

Laser Interferometry in Radiation Harsh Environments

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Introduction

Synchrotron applications can nowadays be found in areas as diverse as biosciences (e.g. protein crystallography), medical research (e.g. microbiology), engineering (e.g. imaging of evolution of cracks with high resolution), and research on advanced materials (e.g. nanostructured materials). In many of these applications, highest resolution in the nanometer regime is desirable when positioning objects such as lenses, Bragg reflectors, slits, or targets. These mechanical setups should be compact and stable as to reduce thermal drifts and positioning errors. Additionally, the masses of moved parts should be kept low in order to improve the mechanical behavior, as well as to minimize positioning errors.

With regards to the applications discussed above, this means that position encoding has to happen in close vicinity of the moved objects, hence, encoders need to be placed inside irradiated areas, if not even on-axis with a focused X-Ray or particle beam.

attocube's FPS3010 laser interferometer featuring picometer resolution, compatibility with vacuum conditions, and remote readout electronics is the tool of choice for such applications. Here we show that the FPS3010 can operate under extreme radiation opening ways to use interferometric systems and subsystems close to synchrotron beams and beamlines, or other environments with high radiation.

Among the existing sensor portfolio, the "M12" sensor heads have been qualified for the operation in radioactive environments at radiation doses of up to 10 MGy. This study focusses on the radiation hardness of these new sensors under irradiation from a ^{60}Co source (1.17 MeV / 1.33 MeV γ - and 0.31 MeV β -rays). We demonstrate that the heads show no significant deviations in the readout during the irradiation of up to 3 MGy. In a second test the heads did not show any significant deviations in position when measuring the fixed target before and after irradiation of the sensor heads up to 10 MGy.

Setup

Two attocube UHV compatible M12-type sensor heads (one with an AR-coated lens and one without AR coating), connected to polyimide fibers were placed in the irradiation area at places with a dose rate of 1 Gy/s. Both heads were mounted in aluminum supports, which were expected to cause a position drift over temperature of 20 nm/ $^{\circ}\text{C}$. The cavities of 3 mm

distance were built using radiation hard mirrors that were gold coated to avoid solarisation.

The FPS3010 controller was placed outside the chamber and located in a temperature controlled chamber located in a non-radioactive zone. The temperature stability inside the chamber was better than 1 $^{\circ}\text{C}$ during the complete measurement cycle. The total cumulated dose at the end of the measurement was 3.024 MGy in water equivalent.

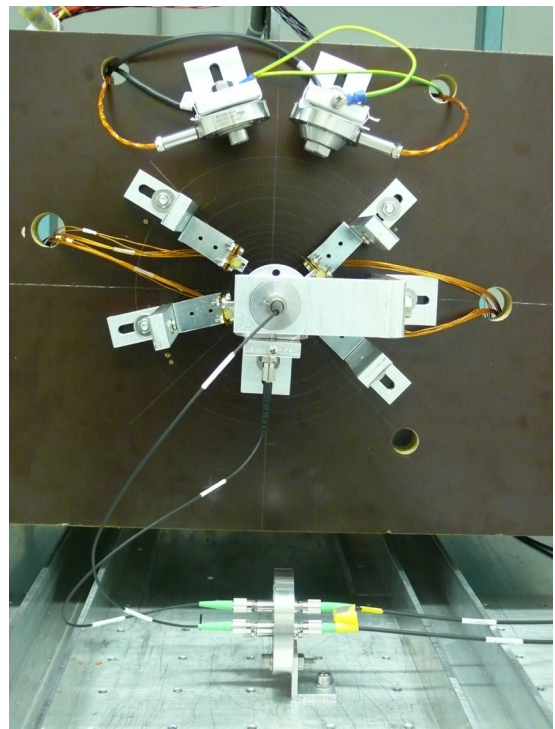
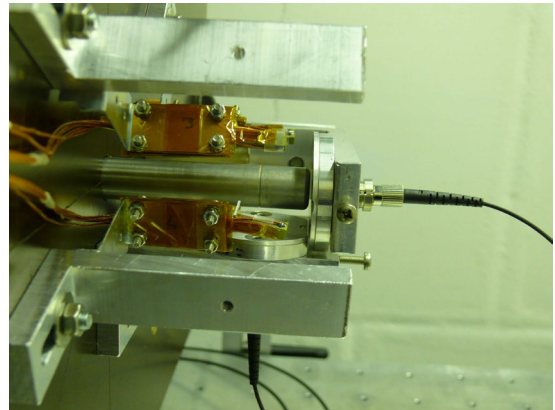


Figure 1: Side and front-view of the setup. Upper Image: Side View. One sensor is positioned axially to the source, one sensor is positioned below the source. The source in the middle radiates homogeneously. Lower Image: Front View of the setup. Note the vacuum feed-through below the setup, which was also irradiated.

Measurements

Figure 2a shows the measured positions during the measurement. The sampling rate of the encoder positions was set to 1 kHz. Each point in the graph represents an average over 100 individual measurements. The position drift observed over the full period of 34 days and a cumulated dose of 3 MGy was only 150 nm with the coated sensor head and 400 nm with the uncoated one. The uncertainty of the positions (standard deviation) was always better than 10 nm, due to the fact that a good signal could be retained throughout the measurement.

On the non-coated sensor head, the drift increased a bit after 2 MGy of total cumulated dose (22.5 days). Until this point, the performance of the two sensor heads was comparable. The graph in Figure 2b shows the temperature drift at the encoder (red) and at the controller positions (blue) which was within 1°C during the whole time.

Summary

This note shows results of radiation tests on two attocube M12 sensor heads for the FPS3010 laser interferometer. The setup and installation were proven to be robust in terms of mechanical vibration, giving a position uncertainty of less than 10 nm over a measurement period of 34 days. The measured positions were stable within a few 100nm during the whole time.

This qualification for radiation harsh environments opens up new applications and advancements. Measurement of beam collimator displacement, Laue-Lens position and many others in radiation harsh environments – inside the ultra-high vacuum assembly – become hence possible.

The work was accomplished by CERN and the radiation tests performed at the Fraunhofer Institute.

References

- [1] S. K. Höffgen, M. Di Castro, *Co-60 Irradiation of Optical Sensor Heads*, Cern Report, EDMS Id 1337167 v.1, 2013.
See <https://edms.cern.ch/file/1337167/1/>

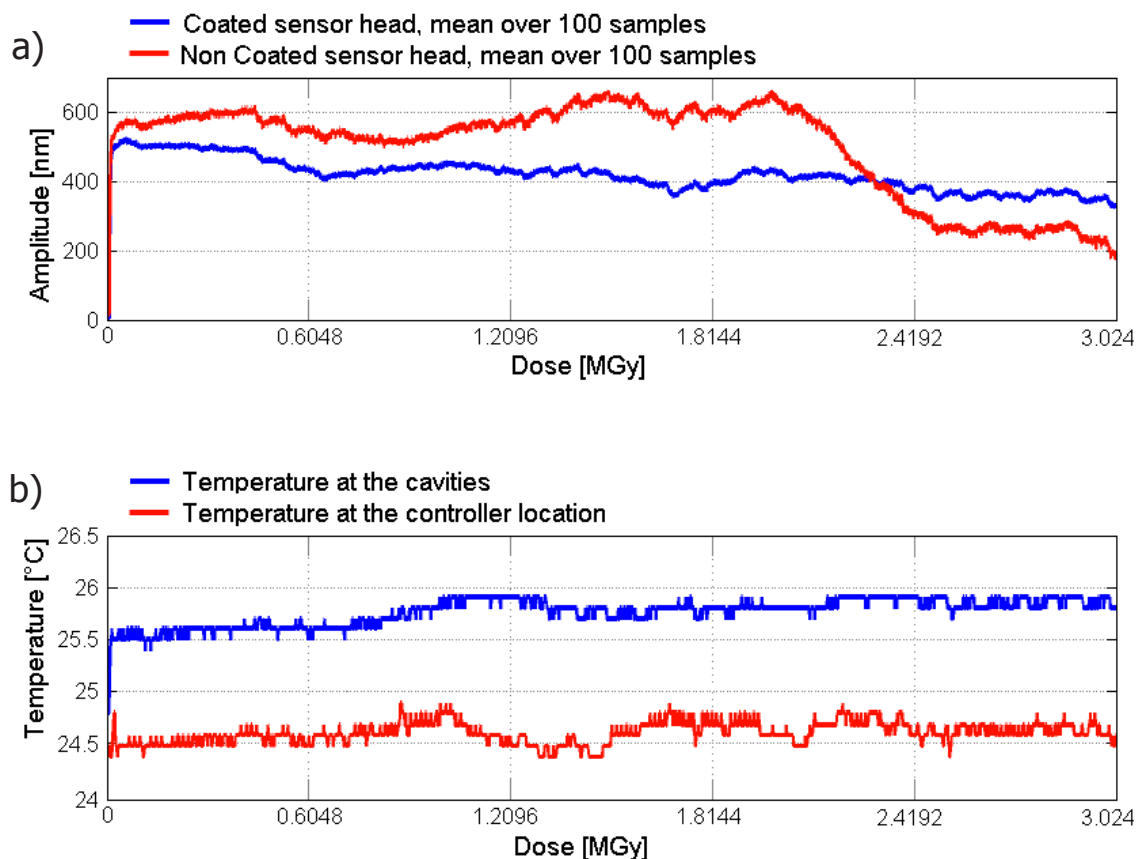


Figure 2: a) Sensor heads comparison (34 days span). Each sensor position point is a mean over 100 samples.

b) Measured temperature at the position of the encoders and in the chamber with the FPS3010 controller.