AVS Science and Technology of Materials, Interfaces, and Processing

Coherent Superposition of Mueller-Jones States: Synthesizing Mueller Matrices with an Ellipsometer

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SPECTROSCOPIC ELLIPSOMETRY FOCUS TOPIC

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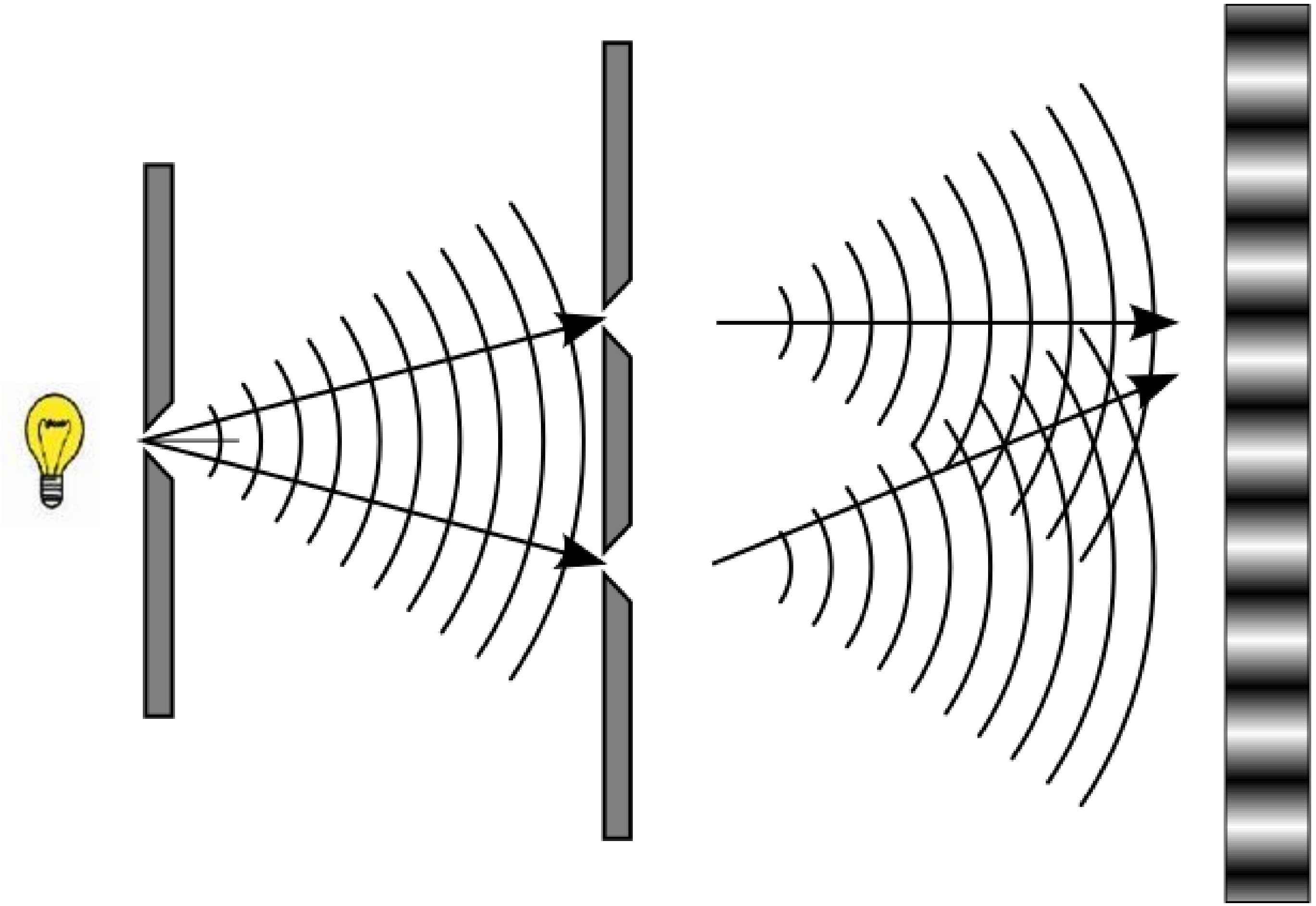
Young’s double slit experiment



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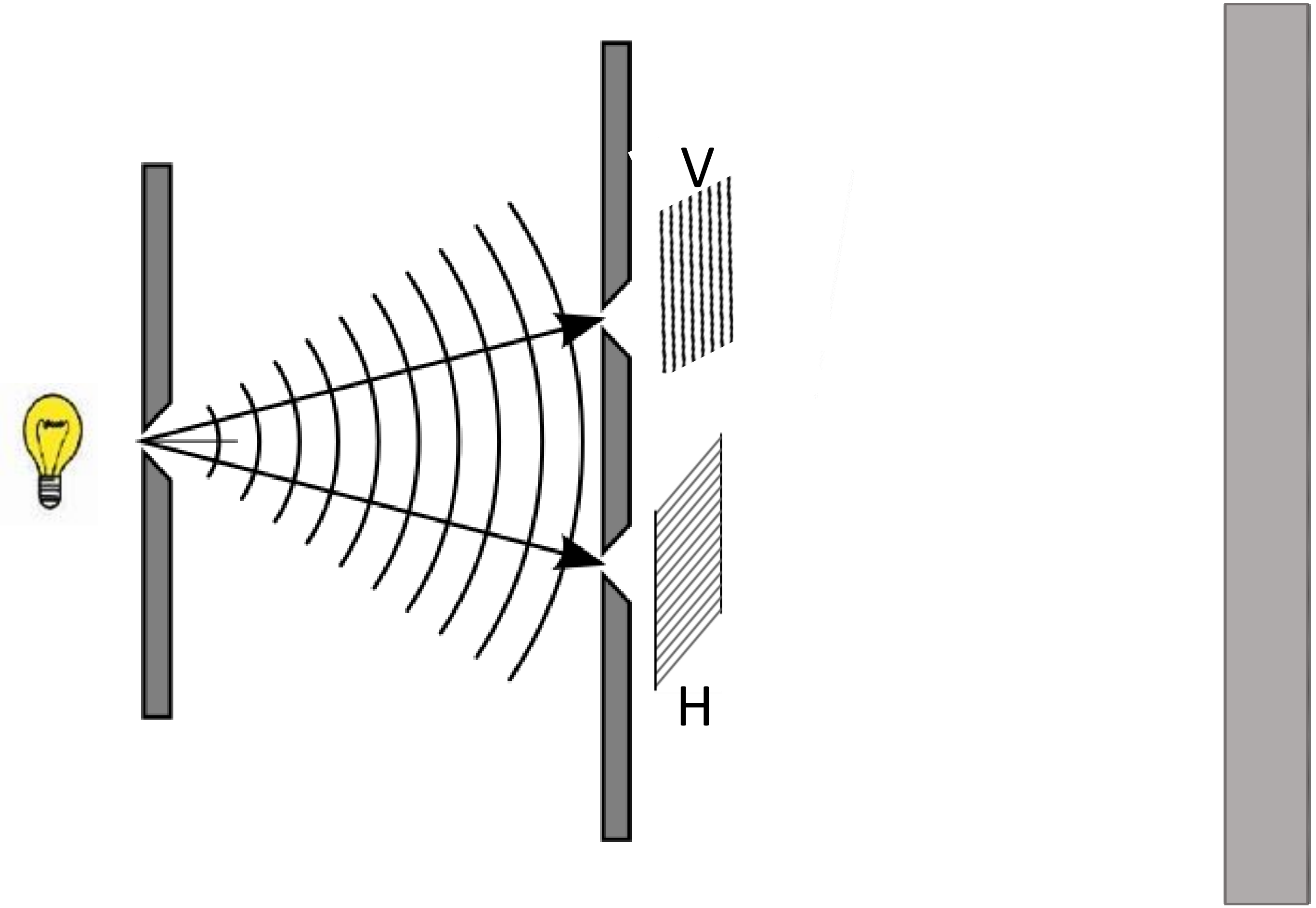
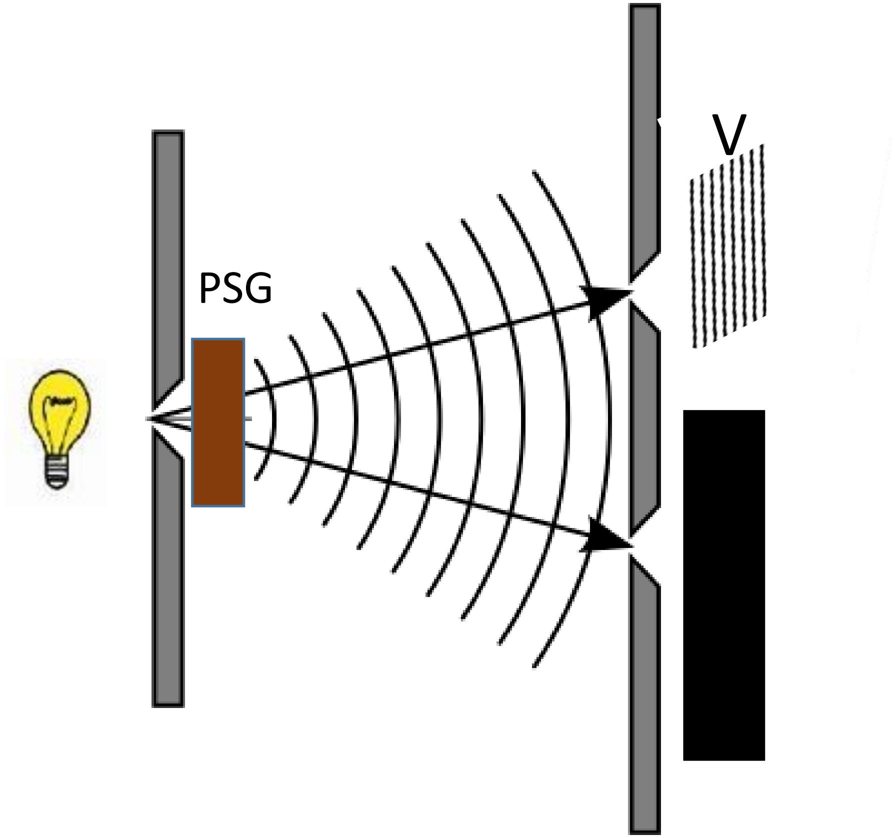
Young’s double slit experiment



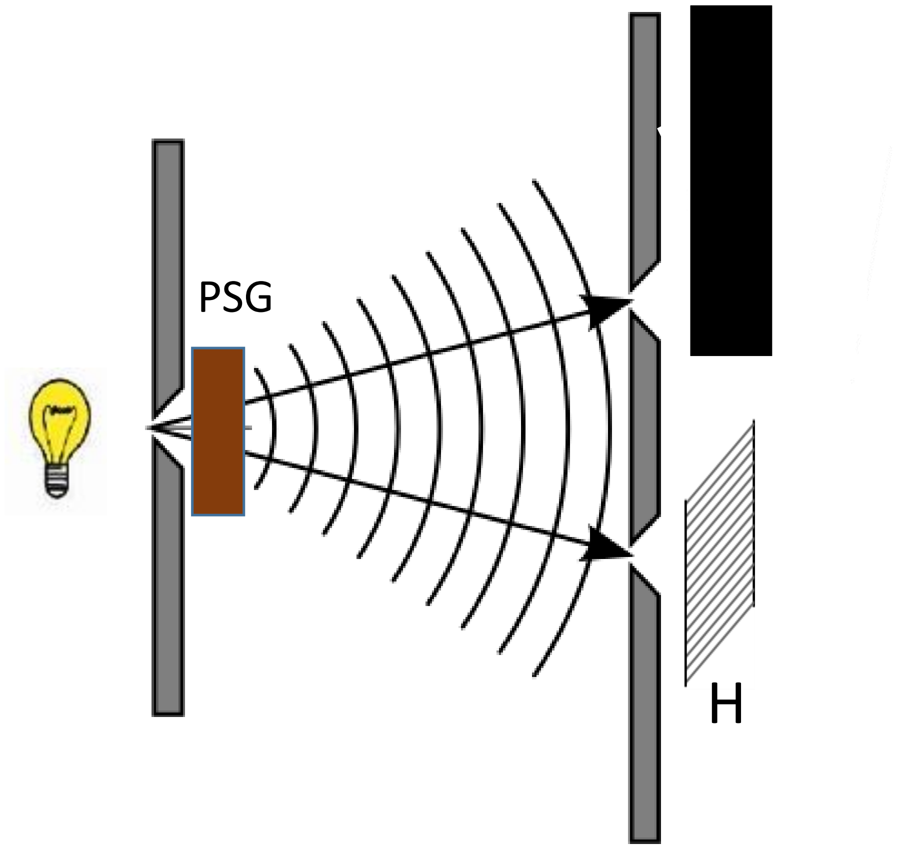
No interference pattern!
But still there is a
coherent superposition

Polarimetric analysis of Young's double slit experiment



$$\mathbf{M_V} = \begin{pmatrix} 1 & -1 & 0 & 0 \\ -1 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{pmatrix}$$

Polarimetric analysis of Young's double slit experiment



PSA Detector

$$\mathbf{M_H} = \begin{pmatrix} 1 & 1 & 0 & 0 \\ 1 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{pmatrix}$$

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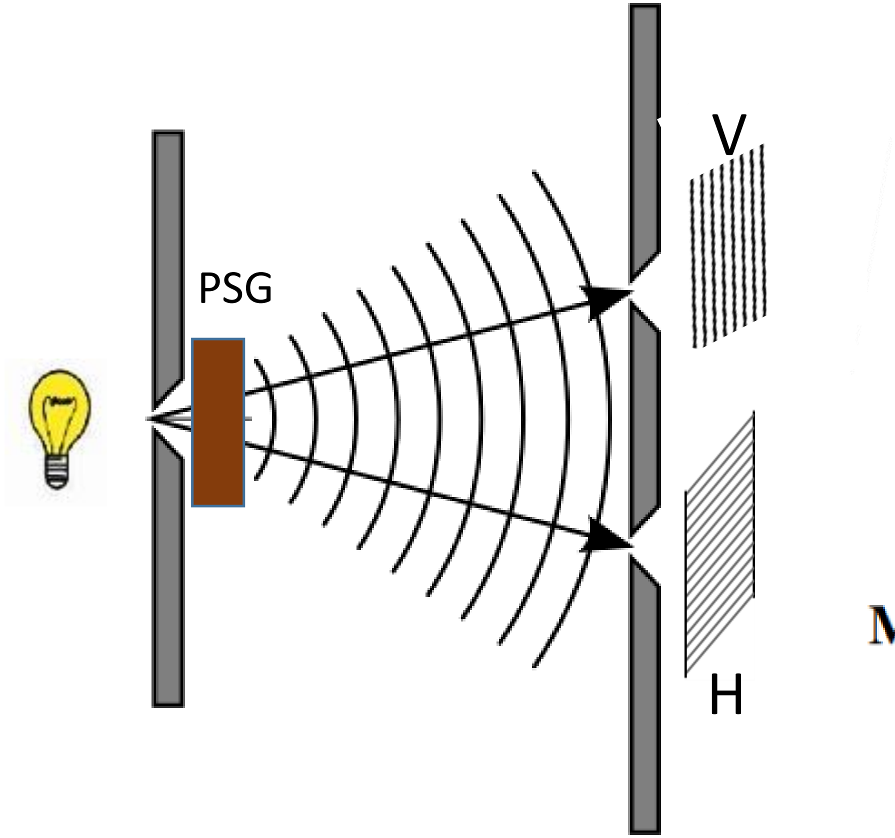
Polarimetric analysis of Young's double slit experiment

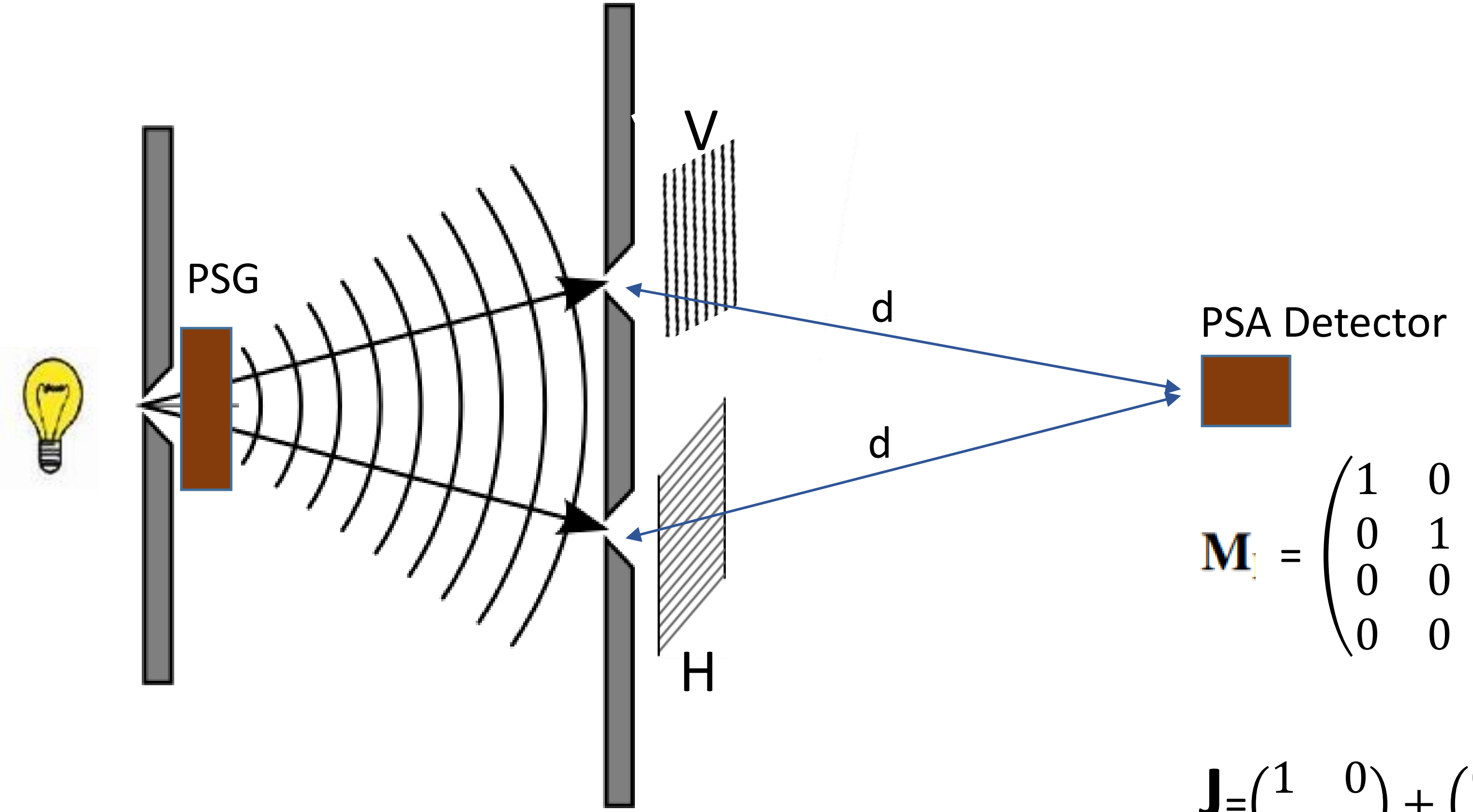


PSA Detector

$$\mathbf{M} = \begin{pmatrix} 1 & 1 & 0 & 0 \\ 1 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{pmatrix} + \begin{pmatrix} 1 & -1 & 0 & 0 \\ -1 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{pmatrix}$$

This is not what is measured!

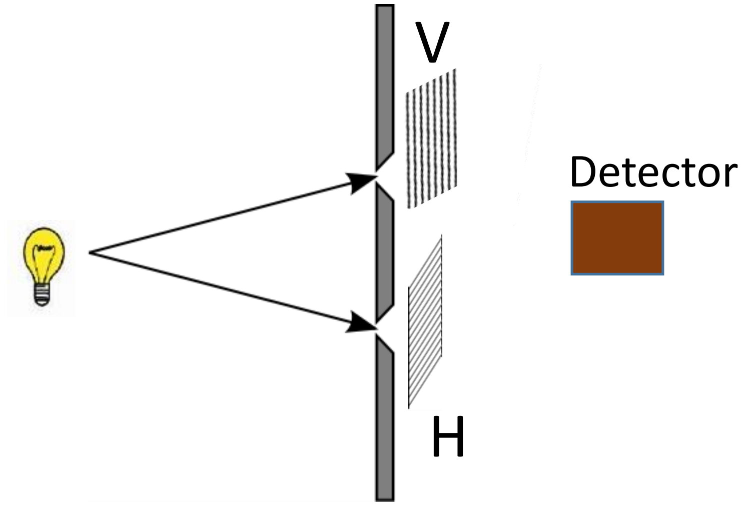
Polarimetric analysis of Young's double slit experiment



$$\mathbf{M} = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

$$\mathbf{J} = \begin{pmatrix} 1 & 0 \\ 0 & 0 \end{pmatrix} + \begin{pmatrix} 0 & 0 \\ 0 & 1 \end{pmatrix} = \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix}$$

Polarimetric analysis of Young's double slit experiment

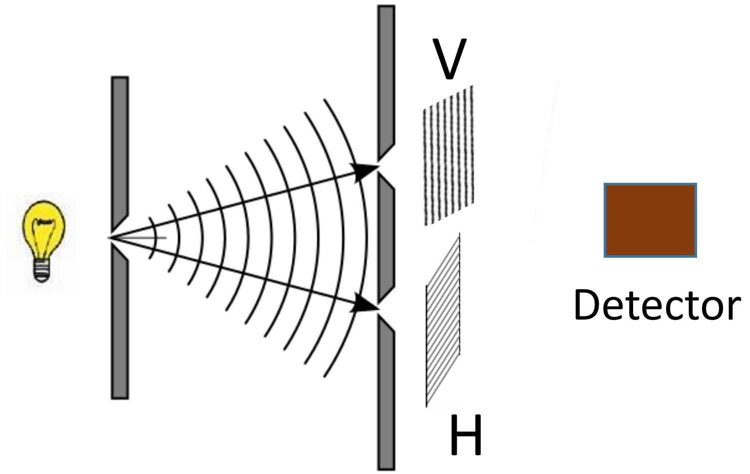


INCOHERENCE

$$\mathbf{M} = \begin{pmatrix} 1 & 1 & 0 & 0 \\ 1 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{pmatrix} + \begin{pmatrix} 1 & -1 & 0 & 0 \\ -1 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{pmatrix}$$

PARTIAL COHERENCE

COHERENCE



$$\mathbf{J} = \begin{pmatrix} 1 & 0 \\ 0 & 0 \end{pmatrix} + \begin{pmatrix} 0 & 0 \\ 0 & 1 \end{pmatrix} = \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix}$$

$$\mathbf{M} = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

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Outline

1. A new formalism for coherence and polarization

2. Ellipsometry (polarimetry) analysis of Young's double slit **experiment**

3. Synthesis of optical components and applications

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1. A new formalism of coherence and polarization

Consider a Mueller matrix, **M.** Mathematically it is useful to transform **M** into a Hermitian 4x4 matrix **H**, defined as follows:

$$\mathbf{H} = \frac{1}{4}\sum_{i,j=0}^{3} M_{ij}\Pi_{ij}$$

$$\Pi_{ij} = \mathbf{A}(\boldsymbol{\sigma}_i \otimes \boldsymbol{\sigma}_j^*)\mathbf{A}^{-1}$$

$$\boldsymbol{\sigma}_0 = \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix}, \quad \boldsymbol{\sigma}_1 = \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix},$$

$$\boldsymbol{\sigma}_2 = \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix}, \quad \boldsymbol{\sigma}_3 = \begin{pmatrix} 0 & -i \\ i & 0 \end{pmatrix}.$$

$$\mathbf{A} = \begin{pmatrix} 1 & 0 & 0 & 1 \\ 1 & 0 & 0 & -1 \\ 0 & 1 & 1 & 0 \\ 0 & i & -i & 0 \end{pmatrix}$$

S. R. Cloude, Optik 75, 26–36 (1986)

1. A new formalism of coherence and polarization

Explicitely:

$$
\mathbf{H} = \frac{1}{4}\left(\begin{array}{c|c|c|c}
\begin{array}{c} M_{00}+M_{11} \\ M_{22}+M_{33} \end{array} & \begin{array}{c} M_{01}+M_{10} \\ -i(M_{23}-M_{32}) \end{array} & \begin{array}{c} M_{02}+M_{20} \\ +i(M_{13}-M_{31}) \end{array} & \begin{array}{c} M_{03}+M_{30} \\ -i(M_{12}-M_{21}) \end{array} \\
\hline
\begin{array}{c} M_{01}+M_{10} \\ +i(M_{23}-M_{32}) \end{array} & \begin{array}{c} M_{00}+M_{11} \\ -M_{22}-M_{33} \end{array} & \begin{array}{c} M_{12}+M_{21} \\ +i(M_{03}-M_{30}) \end{array} & \begin{array}{c} M_{13}+M_{31} \\ -i(M_{02}-M_{20}) \end{array} \\
\hline
\begin{array}{c} M_{02}+M_{20} \\ -i(M_{13}-M_{31}) \end{array} & \begin{array}{c} M_{12}+M_{21} \\ -i(M_{03}-M_{30}) \end{array} & \begin{array}{c} M_{00}-M_{11} \\ +M_{22}-M_{33} \end{array} & \begin{array}{c} M_{23}+M_{32} \\ +i(M_{01}-M_{10}) \end{array} \\
\hline
\begin{array}{c} M_{03}+M_{30} \\ +i(M_{12}-M_{21}) \end{array} & \begin{array}{c} M_{13}+M_{31} \\ +i(M_{02}-M_{20}) \end{array} & \begin{array}{c} M_{23}+M_{32} \\ -i(M_{01}-M_{10}) \end{array} & \begin{array}{c} M_{00}-M_{11} \\ -M_{22}+M_{33} \end{array}
\end{array}\right)
$$

S. R. Cloude, Optik 75, 26–36 (1986)

1. A new formalism of coherence and polarization

If and only if **M** is nondepolarizing, **H** has Rank 1 and can be rewritten as.

$$\mathbf{H} = |h\rangle\langle h|$$

$|h\rangle$ is the eigenvector of **H** corresponding to its single non-zero eigenvalue

If $|h\rangle = \begin{pmatrix} \tau \\ \alpha \\ \beta \\ \gamma \end{pmatrix}$ then $\mathbf{H} = |h\rangle\langle h| = \begin{pmatrix} \tau\tau^* & \tau\alpha^* & \tau\beta^* & \tau\gamma^* \\ \alpha\tau^* & \alpha\alpha^* & \alpha\beta^* & \alpha\gamma^* \\ \beta\tau^* & \beta\alpha^* & \beta\beta^* & \beta\gamma^* \\ \gamma\tau^* & \gamma\alpha^* & \gamma\beta^* & \gamma\gamma^* \end{pmatrix}$

E. Kuntman et al., J. Opt. Soc. Am. A 34, 80-86 (2017)

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1. A new formalism of coherence and polarization

To study coherence and partial coherence it is very interesting to define still a new 4x4 complex matrix :

$$\mathbf{Z} = \begin{pmatrix} \tau & \alpha & \beta & \gamma \\ \alpha & \tau & -i\gamma & i\beta \\ \beta & i\gamma & \tau & -i\alpha \\ \gamma & -i\beta & i\alpha & \tau \end{pmatrix}$$

$$\mathbf{M}_J = \mathbf{Z}\mathbf{Z}^* = \mathbf{Z}^*\mathbf{Z}$$

The **Z** matrix is a complex matrix state that, when multiplied with its complex conjugate, gives a real valued Mueller-Jones matrix with elements that are observable quantities in experimental polarization optics

$\sim$ Analogy with a quantum mechanical wave function, ψ

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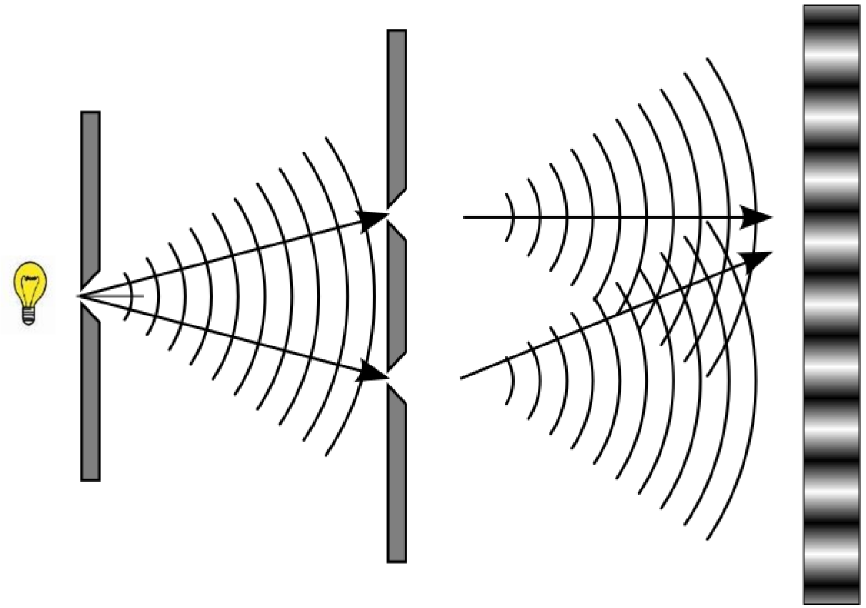
1. A new formalism of coherence and polarization

Superposition of equal states: interference



A composition of two states:

$$\psi = a\psi_a + b\psi_b$$

that are equal except for a phase

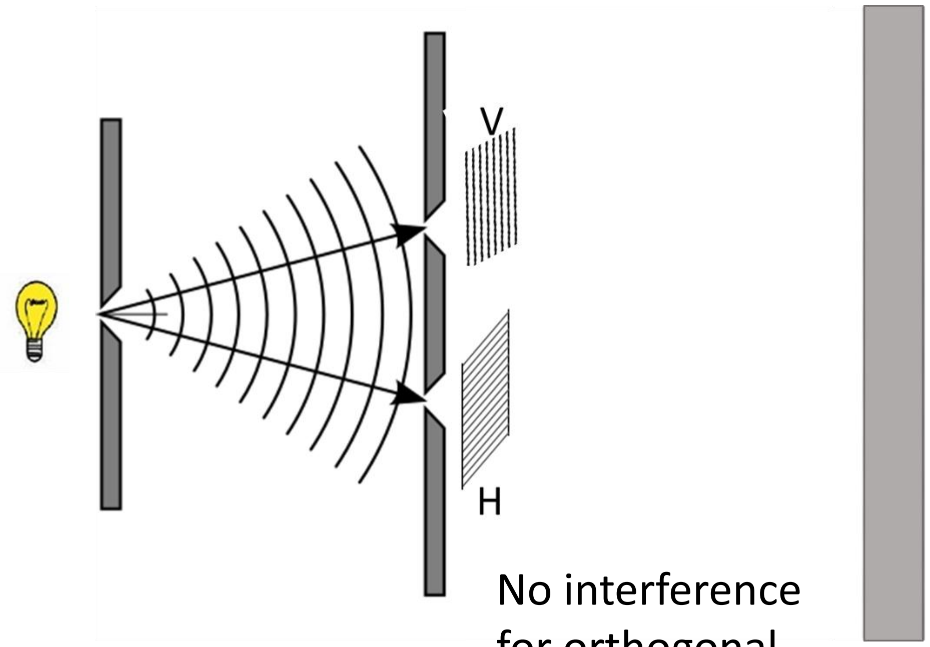
$$\psi_b = e^{i\phi}\psi_a$$

$$a = b = \tfrac{1}{\sqrt{2}}$$

$$\psi\psi^* = \tfrac{1}{2}\psi_a\psi_a^*(1+e^{i\phi})(1+e^{-i\phi})$$
$$= \psi_a\psi_a^*(1+\cos\phi).$$

1. A new formalism of coherence and polarization

Superposition of different Mueller-Jones states



No interference for orthogonal polarizations

Equivalent descriptions

$$\mathbf{J} = a\mathbf{J}_a + b\mathbf{J}_b$$

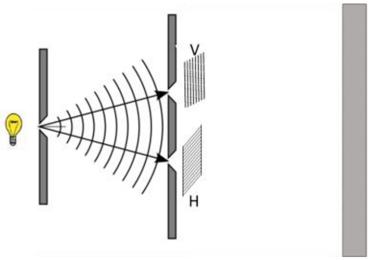
$$\mathbf{Z} = a\mathbf{Z}_a + b\mathbf{Z}_b$$

$$|h\rangle = a|h_a\rangle + b|h_b\rangle$$

In the **Z** matrix description:

$$\mathbf{M}_J = \mathbf{Z}\mathbf{Z}^* = aa^*\mathbf{Z}_a\mathbf{Z}_a^* + bb^*\mathbf{Z}_b\mathbf{Z}_b^* + ab^*\mathbf{Z}_a\mathbf{Z}_b^* + ba^*\mathbf{Z}_b\mathbf{Z}_a^*$$

1. A new formalism of coherence and polarization



Two particular examples of Z superpositions

- **Same** Mueller-Jones states

$$\mathbf{Z} = \frac{1}{\sqrt{2}}\mathbf{Z}_a + \frac{e^{i\phi}}{\sqrt{2}}\mathbf{Z}_a = \frac{1}{\sqrt{2}}\mathbf{Z}_a(1+e^{i\phi})$$

$$\mathbf{M}_J = \mathbf{Z}_a\mathbf{Z}_a^*(1+\cos\phi) = \mathbf{M}_a(1+\cos\phi)$$

Intensity interference

- Horizontal and vertical polarizer Mueller-Jones states

$$\mathbf{Z}_0 = \frac{1}{\sqrt{2}}\mathbf{Z}_H + \frac{e^{i\phi}}{\sqrt{2}}\mathbf{Z}_V$$

$$\mathbf{Z}_\mathrm{V} = \frac{1}{\sqrt{2}}\begin{pmatrix} 1 & -1 & 0 & 0 \\ -1 & 1 & 0 & 0 \\ 0 & 0 & 1 & i \\ 0 & 0 & -i & 1 \end{pmatrix}$$

$$\mathbf{Z}_\mathrm{H} = \frac{1}{\sqrt{2}}\begin{pmatrix} 1 & 1 & 0 & 0 \\ 1 & 1 & 0 & 0 \\ 0 & 0 & 1 & -i \\ 0 & 0 & i & 1 \end{pmatrix}$$

$$\mathbf{Z}_0 = \frac{1}{\sqrt{2}}\begin{pmatrix} 1+e^{i\phi} & 1-e^{i\phi} & 0 & 0 \\ 1-e^{i\phi} & 1+e^{i\phi} & 0 & 0 \\ 0 & 0 & 1+e^{i\phi} & -i(1-e^{i\phi}) \\ 0 & 0 & i(1-e^{i\phi}) & 1+e^{i\phi} \end{pmatrix}$$

$$\mathbf{M}_0 = \mathbf{Z}_0\mathbf{Z}_0^* = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & \cos\phi & -\sin\phi \\ 0 & 0 & \sin\phi & \cos\phi \end{pmatrix}$$

(But no interference in the intensity. **No visible fringes**.)

1. A new formalism of coherence and polarization

Partial coherence and incoherence

At a given time, space, and frequency all phases can be considered as constants, and the linear superposition is coherent. But when **statistical averages** (time average, spatial average, and/or frequency average) that happen during measurement are taken into account the result will be **depolarizing**

Two states

$$\mathbf{Z} = \frac{1}{\sqrt{2}}\mathbf{Z}_a + \frac{e^{i\phi}}{\sqrt{2}}\mathbf{Z}_b \rightarrow \mathbf{M}_J = \frac{1}{2}\mathbf{M}_a + \frac{1}{2}\mathbf{M}_b + \frac{e^{-i\phi}}{2}\mathbf{Z}_a\mathbf{Z}_b^* + \frac{e^{i\phi}}{2}\mathbf{Z}_b\mathbf{Z}_a^*$$

$$\mathbf{Z}' = \frac{1}{\sqrt{2}}\mathbf{Z}_a - \frac{e^{i\phi}}{\sqrt{2}}\mathbf{Z}_b \rightarrow \mathbf{M}'_J = \frac{1}{2}\mathbf{M}_a + \frac{1}{2}\mathbf{M}_b - \frac{e^{-i\phi}}{2}\mathbf{Z}_a\mathbf{Z}_b^* - \frac{e^{i\phi}}{2}\mathbf{Z}_b\mathbf{Z}_a^*$$

For a combined system fluctuating between these two states:

$$\mathbf{M}_{\text{average}} = \tfrac{1}{2}\mathbf{M}_a + \tfrac{1}{2}\mathbf{M}_b$$

1. A new formalism of coherence and polarization

Partial coherence and incoherence

If the there are phase fluctuations within the measurment conditions: Coherence terms are washed out

$$\mathbf{Z} = \frac{1}{\sqrt{2}}\mathbf{Z}_a + \frac{e^{i\phi}}{\sqrt{2}}\mathbf{Z}_b \longrightarrow \mathbf{M}_J = \frac{1}{2}\mathbf{M}_a + \frac{1}{2}\mathbf{M}_b + \frac{e^{-i\phi}}{2}\mathbf{Z}_a\mathbf{Z}_b^* + \frac{e^{i\phi}}{2}\mathbf{Z}_b\mathbf{Z}_a^*$$

A more general formula for the combination of two states when the phases of the complex coefficients fluctuate:

$$\mathbf{M} = |a|^2\mathbf{Z}_a\mathbf{Z}_a^* + |b|^2\mathbf{Z}_b\mathbf{Z}_b^* + \langle ab^*\rangle\mathbf{Z}_a\mathbf{Z}_b^* + \langle ba^*\rangle\mathbf{Z}_b\mathbf{Z}_a^*$$

Coherence index

$$p = \sqrt{\frac{\langle ab^*\rangle\langle ba^*\rangle}{|a|^2|b|^2}}$$

p=0 total incoherence
p=1 total coherence

1. A new formalism of coherence and polarization

Partial coherence and incoherence

The superposition can lead two 3 different situations:

$$\mathbf{M}_J = \mathbf{Z}\mathbf{Z}^* = aa^*\mathbf{Z}_a\mathbf{Z}_a^* + bb^*\mathbf{Z}_b\mathbf{Z}_b^* + ab^*\mathbf{Z}_a\mathbf{Z}_b^* + ba^*\mathbf{Z}_b\mathbf{Z}_a^*$$ Coherence

$$\mathbf{M} = |a|^2\mathbf{Z}_a\mathbf{Z}_a^* + |b|^2\mathbf{Z}_b\mathbf{Z}_b^*$$ Incoherence

$$\mathbf{M} = |a|^2\mathbf{Z}_a\mathbf{Z}_a^* + |b|^2\mathbf{Z}_b\mathbf{Z}_b^* + \langle ab^*\rangle\mathbf{Z}_a\mathbf{Z}_b^* + \langle ba^*\rangle\mathbf{Z}_b\mathbf{Z}_a^*$$ Partial coherence

The same calculus covers all

E. Kuntman et al., Phys. Rev. A **95**, 063819 (2017)

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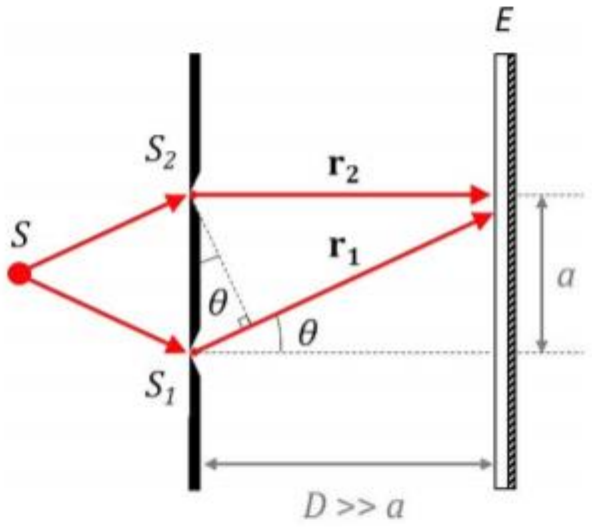
2. Ellipsometry (polarimetry) analysis of Young's double slit **experiment**

Can we study Young's double slit experiment in a polarimeter or ellipsometer?



Yes, but a detector with some spatial resolution is needed

To be interesting the polarization aspect needs to be considered

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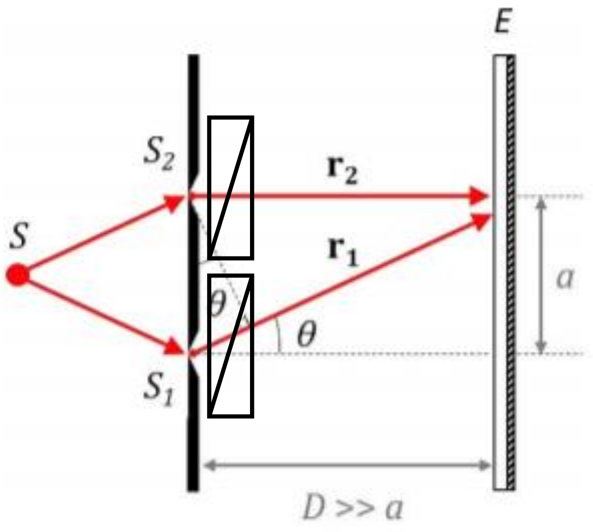
2. Ellipsometry (polarimetry) analysis of Young's double slit **experiment**

Young experiment



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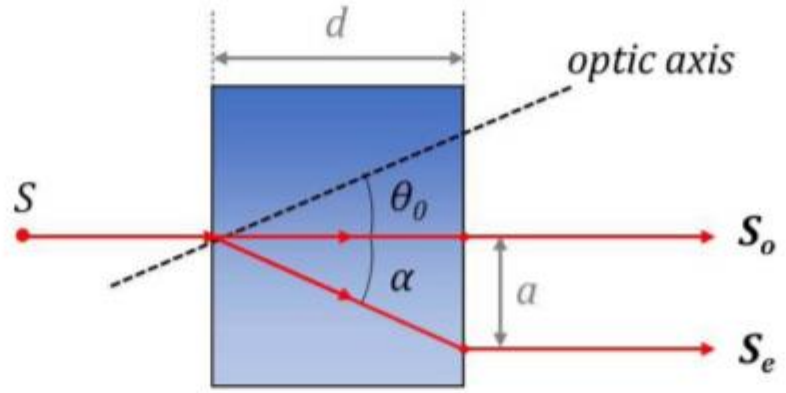
Double refraction in a birefringent crystal

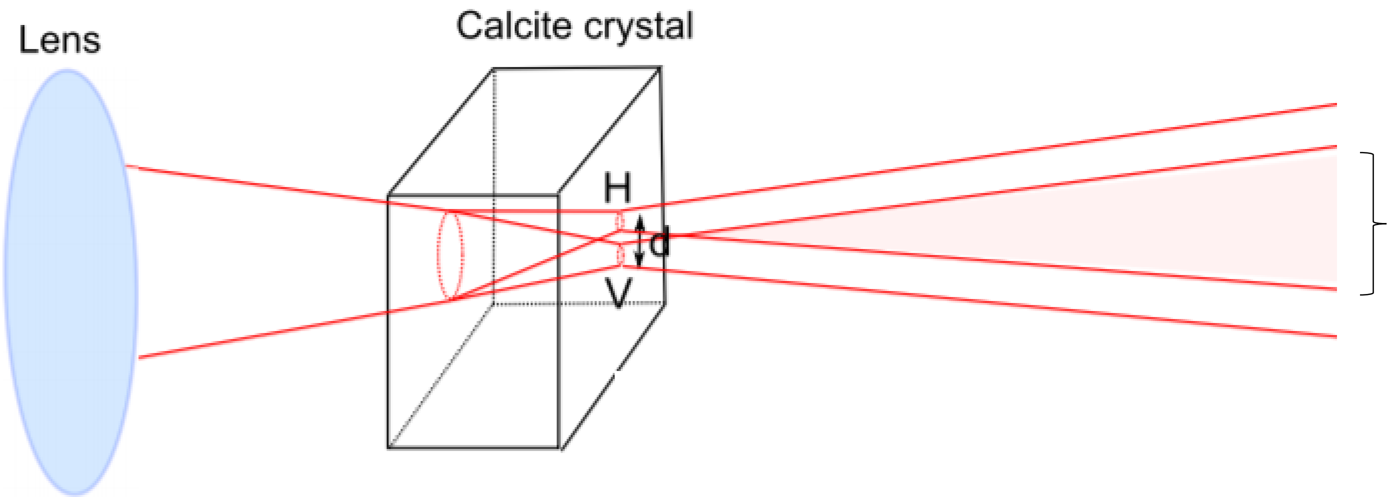


F. Arago and A. Fresnel, "Mémoire sur l'action que les rayons de lumière polarisée exercent les uns sur les autres," Ann. Chim. Phys. 10, 288–305 (1819). (derivation of the laws of interference and polarization)

2. Ellipsometry (polarimetry) analysis of Young's double slit **experiment**

Under common experimental conditions the classic Young's double-slit experiment made with orthogonal polarizers is equivalent to double refraction in a crystal.

R. Ossikovski, et al. , "On the equivalence between Young's double-slit and crystal double-refraction interference experiments," J. Opt. Soc. Am. A 34, 1309-1314 (2017)



Beam superposition
but no interference

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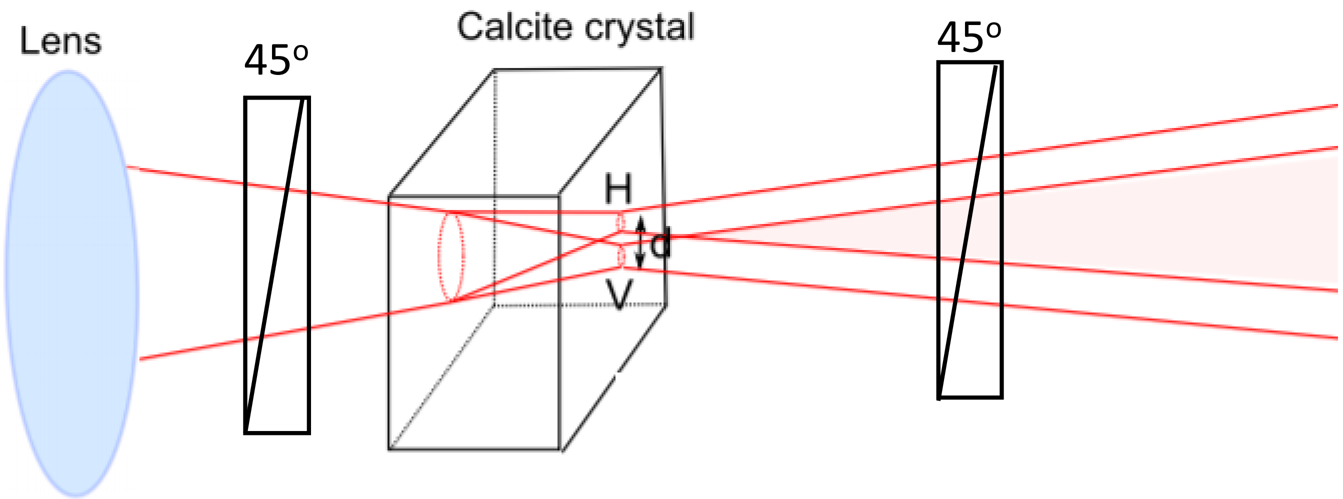
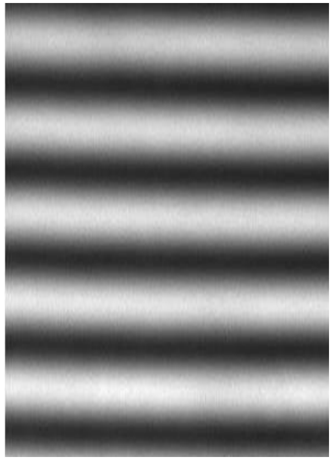
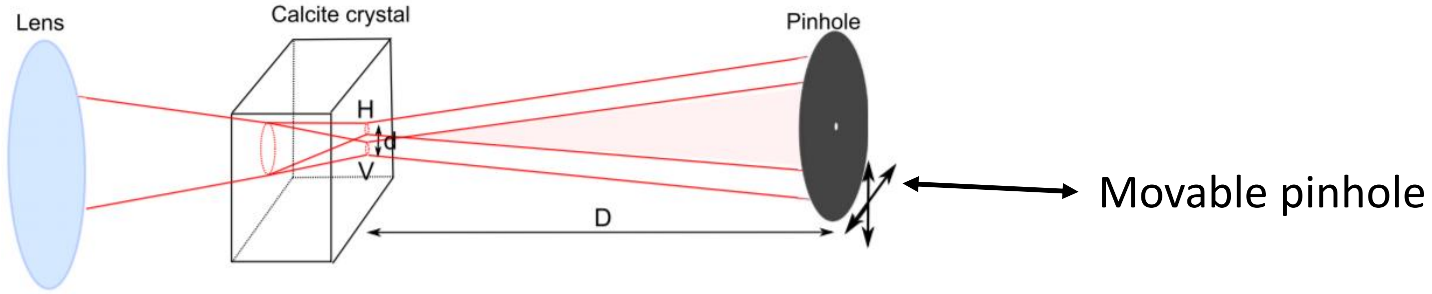
2. Ellipsometry (polarimetry) analysis of Young's double slit **experiment**

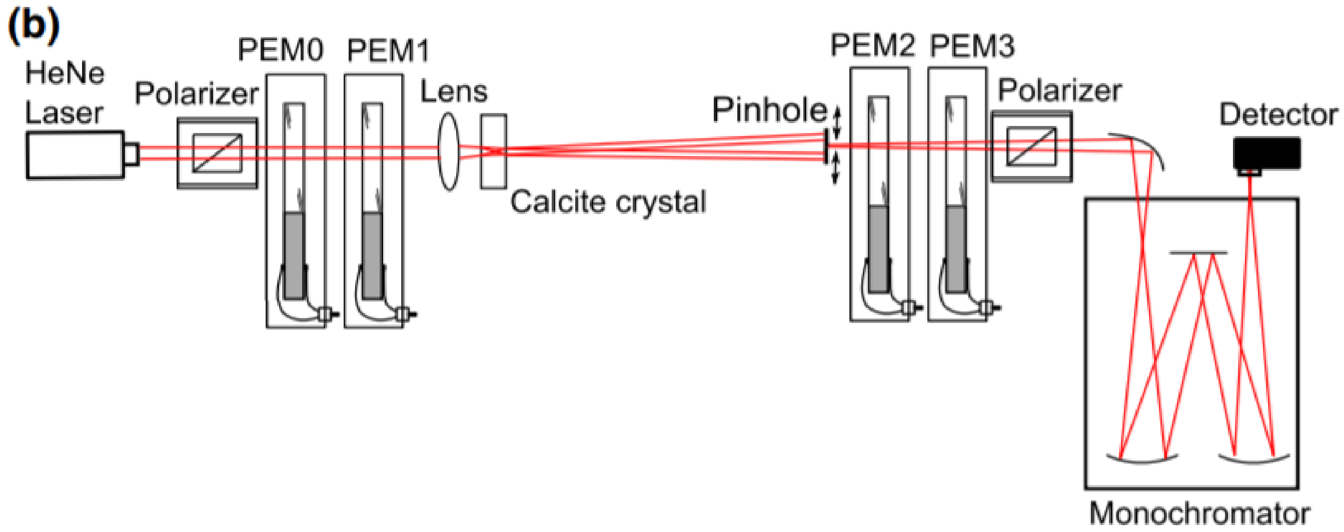
But using polarizers the interference becomes visible for the naked eye or a camera





2. Ellipsometry (polarimetry) analysis of Young's double slit **experiment**





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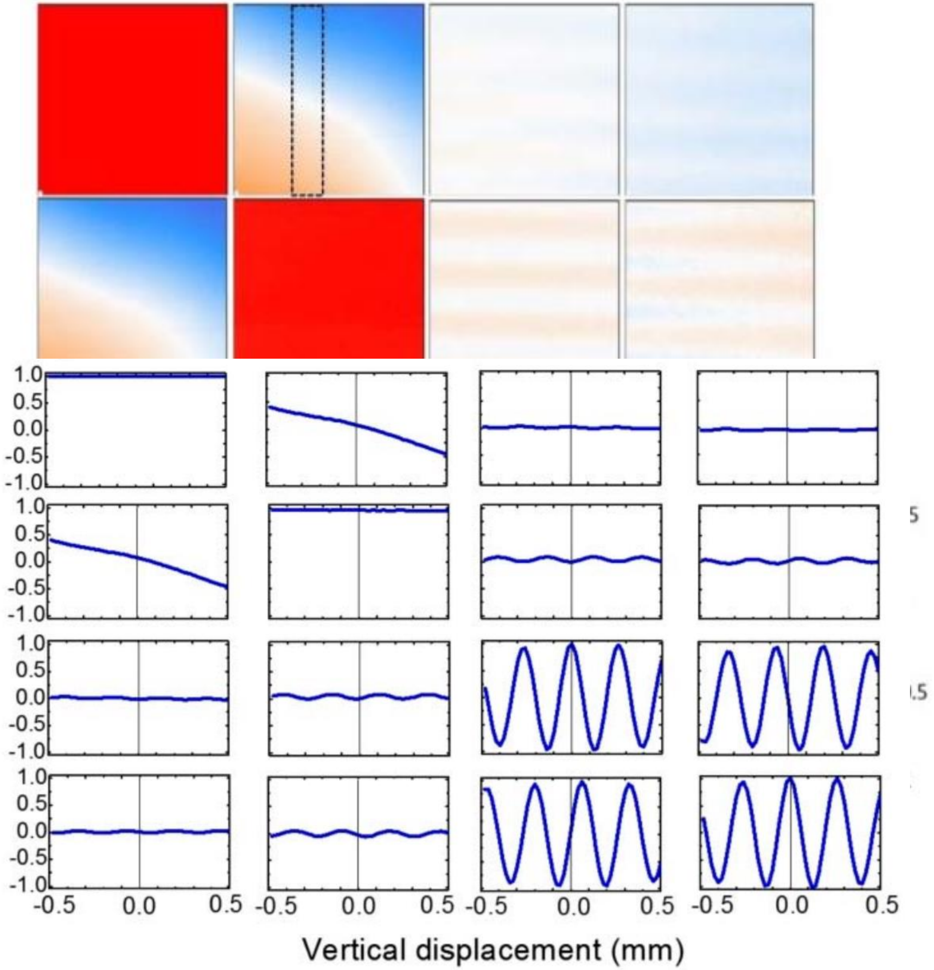
2. Ellipsometry (polarimetry) analysis of Young's double slit **experiment**



$$\mathbf{Z_V} = \frac{1}{\sqrt{2}}\begin{pmatrix} 1 & -1 & 0 & 0 \\ -1 & 1 & 0 & 0 \\ 0 & 0 & 1 & i \\ 0 & 0 & -i & 1 \end{pmatrix} \qquad \mathbf{Z_H} = \frac{1}{\sqrt{2}}\begin{pmatrix} 1 & 1 & 0 & 0 \\ 1 & 1 & 0 & 0 \\ 0 & 0 & 1 & -i \\ 0 & 0 & i & 1 \end{pmatrix}$$

$$\mathbf{Z}_0 = \frac{1}{\sqrt{2}}\mathbf{Z}_H + \frac{e^{i\phi}}{\sqrt{2}}\mathbf{Z}_V.$$

$$\mathbf{Z}_0 = \frac{1}{\sqrt{2}}\begin{pmatrix} 1+e^{i\phi} & 1-e^{i\phi} & 0 & 0 \\ 1-e^{i\phi} & 1+e^{i\phi} & 0 & 0 \\ 0 & 0 & 1+e^{i\phi} & -i(1-e^{i\phi}) \\ 0 & 0 & i(1-e^{i\phi}) & 1+e^{i\phi} \end{pmatrix}$$

$$\mathbf{M}_0 = \mathbf{Z}_0\mathbf{Z}_0^* = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & \cos\phi & -\sin\phi \\ 0 & 0 & \sin\phi & \cos\phi \end{pmatrix}$$

O.Arteaga, et al. Opt. Lett. 42, 3900-3903 (2017)

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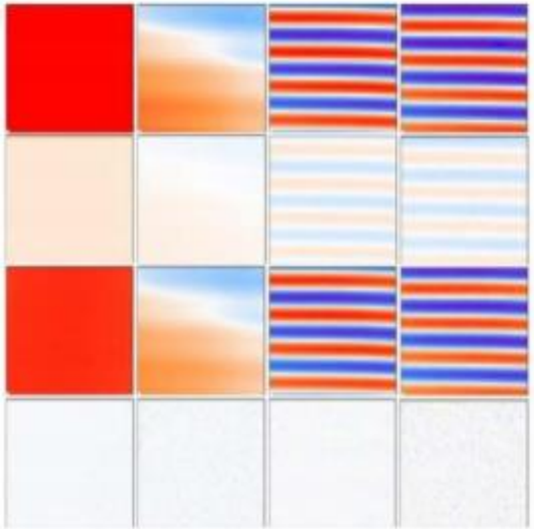
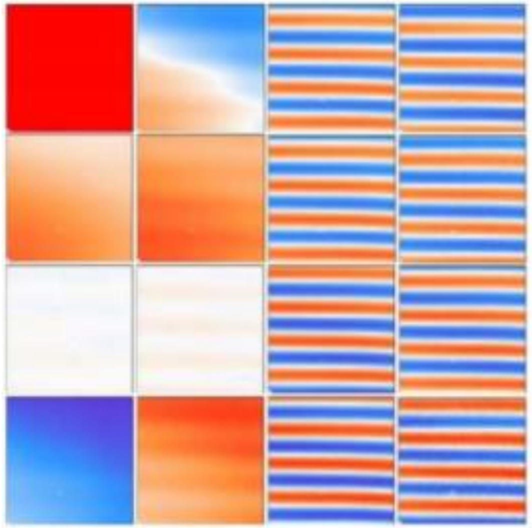
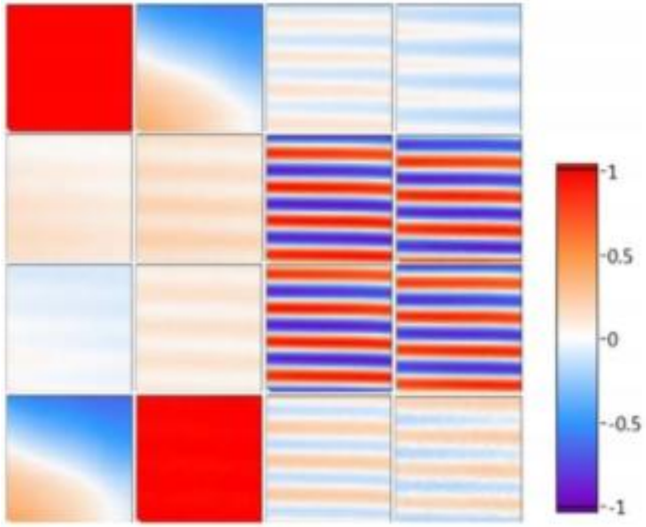
2. Ellipsometry (polarimetry) analysis of Young's double slit **experiment**

Other polarimetric configurations







$$\mathbf{Z}_a = \frac{1}{\sqrt{2}}\mathbf{Z}_{45}\mathbf{Z}_H + \frac{e^{i\phi}}{\sqrt{2}}\mathbf{Z}_{45}\mathbf{Z}_V = \mathbf{Z}_{45}\mathbf{Z}_0.$$

$$\mathbf{Z}_b = \frac{1}{\sqrt{2}}\mathbf{Z}_H + \frac{e^{i\phi}}{\sqrt{2}}\mathbf{Z}_R\mathbf{Z}_V,$$

$$\mathbf{Z}_c = \frac{1}{\sqrt{2}}\mathbf{Z}_R\mathbf{Z}_H + \frac{e^{i\phi}}{\sqrt{2}}\mathbf{Z}_R\mathbf{Z}_V = \mathbf{Z}_R\mathbf{Z}_0,$$

$$\mathbf{M}_a = \mathbf{Z}_a\mathbf{Z}_a^* = \mathbf{M}_{45}\mathbf{M}_0 = \begin{pmatrix} 1 & 0 & \cos\phi & -\sin\phi \\ 0 & 0 & 0 & 0 \\ 1 & 0 & \cos\phi & -\sin\phi \\ 0 & 0 & 0 & 0 \end{pmatrix}$$

$$\mathbf{M}_b = \mathbf{Z}_b\mathbf{Z}_b^* = \begin{pmatrix} 1 & 0 & -\sin\phi/\sqrt{2} & -\cos\phi/\sqrt{2} \\ 1/2 & 1/2 & -\sin\phi/\sqrt{2} & -\cos\phi/\sqrt{2} \\ 0 & 0 & \cos\phi/\sqrt{2} & -\sin\phi/\sqrt{2} \\ -1/2 & 1/2 & \sin\phi/\sqrt{2} & \cos\phi/\sqrt{2} \end{pmatrix}$$

$$\mathbf{M}_c = \mathbf{Z}_c\mathbf{Z}_c^* = \mathbf{M}_R\mathbf{M}_0 = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 0 & -\sin\phi & -\cos\phi \\ 0 & 0 & \cos\phi & -\sin\phi \\ 0 & 1 & 0 & 0 \end{pmatrix}$$

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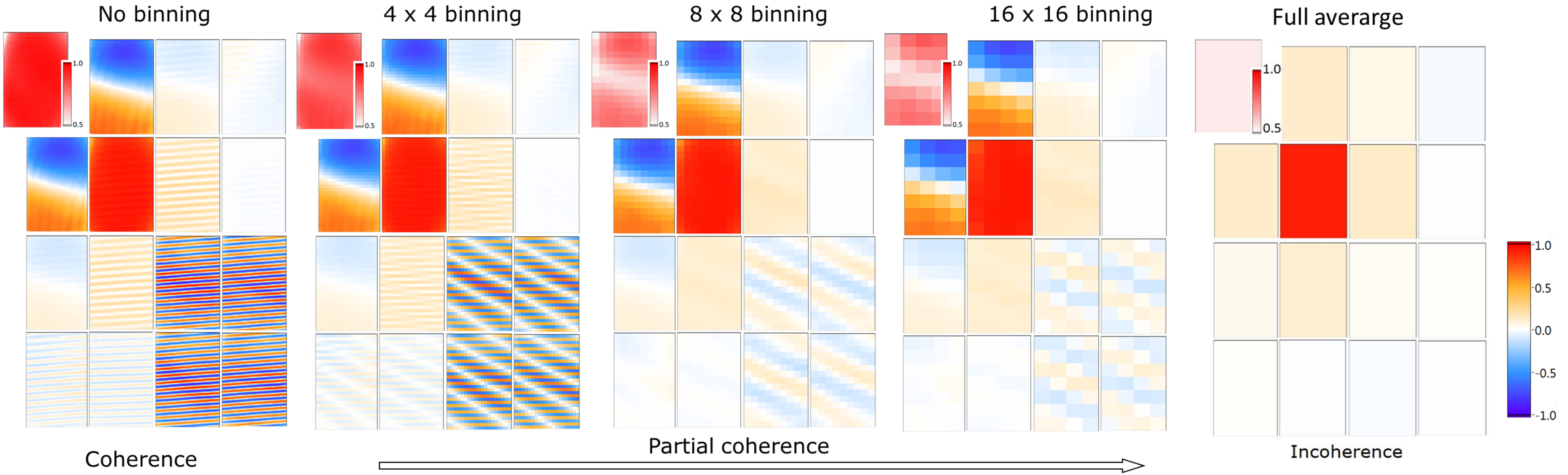
2. Ellipsometry (polarimetry) analysis of Young's double slit **experiment**

What happens with a loss of spatial resolution?

(binning is equivalent to increment the pinhole size)



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2. Ellipsometry (polarimetry) analysis of Young's double slit **experiment**

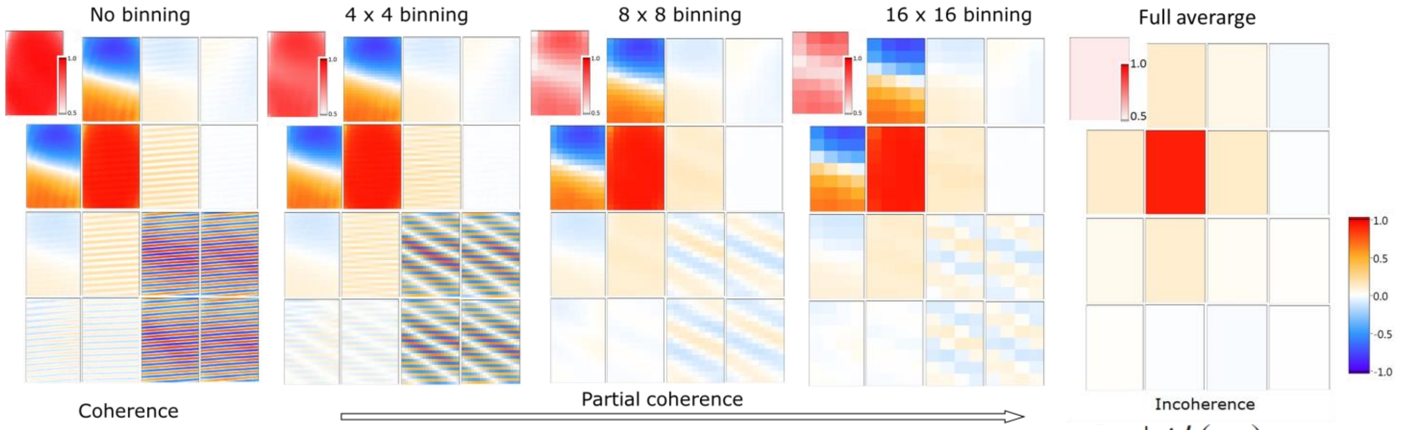
Partial coherence

$$\mathbf{M} = |a|^2 \mathbf{Z}_a \mathbf{Z}_a^* + |b|^2 \mathbf{Z}_b \mathbf{Z}_b^* + \langle ab^* \rangle \mathbf{Z}_a \mathbf{Z}_b^* + \langle ba^* \rangle \mathbf{Z}_b \mathbf{Z}_a^*$$

$$\mathbf{M} = \frac{1}{2}\mathbf{M}_H + \frac{1}{2}\mathbf{M}_V + \frac{\langle e^{-i\phi(x,y)} \rangle}{2} \mathbf{Z}_V \mathbf{Z}_H^* + \frac{\langle e^{i\phi(x,y)} \rangle}{2} \mathbf{Z}_H \mathbf{Z}_V^*$$

$$\langle e^{\pm i\phi(x,y)} \rangle = \frac{1}{A_P} \int_{A_P} e^{\pm i\phi(x,y)} \, \mathrm{d}S$$

A_P is the pinhole area



$$\langle e^{\pm i\phi(x,y)} \rangle \approx 0$$

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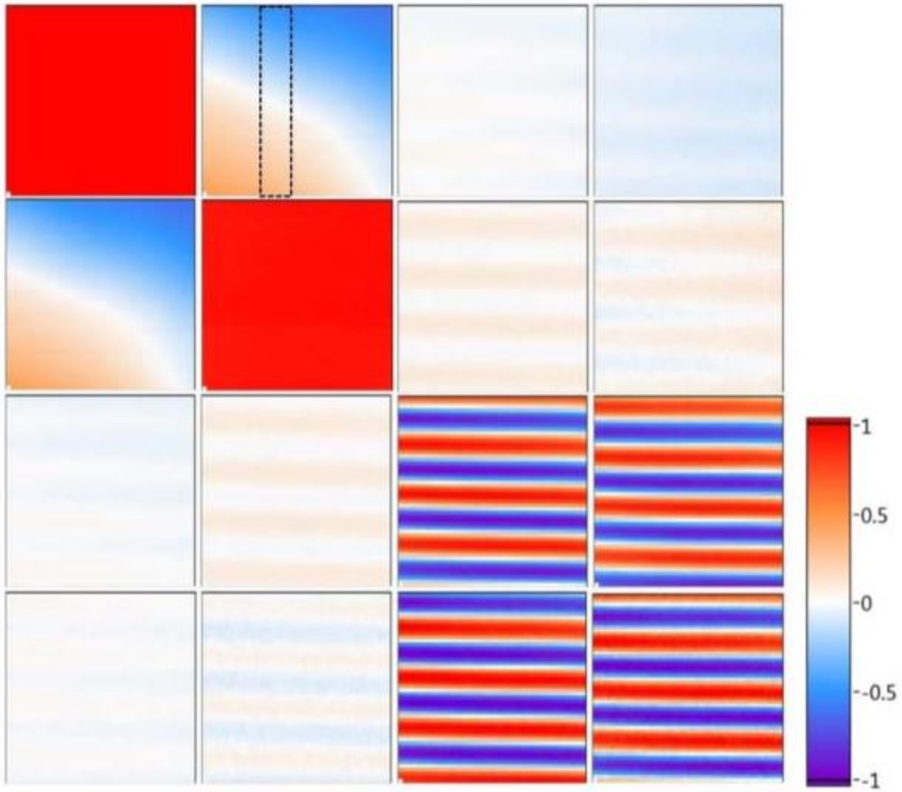
3. Synthesis of optical components and applications



Basic example. A linear retarder is synthetised “polarizers”

$$\mathbf{M}_0 = \mathbf{Z}_0\mathbf{Z}_0^* = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & \cos\phi & -\sin\phi \\ 0 & 0 & \sin\phi & \cos\phi \end{pmatrix}$$

$\phi = -\pi/2$ Horizontal QWP

$\phi = \pi/2$ Vertical QWP

$\phi = \pi$ Half Wave Plate

3. Synthesis of optical components and applications

Which experimental conditions allow the synthesis?

1. The detector needs to have enough spatial resolution to resolve the fringes

$$\Delta x = D\lambda/d$$

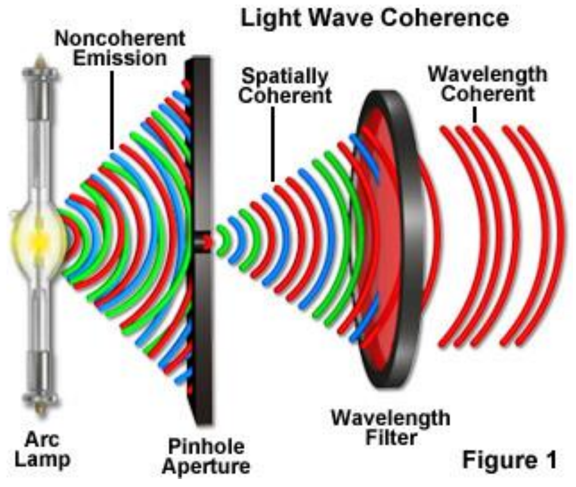
Δx: distance between two fringes
D: distance from the crystal to the detector
d: separation between the H and V beams in the crystal

2. The light source needs to be coherent enough

Can only be made with a laser? NO

In a standard polarimetric experiment the required temporal and spatial coherence is determined by the thickness of double refractive crystal

Thicker crystal → Larger separation of H and V beams



From: http://zeiss-campus.magnet.fsu.edu/tutorials/coherence/indexflash.html

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3. Synthesis of optical components and applications

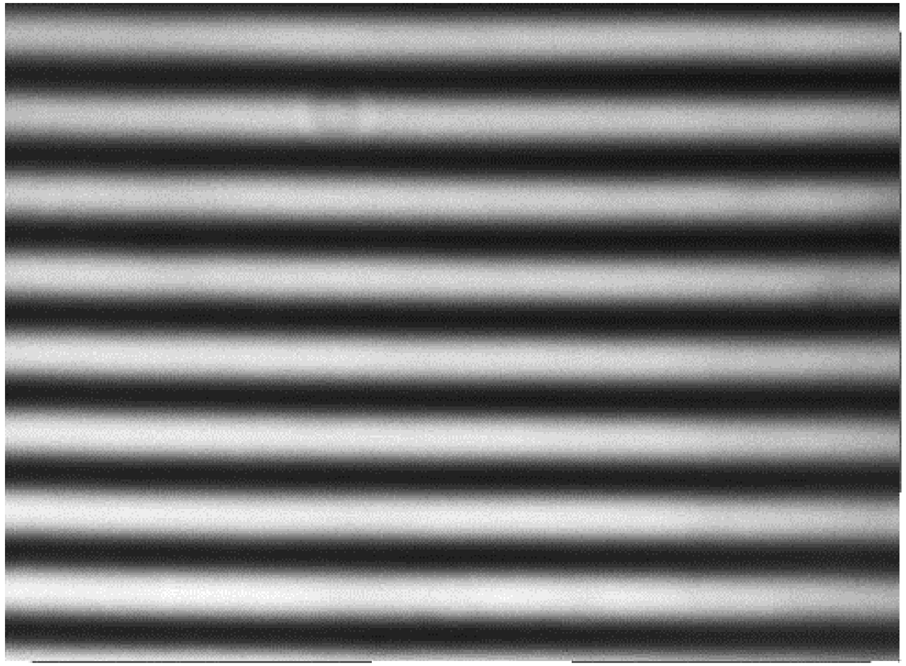
Experimental examples of fringe images recorded with a Xe light source

Xe light source → Monochromator → Pinhole → Polarizer → Double refracting calcite → Polarizer → Camera

460nm

550 nm

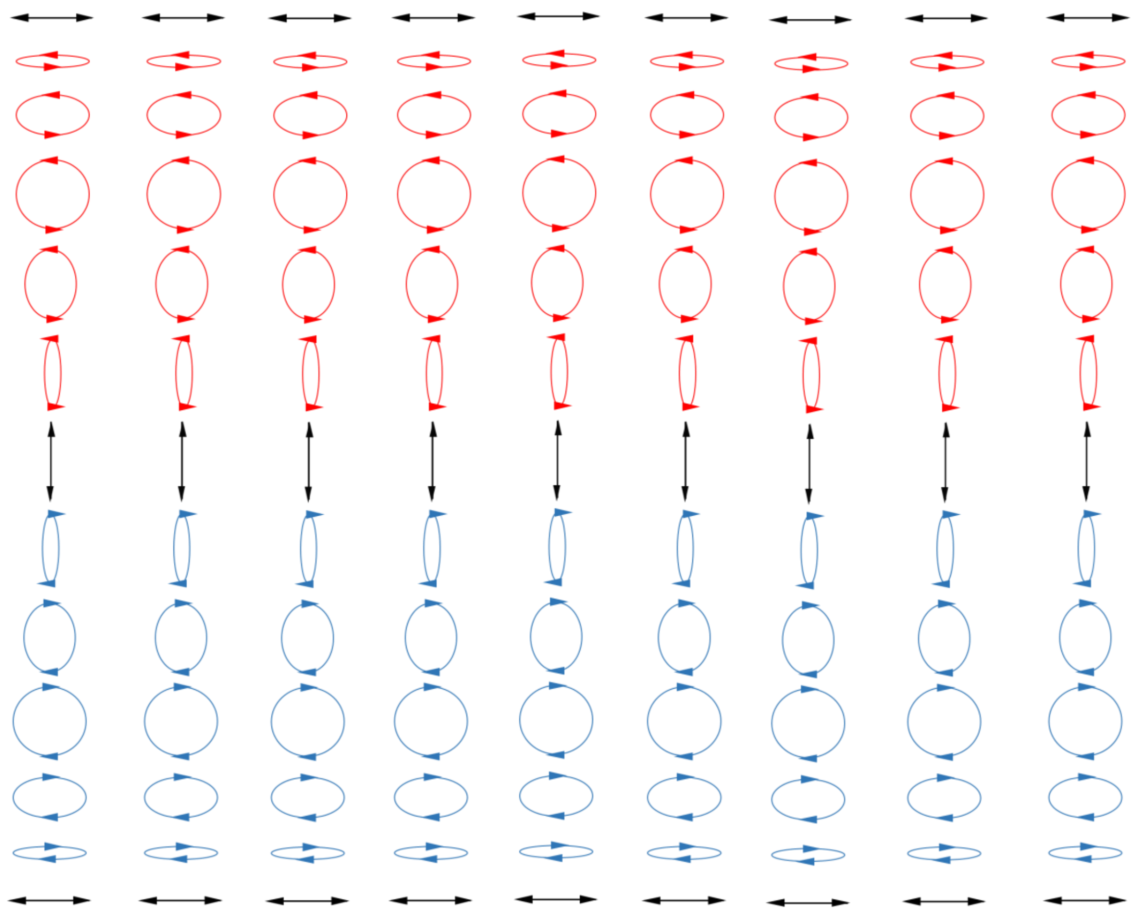
700 nm



3. Synthesis of optical components and applications

Generation of periodic spatial modulation

45º Polarizer → Double refracting crystal with H and V states →



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3. Synthesis of optical components and applications

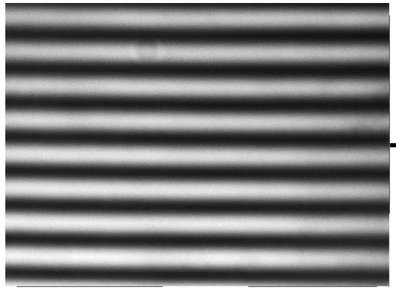
Generation of periodic spatial modulation

45º Polarizer

Double refracting crystal with H and V states

Polarization State Generator that generates **spatial** phase modulation

(in contrast to the common **temporal** PM)



As the modulation is periodic, synchronous detection is possible

Development of **new ellipsometers and polarimeters** based on spatial phase modulation

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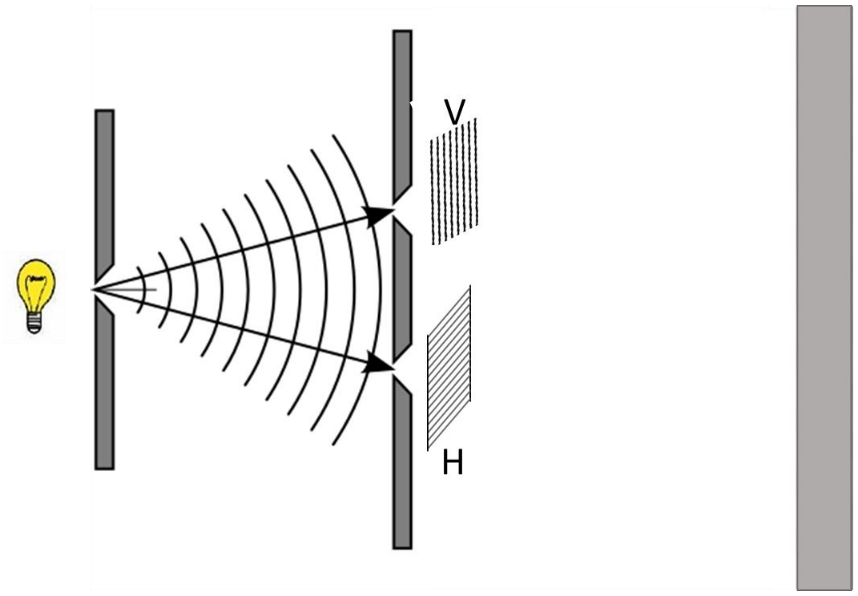
Summary



- A new formalism for polarization and coherence has been introduced to study with the same algebraic tools the three regimes: coherence, partial coherence and incoherence.

- In ellipsometry we are familiar with interference effects occuring in the micro- or nano-scale (e.g., thin films), but we are less familiar with superposition processes that can be macroscopically controlled, such in Young experiment

- Well controlled light superposition processes allow the synthesis of polarization components which can be used for **future ellipsometry and polarimetry instrumentation**

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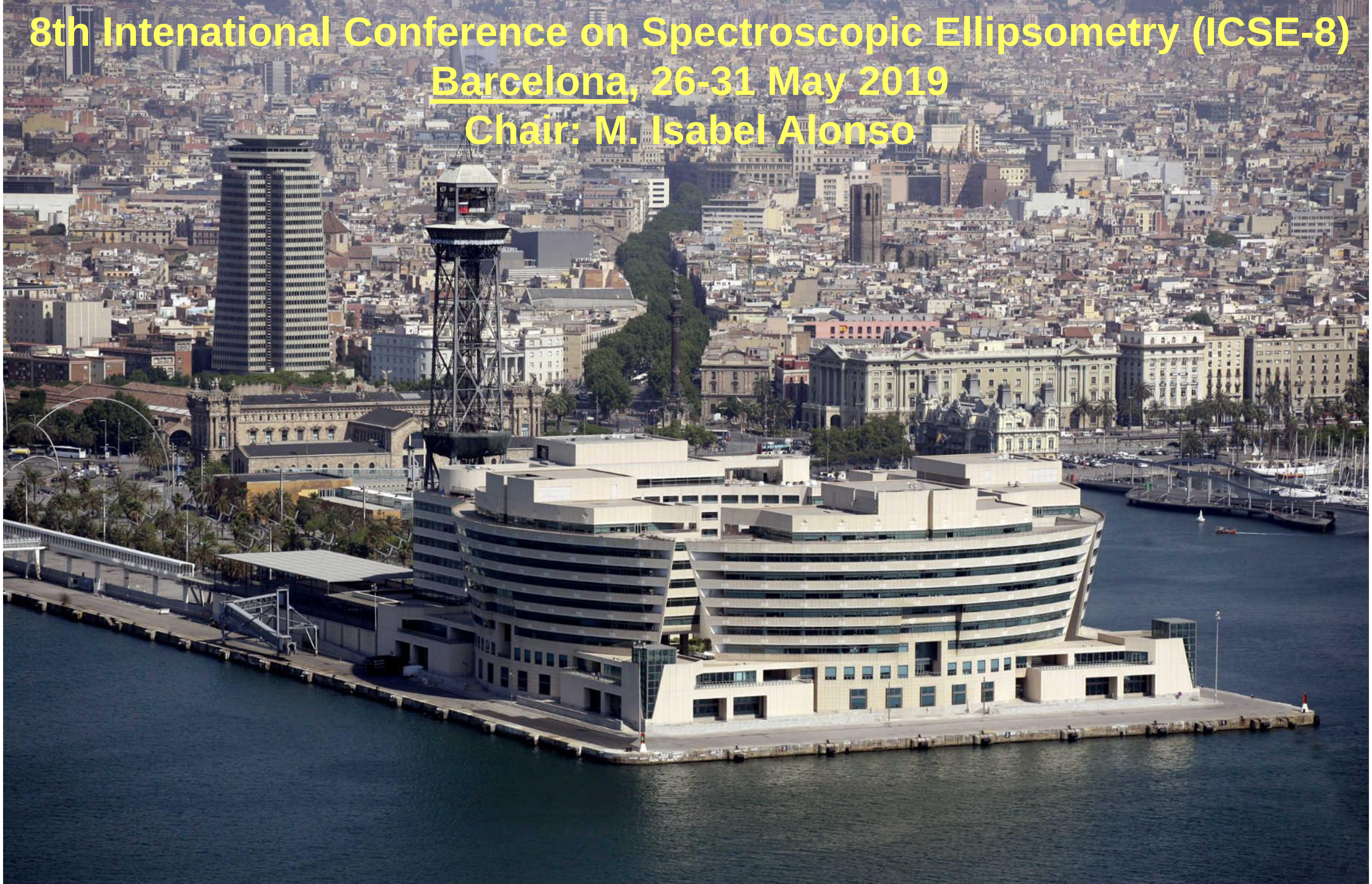
8th Intenational Conference on Spectroscopic Ellipsometry (ICSE-8)
Barcelona, 26-31 May 2019
Chair: M. Isabel Alonso