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Technology for Future NASA Missions

Single Event Effects Accelerated Terrestrial Cosmic Rays on Ferroelectric RAM

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<u>Objective</u>

To assess 4 MB Ferroelectric RAM **(FeRAM)** Soft Error (SER) and Failure in Time (FIT) performance under:

JEDEC 89 Accelerated Terrestrial Cosmic Radiation Environment- using LANSCE WNR Spectra.

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Ferroelectric RAM (FeRAM)

FeRAM is currently one of several "advanced" non-volatile memory (NVRAM) technologies that are attempting to gain acceptance as an alternative to flash by avoiding its key weaknesses – high program and erase voltages, slow programming speed, write-erase endurance that is limited to ~105 cycles.

FRAM Advantages over Non-Volatile Memories

30,000 times faster than EEPROM

100,000 times higher endurance over EEPROM

200 times lower power consumption than EEPROM

Source: Ramtron International

The first commercially available Ferroelectric RAM Memories (4 MB) samples became available in March 2007.

Advanced Terrestrial Cosmic Ray Testing November 2007

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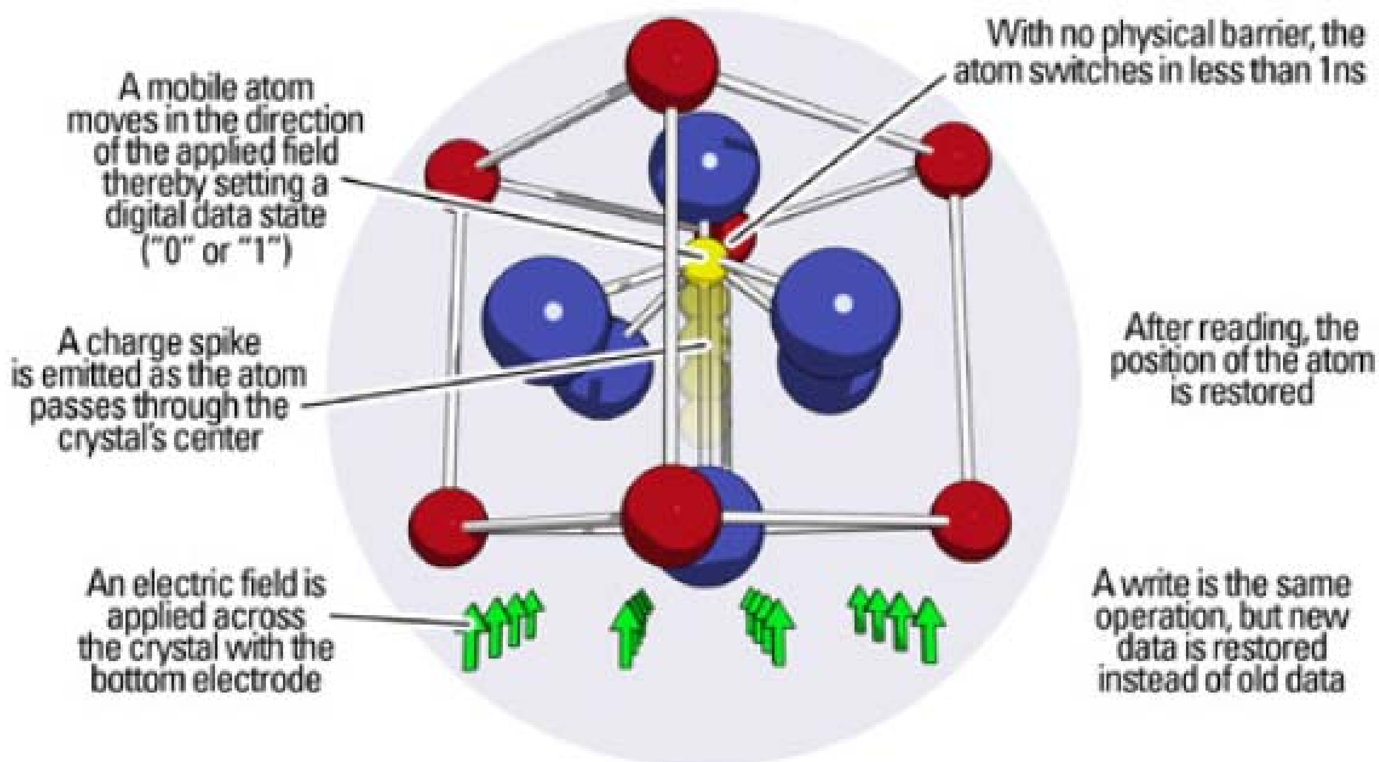
Ferroelectric RAM (FeRAM) Technology Summary



Perovskite Ferroelectric Crystal

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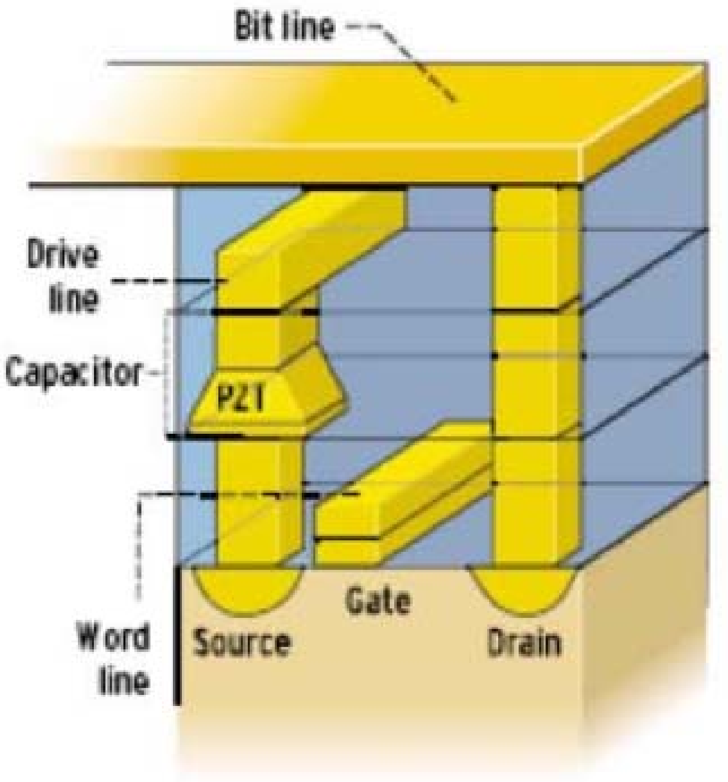

- Capacitor containing PZT insulator.

1 or 0 , ferroelectric domain points up/down.
Program-electric field between plates orients domain.
Read-bit and word lines turned on and short voltage pulse applied to capacitor thru drive line to create E-field.
If domain points in the same direction of the E-field a small current pulse appears on the bit line.
If domain points the opposite direction, a large current pulse occurs as the domains flips
Data is a 1 or 0, depending on whether the bit-line pulse is large or small.

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SPECTRAL PURITY-COMPARISON OF DIFFERENTIAL NEUTRON FLUX NYC-LANSCE WNR MONOENERGETIC NEUTRONS

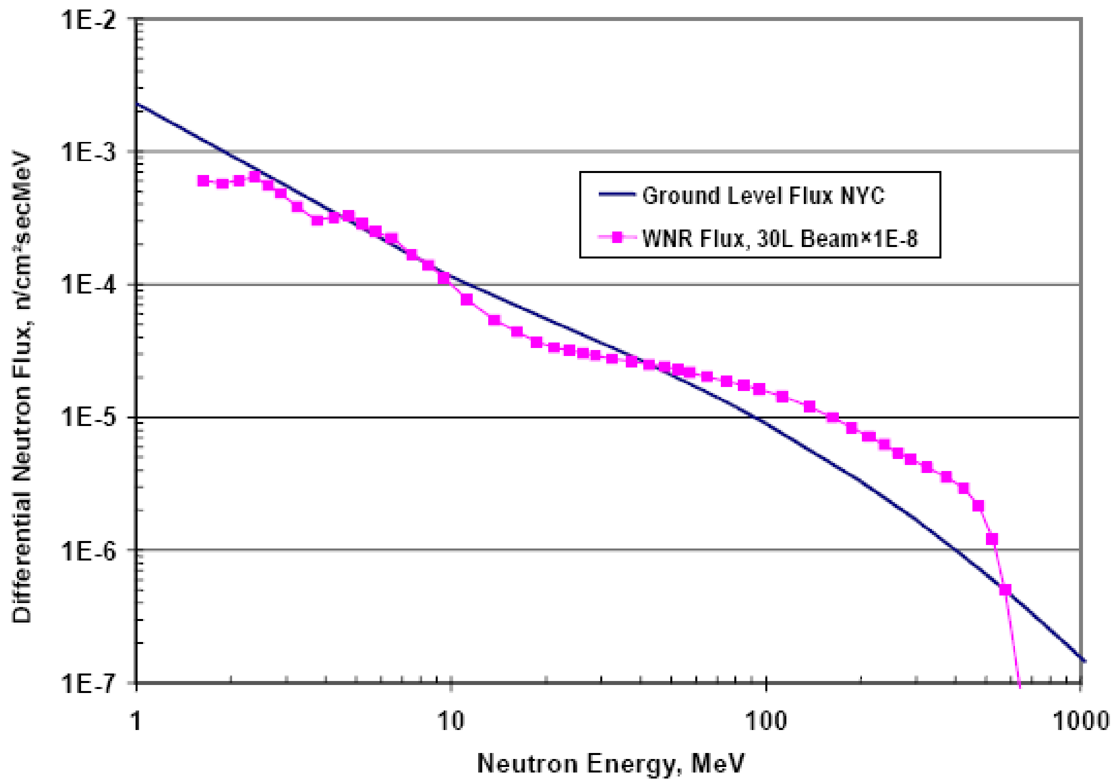

Figure 5.1 — Comparison of Differential Neutron Fluxes, in New York City, and in the WNR 30 Left beam (Reduced by Factor of 1E8) at LANL.

Total Fluence vs. Average Neutron Energy 3 cm Beam

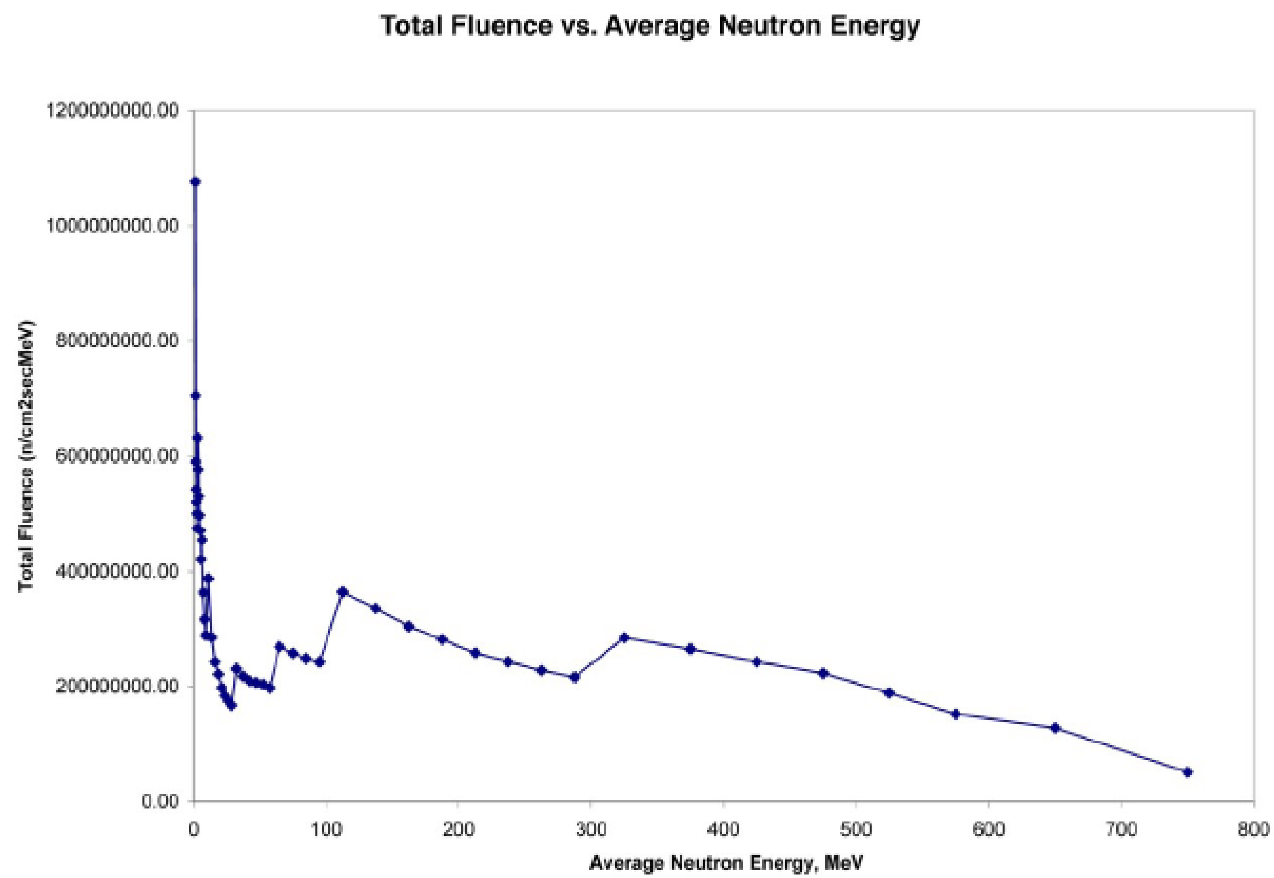

Figure 2. Total Fluence (neutron/cm2secMev) vs. Average Neutron Energy (MeV)
3" Beam Collimation LANCE SPECTRA

Total Fluence vs. Average Neutron Energy 8 cm Beam

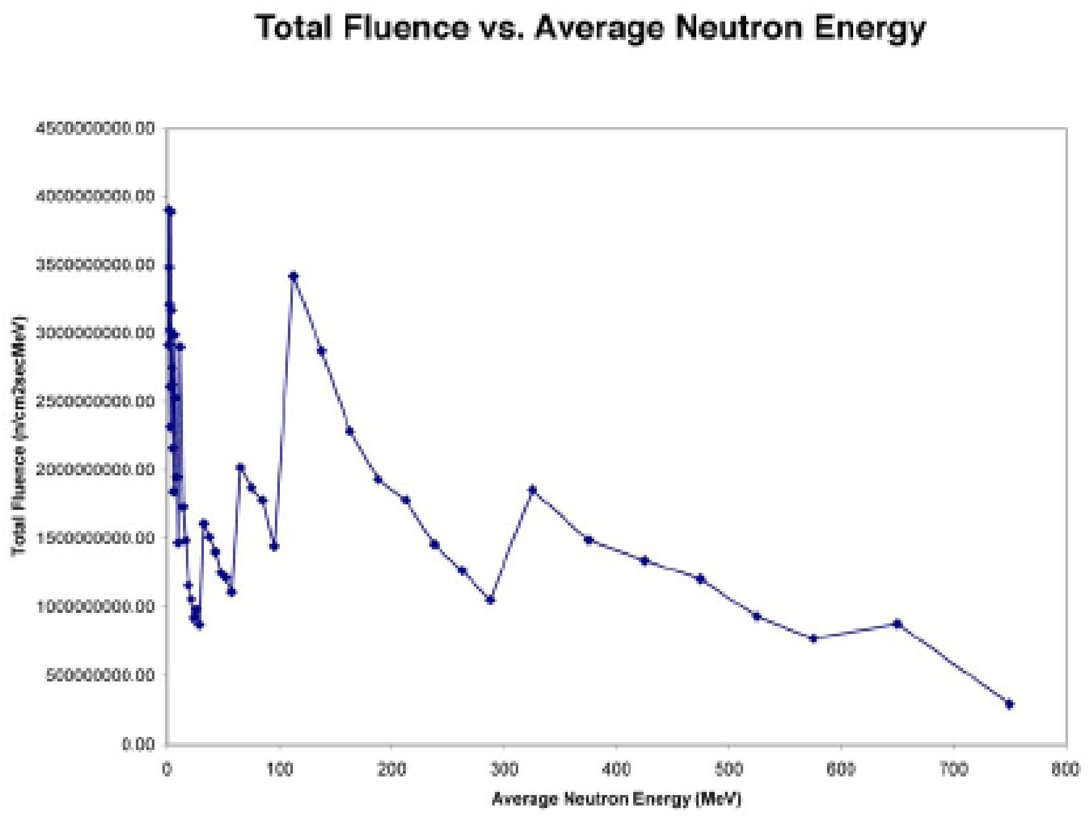

Figure 3. Total Fluence (neutron/cm2secMev) vs. Average Neutron Energy (MeV)

Single Event Effects Accelerated Terrestrial Cosmic Rays on Ferroelectric RAM

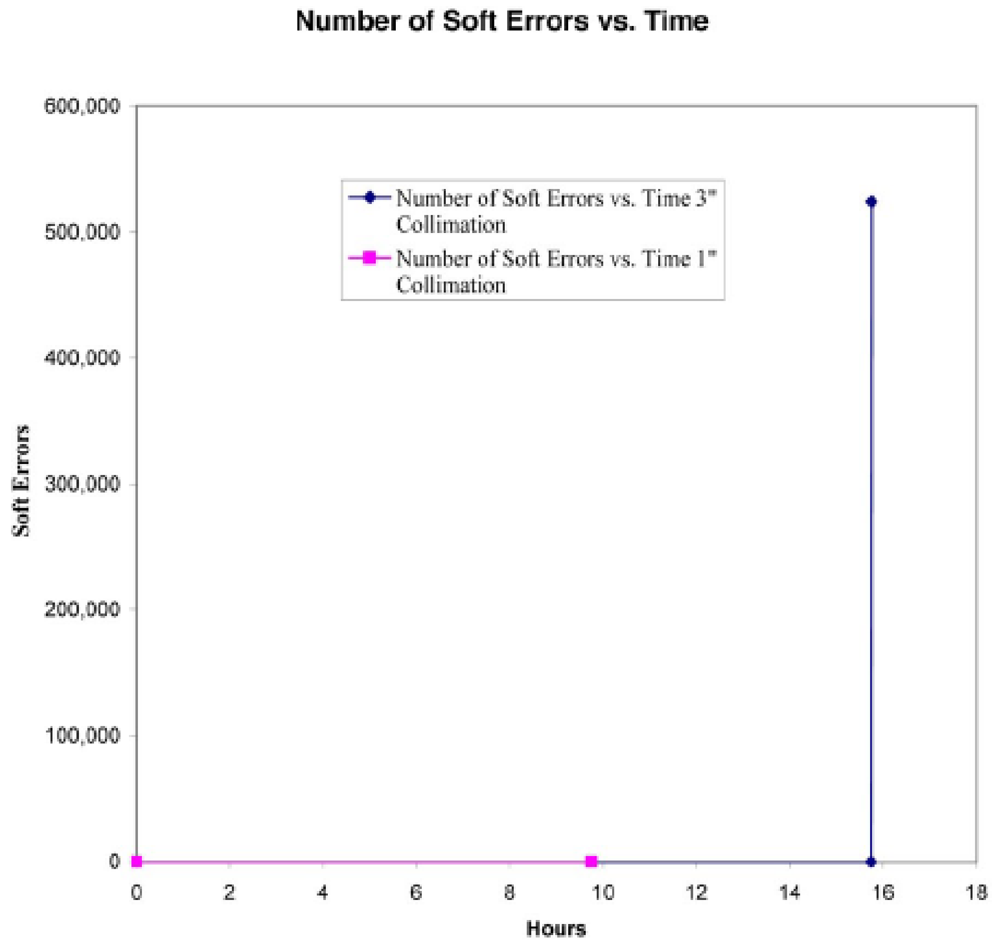

Figure 1. Number of Soft Errors vs. Time for 1" and 3" collimated beam.

DEVICE RUN SUMMARY

DEVICE UNDER TEST: FM22L16 4 MB TSOP44 Ferroelectric RAM
VDD= 0 Volts, **Average Room Temperature=** 25°C, **# of Neutrons/ cm²/ pulse** =1.7310.5 x 10^4,
# of Neutrons/ cm2 = 1.7310.5 x 104 * Neutron Pulse Count, Neutron Energy=LANSCE SPECTRA

Run #	LOT CODE	Beam Time	Start		Stop			
			Date	Time	Date	Time	Neutron Pulse Count	Neutron Flux (neutrons/cm^2)
1	0731	Beam Off 10 min	112707	12:09p	1127 2007	12:19p	0	0
2	0731	3 hrs 53 min	112707	12:25p	1127 2007	4:18p	418,411	7.243 x 10^9
3	**0731 (6 devices)**	**15 hrs 45 min**	**112707**	**4:30p**	**1128 2007**	**8:15a**	**1,716,470**	**2.97 x 10^{10}**
4	0731	Beam Off 10 min	112807	8:16a	1128 2007	8:26a	0	0

Table 1. Beam Run where soft errors were observed is highlighted.

Calculation of Soft Error Rate and FIT Estimation

Calculation of Soft Error Rate [2] $SoftErrorRate = \#ofBits \times \int_0^\infty \sigma\ (E)F(E)dE$,

$$\sigma\ (E) = \frac{NumberofFails}{(NumberofNeutrons\ /\ cm2)^*(NumberofBits)}$$

, where $\sigma\ (E)$ = bit fail cross-section and F is the differential neutron flux as a function of neutron energy, E.

Failure rate estimation from accelerated testing at WNR:

Assume in the terrestrial neutron environment, the neutron flux in the 1 - 10 MeV range, 4.0 x 10-3 n/cm^2s (or 14.4 n/cm^2h) is almost identical to the integral flux of all of the neutrons with energies above 10 MeV. 2 Thus, the terrestrial failure rate is estimated to be: Soft Error Rate, (SER) = 14 × σ (E) × # bits (upset/h), where failure in Time (FIT) represents one failure in 109 (1 billion) device hours.

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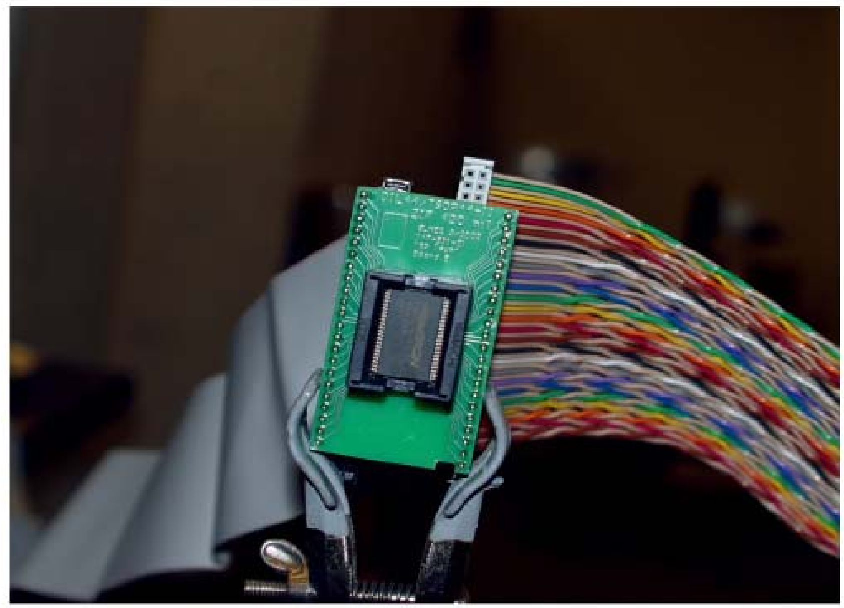
Table of SER & FIT

Calculation $\sigma(E)$,SER, FIT	# of Bits	# of fails	# bits (upset/h)[*]	# of hrs	SER	FIT
$\sigma(E) = 4.209 \times 10^{-12}$	4,194,304	524,288	33288	15.75	**1.962 x 10^-6**	**1962**

Table 2. Values of SER, FIT.

LANSCE SPECTRA Testing Under Bias



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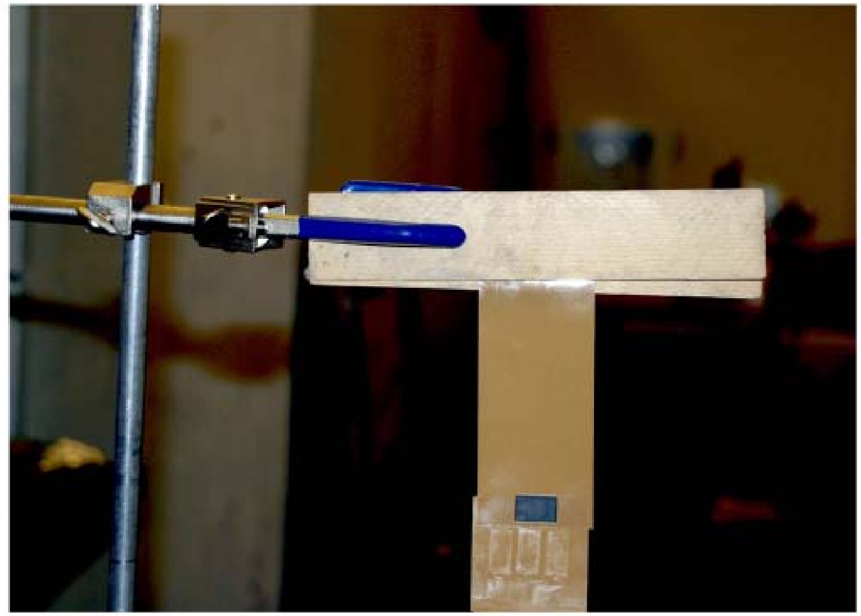
LANSCE SPECTRA
Testing w/o Bias



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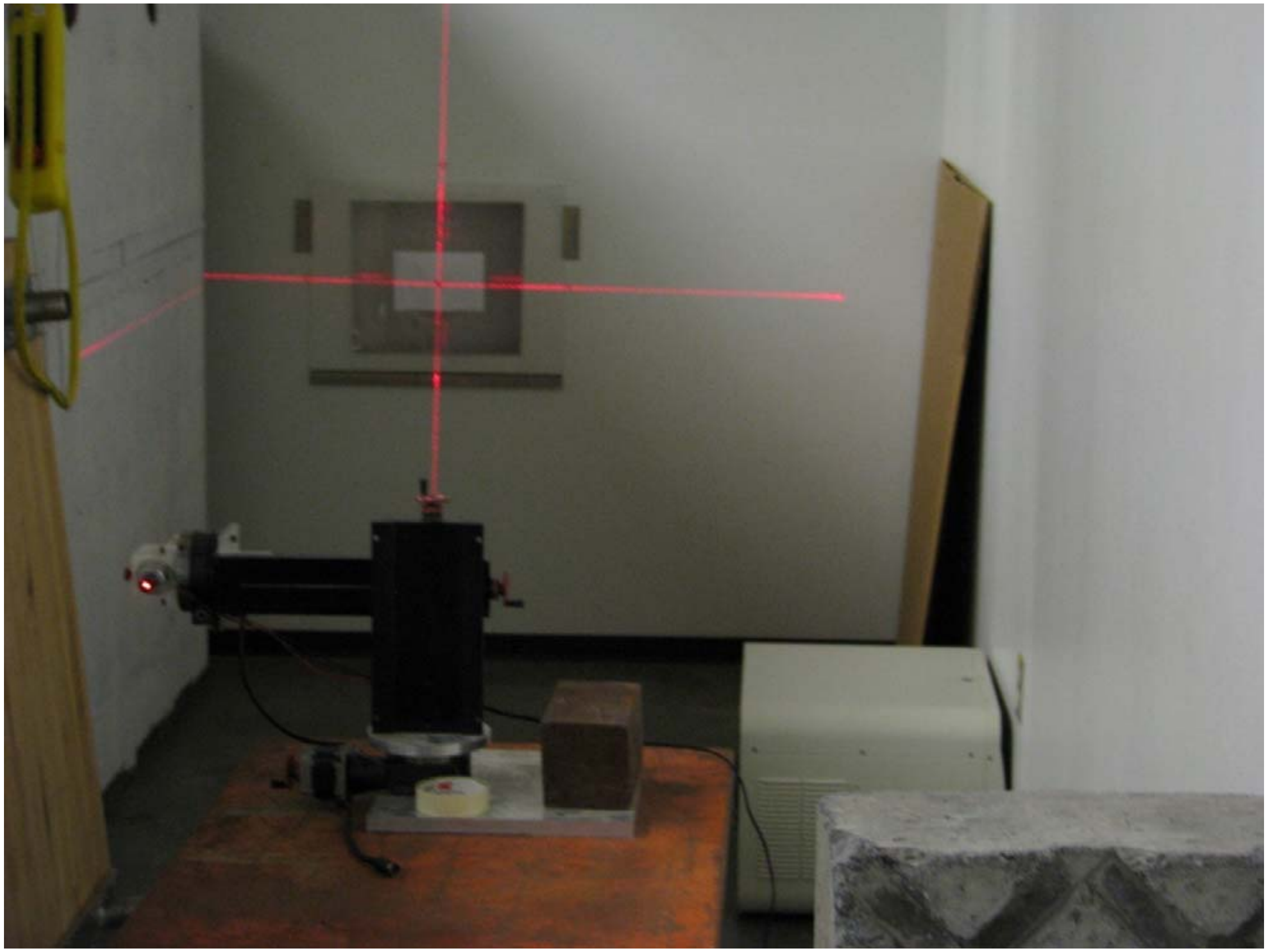
Beam Alignment



Conclusions

- The 4MB FM22L16 FeRAM operated normally without any soft errors under LANSCE SPECTRA for up to 15.75 hrs.
- There were no hard errors observed.
- The devices recovered their data after beam was removed.
- This experiment was a first of its kind for the 4MB FM22L16 FeRAM under Accelerated Terrestrial Cosmic Ray environment.
- Additional Testing Recommended form additional lots.

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