CIMTEC 2012

Versatile Smart Optics Material (SOM) Characterization System

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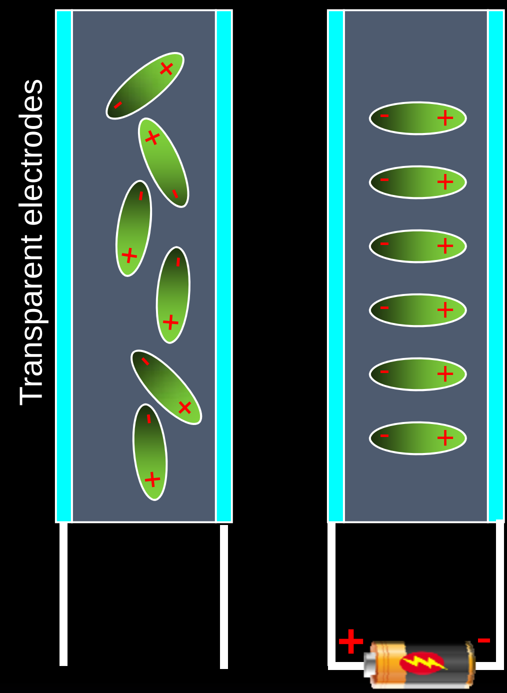
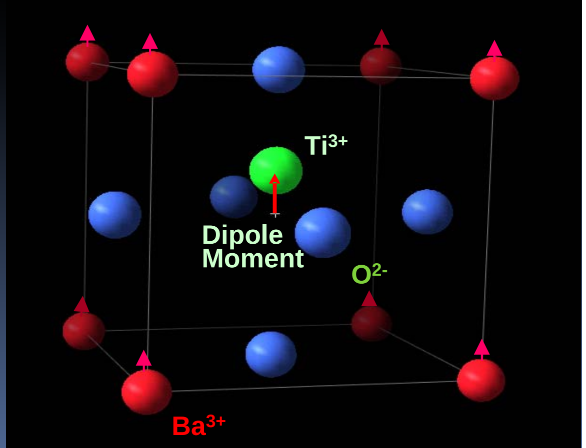
Smart Optics Materials

- Smart Optics Materials (SOM) are various new optical materials that can control deep properties (intensity, phase, polarization, coherence) of passing lights, including
  - electro-optic materials (non-linear optical crystals, liquid crystals, electro-optic polymers)
  - magneto-optic materials (Faraday Effect and Kerr Effect),
  - electro/thermo-chromic materials
  - chemicals that induce refractive index changes
  - optical materials that depend on temperature and pressure
- Characterization of these materials is difficult due to a lack of standard equipment.
- New prototype SOM characterization system with advanced software is under development at NIA and NASA LaRC.
  - It can measure intensity, phase, and polarization of passing lights through many new optical materials while applying various physical/chemical effects on the materials.
  - A miniaturized compact system has standard-PC-interface and inter-changeable components for various R&D and commercial applications.
  - This innovative versatile SOM characterization system and characterized optical materials will be used for complete micro spectrometer system.
  - Commercialization of this system accelerates development of new optical materials and devices.

Liquid crystal





Non-linear optical crystal

Application of Light Phase Control

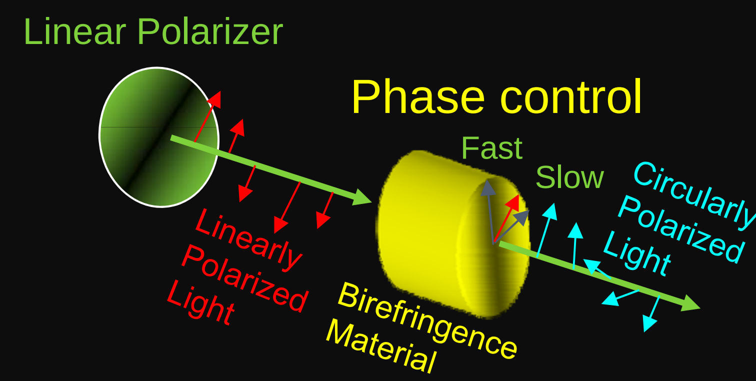
Properties of Light

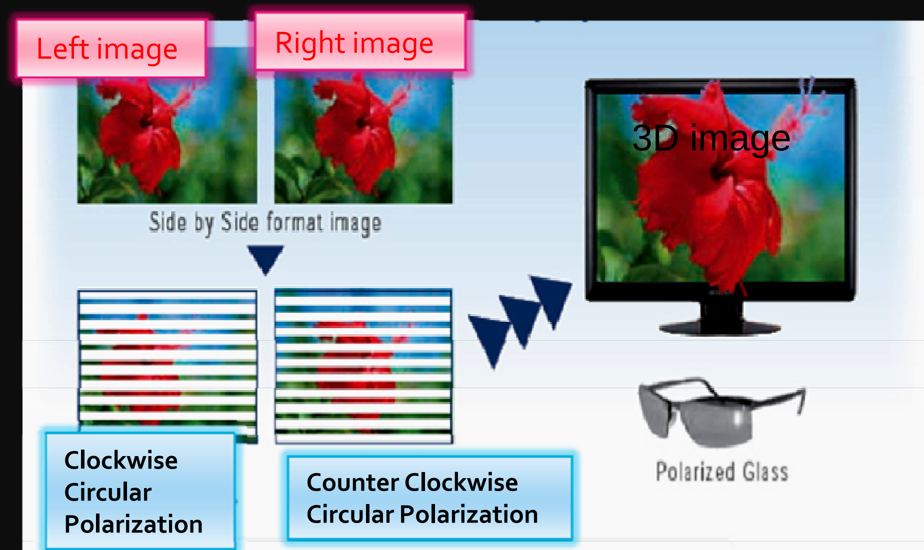
- Intensity
- Wavelength
- Polarization
- Phase
- Coherence

Applications of Phase Control

- 3D monitor
- Phase-shift lithography
- Holography
- Phase contrast microscopy
- Interferometer
- Vibrato meter
- Adaptive optics

Example of Optical Display Industry: 3D TV





From working principle of 3D monitor
*3D image is independent from viewing angle

Industrial Applications

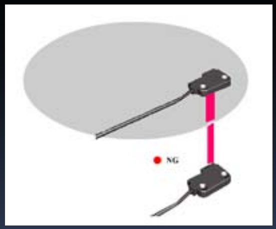
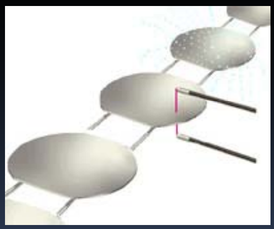
Most of today's photon detectors measure intensity of light only. (No Phase Information) NASA's SOM characterization system measures the phase angle of light as well as its intensity. This ability to measure intensity & phase of light extends industrial applications.

- Medical Industry
  - Syringe bubble inspection
  - Blood inspection
  - Medicine, nutrients inspection
- Food Industry
  - Ingredients in bottle inspection
  - Brewing, fluid flow inspection
  - Sugar level & fruit ripening monitor
- Semiconductor Industry
  - Wafer inspection
  - Substrate inspection
  - LCD/LED panel inspection
- Film and Packaging
  - Film thickness & defect inspection



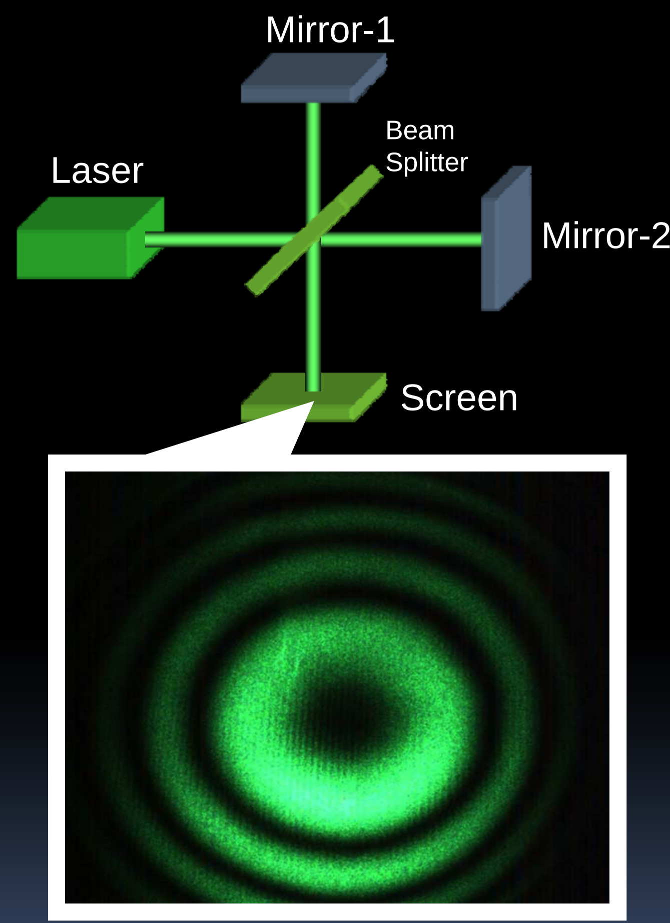




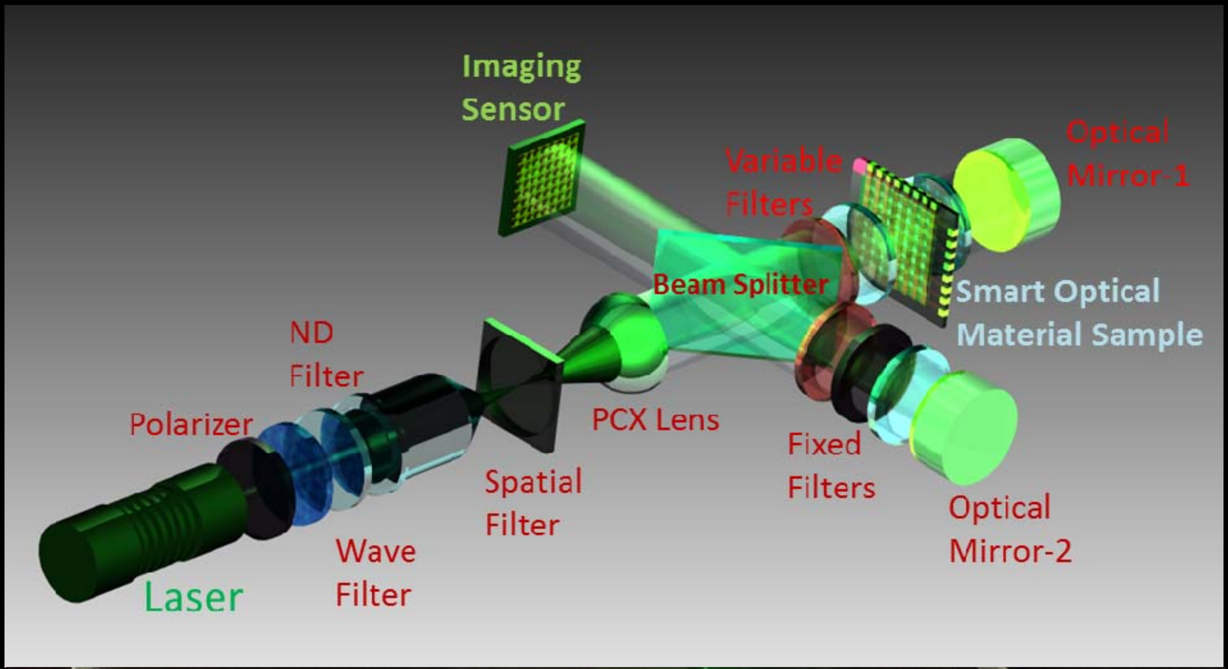

Based on Michelson Interferometer

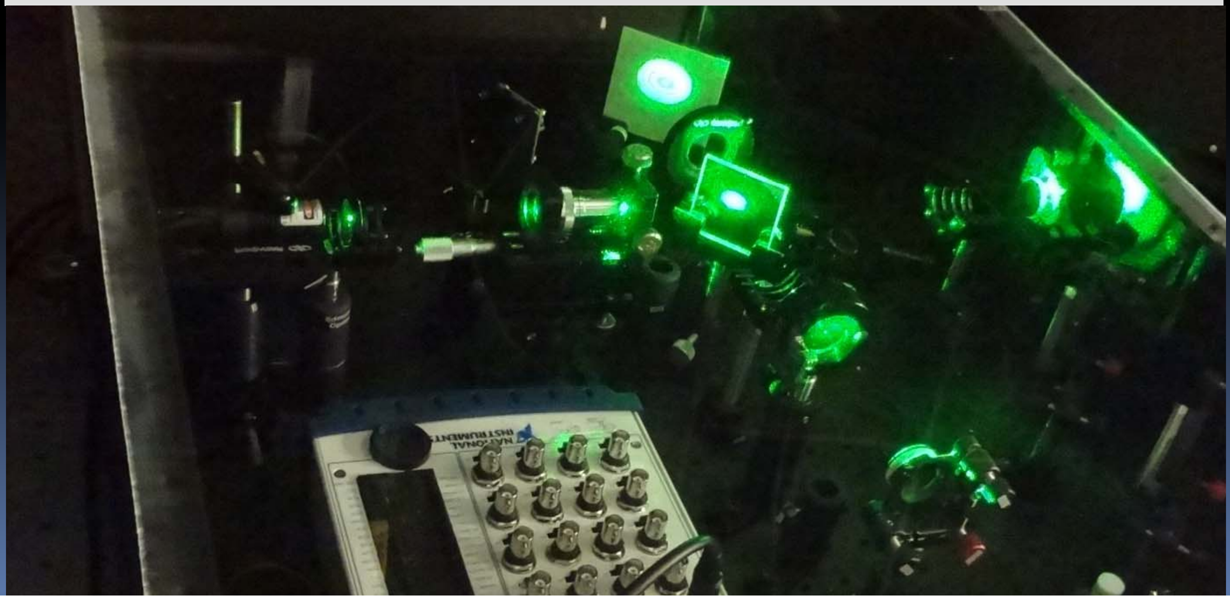
- Michelson interferometer uses a 45° inclined beam splitter, two mirrors, and screen with a coherent light source such as a laser. Interference patterns are made on the screen from two split lights reflected by two mirrors.
- Michelson interferometer is used in many applications, such as FT-IR.
- SOM characterization system uses Michelson interferometer configuration with more advanced optical sample holder components for extended measurement, electronic imaging system, and intelligent software.



Interference Pattern

Smart Optics Material Characterization System





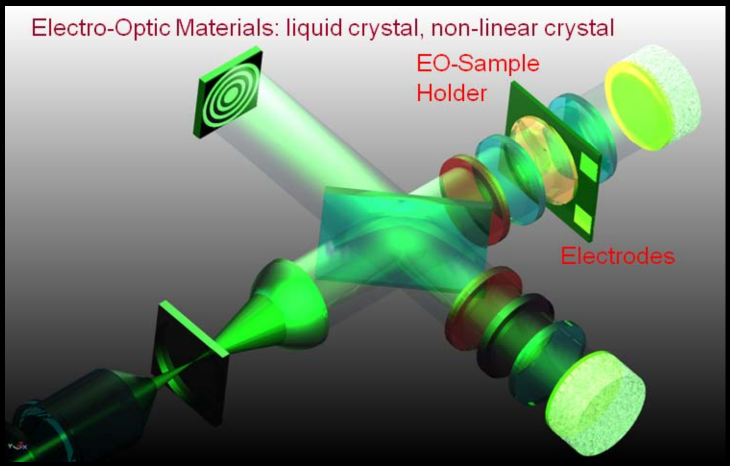
In FT-IR, Optical Mirror-1 or Mirror-2 moves forward /backward to scan the wavelength and the sample is fixed.

In SOM, Optical mirror-1&2 are fixed and the sample changes with electric field, magnetic field, voltage and etc.

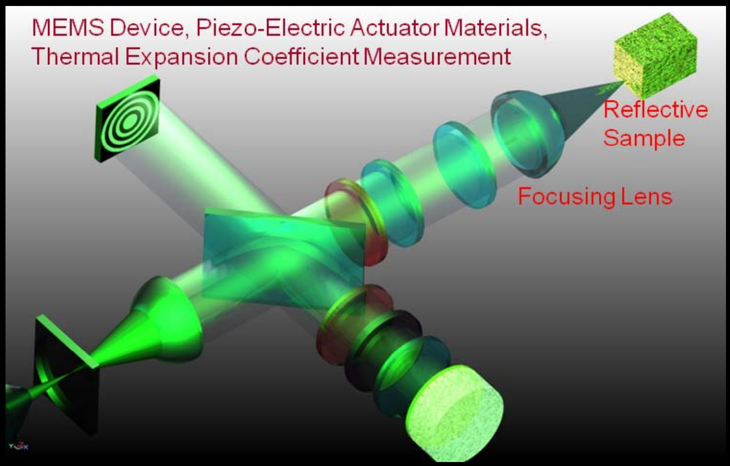
Miniaturization of SOM system is underway.

Supported Sample Types

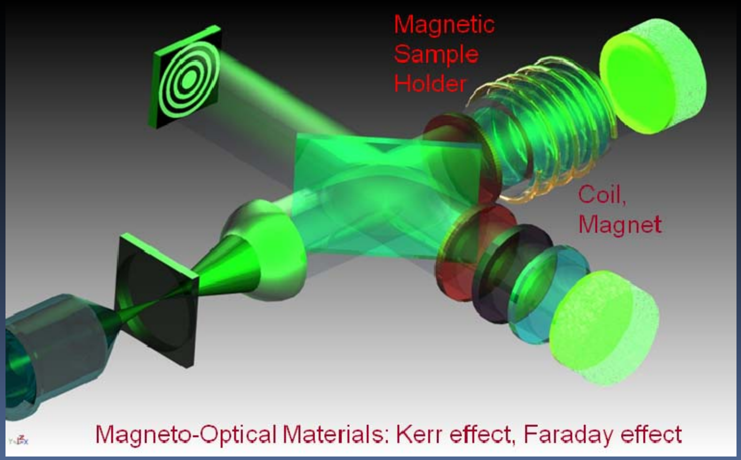
(1) Electro-optic materials



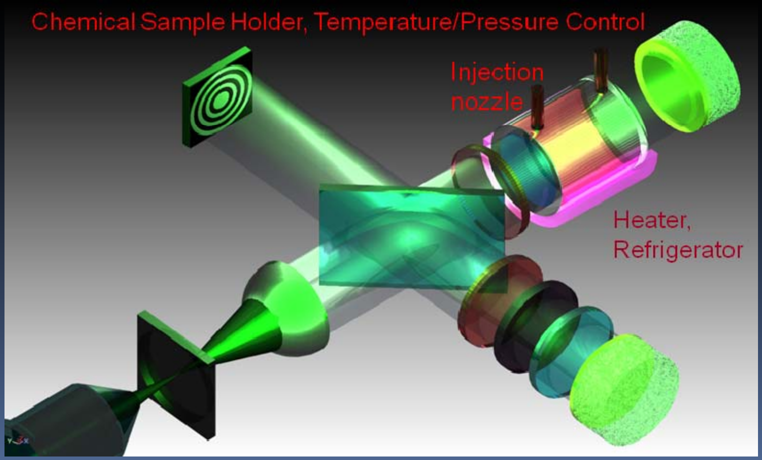
(2) MEMS device, mechanical property



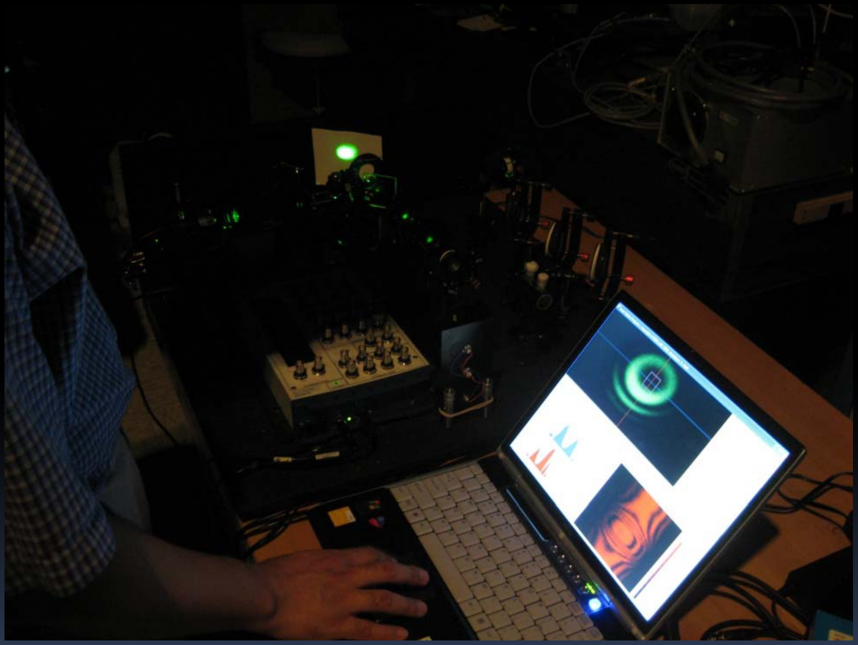
(3) Magneto-optic materials

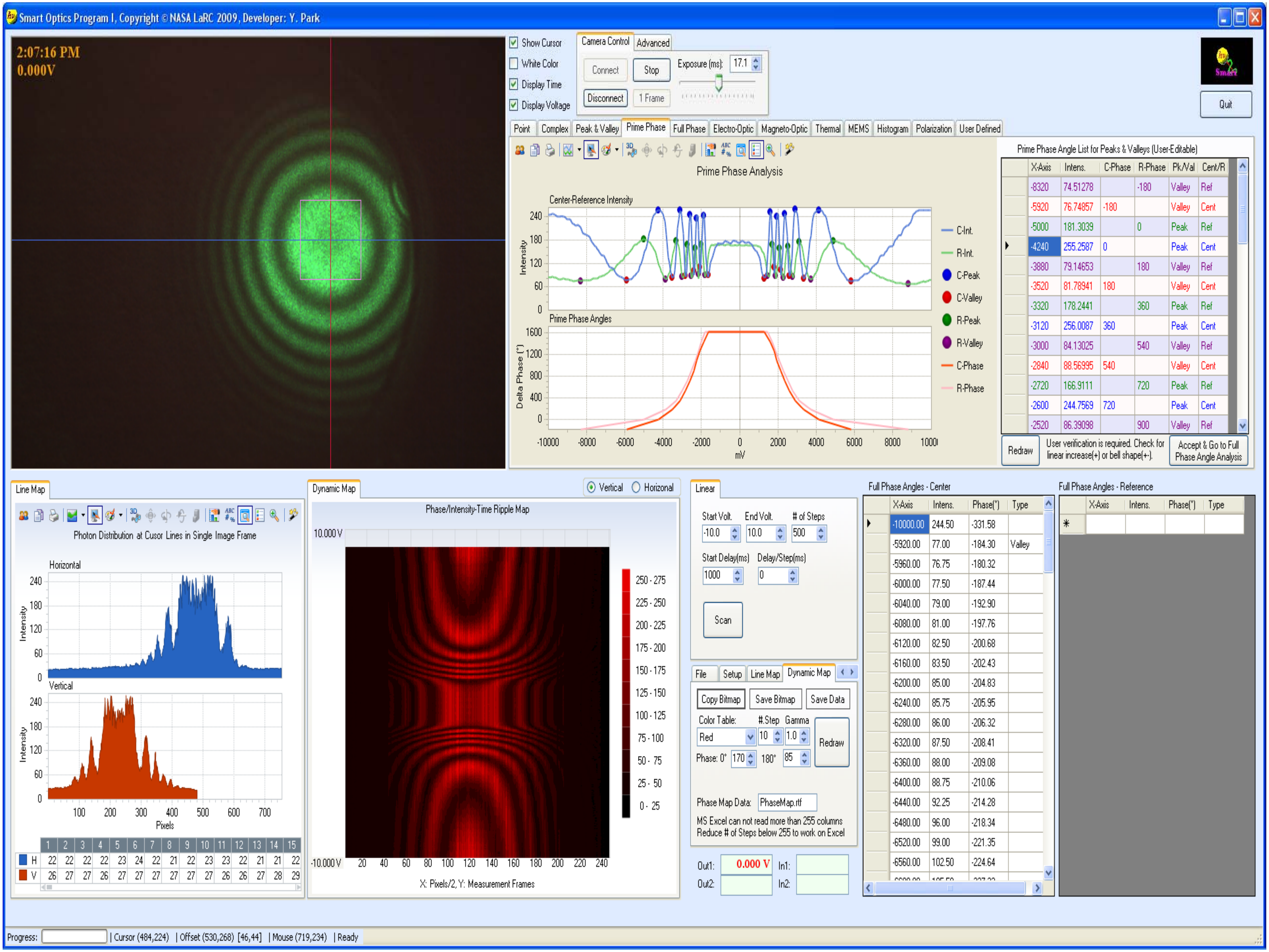


(4) Optical properties of chemicals



Smart Optics Material Characterization System





Smart Optics Program I, Copyright © NASA LaRC 2009, Developer: Y. Park
2:07:16 PM
0.000V
Show Cursor
White Color
Display Time
Display Voltage
Camera Control
Advanced
Connect
Stop
Disconnect
1 Frame
Exposure (ms):
17.1
Quit
Point
Complex
Peak & Valley
Prime Phase
Full Phase
Electro-Optic
Magneto-Optic
Thermal
MEMS
Histogram
Polarization
User Defined
Prime Phase Analysis
Center-Reference Intensity
Intensity
Prime Phase Angles
Delta Phase (°)
mV
C-Int.
R-Int.
C-Peak
C-Valley
R-Peak
R-Valley
C-Phase
R-Phase
Prime Phase Angle List for Peaks & Valleys (User-Editable)
X-Axis | Intens. | C-Phase | R-Phase | Pk/Val | Cent/R
-8320 | 74.51278 | | -180 | Valley | Ref
-5920 | 76.74857 | -180 | | Valley | Cent
-5000 | 181.3039 | | 0 | Peak | Ref
-4240 | 255.2587 | 0 | | Peak | Cent
-3880 | 79.14653 | | 180 | Valley | Ref
-3520 | 81.78941 | 180 | | Valley | Cent
-3320 | 178.2441 | | 360 | Peak | Ref
-3120 | 256.0087 | 360 | | Peak | Cent
-3000 | 84.13025 | | 540 | Valley | Ref
-2840 | 88.56995 | 540 | | Valley | Cent
-2720 | 166.9111 | | 720 | Peak | Ref
-2600 | 244.7569 | 720 | | Peak | Cent
-2520 | 86.39098 | | 900 | Valley | Ref
Redraw
User verification is required. Check for linear increase(+) or bell shape(+).
Accept & Go to Full Phase Angle Analysis
Line Map
Photon Distribution at Cursor Lines in Single Image Frame
Horizontal
Vertical
Intensity
Pixels
Dynamic Map
Vertical
Horizonal
Phase/Intensity-Time Ripple Map
10.000 V
-10.000 V
X: Pixels/2, Y: Measurement Frames
Linear
Start Volt.
End Volt.
# of Steps
Start Delay(ms)
Delay/Step(ms)
Scan
File
Setup
Line Map
Dynamic Map
Copy Bitmap
Save Bitmap
Save Data
Color Table:
#.Step
Gamma
Red
Redraw
Phase: 0°
180°
Phase Map Data:
PhaseMap.rtf
MS Excel can not read more than 255 columns
Reduce # of Steps below 255 to work on Excel
Out1:
0.000 V
Out2:
In1:
In2:
Full Phase Angles - Center
X-Axis | Intens. | Phase(°) | Type
-10000.00 | 244.50 | -331.58
-5920.00 | 77.00 | -184.30 | Valley
-5960.00 | 76.75 | -180.32
-6000.00 | 77.50 | -187.44
-6040.00 | 79.00 | -192.90
-6080.00 | 81.00 | -197.76
-6120.00 | 82.50 | -200.68
-6160.00 | 83.50 | -202.43
-6200.00 | 85.00 | -204.83
-6240.00 | 85.75 | -205.95
-6280.00 | 86.00 | -206.32
-6320.00 | 87.50 | -208.41
-6360.00 | 88.00 | -209.08
-6400.00 | 88.75 | -210.06
-6440.00 | 92.25 | -214.28
-6480.00 | 96.00 | -218.34
-6520.00 | 99.00 | -221.35
-6560.00 | 102.50 | -224.64
Full Phase Angles - Reference
X-Axis | Intens. | Phase(°) | Type
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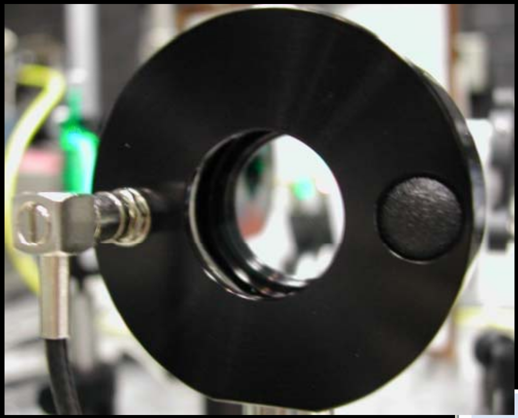
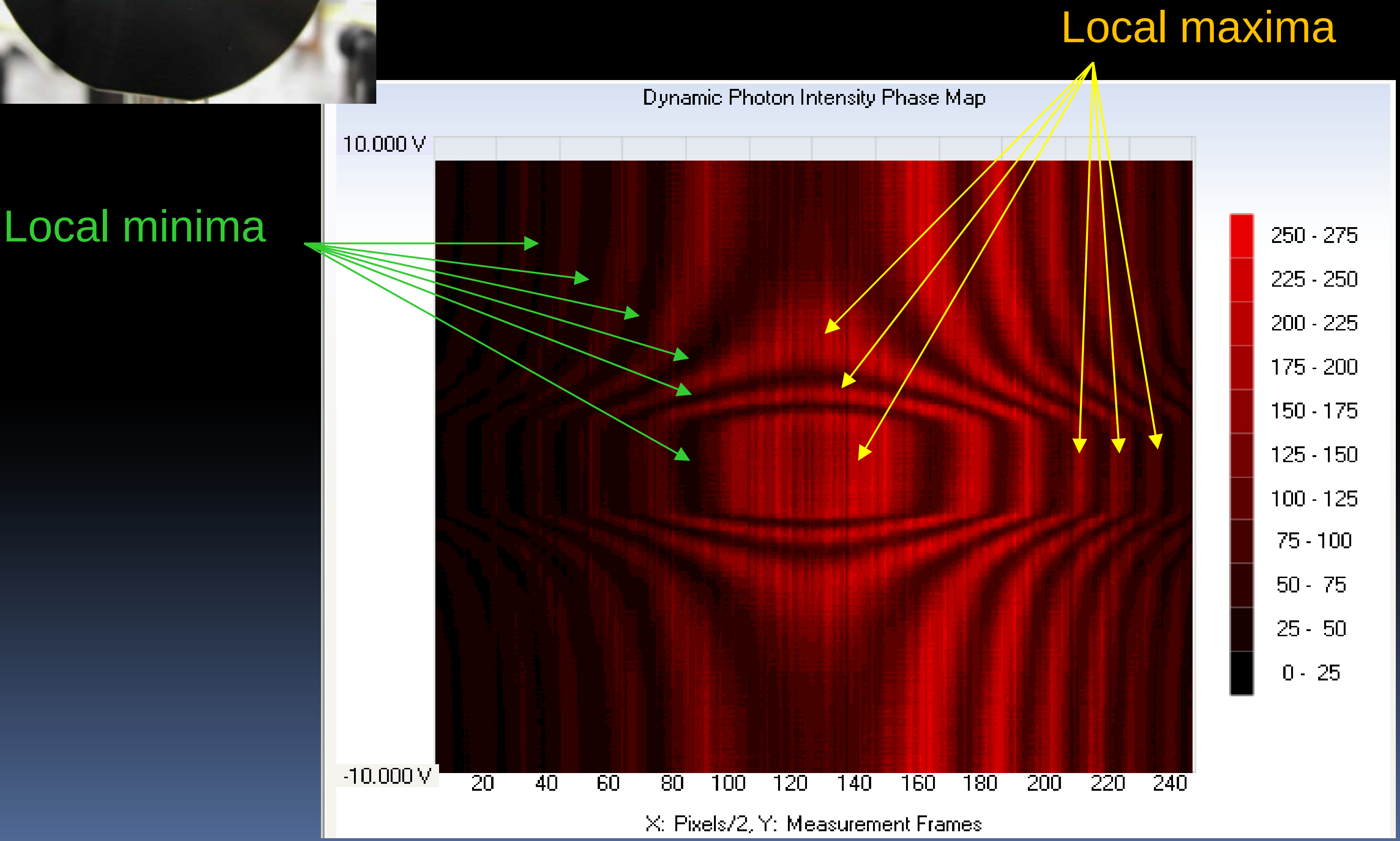
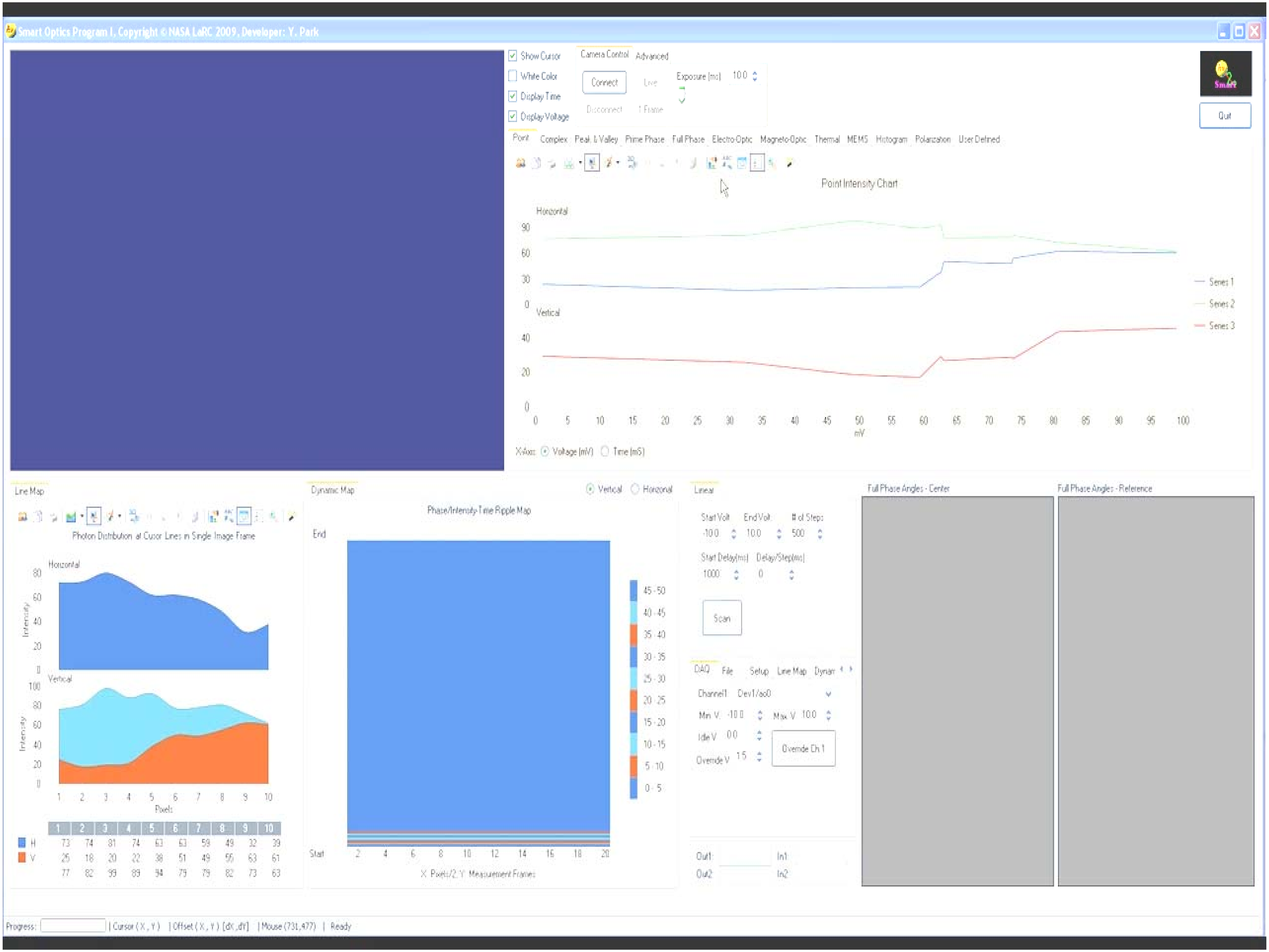
Cursor (484,224)
Offset (530,268) [46,44]
Mouse (719,234)
Ready

Liquid Crystal Phase Retarder

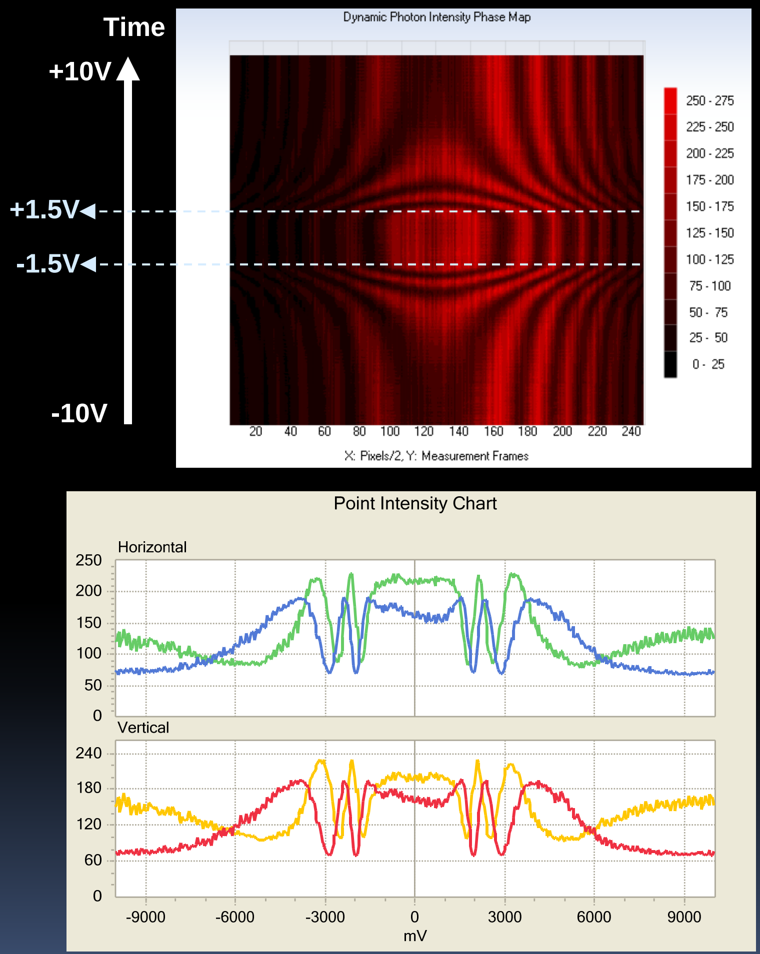




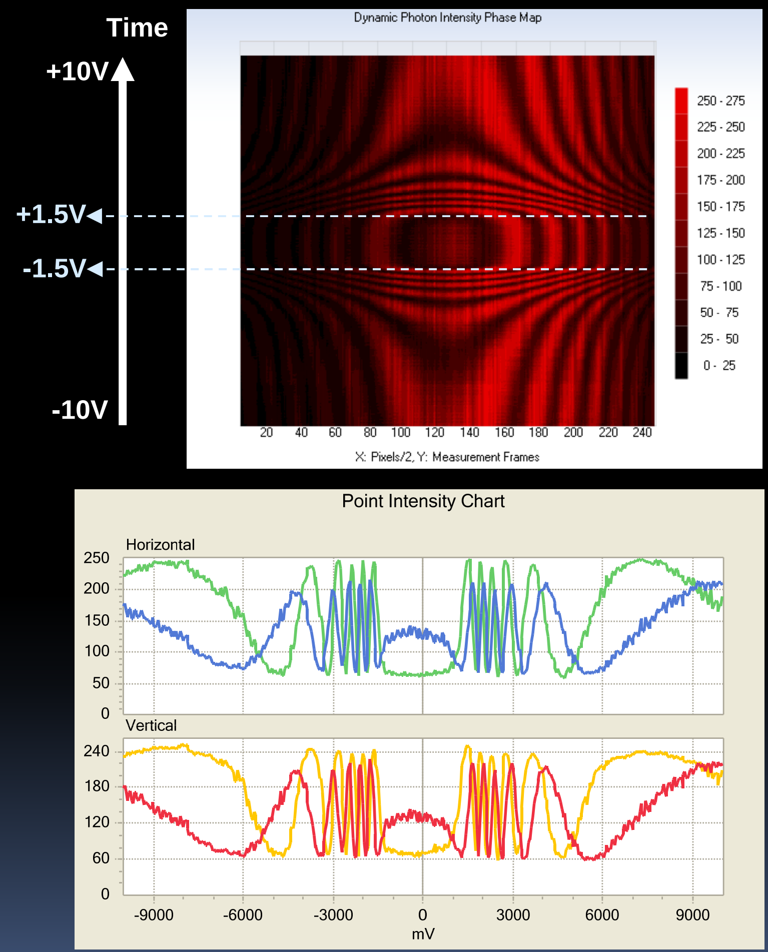


Smart Optics Program I, Copyright © NASA LaRC 2009, Developer: Y. Park
Show Cursor
White Color
Display Time
Display Voltage
Camera Control
Advanced
Connect
Live
Disconnect
1 Frame
Exposure (ms)
10.0
Quit
Point
Complex
Peak & Valley
Prime Phase
Full Phase
Electro-Optic
Magneto-Optic
Thermal
MEMS
Histogram
Polarization
User Defined
Point Intensity Chart
Horizontal
Vertical
Series 1
Series 2
Series 3
mV
X-Axis:
Voltage (mV)
Time (mS)
Line Map
Photon Distribution at Cursor Lines in Single Image Frame
Intensity
Pixels
Dynamic Map
Vertical
Horizontal
Phase/Intensity-Time Ripple Map
End
Start
X: Pixels/2, Y: Measurement Frames
Linear
Start Volt
End Volt
# of Steps
-10.0
10.0
500
Start Delay(ms)
Delay/Step(ms)
1000
0
Scan
DAQ
File
Setup
Line Map
Dynam
Channel1
Dev1/ao0
Min V
-10.0
Max V
10.0
Idle V
0.0
Override V
1.5
Override Ch 1
Out1
Out2
In1
In2
Full Phase Angles - Center
Full Phase Angles - Reference
Progress:
Cursor (X, Y)
Offset (X, Y) (dX, dY)
Mouse (731,477)
Ready

Dynamic Phase Map Analysis



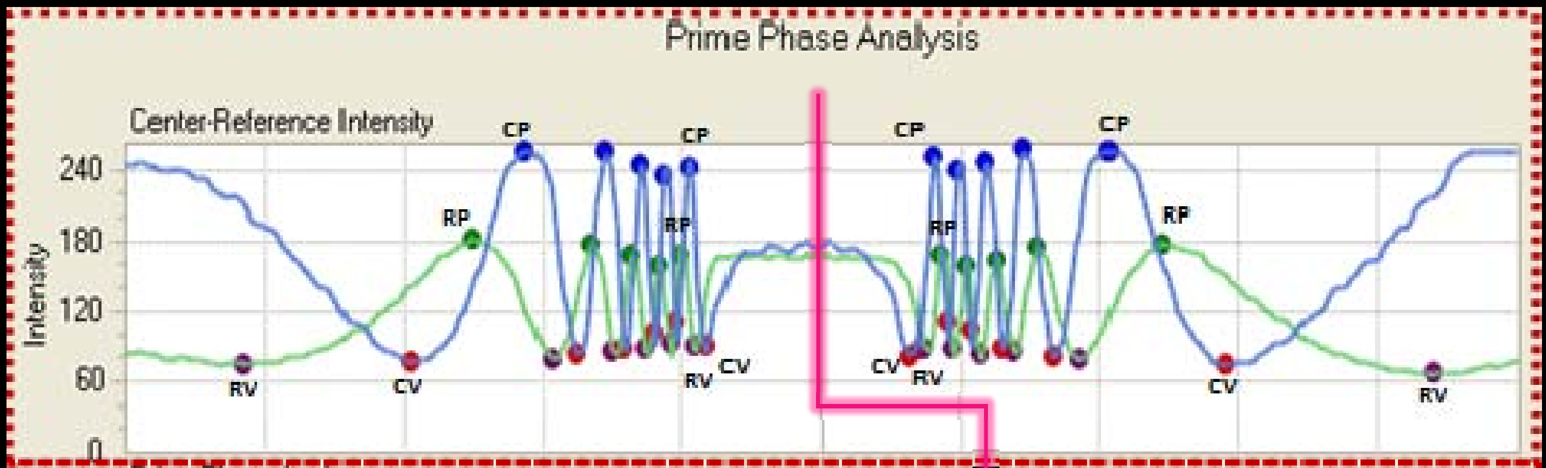
Liquid Crystal Single Layer



Liquid Crystal Double Layer

Absolute Phase Angle Detection with Two Series Permutation

INDEX: CP: Center-point Peak, CV: Center-point Valley, RP: Related-point Peak, RV: Related-point Valley



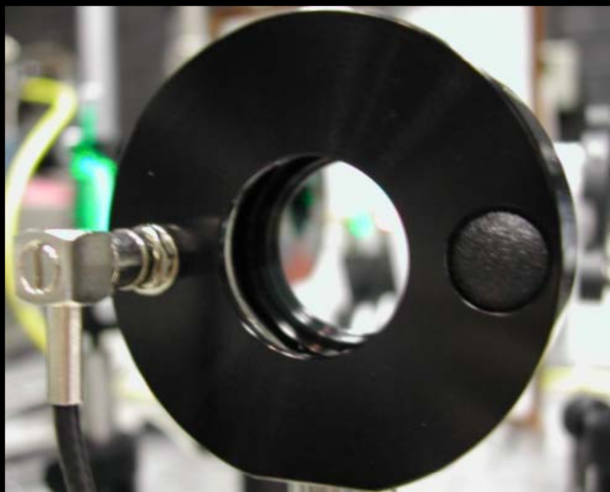
RV, CV, RP, CP, RV, CV, RP, CP, RV, CV, RP, CP, …. RV, CV, RP, CP, RV, CV, CV, RV, CP, RP, … CV, RV, CP, RP, CV, RV.

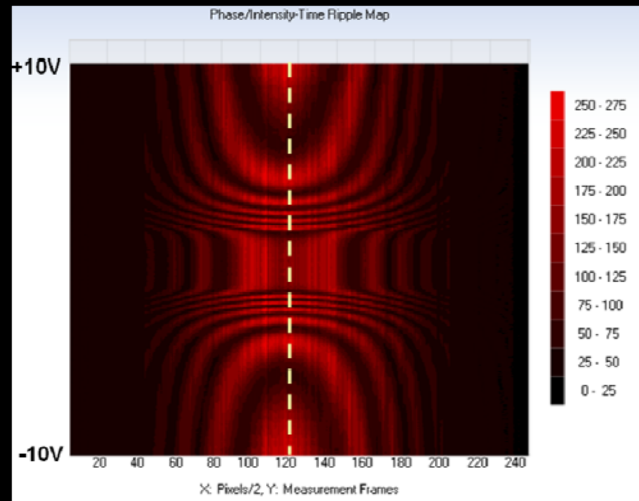
{…RV, CV}, {RP, CP, RV, CV}, {RP, CP, RV, CV}, {RP, CP, …. RV, CV}, {RP, CP, RV, CV}, {CV, RV, CP, RP}, … {CV, RV, CP, RP}, {CV, RV…}

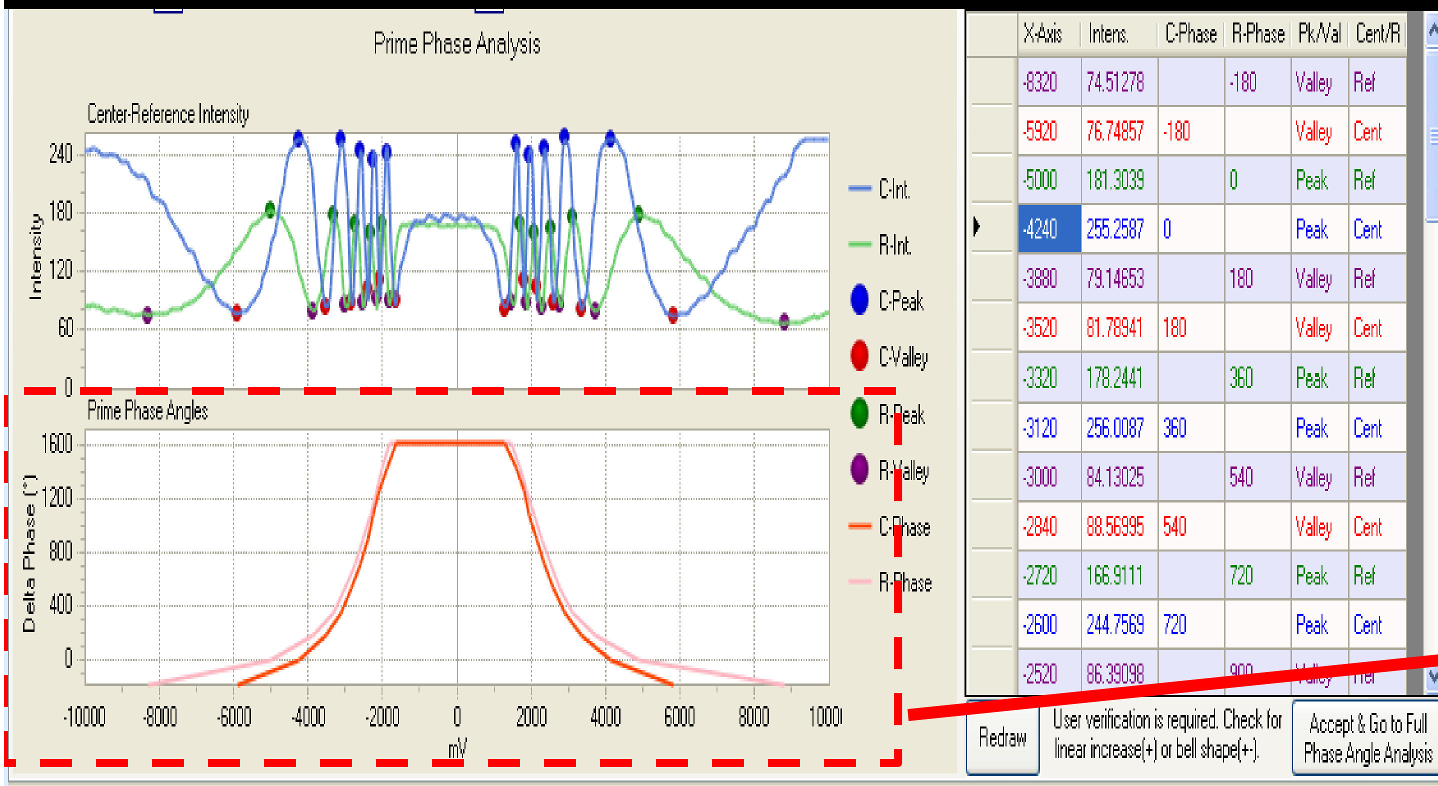
{…C, D}, {A, B, C, D}, {A, B, C, D}, {A, B, …. C, D}, {A, B, C, D}, {D, C, B, A}, … {D, C, B, A}, {D, C…}

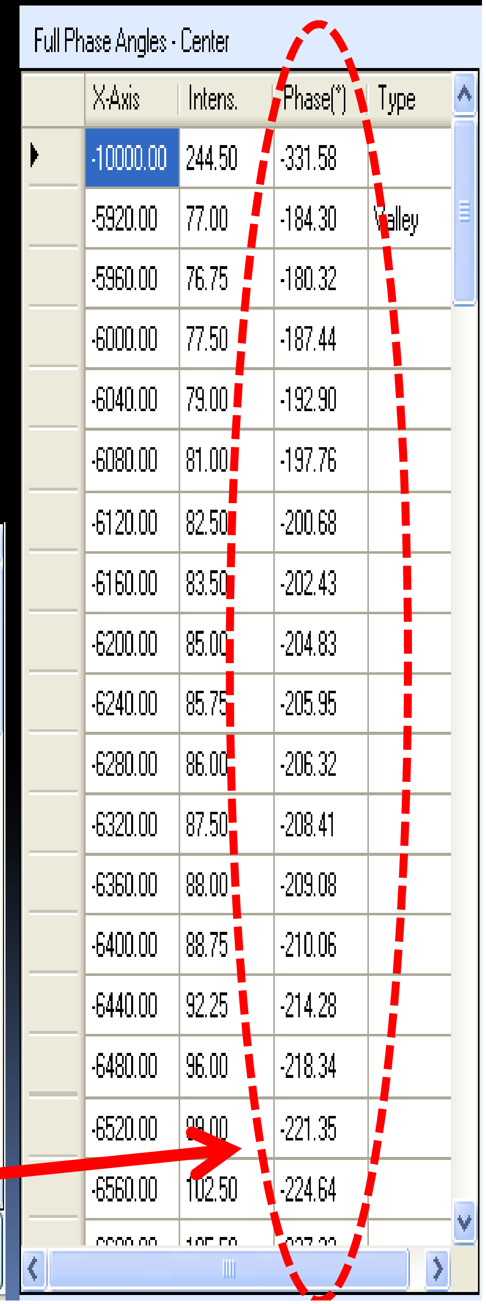
Permutation of peaks and valleys of two-point intensity measurement series determines whether the absolute phase angle increases or decreases.

Phase Angle Measurement

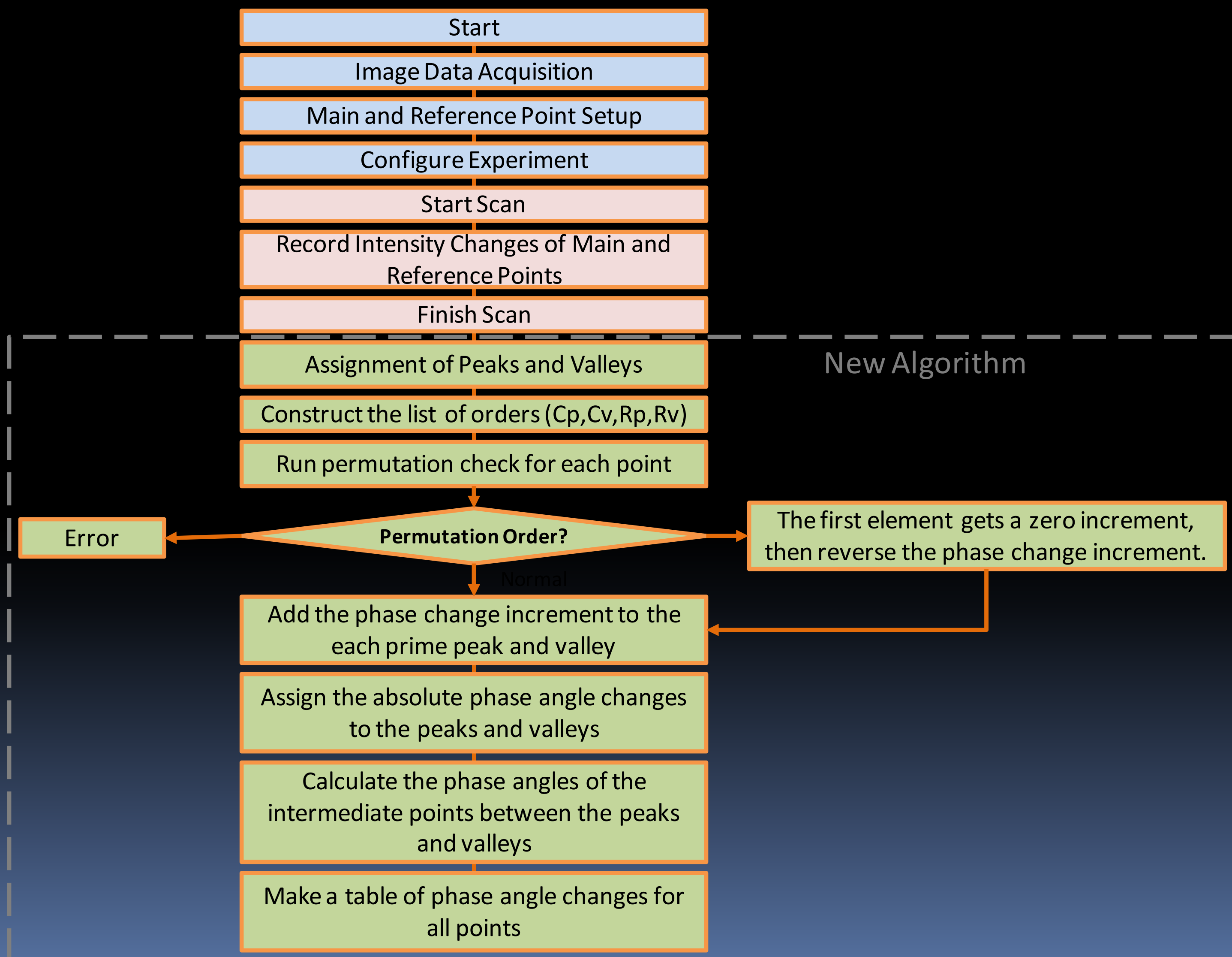




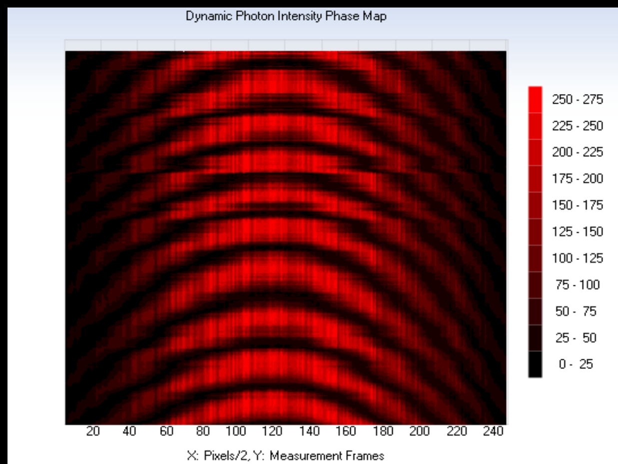




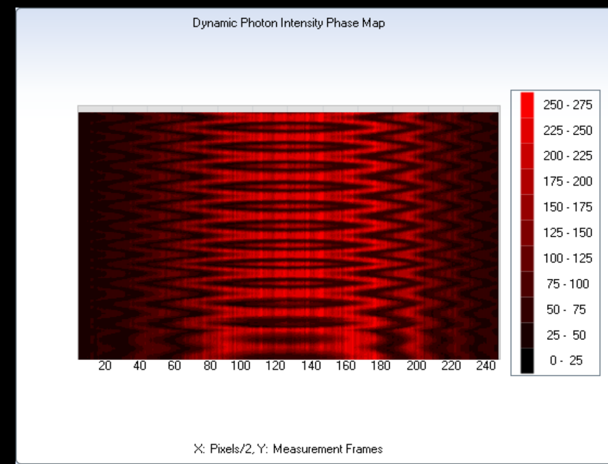
Absolute Phase Angle Change Detection Algorithm



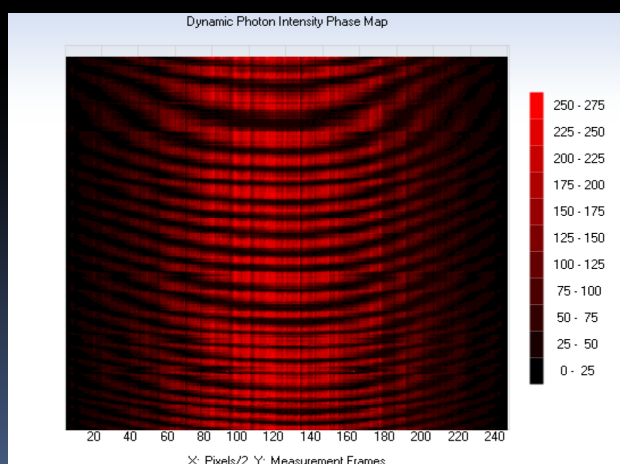
Various Phase/Intensity Ripple Maps
(depending on materials & devices)



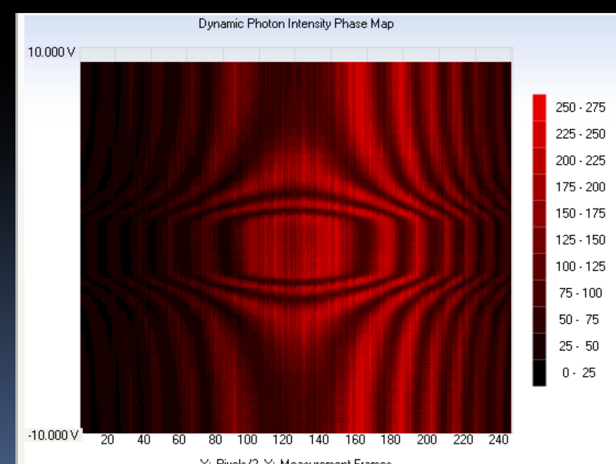
Thermal Expansion



MEMS Vibration & Oscillation



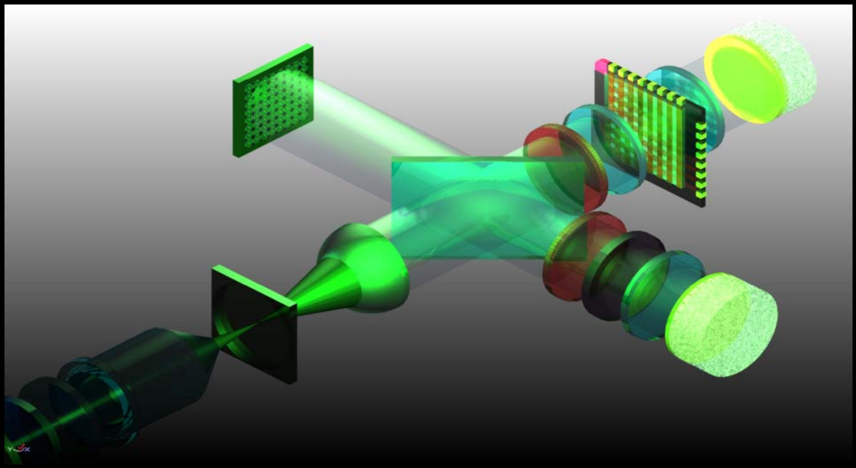
Refractive Index Changes
(electro-chromism)

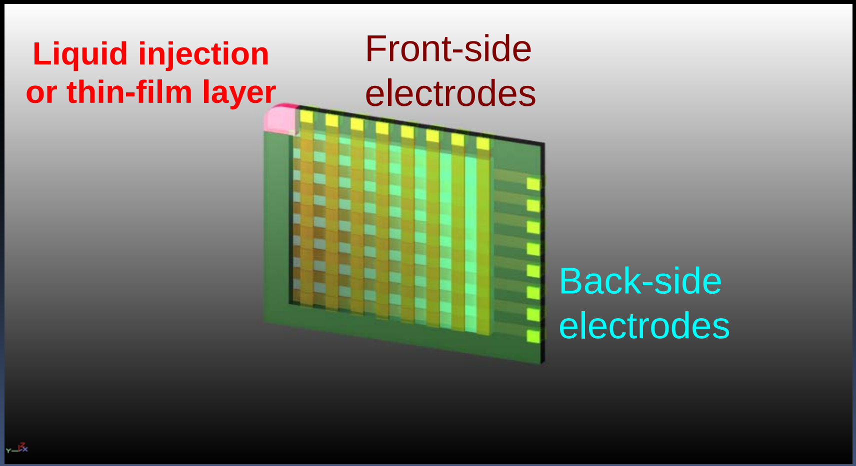


Liquid Crystal under E-field

Phase Measurement of 2D Array

- NASA's SOM characterization system can measure phase changes of multiple points (up to 750 points). It can measure 2D array devices like liquid crystal display, multiple phase retarders, and adaptive optics array.
- Advanced imaging system and software calculate photon intensity and phase information from hundreds of pixels of 2D array devices.





2D array sample holder with double sided electrodes

Summary

- Prototype SOM characterization system has been developed to measure intensity, phase, polarization, and spectral shift of passing lights through many new optical materials while undergoing various physical/chemical effects.
  - A miniaturized compact system has standard computer interfaces and inter-changeable components for various R&D and commercial applications with the support of a customizable software system.
- Following materials and properties can be measured.
  - Electro-optic materials: Non-linear optical crystals, Liquid crystals, Electro-optic polymers
  - Magneto-optic materials: Faraday effect ($\beta = \nu Bd$), Kerr effect ($\Delta n = \lambda KE^2$)
  - Electro/Thermo chromic materials
  - Chemicals that induce change of refractive indices and light attenuation
  - Spectral shift due to electric or magnetic field effect
  - Optical materials under influence of pressure or temperature changes
  - Thermal expansion coefficients
  - Movement of MEMS system or piezoelectric actuator
  - Adaptive optics array element

Industrial Application

- Semiconductor, Optical Display, Food & Medical Industry, Agriculture, Chemical Industry