibration

- 1 turn
- 8 turn

Current (mA) vs. Voltage (mV) graph for BCM calibration.
Square wave, measure decay time constant

\[ V = V_0 \cdot e^{-\frac{t}{\tau}} \]

\[ \tau = \frac{L}{R} \]
Square wave, BPM calibration
Don’t panic if your math is not so good as Jeff and Sarah, or your experiment skill is currently even worse than mine. In fact, I can say that many of you are way better than me, or will in the future. Particle accelerator is a very fun career, there are so many interesting things to do. But as all other jobs, it need a lot of hard works too.

More studies are necessary if you’d like to muster any of accelerator science and techniques, e.g. magnet design and measurement, RF cavity design and measurement, beam diagnostics, accelerator physics, control, design, and project management, ion source, etc, all have special and advanced level classes. And you will learn much more from top experts in the fields.

All your lab reports due Thursday afternoon.
Have fun and good luck!
Lab 1. Measurement of Dipole Magnet

Laboratory Assignment #1

Measure magnetic fields of a dipole magnet with a Hall probe, and characterize properties of the magnet.

Com 1. Calculation of Dipole Magnet

PC Assignment #1

Calculate magnetic fields of the dipole magnet using POISSON and compare the results with Lab 1.
Lab 2. Measurement of Quadrupole Magnet

Laboratory Assignment #2

Measure magnetic fields of a quadrupole magnet with a Hall probe and characterize properties of the magnet

Com 2. Calculation of Quadrupole Magnet

PC Assignment #2

Calculate magnet fields of the quadrupole magnet using POISSON and compare the results with lab 2.
Lab 3. Measurement of RF Cavity

Laboratory Assignment #4

Measure resonant frequencies and Q-factors of RF cavities with a vector network analyzer, and measure different modes and harmonics

Com 3. Calculation of RF Cavity

PC Assignment #3

Calculate different modes and harmonics of RF cavities using URMEL.

Calculate different modes and harmonics of RF cavities using SUPERFISH.
Lab 4. Measurement of BCM and BPM

Laboratory Assignment #5

Measure and calibrate Beam Current Monitor (BCM) and Beam Position Monitor (BPM) using function generator and oscilloscope

Com 4. Calculation of Focusing Lattice

PC Assignments #4 and #5

Calculate doublet focusing

Calculate FODO lattice using ELEGANT
Details of the labs and computer simulations are in the Laboratory and Computer Assignment, with some additions.

Read all the requirements carefully, additional information of using POISSON and of RF cavity can be found in the last pages of the Assignment. Always remember: before turn on power, check the circuit one more time and make sure everything is correct; do not touch any exposed electric thread or connector when energized.

Most computer simulation tasks can be done in a very simple way: copy all the files in \USPASExamples to your own directory and modify the input files with the right parameters. More documents of POISSON and SUPERFISH are in \LANL\Docs.

In the labs and computer works, you will design and measure bending magnet, focusing magnet, RF cavity and fundamental accelerator lattices, you will also learn basic beam diagnostic instruments.
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Lab and computer reports are required and graded for each group – a group report, due on January 24 and on January 27. A hard copy of Laboratory and Computer Assignment is available to each group. If you need electronic version or an additional hard copy, please ask.