SENIS magnetic & current measurement

SENIS Customer Success Story

"Very impressive" SENIS Hall probes support cutting edge material research at MAX IV Laboratory

Creating X-rays from particle streams travelling at almost the speed of light is a challenge. It's one scientists at synchrotrons around the world can and do meet regularly, enabling investigations into bleeding edge materials science which are changing the world around us.

The particles involved are thousands of times smaller than the thickness of a human hair, and moving millions of times the speed of a bullet, so controlling and using the stream takes power and precision. Small parts of the stream are split off into devices called undulators, which use the particles to create X-rays for experiments.

SENIS sensors are now a key part of the control mechanism for MAX IV's undulators.

Objective – quality control

Each undulator consists of a series of alternating polarity magnetic dipoles. It creates coherent synchrotron radiation – in this case X-rays – by injecting an off take of the particle stream through the changing magnetic field, forcing the particles to oscillate and so radiate energy.

The Hall probe mapper assessing the HIPPE EPU

To ensure it will deliver the correct specification of X-rays, each undulator requires characterisation and tuning. To do that, Hall probes are used to map out the magnetic fields.

MAX IV has been operating its beamlines since 2016, and during a recent upgrade to a new 7x APPLE-II Elliptically Polarizing Undulator, SENIS were invited to provide the Hall Sensor for an improved Hall mapping system.

Challenge – environment and requirement

The magnetic fields in undulators are thousands of times stronger than Earth's magnetic field, while the stream of particles is travelling at close to 300,000 km/s. Going through the undulator the stream oscillates at about 500 Hz, creating significant electronic noise.

The Hall mapping system must include both a low-noise transducer and a low-noise, high resolution Hall probe capable of mapping in 3D, necessary for measuring magnetic fields of +/- 2 T in a gap of <3 mm.

So characterisation of the undulator's magnetic field is a challenge, demanding tight tolerances and accurate, high resolution measurements in a noisy environment.

The challenge for SENIS during the upgrade was to provide a Hall sensor which could meet this requirement while improving accuracy, linearity, offset, drift, and noise levels over those of the probes previously used.

About the Customer

Of human's five senses, sight is arguably the most important. But there are limitations to sight - without assistance, what we can see is limited to the resolution of our eyes, and the visible spectrum. So humans build tools to expand their ability to see, such as telescopes, microscopes, and X-ray machines.

Sweden's Max IV Laboratory makes visible the invisible nano-scale world by producing the highest quality brilliant X-rays in the world. It makes these X-rays available to academic and industrial scientists to test and develop innovative materials in medicine, computing, packaging, and environmental protection, rather than medical diagnosis.

Inaugurated on 21 June 2016 in Lund, the MAX IV synchrotron has more than 30 beamlines - stations where experiments can be run - operating from two electron storage rings - 1.5 GeV and 3 GeV - and a linear accelerator driving a Short Pulse Facility. The 3 GeV ring delivers hard X-rays, while the 1.5 GeV ring serves soft X-ray and UV users. The beamlines support research projects in biology, physics, chemistry, environmental science, geology, engineering, pharmacology and cultural heritage, as well as confidential industrial projects.

The laboratory is the world's first 4th generation synchrotron light source and relies solely on Insertion Device (ID) radiation for all the beamlines.

Solution – compact package

SENIS' low noise I3C, including a magnetic field transducer and 3D Hall probe, satisfied these requirements, providing an integrated solution including 3 Hall elements, transducer, amplifier, temperature sensor and more, all in 70 mm^3. The resulting installation offers resolution of 100 x 10 x 100 μm^3 and accuracy of <0.1 %. (See SENIS I3C implementation specification for more details.)

SENIS I3C implementation specification


The SENIS Hall probe transducer used at MAX IV Laboratory

MAX IV scientists integrated a SENIS advanced 3-axis low-noise magnetic field I3C transducer into a medium length 3-axis Hall probe with external dimensions of 47 x 2 x 0.75 mm. This ceramic Hall probe is based on a fully integrated 3-axis CMOS Hall IC, which already incorporates three groups (2 x By, 2 x Bz and 1 x By) of mutually orthogonal Hall elements, as well as biasing circuits, amplifiers, and a temperature sensor. The orthogonality error of the three measurement axes of the HM probe is < ±1°, and accuracy better than 0.1° can be determined by applying SENIS' well proven measurement method during the calibration (for more information on this method see the paper *High-accuracy teslameter with thin high-resolution three-axis Hall probe*, https://doi.org/10.1016/j.measurement.2015.06.023). Measurement of the angular errors of the Hall probe can be ordered optionally, and SENIS' accredited calibration laboratory can provide a measurement report. The 3D Hall IC's spatial resolution of the magnetic field sensitive area is only 100 x 100 x 10 μm^3. The transducers provided improved measurement DC accuracy and linearity of the three measurement outputs of <0.1 %. The DC resolution is 3 - 4 μTpp @ ±2 T range, and the white noise is 0.08 - 0.10 μT/sqrt(Hz). Planar Hall effect and cross-talk between the probe channels in the transducers is negligible.

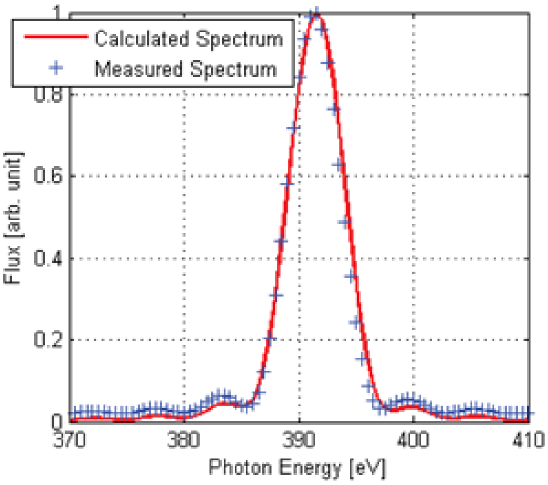
Result – impressive accuracy and precision

According to Mohammed Ebbeni, Research engineer at MAX IV Laboratory, "Our Hall probe mapper system relies on a 3D SENIS Hall probe transducer, which provides high accuracy, linearity and low noise that enabled very precise and accurate tuning of the IDs.

"The performance of the SENIS transducer incorporated in the whole mapper system, including the motion system (Kugler) and the data acquisition (Keithley Multimeters) as well as the synchronisation of the components. The results are presented as the error in the measured parameters of an Insertion Device. In my opinion, the results are very impressive."

Top notch probe performance

The new Hall probe mapper with the SENIS transducer measured the undulator's main parameters very precisely. Ebbeni went on to explain "As the goal of an ID is to produce high quality synchrotron radiation, we compare the measured radiation spectrum that is directly measured from the ID in the beamline against the calculated spectrum from the measured magnetic field."



The excellent performance is further shown by comparing the X-ray spectrum measured by the beamline against the spectrum calculated from the measured magnetic field maps as shown here. The measured magnetic field of HIPPE EPU (53mm period length) was used to calculate the radiation spectrum (red) and the radiation spectrum measured directly from the beamline (blue).

(More information on the probe performance can be found in *First commissioning results of phase I insertion devices at MAX IV Laboratory*, https://doi.org/10.1063/1.5084586.)

About SENIS

SENIS AG of Zug, Switzerland, develops, manufactures, and supplies advanced sensors and instruments for magnetic field and electric current measurement, as well as offering corresponding development and engineering services.

Our solutions and services help our clients in research institutes and the automotive, consumer electronics, test and measurement industries to create powerful, robust and effective products.

SENIS is moving the feasible limits in magnetometry and current measurement.

We find elegant and simple solutions to our customers needs.

www.senis.swiss
+41 43 205 26 37
info@senis.ch

Hertizentrum 11, 6300
Zug Switzerland