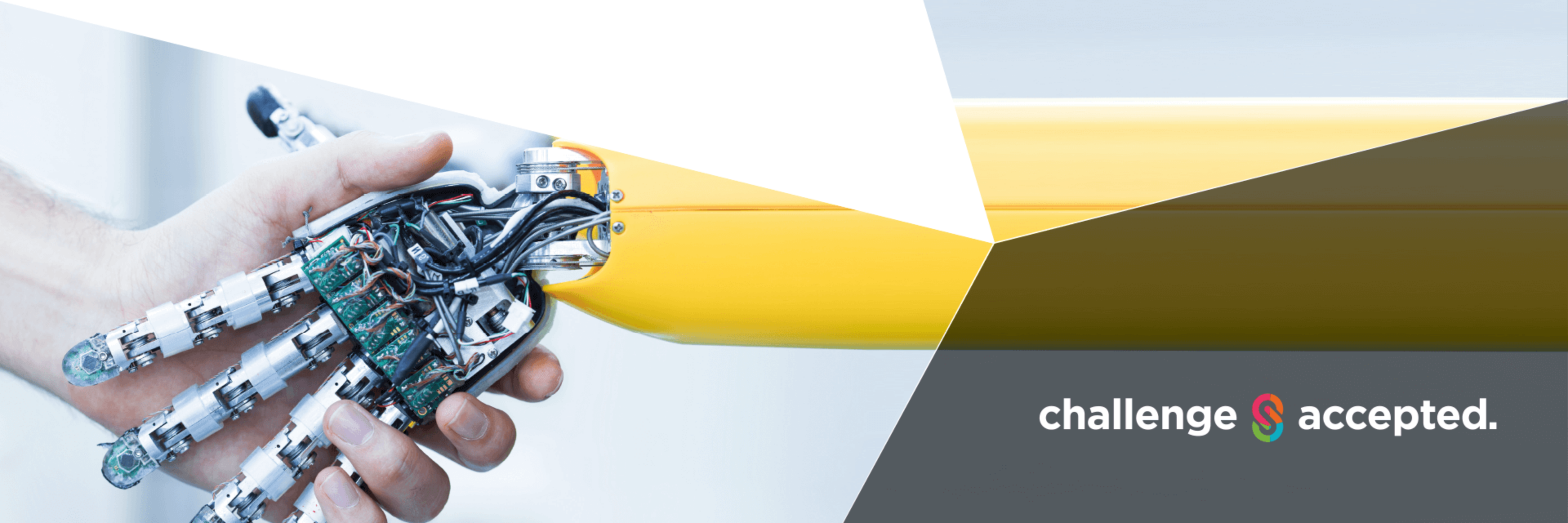
sentech
the sensor integrators

STIL
Precision in focus



challenge accepted.

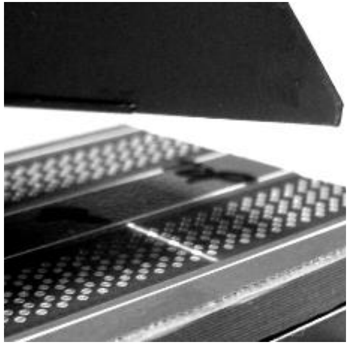
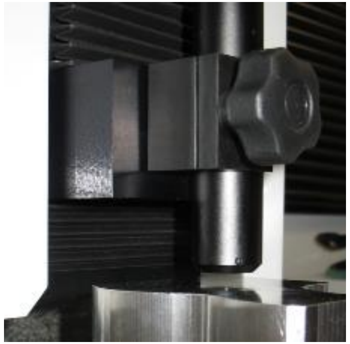
Chromatic Confocal sensors

for non-destructive measurement and inspection in nanometric scales

Presentation by STIL

Sciences & Techniques Industrielles de la Lumière

Matthieu DESJACQUES
STIL Sales Manager
Institute of Optics Engineer, France

Core Competencies

Designer & Manufacturer of Non-Contact Position Sensors

- Distance & Thickness Measurements
- Vision & Inspection

PICO	NANO	MICRO	MILLI	CENTI	DECI	METRE	HECTO	DECA	KILO	MEGA	GIGA	TERA
10^{-12}	10^{-9}	10^{-6}	10^{-3}	10^{-2}	10^{-1}	1	10^{1}	10^{2}	10^{3}	10^{6}	10^{9}	10^{12}
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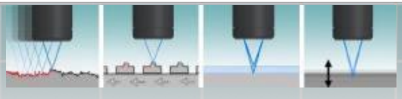


Sensors Timeline: 25 years of R&D

Based in Southern France

1993
STIL creation
- 3 PhDs
- 300 sqf

2000
Staff: 21
- 3 PhDs
- 8 Engineers
- 9 Technicians
- 3000 sqf

2007
Staff: 30
- 3 PhDs
- 14 Engineers
- 13 Technicians
- 7000 sqf

2016
Staff: 38
- 3 PhDs
- 15 Engineers
- 20 Technicians
- 11 000 sqf

2015
New ownership

New CEO
New strategy

STIL Awards

- 1997 – Award creative industries
- 2003 – Award technology showcase
- 2008 – Silver Photon – Innovation showcase
- 2016 – Créative Industry Nominee

Chromatic Confocal Technology

Inventor of chromatic confocal imaging, leading technology for non-contact sensors, STIL designed several ranges of sensors based on this innovative technology:

Point sensors - from 0,1 mm to 100 mm measuring range

OPTICAL SENSORS

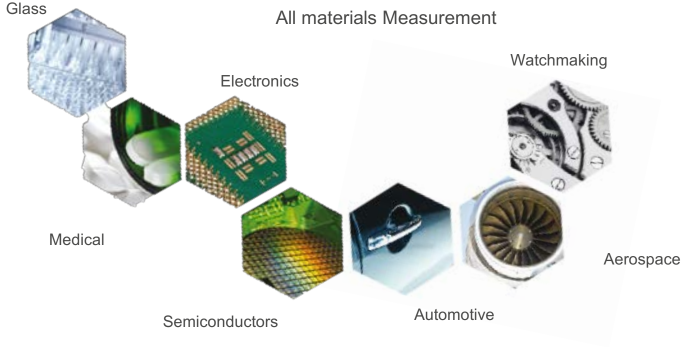
- Point
- Line
- Multipoint
- Vision

ADVANTAGES

- Non-contact
- High- Resolution
- Precision
- Fast Results

CAPABILITIES

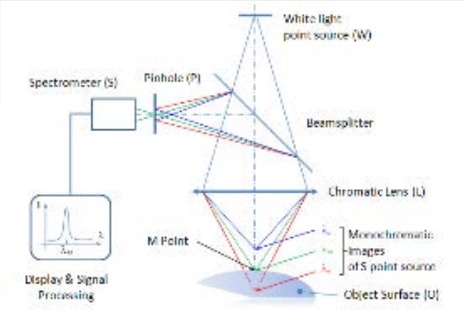
- Distance
- Roughness
- Thickness
- Dimension
- Inspection
- Multilayer



STIL
Precision in focus

Key product

From micrometric to nanometric
Chromatic confocal principle



1995
Creation first generation
Point Sensor
(CHR)

2016
Creation first
Multipoint Sensor
(X-DM)

2005
Creation second generation
Point Sensor
(CCS)

2008
Creation first generation
Line Sensor
(MPLS180)

2012
Creation first generation
Vision Sensor
(MC2)

Ready-made products - Adaptive technology - Proven track record - Plug & play measurement solutions

STIL
Precision in focus

Technology: Confocal Imaging

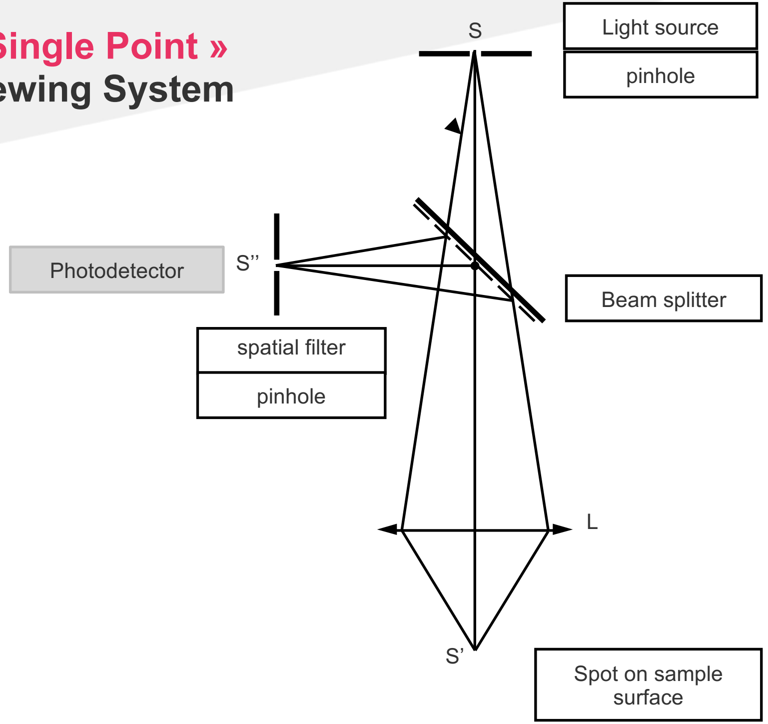
Confocal imaging consists in:

- Imaging a point source S on a sharply-focused spot S'
- Reversely, imaging S' on a small filtering pinhole S''

Features:

- 2 optically conjugated pinholes located at points S and S''
- Coaxial imaging
  - ✓ same light path for illumination and detection
  - ✓ double crossing of the lens
- "Single point" viewing system
  - ✓ scanning along X and Y s is required in order to obtain a full-field system
  - ✓ 'Optical sectioning'

« Single Point » Viewing System



Technology: Confocal Imaging

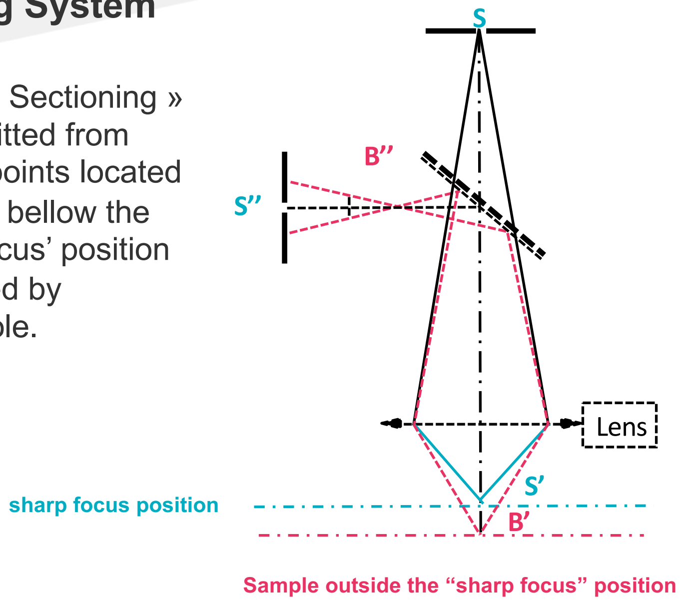
Optical sectioning

Confocal systems are practically "blind" for all space except for the sharply focused point S'. Light emitted by points located beside, below or above S' cannot reach the detector located behind the filtering pinhole at S''. This property is true both for scattering samples and for specular (polished) samples.

When scanned in X,Y directions, the confocal system generates a sharply focused observation plane. This property is called "Optical Sectioning". Points located above or below the sectioning plane are completely out of focus. As a result, image contrast is excellent.

« Single Point » Viewing System

« Optical Sectioning »
Light emitted from sample points located above or bellow the 'sharp focus' position is stopped by the pinhole.



Technology: Axial chromatism

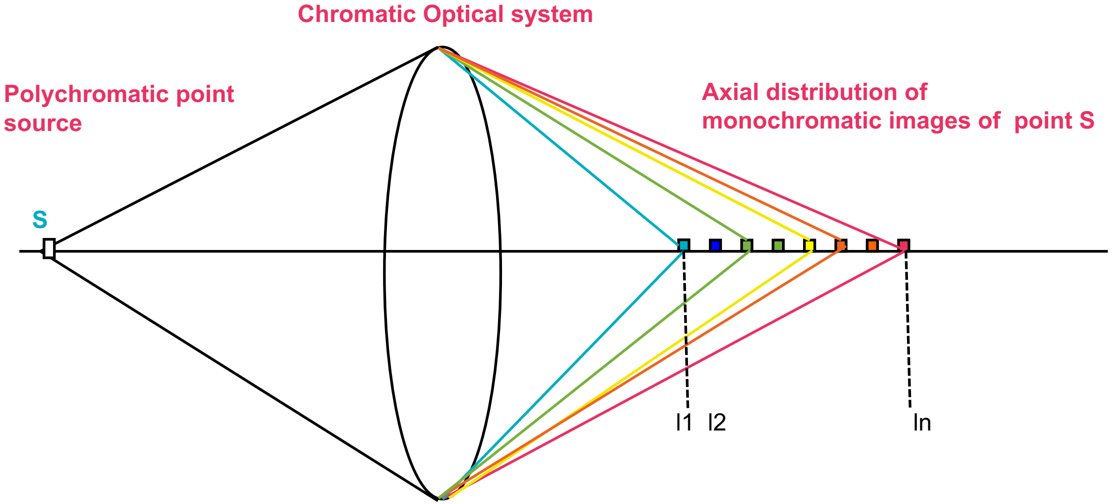
In a chromatic optical system the position of the image of any given point depends on the wavelength of incident light.

Axial Chromatism is a physical property of refractive optical systems, observed for all types of glasses.
It results from the spectral dispersion (dependence of the refractive index on wavelength).

In most cases, optical designers work hard to eliminate the axial chromatism which is usually considered to be a geometrical aberration of refractive optical systems.

However, in some very specific applications, the presence of a controlled amount of chromatism may be very useful. This is the case of Chromatic Confocal Imaging.

A controlled amount of chromatism may be obtained by carefully selecting the type of glass and the radii of all the surfaces in the optical system.



Technology: Confocal Imaging

Chromatic Confocal Imaging

Chromatic confocal imaging consists in introducing an optical element with axial chromatism in the setup of a confocal imaging system.

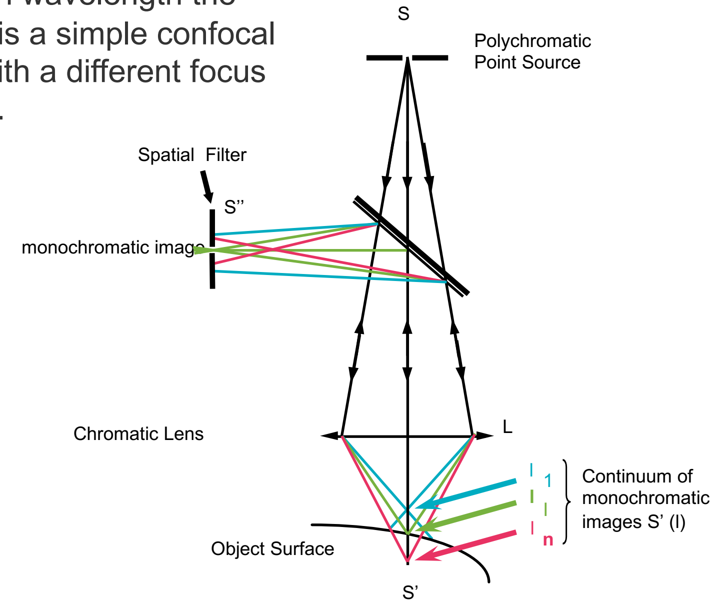
For each wavelength the system behaves as a classical confocal system, but the position of the sharply focused point S' depends on the wavelength.

When the point source S is polychromatic, the system generates a continuum of sharply focused monochromatic images S(λi) corresponding to the spectral content of the point source.

The chromatic confocal imaging system is "blind" for all space except for the color-coded segment generated by axial chromatism. We call it the "single line" viewing system.

« Single Point » Viewing System

For each wavelength the system is a simple confocal setup with a different focus position.



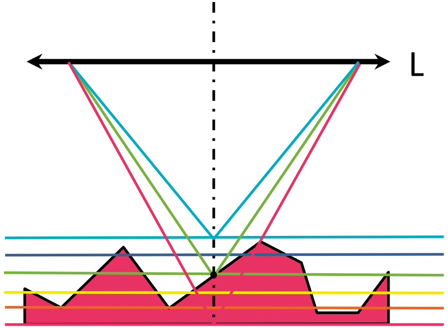
Technology: Chromatic Confocal Imaging

The Chromatic confocal viewing system presents the unique property of « perfect focus » over all the chromatic extended measuring range

Since at any given point of the axial field of view there is only one wavelength perfectly focused on the object, all the other wavelengths being inactive.

The Property of 'Perfect Focus'

Multi Confocal Extended depth of focus coded by the 'Rainbow Effect'



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Precision in focus

Technology: Chromatic Confocal Sensors

- Using Chromatic Confocal Imaging for 3D Metrology
- Distance measurement consists of 2 steps

COLOR-CODING OF SPACE

By using the axial chromatism of the illuminating beam

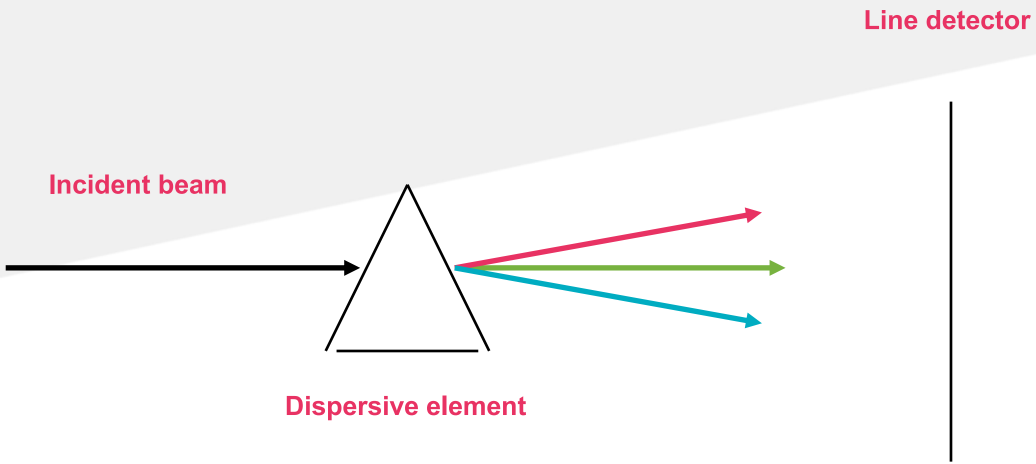
COLOR DECODING

By analyzing the spectral content (wavelength) of the beam which has passed through the pinhole

STIL
Precision in focus

Technology: Chromatic Confocal Sensors

Color decoding



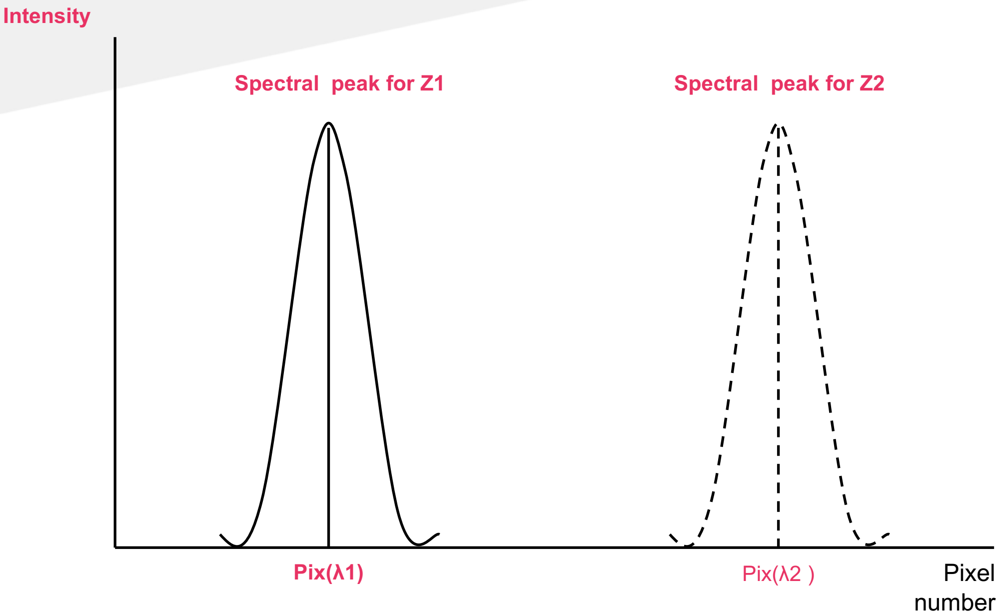
There exist many different means for analyzing the spectral content of the light beam filtered by the pinhole. One of them is the traditional spectrometer, comprising a dispersive element (a grating or a prism) and a line detector.

The position of the spectral peak along the line detector indicates the location of the sample inside the measuring range.

Technology: Chromatic Confocal Sensors

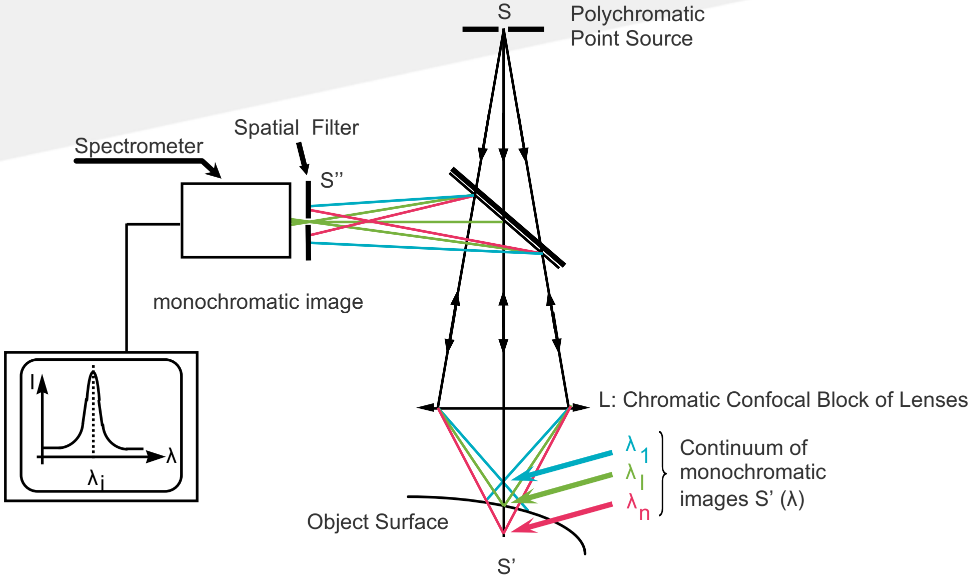
Spectrometer Signal

When the sample moves inside the measuring range, the wavelength reaching the spectrometer changes and the barycentre as well.



Technology: Chromatic Confocal Sensors

Color decoding



STIL
Precision in focus

Technology

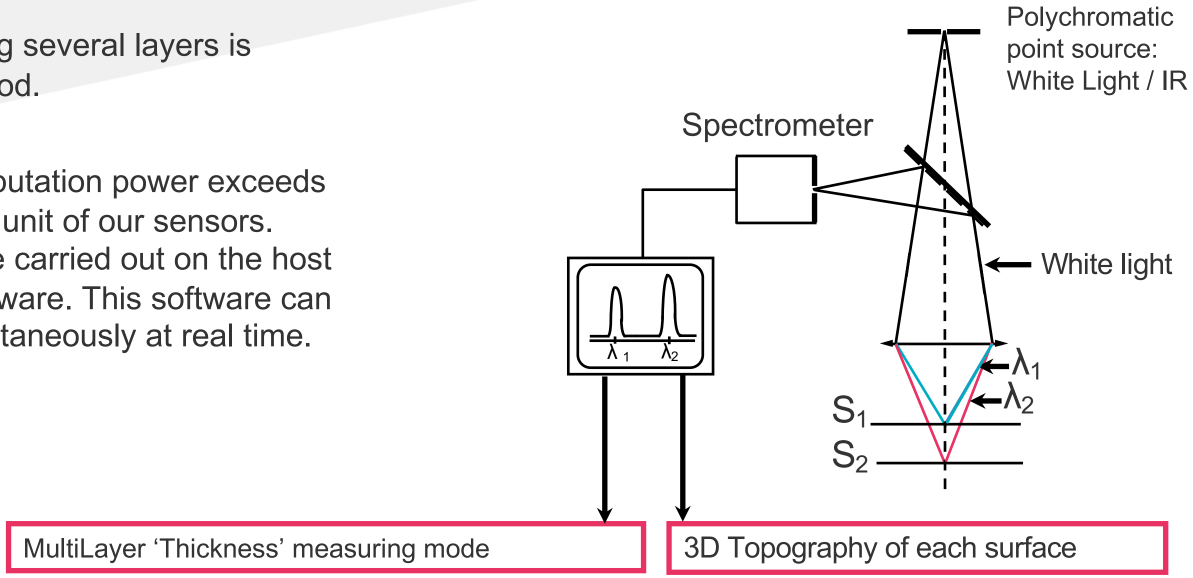
Measuring thickness of transparent samples

Principle

Multi-layer samples

Measuring samples comprising several layers is possible using the same method.

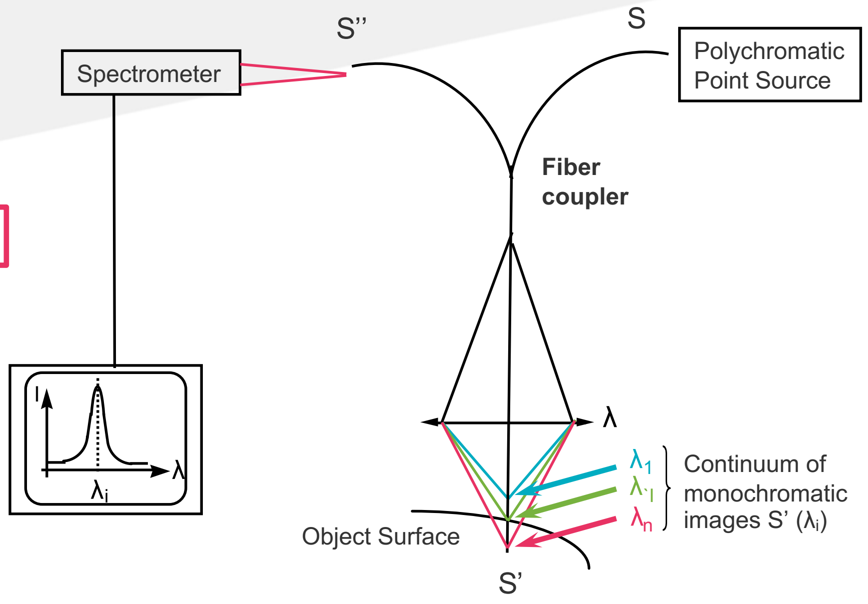
As of today, the required computation power exceeds that of the internal processing unit of our sensors. However this operation can be carried out on the host PC, using our “Multipeak” software. This software can measure up to 10 layers simultaneously at real time.



Technology: Chromatic Confocal Sensors

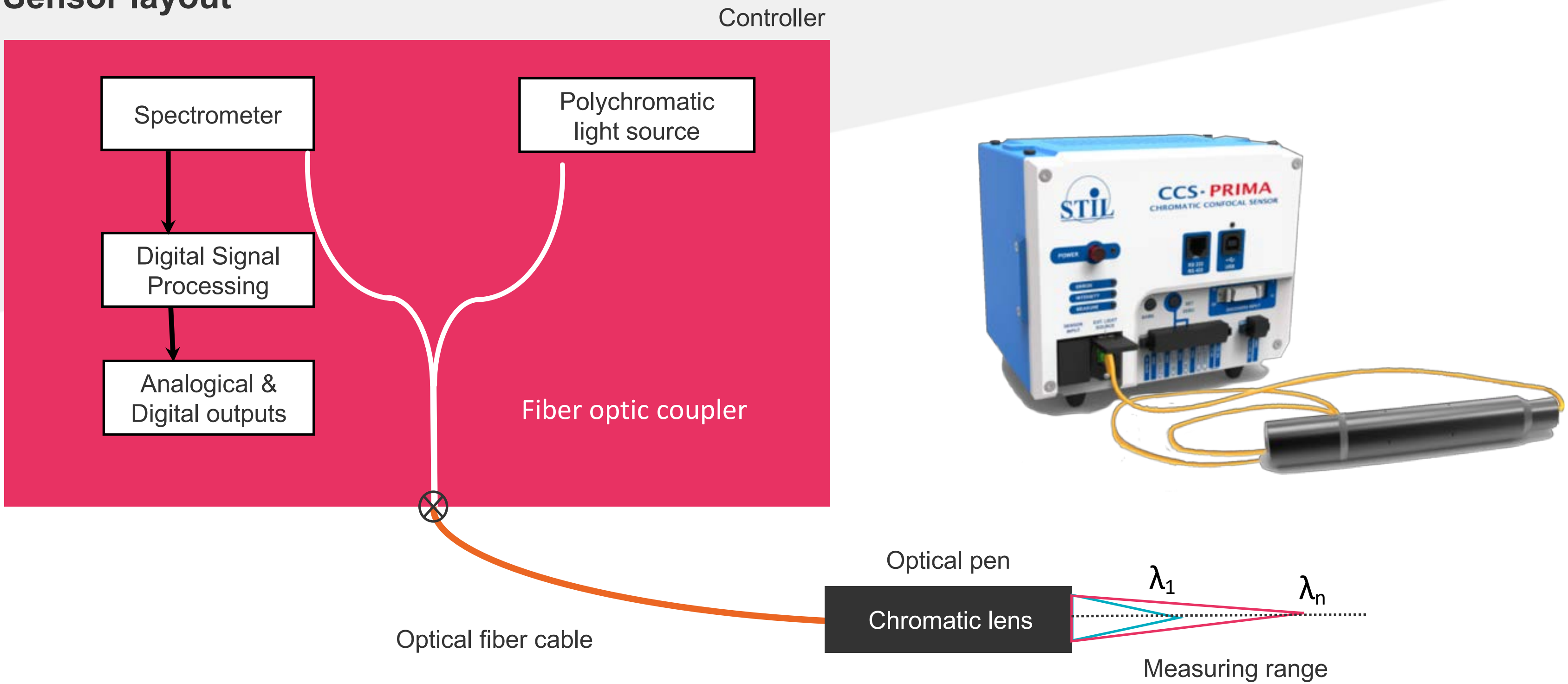
Implementation

Setup using fiber optics



Technology: Chromatic Confocal Sensors

Sensor layout



Technology: Confocal Imaging

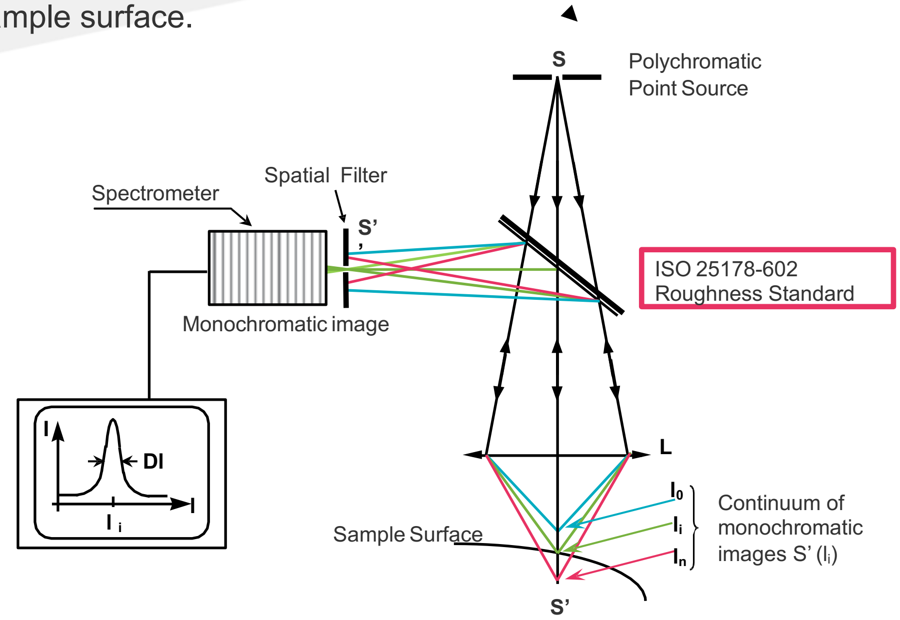
Distance sensor

Confocal spatial filter limits wavelengths bandwidth Dl to a narrow band centered on the wavelength l_i which is perfectly focused on the sample surface.

Measurement Solutions Features:

- Dimension
- Distance
- Displacement
- Thickness
- Profilometry
- Topography
- Roughness
- Tribology
- 3D Measurement
- Waviness, Bow, Warp Shape

Spectral decoding is performed by the spectrometer (position of the quasi monochromatic beam on the CCD/CMOS linear array).



Technology: Chromatic Confocal Sensors

STIL sensors hardware

Axial properties

- Measuring range: Directly dependant from the choice of Chromatic Block of Lenses used.
- Working distance: Distance from the optical pen and the first point of the Measuring Range.
- Accuracy: Along the Measuring Range - No Speckle Effects.
- High Axial resolution: From 7 nanometers (nm) without averaging and 2 nm with avg 10.

Lateral properties

- Spot size: Directly dependant of the Pinhole Diameter and Optical pen Magnification
- Lateral resolution: correspond to half the spot size Diameter – from less than 1 micrometer.

Optical properties

- High Numerical Aperture which allows to measure High slope angle: +/-45° on Mirror and >80° on Diffusive Surfaces.
- Coaxial Beam: No shadow effects.
- Works on Every Kind of Surfaces thanks to the AutoModulation of Light Source Intensity.
- Several ranges of Frequency: From 100Hz to 10 KHz.

Mechanical properties

- Optical pens composed of Passive components: Dimensions from 4mm Diameter and Weight from 15g
- Straight measurement or Radial measurement (90°)

Technology: Chromatic Confocal Sensors

STIL controllers

- CCS PRIMA: From 100Hz to 2KHz, available with 2 or 4 channels
- CCS OPTIMA+: until 10 KHz
- STIL VIZIR: InfraRed Light Source, until 2KHz

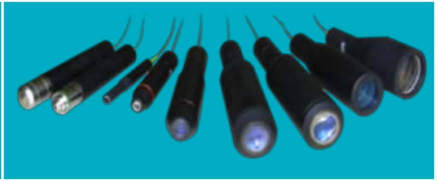
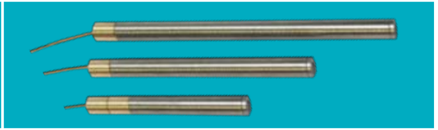
Technology: Chromatic Confocal Sensors

STIL Optical fibers / cables

Typical length : 3, 5 and 10m …

Technology: Chromatic Confocal Sensors

STIL optical pens

Modular Line (CL + MG)	• Consist of a chromatic lens and a magnifier allowing a “spot size vs. photometry” tradeoff • Measuring Ranges: 100 µm – 24 mm • Easily interchangeable – same diameter	
Dedicated Line (OP)	• Developed for specific applications, e.g. : long working distance • Measuring Ranges: 300 µm –100 mm	
Miniature Line (Endo)	• Very small diameter • Measuring ranges : 100 µm - 10 mm	

Vacuum or

Radio Active Chamber Compatible

because STIL Optical pens are composed of passive components.

Technology: Chromatic Confocal Sensors

STIL CL-MG references (D=27mm)

Model	unit	CL1-MG210	CL2-MG210	CL3-MG140	CL4-MG35	CL5-MG20	CL6-MG20
Measuring range	µm	150	400	1400*	4000	12000	24000
Working distance	mm	3,3	10,8	12,2	16,5	26,6	20
Numerical aperture		**0,71**	**0,46**	**0,41**	**0,32**	**0,2**	**0,12**
Max. sample slope	°	**42**	**28**	**25**	**21**	**14**	**8,5**
Reference plate		no	yes	yes	yes	yes	no
Axial model		standard					
90° folded model		option					
Spot size	µm	2,7	4	6,8	12,3	40	43
Lateral resolution	µm	**1,1**	1,7	2,6	4,6	14	18
Static noise	nm	**7**	17	50	110	425	800
Max. linearity error	nm	25	55	150	300	550	1200
Min. measurable thickness	µm	7,5	14	38	110	550	725
Length	mm	243,8	243,3	208,9	145,4	130	155,6
Diameter	mm	**27**					
Weight	g	268	248	215	155	160	180

Technology: Chromatic Confocal Sensors

STIL Optical pen references

Model	unit	OP300VM	OP300VM/90°	OP350	OP6000	**EVEREST-K1**
Measuring range	µm	220	220	350	6000	**1000**
Working distance	mm	5	4,4	12,8	28	18,5
Numerical aperture		**0,5**	**0,5**	0,54	0,39	**0,7**
Max. sample slope	°	**25**	**25**	30	22	**44**
Reference plate		no	no	yes	no	no
Axial or folded model		axial	90° folded	axial	axial	axial
Spot size	µm	**6,4**	**6,4**	7	12,5	**5**
Lateral resolution	µm	**3,2**	**3,2**	3,5	6,25	**2,5**
Static noise	nm	**25**	**25**	30	200	**50 (28)**
Max. linearity error	nm	70	70	75	500	100
Min. measurable thickness	µm	25	25	25	200	50
Length	mm	127	128	257	205,5	260,5
Diameter	mm	15	15	50	60	82
Weight	g	27	39	781	760	1400

Technology: Chromatic Confocal Sensors

STIL Endo/Probe references

Model	unit	ENDO 2,0/D4	ENDO 0,1/D6	ENDO 1,5/D6-90	ENDO 0,2/D8	PROBE 10/D8	ENDO 10/D8-90
Measuring range	µm	**2000**	100	1500	200	10000	10000
Working distance	mm	5,6	1,1	0,8	4,8	9	5
Numerical aperture		0,12	**0,41**	0,19	**0,39**	0,1	0,095
Max. sample slope	°	5	24	10	23	±4,5	5,4
Axial or radial model		axial	axial	radial	axial	axial	radial
Spot size	µm	30	6,25	19,5	4,6	35	41,6
Lateral resolution	µm	15	3,2	10	2,3	17,5	21
Static noise	nm	300	**25**	220	**30**	900	900
Max. linearity error	nm	400	45	300	70	1000	1200
Min. measurable thickness	µm	500	35	210	25	900	1000
Length	mm	53,8	58,9	89,2	67,8	141	87
Diameter	mm	**4**	6		8		
Weight	g	8	10	12	15	26	20

Technology: Chromatic Confocal Sensors

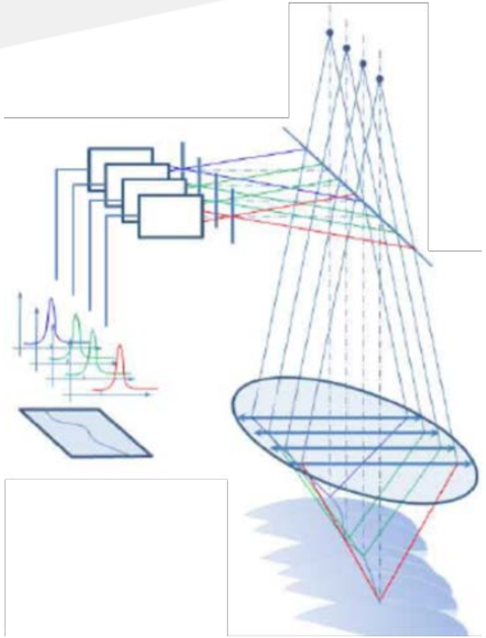
Multipoint configuration

A Multipoint chromatic confocal sensor consists of N independent channels sharing a common chromatic lens, while preserving the confocal principle and its advantages (high resolution and contrast).

Each channel projects a single point on the sample surface and focalizes the collected light on its own dedicated spectrometer.

Multipoint Confocal Chromatic sensors present a real technological challenge:

- Simultaneous acquisition and treatment of 180 spectrums
- Design of Field Chromatic lens



STIL
Precision in focus

Technology: Chromatic Confocal Sensors

STIL multipoint line sensors

Model	unit	NanoView	MicroView	DeepView	**WireView**
Line Length	mm	1,34	1,79	4,05	**1,51**
Measuring range 2kHz	µm	100	500	2600	**900**
MR 4kHz	µm	45*	235*	1150*	450*
MR 6kHz	µm	25*	120*	650*	240*
Working distance	mm	4,6	10,1	47,8	7,8
Numerical aperture		**0,7**	0,5	0,35	**0,75**
Max. sample slope	°	40	30	20	46
Pitch (dist. between 2 points)		7,4	10	22,4	8,4
Spot size	µm	3,75	5,2	11,5	4,2
Static noise	nm	**25**	100	350	150
Max. linearity error	nm	50	80	150	100
Min. measurable thickness	**µm**	**18**	**50**	**300**	**110**
Optical Part : Length	mm	436,8	425,6	445,9	480,7
Optical Part: Diameter	mm	50	50	75	70
Optical Part : Weight	g	1600	1600	3400	2200

Chromatic Confocal Sensors

STIL multipoint sensors

Up to N independant measuring channels

- multiple optical probes (standard)
- multiple points inside the same optical probe (custom design)

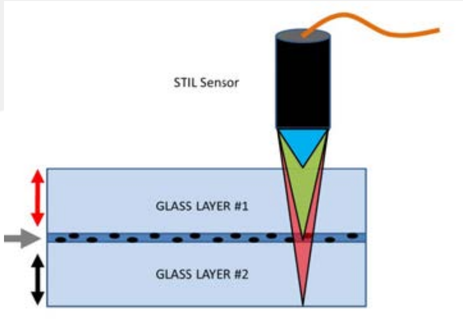
Applications: Chromatic Confocal Sensors

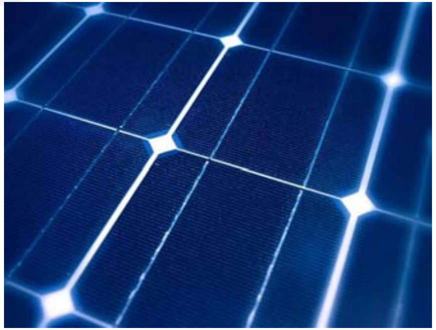
« Single Point »

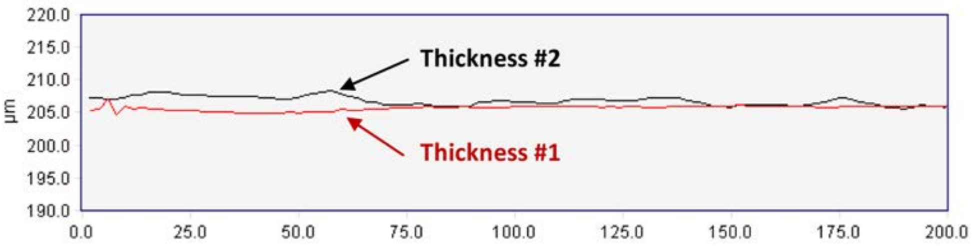
Application Example

Dimension & thickness control on laminated glass (multiple layers)

THICKNESS
AIR GAP
SHAPE







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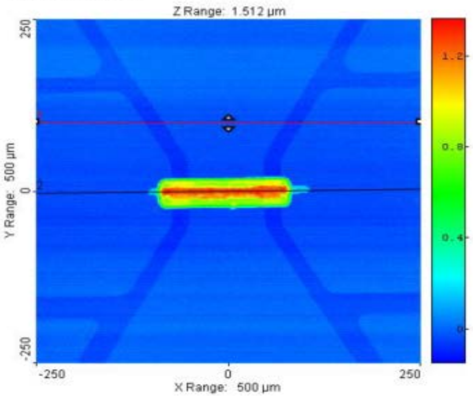
Applications: Chromatic Confocal Sensors

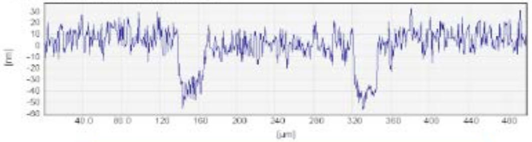
Thickness measurement

Measurement of nm-range step heights (ITO coating)

Topographic image

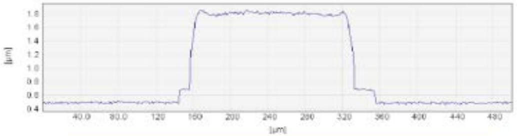


Extracted profile #1 (red line):



We measure a thickness of ITO coating = 40nm

Extracted profile #2(black line):



We measure a height of the metal jump = 1.31µm

Measurement parameters:

Sensor: CCS PRIMA

Optical pen: CL1-MG210

Measuring Range: 150µm

Spot size (diameter): 1.8µm

Static noise (without averaging): 7nm

STIL Sensors are able to measure step heights in the nm range.

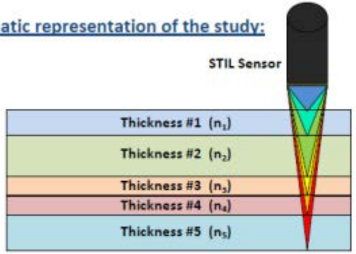
Here, ITO thickness = 40nm.

Applications: Chromatic Confocal Sensors

« MultiPeak»

For multi layer thickness measurement

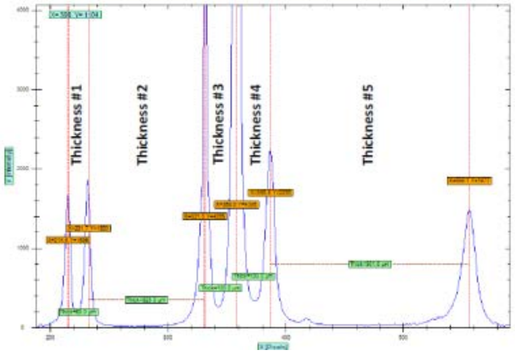
Schematic representation of the study:



Measurement parameters:

- Technology: Confocal Chromatic Sensor
- Point Sensor
- Controller: STIL-DUO
- Optical pen: CL3-MG70
- Measuring Range: 1200µm
- Spot Diameter: 11 µm
- Software: STIL MultiPeak

Screenshot of the running MultiPeak Software:



Statistics:

Name	Thickness							
Layer 1	Min:	59.6 µm	Max:	59.7 µm	Avr:	59.7 µm	Std Dev:	0.02 µm
Layer 2	Min:	323.2 µm	Max:	323.2 µm	Avr:	323.2 µm	Std Dev:	0.02 µm
Layer 3	Min:	102.9 µm	Max:	102.9 µm	Avr:	102.9 µm	Std Dev:	0.00 µm
Layer 4	Min:	102.8 µm	Max:	102.9 µm	Avr:	102.9 µm	Std Dev:	0.02 µm
Layer 5	Min:	301.1 µm	Max:	301.1 µm	Avr:	301.1 µm	Std Dev:	0.02 µm
Total	Min:	889.7 µm	Max:	889.7 µm	Avr:	889.7 µm	Std Dev:	0.02 µm

STIL DUO with MultiPeak Software is able to measure simultaneously the thicknesses of a multilayer sample (up to 10 layers).

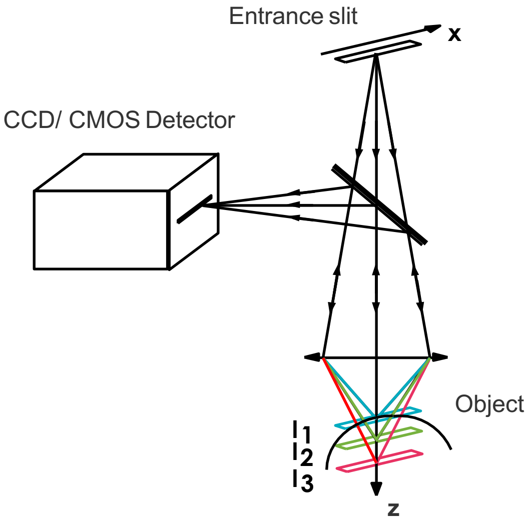
STIL
Precision in focus

Chromatic Confocal Camera

STIL Inspection System Principle: AOI

If the spectrometer of each individual channel is replaced by a single photon detector, or a single pixel, one gets a system which can see the observed sample point at perfect focus at any axial position inside the depth of focus.

However this system is unable to determine the axial position: otherwise stated, one gets a microscope with an extended depth of focus.



Chromatic Confocal Camera

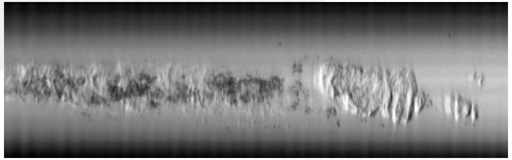
STIL Chromaline Camera

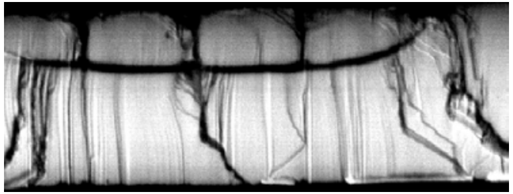
Model	unit	NanoView	MicroView	DeepView	**WireView**
Line Length	mm	1,35	1,8	**4**	1,5
Depth of field	µm	100	500	**2600**	**900**
Working distance	mm	4,6	10	47,8	7,8
Magnification		17,3	12,5	5,6	15,6
Numerical aperture		**0,7**	0,5	0,35	**0,75**
Max. sample slope	°	40	30	20	46
Pixel size on the sample	µm	**0,41**	**0,56**	1,23	**0,45**
Optical Part : Length	mm	393,3	382,1	403,9	437,2
Optical Part : Diameter	mm	50	50	75	70

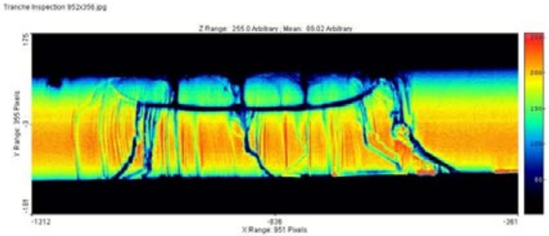
- Maximum Frequency Acquisition: More than 100 000 lines/second
- Minimum Default Size Inspection: Less than 1 micrometer

Applications: Chromatic Confocal Inspection

Manufacturing Defects Inspection on Wafer Edge

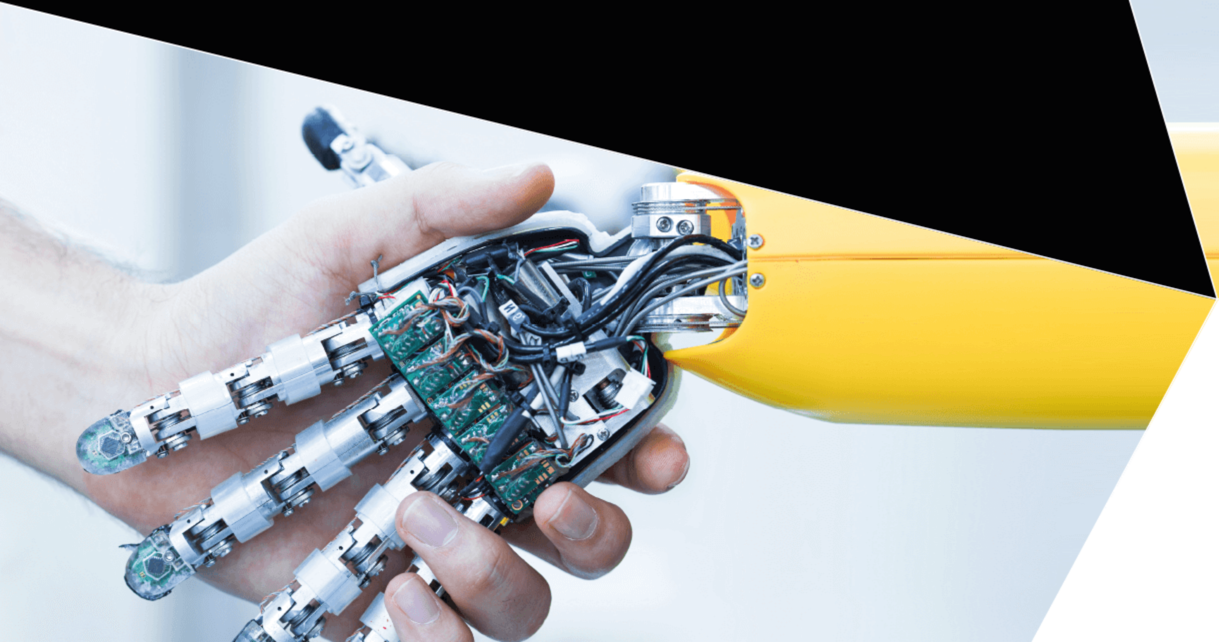






sentech
the sensor integrators

STIL
Precision in focus



challenge accepted.