Grenoble High Magnetic Field Laboratory

Laboratoire des Champs Magnétiques Intenses

Hochfeld Magnetlabor

MAGNET FIELD MAPPING AND CALIBRATION SYSTEM AT GHMFL

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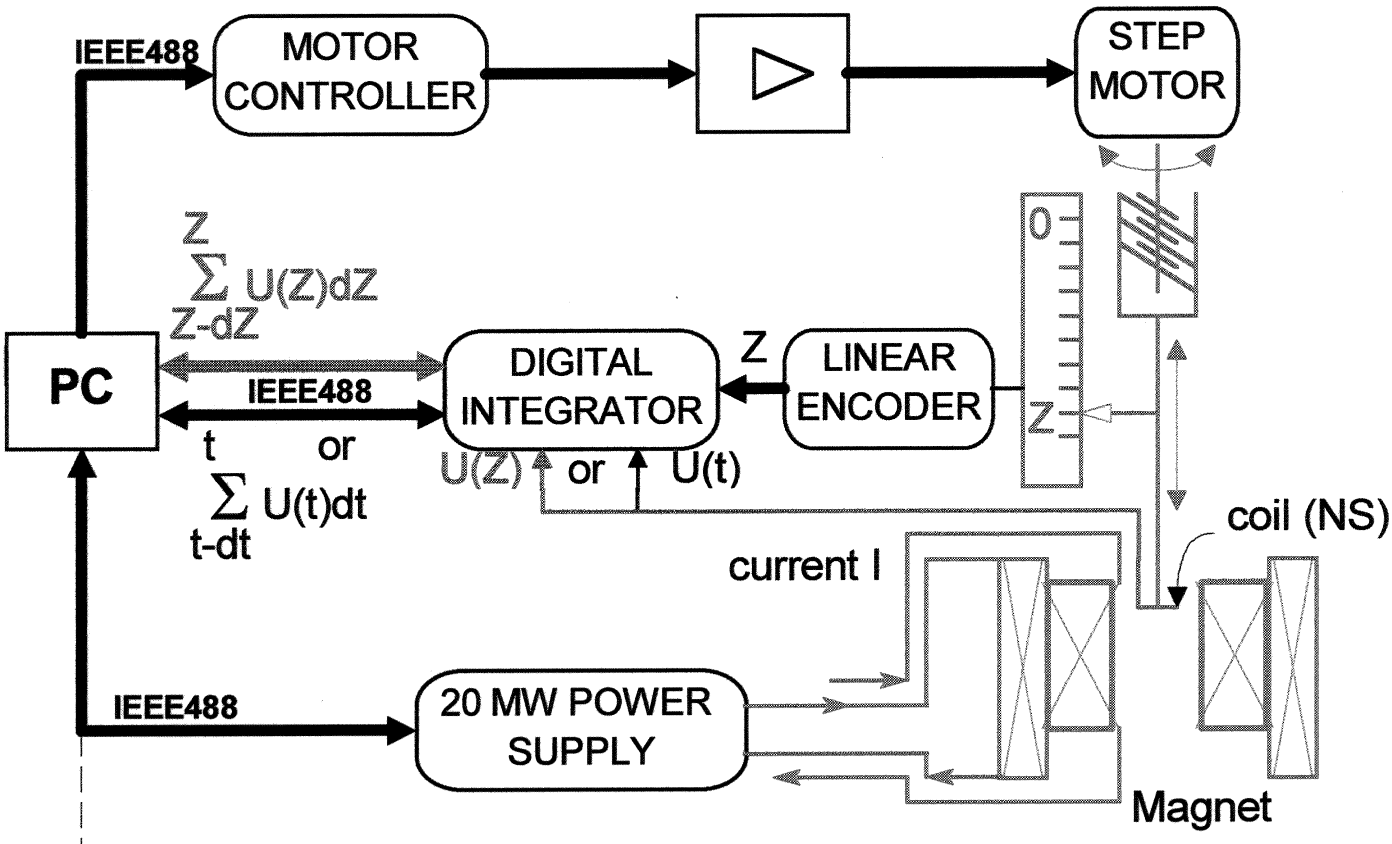
I. System currently in use

II. New prototype design

System diagram and features

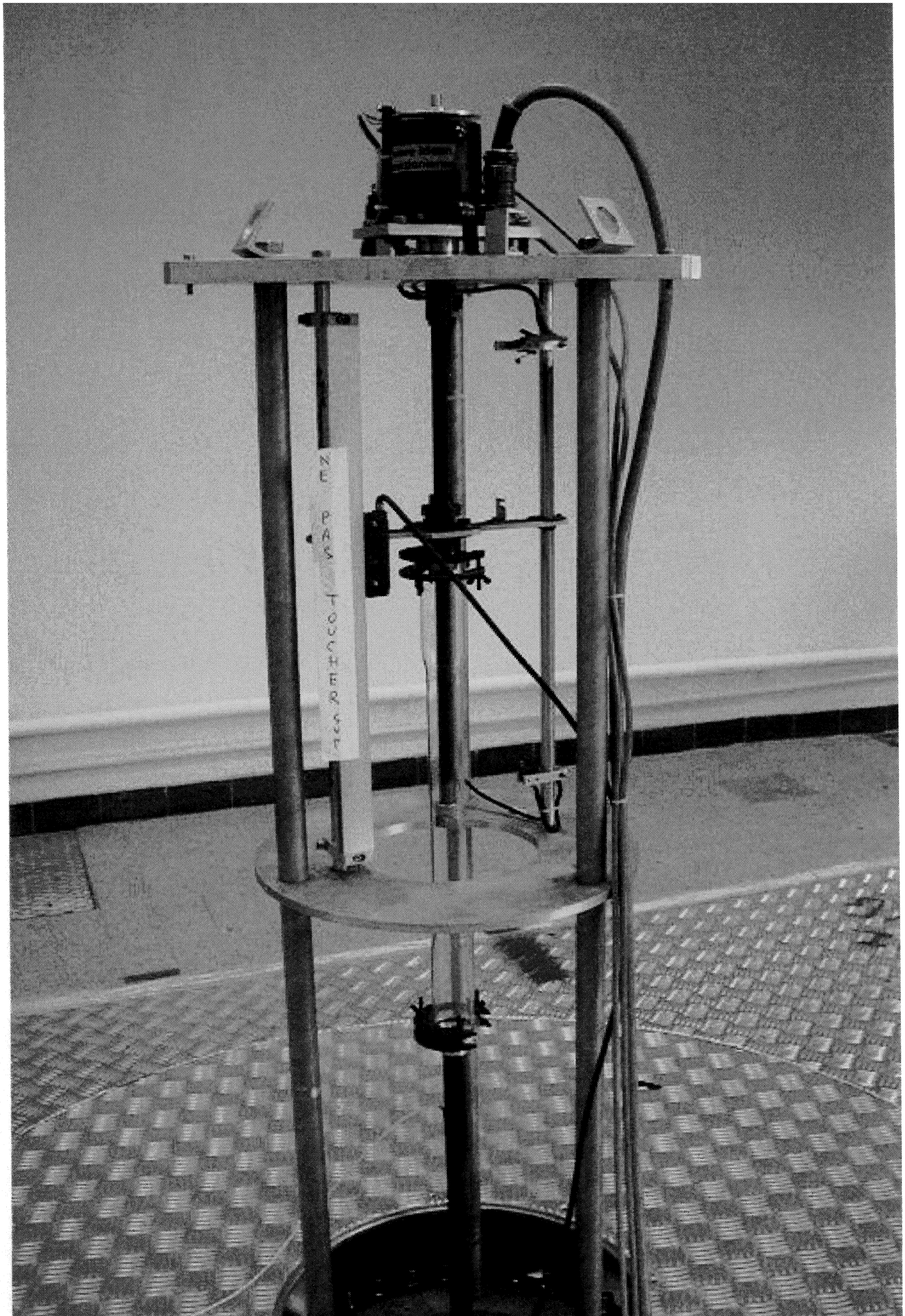


Space integration (constant I, variable Z) → $\sum_{0}^{Z} U(Z)dZ = -NS(B(Z) - B(0))$

Time integration (variable I, constant Z) → $\sum_{0}^{t} U(t)dt = -NS(B(t) - B(0))$

- ★ Coil parameters :
  - . 600 turns
  - . NS = 1018 cm^2
  - . thickness = 1mm
- ★ Encoder resolution : 5 µm
- ★ Travel length : 390 mm
- ★ Speed : 4 mm/s

- ★ Use of low level C programming control and acquisition software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Main applications

Magnet Field mapping :

★Minimum space integration interval = encoder resolution (5 µm)
→ Practical value (limited mostly by magnet current noise) = 0.1 mm

★Magnet current drift effects minimized by coil motion speed involving fast acquisition (40 points/s)

★Apparatus drift effects (integrator offset) minimized by averaging up and down motion measurements

★All distances are referenced to the encoder index (zero)
⇒ Maps for different coaxial magnets enable magnetic centers alignment

★Mapping is linked to absolute field units by measuring field in center
→ This is done after center position determination by :
1- Moving the coil accurately in the center (encoder software feedback)
2- Determining magnet field factor (field over current ratio)

Coil motion and positioning:

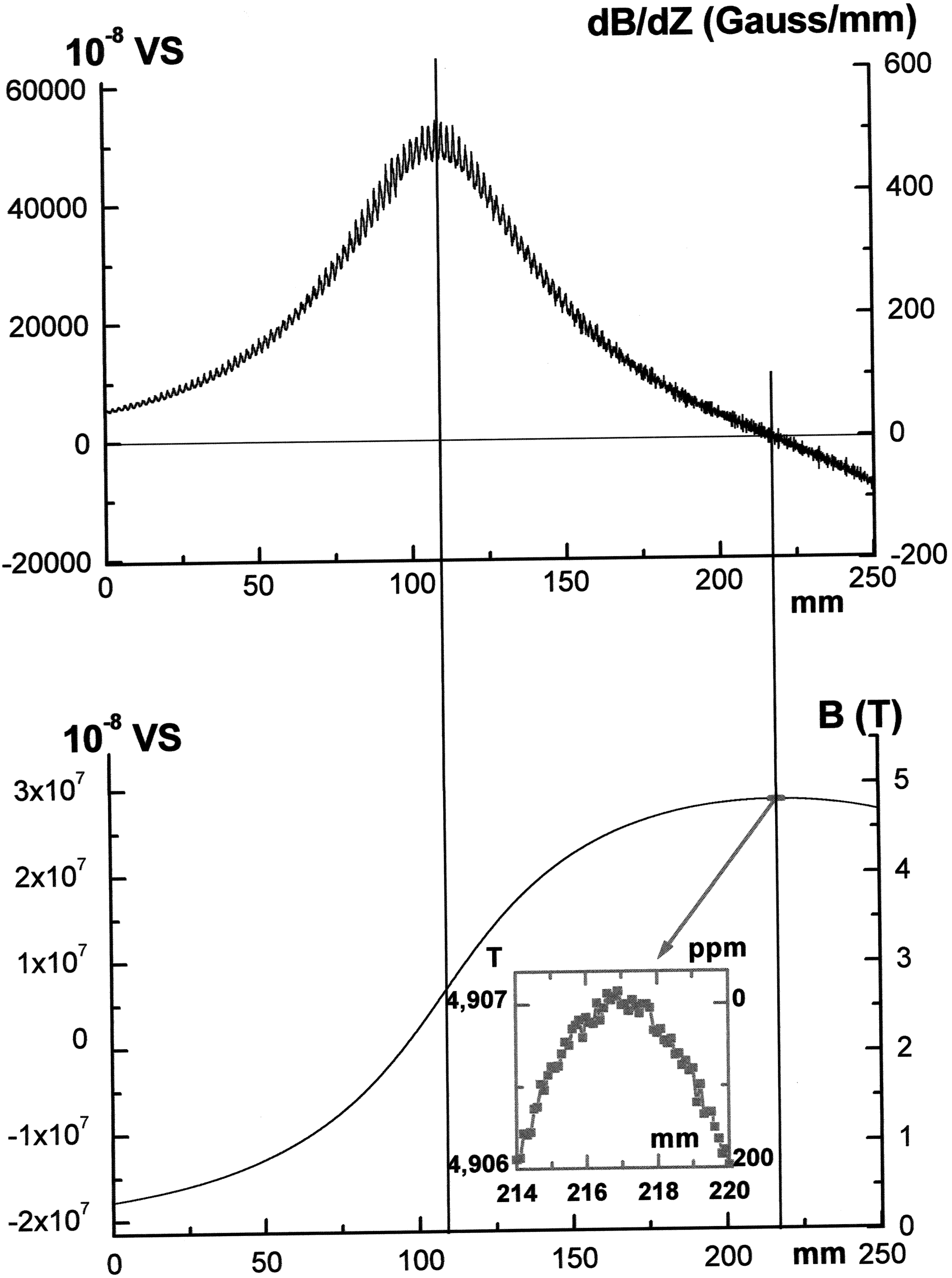
★Feedback and regulation done by software from encoder reading
→ Positionning at +/- 5 µm

Magnet Field factor measurement:

★Power supply trapezoidal modulation cycles
→ Maximum ramp slope dI/dt = 200 A/s

★Software modulation control and data treatment with :
→ Amplitude flat top levels averaging procedure to minimize power supply regulation "overshoots" effects
→ Averaging of up and down cycles to cancel drift effects

★Range of field factors of 10 MW resistive magnets ≈ 3 to 11 Gauss/A



Typical curves of Field gradient and Field maps (M9 polyhelix magnet, 5 KA current)

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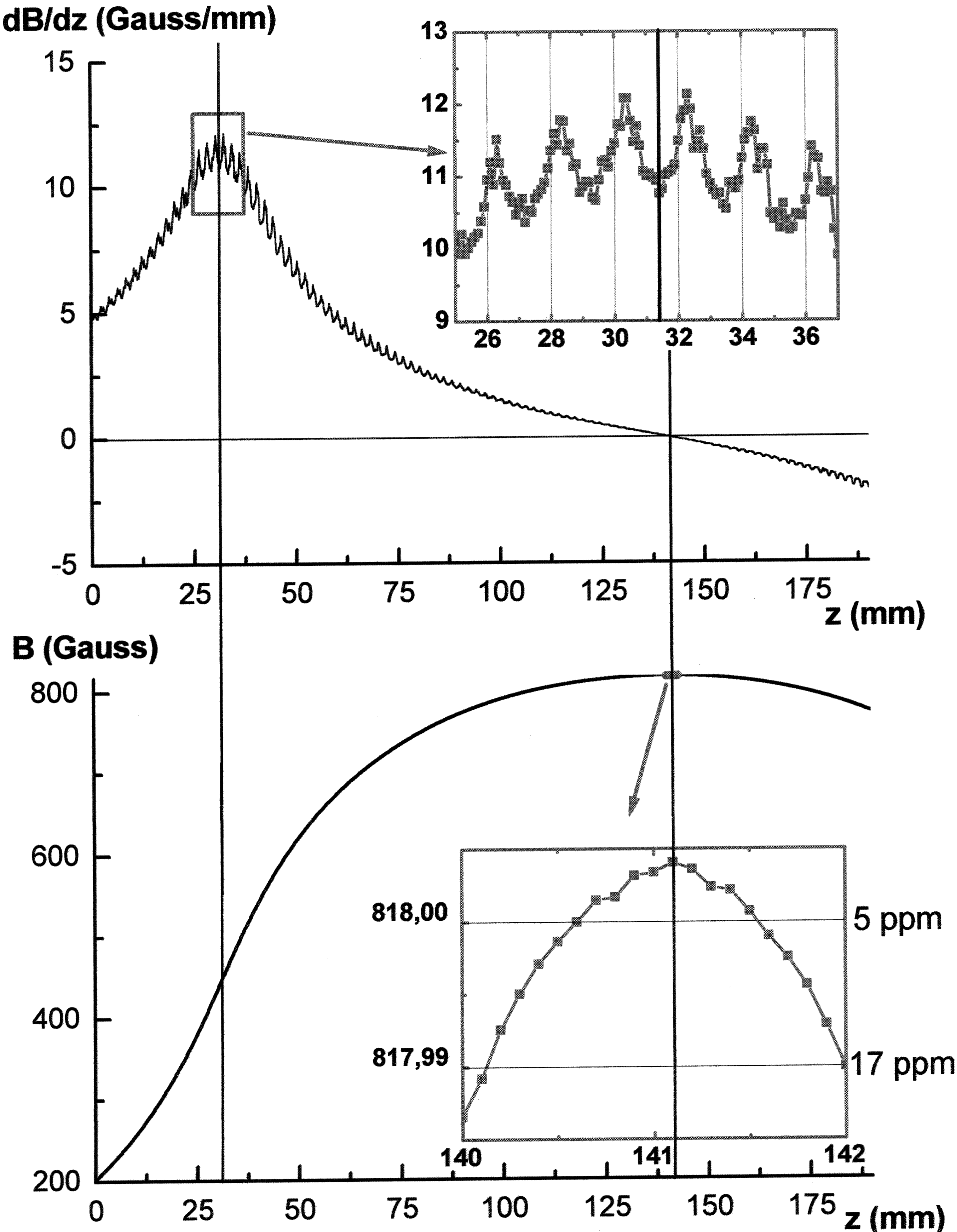

Field map of a magnet designed for 60 T (pulsed field)

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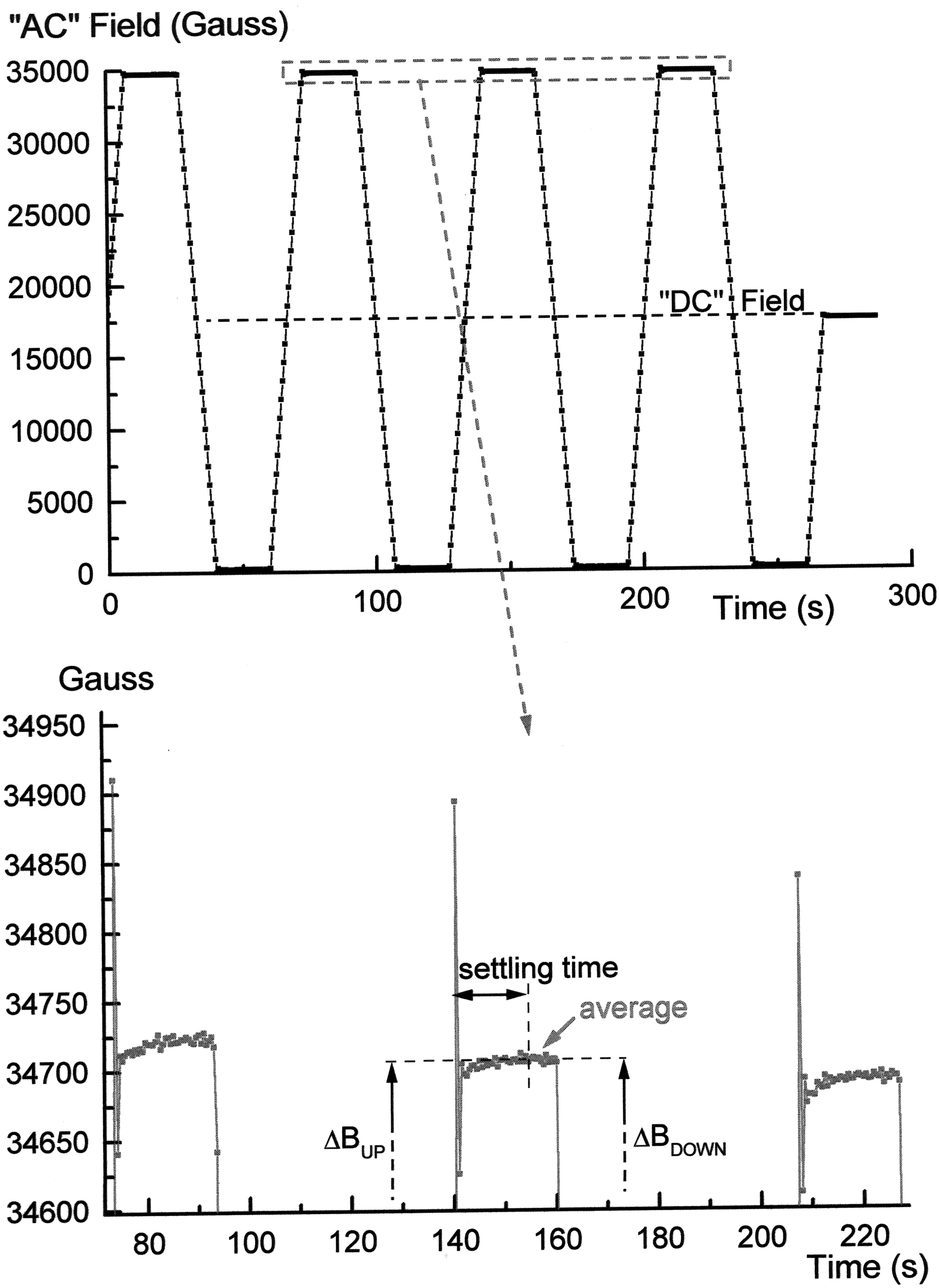
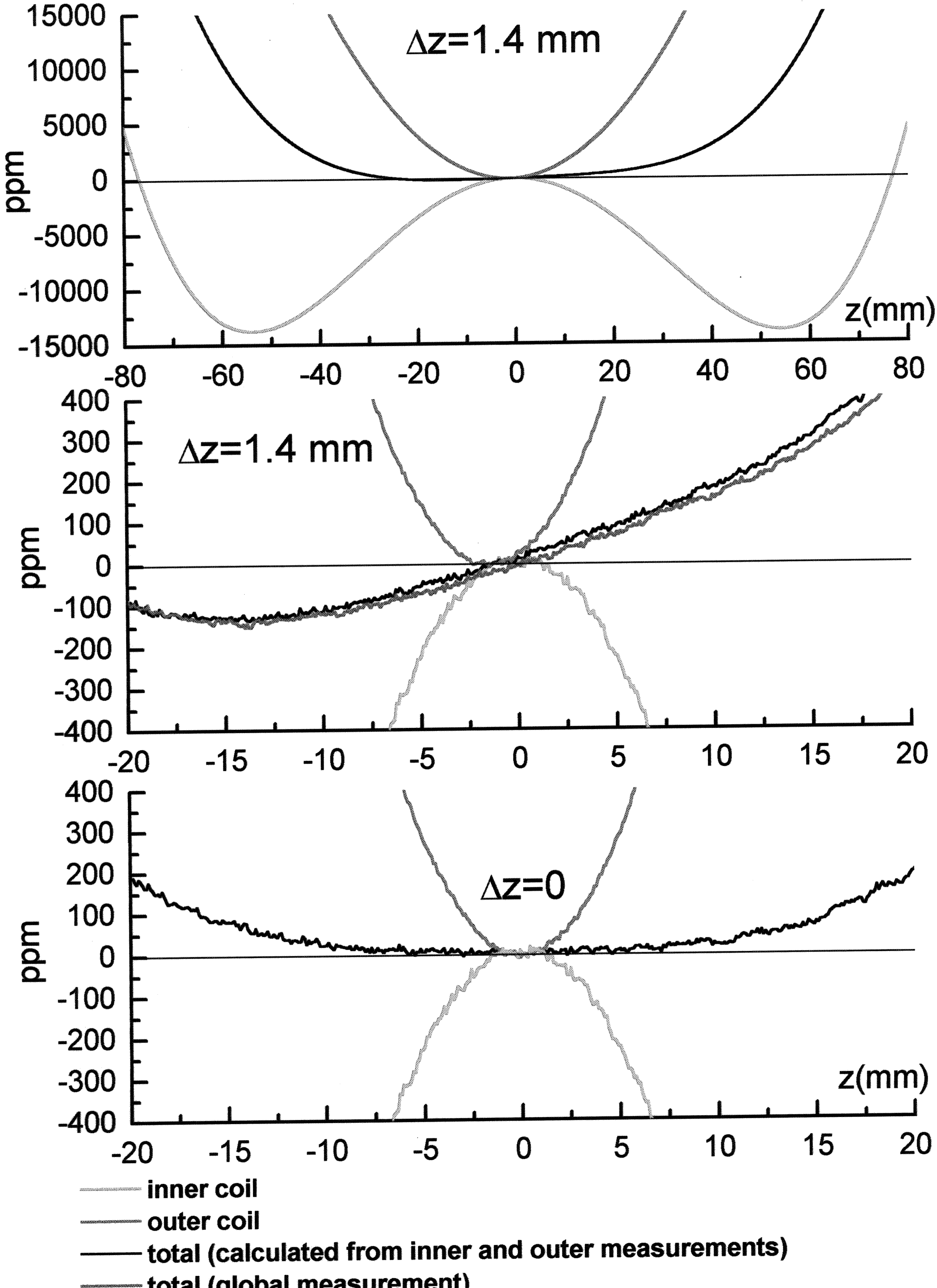
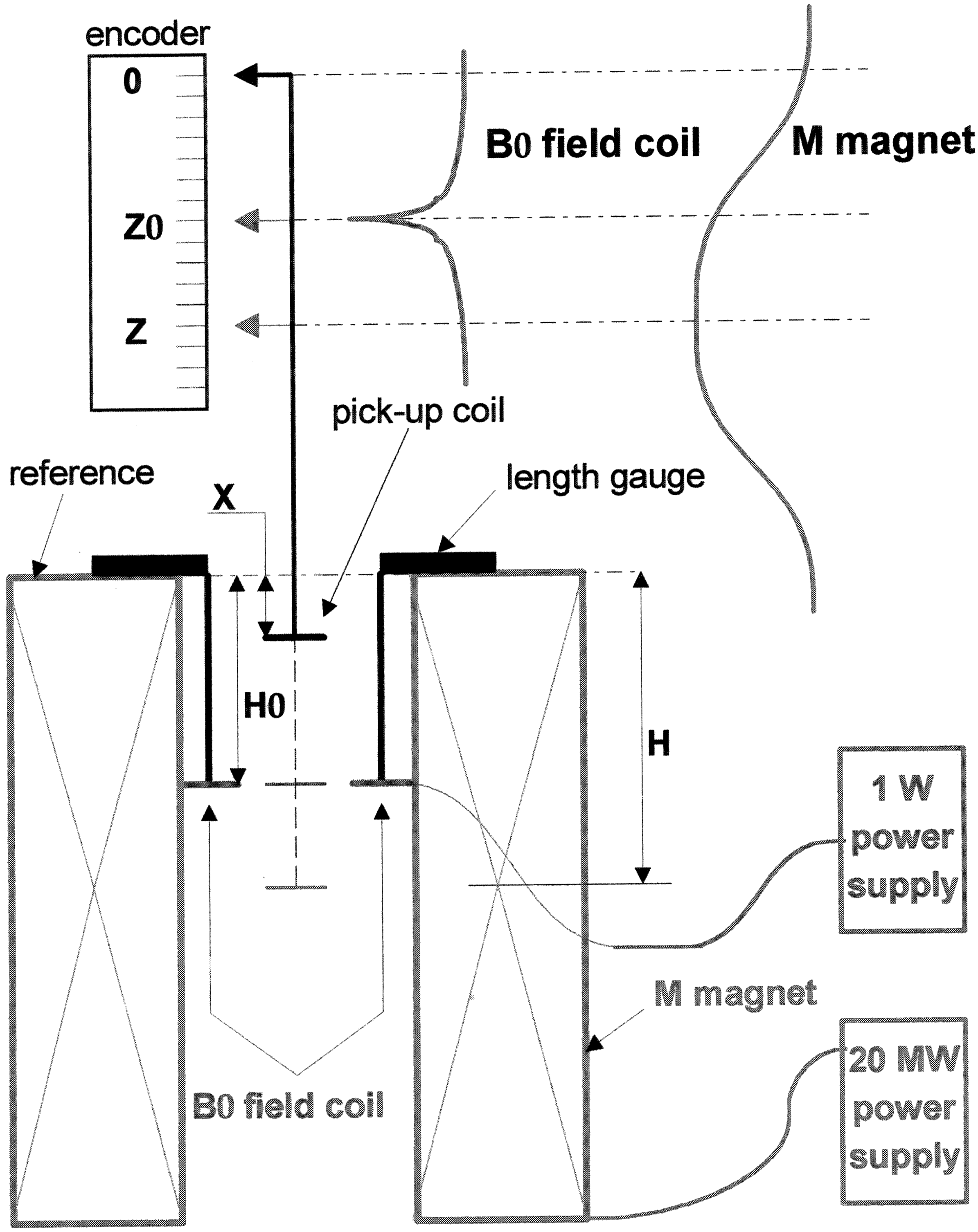


Field factor determination using modulation cycles (+/- 2 KA) on M6 magnet



Effects of a misalignment of inner and outer coils on a homogeneous magnet (M5)

METHOD FOR REFERENCING MAGNETIC CENTER POSITION



X : difficult to measure precisely (or variable)

H0 : precisely known (gauge)

1- B0 field alone (~ 10 Gauss) → Z0 → X = H0 - Z0

2- M magnet field alone → Z → H = Z + X = Z + H0 - Z0

New mechanical motion system prototype

Reasons for a new system:

★Spare parts for current system now hard to find

★Current mechanical structure is big and heavy
→Difficulties for transportation and mounting on different magnet sites

★Global measurement system has high performances but now limited by mechanical system

New design orientations:

★Non magnetic lightweight and compact structure but with high stiffness and dimensional stability

★Easy and direct mounting on different magnet sites in the lab

★High speed motion over the entire travel length **(>300 mm)**

★Alternative application as a "simple" high resolution positionning system for other types of probes (NMR,...)

★No rotation/translation conversion wanted (linear motor)

⇒ **Design of a prototype using a piezoelectric linear motor**

Prototype main features

Main general features of piezoelectric motors :

★High resolution positionning

★No magnetic field sensitivity / generation

★Wide dynamic range of velocity

★Inherent brake at power off (preload)

Linear piezoelectric motor main additional features :

★No magnetic parts

★Theoretical resolution : 5 nm

★Theoretical maximum speed : 230 mm/s

Practical limitations :

★No "off-the shelf " mechanical solutions commercially available

★Mechanical linear guiding system must be designed for application

★Real performances depend highly on mechanical design and control

★Most applications limited to low travel and loads (micropositionning)

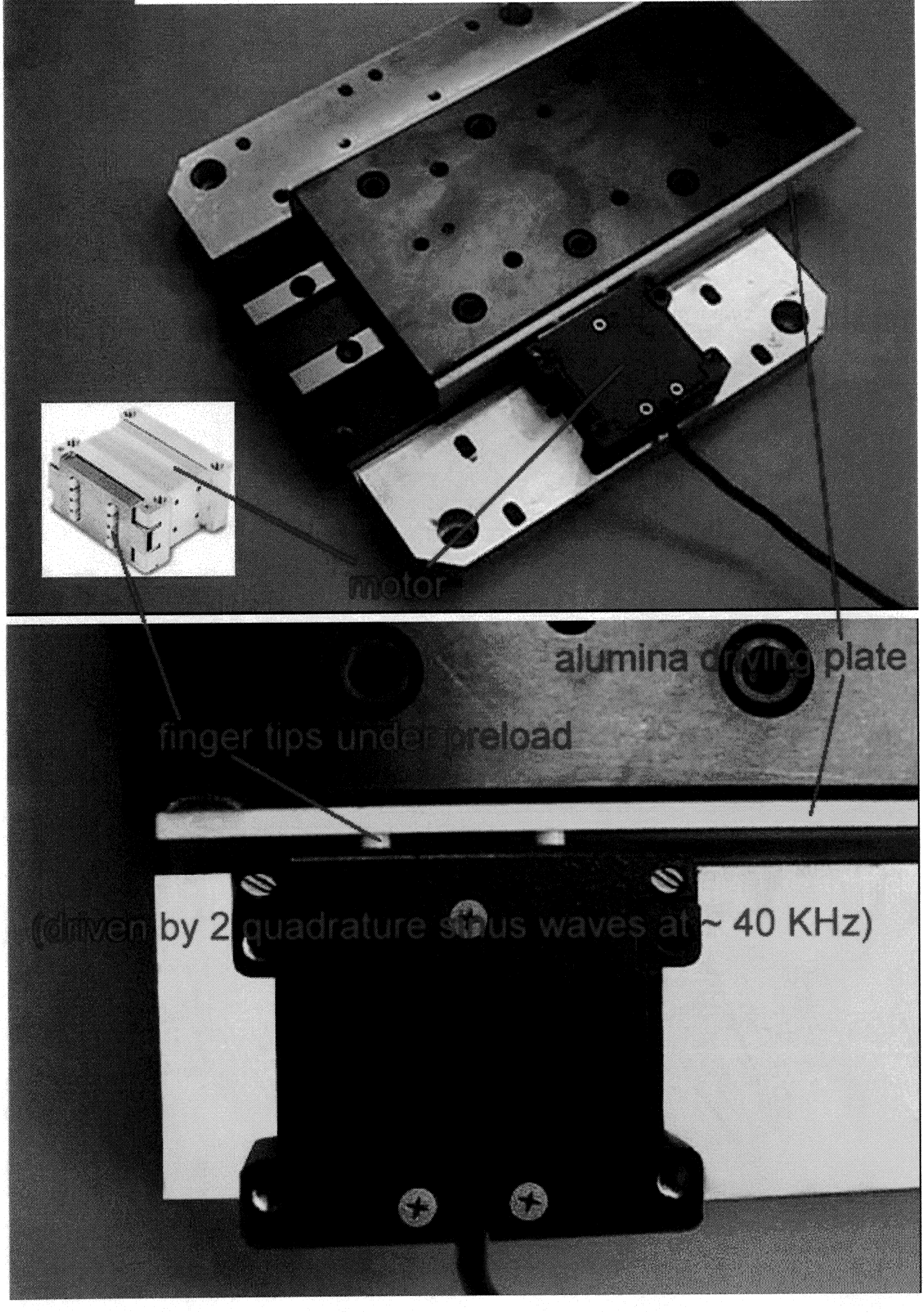
Particular problems for prototype design :

★Vertical motion (strong influence of weight of all moving parts)

★No magnetic parts wanted for the complete system

★"Long" travel length

Linear stage motor mounting



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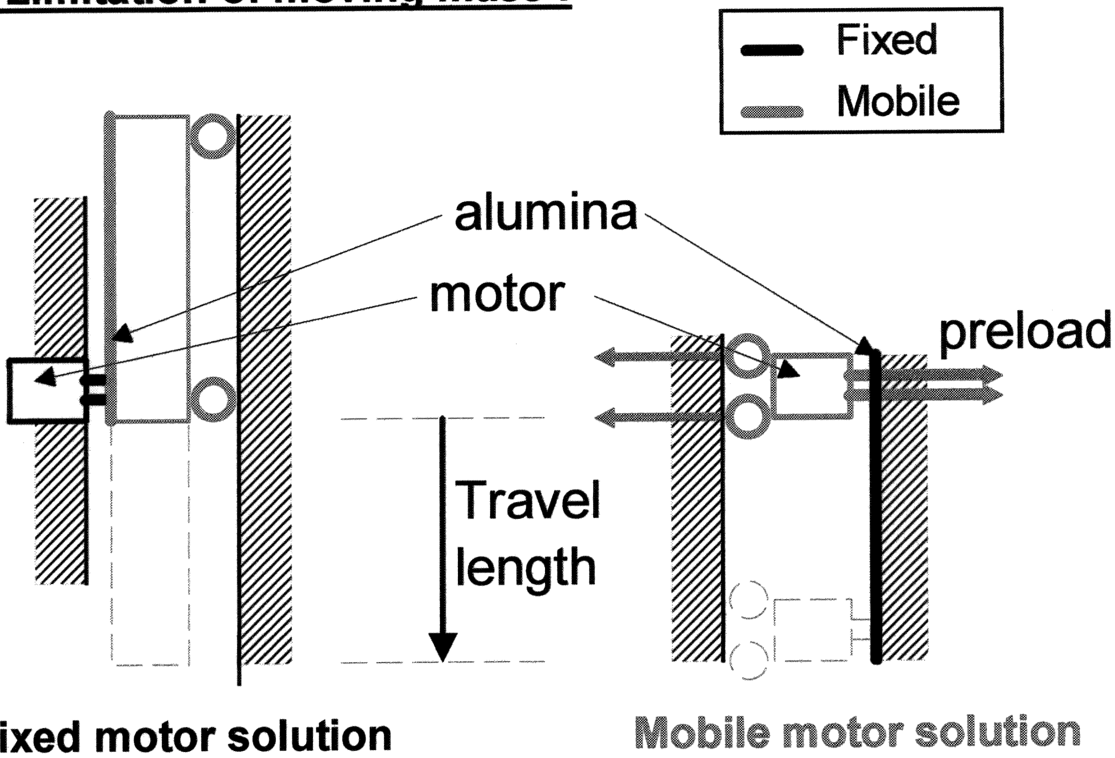
Mechanical design : Major problems and solutions

1-Limitation of moving mass :



2-Static friction (stick-slip) created by preload :

> 2 linear ceramic ball (micro)bearings on cuproberyllium V rail

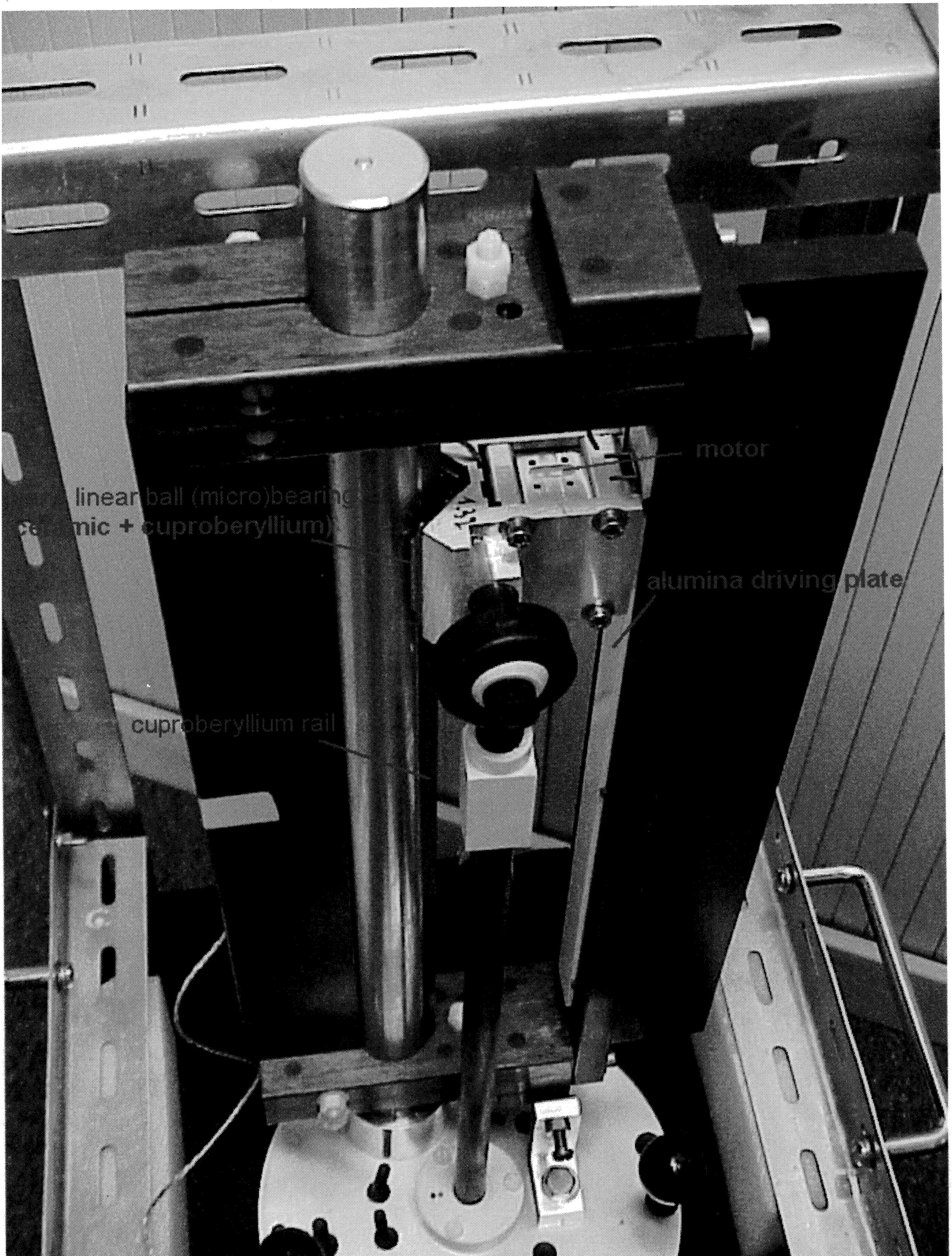
3-Stiffness and dimensional stability :

- Parallelism tolerances + flexion deformation < 10 μm/100 mm
- Thermal stability of distance measurement

> Use of machined carbon/epoxy profiles

Other prototype features and performances :

> Magnetic center position referencing tool integrated (active coil)
> Travel length : 326 mm
> Maximum "usefull" mass ~ 0.9 kg


motor
linear ball (micro)bearing
cuproberyllium)
alumina driving plate
cuproberyllium rail

FUTURE DEVELOPMENTS

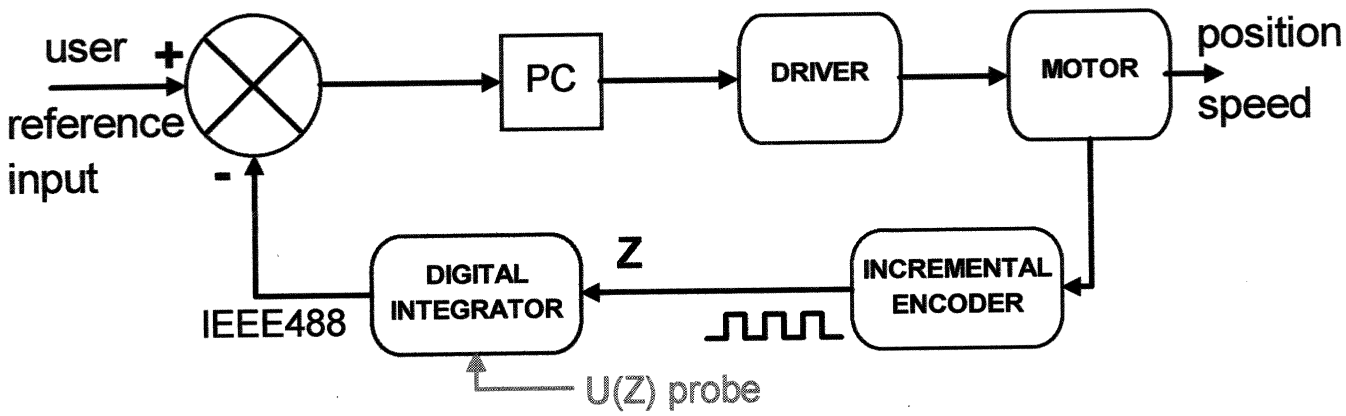
- **Main Feasability Study OK**
- **Performances depend now on closed loop feed back**

1-Distance measurement :

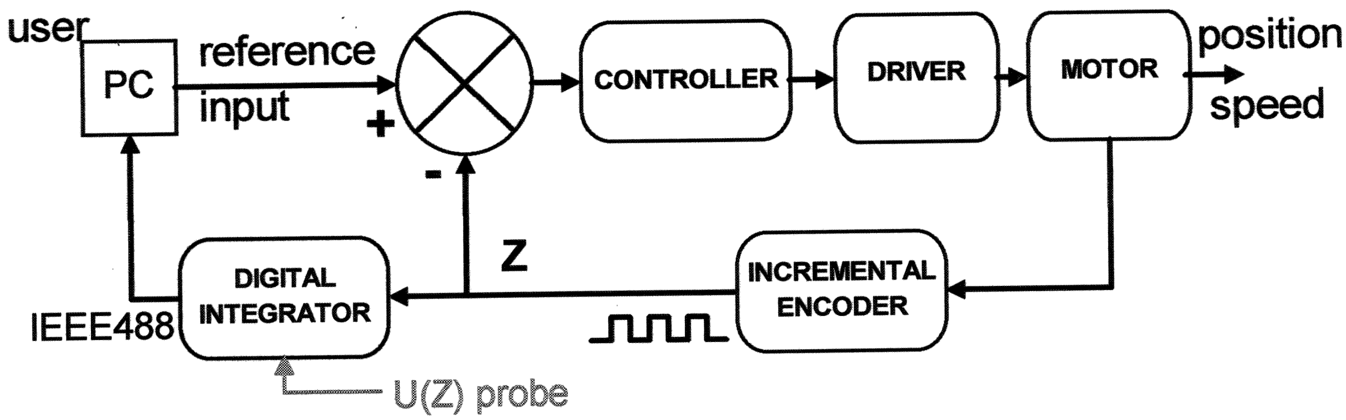
Use of a non contact optical linear encoder with no magnetic parts

2-Control : 2 types of solutions :

A : "Soft" regulation



B : Regulation with controller chip (digital PID microcontroller)



B gives a higher loop frequency (better response time and resolution)

3-Software :

Modification of existing software for position and speed control