



# The scanning magnets for proton therapy designed by SINAP

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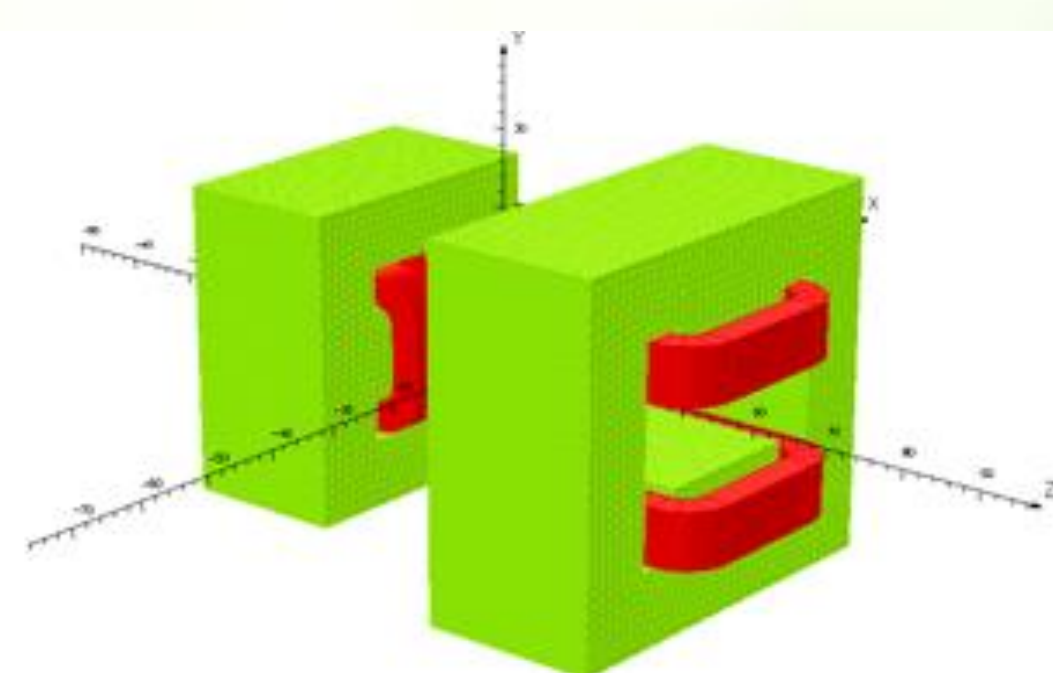
## Abstract

A new proton therapy scanning system for the treatment of cancer has been accomplished at the Shanghai Institute of Applied Physics (SINAP/China). It is mainly comprised of two separate dipole magnets, each controlling horizontal and vertical directions scanning independently. According to the design requirements, we have confirmed the dimensions of the magnets and optimized the local and integrated field quality. The static electromagnetic field analysis has been completed in OPERA 3D, including the spatial distribution and interference of the magnetic fields, the optimization of the pole, the verification of the scanning scope. The dynamic behaviors of the two dipole magnets were analyzed respectively and approaches to reduce the effects of the eddy currents were integrated into the design. In addition, the static and dynamic magnetic field measurements were finished. All the specific design results of the scanning magnets are concluded in this paper.

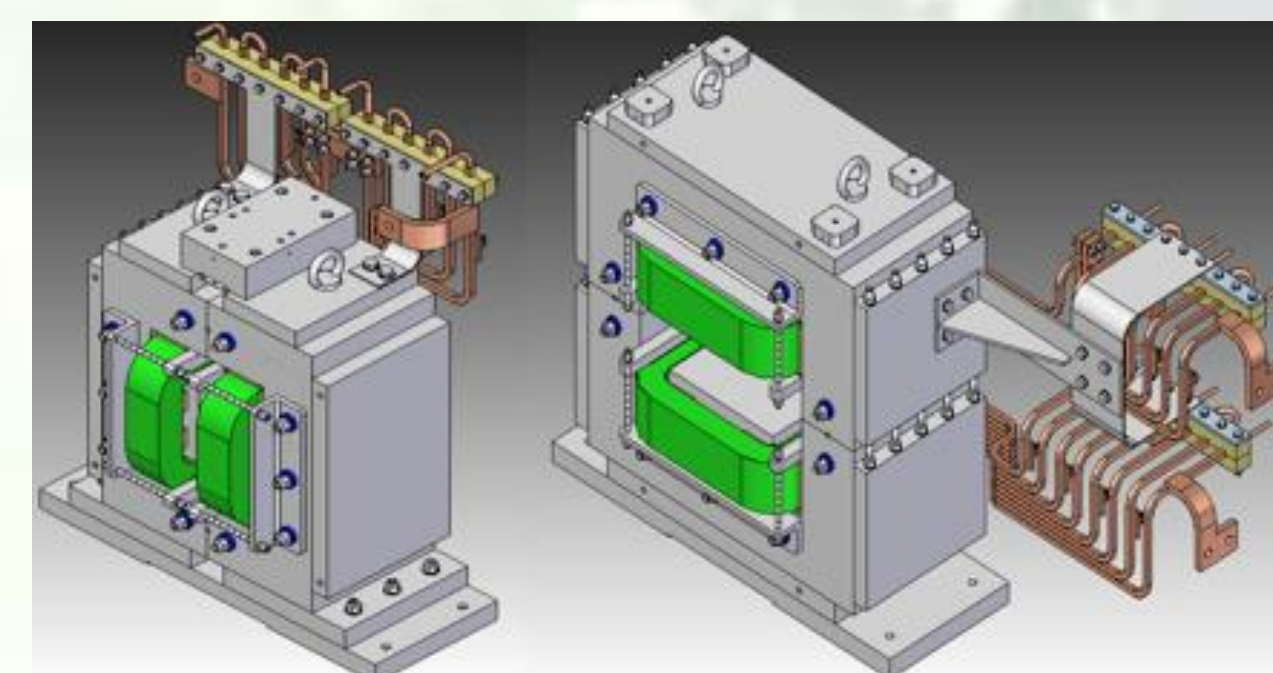
## Design

### Required Design Parameters of Scanning Magnets

Parameter	Unit	SMU (U)	SMV (V)
Energy	MeV	235	
Scanning area	cm	40	30
Scan speed	mm/ms	20	5
Distance away from iso-center	m	2.87	2.42
Good field region	mm × mm	14 × 31	94 × 34
Field uniformity		$\pm 2 \times 10^{-3}$	$\pm 5 \times 10^{-3}$



3D simulation model



Mechanical models

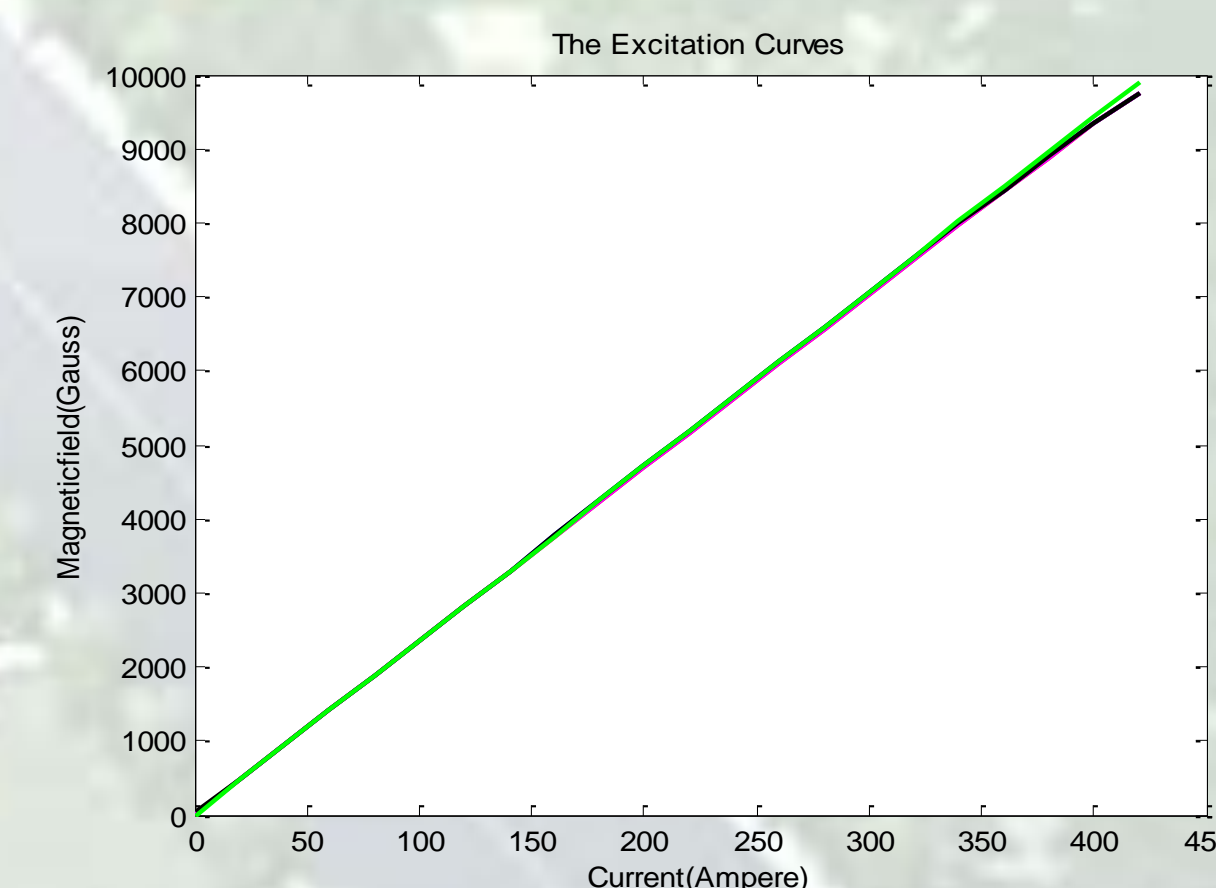
### Main Parameters of SMU

Mechanical length (m)	0.205	Current density (A/mm <sup>2</sup> )	10.25
Gap (mm)	30	Voltage (V)	172.0
Field strength (Gs)	0-7987	Power (kW)	1.302
Amper-turn per pole	10701.5	Num. of water circuit	2
Turns	24 (6 × 4)	Water pressure (kg/cm <sup>2</sup> )	2.75
Dimension of cond. (mm)	8 × 8 φr1	Speed of water (m/s)	2.0
Resistance (mΩ)	19.65	Volume of water (L/min.)	4.8
Inductance(mH)	3.84	Temperature rise (° C)	4.0
Current (A)	445.90	Weight (kg)	213

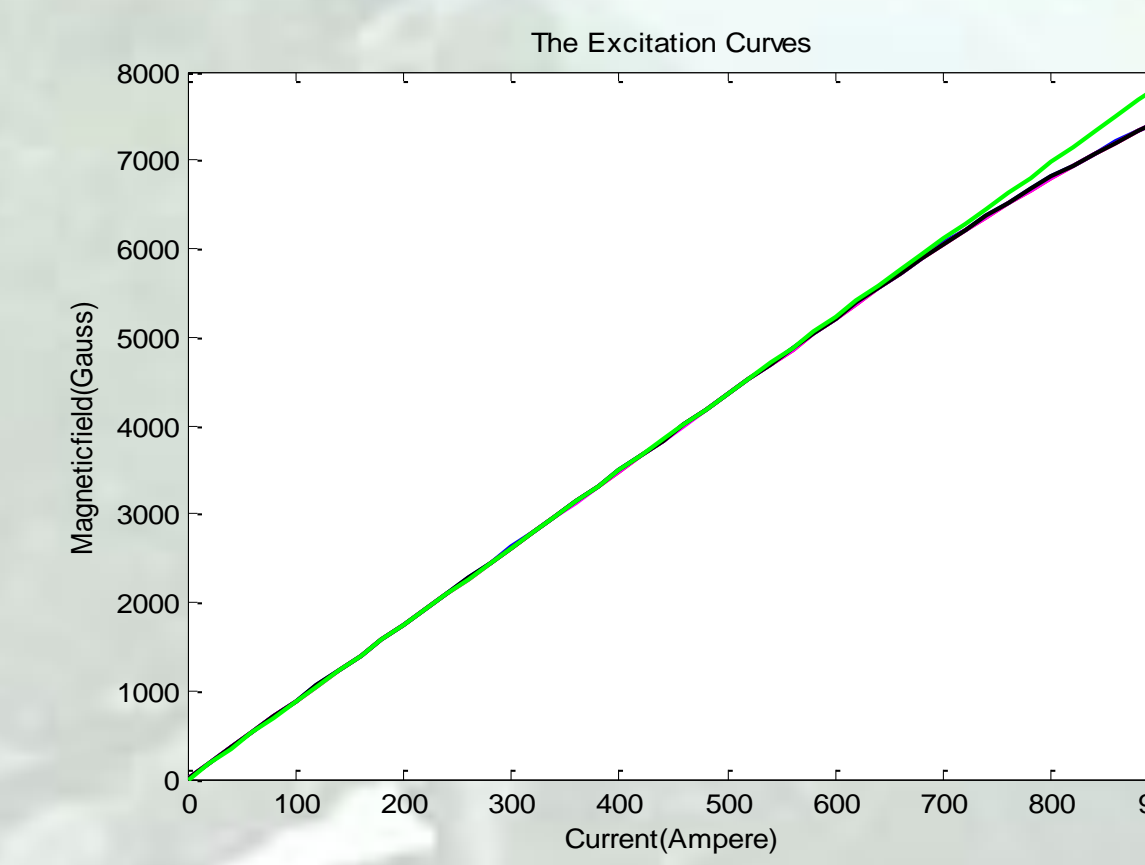
### Main Parameters of SMV

Mechanical length (m)	0.23	Current density (A/mm <sup>2</sup> )	20.13
Gap (mm)	109	Voltage (V)	154.3
Field strength (Gs)	0-6332	Power (kW)	9.503
Amper-turn per pole	28022.75	Num. of water circuit	4
Turns	32 (4 × 8)	Water pressure (kg/cm <sup>2</sup> )	2.75
Dimension of cond. (mm)	8 × 8 φr1	Speed of water (m/s)	3.4
Resistance (mΩ)	32.20	Volume of water (L/min.)	10.7
Inductance(mH)	4.32	Temperature rise (° C)	12.6
Current (A)	875.71	Weight (kg)	382

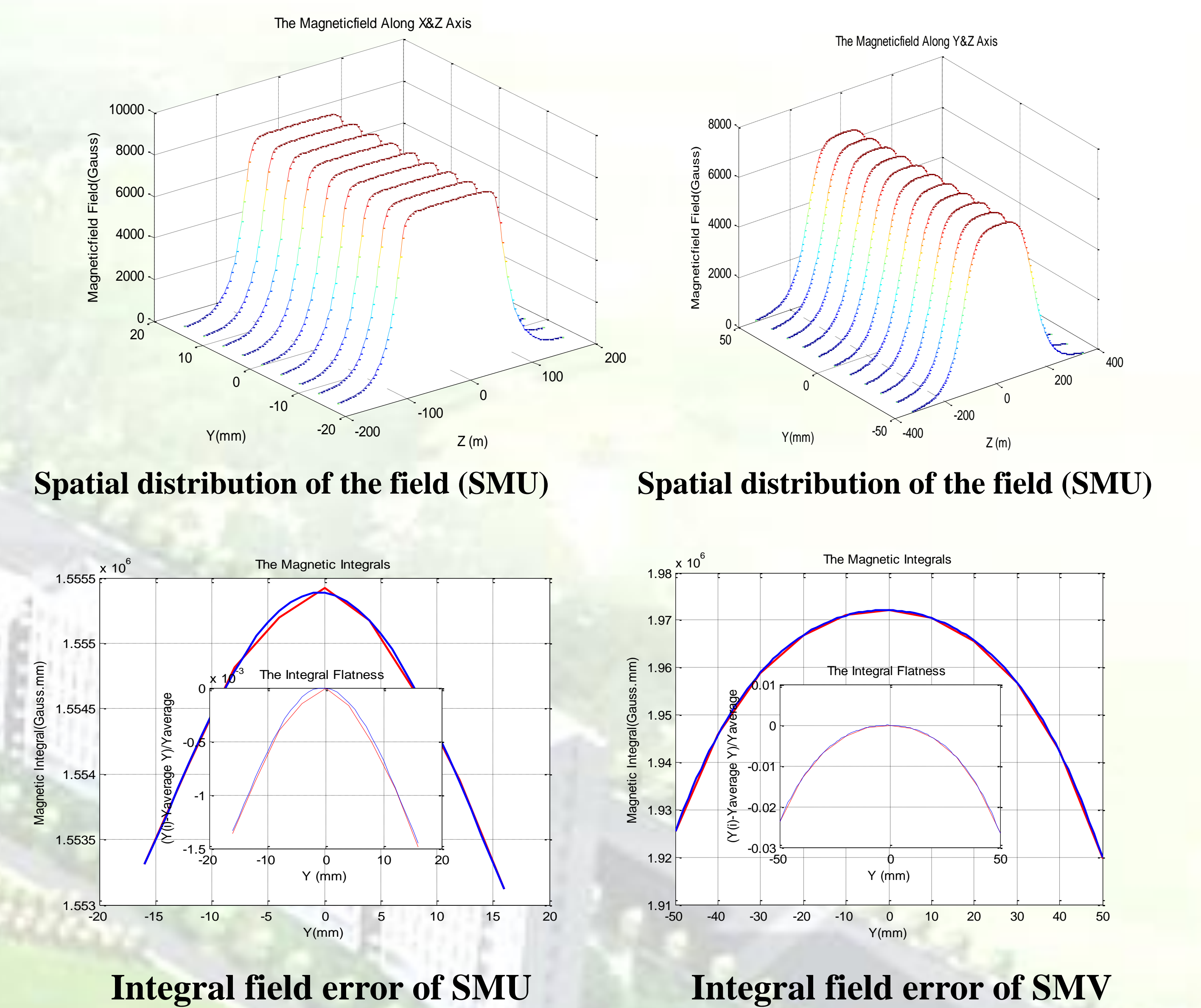
## Static measurement results



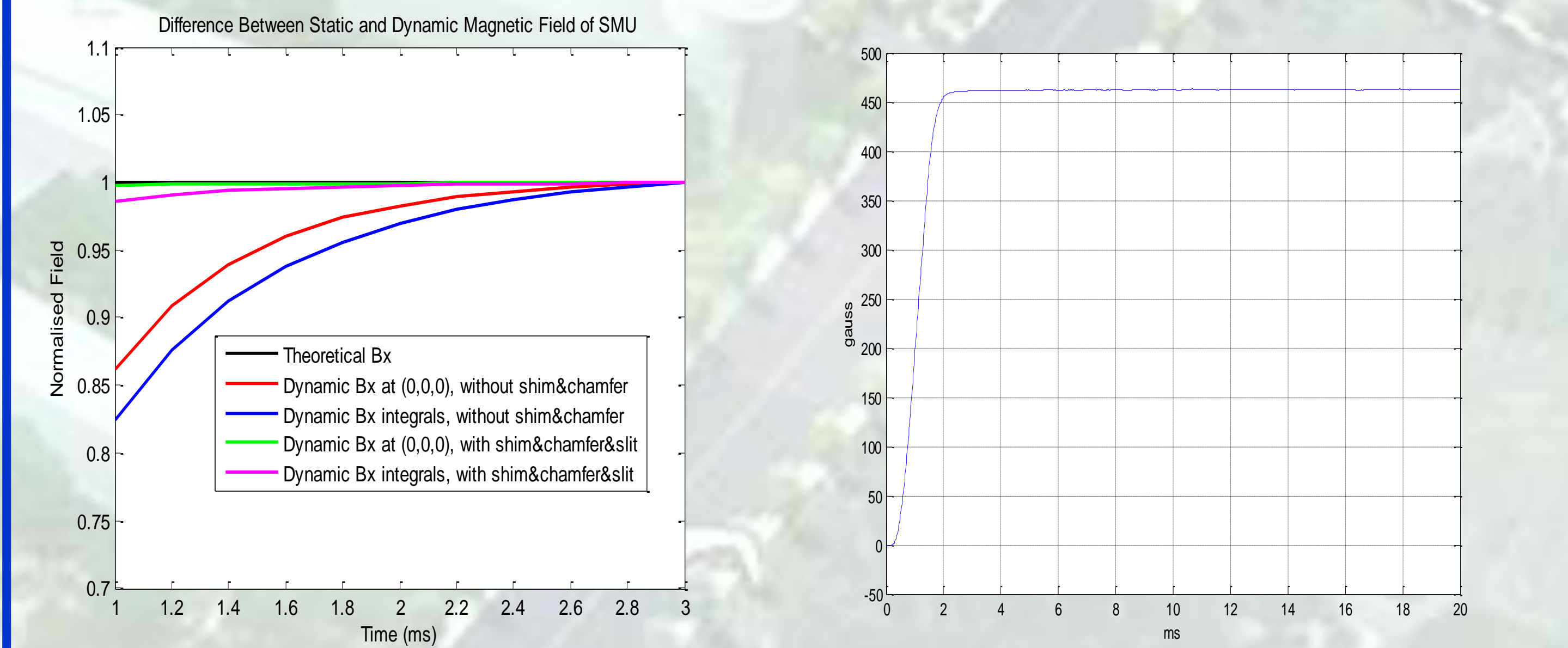
Excitation curve for SMU



Excitation curve for SMV



## Dynamic measurement results



Simulation result of the field delay (SMU) Measurement result of the field delay (SMU)