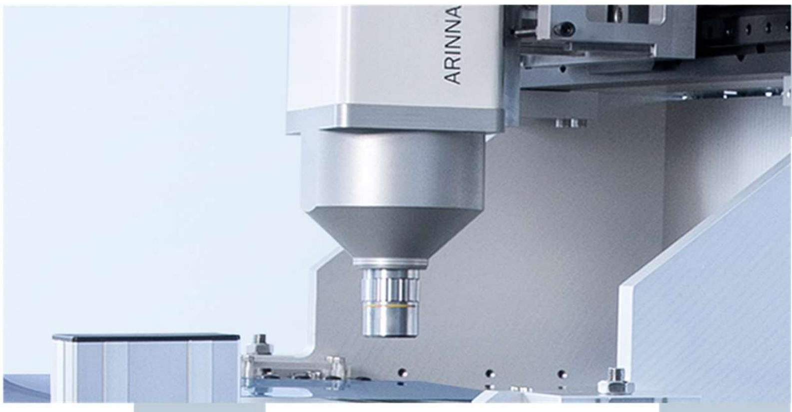
ARINNA Wavelength Scanning Interferometer



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1 ARINNA Wavelength Scanning Interferometer

A new measurement tool is introduced for fast and high precision areal surface measurements of micro and nanoscale structures; including stepped and freeform surfaces. ARINNA uniquely combines high speed, large vertical range, nanometer resolution and millimeter area sampling.

Through the addition of a novel vibration compensation technique, the system has also been made suitably small, flexible and robust for on-line integration. The measurement principle and system performance evaluation are described in this note.

2 Background

The topographic measurement of surface features at the micro and nanoscale, including steps and freeforms, is an important challenge in many research and manufacturing fields. Such features may be deliberate, as in structured surfaces designed for a particular function, or unintended, as in surface damage or unwanted particulates.

IBS Precision Engineering has developed an aerial interferometer capable of measuring (discontinuous) structures over a large area with nanometer resolution. It is fast and has integrated vibration compensation allowing for in-line measurements.

ARINNA is able to measure discrete step heights and surface quality with a vertical resolution <2nm. A mega pixel camera captures a surface scan in under 1 sec. With a x2 objective the system provides a 96μm vertical range, 5 μm lateral resolution and 8mm^2 FOV. It can be used for in-line defect detection and characterization, optical surface and structure measurement, 3D surface topology measurement, MEMS/NEMS inspection and more. A measurement of a multi-step IC is shown in Figure 1.

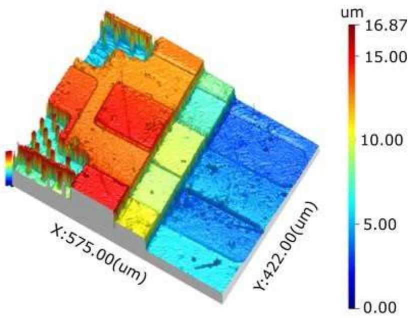

Figure 1 Multi-Step IC

3 Wavelength Scanning Interferometer Principle

The measurement technique employed by ARINNA is based on the principle of wavelength scanning interferometry (WSI). The technique involves the capture of a set of interferograms across a range of wavelengths incident on the sample or product. Within a single camera pixel, a sinusoidal change of intensity with wavelength (frame number) is observed, as shown in Figure 2. Using the phase shifts generated between the interferograms, a height map of areal surfaces can be produced.

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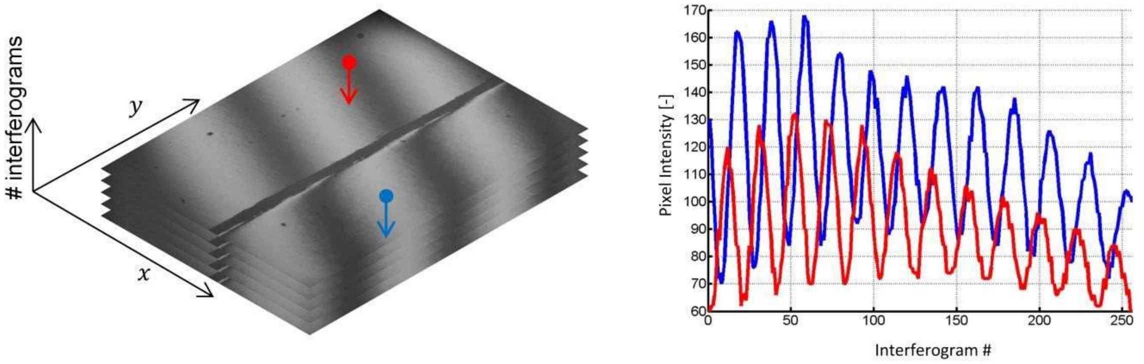

Figure 2 Measurement of step height with representation of 3D image array (left) and signal of two pixels over the scanned wavelength (right).

The wavelength scanning technique employed by ARINNA avoids the need for mechanical scanning in the measurement head, as employed by some interferometric systems. This overcomes associated limitations to both the measurement speed and system integration (such as the ability for 360° orientation of the head).

4 Vibration compensation

For many applications, the ability to measure in-line can critically enhance the value provided by the metrology system. Where surface features are required to meet specific targets, yields will be enhanced through better process control or process optimization will be accelerated.

For in-line use, a patented vibration compensation technique has been integrated into the design of ARINNA. This technique avoids the need for large and/or complex isolation systems; at times a limiting factor in the application of high precision optical measurement systems in the field.

In Figure 3, data capture with and without the vibration compensation option applied is shown, highlighting the significant improvement in surface measurement data achieved following such noise removal.

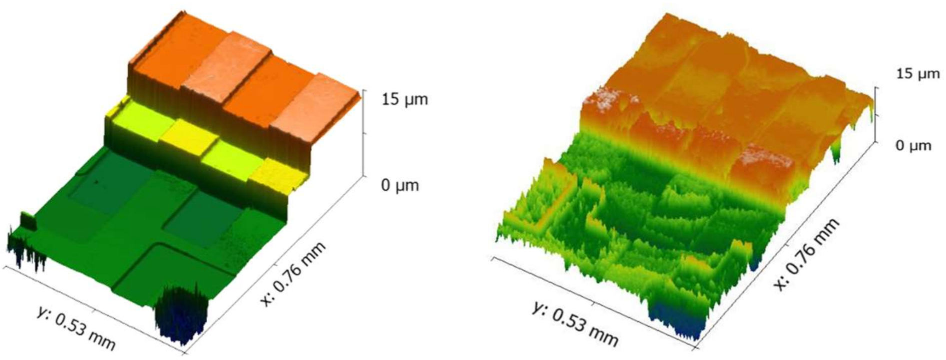

Figure 3 Surface scan on stepped surface with (left) and without (right) vibration compensation

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5 ARINNA Specifications

Both the wavelength scanning and the vibration isolation techniques employed by ARINNA, allow for a design with an extremely small footprint, as shown in Figure 4. By changing microscope objectives, the user is given the possibility to change the magnification of the system. Specifications at 2x and 5x are given in Table 1; however, a range of objectives, up to 50x (even 100x), can be used.

Height measurement derived by ARINNA is based on the phase change observed during wavelength. Thus, height resolution does not change with magnification. Other lens specific parameters, such as vertical range (depth of focus) and lateral range (field of view) do vary. In Table 1, an overview of specifications of ARINNA is given.

Table 1 Specifications of ARINNA 2x and 5x. A range of objectives up to 100x can be used.

Specification	Value	Unit
Vertical Range (lens dependent)	96 (2x objective) 14 (5x objective)	µm
Vertical Resolution	< 2	nm
Vertical Accuracy	~15	nm
Lateral Range (lens dependent)	2.8 x 2.8 (2x objective) 1.1 x 1.1 (5x objective)	mm
Lateral Sampling	1000 x 1000	pixels
Lateral Resolution (lens dependent)	5 (2x objective) 2 (5x objective)	µm
Measurement time	< 1	s
Autofocus time	< 1	s

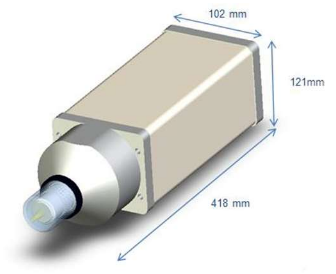

Figure 4 System dimensions

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6 System accuracy

As a metrology tool, it is essential that the accuracy of ARINNA is qualified in a traceable manner. To determine this, data has been compared for measurements taken on an artefact by both ARINNA and that of a coordinate measurement machine with traceable uncertainty proven to 11 nm.

Here, a bridge gauge has been used as an artefact. This gauge contains three surfaces, with a defined step height between each surface. This is depicted in Figure 5.

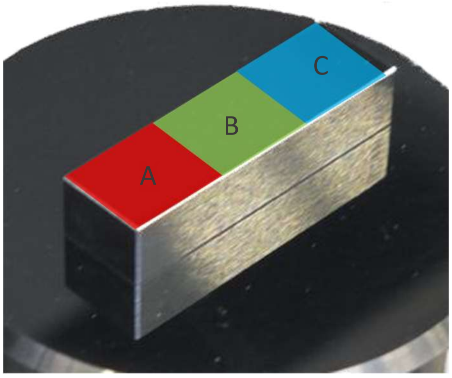

Figure 5 Bridge gauge layout

7 ARINNA measurement

In Figure 6a) a standard measurement setup is shown, where the ARINNA measurement head is mounted on a horizontal translation stage to be able to move over the sample (in this instance a convex lens). Figure 6b) shows a close up of the bridge gauge measurement. A z-stage is used to autofocus with respect to the object.

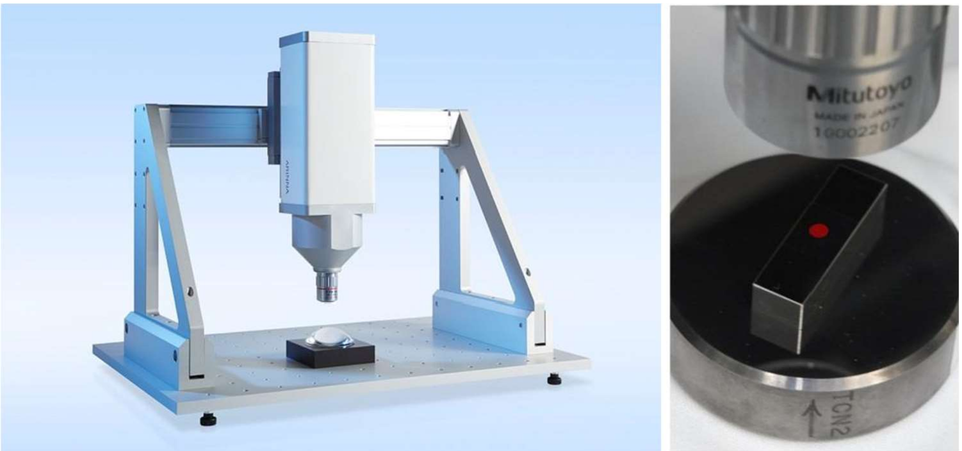

Figure 6a) ARINNA mounted on a measurement setup (left). Figure 7b) the measurement setup of the bridge gauge, showing the microscope objective and measurement spot.

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Measurement of the bridge gauge step heights AB and BC were completed using 5x magnification. Measured step height data is given in Figure 7.

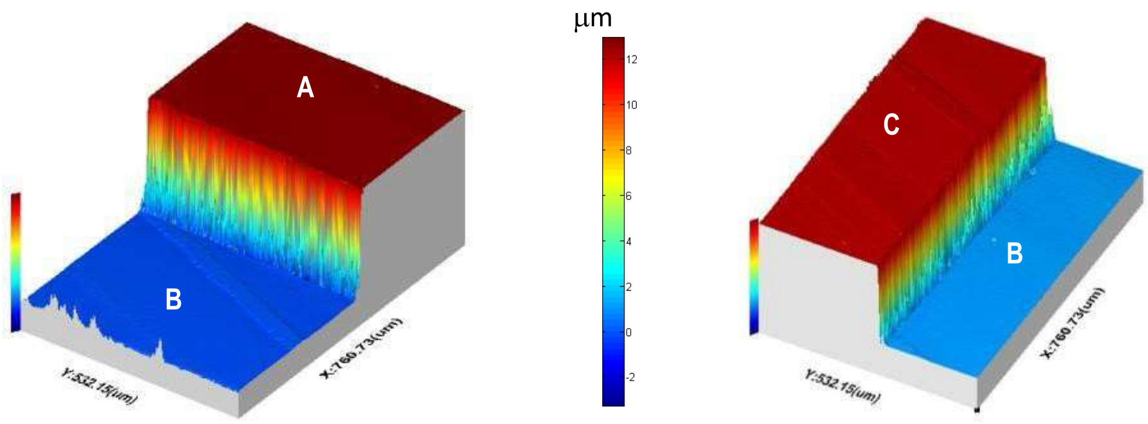

Figure 7 ARINNA measurement results on the two step heights in the bridge gauge, with the step AB (left) and BC (right)

The step height is calculated by measuring the distance between the average heights of each surface. This gives a step height of 12.649 µm for step AB and 12.479 µm for step BC. With the measurement competed, the artefact was transferred to an ISARA 400 CMM and step height data once again collected.

8 Comparison with ISARA 400

The ISARA 400 coordinate measuring machine has been used as a reference measurement system for assessment of the WSI measurement technology employed by ARINNA.

To verify the accuracy of the ISARA 400, a Ø150 mm zerodur flat mirror reference artefact has previously been measured. The flatness of this mirror was measured using Fizeau interferometry at Germany's national metrology institute, the Physkalisch-Technische Bundesanstalt (PTB). The result of this flatness measurement is directly traceable to international standards. For the PTB sample measured, it was found that 95.5% of the data points match to less than 11 nm with the PTB calibration[1].

9 Measurement setup on the ISARA 400

Figure 8 shows the ISARA 400 3D ultra-precision CMM and the measurement setup on the machine. To measure the bridge gauge, a CAD model was first imported in the CMM software and 5 points probed manually on the part for alignment. Measurement was then executed, with each of the three surfaces sampled at 950 points.

[1] I. Widdershoven, M. Baas and H. Spaan, "Ultra-precision 3D coordinate metrology results showing 11 nm accuracy", Proceedings of the 11th international symposium of measurement technology and intelligent instruments (ISMTII), July 2013

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The step heights are calculated by levelling all surfaces to the surface B and comparing the mean heights. This gives a step height of 12.631 µm for the step AB, where a height of12.495 µm is measured for the BC step. These results are represented in Figure 9.

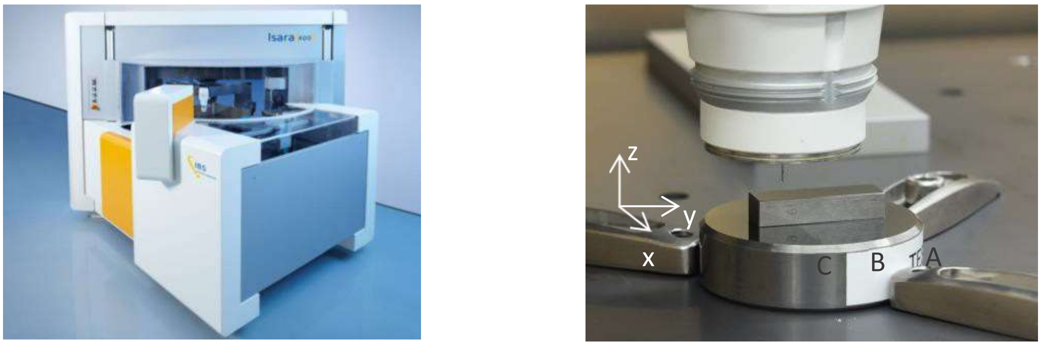

Figure 8 The ISARA 400 3D ultra-precision CMM (left) and the measurement setup of the bridge gauge, showing the Triskelion touch probe (right)

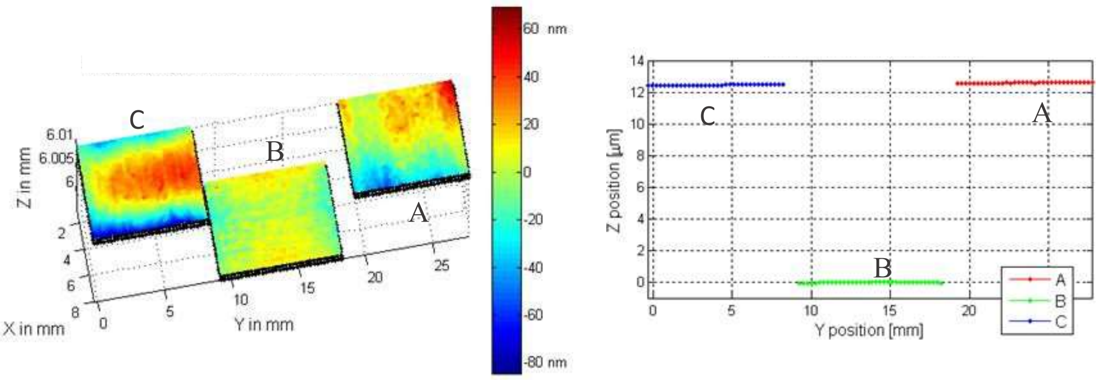

Figure 9 Measurement results of the bridge gauge on the ISARA 400 with surface representation (left) and cross section of the surfaces (right)

10 Results

Comparison of the measurement data between ARINNA and the ISARA 400 shows a maximum deviation in step height measurement of 18 nm. This deviation is consistent with the combined measurement uncertainty of the ISARA 400 and ARINNA. This shows that ARINNA can be used as a fast and high accuracy metrology instrument to measure micro- and nanoscale surfaces.

Step	WSI	ISARA 400	Difference
A-B	12.649 µm	12.631 µm	18 nm
B-C	12.479 µm	12.495 µm	16 nm

Figure 10 Measurement comparison between ARINNA and the ISARA 400

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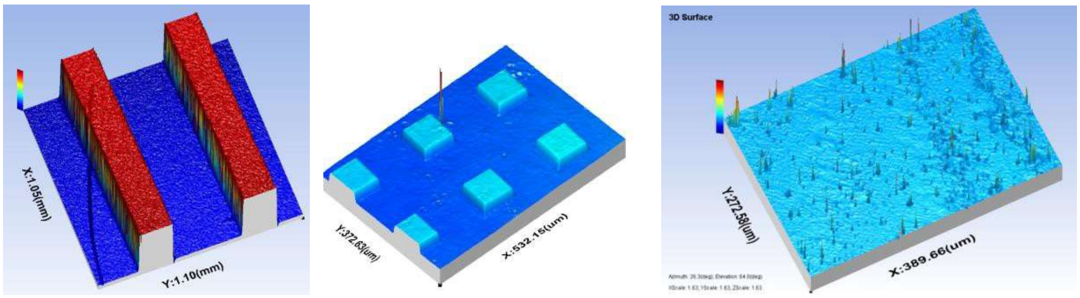
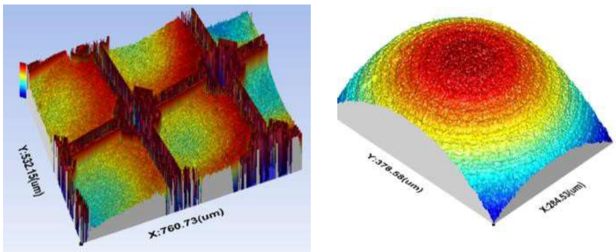
10.1 Applications

ARINNA is suitable for the calibrated measurement of a range of industrially relevant structures. A selection of measurements is shown in Figure 11, demonstrating the combined capability of large vertical range, sub 2 nm resolution and the ability to measure discontinuous surfaces.



a) b) c)



d) e)

Figure 11 ARINNA measurement results: a) 5 µm pillars on IC b) Structured surface with 100nm raised platforms c) Contaminant particles on PET foils (z- range 20 µm) d) MEMS mirror array (z-range 230nm) e) Fresnel lens (z-range 2 µm)

11 Conclusion

ARINNA has been introduced as a new measurement tool for fast and high precision areal surface measurements of micro and nanoscale structures; including stepped and freeform surfaces. The absolute uncertainty has been proven to lie below 18nm by comparison to a traceable contact measurement system. Testing on a range of samples has confirmed its combination of high speed, large vertical range, nanometer resolution and millimeter area sampling.

Through the addition of a novel vibration compensation scheme, the system has also been made suitable for on-line integration.