Ground testing of the PHI Image Stabilisation System (ISS) for Solar Orbiter

Abstract

The Photospheric and Helioseismic Imager (PHI) on board of the ESA mission Solar Orbiter, to be launched in 2017, will provide measurements with high polarimetric accuracy of the photospheric solar magnetic field at high solar latitudes. The required pointing precision is achieved by an image stabilisation system (ISS) that compensates for spacecraft jitter. The ISS consists of a high-speed correlation tracker camera (CTC) and a fast steerable tip-tilt mirror operated in closed loop.

This poster will present the test setup being used to demonstrate that the performance of the ISS is according to the requirements, and the results of these tests.

A detailed description of the PHI ISS is given on poster 27 „Image stabilisation system of the Photospheric and Helioseismic Imager" by Volkmer et al.

ISS Test Setup

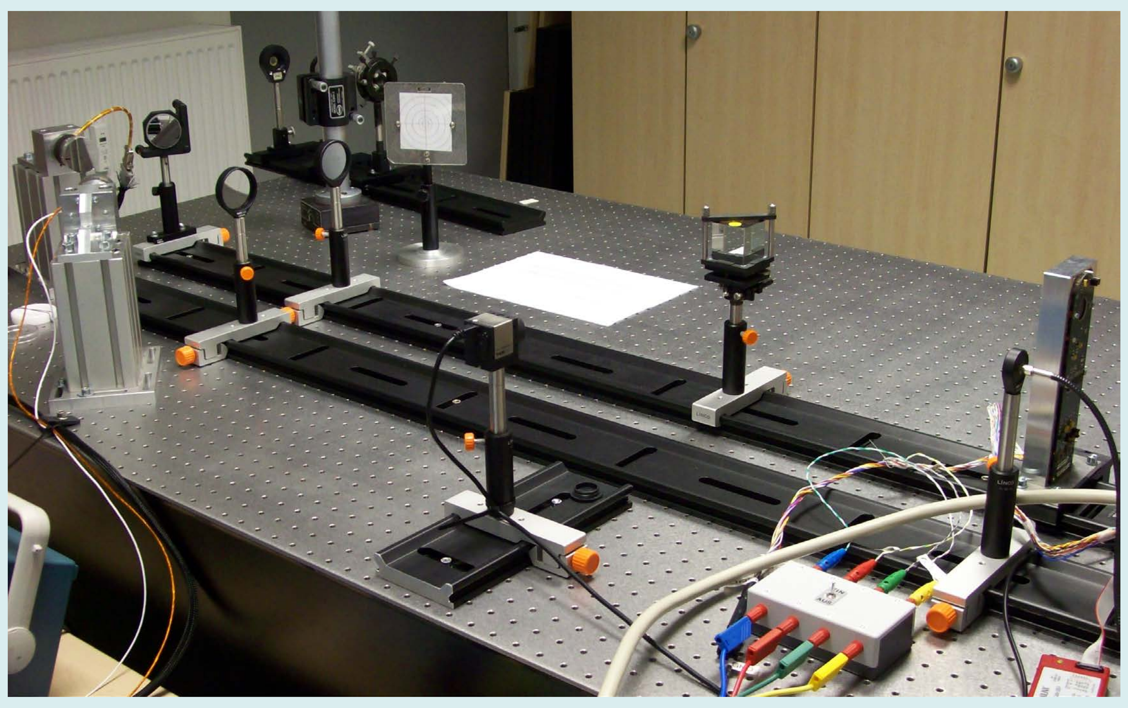


Figure 1: ISS test setup in optical lab

The PHI ISS test setup has the same tip-tilt-scale as the telescope on board of Solar Orbiter (7.6 µrad / pixel) and consists of the following optical components:

- Light source (LED emitting at 617 nm)
- Optical fiber to simulate solar granulation
- Collimator and re-imager lenses (f = 1000 mm)
- M1 disturbance TT-mirror (positioned close to pupil)
- M2 stabilisation TT-mirror (positioned in pupil)
- M3 mirror
- Beam splitter
- CT-Camera
- USB camera (providing "science" images for analysis of the pointing stability at up to 50 fps)

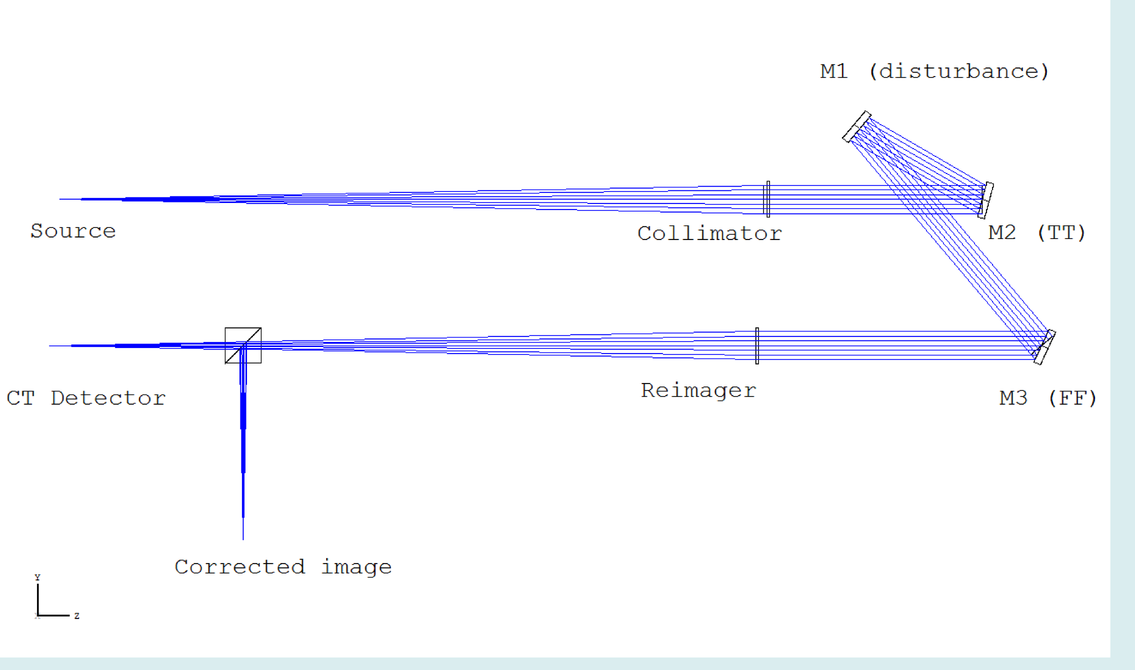


Figure 2: Schematic ISS test setup

CT-Camera

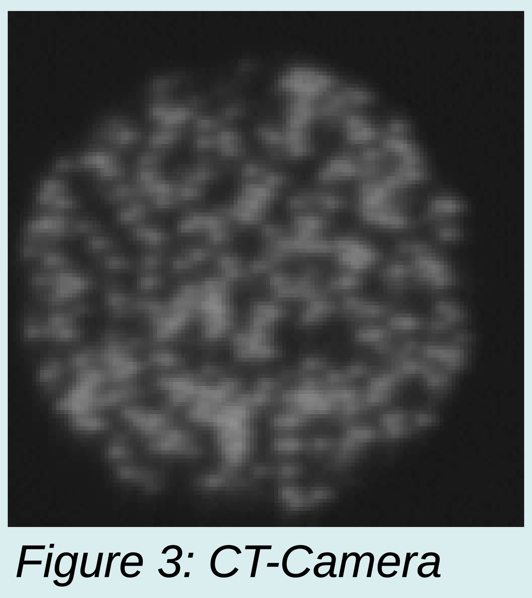


Figure 3: CT-Camera image showing simulated granulation (128x128 pixel)

Specifications:

- 0.8 arcsec / pixel resolution
- 12 bit ADC (10 bits being used)
- ~500 DN nominal signal level
- ~85 DN bias, dark current negligable
- Noise: 0.5 DN std dev (at 20-65°C)
  - ➢ 8 effective bits

The camera has been successfully tested in correlation mode at a frame-rate of 400 fps with 128x128 images and at 800 fps with 64x64 images.

TT-Controller

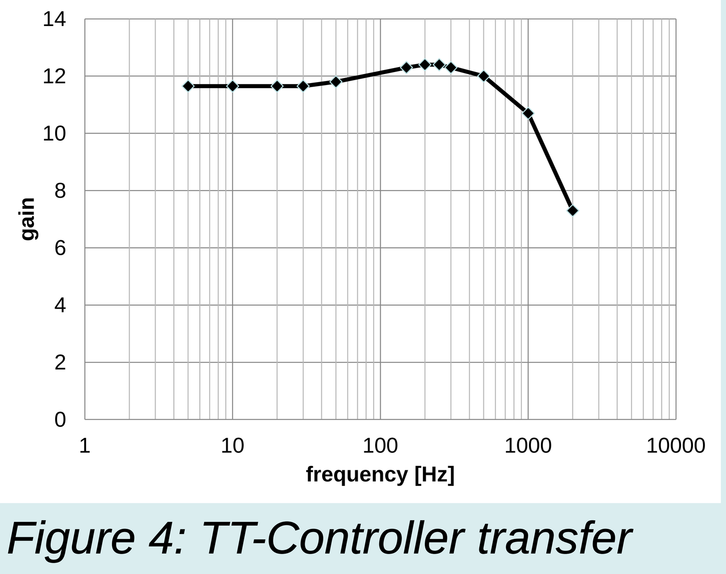


Figure 4: TT-Controller transfer function

Specifications:

- 12 bit D/A converter
- Output voltage: 0 - 55 V
- Frequency range: 0 Hz – 1 kHz
- Noise: ~10 mV (< 1 DN)

For frequencies < 100 Hz the delay time of the TT-Controller is < 0.1 ms.

TT-Drive

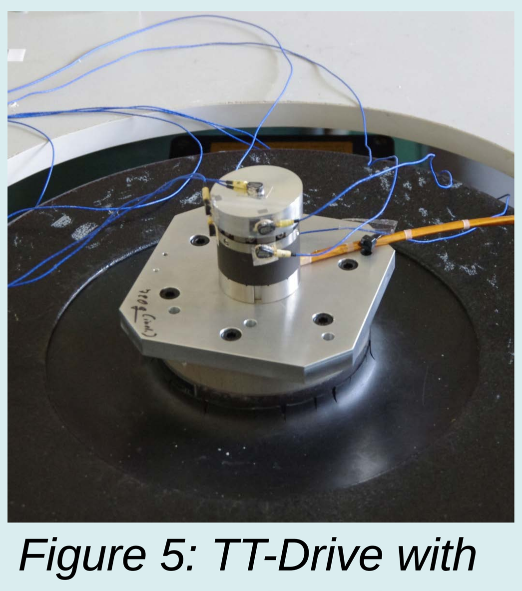


Figure 5: TT-Drive with M2 mounted on shaker

Specifications:

- 1.5 µF per piezo stack
- ±270 µrad (±28 arcsec on sky) tilt angle
- Lowest TT-Drive resonance at 1.3 kHz
- Lowest M2 mirror cell resonance at 1 kHz

During a vibration test at qualification level, the maximal piezo induced voltages were < 15 V.

➢ No harm to TT-Controller electronics.

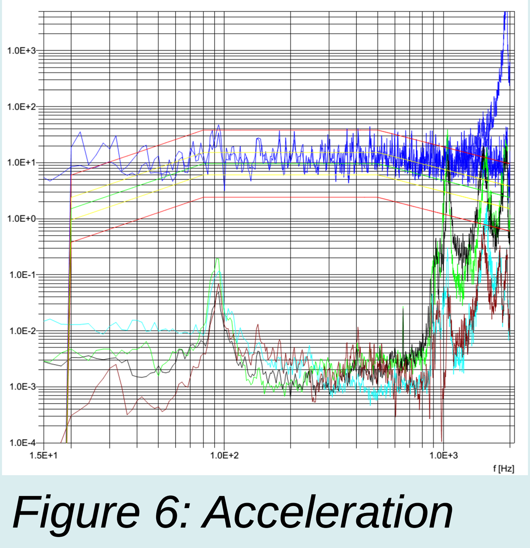


Figure 6: Acceleration during vibration test

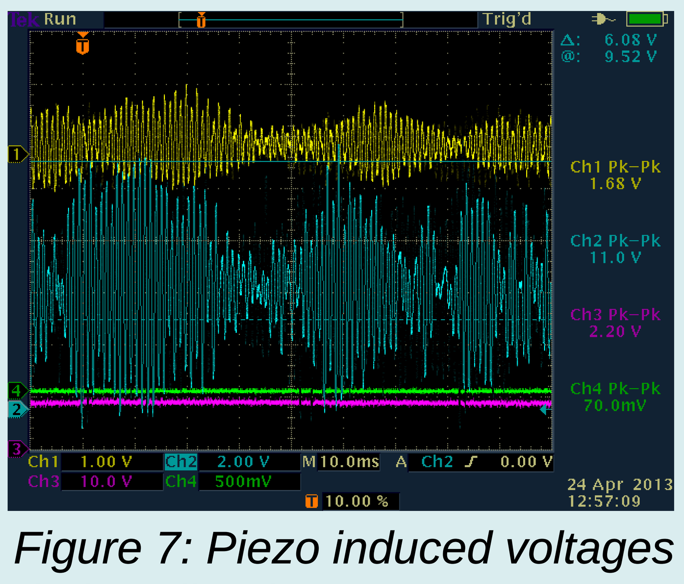


Figure 7: Piezo induced voltages during vibration test

ISS Test Results

Cohen-Coon tuning method

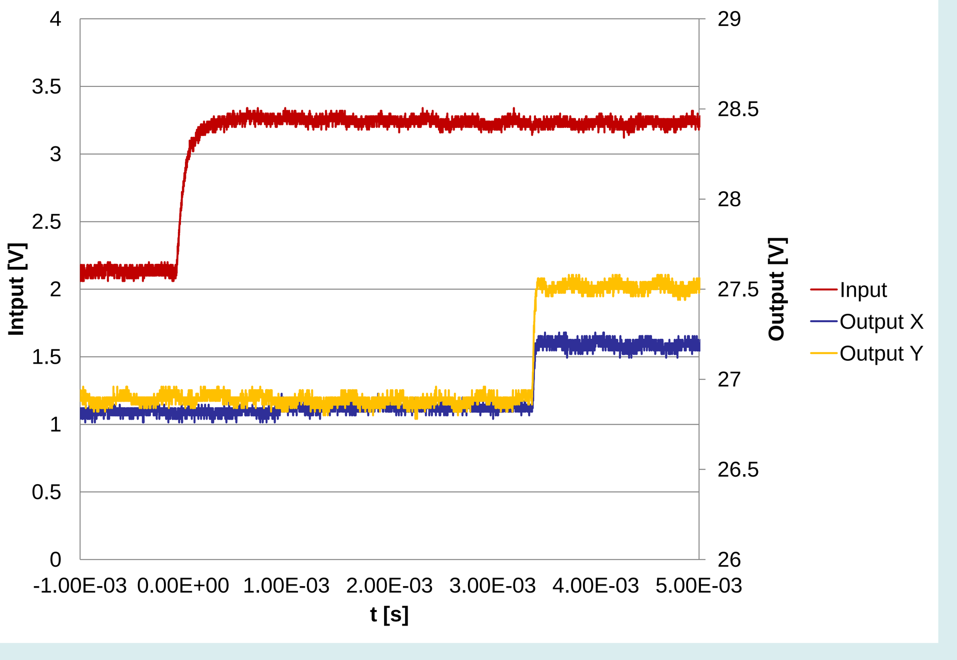


Figure 8: ISS step response in open loop

To derive the PID-parameters for the ISS control servo, the Cohen-Coon tuning method has been applied.

The latency between input (via M1) and output signal was measured as well as the rise time of the step response.

T_s = 1 / 400 fps = 2.5 ms

τ = 0.02 ms

τ_{del} = 3.4 ms (average of 40 measurements)

The derived PID parameters are:

τ_{int} = 2.5 ms

τ_{der} = 0.036 ms (set to 0 ms for initial tests)

PID parameter test

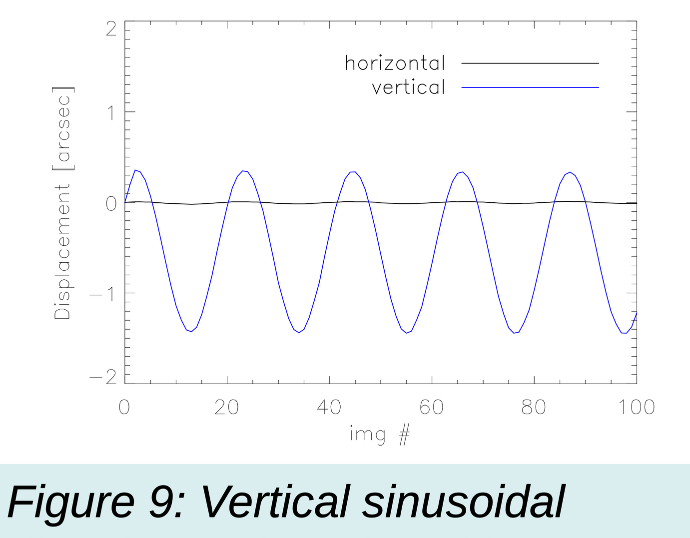


Figure 9: Vertical sinusoidal disturbance introduced by M1

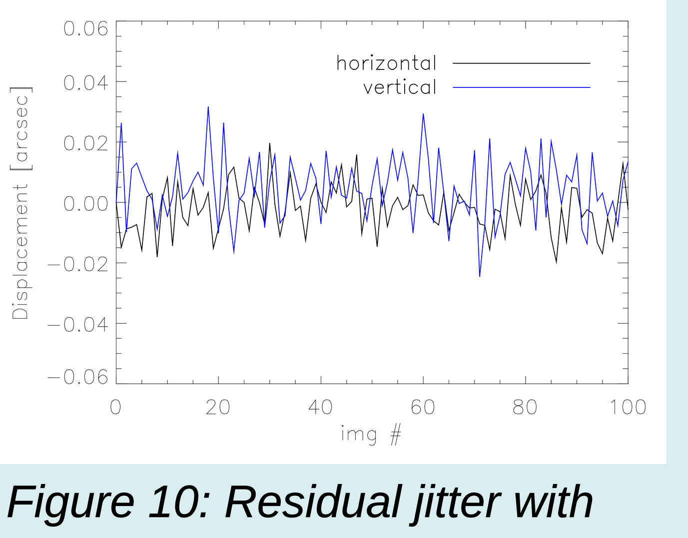
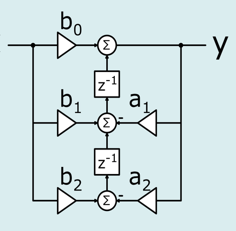


Figure 10: Residual jitter with ISS on

Implementation of PID servo in ISS control:



$$y = x \cdot H(z) = \frac{b_0 + b_1 z^{-1} + b_2 z^{-2}}{a_0 + a_1 z^{-1} + a_2 z^{-2}} x$$

with

a = [1, -2, 1]

b = [1.5, -0.75, 0]

Attenuation

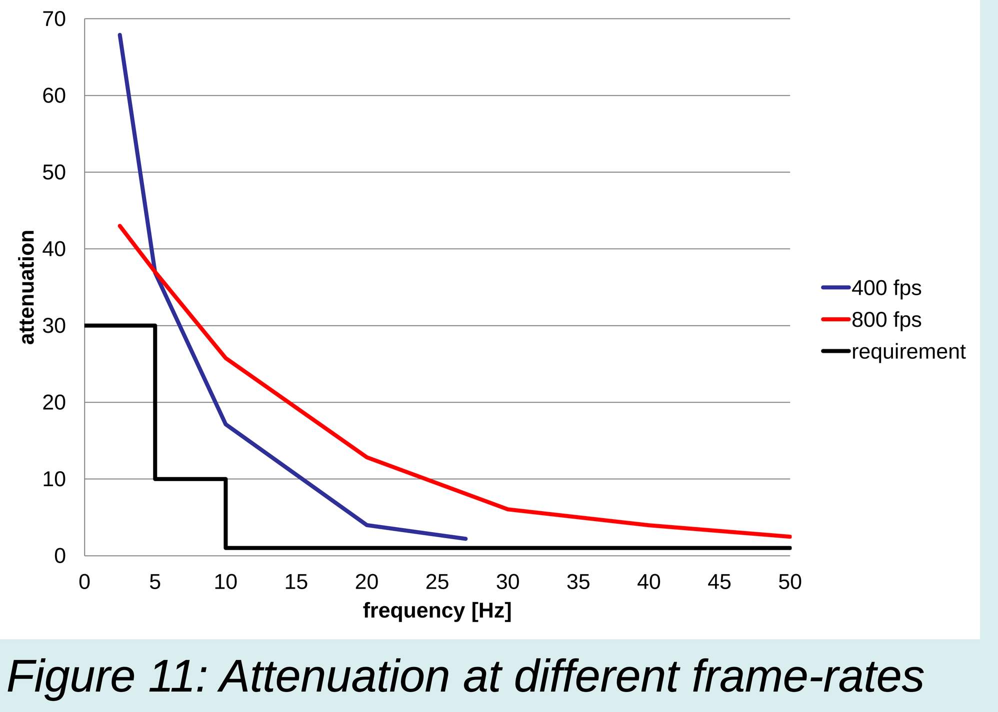


Figure 11: Attenuation at different frame-rates

gain = 75 DN / pixel (at 400 fps)

gain = 50 DN / pixel (at 800 fps)

The standard deviation of the image displacements on the USB camera is measured and the attenuation is calculated

$$attenuation = \frac{std\_dev(ISS\_off)}{std\_dev(ISS\_on)}$$

The achieved performance exceeds the required attenuation.

Noise

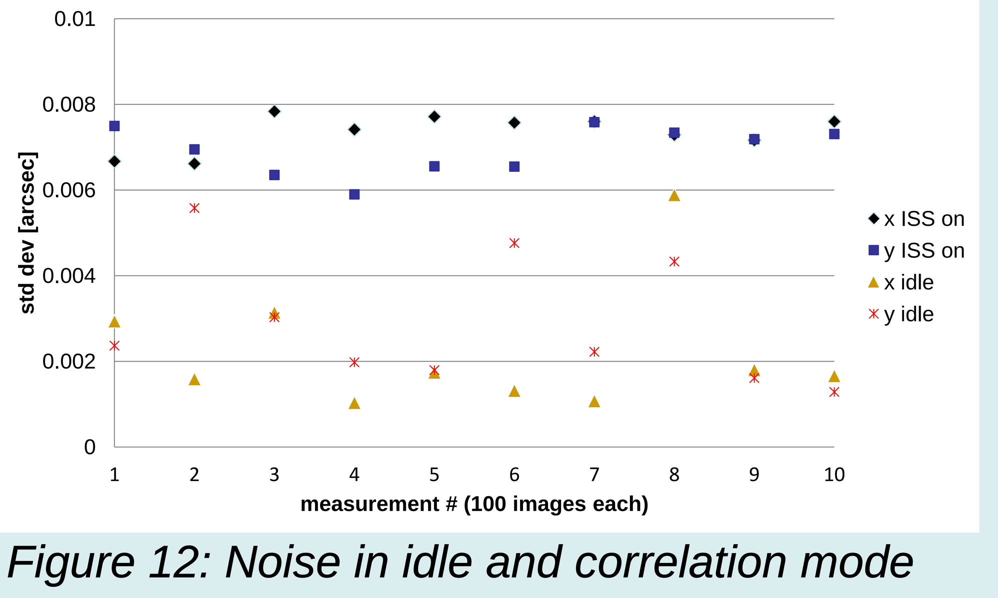


Figure 12: Noise in idle and correlation mode

The noise (vibrations on optical bench and electronic noise seen by the TT-Drive) is ~0.002 arcsec std dev in idle mode.

It increases to ~0.007 arcsec std dev in correlation mode which corresponds to only ± 1 DN peak-peak being added by the correlation algorithm.

This is far better than the required pointing stability of 0.1 arcsec.

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