A Metrology System for *Astro-H*

L. C. Gallo[1], S. Ruel[2], S. Zhu[2], V. Kaspi[3]

[1] Department of Astronomy and Physics, Saint Mary's University, 923 Robie Street, Halifax, NS, B3H 3C3, Canada
[2] Neptec Design Group, 302 Legget Drive, Ottawa, ON, K2K 1Y5, Canada
[3] Department of Physics, McGill University, 3600 University Street, Montreal, QC, H3A 2T8, Canada
E-mail(LCG): lgallo@ap.smu.ca

Abstract

Metrology systems will play an increasingly important role in the design of future space telescopes. Long extendible benches and multiple spacecrafts flying in formation will be employed in order to create space-based interferometers and increased focal length. Determination of the optical bench alignment for these future observatories requires a sophisticated metrology system. *Astro-H* serves as a path-finder for many of these future missions in that it will possess an extendible optical bench for the hard X-ray telescopes and an advanced metrology system. One possible solution for the *Astro-H* metrology system is discussed here, as well as its applicability to the International X-ray Observatory (*IXO*).

Key words: metrology — Astro-H HXD — IXO

1. Metrology Systems and Future X-ray Missions

To advance high-energy ($E \approx 10 - 100$ keV) X-ray astronomy to the next stage requires improving angular resolution and minimising the background level. Both goals can be achieved by increasing the focal length of hard X-ray telescopes. However, there are limits to how long a focal length can be realised with a rigid optical path since: (i) unlike for optical telescopes, we cannot fold the focal length along the optical path of an X-ray telescope; (ii) we need to launch compactly.

Upcoming X-ray missions, such as *Astro-H* and the International X-ray Observatory (*IXO*), intend to achieve a long focal length by placing the detector platform at the end of an extendible optical bench (EOB) that will be deployed once in orbit. In the case of the two Hard X-ray Telescopes (HXTs) on *Astro-H*, the EOB will extend an additional 6-metres from the fixed telescope structure to achieve a focal length of 12-metres. The EOB will not be completely rigid and will be subject to distortion due to day/night temperature variations in low-Earth orbit (LEO), and spacecraft attitude manoeuvres. Precise alignment of the HXTs and detectors must be maintained so a sophisticated metrology system to measure deviations is demanded.

2. The Metrology Concept for *Astro-H*

The metrology system on *Astro-H* needs to be compact and light-weight; consume little power (less than 5 W); and operate for at least 3-year in a LEO environment. The currently proposed system consists of two modules

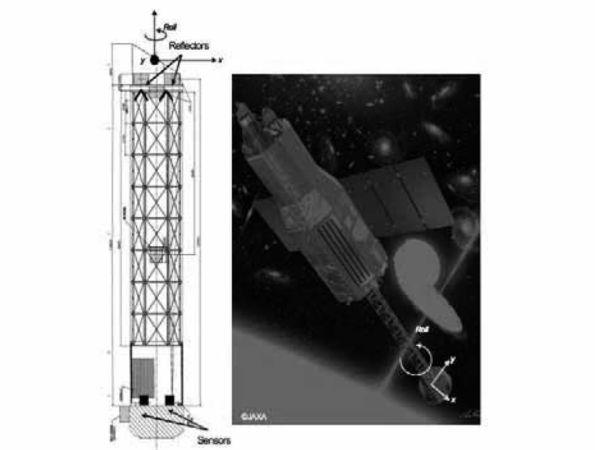

Fig. 1. Two metrology systems located inside the spacecraft will measure lateral and roll displacements in the structure.

designed to measure the lateral (X/Y) and rotational (Roll) shifts of the spacecraft's optical bench relative to the instruments. The modules are installed inside the spacecraft's main body where the telescope mirrors are located (Figure 1).

Each system is capable of measuring absolute lateral displacement from the optical bench to an accuracy of at least 60μm, exceeding the *Astro-H* requirements. By comparing the measured lateral displacement on each sensor, the rotation about the telescope main axis can be determined.

The system uses a laser reflected off a corner reflector

Fig. 2. The basic concept is sketched in the left panel. The right panel illustrates how the concept is robust to reflector misalignment.

and recorded on a two dimensional detector. The reflector returns the beam in the same direction it came from, but offset by a known distance along both lateral axes. If the detector moves laterally, the reflected beam will move on the detector (Figure 2).

The mechanical interface and laser launch optic mounts are made of thermally stable materials to ensure laser pointing stability. To further decrease the sensitivity of the system to errors in laser pointing, the size of the detection surface is increased to about 7.5 cm via the use of a fiber optic taper (Figure 3).

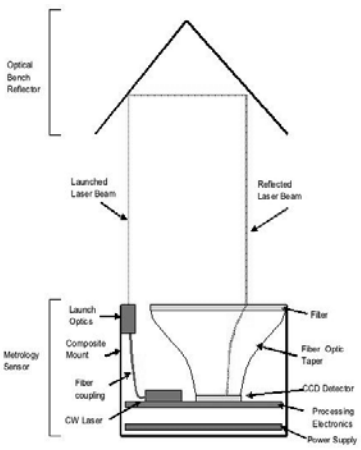

Fig. 3. The design of the metrology sensor is outlined.

The metrology system approach has several advantages: (i) it provides an absolute shift relative to a calibrated position; (ii) is immune to solar background; (iii) is robust to angular changes of the bench; (iv) the spot shift is linearly proportional to lateral movement; (v) it requires little processing power; and (vi) it is compact and light-weight.

3. Metrology on Future Astrophysical Missions

Future X-ray missions such as *IXO* will also require a metrology system to measure distortions in the optical path. The *IXO* mirrors will have a better point spread function and longer focal length ($\sim$ 20 m) than *Astro-H*, so will require better positional resolution. However, the basic concept for the *Astro-H* metrology system is largely transferable to *IXO*.

Metrology systems will play an increasingly important role in the design of future space telescopes. Long extendible benches are proposed for far-infrared missions to create space-based interferometers to improve resolution. Formation-flying, in which telescopes fly in formation to create very large interferometers (e.g ESPRIT, LISA); or where telescopes and detectors fly on separate spacecrafts to create very long focal lengths, will be the next step in the field of metrology. *Astro-H* plays a fundamental role in serving as a stepping-stone to these future endeavours.