

Image Processing, Image Analysis and Computer Vision

Measuring large areas by white light interferometry at the nanopositioning and nanomeasuring machine (NPMM)

Authors: Daniel Kapusi¹ Torsten Machleidt Karl-Heinz Franke Eberhard Manske Rainer Jahn

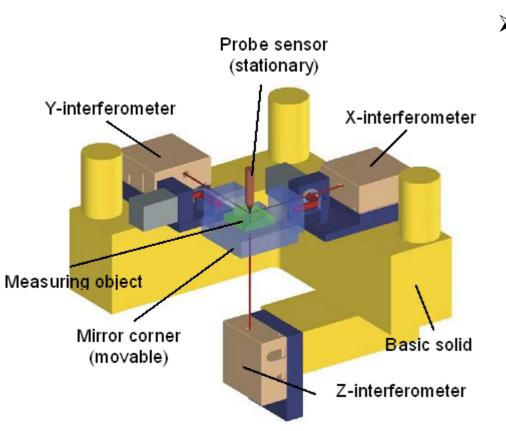
¹daniel.kapusi@tu-ilmenau.de



Outline

- Motivation
- Measurement setup
- Principles of scanning white light interferometry
- Interferogram analysis methods
- Measuring large areas
- Determination of sensors orientation and scaling
- Correction of sensors tilt
- Exemplary results
- Software environment
- Conclusion
- Outlook





Motivation

Basic set-up of the NPMM according to the comparator principle of Abbe

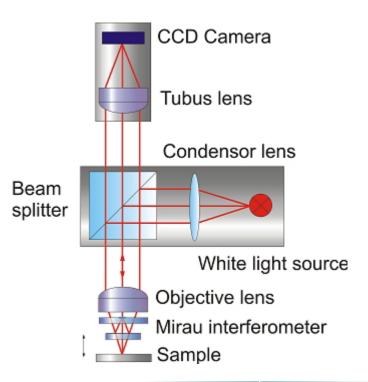
- NPMM features a measuring volume of 25 x 25 x 5 mm³ with a resolution of 0.1 nm
 - Advantages for white light interferometry
 - ✓ Low positioning noise
 - ✓ Large perpendicular pass trough range with 5 mm
 - ✓ Stitching of adjacent single measuring results to a common large height map



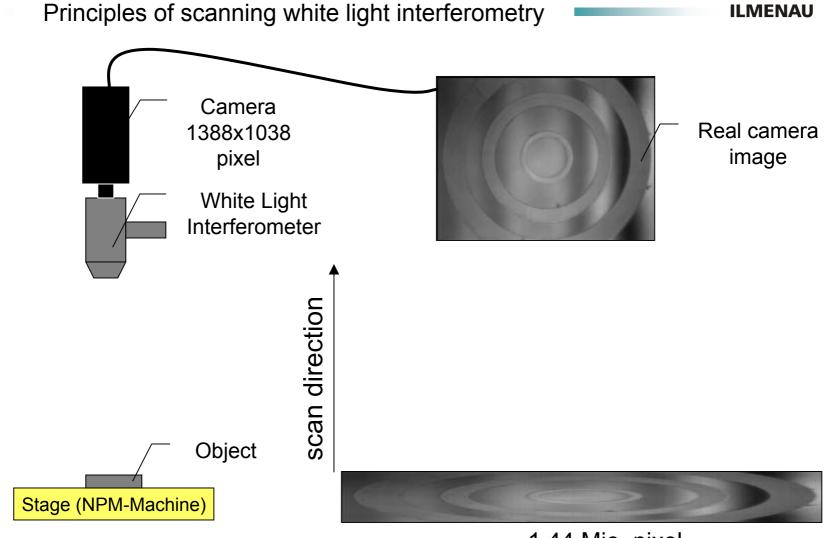
Measurement setup

- White light interferometry sensor
 - Tube from a focus sensor coupled with a Mireau-interference objective
 - 14-bit monochromatic CCD camera (FireWire 1394b, up to 30 fps)
 - Halogen light source
- > NPMM is placed on an oscillation-damping system
- Acoustic hood



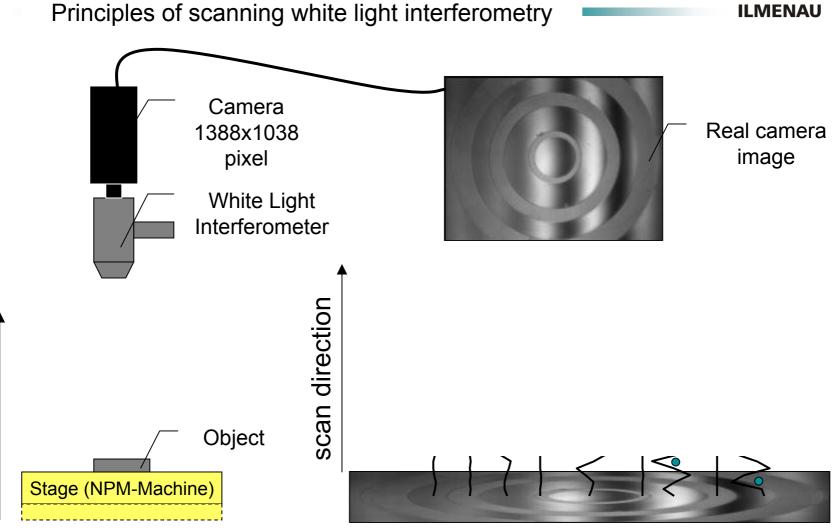






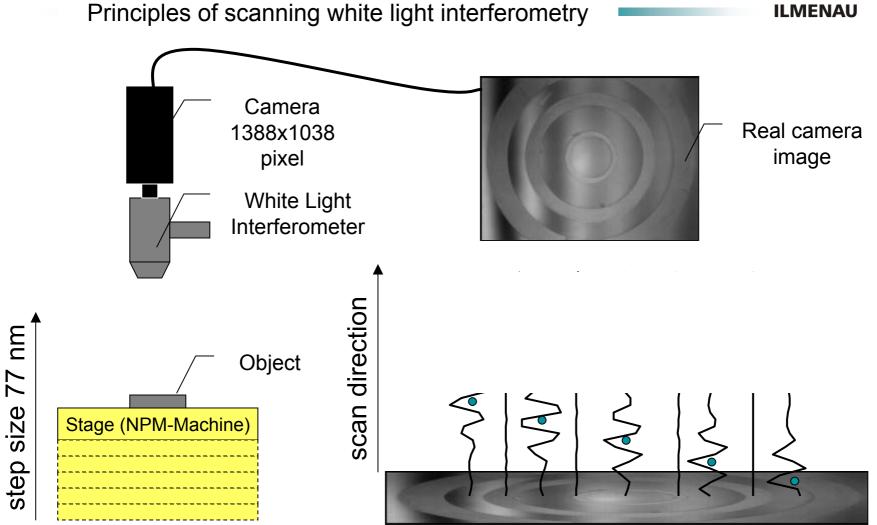
step size 77 nm



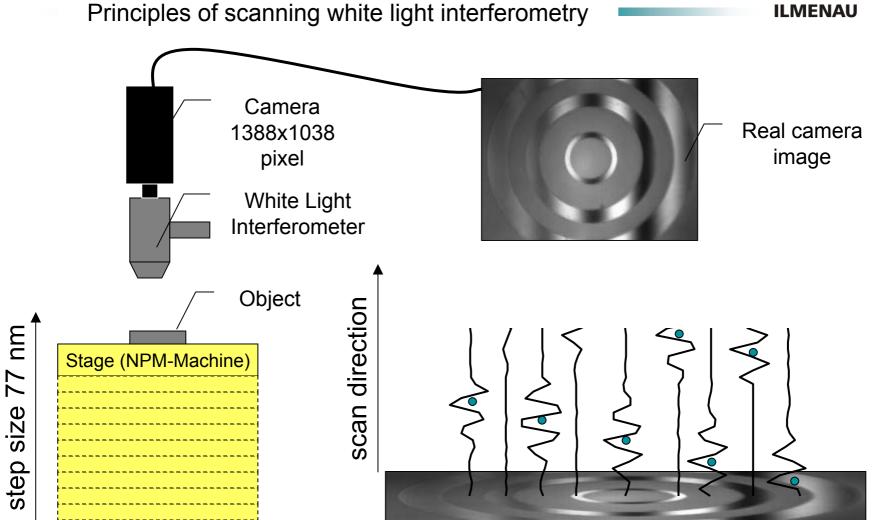


step size 77 nm

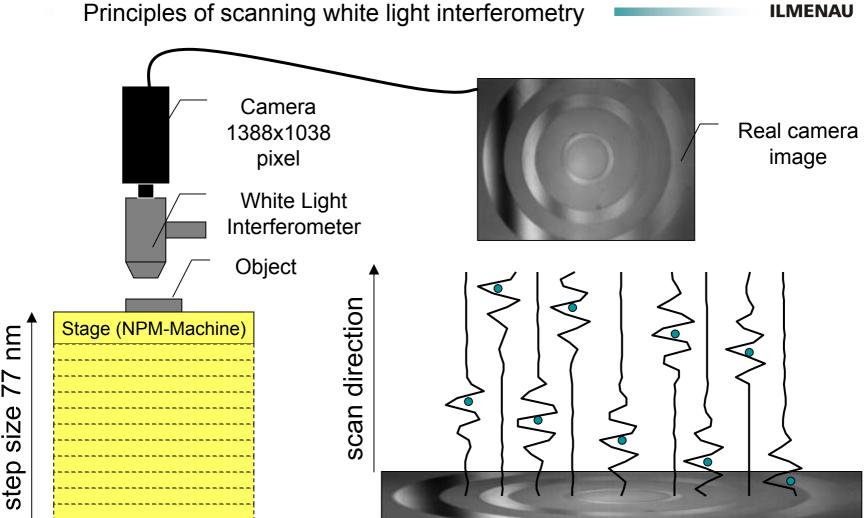










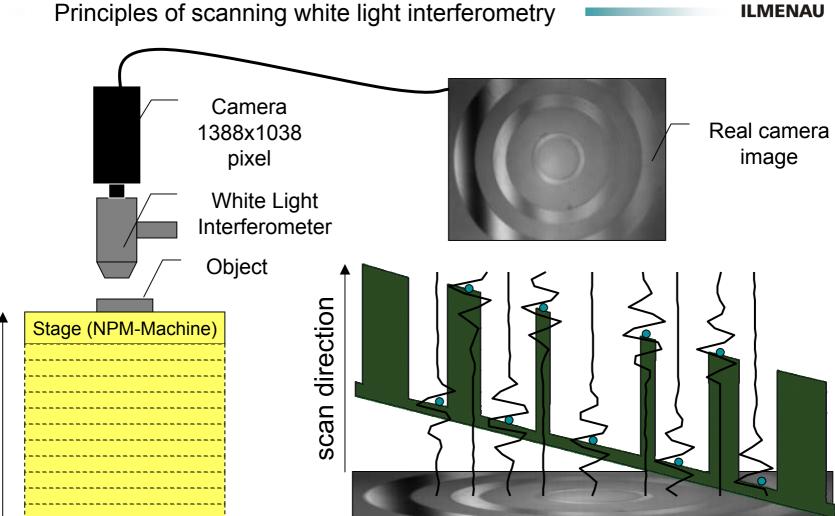


ШU

77

size





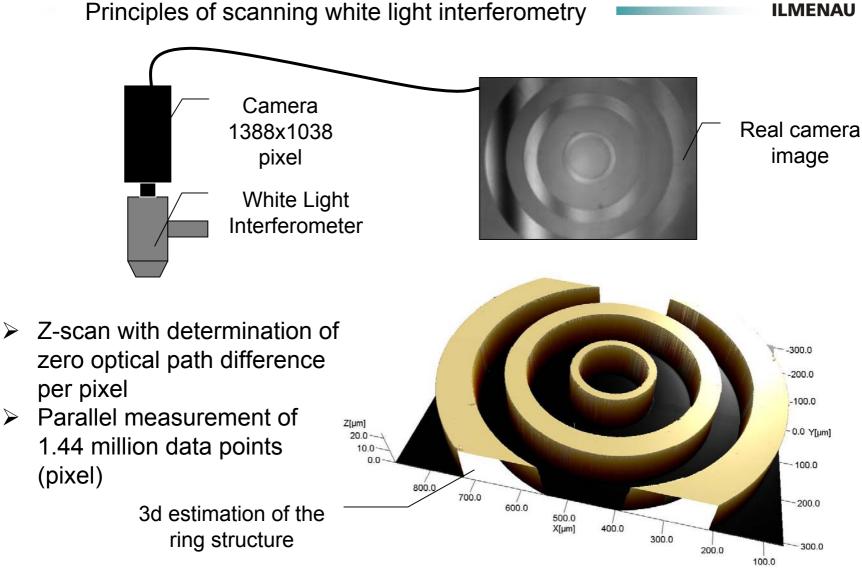
ШU

77

size

step



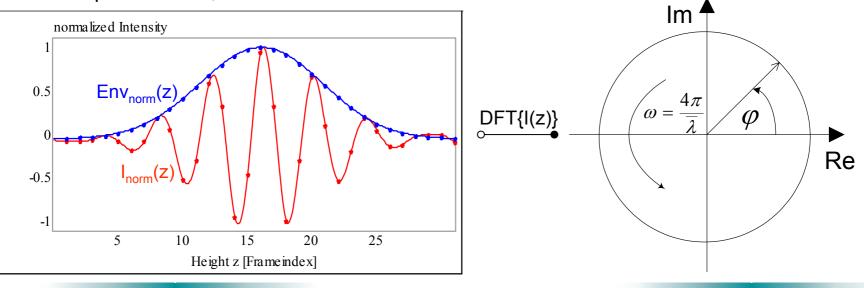




Interferogram analysis methods

- Envelope evaluation
 - Suitable for rough and smooth surfaces
 - Envelope extraction by Matched Filters, Hilbert-Transformation, fast Bucket methods, et al
 - Approximation of the envelopes peak position by Gaussian or parabola fit, iterative gradient-based peak search, et al

- Phase evaluation
 - Suitable for smooth surfaces
 - Phase shift determination by fast Bucket methods (such as Carré) or more precise Fourier analysis
 - Allocation of fringe order by envelope evaluation or spatial phase unwrapping



Speaker: Daniel Kapusi

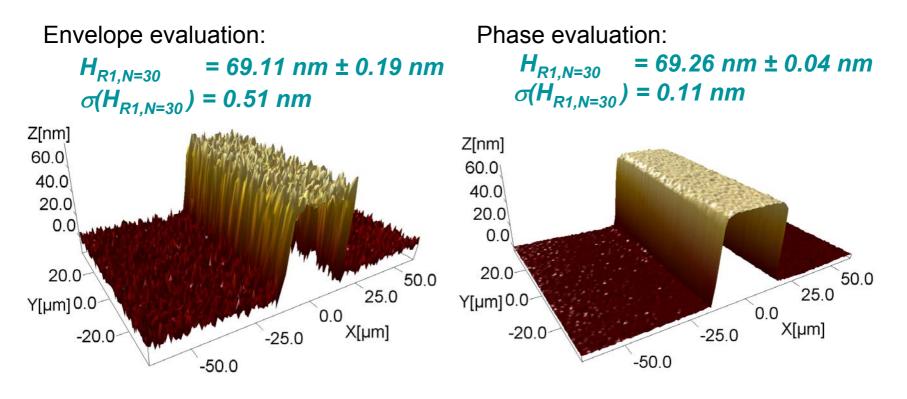
52. International Scientific Colloquium



Interferogram analysis methods

Comparison of the results of measuring a PTB layer thickness standard:

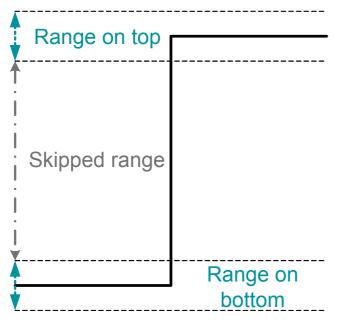
- Sampling step width in perpendicular direction: dz = 77 nm
- > Given step height (ISO 5436-1) of section R1: H_{R1} = 69.1 nm ± 1.2 nm



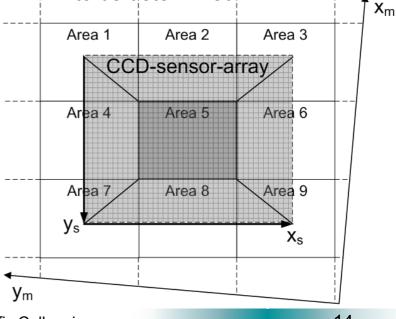


Measuring large areas

- Perpendicular orientation
 - Skipping of height-steps with high speed, where no fringes occurring
 - Definition of multiple passthrough ranges per measuring area



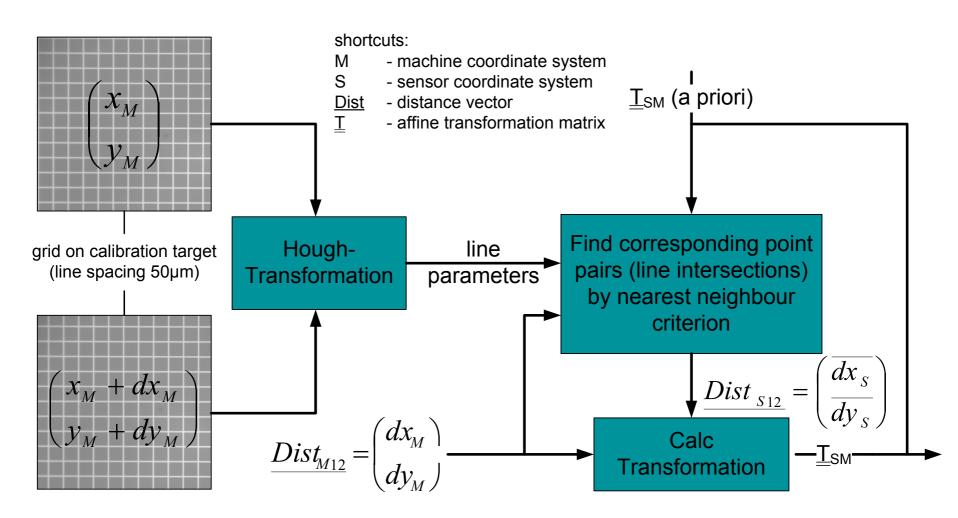
- Lateral orientation
 - topography independent stitching of adjacent measuring areas
 - orientation and pixel scaling of the camera according to the machine coordinate system has to be determined



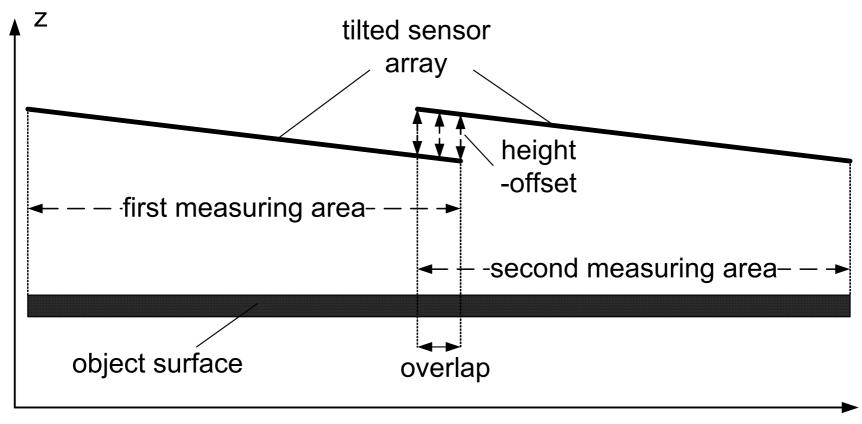
Speaker: Daniel Kapusi 52. International Scientific Colloquium



Determination of sensors orientation and scaling



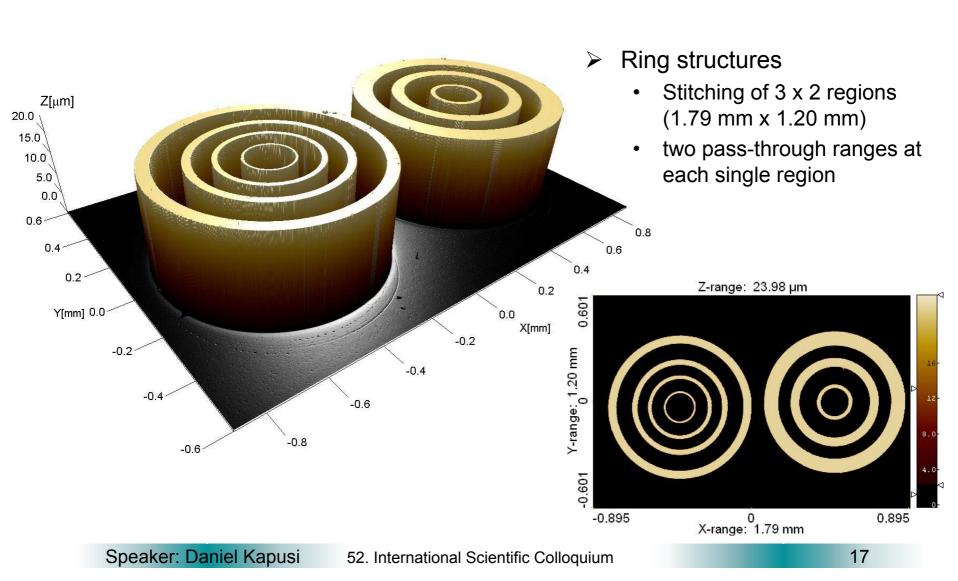




 x_s resp. y_s



Exemplary results





Software environment

- Software package VIP (Visual Image Processing) –Toolkit from
 - ✓ Rapid prototyping of image processing solutions
 - ✓ Includes large and extensible algorithm libraries
 - ✓ Graphical pipeline editor
 - ✓ Graphical user interface

I		Abort Position SetMinZ Aborted -	
White light interferometry for nanopositioning and nanomeasuring machines			
Calibration MoveToPoint			Hoehendaten extrahieren localhost / 2
Supervised positioning	Settings 3d	l Heightdata	outi — Bildeingang HeightData — max. Bildanzahi
*	-z z-Range [mm]	- Z-Koordinate [mm]	Bildinformationen
		0.026	Reset
	Lock/ Unlock		
		0.024	
		0.022	
	upper bound	-0.02	Elio Elio
	Lock/ Unlock	0.018	FiFo Measuring Pic localhost / 0
The second	5	310.0	ten Muttipleser
		0.014	am Startsammler
	z-Stepwidth [nm]	0.012	i Output
	77 ÷	-0.01	
and the second sec			
	Frame count	0.008	Gruppe von Operatoren Gruppe Bildeinzun
	64936	0.006	Einfacher Triggen Kamerareset Gruppe Bildeinzug Localhost /0 (Dauer: 0 ms) — Start MeasFioName
	Moving	0.004	Trigger er Stop Measuring Pic
	→ false	0.002	Bit Pic - ExtTrigParam CalibPic -
+x -y 4		0	LiveCaptParam
x-Position [mm] z-Position [mm]	Position [mm]	C:\Dokumente und Einstellungen\daniel\Desktop\test_si01_mitendkontrolle.bcrf	
10.7461651649 11.565135602	2.45525635122	2d view Select Filename Save 3d Data	
Measuring Regions			Cares-Molinierez 1
Stitch CamCoord X Stitch Cam	mCoord Y	Z- Passtrough Ranges	Cam Stopsammler localhost / 0
left border: 0 right border: 0 upper bor	rder: 0 lower border: 0	count: 1 current index:0	Control Output
<- Add/Select left Add/Select right -> <- Add/Se	elect upper Add/Select lower ->	<- previous next ->	— Input 2
<pre></pre>	ove upper Remove lower ->	current index: 0	— Input 3 — Input 4
Control Measuring progress		Calculation progress	
		Thread1	
Start Measurement Abort		Thread2	
		Thicauc	



Conclusion

- Development of a white light interferometry application for the NPMM
 - ✓ Based on a focus sensor measurement setup
 - ✓ Precise height extraction by envelope or phase evaluation
 - ✓ Skipping of large height differences by jumping to multiple defined passthrough ranges
 - ✓ Stitching of adjacent measuring regions independent of topography
 - Determination of sensors orientation and scaling in advance by a measuring procedure
 - · Correction of sensors tilt needs only a small overlap



Outlook

- Redesign of the measurement head
 - ✓ Zerodur base plate with sensor insertion apparatus
 - ✓ Sensor set-up made of Invar for inserting into the base plate
 - ✓ More high-grade compact microscope tube with higher magnification
 - ✓ Set-up for manual sensor aligning



- This project is sponsored by the ministry of education and arts of the Free State of Thuringia (Germany) under the sign B 514-06 007
- Thanks all those colleagues at the Technische Universität Ilmenau and the ZBS Ilmenau e. V., who have contributed to these developments

Thank you very much for your attention!