**TOM III SWZ**

**Order description**

The subject of the procurement procedure is the delivery to the Orderer of a magnetic measurement systems to be installed on the Orderer premises:

* Measuring system for undulators with a Hall probe and with a flip coil placed on granite benches

1. **Description of the Hall probe and flip coil system**

Typical configuration of the measurement system is illustrated in Figure 1. A high precision Hall probe and a flip coil is driven by a motorized positioning systems which is mounted on Diagram, engineering drawing

Description automatically generated

Figure 1. a) Granite benches for flip coil and Hall probe measurement systems, b) view of a typical Hall probe measuring bench, c) view of the a flip coil with respect to a Hall probe

granite blocks to assure required stability and accuracy (Figure 1 a). A typical standard flatness of the upper reference surface of the granite benches is better than 20 μm. There are precision guiding rails assembled with the standard parallelism of 5 μm ± 2 μm on the top surface of each bench.

The Hall Probe Bench is dedicated to the measurements of the magnetic field profiles along the insertion axis. The linear motor is responsible for the movement of the carriage along the beam direction (z), whereas two other stages are responsible for the horizontal (x) and vertical (y) displacement of the Hall probe holder with respect to the linear motor carriage (Figure 1 b)

The Hall probe holder consists of integrated sensors responsible for measuring of the magnetic field induction uniquely in the respective x (transverse), and y (vertical) directions. It is mounted on an arm. The total length of this assembly is about 0.5 m. The measurements of the magnetic field profile along the bench are executed on the fly with the typical measurement speed of 25 mm/s. Hall probe sensors should exhibit ultra-low noise, have a compensation for the planar hall effect and excellent low signal drift. This should enable a good measurement of magnetic field profiles of the insertion devices as well should enable to extract the first and second field integrals from field profiles with a good accuracy. The extracted field integrals can be compared with the values extracted from flip coil measurements and used for crosscalibration purposes.

The ﬂip coil technique is used to directly measure the first and the second field integral. The first field integral corresponds to the net angular deviation and the second field integral the net displacement of the electron beam referred to the center of the device.

In the ﬂip coil technique a long coil is rotated within the magnet by 180° during the measurement, and the induced voltage V is recorded. A typical coil consist of several tens of turns of wire. The ﬂux change Δφ during the measurement is equal to twice the ﬂux φ0 linked with the coil in the initial angular position. If the loop of the coil forms two parallel wires with a small distance of W along the magnet’s length, φ0 = WI1, where I1 is the ﬁrst ﬁeld integral of the ﬁeld component. If the coil’s width is set to zero at one of the ends φ0 = WI2/L, where L is the coil’s length and I2 is the second ﬁeld integral. Therefore, by integrating the induced voltage during the coil’s flip one can straightforwardly determine the first or the second filed integral when the dimensions of the coil are known.

The flip coil is stretched between two units, mounted on granite supports each consisting of translation and rotary stages as indicated in Figure 1 c. Translation stages are responsible for the horizontal and vertical positioning of the coil. The rotary stages, mounted on the translation stages assembly are used to flip the coil.

1. **System requirements**
2. **Overall requirements:**

Delivered system should be brand new, operational and integrated with control and data acquisition systems.

After delivery of the system, the vendor will commission the system at Orderer site and train the Orderer personnel. The duration of the commissioning and the training will be together at least two weeks (10 working days).

The measuring systems should come with at least 12 months guarantee from the date of reception, for any of construction defects.

1. **Parameters of measured magnetic devices**

The measuring benches will be used to characterize undulators and additionally accelerator dipole magnets. The undulators are not longer than 2 m and its minimal gap width is 8.5 mm. The accelerator magnets are not longer than 1 m. The minimal gap in the dipole magnets is 20 mm.

1. **Control and the data acquisition systems**

The measuring systems should come equipped with a PC and a dedicated GUI program which enables a very straightforward operation of the bench. The program enables the operator to move the motorized axes, monitor the bench status and run measurement procedures that are prepared by the operator. The bench should come with a set of standard measurement procedures that can be used out of the box and can be also elaborated by the operator to perform more complex measurements tasks. The measurement can be conveniently presented on a graph inside the PC program. The measurement data can be also exported to text files to be further analyzed in a data analysis software of choice.

1. **Alignment**

The measuring benches should be equipped with fiducial systems that can be used to align the axes of the measuring benches with respect to magnets reference system with sufficient accuracy. The tolerances are not worse than 50 microns regarding alignment with respect to magnet axes positions and 0.1 milliradians with respect to magnet axis orientations.

1. **Accuracy of determining main magnet parameters:**
   1. Undulators:
      * Magnetic field measurement accuracy inside undulators: < 2 mT
      * Spatial resolution: ≤ 0.1 mm in all directions
      * First field integral accuracy: ≤ 1 \*10⁻5 Tm
      * First field integral sensitivity: ≤ 2.5\*10⁻⁶ Tm
      * Second field integral accuracy: ≤ 2\*10⁻5 Tm2
      * Second field integral sensitivity: ≤ 4\*10⁻⁶ Tm2
2. **Requirements for Hall probe measuring bench**
   1. Mechanical system
      * Range of horizontal movement along longitudinal axis: ≥ 2500 mm
      * Range of horizontal movement perpendicular to longitudinal axis: ≥ 300 mm
      * Range of vertical movement perpendicular to longitudinal axis: ≥ 300 mm
      * Repeatability: not worse than ± 3 μm for each axis
      * Movement parallelism: not worse than ± 20 μm
   2. 3 - axis (Bx,By,Bz)\_Hall probe sensor
      * Angular accuracy: orthogonality error < 0.1°)
      * Maximum magnetic flux density: not less than ±2 T, no saturation of the outputs
      * Linear range of magnetic flux density: not less than ±2 T, fully calibrated measurement range
      * Total measuring Accuracy: ≤ 0.1%
      * Sensitivity to DC magnetic field: not worse than 5 V/T, differential output
      * Tolerance of Sensitivity: ≤ 0.02%
      * Nonlinearity: ≤ 0.05%
      * Planar Hall voltage: < 0.01 % of V normal
      * Temperature Coefficient of Sensitivity: < ±50ppm/°C @ temperature range 23°C ± 5°C
      * Long-term instability of sensitivity: < 1% over 10 years
      * Offset (@ B = 0T) : < ±2 mT @ temperature range 23°C ± 5°C
      * Temperature Coefficient of the Offset: < ±4 µT/°C
      * Offset fluctuation & drift within 0.01-10 Hz: < 3 µT Peak-to-peak values
      * Output noise:
        1. Noise Spectral Density @ f = 1 Hz: < 0.12µT/ Hz
        2. Noise Spectral Density @ f > 10 Hz: < 0.1 µT/ Hz
        3. Broad-band Noise: < 3 µT RMS noise
        4. Frequency Bandwidth: 500 Hz
      * The sensor should have Integrated temperature sensor on the probe for temperature compensation
   3. Standard measuring procedures:
      * Single point Hall probe acquisition.

A single point acquisition can be made at any desired point within the travel range of motorized stages

* + - On the fly Hall probe scan

Scan interval can be set at any choice above 0.1 mm. The scan speed should be adjusted to the scan interval to preserve full resolution of acquisition. The system should support scans with 1 mm resolution at the speed not lower than 12.5 mm/s

1. **Requirements for Flip Coil measuring bench**
   1. Mechanical system
      * Range of horizontal movement perpendicular to longitudinal axis: ≥ 300 mm
      * Range of vertical movement perpendicular to longitudinal axis: ≥ 300 mm
      * Rotary motion: multiturn
      * Accuracy of position: ≤ 20 μm for each axis
      * Repeatability of position: ≤ 5 μm for each axis
      * Accuracy of angular position: ≤ 0.05⁰
      * Repeatability of angular position: ≤ 0.02⁰
      * Coil width: ≥ 6 mm, ≤ 10 mm
      * The coils should support the first and second field integral measurements
   2. Standard measuring procedures:
      * Single point acquisition of field integrals

A single point measurements of field integrals can be made at any desired point in xy plane within the travel range of motorized stages. The rotation speed and the acceleration can be adjusted up to 1,5 turns/s and 1,5 turns/s2 respectively. The user can also adjust the integration time of the voltage integrator in the intervals of 20 ms

1. **Parameters of nanovoltmeter used to integrate induced voltages by flip coil**
   * + Two input channels
     + Noise level: ≤ 15nVp-p noise at 1s response time
     + Synchronization to line frequency
     + At least 110dB NMRR rejection of the effect of AC common-mode currents
     + Built-in thermocouple linearization and cold junction compensation