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## Surface Finish Measurement Methods and Instrumentation

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  - Atomic Force Microscopy (AFM)

# Initial Visual Inspection

- Hold Component up to the Light.
  - Use Eye Glass if required.
- Observe:
  - Direction of Lay
  - Process Marks
  - Defects / Scratches

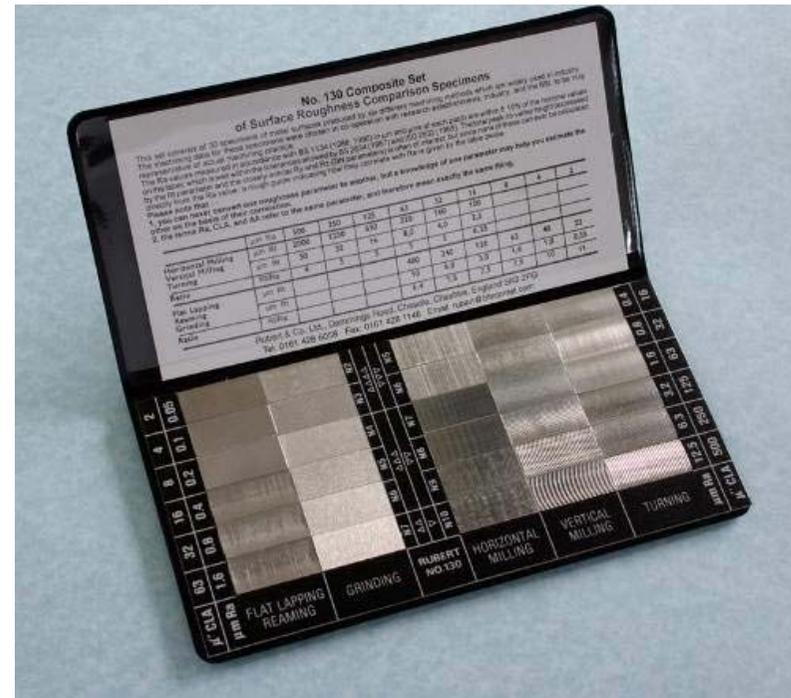


- *Do not underestimate the importance of initial visual inspection.*
- *It will help in deciding how to make the measurement.*
- *It can help in understanding the part being measured, save time, and can be a useful as a cross check with results shown on the screen or printout.*

# Surface Finish Comparison Plates

- Rubert 130 Composite Set

- A basic method of surface finish measurement is by using a comparison plate. These plates consist of a range of metal blocks which have been machined to give various calibrated surface finish values.
- A components surface can be compared against these machined blocks either visually or by touch. Obviously this method of measurement is a bit subjective. Using this method it is difficult to attach an absolute value to a surface.
- This set consists of 30 comparison specimens, covering six commonly-used machining methods (6 turned, 6 end-milled, 6 horizontally milled, 6 surface-ground, 3 lapped, 3 reamed/drilled). A label gives the Ra values of each specimen in both metric and imperial units, but also identified with Roughness Grade Numbers, N12 to N1. These grades correspond to nominal preferred Ra values. N12 would be an Ra value of 50µm, N1 a value of 0.0125µm Ra.
- Note: The N grades used in the USA are not identified in the same way as the European grades shown above. Germany, USSR, and Japan also have had such N systems.
- High N means rough for some countries yet for others it means smooth. Unfortunately, the N numbers are still used! Great care has to be taken to make sure which N scale is being used. Also remember that the letter N is also used for the numbering of sampling lengths in the assessment length.

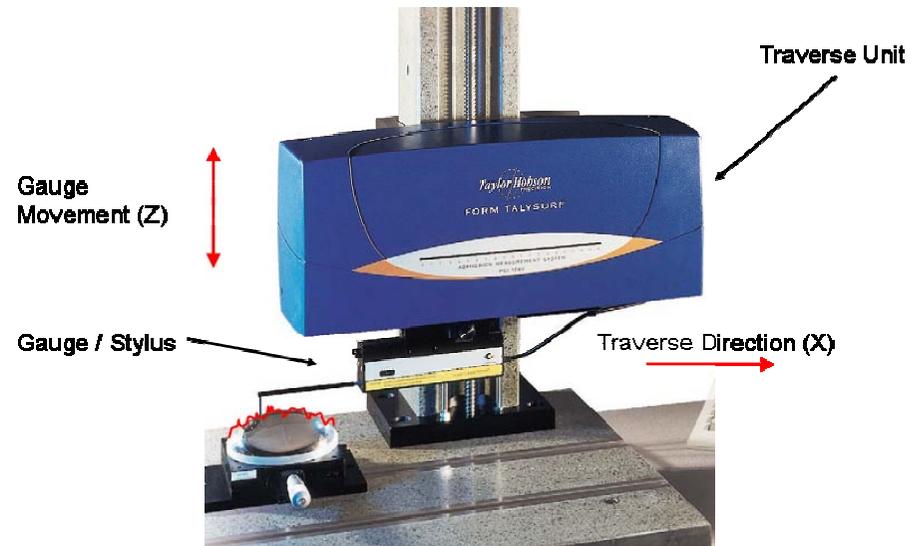


# Comparison Plates - 'N' Numbers (UK)

Nominal Ra in $\mu$ in	50	2000		N12	Roughness Grade Number
	25	1000		N11	
	12.5	500		N10	
	6.3	250		N9	
	3.2	125		N8	
	1.6	63		N7	
	0.8	32		N6	
	0.4	16		N5	
	0.2	8		N4	
	0.1	4		N3	
	0.05	2		N2	
	0.025	1		N1	

The UK 'N - System' used on comparison plates and on many old drawings is given here in microns & micro inches

# Contact Type Instruments



*The contact type of instrument consists of a stylus which tracks across the surface under test. A gauge or pick-up which is a transducer that translates the movements of the stylus in the Z (height) direction as it tracks across the surface (X axis) into a usable electronic signal. This signal is then processed via software to present the operator with a value which represents the surface finish.*

*The traverse mechanism will also provide X co-ordinate positions of the surface data by using a grating which has a fixed spacing. The Form Talysurf instrument has data point spacing in the X axis of  $0.08\mu\text{m}$  (0-15mm)  $0.25\mu\text{m}$  15-30mm &  $1\mu\text{m}$  (30-200mm).*

*Another method of data point collection is by utilising the motor driving the traverse unit. This method involves some form of positional feedback from the motor. Because the speed of the motor is known the position of the stylus can be determined at a set time period during the measurement, which dictates the data point spacing. This method, however, relies on the motor speed being constant to give accurate spacing between data points. An instrument which uses a fixed grating will always give a consistent data point spacing.*

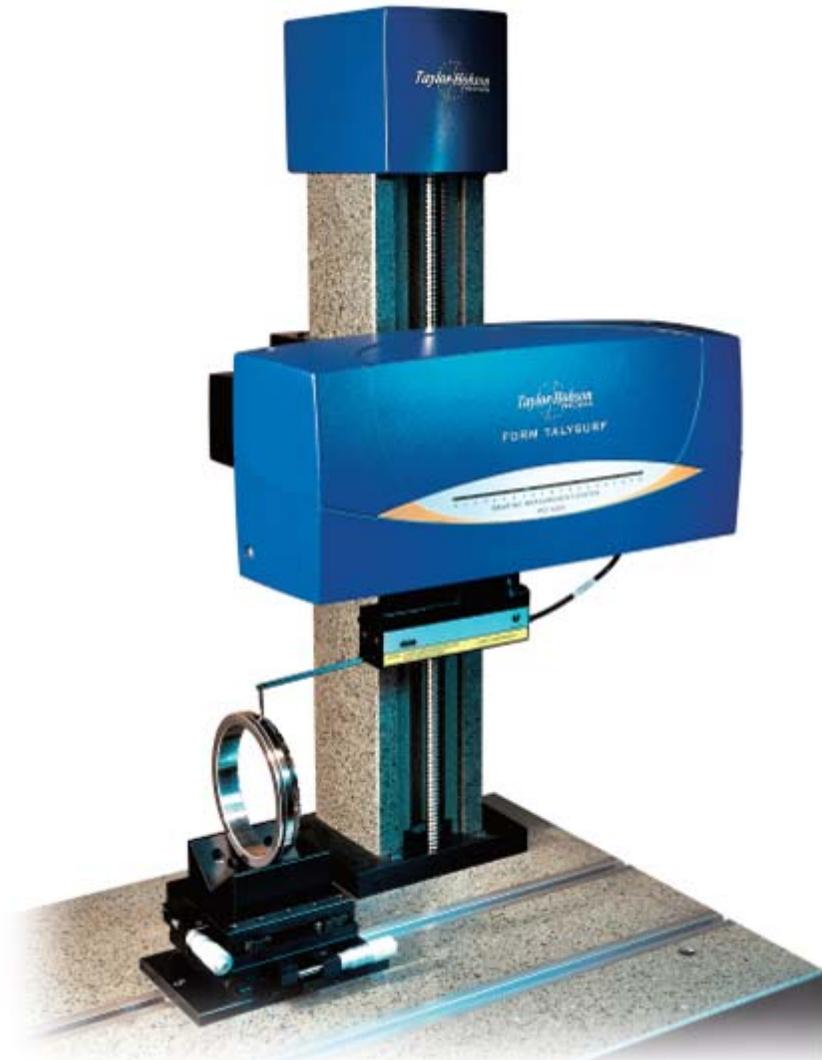
# Early Contact Type Instrument

- Talysurf 1 (1941)
  - Traverse moves in X
  - Stylus moves in Z
  - Pickup with skid datum
  - Manual Column
  - Valve Electronics to drive traverse
  - Analogue gauge signal Magnification / Analysis
  - Meter to integrate signal and display CLA
  - Printout

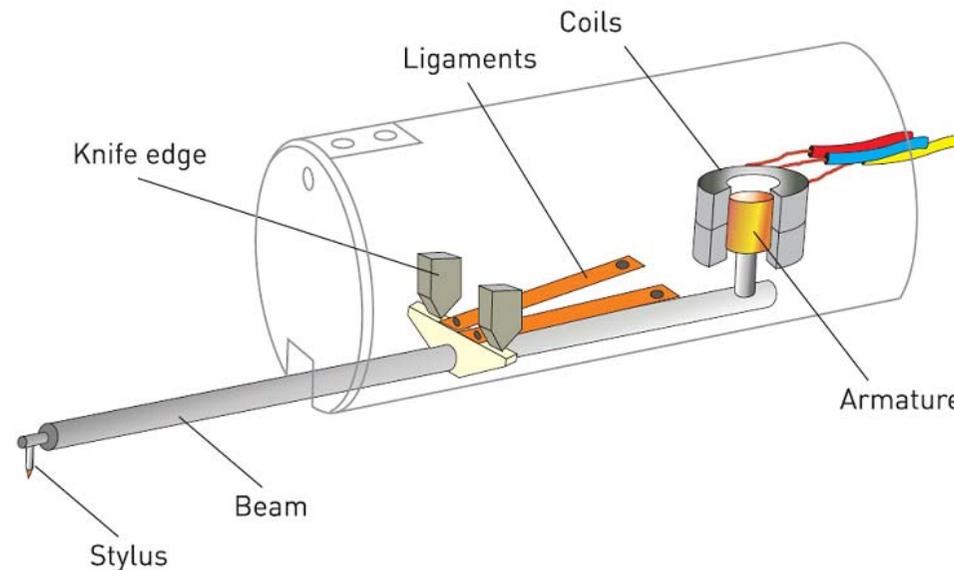


# Current Contact Type Instrument

- Form Talysurf
  - Traverse moves in X
  - Stylus moves in Z
    - Optional Lift Lower
  - Internal Straightness datum
  - 60/120/200mm Traverse
  - Motorised Column
    - Optional Tilt
  - Joystick Control
  - Digital Processing
  - Fully Programmable



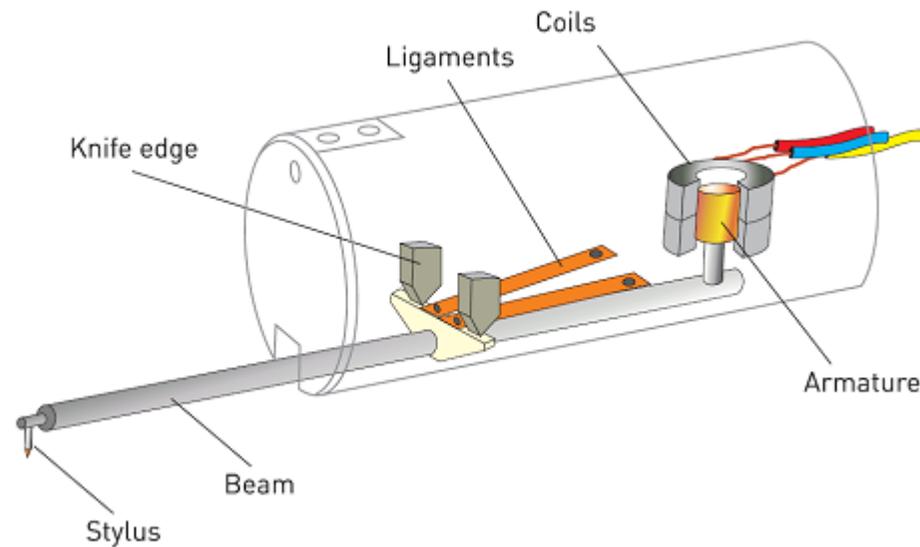
# Inductive Transducer



- *The stylus is located at one end of a beam which pivots on knife edges, the other end of the beam consists of a coil with a ferrite slug (armature) which moves inside two coils causing a change in relative inductance.*
- *As the stylus moves down a valley the ferrite slug will rise, when the stylus rides up a peak the slug will move down.*
- *Two 10kHz signals in anti-phase are supplied to the transducer coil ends. The return signal, from the coil centre-tap, is demodulated to represent any stylus movement. (When the slug is in the central position, the return signal is zero.)*
- *The stylus remains in contact with the surface and the knife edges by using a fine spring which acts on the beam.*
- *As well as the INTRA, The Form Talysurf i60 / i120 incorporates this system.*

# Inductive Transducer

- Advantages
  - Low Cost
  - Needs only simple processing electronics
  - Proven technology
  - Can be used in inverted orientation
- Disadvantages
  - Limited Range
  - Low Linearity
  - Temperature Sensitive



# Instrument with Inductive Transducer

- Form Talysurf Intra
  - Portable Instrument
  - Skid less Pickup
  - Internal Datum
    - 0.40um / 50mm straightness error
  - 1mm vertical range / 16nm resolution
  - Measures
    - Form
    - Roughness
    - Waviness



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# Instrument with Variable Reluctance Transducer

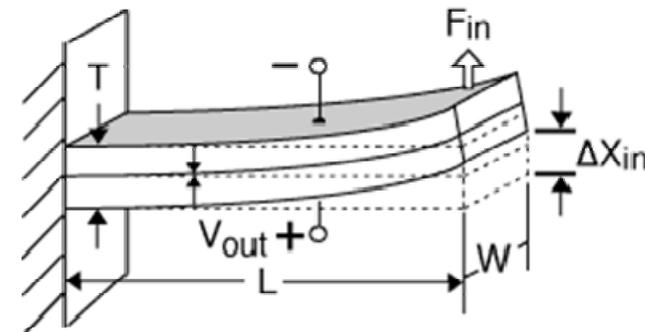
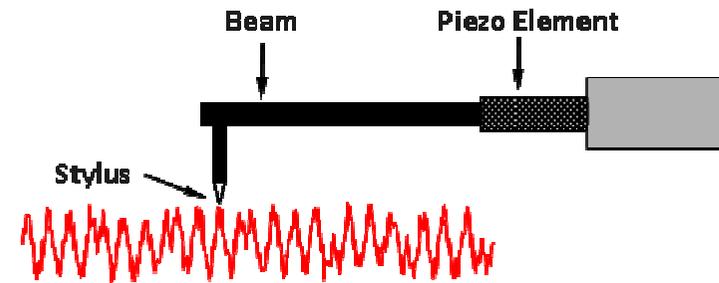
- Surtronic 25
  - Portable Instrument
  - Unique stylus lift mechanism for total flexibility
  - Parameter options to suit your application



- Skidded Pickup
- Similar to Inductive Transducer
- Measures:
  - Roughness

# Piezo-Electric Transducer

- Advantages
  - Ideal for small portable instruments
  - Needs only simple processing electronics
  - Good High Frequency Response
- Disadvantages
  - Small Range
  - Low Linearity
  - Temp / Humidity Sensitive
  - Limited Low Frequency Response



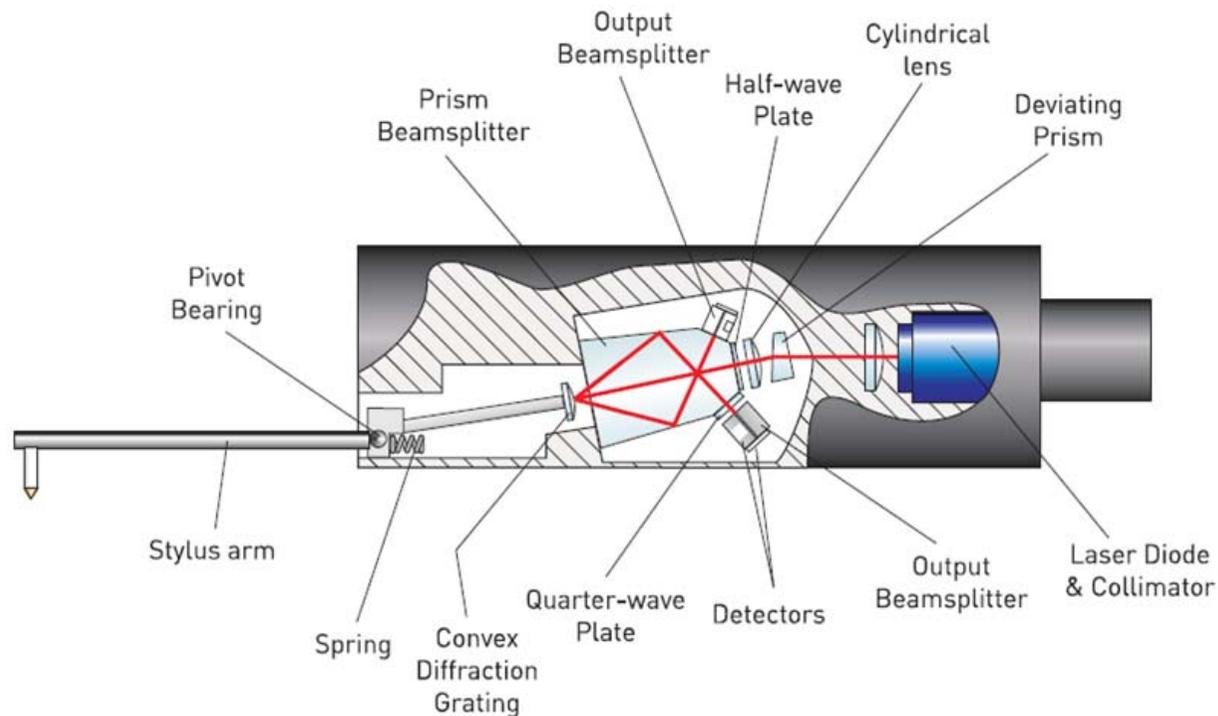
- *The piezo-electric transducer contains a piezo-electric crystal element which has the property of developing a voltage across electrodes on the faces of the elements when the crystal is deformed.*
- *The movement of the stylus creates a bending moment and the subsequent voltage output is translated into Z co-ordinates.*
- *The low frequency response of the piezo transducer makes it unsuited for FORM (low frequency, long wavelength) measurements.*

# Instrument with Piezo-Electric Transducer

- Surtronic Duo
  - Portable Instrument
  - No setting up or programming required
  - Ready to use out of the box
  - Skidded Pickup
  - Simple Calibration
  - Measures
    - Roughness



# Phase Grating Interferometric Transducer (PGI)



*On this particular gauge a curved phase grating is fitted to the end of the pivoted stylus arm which is the moving part of the interferometer.*

*The wavelength of the grating provides the reference for the measurement. Four photodiodes detect the interference fringe pattern created by the stylus movement, which then interpolate the output signal. This type of transducer gives a very large range to resolution ratio.*

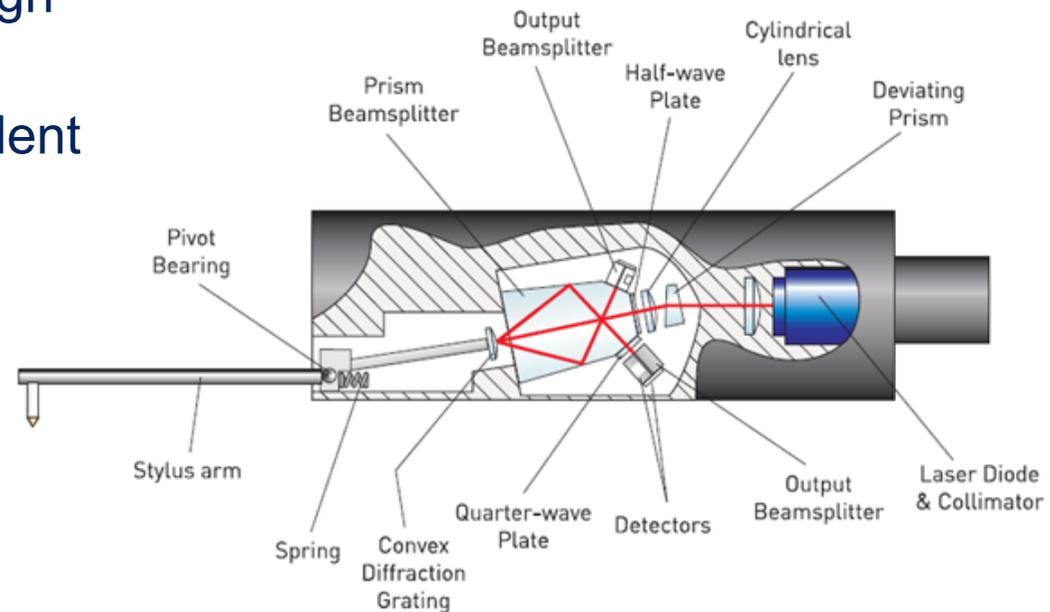
- 25mm / 12.5mm / 8mm / 400mm Ranges
- 12.8nm / 3.2nm / 0.8nm / 0.2nm Resolution

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# Phase Grating Interferometric Transducer (PGI)

- Advantages
  - Extremely High Accuracy and Linearity
  - Large Range and High Resolution
  - Resolution Independent of Gauge Range
- Disadvantages
  - High Cost
  - Not suited to Shop Floor environments



# Instrument with Phase Grating Interferometric Transducer (PGI)

- Form Talysurf PGI
  - Laboratory Instrument
  - Anti-Vibration
  - Very low noise, 1nm (0.04 $\mu$ m) RMS
  - User programmable, including stylus lift
  - Large capacity, 200mm traverse unit
  - Measures
    - Form
    - Roughness
    - Waviness

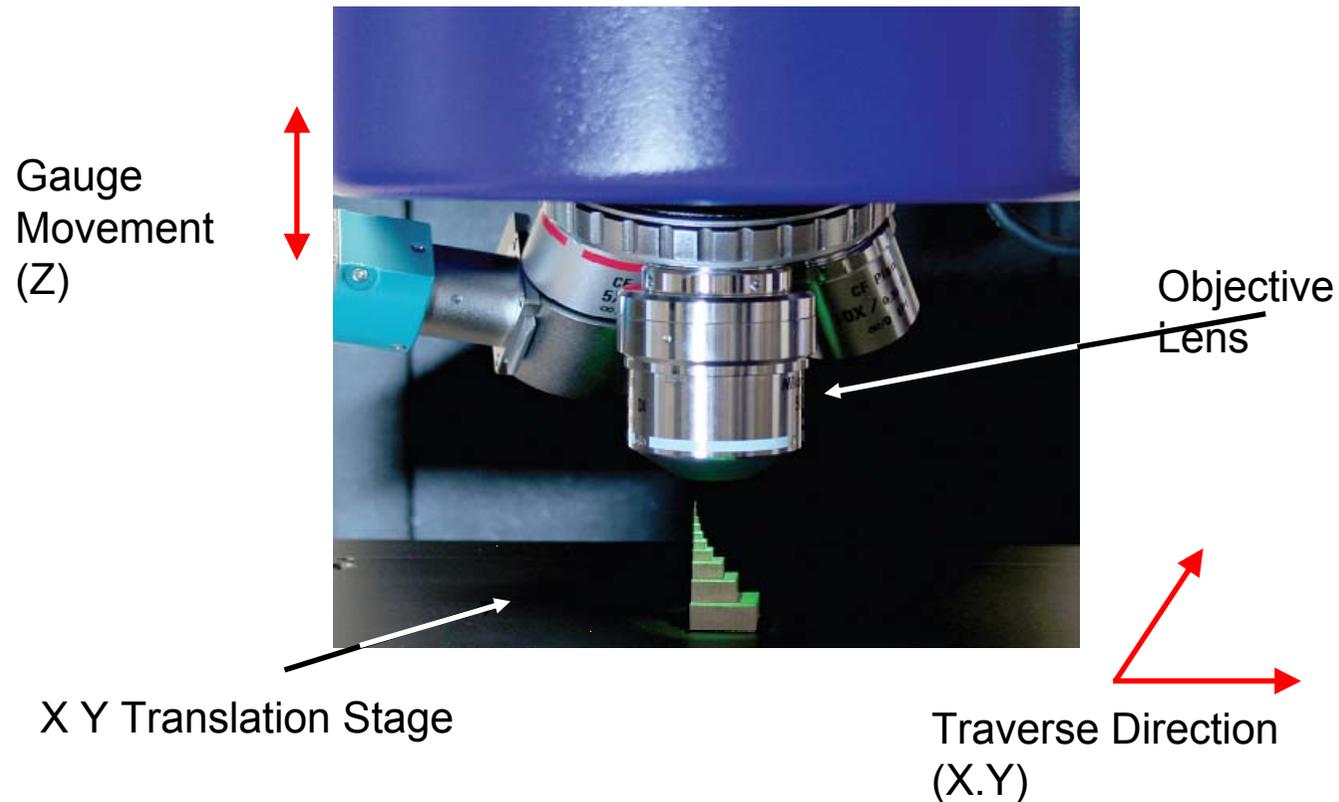


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# Non-Contact Type Instruments



*There are a number of non-contact gauges on the market that can be mounted on a standard surface measuring system.  
Two Variants:*

- 3D area measurement similar to looking through a microscope*
- 2D or 3D raster scanning, traditional measurement with translation of X stages (and Y to build up the 3D image).*

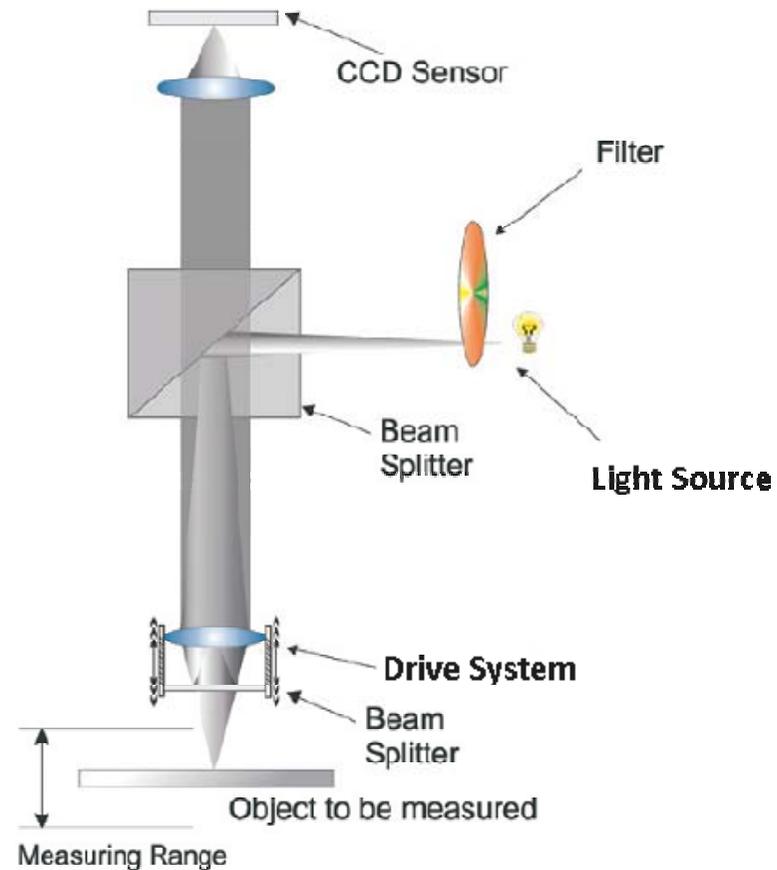
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# Coherence Correlation Interferometer

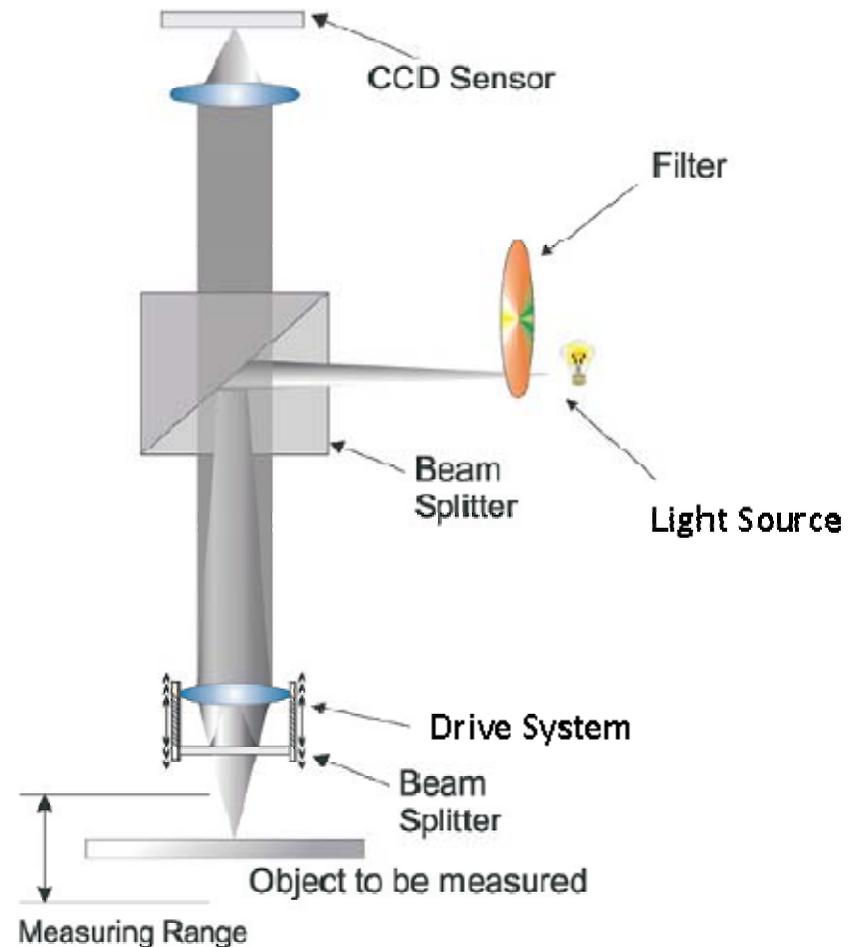
A scanning interferometer uses conventional white or Green light as its light source. A 100 or 400µm piezo drive system or more recently a 2.2mm Closed Loop Precision Z Stage is used to “scan” the objective lens about a focal point. The sample to be measured is usually positioned on a precision X/Y stage. As the imaging system is “traversed” through its range by the drive system the focal point is noted for each pixel in the CCD array. The major benefit of such a measurement system is that large numbers of points (typically 1 or 4M Pixels) can be measured with very high lateral resolution and vertical resolution in just a few seconds.

By changing the magnification of the objective lens, larger areas can be assessed in a single measurement. It should be noted that in this case the lateral resolution is reduced proportionally: for an instrument with a 1 megapixel CCD measuring an area of 5mm by 5mm the lateral resolution will be 5 microns.



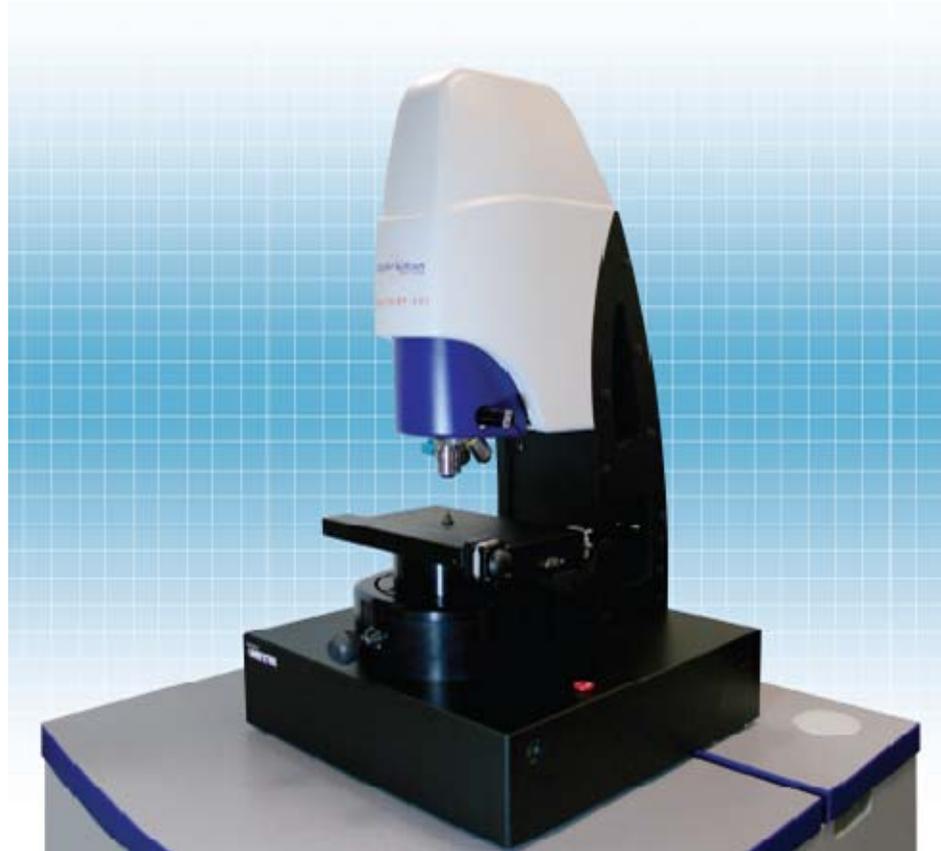
# Coherence Correlation Interferometer

- Advantages
  - Up to 4M Data points in one measurement
  - High Lateral and Vertical Resolution (Sub Angstrom)
  - Many Objective lens options
  - Fast Measurement Cycles
- Disadvantages
  - Non-Measured Points / Optical Effects on some Substrates
  - Steep Slopes

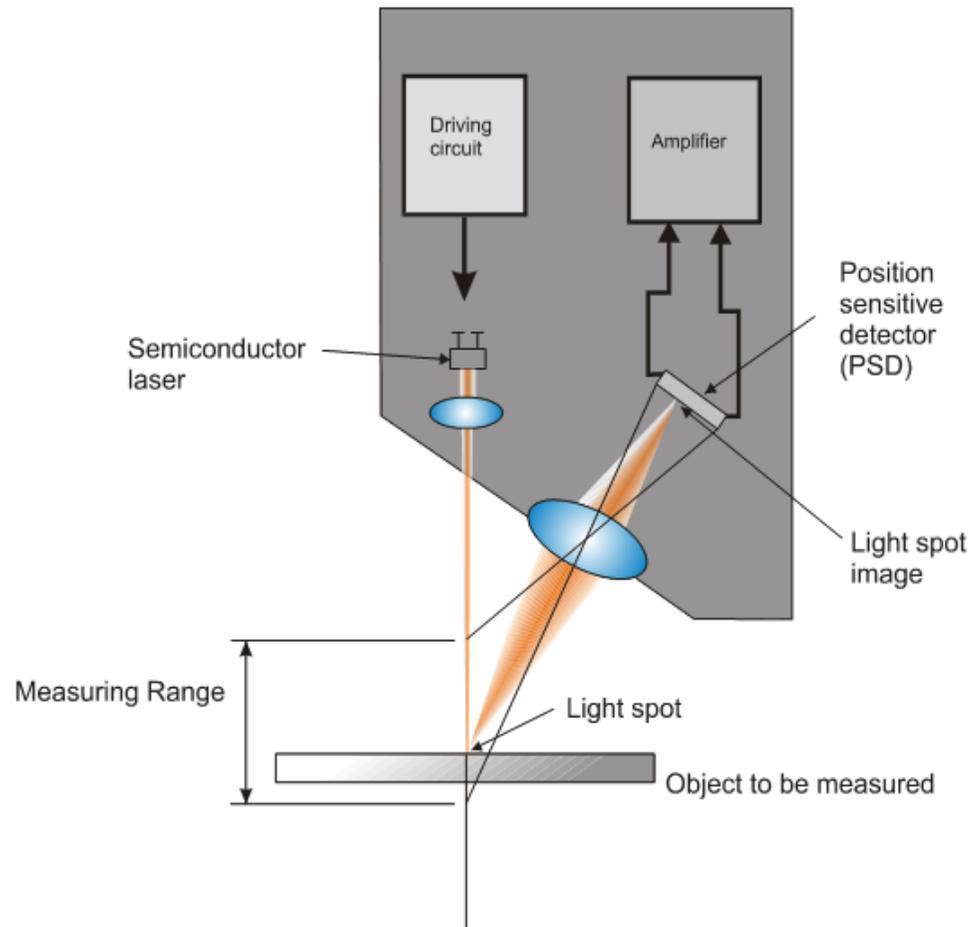


# Instrument with Coherence Correlation Interferometer (CCI)

- Talysurf CCI Lite
  - Robust - strong & stable Z scanning mechanism
  - Fast - auto XY & Z with Autofocus & Turret
  - Flexible - 2.2 mm Z range (>10 mm with Z stitching)
  - Over 1 million data points as standard
  - Simple - one measurement mode for all surfaces



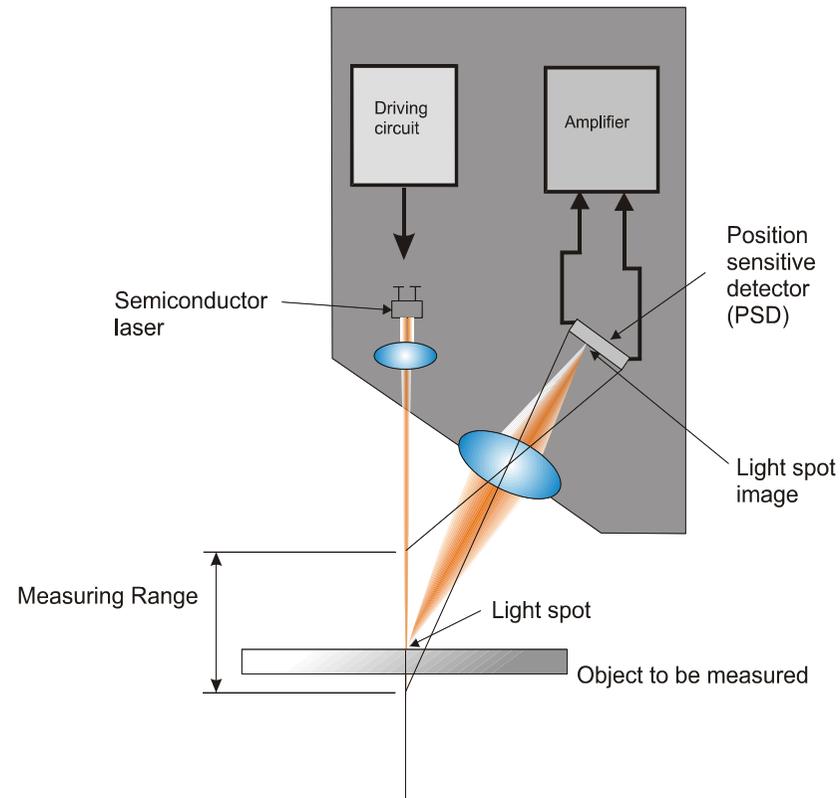
# Scattering Laser Triangulation



*The principle of Scattering Laser Triangulation is shown in the above diagram. The laser emits a beam of light, which is reflected back of the sample surface at an angle, into a PSD detector receptor. The image is seen as a spot, the centre of which is calculated and its position on the PSD grating to give the altitude of the surface.*

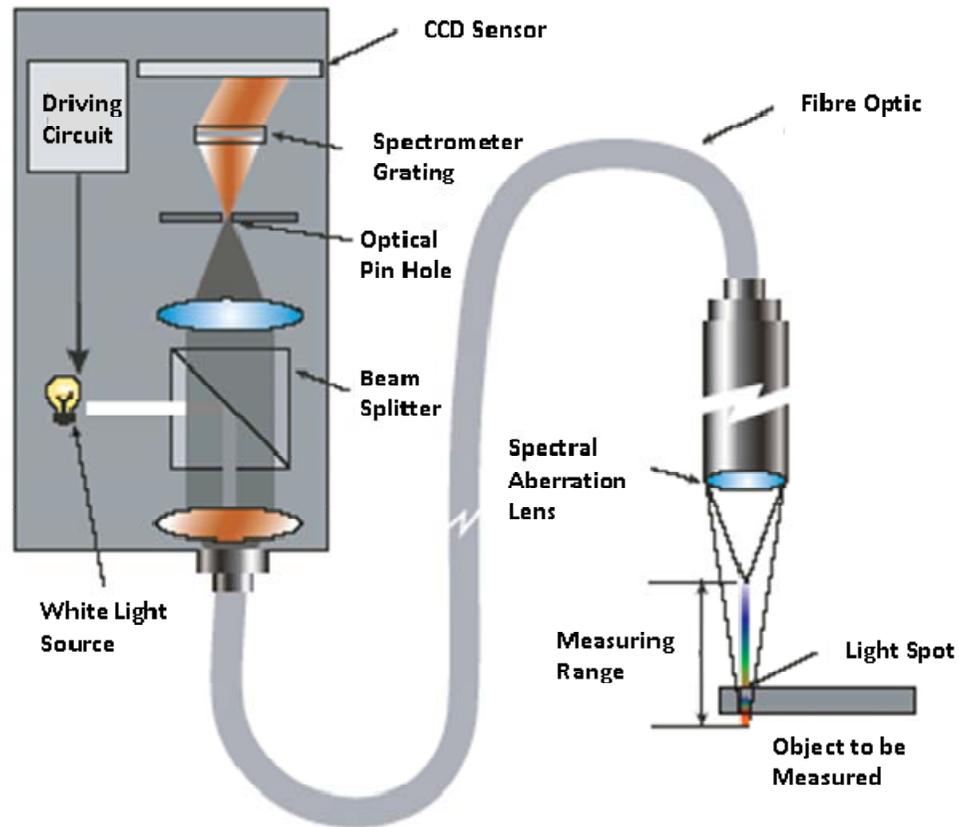
# Scattering Laser Triangulation

- Advantages
  - High Speed (50,000pps)
  - Slopes up to 45°
  - Relative Low Cost
- Disadvantages
  - Spot size Variation
  - Scattering Only
  - Shadow Areas
  - Non-Measured Points / Optical Effects on some Substrates / Edges
  - Limited Resolution (1 $\mu$ m)



*This type of gauge has certain limits with regard to surface finish measurement due to spot size and the limited gauge resolution of over very large gauge ranges; however, this can be overcome to some extent by using a laser system which provides a smaller gauge range and better resolution.*

# Confocal Chromatic Aberration (CLA)



*White light is directed by a beam splitter through a spectral aberration lens onto the surface. The lens splits the light into different wavelengths and at any point on the surface only a certain wavelength will be in focus. Light is reflected from the surface to a pin hole which permits only the wavelength in focus to pass through. A spectrometer deflects the light onto a CCD sensor to interpolate spatial position of the data point.*

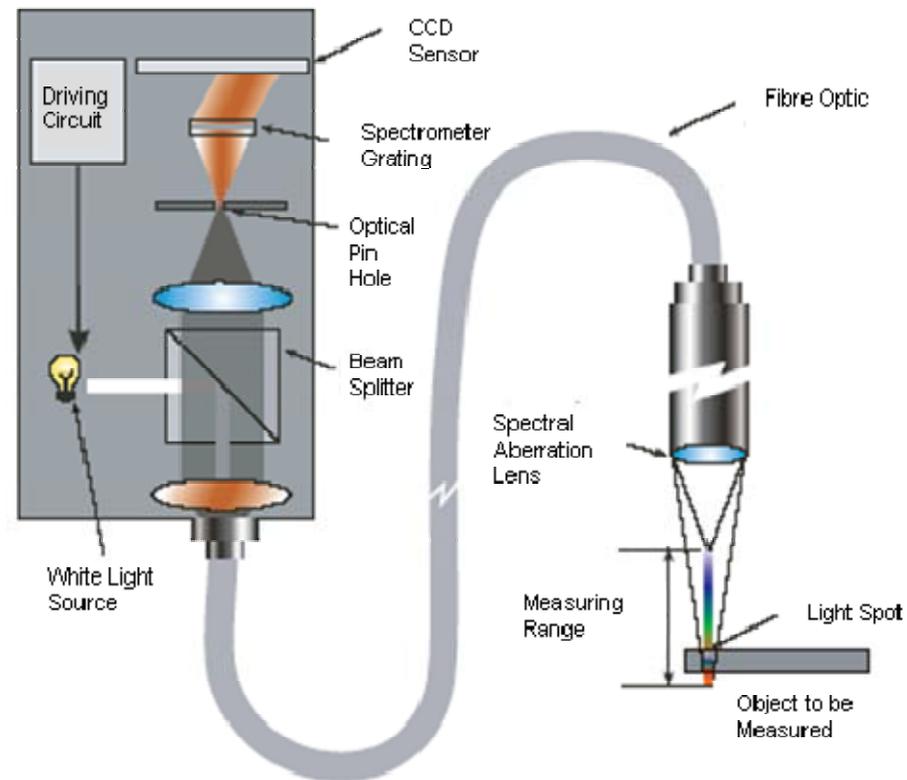
*The Confocal Gauge and Laser Gauges were both used on the Talysurf CLI, until it was withdrawn from the Product Line up in 2009*

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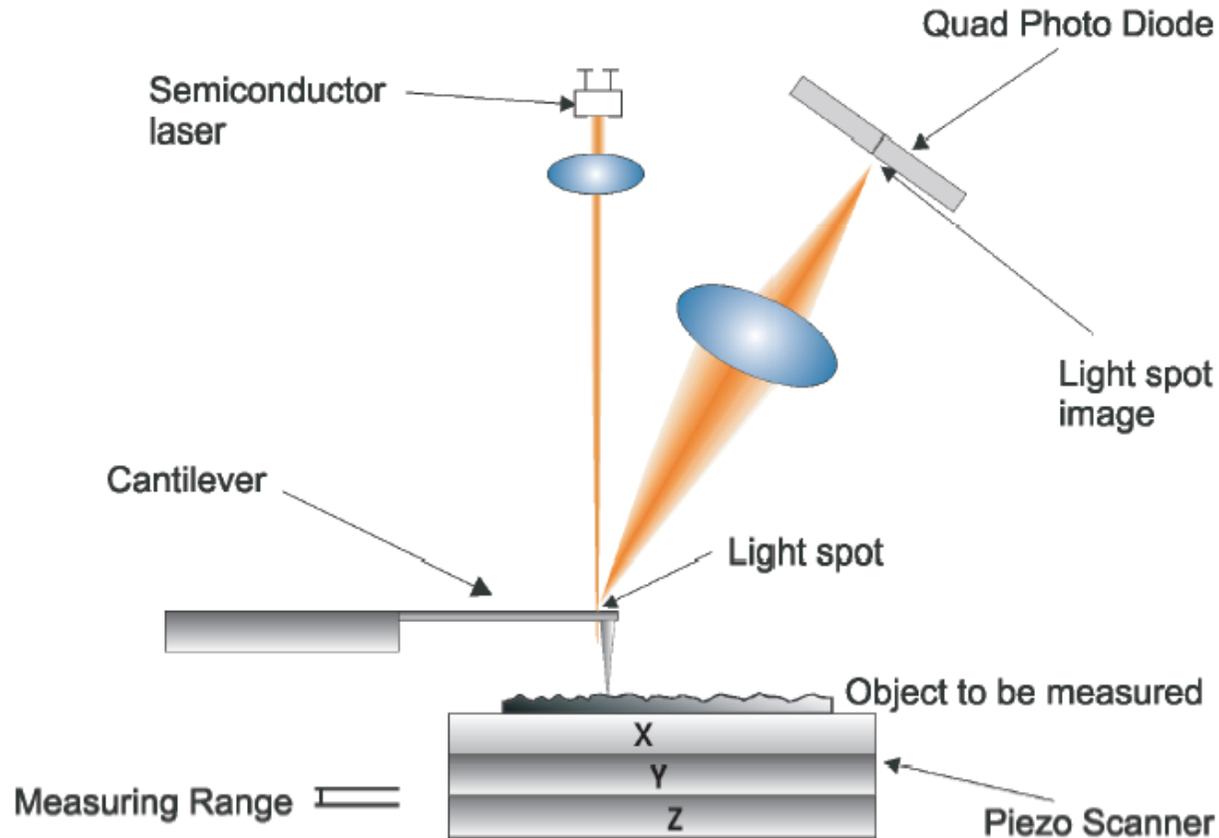


# Confocal Chromatic Aberration (CLA)

- Advantages
  - Fast - Up to 5KHz Scanning Frequency
  - Easy to Calibrate and Setup
  - Ideal for Large 3D areas Scans
- Disadvantages
  - High Cost
  - Non-Measured Points



# Atomic Force Microscopy



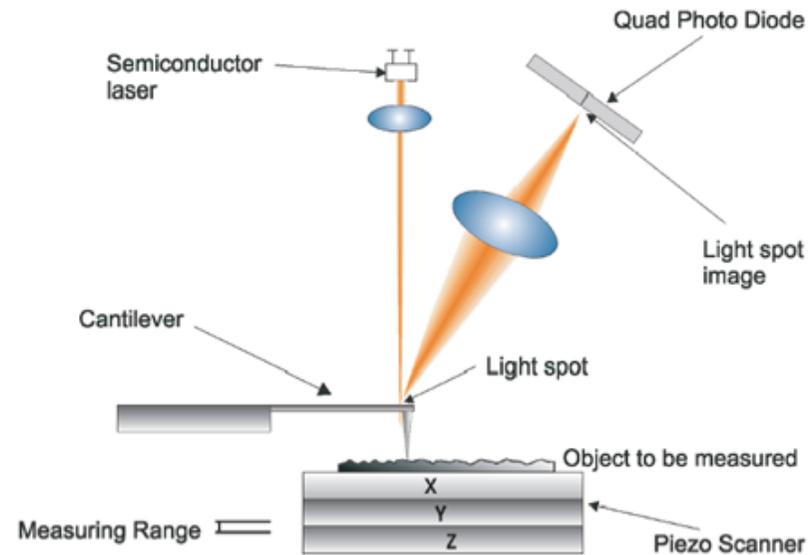
*The AFM stylus is made out of silicon using MEMS etching technology. The cantilever is about 50 $\mu$ m long and the stylus tip as small as 1nm diameter. The cantilever arm is moved up and down using piezo electric activators built into the silicon. Deflection of the arm is measured by noting the deflection of a light beam reflected off the top of it, near the stylus. Horizontal actuators allow a scanning motion of the stylus.*

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# Atomic Force Microscopy

- Advantages
  - High Resolution
  - Can resolve to individual Atoms
- Disadvantages
  - Only Measures Small Areas (100x100 $\mu$ m) & Small Range (circa 5 $\mu$ m)
  - Difficult to Calibrate
  - Primary Measurement based on Force



*Strictly speaking, Atomic Force Microscopes (AFMs) are contact measurement devices but, due to the very low stylus force involved, are usually considered non-contact for practical purposes. AFMs offer a very high resolution 3D measurement capability: in the limit AFMs can resolve individual atoms. They are often used by semiconductor companies and in materials research. While very versatile in their measurement capabilities it should be remembered that they can only measure over a small area (circa 100 $\mu$ m x 100 $\mu$ m) and over a small height (circa 5 $\mu$ m) and produce very small data sets. AFMs are notoriously difficult to calibrate and are better used for qualitative imaging of a surface rather than for quantitative analysis.*

*Another key factor which should not be ignored is that the primary measurement is based on force and not displacement. It is therefore possible to introduce distortions to the surface as a result of material interactions between the surface and the probe, which affect the force on the stylus rather than its displacement.*

# Summary

- Initial Visual Inspection is Important and will help in deciding how to make any measurements.
- Surface Finish Comparison Plates can be used as an estimation, but difficult to attach an absolute value to a surface.
- Contact Gauges tend to be based on proven technology, however improvements over the years have lead to Large Range (25mm) to Low Resolution (0.2nm) ratio. Because they contact the actual surface during measurement, damage can be caused to delicate substrates.
- Non-Contact Gauges tend to be based around Optics, light source and detectors. Non-contact measurements are more commonly used to measure 3D Surface Finish. Some substrates can exhibit optical effects that sometimes lead to flawed results.

# Contact us

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We offer standard and bespoke Training Courses in Surface Finish and Roundness, coupled with contact and non-contact Instrument Operator Training. To improve the understanding and application of Roundness and Surface Finish principles by your operators, inspectors and engineers.

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Without question, the benefits of training are exponentially greater than the cost. When your operators, inspectors and engineers are well versed in the theory and application of metrology they are more confident, more efficient, better informed and more likely to avoid mistakes or misrepresentation of results.

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