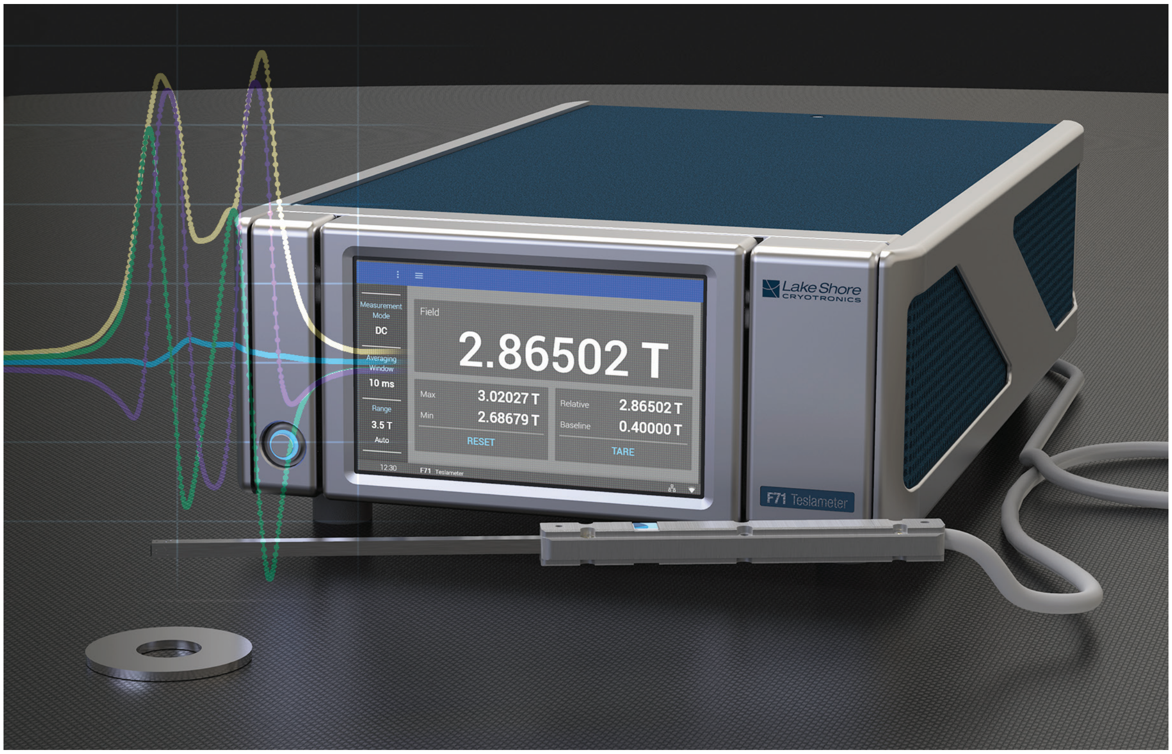
APPLICATION NOTE

Fast Magnetic Field Mapping with F71/F41 Teslameters



Lake Shore CRYOTRONICS

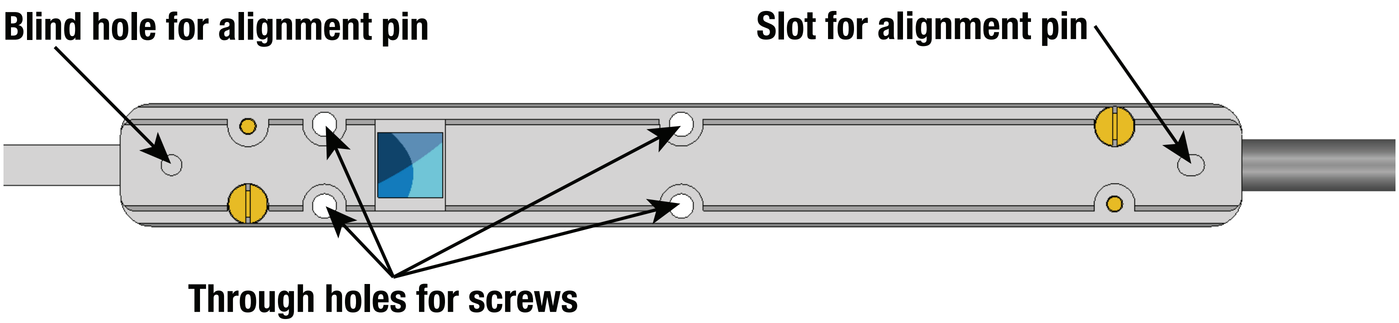
Magnetic field mapping usually requires a trade-off between speed and spatial resolution. The Lake Shore F71 and F41 teslameters and FP-series Hall probes include several features to take reliable measurements as fast as possible, allowing more points to be taken in a given time.

High speed data collection

Buffered measurements can be streamed to a PC at up to 100 readings per second, allowing field maps to be both fast and detailed. LabVIEW™, .NET, and Python drivers make it easy to write software for instrument integration.

Fixture-friendly probes

The precisely machined mountable probe handles were designed with repeatable fixturing in mind. Detailed mechanical drawings of the probes make it easy to integrate into a system.



Offsets always eliminated

TruZero™ technology constantly isolates and removes measurement offsets without a zero gauss chamber. Save time by removing the need for a compensation procedure before each map.

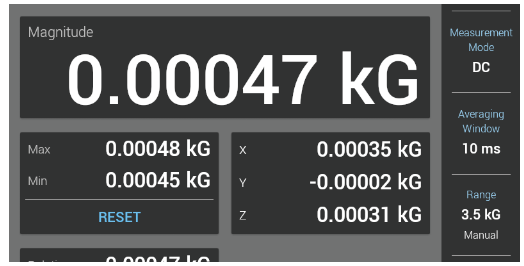
The system in action

To demonstrate the teslameter's mapping capabilities, a ring magnet was analyzed using a 3-axis probe. The rate of travel was adjusted to show how reliable measurements can be taken, even when the probe is moving quickly.

The setup

Hardware

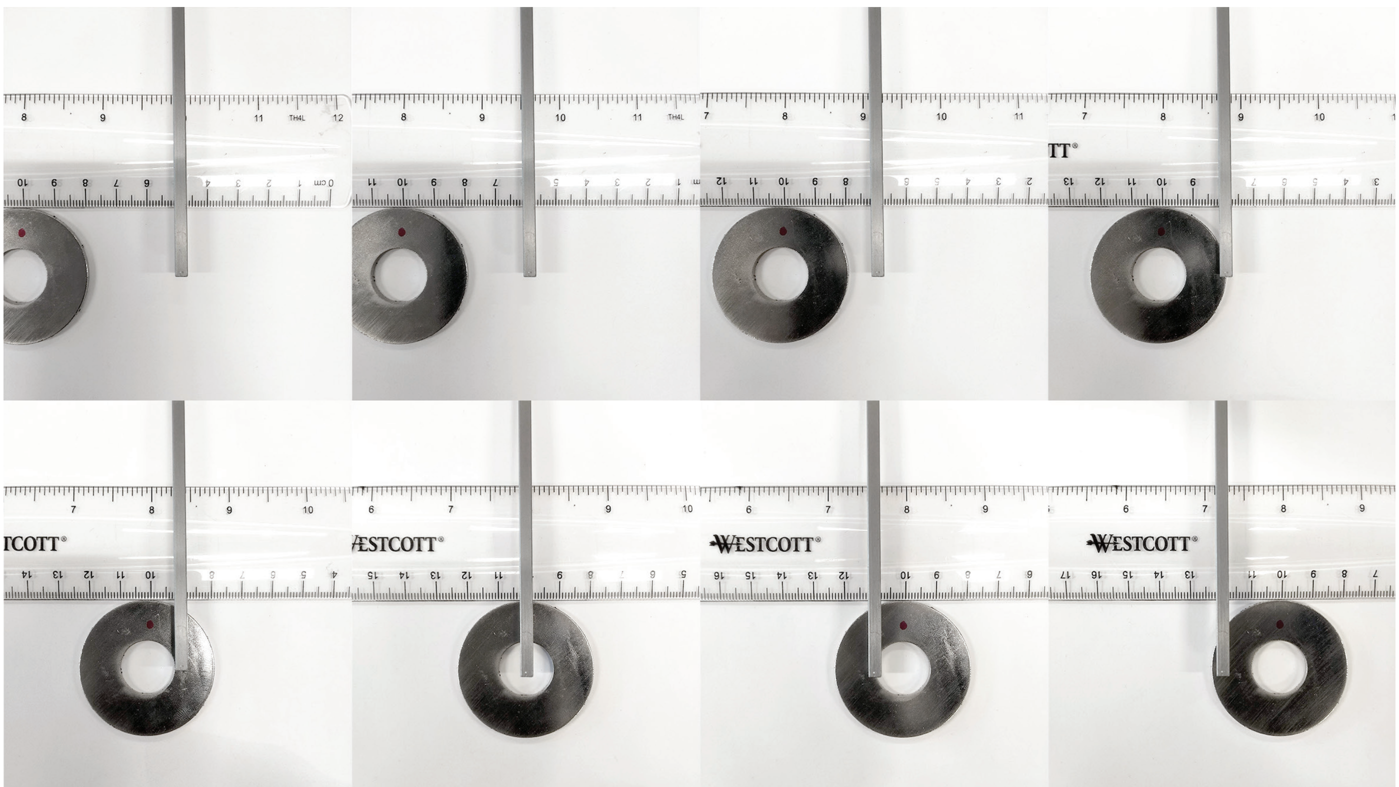
An F71 teslameter was connected to a PC via a serial USB cable. A standard mountable 3-axis probe (part number FP-2X-250-ZS15M) was connected to the F71. The ring magnet remained fixed while the probe was swept across the face of the magnet, then back again, returning to its starting position.

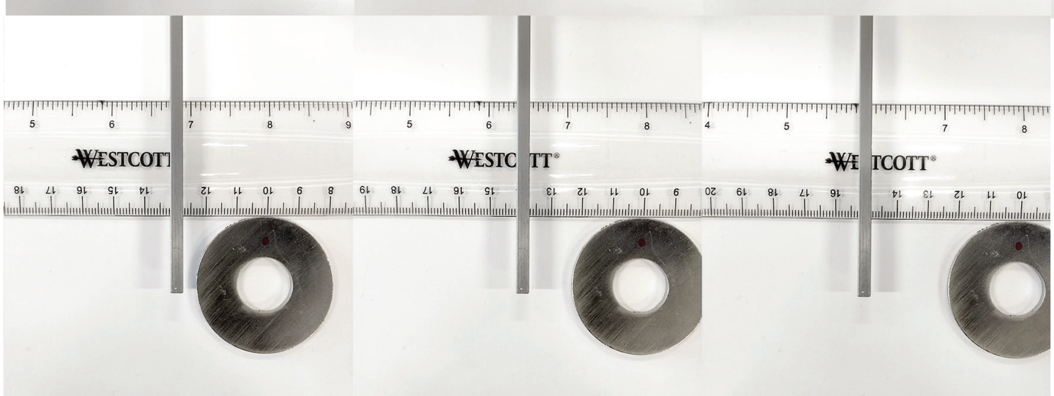


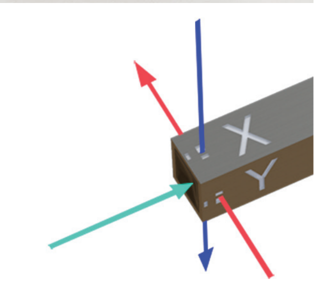
F71 front panel, showing settings

Settings

The averaging window of the teslameter was set to 10 ms and the range was set to 3.5 kG.







Close-up of the end of the 3-axis Hall probe used

Software

The following Python script collected data from the instrument. It uses the Lake Shore Cryotronics Python driver to establish a connection to the F71 and write measurement data with the following parameters:

- File name: field_map_data.csv
- Duration: 20 s
- Time step: 10 ms

```python
from lakeshore import Teslameter

instrument = Teslameter()
file = open('field_map_data.csv', 'w')
instrument.log_buffered_data_to_file(20, 10, file)
```

The raw data collected:

field_map_data.csv - Notepad

File Edit Format View Help

```
time elapsed,date,time,magnitude,x,y,z,field control set point,input state
0.01,01/31/2019,19:38:02.177000,20.973648,-17.079938,12.140864,0.8769578,0.0,0
0.02,01/31/2019,19:38:02.187000,20.969758,-17.061547,12.160272,0.8730027,0.0,0
0.03,01/31/2019,19:38:02.197000,20.970457,-17.071455,12.147681,0.8713963,0.0,0
0.04,01/31/2019,19:38:02.207000,20.965125,-17.05982,12.153833,0.8850653,0.0,0
0.05,01/31/2019,19:38:02.217000,20.96726,-17.078848,12.131212,0.879004,0.0,0
0.06,01/31/2019,19:38:02.227000,20.968328,-17.080196,12.131243,0.8778669,0.0,0
0.07,01/31/2019,19:38:02.237000,20.970968,-17.062941,12.158847,0.8944009,0.0,0
0.08,01/31/2019,19:38:02.247000,20.96168,-17.072212,12.131288,0.8737601,0.0,0
0.09,01/31/2019,19:38:02.257000,20.967698,-17.068288,12.14709,0.8752759,0.0,0
0.1,01/31/2019,19:38:02.267000,20.954405,-17.062683,12.130728,0.8929613,0.0,0
0.11,01/31/2019,19:38:02.277000,20.970994,-17.075288,12.142985,0.8746845,0.0,0
0.12,01/31/2019,19:38:02.287000,20.971191,-17.070546,12.149515,0.8812466,0.0,0
0.13,01/31/2019,19:38:02.297000,20.970037,-17.077878,12.137122,0.8824894,0.0,0
0.14,01/31/2019,19:38:02.307000,20.967334,-17.077045,12.13441,0.8716235,0.0,0
0.15,01/31/2019,19:38:02.317000,20.969297,-17.074319,12.140833,0.8827315,0.0,0
0.16,01/31/2019,19:38:02.327000,20.965131,-17.076727,12.12997,0.8865358,0.0,0
0.17,01/31/2019,19:38:02.337000,20.961691,-17.06797,12.137,0.877564,0.0,0
0.18,01/31/2019,19:38:02.347000,20.963586,-17.067819,12.140197,0.8815497,0.0,0
0.19,01/31/2019,19:38:02.357000,20.979584,-17.077378,12.154529,0.8795038,0.0,0
```

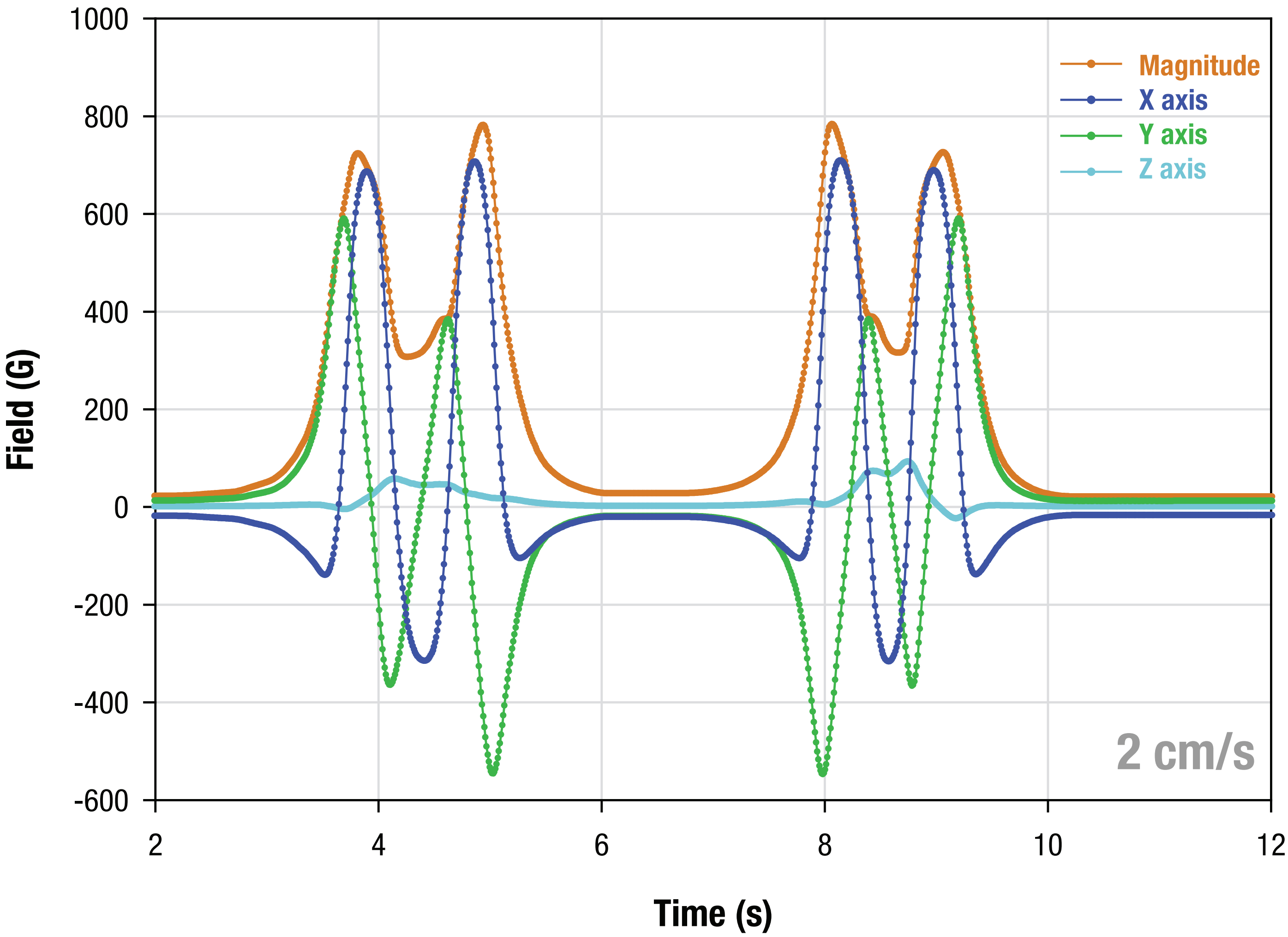
The format of this data takes the following form, with line 1 and 2 shown as an example:

Time elapsed	Date	Time	Magnitude	X	Y	Z	Set point	Input state
0.01	01/31/2019	19:38:02.177	20.973648	-17.079938	12.140864	0.8769578	0.0	0
0.02	01/31/2019	19:38:02.187	20.969758	-17.061547	12.160272	0.8730027	0.0	0

Results

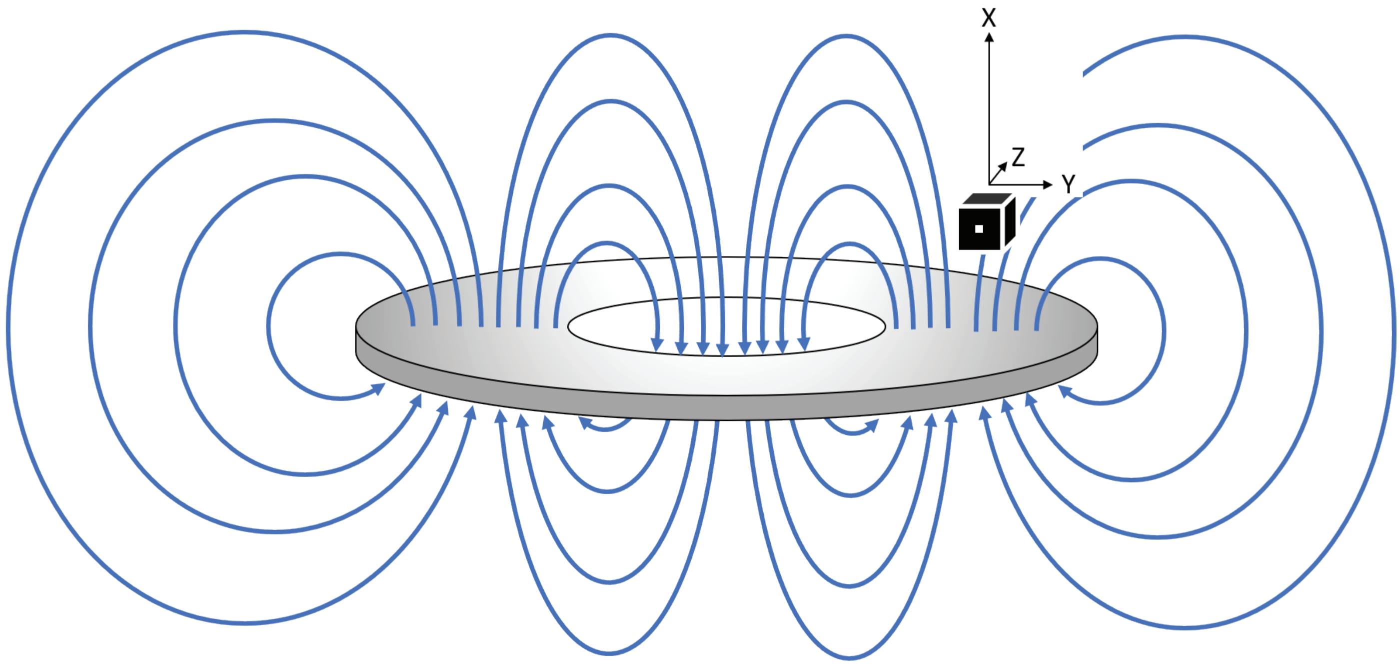
Detailed field map

In the data below, the probe passes over the magnet twice, first forwards, then backwards at a speed of about 2 cm/s. The sweep takes about 3 s to pass over the ring magnet. At this speed, a very detailed map of the ring magnet emerges. The two sweeps closely mirror one another. The plot reveals an asymmetry in the magnetization.

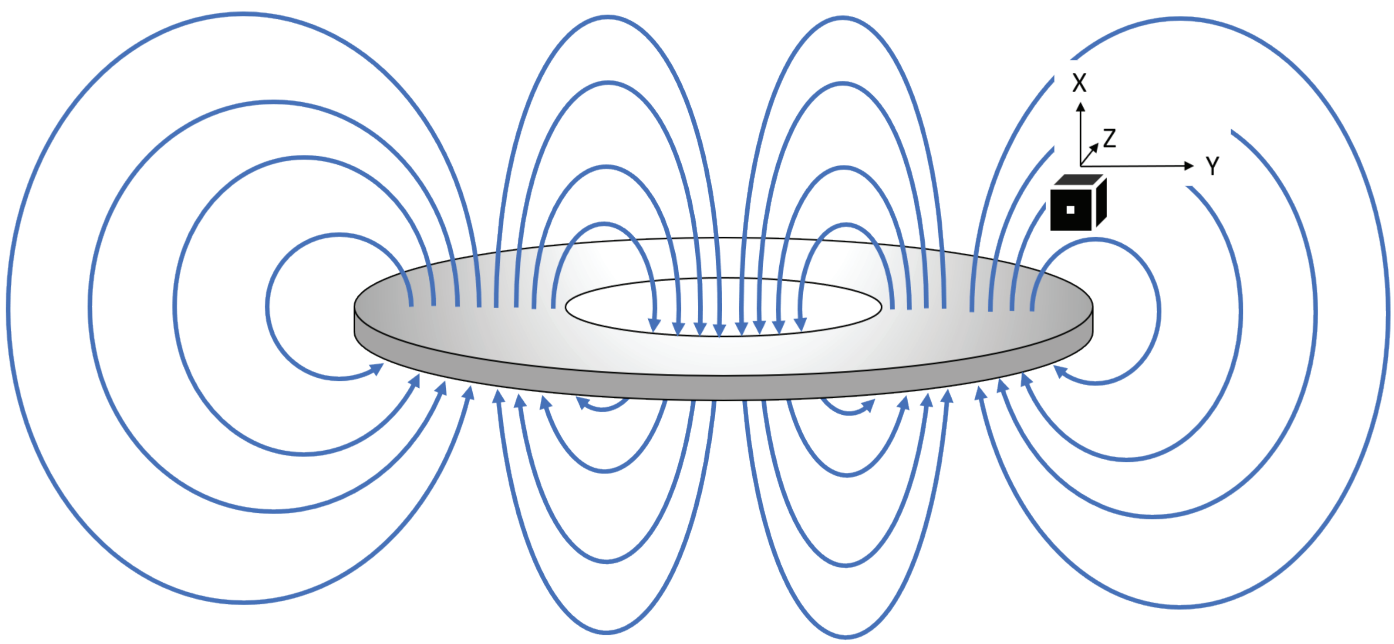


Detailed 3-axis map of magnet field strength

The data also shows the direction of the field. The X component is largest when the sensor is located over the face of the magnet.



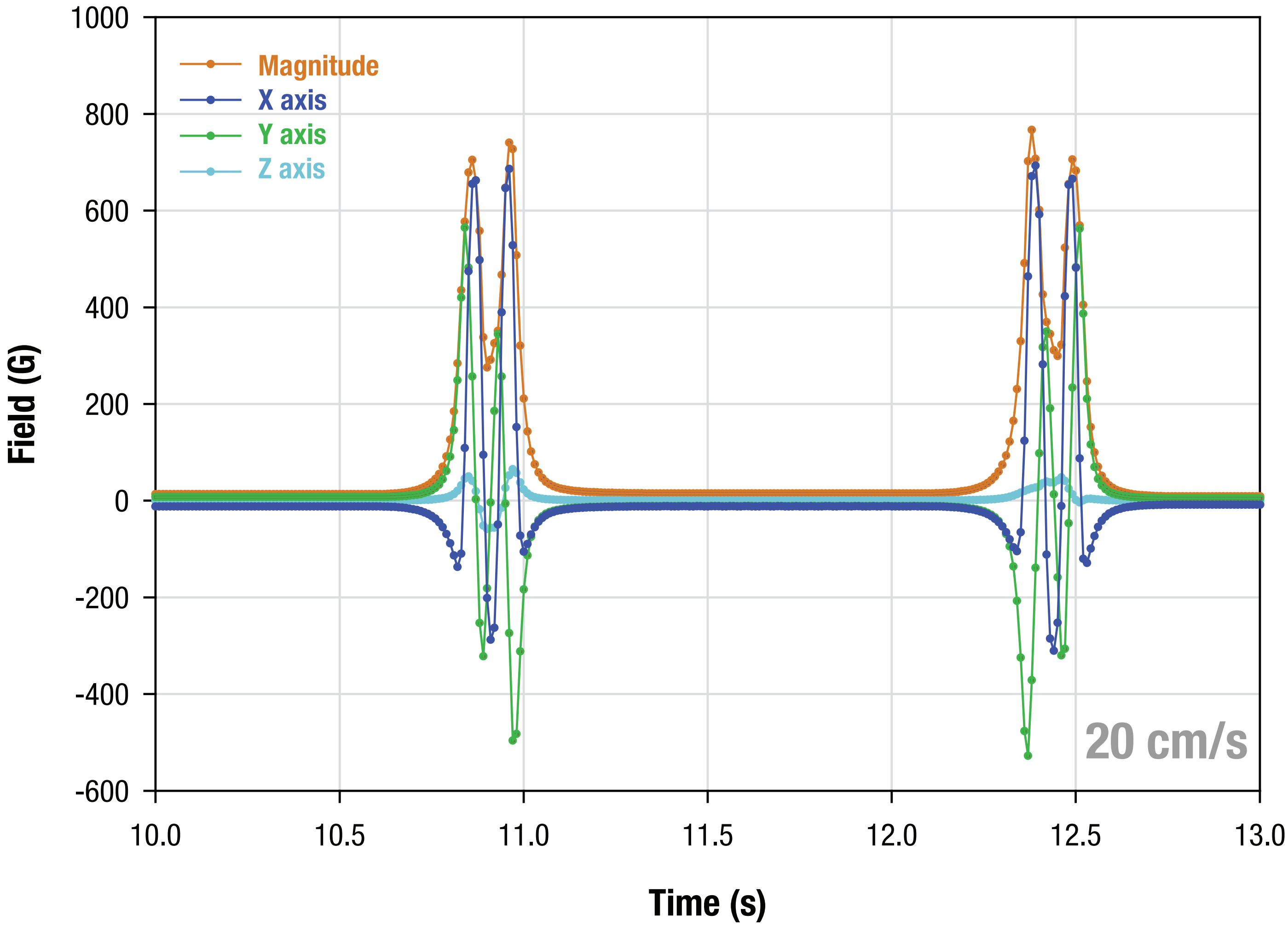
While the Y component is larger near the ring's edges.



As expected, the Z component is small since the Z sensor is kept approximately along the center of the magnet's Z dimension. Ideally it would measure zero field.

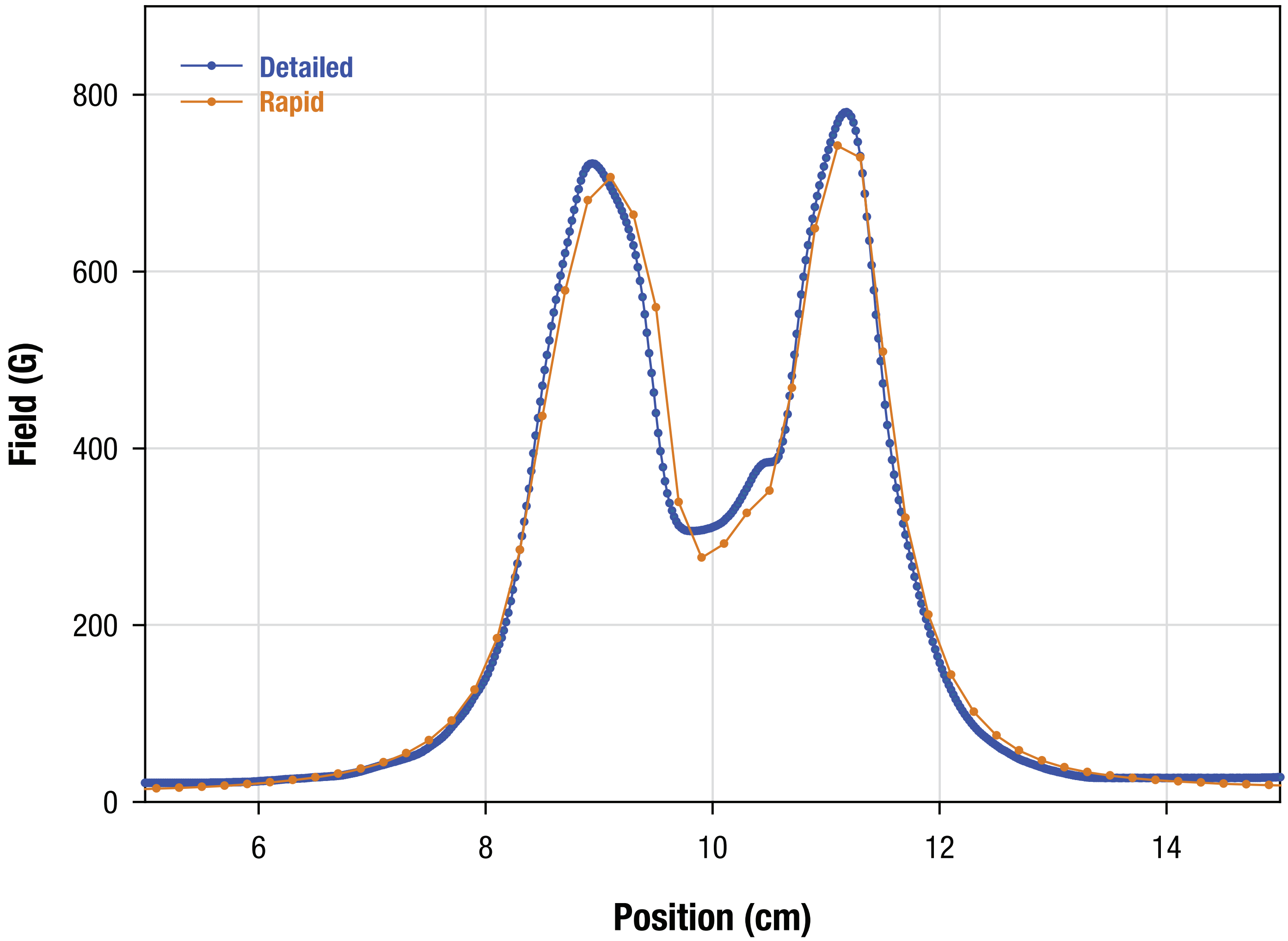
Rapid field map

Let's try sweeping the magnet even faster. The next chart shows a 0.3 s sweep. This corresponds to a speed of about 20 cm/s. Even at this speed, the shape of the ring's magnetization is captured.



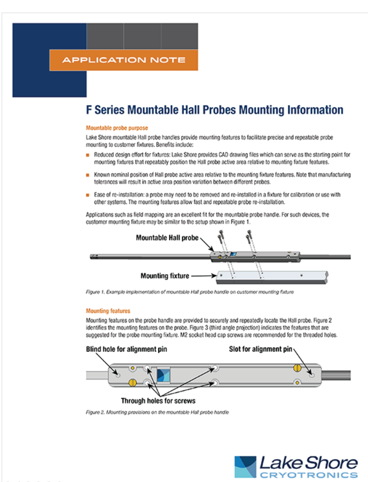
Rapid 3-axis map of magnet field strength

The following chart shows magnitude data from both the slow and fast sweeps plotted vs. approximate position. Note that although some resolution and accuracy has been lost at the higher speed, the magnetization asymmetry is still visible.



The remaining observed error between the rapid and detailed scans could be attributed to the probe being swept over the magnet by hand. Give yourself the best chance of having repeatable field maps by using one of the mountable probe options discussed in the following application note: FP Series Mountable Hall Probes Mounting Information

Note: Each reported field reading will be spaced at precisely 10 ms, with each reported value being an average of 2,000 field reading collected during the preceding 10 ms. This means that data collected on a moving probe will result in locational averaging. In the second example where the probe is moving at 20 cm/s, this would equate to averaging over a distance 2 mm for each measurement.



APPLICATION NOTE

F Series Mountable Hall Probes Mounting Information

Mountable probe purpose

Lake Shore mountable Hall probe handles provide mounting features to facilitate precise and repeatable probe mounting to customer fixtures. Benefits include:

- Reduced design effort for fixtures: Lake Shore provides CAD drawing files which can serve as the starting point for mounting fixtures that repeatably position the Hall probe active area relative to mounting fixture features.
- Known nominal position of Hall probe active area relative to the mounting fixture features. Note that manufacturing tolerances will result in active area position variation between different probes.
- Ease of re-installation: a probe may need to be removed and re-installed in a fixture for calibration or use with other systems. The mounting features allow fast and repeatable probe re-installation.

Applications such as field mapping are an excellent fit for the mountable probe handle. For such devices, the customer mounting fixture may be similar to the setup shown in Figure 1.

Mountable Hall probe

Mounting fixture

Figure 1. Example implementation of mountable Hall probe handle on customer mounting fixture

Mounting features

Mounting features on the probe handle are provided to securely and repeatedly locate the Hall probe. Figure 2 identifies the mounting features on the probe. Figure 3 (third angle projection) indicates the features that are suggested for the probe mounting fixture. M2 socket head cap screws are recommended for the threaded holes.

Blind hole for alignment pin

Slot for alignment pin

Through holes for screws

Figure 2. Mounting provisions on the mountable Hall probe handle

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