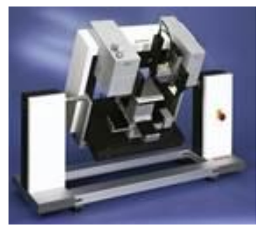
Difference between most common commercial contact angle meters around the world

Item			KINO		KRUSS	KSV	Ramehart	KYOWA
Model			C602	SL200KS	DSA100E	Theta	Model 590	DM901
Components					standard component + PA3220 Tilting Base Assembly for DSA100 + EM3210 Electronic Module + DS3210 Single Direct Dosing System	standard component + T330 Motorized XYZ sample stage + C204A Tilting cradle		Standard component + DM-SA01 sliding method kit
Appearance								
1	Sample stage and its control system *1	X axis*2	Automatic, Motorized linear stage controlled by software with slide guide, travel range: 100mm, accuracy: 5um, resolution:0.1 um	Manual, linear stage with slide guide, travel range: 60mm, accuracy: 20um, resolution:10um	Automatic, common motion system controlled by software, travel range: 100mm	Automatic, controlled by software, travel range: 180mm, Resolution: 0.01mm	Manual, travel range is not mentioned	Automatic, controlled by software, travel range: 150mm
2		Y axis				Automatic, controlled by software, travel range: 60mm, Resolution: 0.01mm, provide a long travel dovetail guide for quick movement		Automatic, controlled by software, travel range: 75mm
3		Z axis*3	Manual, controlled by crossed-roller guide positioner with micrometer, travel range: 50mm, accuracy: 0.01mm		Manual, controlled by rack and pinion dovetail stage, travel range:40mm	Automatic, controlled by software, translating optical post holder, travel range: 30mm, Resolution: 0.01mm	translating optical post holder	Manual, Z-axis: 35 mm Moving camera

4		Levelness adjustment*4	Dual-axes tilting stage with micrometer	N.A.	Simple screw adjusting structure	Simple screw adjusting structure	N.A.
5		Size of sample stage	100*100mm/120*120mm	105*105mm	75*75	51 x 76mm	150*150mm
6		Max sample size	Unlimited x 310 x 100 mm	Unlimited x 300 x 100 mm	W unlimited x L 180 x H 95mm	up to 300 x 300mm	150 mm x ∞, thickness 35mm, 400g max
7		Tilting stage *5 (For measurement of roll-off angle and advancing and receding contact angle)	Specially designed mechanical Structure: Rotating only Lens, sample stage and its control system.	Complete machine rotated	Complete machine rotated	Complete machine rotated	Complete machine rotated
8	Dosing system and it control system	Dosing system*6	Automatic direct single syringe pump	Automatic direct single syringe pump	Manual singe syringe pump or automatic syringe pump	automatic syringe pump	Automatic direct single syringe pump
9		Drop transferring*7	Automatic Needle up and down	Automatic Needle up and down	Automatic Needle up and down	Manual Needle up and down	Automatic, sample stage up and down
10		Positioning of needle X axis	Manual, controlled by crossed-roller guide positioner with micrometer, travel range: 12.5mm, accuracy: 0.01mm	N.A.	Not Mentioned	Not Mentioned	Not Mentioned

11		Focus distance adjustment			N.A.	Not Mentioned	Not Mentioned	Not Mentioned
12	Vision system	Camera*8	1/1.8" HD and high speed camera (Image resolution:1280*1024, Speed: 60FPS (1280*1024)-119FPS(640*512)-221FPS(320*256)-427FPS(800*120); USB3.0)	1/3" HD and high speed camera (Image resolution:752*480, Speed: 87FPS (752*480)-340FPS(752*120); USB2.0)	1/2" VGA camera, Image resolution: 780*580, speed: 61FPS (780×580)- 73FPS (780×480)-212FPS (780×120)-311FPS(780×60); IEEE1394b interface; IEEE1394b PCI express card must be needed.	1/2" VGA camera, Image resolution: 640 x 480, Speed: 60 FPS (640*480) (Or choose camera model A602 656*491 100FPS) IEEE1394b interface; IEEE1394b PCI express card must be needed.	1/3" VGA camera, Image resolution: 768x494, 70FPS IEEE1394a interface; IEEE1394a PCI express card must be needed.	VGA camera, Standard camera with speed max. 60fps
13		Lens*9	Telecentric Lens Field of view with 1/2" camera: 3.5 ... 22.8 mm diagonal. (about 0.5X)	Zoom Lens Field of view with 1/2" camera: 3.5 ... 22.8 mm diagonal. (about 0.5X)	Common zoom lens 0.5X Field of view with 1/2" camera: 3.2 ... 22 mm diagonal. (about 0.5X)	Common zoom lens Field of view with 1/2" camera: 2...12.8 mm diagonal. (about 1X)	Fixed focus lens	3 Step Zoom lens, field of view (width -6.6mm, 11.8mm, 17.0mm, about 8.25, 14.75,21.25mm diagonal) (about 0.24X, 0.18X)
14		Tilted angle of camera	Manual, controlled by micrometer	Manual, controlled by micrometer	Manual, controlled by micrometer	N.A.	N.A.	N.A.

15		Background Light*9	parallel light background light LED light with adjustable brightness	LED background light with adjustable brightness	halogen illumination with adjustable brightness diffuse light	LED light with adjustable brightness, diffuse light	Variable Fiber Optic Illuminator	tungsten lamp with adjustable brightness diffuse light
16	Software	Calculating method of contact angle Auto calculating	θ/2 (WH), circle fitting , ellipse fitting , curve ruler (tangent fitting), Spline curve-fitting , and Young-Laplace equation fitting (RealDrop)		WH method, Tangent method （composite curve “y=a+bx+cx^{0,5}+d/lnx+e/x^{2}“ used only in Kruss’s software, ellipse fitting）, Circle fitting, Young-Laplace equation fitting (>30°)	Circular fit, Polynomial fit, Young-Laplace	Circle method, extrapolated Secant method, Line method, full Drop method (Young-Laplace equation fitting) (>45°)	θ/2 method, Circle fitting, Ellipse fitting, Tangent method
17		Automatic tracking	Yes		Yes	Yes	Not mentioned	Yes
18		Recalculate contact angle by manual if automatic calculation is failure due to quality of image is poor.	Yes Includes all methods		No	Yes	No	Not mentioned

19		Method of Young-Laplace equation fitting * 10	Based on ADSA and RealDrop method	B. Song's method Young-Laplace equation fitting based on select plane method	Jennings's method Young-Laplace equation fitting method based on rotational discrim ination method (Langmuir, 1988, page 9592)	Hansen's method Young-Laplace equation fitting based on select plane method	Algorithm of Young-Laplace and ds/de methods (simplified select plane method)
20		Data managem ent	Managing measured values and captured images. one-to-one correspondence of data and drop images; backup, compression, and exporting to Excel files; measured values and curve-fitting results can all be saved into exported image.	measure, store and report measured contact angle values	Managing measured values and videos.	Managing only measured values.	Managing only measured values.
21		Method for calculating surface free energy (SFE)	12kinds Equation of State (Neumann et al.), Good-Girifalco, Owen-Wendt-Rabel, Simple Fowkes, Extended Fowkes, WU method 1-2, Schultz method 1-2, Acid-base (Van OSS & Good), Jhu, and Zizman Plot (critical surface tension) method, Chibowski method	9kinds Equation of state, Fowkes, Fowkes (Extended), Owen- Wendt- Rabel- Kaelble, Acid-Base, Wu1, Schultz-1 /2, Zisman	5 kinds Zisman Plot, OWRK/ Fowkes, van Oss Acid-Base, Wu, Neumann's Equation of State	7 kinds Acid – Base tool, geometric mean (Owens), Rabel, Equation of stage (Neumann), Zisman's Plot Tool, Schultz 1, 2	4 kinds Geometric mean, Harmonic mean, acid-base, Zisman
22		Liquid database	300 kinds liquid and about 800 data	50 kinds liquids and 102 data	18 kinds liquids includes Mercury	Yes	Not mentioned
23		wetting envelope	Yes 3 methods	Yes 1 methods	No	No	No

24		Calculating thermodynamics intrinsic contact angle	Yes	No	No	No	No
25		Curve surface base line	Curve ruler method: any shape surface	Circle fitting method:	Circle fitting		Curve surface base line
26		Auto Base line	Yes	Yes	Yes	No	Yes
27		Software triggering technology	Yes	yes	Yes	Yes	Yes
28		Image Sharpness Measurement	Yes	Yes	No	NO	NO
29		Auto threshold	3 methods	No	No	No	No
30		Function of export to AVI after deleting some images.	yes	No, just record	Yes, Record image and export to AVI file. Without fitting curve.	No, just record	No, just record

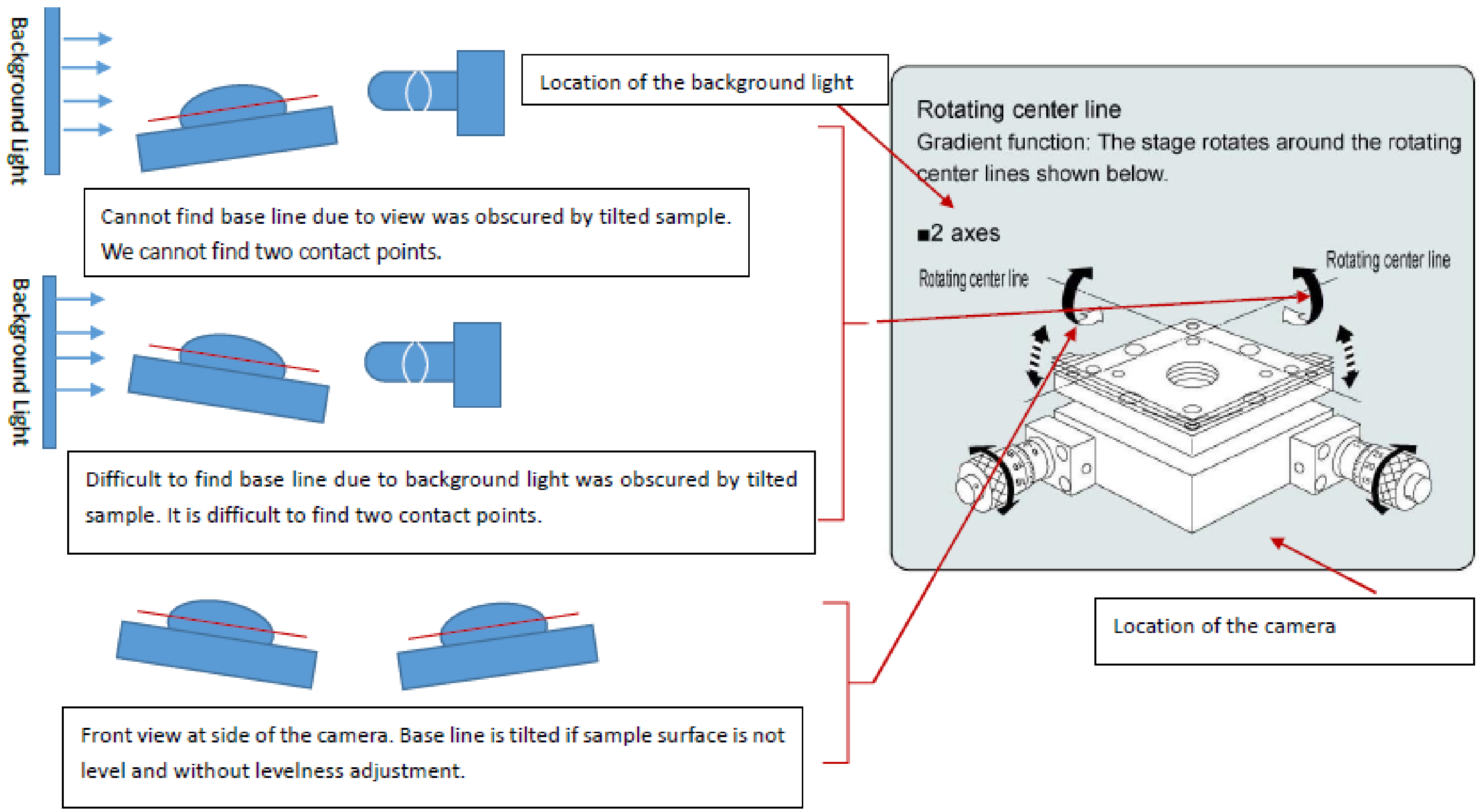
31		Writing fitting curve to captured image	Yes	No	No	No	No
32		Export to EXCEL files and BMP format picture	Yes	Only Value export to EXCEL or TXT files Images should save or record into video.	Only Value export to EXCEL PNG image should save by manual one by one	Only Value export to EXCEL	Only Value export to EXCEL
33		Control hardware such as dosing and positioning	Yes	Yes	Yes	Yes	Yes

Note:

1, 2, 3 Control of sample stage along XY axis is used for measuring contact angle of different position on sample surface. And, control of sample stage along Z axis is used for measuring sample with different thickness. KINO is only manufactory of contact angle meter that adopts motorized linear stage or manual positioner for motion control system. By comparison, contact angle meter made by other factory always uses common adjustment mechanism such as "dovetail stage" or just one optical bench with holder unit and height adjustable rod stand. (Note: these is always used for quick and long travel range adjustment that need no accuracy.)

For more information of them, visit https://www.newport.com/Products/5465115/1033/nav.aspx or http://www.sigma-koki.com. KINO's contact angle meter adopts such motion control system as this manufactory's and accords with its design accuracy. You can find difference such as load capacity and travel accuracy between rack and pinion dovetail stage, translating optical post holder and crossed-roller guide positioner with micrometer. It is shown that crossed-roller guide positioner with micrometer is most suitable for vertical position. Motorized linear stage controlled by software with slide guide provide more stable and smooth movement and positioning of drop.

4, Level adjustment of sample stage except adjusting complete machine by four adjustable legs is most important. For example, after you adjusted levelness of sample stage at first, when you measure sample with poor level surface, it is more difficult to get good base line and obtain two contact points. As shown below:



5, Tilting system for measurement of roll-off angle of KINO's contact angle meter adopts motorized rotation stage with very low backlash, low wobble (about 40urad) and high absolute accuracy (about 0.01°) . KINO exclusively provides you specially designed mechanical Structure (Rotating only Lens, sample stage and its control system) instead of rotating complete machine. Accuracy and backlash of latter is very poor due to control complete machine is very difficultly.

6, We suggest our customer to choose direct single syringe pump instead of syringe pump with tee-junction because latter is difficult to clean and easily lead to cross contamination e.g. water for measurement of contact angle is contaminated by oil.

	 
direct single syringe pump **- Advantage:** Easy to clean and remove syringe, High precision, pollution-free. **- Shortcoming:** inconvenient to measure contact angle with multiple liquid.	**syringe pump with 3 port value** **- Advantage:** Difficult to clean pump, value and tube, easily lead to cross contamination, cannot dosing liquid with viscosity **- Shortcoming:** convenient to measure contact angle with multiple liquid when equipped with multi-channel pump.

7, usually, there are two drop transferring method- by move needle down and then up or by move sample stage upside and downside. We prefer first method due to we can easily control the base line of contact angle (it remains at same position) by first one. By second one, base line is bound to move because sample surface moved during this process. And for measuring contact angle of super-hydrophobic surface, movement of needle must be very carefully because it is difficult to transfer drop to this surface. So, we adopt positioner stage with micrometer or controlled by step motor to get high precision of control.

8, Interface of Camera that USA KINO adopted is USB2.0 or USB3.0, which is more mutually compatible with PC than IEEE1394a or IEEE1394b. Most suitable resolution of camera for contact angle meter is about 130M, and 40M is most common resolution that used. Visit http://www.uskino.com/news/50.html to find more information about this topic.

9, Telecentric Lens and Parallel light Background light are most suitable for contact angle measurement for the following reasons. With them, we can benefit highest precision measurement values at sub-pixel resolution.

(1) Magnification Constancy

Common lenses give different magnifications at different conjugates: as such, when the object is displaced, the size of its image changes almost proportionally with the object-to-lens distance. This is something anybody can easily experience in everyday life, for example when taking pictures with a camera equipped with a standard photographic lens.

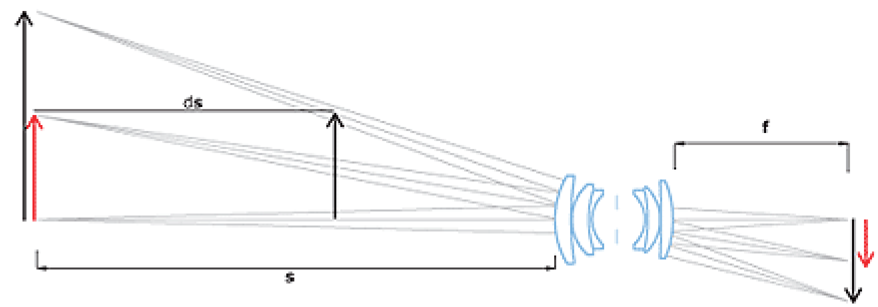


Fig. 1: a standard lens generates different size images when changing the object-to-lens distance (indicated as ”s” in the drawing). On the other hand, objects of different sizes would look as if they had the same dimensions, provided they subtend the same viewing angle.

With telecentric lenses the image size is left unchanged with object displacement, provided the objectstays within a certain range often referred to as “depth of field” or “telecentric range”. This is due to the particular path of the rays within the optical system: only ray cones whose barycentric ray (or “principal ray”) is parallel to the opto-mechanical main axis are collected by the objective. For this reason, the front lens diameter must be at least as large as the object field diagonal. This optical behaviour is obtained by positioning the stop aperture exactly on the focal plane of the front optical group: the incoming rays aim at the entrance pupil which appears as being virtually placed at the infinity. The name “telecentric” derives from the words “tele” (which means “far” in ancient Greek) and “centre” which accounts for the pupil aperture, the actual centre of an optical system.

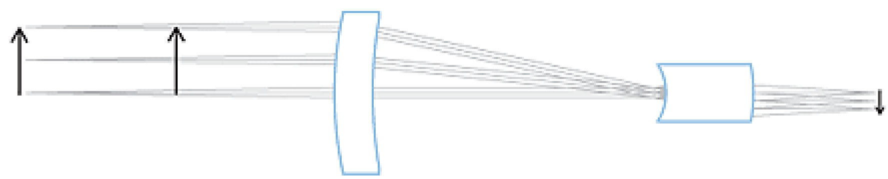


Fig. 2: in a telecentric system rays get into the optics only with an almost parallel-to-the-axis path.

(2) Low Distortion

Distortion is one of the worst problems limiting measurement accuracy: even the best performing optics are affected by some grade of distortion, while often even a single pixel of difference between the real image and the expected image could be critical.

Distortion is simply defined as the percentage difference between the distance of an image point from the image center and the same distance as it would be measured in a distortion-free image; it can be thought of as a deviation between the imaged and the real dimensions of an object. For instance, if a point of an image is 198 pixels distant from the center, while a distance of 200 pixels would be expected in absence of distortion, the radial distortion, at that point, would be

Distortion = (198-200)/200 = -2/200 = 1%

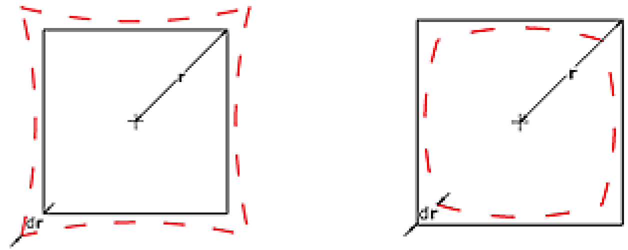


Fig.3: “pincushion” type distortion   “barrel” type distortion

Positive radial distortion is also called “pincushion” distortion, negative radial distortion is called “barrel” distortion: note that the distortion depends on the radial position and can also change of sign. Distortion can be also viewed as a 2D geometrical transformation of the real world into the virtual space created by the lens; as this transformation is not perfectly linear but is approaching 2nd or 3rd degree polynomials, the image becomes slightly stretched and deformed.

Common optics show distortion values ranging from some percent to some tens percent, making precise measurement really difficult; things get even worse when non-telecentric lenses are used. Since most machine vision optics have originally been developed for video-surveillance or photography applications, relevant distortion values have usually been considered acceptable, as the human eye can compensate distortion errors up to 1-2%. In some cases, like in fish-eye lenses or webcam-style lenses, distortion is intentionally introduced to make the lens work on large angles also providing an even illumination of the detector (in these cases distortion is helpful in reducing cosine-to-the-fourth law effects).

High quality telecentric lenses normally show a very low distortion degree, in the range of 0,1%; although this amount seems to be very small it would actually result into measurement errors approaching the size of one pixel of an high resolution camera. For this reason, in most applications, distortion has to be software calibrated: a precise pattern (whose geometrical accuracy must be at least ten times better than the needed measurement accuracy) is placed at the center of the field depth; distortion is then computed at several image points and, based on these data, the software algorithm transforms the native image into a distortion-free image. Few people know that the distortion also depends upon the distance of the object, not only upon the optics itself; for this reason it is very important

Few people know that the distortion also depends upon the distance of the object, not only upon the optics itself; for this reason it is very important that the nominal working distance is strictly respected.

A fine perpendicular alignment between the lens and the inspected object is recommended in order to avoid non-axially symmetric distortion effects. Trapezoidal distortion (also known as “keystone” or “thin prism” effect) is another important parameter to be minimized in an optical inspection system as it is asymmetric and very difficult to software calibrate. Lens focusing mechanism can also introduce some symmetric or non-symmetric distortion effect because of mechanical play or optical element decentering.

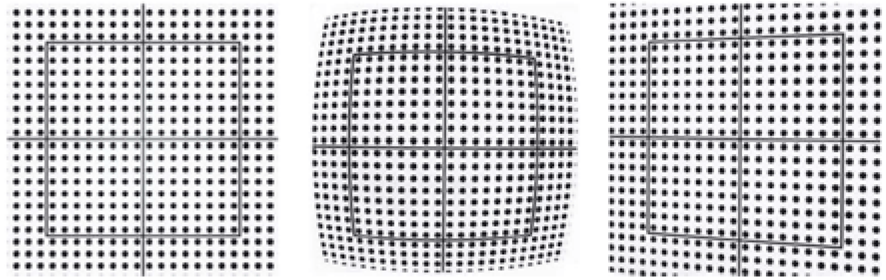


Fig. 4: on the left an image of a distortion pattern taken with a telecentric lens, where no radial or trapezoidal distortion is present. In the middle the image of the same pattern showing strong radial distortion. On the right an example of trapezoidal distortion.

(3) Perspective Errors limitation

When using common optics to image 3D objects (non completely flat objects) far objects will look smaller than close objects. As a consequence, when objects like a cylindrical cavity are imaged, the top and the bottom crown edges will appear to be concentric although the two circles are perfectly identical.

On the contrary, by means of a telecentric lens, the bottom crown edge will disappear because the two crown edges are perfectly overlapping.

Fig. 5: Common optics showing significant image perspective error (on the left). A telecentric lens is able to cancel any perspective effect (on the right).

This effect is due to the specific path of the rays: in the case of common optics, any geometric information that is “parallel” to the main optical axis also shows a component on the detector plane direction, while in a telecentric lens this perpendicular component is totally absent.

One could describe a common lens as a mathematical function building a correspondence between the 3-dimensional object space and the 2-dimensional detector (image) space while a telecentric would build a 2D-2D correspondance as would not display an object’s third dimension thus making it the perfect component for profile imaging and measurement.

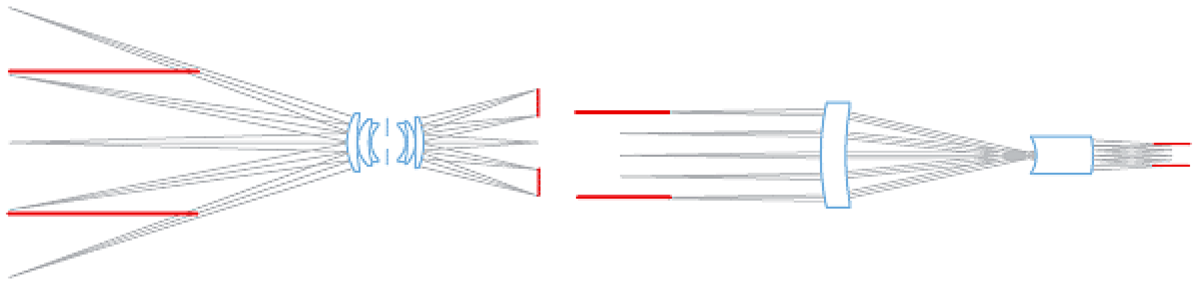


Fig. 6: Common optics (left) project longitudinal geometrical information onto the detector, while telecentric lenses are not.

(4) Good image resolution

Image resolution is decribed by CTF (contrast transfer function) which quantifies the contrast ratio at a given spatial frequency on the camera detector plane, expressed in lp/mm (line pairs per millimeter).

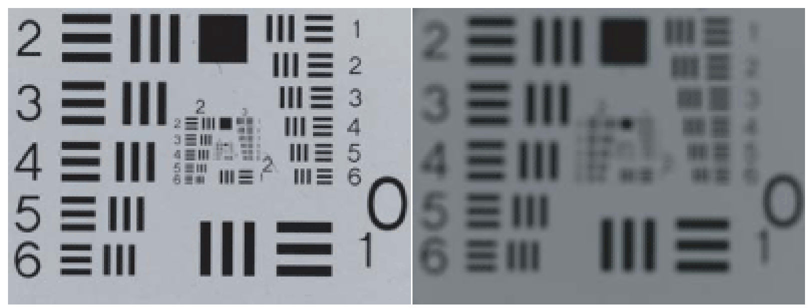


Fig. 7: good and bad contrast achieved with optics of varying CTF looking at a standard USAF test pattern.

Quite often, machine vision integrators tend to combine cameras having tons of small pixels with cheap, poor resolution lenses, resulting in blurred images; the resolution provided by telecentric lenses is compatible with very small pixel sizes and high resolution cameras thus increasing the measurement resolution.

(5) No edge position uncertainty

When common back lighting an object it can often be difficult to determine the exact position of its edges.

This can happen because the bright pixels in the background tend to overlap with the dark pixels at the object edges. Moreover, if the object is highly 3D-shaped, also a border effect could furtherly limit the measurement precision; as shown in the following drawing, rays grazing the object edges at certain incidence angles could be reflected by the surface, but still be collected by the lens.

The lens would then see those rays as if they were coming from behind the object; as a result, slices of the image could disappear, thus making the measurement very much imprecise and unstable.

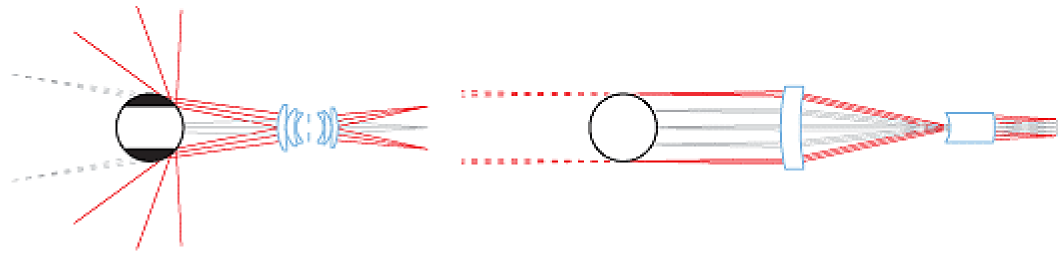


Fig. 8: Border effects in a common imaging lens are strongly reduced by means of a telecentric lens

This effect can be efficiently limited by means of a telecentric lens: if the pupil aperture is small enough, the only reflected rays which could enter the lens would be those nearly parallel to the optical main axis.

As these rays are affected by very small deflection, the reflection from the object surface doesn't jeopardize the measurement accuracy.

To get rid of such issues, ***Parallel light Background light*** (also called "collimated" or "telecentric") illuminators can be interfaced to telecentric lenses, taking care of matching the lens aperture and FOV with the collimated source divergence. With this option, all the light coming out of the illuminator is collected by the lens and delivered onto the detector, allowing extremely high signal-to-noise ratios and incredibly low exposure times. On the other hand, only "expected" rays come into the imaging lens so that no problems occur at the borders.

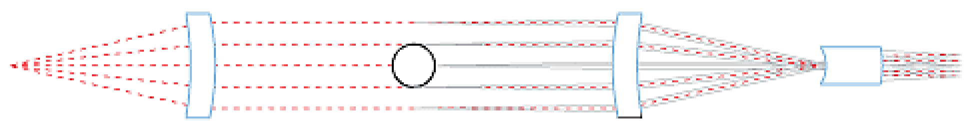


Fig. 9: ***Parallel light Background light*** (Collimated light, telecentric) illumination projects only the expected rays into the imaging system.

We captured some images use using 2 different combinations of lens and background (one is common lens and diffused background light as used in general contact angle measurement instrument, another is used telecentric lens and Parallel light Background light)

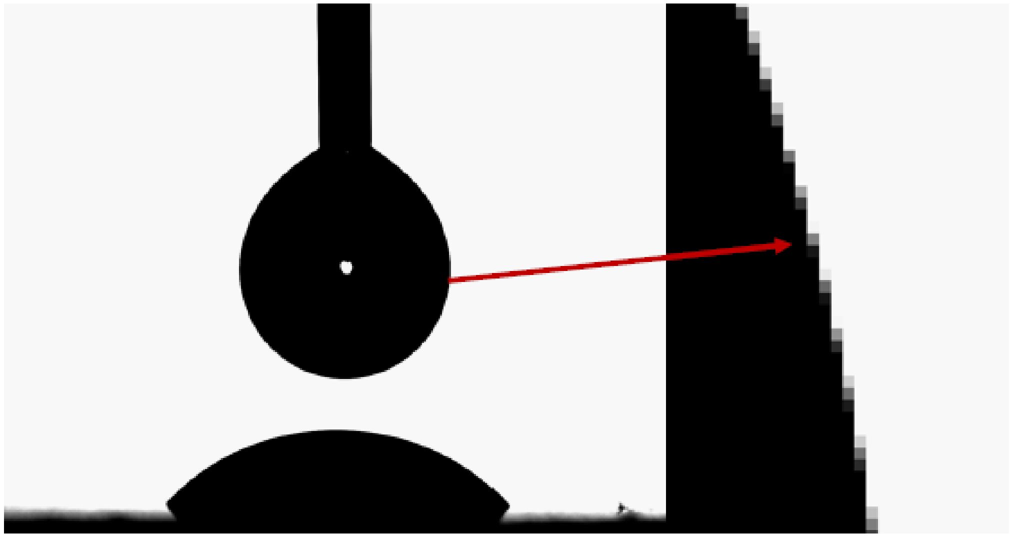


Fig. 10: Image of pendant drop used Parallel light Background light and telecentric lens. We can find little change range of sharpness at image edge when zooming it about 1500X.

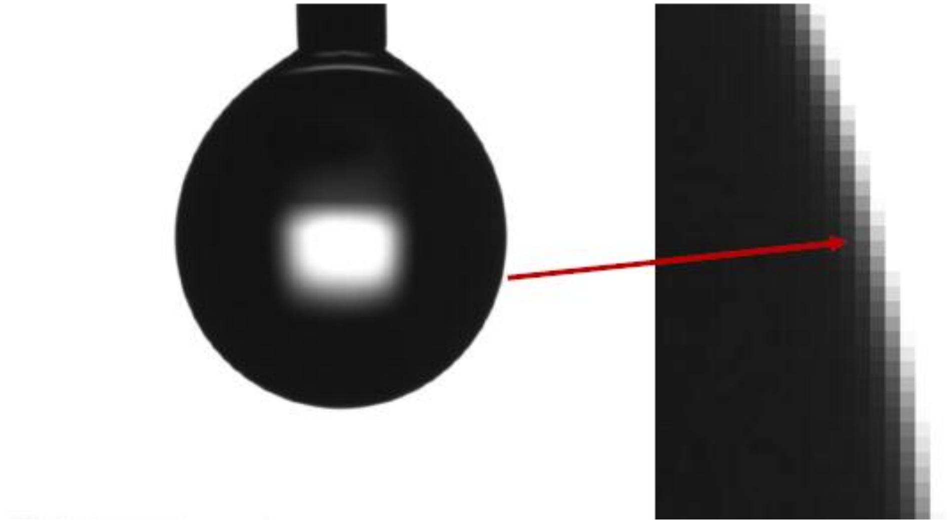


Fig. 11: Image of pendant drop used common Background light and lens. We can find more change range of sharpness at image edge when zooming it about 1500X.

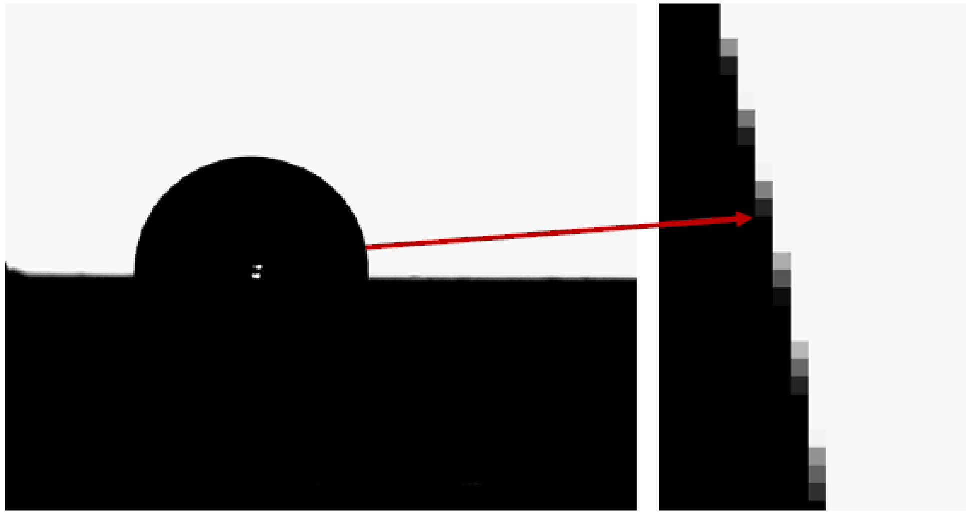


Fig. 12: Image of sessile drop with little change range of sharpness used Parallel light Background light and telecentric lens.

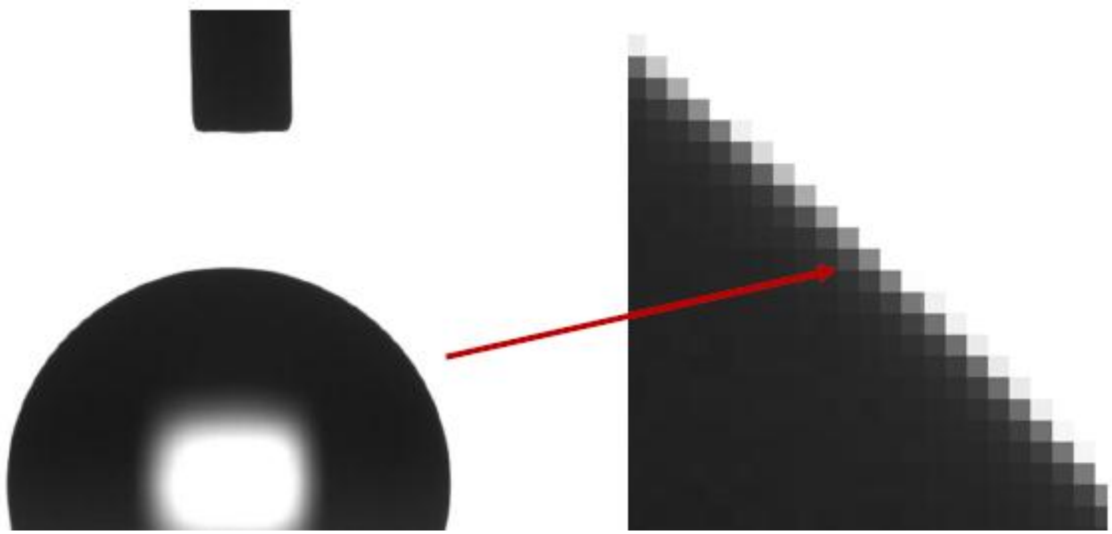


Fig. 13: Image of sessile drop with more change range of sharpness used common Background light and lens.

(5) Not disturbed by flare veiling glare

Flare veiling glare cannot disturb image capture process.