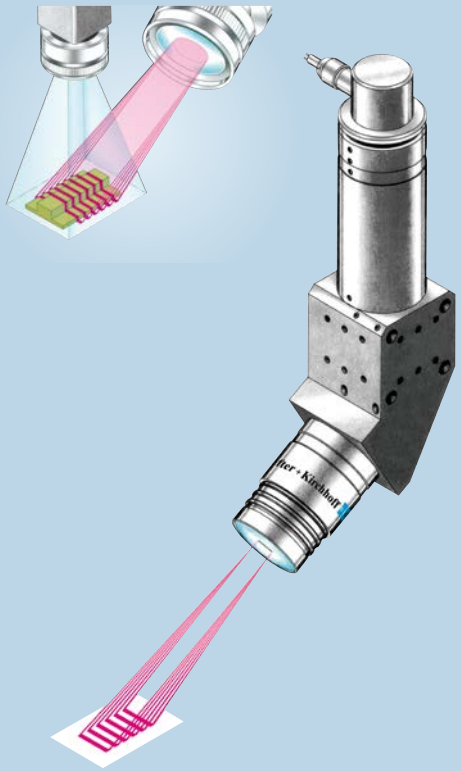
3D Measurements

Structured Illumination for 3D Measurements



Structured Illumination for 3D Measurements

Precision Grid Projector SK5732

Structured Illumination for 3D Measurements

Multi-line light-sectioning is a technique to measure small height differences in structured objects by using a grid projected onto the object surface at a low angle. A matrix camera perpendicular to the object is used to record the image of the projected grid lines. A structured object distorts or displaces the grid image and this is recorded by the camera for evaluation of the line displacement and calculation of the object height, contour or profile.

The grid lines are generally projected onto the object at an angle of 30° to the object plane (60° to the optical axis of the imaging camera) using the Scheimpflug principle to generate evenly illuminated grid lines with a rectangular intensity profile.

The use of a broadband and incoherent light source is advantageous because the resulting structured illumination of the Precision Grid Projector is totally free of the inherent speckling of structured illumination laser sources.

Main features:

- **Uniformly sharp grid in whole projection field due to 30° Scheimpflug projection**
- **Incoherent light source: high power LED, suitable for high frequency external modulation for grid projection without speckle and diffraction fringes**
- **Projection field 5 mm x 10 mm**
- **Height measurement range (projection limited) ± 0.5 mm**
- **Height resolution <4 µm with standard matrix cameras**

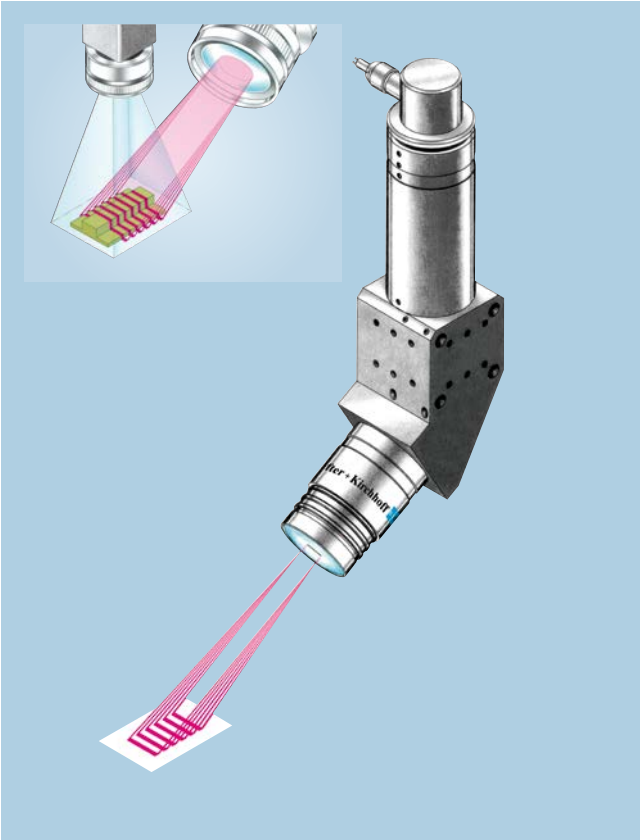


Table 1 Parameters of 3D measurement for camera magnification β = 1, depending on pixel size

Sensor	1/3''	1/2''	2/3''	CMOS 1024
Pixel number (horiz.)	756	756	756	1024
Pixel size / µm	6.3	8.5	11.6	10
Image field width / mm	4.8	6.4	8.8	10.2
Height resolution /µm	3.7	4.9	6.7	5.8
Measurement range continuous / mm	±0.5			
Meas. range non-continuous / mm	0.58			

Table 2 Depth of focus for camera magnification β = 1, depending on pixel size

f-Number	Depth of focus / mm			
2.8	0.07	0.09	0.13	0.11
4	0.10	0.14	0.19	0.16
4.5	0.11	0.15	0.21	0.18
5.6	0.14	0.19	0.26	0.22

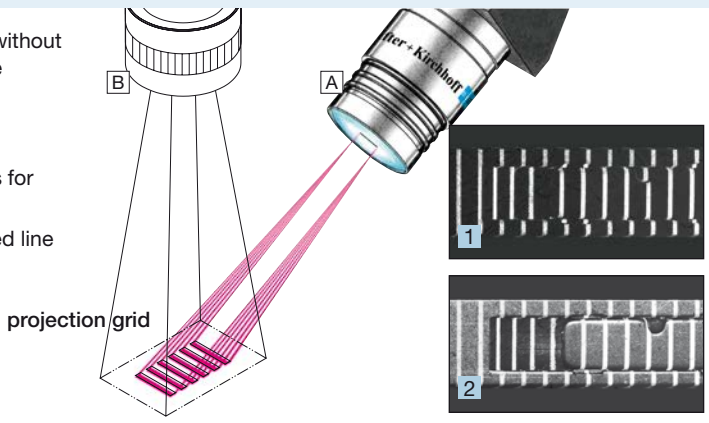
Precision Grid Projection

Projection setup showing the grid projection pattern without an object and the displacement of the grid lines in the presence of the object to be measured.

A Precision Grid Projector SK5732

B Perpendicularly mounted camera with macro lens for recording the projection grid displacement

The imaged object is shown using projected structured line illumination at low 1 and high 2 levels of incident illumination.



03-2018 E Grid-Projector_LaserLines_2018.indd • Page 130

Height Resolution

The height resolution of this measurement technique is determined by the projection angle of the grid and by the spatial resolution of the matrix camera.

$$\Delta h = \beta \ \Delta x \ \tan(\alpha)$$

where

Δh: Height difference corresponding to a single pixel width of the sensor

β: Magnification, β = Object width / Sensor width

Δx: Pixel size in direction x

α: Projection angle of the grid in respect of the object plane (30°).

Example:

1/3'' CCD camera with 756 x 581 pixels,
sensor size 4.8 mm x 3.6 mm
pixel size Δx = 6.3 µm, magnification β = 1,
region recorded on object of 4.8 mm x 3.6 mm

$$\Delta h = 1 \ x \ 6.3\ \mu m \ x \ \tan(30°) = 3.7\ \mu m$$

The displacement of a grid line by
1 pixel = a height difference of **3.7 µm**.

Due to the speckle free projected grid lines, subpixel algorithms can be used to further increase the measurement resolution. The resolution achieved in practice also depends on properties of the object surface.

A rough surface texture, for example, complicates the edge detection and thus also decreases the measurement resolution.

Meaurement Range

The measurement range is different for continuous and non-continuous height changes.
Non-continuous height changes (steps or leaps) lead to ambiguous recordings if the line displacement is equal to or greater than the distance between two grid lines. This limit corresponds to the height difference

$$\Delta H = \Delta L \ \tan(\alpha)$$

where

ΔH: Height difference measurable from the grid line spacing interval

ΔL: Grid line spacing interval

α: Projection angle of the grid, with respect to the object plane (30°).

Example:

A grid line interval of **1 mm** = a height discrimination distance of **0.58 mm**.

Gradual height changes lead to unambiguous and traceable grid displacements.

The depth of focus of the grid projection thus limits the height measurement range to approximate ±0.5 mm.

Dimensions for Precision Grid Projector SK5732

Specifications

Projection field	5 x 10 mm
Projection angle	α = 30°
Structure	15 strips
Light source	LED
Lifetime	30 000 hours
Wavelength	627 ± 30 nm
Weight	700 g
Dimensions	110 x 227 x 52 mm
Free working distance	38 mm
Power supply	5 V / 1.4 A