# Definition of a Comparable Data Sheet for Optical Surface Measurement Devices

**Fair Data Sheet Initiative**

**Version 1.2α**

41. April 2016

www.optassyst.de/fairesdatenblatt

© 2015 Fair Data Sheet Initiative and the authors

# Contents

Page

## Terms of use

This document and all other documents belonging to the complete *Fair Data Sheet* package are protected by copyright. The *Fair Data Sheet Initiative* and the authors grant a license, with unlimited scope in terms of time and space, to duplicate, distribute and use the *Fair Data Sheet* as a complete and unmodified package, including these terms of use. An exception to this rule is the document "Brief Descriptions for Data Sheets of Optical Surface Measurement Devices." It may be distributed and duplicated without modifications and without the complete package.

The "OptAssyst" logo is a registered trademark of PTB (National Metrology Institute of Germany).

The logo of the *Fair Data Sheet Initiative* is a registered word-image logo of PTB.

The most recently published edition of the *Fair Data Sheet*, along with related information can be found online at:

http://optassyst.de/fairesdatenblatt/

# Preface

People who use and buy optical measurement devices are often overwhelmed by the choices: Many different manufacturers offer a vast range of 3D measuring methods designed to analyze the topography of surfaces. When faced with such a situation, a comparison of the data sheets should help to identify the most suitable device. But what usually happens is that one has more questions after reading the data sheets than before. Different terms to describe the same features and similar terms for different features serve only to confuse the reader.

This is where the *Fair Data Sheet Initiative* comes into play: By defining uniform specifications for equipment and processes, it helps users to objectively compare devices and technologies. The initiative is supported by manufacturers of measuring instruments (Alicona GmbH, NanoFocus AG and Polytec GmbH), by important users of measurement technology (Audi AG, Robert Bosch GmbH, Daimler AG), the Technical University of Kaiserslautern, the Physikalisch-Technische Bundesanstalt (PTB, National Metrology Institute of Germany) and not lastly by relevant industrial associations, such as the Zentralverband Elektrotechnik- und Elektronikindustrie e.V. (ZVEI, German Electrical and Electronic Manufacturers' Association) and the Verein Deutscher Ingenieure e.V. (VDI, Association of German Engineers).

# Introduction

The *Fair Data Sheet* is made up of three components: The actual definition of the feature described in the document, a brief description and a recommended structure. The definition of the feature and the regulations on how to specify it have been developed over the last two years by a task force made up of members of international standardization bodies and experienced users. Whenever possible, existing standards and guidelines were used as a basis. The procedure is intended to provide a reliable way for different devices and technologies to be compared to one another. And it also serves as an aid to the manufacturers of measuring instruments, enabling them to create data sheets with reproducible specifications.

A compact *Brief Description for Data Sheets of Optical Surface Measurement Devices,* compiled by the *Fair Data Sheet Initiative*, is intended to convey a fundamental understanding of the features to the user and to enable them to best utilize the data sheet. A recommendation on how to clearly structure the data sheet, specifying the sequence of the data, rounds off the *Fair Data Sheet*.

The next step planned is to integrate the *Fair Data Sheet* in the international standardization process. The intention and hope is that the inclusion in the standardization process as well as the wish for greater transparency expressed by users of optical measurement technology will ensure that the *Fair Data Sheet* is quickly adopted and used by many equipment manufacturers and users.

## Documents that make up the Fair Data Sheet

The documents listed here, when taken all together, are the components of the *Fair Data Sheet*. They may be distributed only as an unmodified complete package.

- "Definition of a Comparable Data Sheet for Optical Surface Measurement Devices":
  Contains all definitions of terms as well as instructions on determining the features of the specification

- "Brief Description for Data Sheets of Optical Surface Measurement Devices", compiled by the *Fair Data Sheet Initiative*:
  A compact, one-page document that helps readers to better understand the data sheets created in compliance with these specifications; contains brief explanations of the terms.

- Description of the brands *Fair Data Sheet Initiative* and *Initiative Faires Datenblatt*: Description of brands and provisions for the reproduction and use.

# Definition of a Comparable Data Sheet for Optical Surface Measurement Devices

## 1 Definition format

The definitions contained in the following sections are composed following the guidelines described here: The section number is followed immediately by the term to be defined and a colon. The unit(s) is/are stated after the colon. Just below that, the symbol used to designate the variable appears (if applicable). The definition follows. The subsequent notes explain more precisely how a variable is to be determined and handled. When helpful, an example will be cited for better comprehension.

Example of the definition format:

**1.1**
**Term: Unit(s)**
**Symbol (optional)**
Definition

NOTE Explanatory remark

EXAMPLE Optional example

## 2 Device-specific features

The device-specific features provide specification of a device for a certain application.

### 2.1 General features

**2.1.1**
**Positioning volume: m³**
Volume range in which measuring positions can be approached

NOTE The effectively usable path lengths of all positioning axes as well as the total volume must be stated.

EXAMPLE $0.8 \times 0.8 \times 1.5\ m^3 = 0.96\ m^3$

**2.1.2**
**Maximum number of measuring points in a single measurement: 1**
Maximum number of measuring points in a single measurement in X and Y as well as the total number of measuring points X·Y

EXAMPLE X: 1024, Y: 1024, X·Y: 1 048 576

**2.1.3**
**Maximum number of measuring points: 1**
Maximum total number of measuring points in a stitched measurement that the instrument can process in X and Y as well as the total number of measuring points X·Y

NOTE 1 The total number of measuring points can be less than the product of the number of measuring points in *X* and *Y*.

NOTE 2 The specification should take into consideration all system restrictions that limit the number of measuring points.

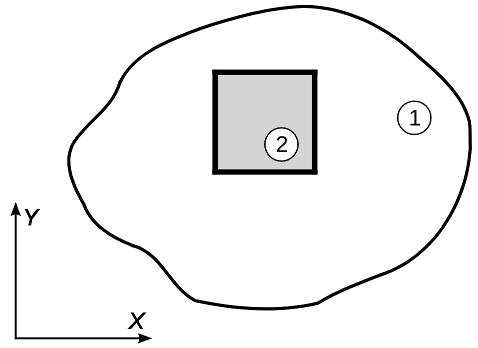
EXAMPLE X: 32 768, Y: 32 768, X·Y: 100 000 000

## 2.2 Objective-specific features

**2.2.1**
**Measuring area: m, m²**
Maximum area that can be detected with a single measurement as well as its extension in *X* and *Y* (Refer to Figure 1, no. 2)

NOTE The dimensions of the lateral measuring range in *X* and *Y* as well as the area *X*·*Y* must be stated.

EXAMPLE X: 1.4 mm, Y: 1.2 mm, X·Y: 1.68 mm²

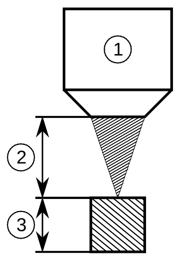



**Legend:**

1) Measured object
2) Measuring area

**Figure 1 — Definition of measuring area**

**2.2.2**
**Working distance: m**
Distance between measuring area or measuring point and the front edge of the optics (Refer to Figure 2, no. 2)




**Legend:**

1) Objective
2) Working distance
3) Vertical measuring range

**Figure 2 — Definition of working distance and vertical measuring range**

**2.2.3**
**Vertical measuring range: m**
Height measuring range detectable within a single measurement (Refer to Figure 2, no. 3)

NOTE All of the subsequent specifications in the data sheet must be based on the specified vertical measuring range. If e.g. better specifications would be achieved with a smaller measuring range, the smaller measuring range should be stated as the vertical measuring range.

EXAMPLE 500 µm

**2.2.4**
**Objective magnification: 1**
Nominal lateral imaging scale of an objective

NOTE 1 The manufacturer normally indicates the objective magnification directly on the objective.

NOTE 2 The objective magnification is generally not a suitable basis for comparison. The measuring area is decisive.

EXAMPLE 10x for an objective with 10x magnification

**2.2.5**
**Numerical aperture: 1**
***$A_N$***
Sine of half of the aperture angle of the objective towards the object, multiplied by the refractive index of the surrounding medium

NOTE 1 A high numerical aperture can have a positive impact on the lateral and axial resolution of a measuring method.

NOTE 2 The theoretical minimum value of $A_N$ is 0.

NOTE 3 The theoretical maximum value is a factor of the surrounding medium. The value of air is close to 1.

NOTE 3 When using immersion objectives, the surrounding medium has a refractive index greater than 1. Thus these objectives can achieve an $A_N > 1$.

NOTE 4 The abbreviation NA is often used in technical documents and on objective labels.

**2.2.6**
**Calculated maximum angle: °**
**α**
The maximum angle limited by the aperture angle that could theoretically be measured on mirror-like reflecting surfaces

$$\alpha = \sin^{-1} \frac{A_N}{n}$$

- $\alpha$ Calculated maximum angle
- $A_N$ Numerical aperture
- $n$ Refractive index of surrounding medium

NOTE 1 This method does not apply to measuring methods that cannot detect reflective surfaces.

NOTE 2 The angle is specified in relation to the X-Y plane, which is perpendicular to the optical axis.

NOTE 3 The refractive index of air can usually be assumed to be 1.0.

NOTE 4 The effective maximum angle of a system has to be determined by trial and error for each application.

**2.2.7**
**Measuring point spacing: m**
Sampling interval of measuring points in the measuring volume, both in X and in Y direction

NOTE 1 In ISO 25178-600, the measuring point spacing in object coordinates is defined as "sampling interval," which should not be confused with the lateral resolution of an optical system.

NOTE 2 The minimum and maximum value should be specified for systems with variable or switchable measuring point spacing.

EXAMPLE X: 1.5 µm or 3.0 µm, Y: 2.0 µm

**2.2.8**
**Calculated lateral optical resolution: m**
***$\delta_L$***
Minimum theoretical distance between two adjacent, barely distinguishable features of an object, calculated from the numerical aperture

$$\delta_{\mathrm{L}} = \frac{0{,}61 \cdot \lambda}{A_{\mathrm{N}}} \quad (1)$$

— $\lambda$ Average wavelength of light used

— $A_{\mathrm{N}}$ Numerical aperture of objective

NOTE 1 The maximum value of the calculated lateral optical resolution and the measuring point spacing (Refer to definition 2.2.7) should always be stated for $\delta_{\mathrm{L}}$.

NOTE 2 The Raleigh resolution serves as the criterion for calculation.

NOTE 3 The optical resolution can be achieved only under ideal conditions (including complete illumination of the pupil) on planar objects. This value is usually not reached on textured surfaces.

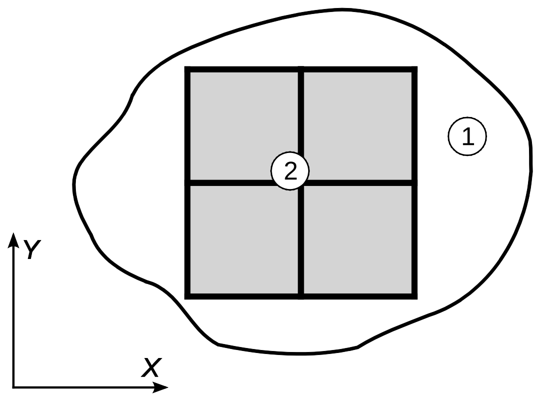
## 2.3 Extended measuring area

**2.3.1**
**Extended measuring area: m, m²**
Maximum size of lateral measuring range that can be detected by stitching multiple single measurements when using the maximum number of measuring points in a single measurement (Refer to definition 2.1.2) in the measuring area (Refer to Figure 3).

NOTE 1 The maximum length of the extended measuring range in X- and Y-direction as well as its maximum area are specified.

NOTE 2 When specifying the measuring area, all limiting factors of the device must be taken into consideration, particularly the positioning volume (Refer to definition 2.1.1) and the maximum number of measuring points (Refer to definition 2.1.3).

NOTE 3 Compounding multiple single measurements is called "stitching."




**Legend:**

1) Measured object

2) Extended measuring area

**Figure 3 — Definition of extended measuring area**

**2.3.2**
**Extended measuring area with data reduction: m, m²**
Maximum size of lateral measuring range that can be detected by stitching multiple single measurements, each with a respectively reduced number of measuring points

NOTE 1 Decreasing the number of measuring points usually serves to increase the extended lateral measuring range and/or to reduce the measurement and evaluation time.

**2.3.3**
**Extended vertical measuring range: m**
Maximum height range that can be detected by stitching multiple single measurements at a single lateral position

NOTE The maximum height range in Z that can be detected in this way is specified. All limiting factors of the specified device and objective must be taken into consideration, particularly the vertical measuring range (Refer to definition 2.2.3) and the working distance of the objective (Refer to definition 2.2.2).

## 2.4 Performance features

**2.4.1**
**Measurement noise: m**
Temporal noise of height values, determined during normal usage under ideal ambient conditions

NOTE 1 The value is determined applying the subtraction method[1)] [2]: The pointwise difference is calculated between two immediately consecutive measurements of a planar surface in the same position, under ideal laboratory and measurement conditions. The $S_q$ parameter [ISO 25178-2] is calculated from the S-F surface *without* using an S filter. The result is divided by √2. There may be no time-related averaging and no optional filtering of measurements; only signal processing specific to the procedure is permitted.

NOTE 2 If there is a significant drift in time between the measurements, the drift can be eliminated through leveling by subtraction or rotation before the subtraction of the single measurements.

NOTE 3 An S filter may be used on single measurements only when it is part of the normal measuring process.

NOTE 4 Measurement can be repeated several times to stabilize the estimate of the measurement noise. The stabilized measurement noise is determined as an arithmetic average applying the following formula:

$$\overline{N}_{\mathrm{M}} = \frac{1}{n} \sum_{i=1}^{n} N_{\mathrm{M},i} \tag{2}$$

with

$\overline{N}_{\mathrm{M}}$ Stabilized measurement noise

$N_{\mathrm{M},i}$ Measurement of the *i*-th measurement

$n$ Number of times measurement of the noise is repeated.

NOTE 5 Averaging the measurement noise does not cause it to decrease; it leads only to stabilization of the estimate.

EXAMPLE 15.8 nm

**2.4.2**
**Vertical resolution: m**
***$\delta_A$***
Smallest distinguishable level calculated from the measurement noise, with a 95% probability of being detected

$$\delta_A = N_{\mathrm{M}} \cdot \sqrt{8}$$

NOTE 1 The fundamental assumption is normally distributed measurement noise. Thus 95% of the measuring points are within an interval of the width $2 \cdot N_{\mathrm{M}}$. To prevent the intervals of two levels from overlapping, the distance between two levels must be at least √8-fold of $N_{\mathrm{M}}$.

1) Specification in ISO 25178-700 planned

NOTE 2 Also refer to chapter 7.1 [1] and to [2]

EXAMPLE 44.7 nm

## 2.5 Dimensions and ambient conditions

### 2.5.1
### Dimensions: m
Dimensions of the instrument and accessories. Used to plan the space in which the equipment will be set up. Specified in the three dimensions in space: width, depth and height

NOTE When devices consist of several physically separate components, each component should be specified individually.

EXAMPLE W×D×H: 0.521 × 0.780 × 0.430 $m^3$

### 2.5.2
### Mass: kg, t
Total mass of equipment, including all components needed for operation

NOTE Optional components can be specified separately when they constitute a relevant portion of the total mass.

EXAMPLE 43 kg

### 2.5.3
### Ambient temperature range: ° C
Permitted range of ambient temperature during measurement in which the specifications in the data sheet are met

NOTE The operating temperature range of the instrument may be greater than the ambient temperature range.

BEISPIEL 18°C to 22°C

### 2.5.4
### Permitted temperature gradient: K/h
Maximum rate of temperature change during measurement

EXAMPLE 0.7 K/h

### 2.5.5
### Permitted relative humidity: %
Permitted range of relative humidity (non-condensing)

EXAMPLE 30% to 70%

### 2.5.6
### Supply voltage and type of current: V,$V_{eff}$, Hz
Permitted voltage and frequency range of power supply voltage

NOTE 1 The supply voltage should be stated as an absolute value or, in the event of AC voltage, as an effective value.

NOTE 2 The type of current should be specified as direct current or two-phase alternating current or as three-phase current.

EXAMPLE 230 to 240 $V_{eff}$ / 50 to 60 Hz AC

### 2.5.7
### Electrical power: W
Maximum electrical power consumption

EXAMPLE 250 W

## 2.6 Other features

**2.6.1**
**Measuring principle: Text**
Name of fundamental physical phenomenon

EXAMPLE 1 Phase-shifting interferometry

EXAMPLE 2 Confocal microscopy

EXAMPLE 3 White-light interferometry

EXAMPLE 4 Focus variation

**2.6.2**
**Export formats: Text**
Data formats to which the topography data can be exported

EXAMPLE X3P, FDS, STL, TIFF

# 3 Application-specific features

The application-specific features provide specification of a device for a certain application.

**3.1**
**Flatness deviation: m**
$z_{\mathrm{FLD}}$
Deviation of the measured topography of ideal optical flat from a plane for the single measuring area[2)]

NOTE 1 The flatness deviation is determined based on a flatness standard. The standard has to be leveled mechanically, while the measured data has to be leveled mathematically. The parameter for flatness deviation is $S_z$.

NOTE 2 The flatness standard should be measured in several positions to stabilize the estimate of the flatness deviation. All measurements are averaged point by point. The standard averaging method is the media operator. The $S_z$ parameter of the resulting averaged topography is the stabilized flatness deviation $z_{\mathrm{FLD}}$. The number of measurements performed must be stated.

NOTE 3 When filters are used in applications with topographies with limited bandwidth, the same filters must be used when determining the flatness deviation. The filter conditions have to be specified.

EXAMPLE 1 35.0 nm (20 measurements)

EXAMPLE 2 0.5 nm (15 measurements, S filter cut-off wavelength 150 µm)

**3.2**
**Maximum deviation of a step height measurement: m**
Greatest deviation of step heights in the total vertical measuring range obtained by multiple measurements

NOTE 1 The step height is checked with a step standard with planar reference surfaces (e.g. groove standard A-1 pursuant to ISO 5436-1).

NOTE 2 Different step heights are measured across the entire measuring area.

NOTE 3 The step is measured once to determine the height. Two plane-parallel planes with a total least squares fit analog to the description for single profiles in ISO 5436-1 section 7.1. are fitted[3)]. The distance between the parallel planes is the measured step height.

---

2) Definition planned in ISO 25178-700

3) Definition of step height measurement planned in ISO 25178-700

NOTE 4 The maximum deviation can also be specified for different step height ranges as a table.

NOTE 5 Each step should be measured in at least five positions, starting from the middle of the vertical measuring range, such that the entire measuring range is covered.

EXAMPLE 1.5 µm (step height 100 µm )

# 4 General application guidelines

## 4.1 Expansion of the data sheet

The definitions in the *Fair Data Sheet* do not restrict or confine the document. Additional information may always be included in the data sheet. However, the specifications defined in the *Fair Data Sheet* have to be clearly recognizable as such.

## 4.2 Maximum specification

All of the devices in the series must comply with specifications in the data sheet. So there must always be a "maximum specification" that is always complied with under the specified measurement conditions. By limiting its scope of application, e.g. by selecting a smaller vertical measuring range, a device can acquire better properties. This procedure is permitted when the restrictions are specified by the respective properties. Multiple scopes of application can be specified if standard use of the device can accommodate this.

EXAMPLE Measurement noise 4.4 nm at 20 µm vertical measuring range
Measurement noise 6.5 nm at 150 µm vertical measuring range

## 4.3 Voluntary commitment

Equipment manufacturers who publish a *Fair Data Sheet* in compliance with the stipulations of this document agree to conform to all of the specifications of this document when defining the properties. This is the requirement for designating a data sheet as a *Fair Data Sheet* and displaying on it the logo of the *Fair Data Sheet Initiative*. The parameters determined pursuant to the stipulations of the *Fair Data Sheet* as well as additional parameters should be clearly labeled.

**Figure 4: Logo of *Fair Data Sheet Initiative* The copyright holder of the "Fair Data Sheet Initiative" word-image logo is the Physikalisch-Technische Bundesanstalt (PTB), Braunschweig.**

# 5 Acknowledgments

The *Fair Data Sheet Initiative* wishes to thank everyone who contributed to the productive discussions and offered suggestions. Thanks also go to the supporters of the *Fair Data Sheet Initiative*: Audi AG, Robert Bosch GmbH, Daimler AG, Physikalisch-Technische Bundesanstalt (PTB), ZVEI – Zentralverband Elektrotechnik- und Elektronikindustrie e.V., VDI – Verein Deutscher Ingenieure e.V.

## 5.1 Authors

In alphabetical order: Wilfried Bauer (Polytec GmbH), Franz Helmli (Alicona GmbH), Jörg Seewig (Technical University of Kaiserslautern), Rolf Krüger-Sehm (formerly Physikalisch-Technische Bundesanstalt, retired) and Georg Wiora (NanoFocus AG).

## 5.2 Other contributors

Other contributions and suggestions were submitted by Sebastian Boedecker (Polytec GmbH), Till Grübler (Robert Bosch GmbH, Bamberg), Tobias Hercke (Daimler AG), Ludger Koenders (Physikalisch-Technische Bundesanstalt) and Sebastian Pehnelt (Audi AG).

# Annex A
(informative)

## Recommended structure

We recommend always structuring the data sheet as shown in Table A.1. This enables readers to easily compare different measurement systems. Each manufacturer can design the data sheet and add features and illustrations to best serve his purpose.

A further breakdown of the structure is helpful when the device e.g. has multiple scan axes, the use of which leads to different specifications.

**Table 1 — Recommended data sheet structure**

| **Type of measurement instrument** | | |
|---|---|---|
| Measuring principle | | |
| General specifications | | |
| Objective-specific features | | |
| Objective designation 1 | Objective designation 2 | Objective designation *n* |
| Objective-specific features 1 | Objective-specific features 2 | Objective-specific features *n* |
| Extended measuring range 1 | Extended measuring range 2 | Extended measuring range *n* |
| Performance features 1 | Performance features 2 | Performance features *n* |
| Dimensions and ambient conditions | | |
| Other specifications | | |
| **Application-specific features** | | |
| May be dependent on objective | | |

# Bibliography

[1] Richard Leach, *Optical Measurement of Surface Topography*, Springer 2011, ISBN 978-3-642-12011-4

[2] VDI/VDE 2655 - Optische Messtechnik an Mikrotopographien, Blatt 1.1 "Kalibrieren von Interferenz-mikroskopen und Tiefeneinstellnormalen für die Rauheitsmessung"