Controlling PI Positioners with External Zygo Interferometers

1 Introduction

Developing high-precision position technology that meets the highest standards of various different technologies is the core business of PI (Physik Instrumente). Integrating different measuring technology often requires creating new interfaces to extend the possibilities for use.

Therefore, a possibility was created to control PI positioners via the high-resolution signal of a Zygo interferometer. The difficulty was linking the different data protocols and achieving fast transmission in order to make real-time control possible.

However, the advantages are obvious: The interferometer signal with a resolution of approx. 154.5 pm is comparable to the best path-measuring systems currently available for internal use. In addition, eliminating or not using an internal sensor reduces the heat transfer in the mechanics, which can contribute increased precision.

If for example, the mirror element is attached directly next the part to be positioned, the influence of mechanical faults – such as deformation, thermal expansion or bearing play – is reduced.

2 System Layout

Fig. 1 shows a schematic test setup.

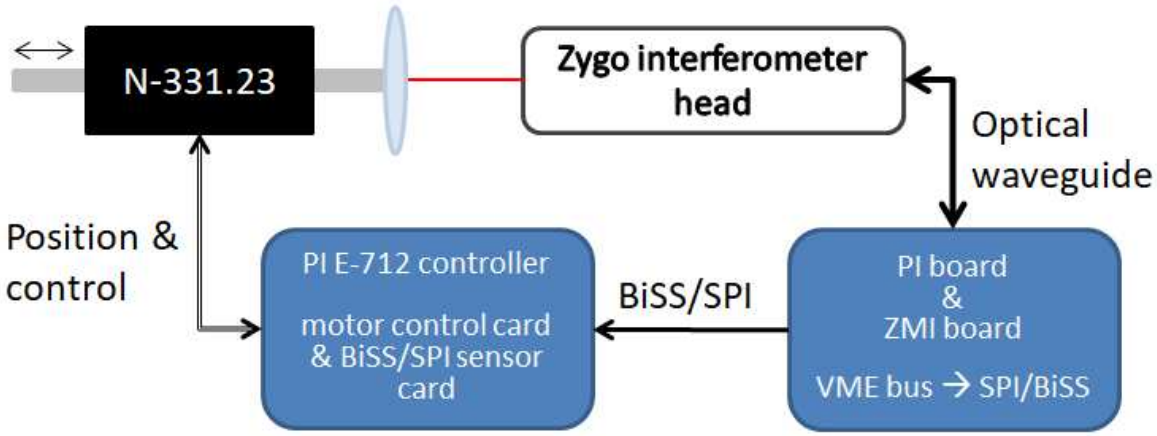

Fig. 1 Schematic representation of the experimental setup (image: PI)

An N-331.23 PICMAWalk walking drive was used as positioner, which was equipped with an internal sensor with approx. 10 nm resolution. A mirror was fixed to the end of the runner. A Zygo interferometer head (ZMI, model 7702) was positioned directly in front and its laser beam is aligned to the mirror. The measuring environment was a closed room with a foundation decoupled from the vibration and a temperature regulated to 20 °C (±0.1 °C), where all devices could be controlled from the outside. The positioners and the interferometer were mounted on an air-suspended bench. An E-712.1AN controller from PI was used with plug-in cards for controlling the positioner and tapping the sensor signals (E-711.C82 motor control card and E-711.IS3 SPI/BiSS card).

To reduce heat transfer, the control electronics for the interferometer (ZMI-4104C board and PI board for further communication via BiSS/SPI) and the PC were positioned outside of the measuring chamber. The ZMI-4104C board supplies the interferometer head and acts as optical interface to the head. It communicates with the PI electronics via the VME bus protocol, which can output the position signal via a BiSS or SPI interface, e.g., to a controller or a PC.

The laboratory setup is shown in Fig. 2:

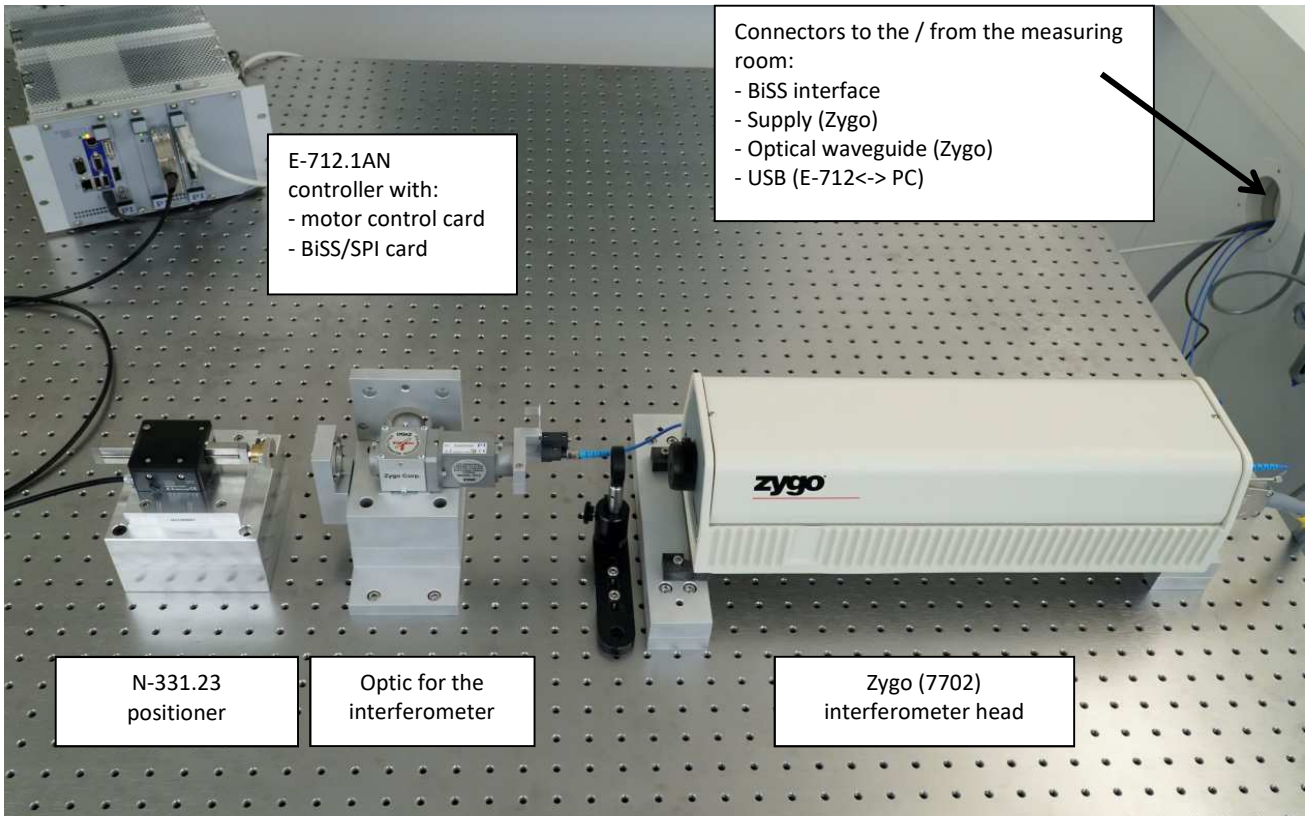

Fig. 2 Test setup in the measuring room (image: PI)

3 Results

3.1 Control via the Interferometer

3.1.1 Setup

The E-712 controller from PI takes care of the actual control, controls the positioner, and taps the internal sensor signal. In addition, the controller gets the position signal from the interferometer via a BiSS or SPI interface.

It is possible to decide in the E-712.1AN controller whether the internal sensor signal or the interferometer signal is to be used for the closed servo loop. Referencing is only done via the internal sensor.

It would also be possible to use the interferometer signal as superordinate position feedback outside of the servo loop. However, this is not discussed in more detail below.

3.1.2 Comparison: Control via Internal Sensor and Interferometer

If the interferometer signal is activated for control, it is possible to continue with commanding and positioning as usual.

3.2 Noise

The noise from the position signals of the internal sensor and the interferometer is shown in Fig. 3 without control and at rest. The specified values for "d_max" are the peak-peak values of the measured signals. In the case of the interferometer, it can be seen that the position noise 20 less that with the internal sensor, which basically allows higher accuracy.

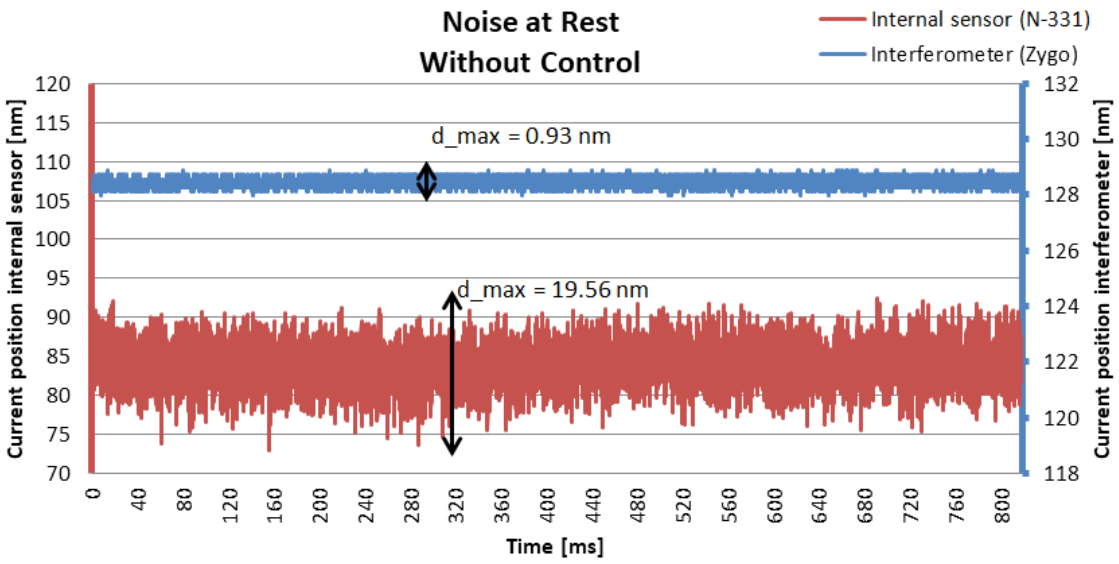

Fig. 3 Sensor's noise signals (image: PI)

3.3 Improved Position Control – Higher Resolution

If you consider the difference in position control irrespective of which sensor is used, there are considerable differences. This is immediately apparent when moving the positioner stepwise close to the resolution limit of the sensors (Fig. 1).

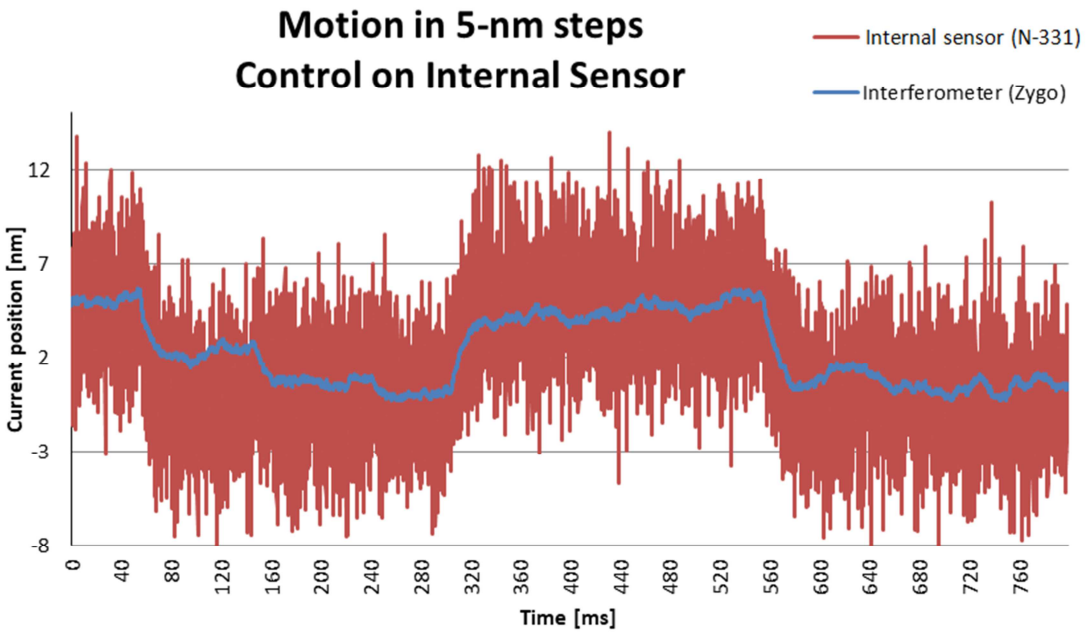

Fig. 1 Sensor signals at 5-nm steps – control on internal sensor (image: PI)

The result of measuring with an internal sensor in a closed servo loop is shown in Fig. 1. The red signal shows the internal sensor signal. The step size set to 5 nm is just below the noise band. On the other hand, in the case of the interferometer signal, the steps are clearly recognizable. In addition, the inaccuracies in position control are also clearly visible and the results from operating at the resolution limit.

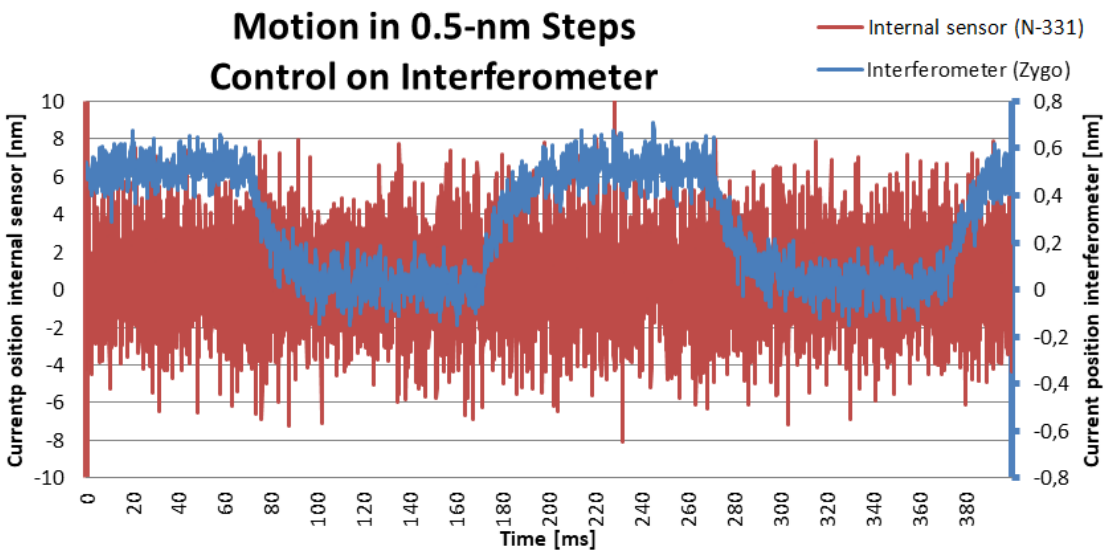

Fig. 2 Sensor signal at 0.5-nm steps – control on interferometer (image: PI)

Finally, the interferometer signal was used for the closed servo loop and the results are shown in Fig. 2. The step size is only 0.5 nm. It becomes quite clear that the internal sensor (red signal) cannot detect motion anymore, whereby the interferometer (blue) is still able to resolve very well. Unfortunately, the actual position stability can no longer be checked here because a it would be be necessary to use measuring equipment with a much higher resolution.

4 Usability and Exceptions

Successful control of a positioner via a Zygo interferometer has some requirement:

- PI controller that also acts as BiSS or SPI master (here, E-712.1AN controller with motor control card (E-711.C82) and additional BiSS respectively SPI-capable card (E-711.IS3)
- An ACS controller could be used instead as long as it is capable of BiSS or SPI
- PI positioner that is available with one of the above-mentioned controllers (here, N-331.23)
- ZMI board (ZMI-4104C) for supplying and for optical communication with the interferometer head
- PI board for communicating with the ZMI board via the VME bus and for outputting the position via SPI/BiSS
- Zygo interferometer head (ZMI, model 7702)
- Possibility of mounting the mirror element on the positioner
- Preventing beam interruption between the Zygo and mirror

In some cases, it is not possible to use this method:

- In cases of low stiffness between the motor and the measuring point of the interferometer, the system is sensitive to resonances in the feedback loop. For example air bearing or magnetic drive positioners could be affected. The applicability of this technique must therefore be decided from case to case.
- In addition, the drive system properties must be taken into account – e.g., whether this has sufficient minimum incremental motion

5 Conclusion

In some applications, it can be helpful to control a positioner via an external interferometer rather than via the internal sensor. PI has succeeded in link different protocols and systems and use the interferometer signal directly for controlling in the closed servo loop.

The advantage over internal sensors is the ability to attach the mirror for the interferometer directly to a place that is interesting for positioning. This reduces errors resulting from both mechanical and thermal influence. It is possible that the Zygo interferometer could also serve as calibrated measuring equipment. All components, except the interferometer head and the ZMI board, are offered by PI and therefore come from a single source.

Of course, this method is not suitable for all positioners or applications. Our experts are at your disposal for any advice you may require.

6 Author

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7 About PI

Well known for the high quality of its products, PI (Physik Instrumente) has been one of the leading players in the global market for precision positioning technology for many years. PI has been developing and manufacturing standard and OEM products with piezo or motor drives for more than 40 years.

Continuous development of innovative drive concepts, products, and system solutions and more than 200 technology patents distinguish the company history today. PI develops, manufactures, and qualifies all core technology itself: From piezo components, -actuators, and motors as well as magnetic direct drives through air bearings, magnetic and flexure guides to nanometrological sensors, control technology, and software. PI is therefore not dependent on components available on the market to offer its customers the most advanced solutions. The high vertical range of manufacturing allows complete control over processes and this allows flexible reaction to market developments and new requirements.

By acquiring the majority shares in ACS Motion Control, a worldwide leading developer and manufacturer of modular motion controllers for multi-axis drive systems, PI can also supply customized complete systems for industrial applications that make the highest demand on precision and dynamics. In addition to four locations in Germany, the PI Group is represented internationally by fifteen sales and service subsidiaries.