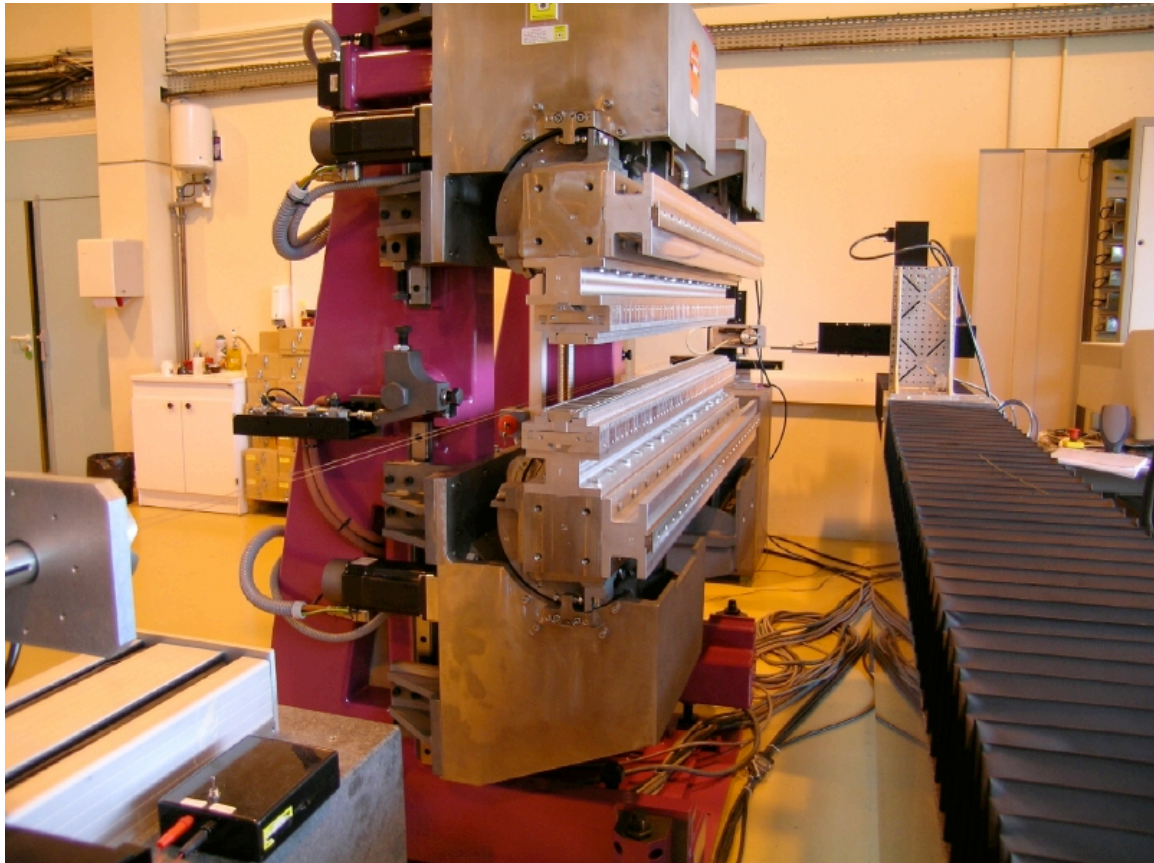


ESRF INSERTION DEVICE FIELD MEASUREMENT BENCHES

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1- INTRODUCTION

The Insertion Device field measurement systems developed at the ESRF rely on a 18 years experience. More than 100 devices (undulators, wigglers, helical undulators, in-vacuum undulators) have been successfully processed with accurate and fast measuring systems. The performances of the measuring benches has been regularly upgraded with more performing components commercially available. In particular motion control and software implementation are areas requiring permanent survey in view of

gaining accuracy and simplification as well. The standard measuring system for Insertion Devices includes a local field bench based on hall effect sensors and a field integral bench using a flip coil or a stretched wire.

2- HALL PROBE BENCH

The hall probe bench is based on a granite support with a cross section of 350 x 600 mm² (width x height). Two different standard lengths are available : 4 m and 6 m, longer supports (up to 11 m) can be provided on demand. In all cases the effective measuring length corresponds to the length of the granite minus 0.5 m. The main granite beam is mounted on vertically adjustable feet, the positioning of supporting feet is tuned for the limitation of the pitch angle resulting from the vertical natural deflection of the granite due to the gravity. The upper granite surface is accurately machined with a resulting flatness lower than 15 μm (for 4 m and 6 m versions). The upper surface of the granite beam is equipped with high precision guide rails assembled with a parallelism of $5 \mu\text{m} \pm 2 \mu\text{m}$. The magnetic assembly of a linear motor is also directly mounted on the granite. The type of linear motor has been selected to ensure negligible magnetic perturbations during field measurement. The linear motor is controlled in closed loop using an optical ruler. The main carriage mounted on the guide rails include two transverse stages (x,z) with a travel range of 250 mm. The hall probe sensor has been developed specifically for Insertion Device measurements. The figure 1 shows a hall probe bench under laser calibration.

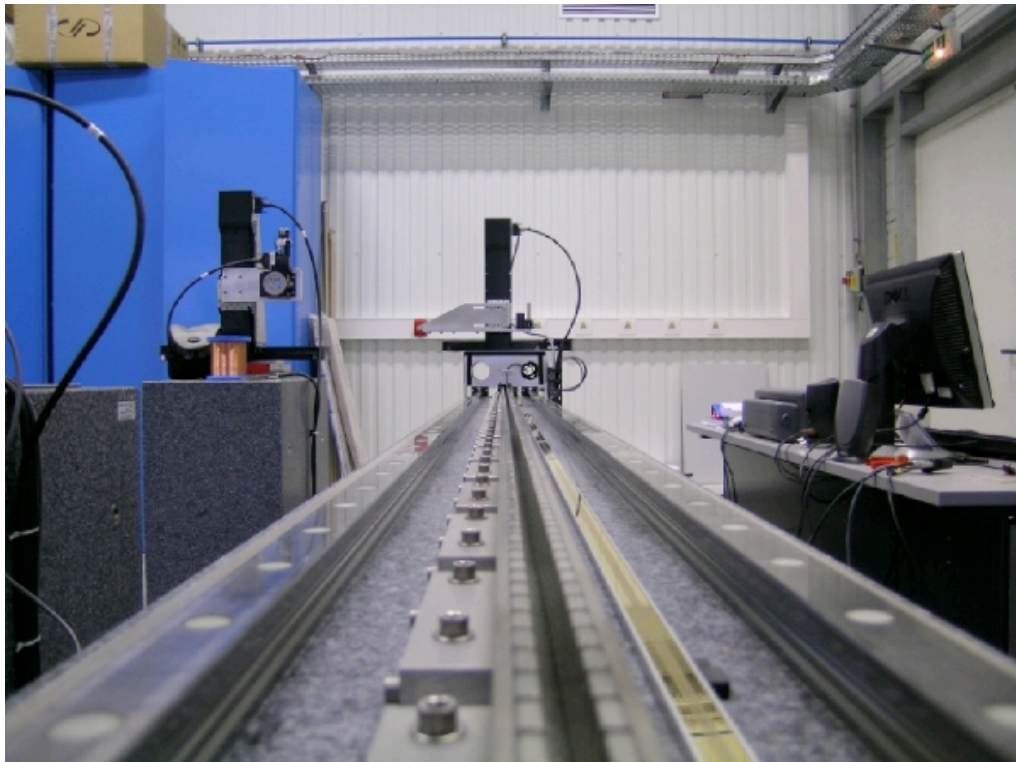


Figure 1: Hall probe bench under laser calibration (5.5 m long)

The local magnetic measurements are performed at constant speed “on the fly” with a programmable spatial triggering. A typical measuring speed is 50 mm/s, speed as high as 100 mm/s can be used. The trigger signal is provided by the electronic of the linear motor. It is connected to three voltmeters (one per field component) storing the hall voltages in their internal buffers at the triggering frequency. The hall probe is mounted on an aluminium arm with a typical length of 0.5 m.

Specification for the hall probe bench

Granite block and associated supporting parts:

- 350 mm (X), 600 mm(z), 4000 mm or 6000 mm (s)
- granite supporting feet including tuning wedges
- nominal height of the Hall probe at zero position (reference) 1200 to 1400 mm
- reference surface flatness $\leq 15 \mu\text{m}$
- weight of granite block : 2260 kg (3390 kg) for L=4 m (6 m)

Motions:

Longitudinal:

- Effective travel range: 3500 mm (5500 mm)
- Encoder resolution 0.1 μm
- Programmable spatial trigger
- Pitch, yaw and roll angles $\pm 10 \mu\text{rad}$
- Absolute accuracy at the hall sensor position (0.6 m horizontal & 0.5 m vertical from granite surface axis) $< 1 \mu\text{m}$ at 20 deg. C after software correction based on laser calibration

Transverse x and z stages:

- Travel range : 250 mm
- Encoder resolution 0.5 μm
- Absolute accuracy: $\leq 5 \mu\text{m}$
- Pitch and yaw angles; $\pm 50 \mu\text{rad}$
- Perpendicularity error between x and z axis: 20 μm max.

Hall probe:

- 3 hall sensors mounted on a printed circuit
- Output sensitivity: 1 T/V fully calibrated with NMR reference magnet
- Residual non linearity after correction: $< 0.05 \%$
- Calibrated range: $\pm 1.8 \text{ T}$
- Output noise @ 20 ms integration time: $\leq 0.06 \text{ G}$.
- Input current: 5 mA

3- FIELD INTEGRAL BENCH

The field integral bench can be based on a flip coil or a stretched wire. The geometrical layout for both types is the same. The bench consists in two motorized parts placed at either side of the insertion device to characterize. The figure 2 shows the typical assembly for one side. It includes three motorized stages x, z and Theta (flip coil) mounted on a granite support. The standard travel range in x and z is 250 mm. All axes are based on DC motorization operated in closed loop with linear or rotary encoders. In addition to the usual point by point measurements, an important feature in this field integral bench is the capacity to perform “on the fly” measurements. A typical measurement over 100 mm with 41 points takes 45 s with a reproducibility lower than 10 G.cm (20 turns coil). The bench has also the capacity to measure second field integral components. In the case of the stretched wire, the measurement of the two components of the field integral is performed point by point. Nevertheless, for the measurement of the vertical component alone, the “on the fly” method is available. The bench includes a coil/wire stretching mechanism based on a manual translation table.



Figure 2: View of a motorized assembly of a flip coil bench

Specification for the field integral bench

Granite supports:

- 400 mm (X), 900 mm(z), 650 mm (s)
- 3 granite supporting feet including tuning wedges
- reference surface flatness: 5 μm
- weight of each granite support: 630 kg

Transverse x and z stages:

- Travel range : 250 mm
- Encoder resolution 0.5 μm
- Absolute accuracy: $\leq 5 \mu\text{m}$
- Pitch and yaw angles; $\pm 50 \mu\text{rad}$
- Perpendicularity error between x and z axis: 20 μm max.

Rotary stage:

- Full 360 deg capacity
- Encoder resolution: 0.001 deg
- Absolute accuracy: $\leq 0.02 \text{ deg}$

4-ELECTRONIC PARTS AND CONTROL

The totality of the controllers, power supplies and voltmeters is integrated in a single cabinet (600 mm x 600 mm x 1000 mm). The figure 3 shows the typical layout of the control cabinet.

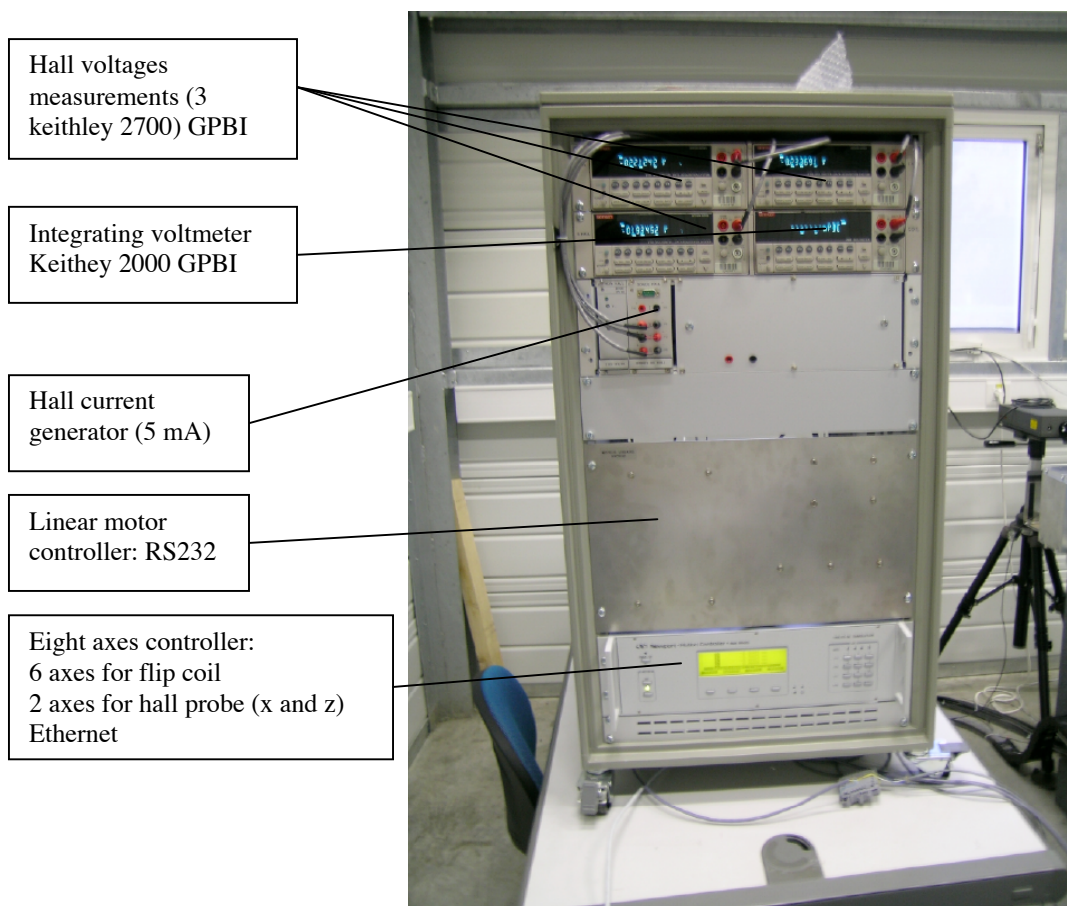


Figure 3 Layout of the electronic parts and controllers of the hall probe and flip coil bench

Software control and field processing

The complete control of the measuring benches is done on a PC under Igor PRO. The necessary functionalities have been implemented in C/C++ and interfaced to Igor. The control is highly customisable using the Igor programming language. The user interface is either menu driven or command line oriented. The control of the measuring benches do not require a specific type of PC, the simplified interfacing make use of standard communication protocols : serial RS232, GPIB and Ethernet.

The magnetic field measurements can be further processed using B2E also developed at ESRF under Igor Pro. The B2E Xop allows the computation of electron trajectory, X-ray spectrum, phase error, ..etc. The different functions available for the control of the benches are documented with on line help.