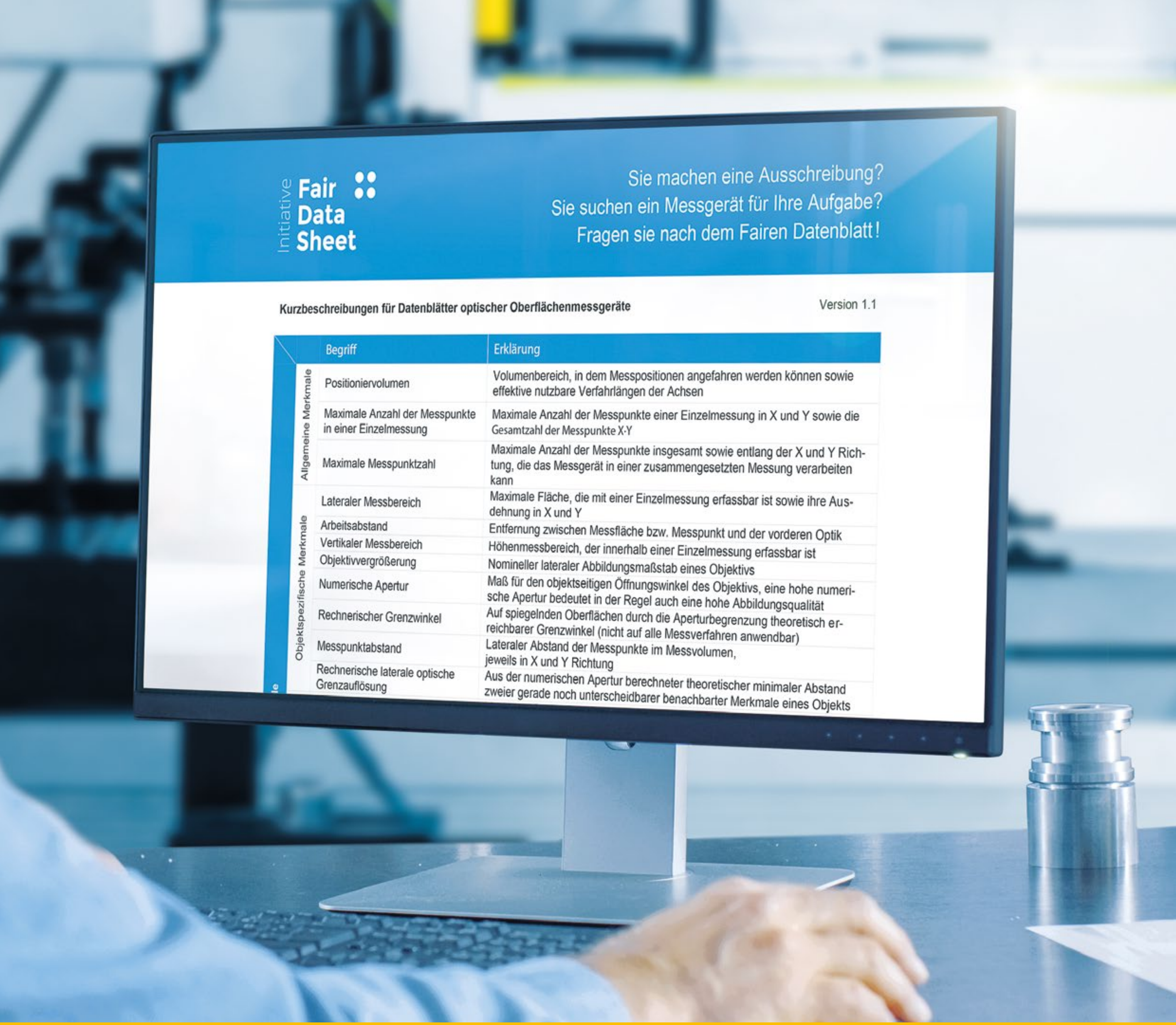

How fair are specifications in optical surface metrology?

“Fair Datasheet” as a guideline for comparing specifications of different optical surface measurement systems

In manufacturing metrology, measurement results are the necessary feedback for monitoring and regulating the production. While surface metrology checks sample tolerances, the evaluation of the entire topography of work pieces provides valuable hints for the production process itself.

With the right evaluation procedure on measurement data, manufacturing benefits from additional information like the presence of environmental vibration, unbalanced machining conditions, wear or changing material properties. In the end, the selection of the right measurement technique regarding surface inspections is key for quality, functionality and durability of produced parts. So what details should we look for in the selection process? Datasheets provide general technical specification and are crucial for the decision. But are datasheets standardized enough, so technicians and purchase departments can compare them easily? The specifications comprise general information about the metrological performance of a particular optical instrument, like vertical or lateral resolution, but the measurement of specific samples remains a quite individual task.

First of all, there are many more factors like environmental conditions, individual characteristics or the sample material itself, which should be considered. And the determination of the measurement uncertainty, when considering many influencing factors (operator, sample, environment, ...) is the right way to understand the "measurement" itself. The measurement uncertainty is a strong method which can be estimated by declared and accepted procedures, described in the *ISO Guide to the Expression of Uncertainty in Measurement* or GUM, published in 1993. Though the measurement uncertainty is specific to a measurement and not a characteristic for the instrument, on the other hand any information in datasheets regarding measurement uncertainty is helpful.

Secondly, there are different approaches in the datasheets of optical surface metrology on what to specify and how to specify. This shows differences among available datasheets, as the conditions under which they are specified are not always clear and practice-oriented, which makes datasheets not comparable and the customers are left alone.

Looking at elementary specifications like the lateral and vertical resolution for optical surface measurement instruments, we can even see different approaches from manufacturers from Europe, Asia and North America.

Varying definition of the lateral resolution

Originated from microscopy (not optical surface metrology), two peaks are accepted to be resolved if the image complies with the Rayleigh's criterion. To get the shortest distinguishable distance between two points, Lord Rayleigh said, that two points are resolved if the distance between them is larger than the distance between the main maximum and minimum of the diffraction pattern. Thus, the resolution is a function of the wavelength (λ) and the numerical aperture (NA) of the objective:

$$\text{Lateral resolution} = \frac{1.22 \cdot \lambda}{2 \cdot NA} = 0.61 \frac{\lambda}{NA}$$

The achieved minimum separation between resolved asperities determines the best lateral resolution of the system. The Sparrow criterion, however, calculates the resolution with a factor appr. 20% smaller than the Rayleigh factor. This means, Sparrow is not as strict as Rayleigh and the calculated resolution is specified smaller. Regarding the lateral resolution, some manufacturers specify according to the Rayleigh criteria, some follow the Sparrow criteria and others even use their own definitions.

Comparing approaches for lateral resolution	
Manufacturer A	*“Lateral Resolution = Sparrow criterion”*
Manufacturer B	*“Spatial sampling = Pixel size on the surface. Optical resolution = Half of the diffraction limit according to the Rayleigh criterion. Values for white LED. Spatial sampling could limit the optical resolution.”*
Manufacturer C no direct information in the data sheet	*“Width measurement accuracy: Value obtained using manufacturers` specified standard gauge with measurement in manufacturers` specified measurement mode.”*

Different approaches for vertical resolution

From a practical point of view, the term “vertical resolution” basically tries to specify the smallest step-height measurable before the measurement data disappears in noise. An approach for reducing noise is repeating the measurement and taking the average, which in a real production environment is hardly possible.

Comparing approaches for vertical resolution	
Manufacturer A no direct definition but related information in the foot notes	Footnote 1) *“Repeatability of the RMS surface roughness parameter Sq, under the same conditions as for (2). Note that the repeatability of the Sq is sometimes referred to informally as vertical resolution.“* Footnote 2): *“Surface topography repeatability for SmartPSI mode, 1-sec acquisition, full FOV with 3x3 median filter, in a lab environment”*
Manufacturer B	Vertical resolution: *“System noise measured as the difference between two consecutive measures on a calibration mirror placed perpendicular to the optical axis.* *For interferometric objectives, PSI, 10 phase averages with vibration isolation activated. The 0.01 nm are achieved with Piezo stage scanner and temperature controlled room.”*
Manufacturer C	A value for vertical resolution is provided, but no information about how to calculate / measure.

The rising need for comparison

- Identical definitions are lacking, which allows manufacturers to define their own attractive values.
- Datasheets are not comparable and can easily confuse non-expert users, possibly resulting in sub-optimal investment decisions.
- Values can be obtained under ideal conditions or with some averaging techniques. But those are not practice-oriented and in most cases, it is not the information that a customer looks for.

The fair datasheet

An association consisting of optical surface instrument manufacturers (e.g. Polytec, Alicona and Nanofocus), key users of such equipment (e.g. Audi, Bosch and Daimler) and scientific supervisors (Technical University of Kaiserslautern, PTB Physikalisch Technische Bundesanstalt and industrial institutions like ZVEI and VDI) have developed the "Fair Data Sheet". The results of the working group not only cover the definition of metrologcial features but also recommend a general structure for datasheets in optical surface metrology. The full version of all documents, issued by the Fair Data Sheet Initiative can be downloaded on
http://optassyst.de/fairesdatenblatt/

The approach of the Fair Data Sheet allows the comparison of different instruments and technologies with each other, and it also helps manufacturers in purchase processes by providing understandable and reproducible specifications.