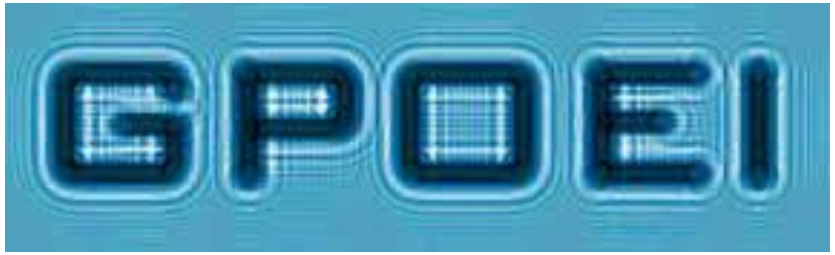
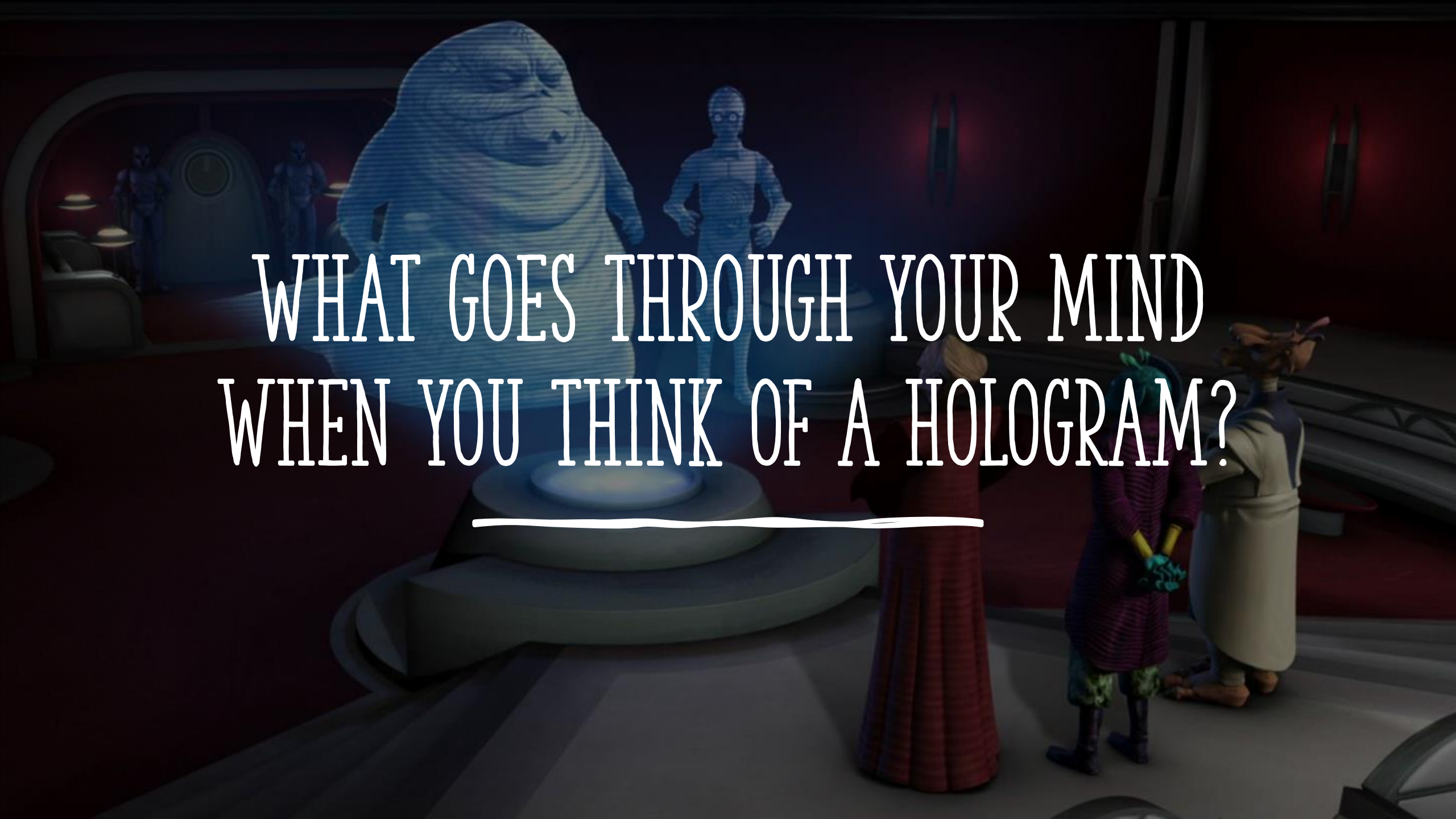
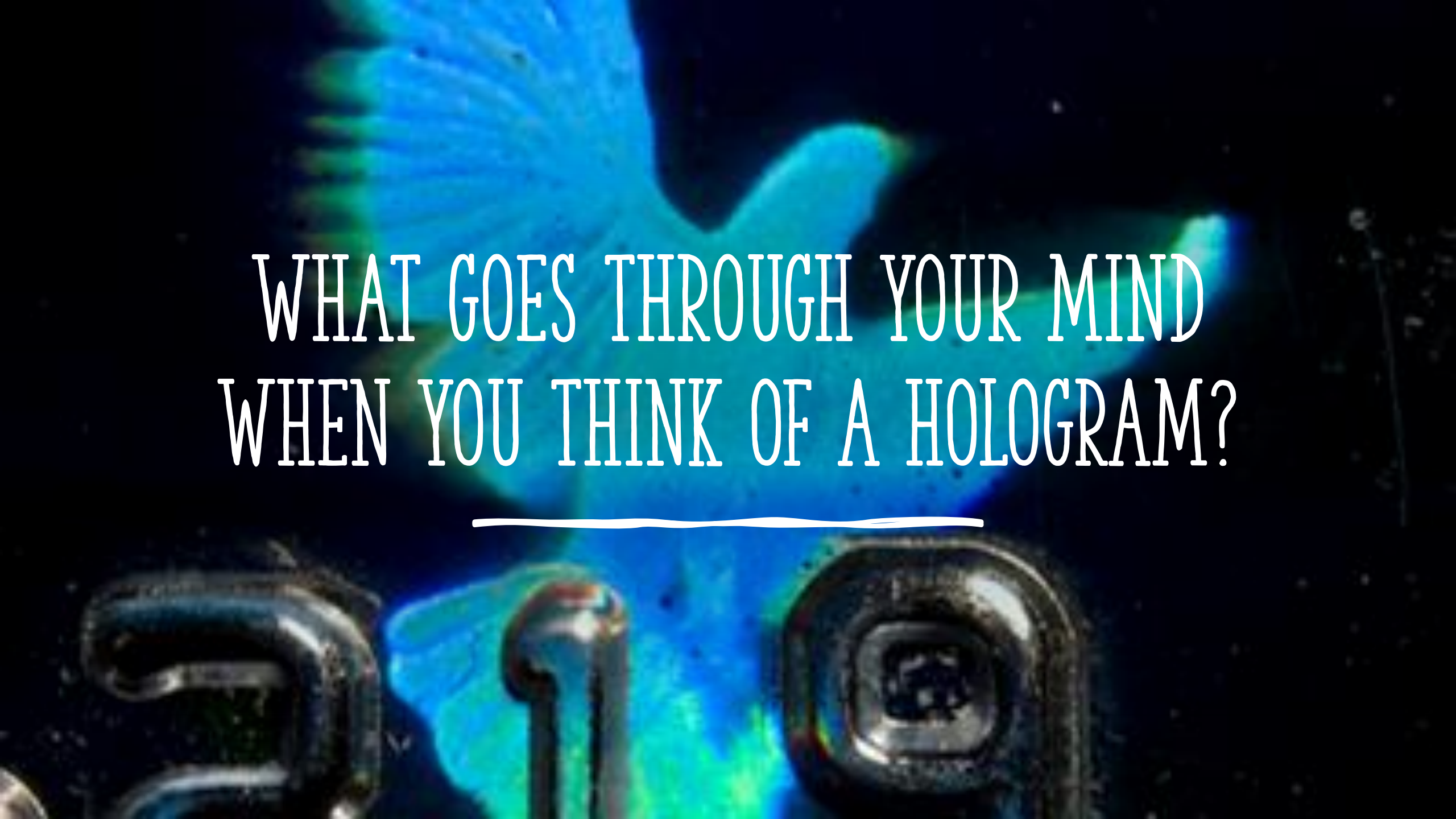
HOLOGRAPHY: FROM PHYSICS TO DAILY LIFE



Rosa Vila Andrés

Sixth Physics Erasmus Summer School


WHAT GOES THROUGH YOUR MIND
WHEN YOU THINK OF A HOLOGRAM?

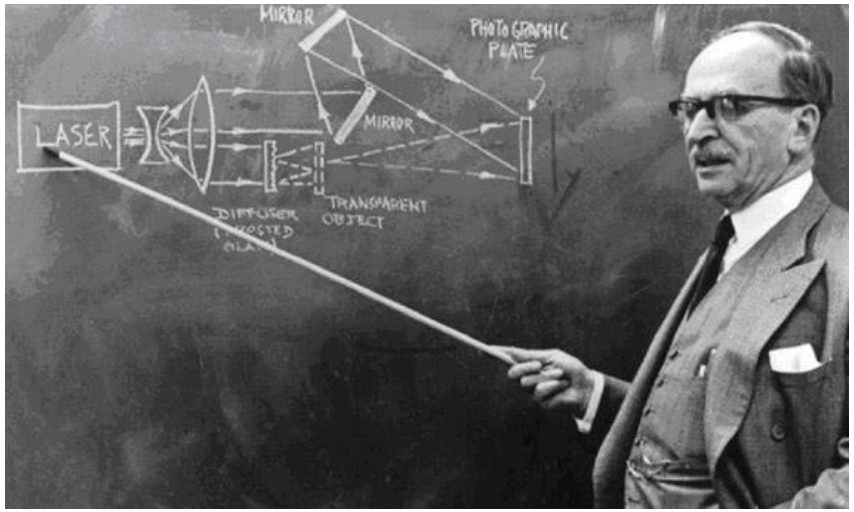

WHAT GOES THROUGH YOUR MIND
WHEN YOU THINK OF A HOLOGRAM?

WHAT GOES THROUGH YOUR MIND WHEN YOU THINK OF A HOLOGRAM?

ETYMOLOGY

Holo- : ALL

-graphy: Written representation



ORIGINS

1948

Dennis Gabor

A NEW MICROSCOPIC PRINCIPLE

By Dr. D. GABOR
Research Laboratory, British Thomson-Houston Co., Ltd., Rugby

IT is known that the spherical aberration of electron lenses sets a limit to the resolving power of electron microscopes at about 5 A. Suggestions for the correction of objectives have been made; but these are difficult in themselves, and the prospects of improvement are further aggravated by the fact that the resolution limit is proportional to the fourth root of the spherical aberration. Thus an improvement of the resolution by one decimal would require a correction of the objective to four decimals, a practically hopeless task.

The new microscopic principle described below offers a way around this difficulty, as it allows one to dispense altogether with electron objectives. Micrographs are obtained in a two-step process, by electronic analysis, followed by optical synthesis, as in Sir Lawrence Bragg's 'X-ray microscope'. But

THE FIRST HOLOGRAM

A NEW MICROSCOPIC PRINCIPLE

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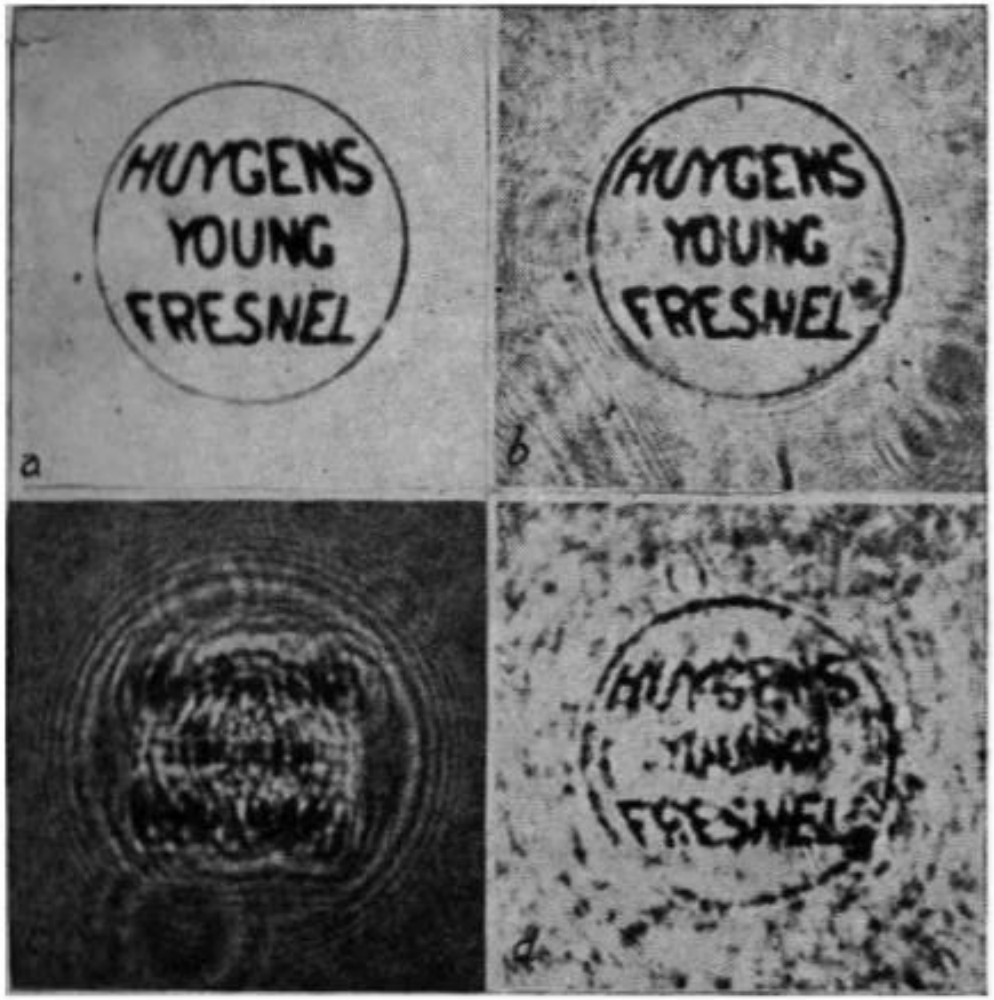
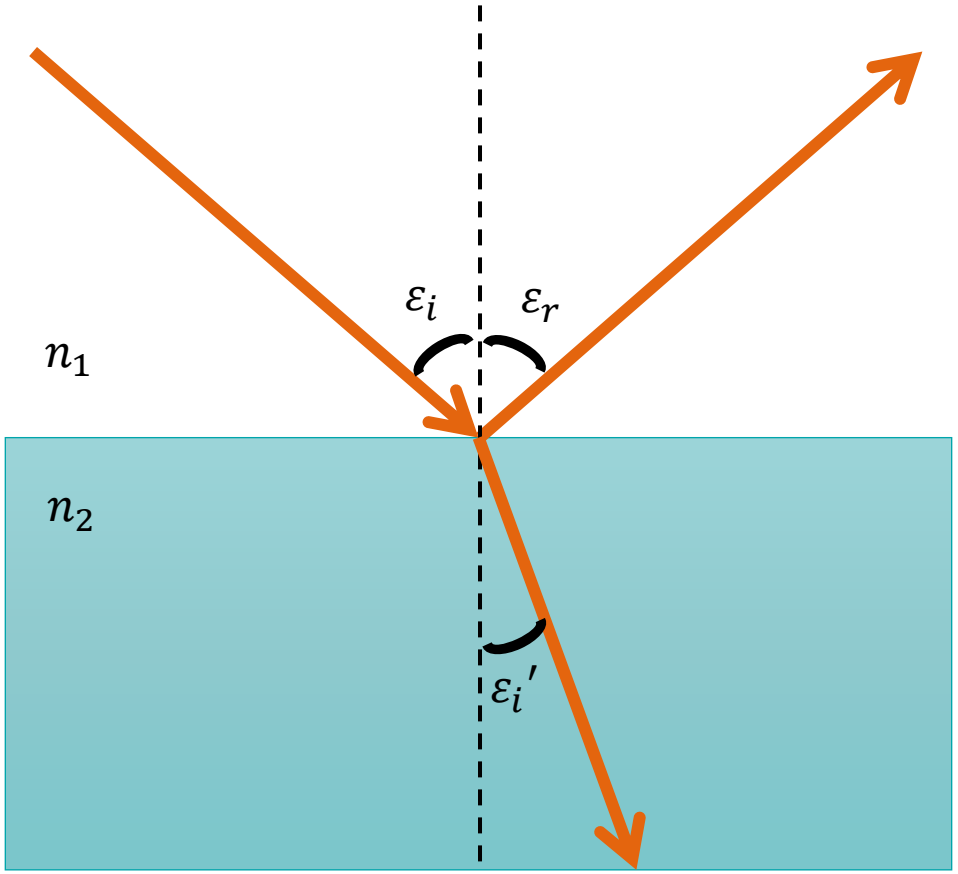


Fig. 2. (*a*) ORIGINAL MICROGRAPH, 1·4 MM. DIAMETER. (*b*) MICROGRAPH, DIRECTLY PHOTOGRAPHED THROUGH THE SAME OPTICAL SYSTEM WHICH IS USED FOR THE RECONSTRUCTION (*d*). AP. 0·04. (*c*) INTERFERENCE DIAGRAM, OBTAINED BY PROJECTING THE MICROGRAPH ON A PHOTOGRAPHIC PLATE WITH A BEAM DIVERGING FROM A POINT FOCUS. THE LETTERS HAVE BECOME ILLEGIBLE BY DIFFRACTION. (*d*) RECONSTRUCTION OF THE ORIGINAL BY OPTICAL SYNTHESIS FROM THE DIAGRAM AT THE LEFT. TO BE COMPARED WITH (*b*). THE LETTERS HAVE AGAIN BECOME LEGIBLE

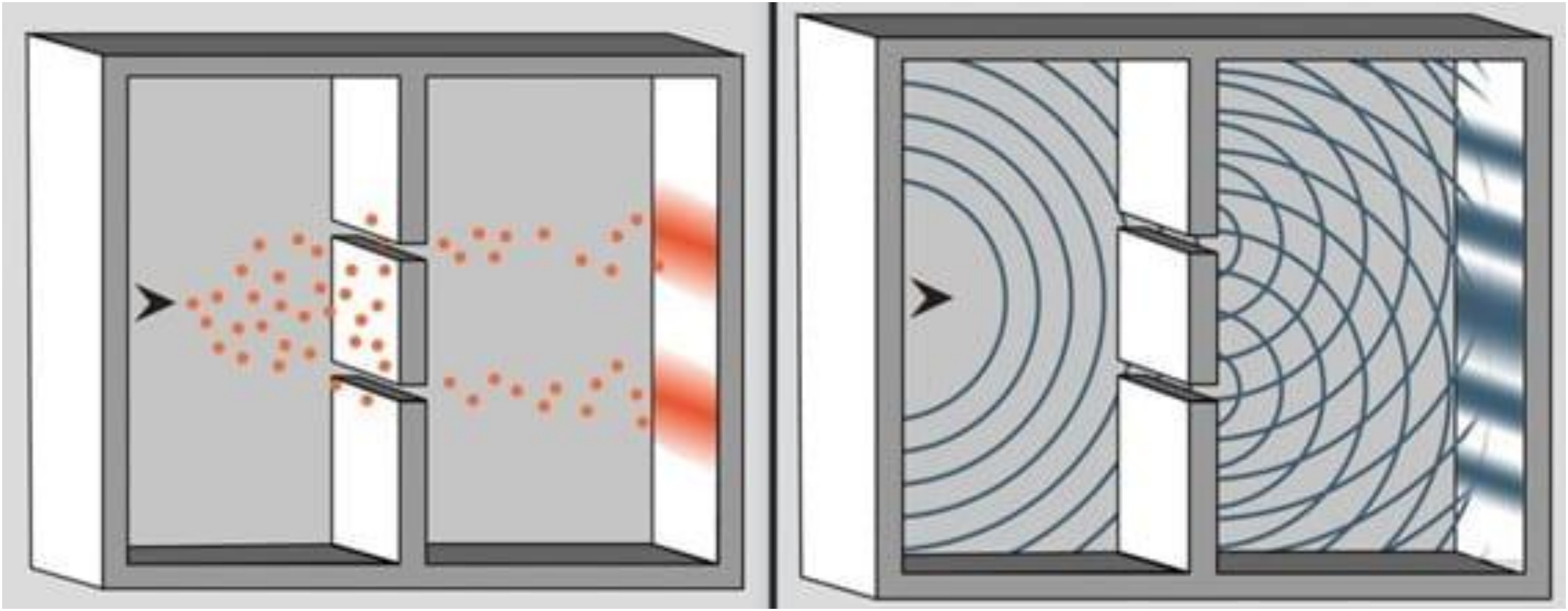
WHAT IS LIGHT... A WAVE OR A PARTICLE?

LIGHT PROPERTIES - GEOMETRIC OPTICS



DIFFRACTION

- What happens when light comes across an obstacle?



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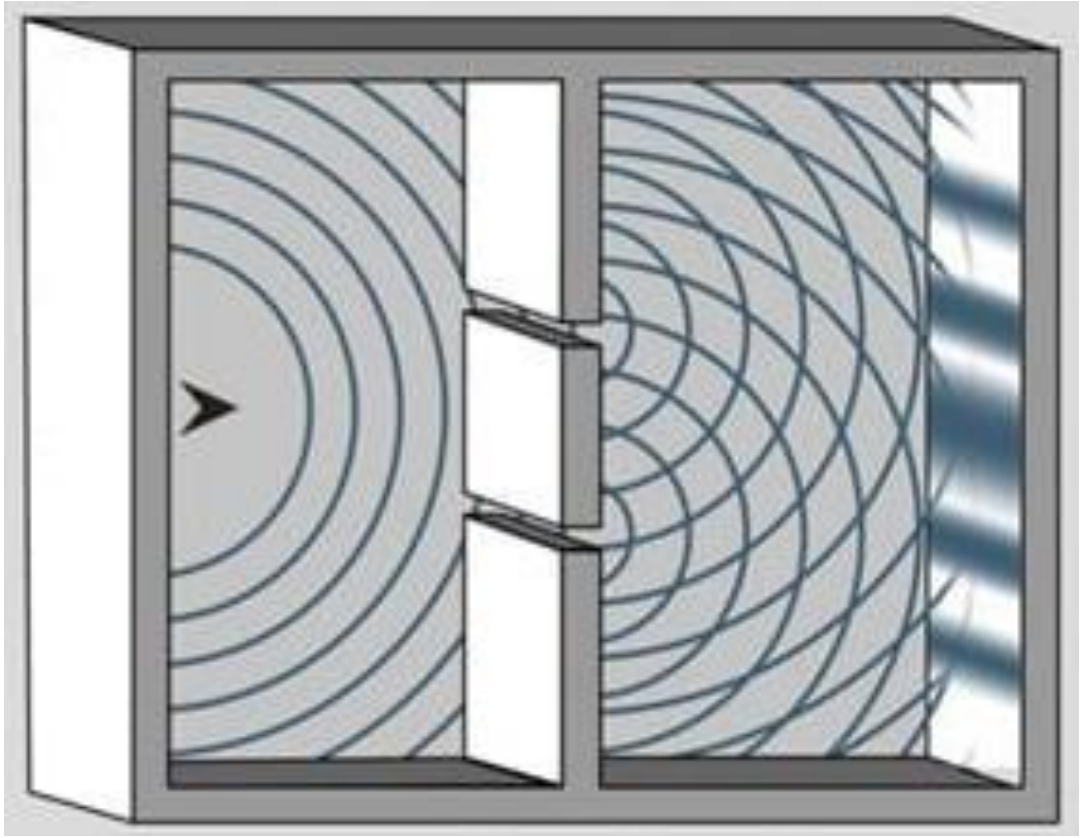
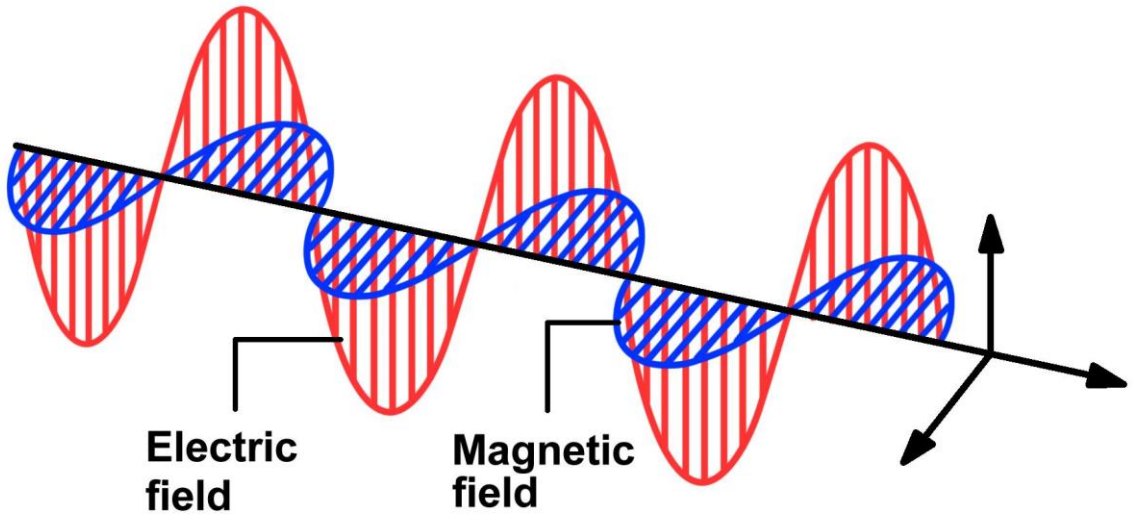
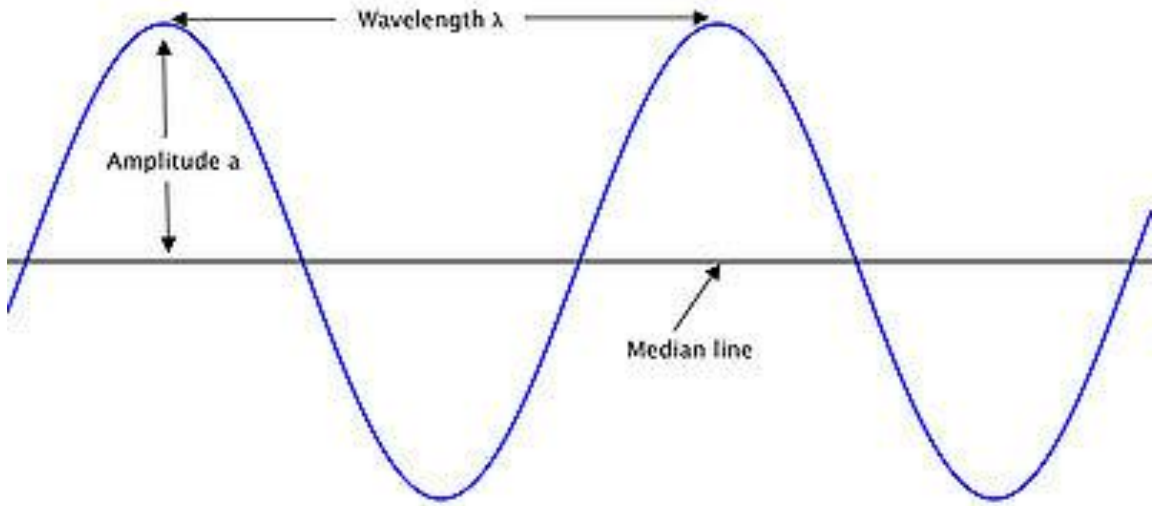


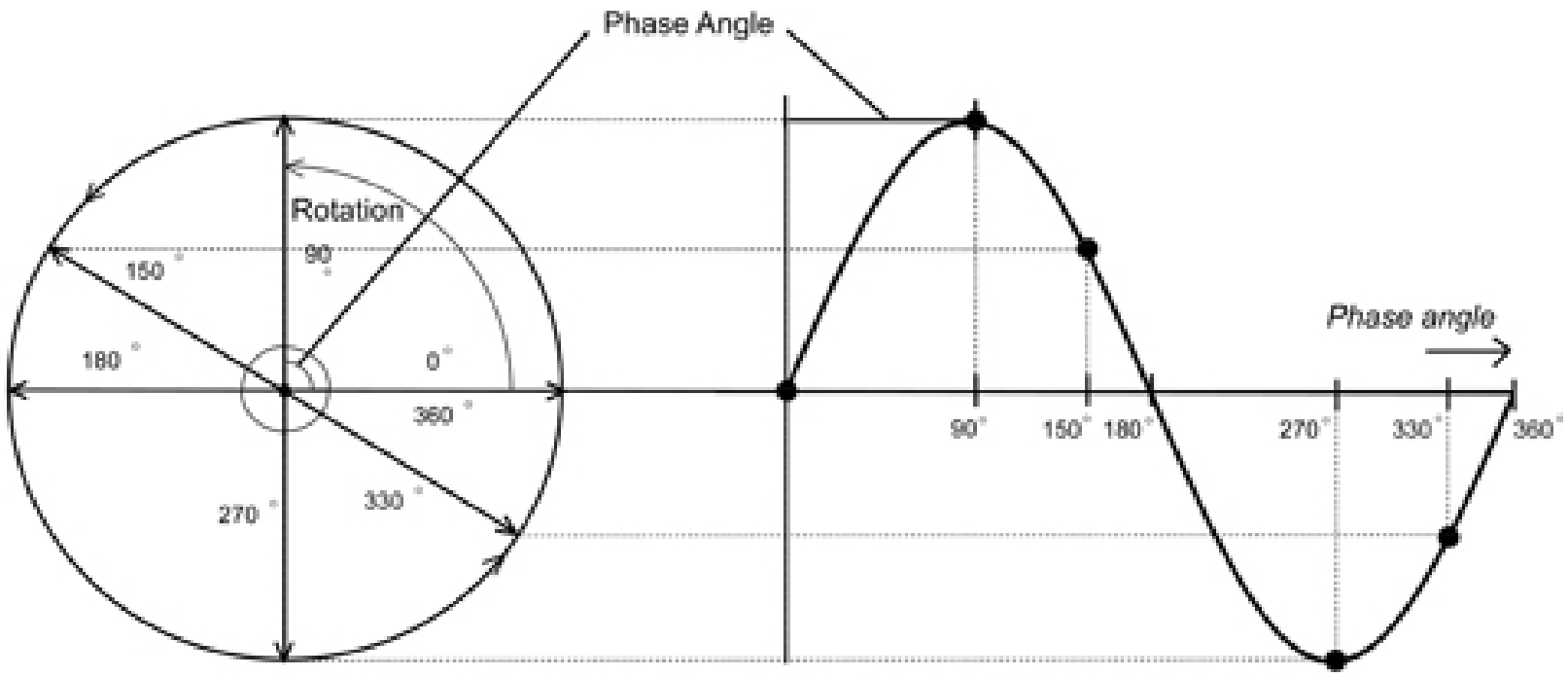
LIGHT AS AN ELECTROMAGNETIC WAVE

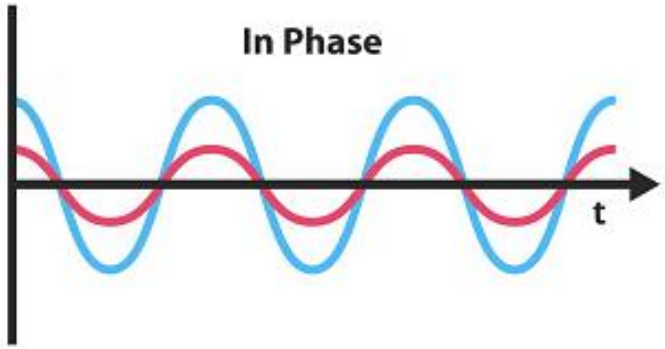


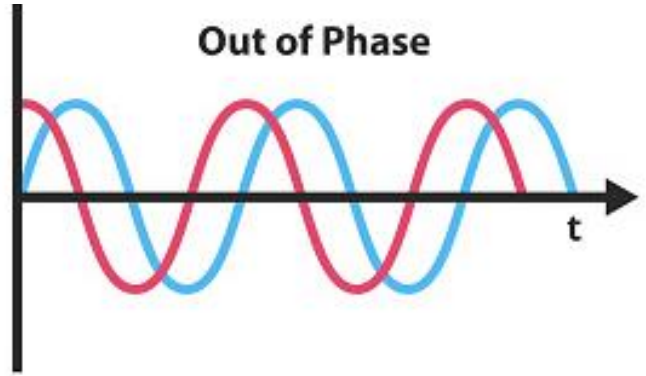


$$\psi(x,t) = A \cdot \cos(kx - \omega t + \varphi_0)$$

LIGHT AS AN ELECTROMAGNETIC WAVE

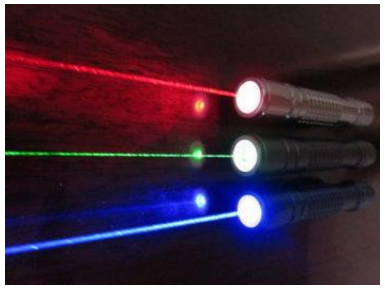




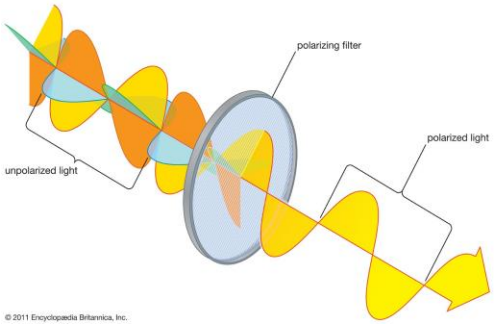


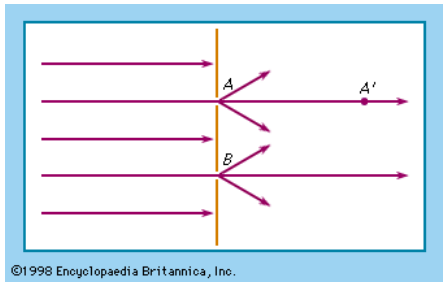
INTERFERENCE CONSTRICTIONS

Coherency



Amplitude

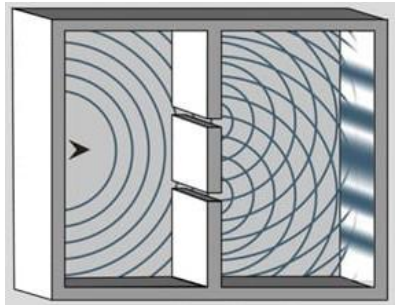


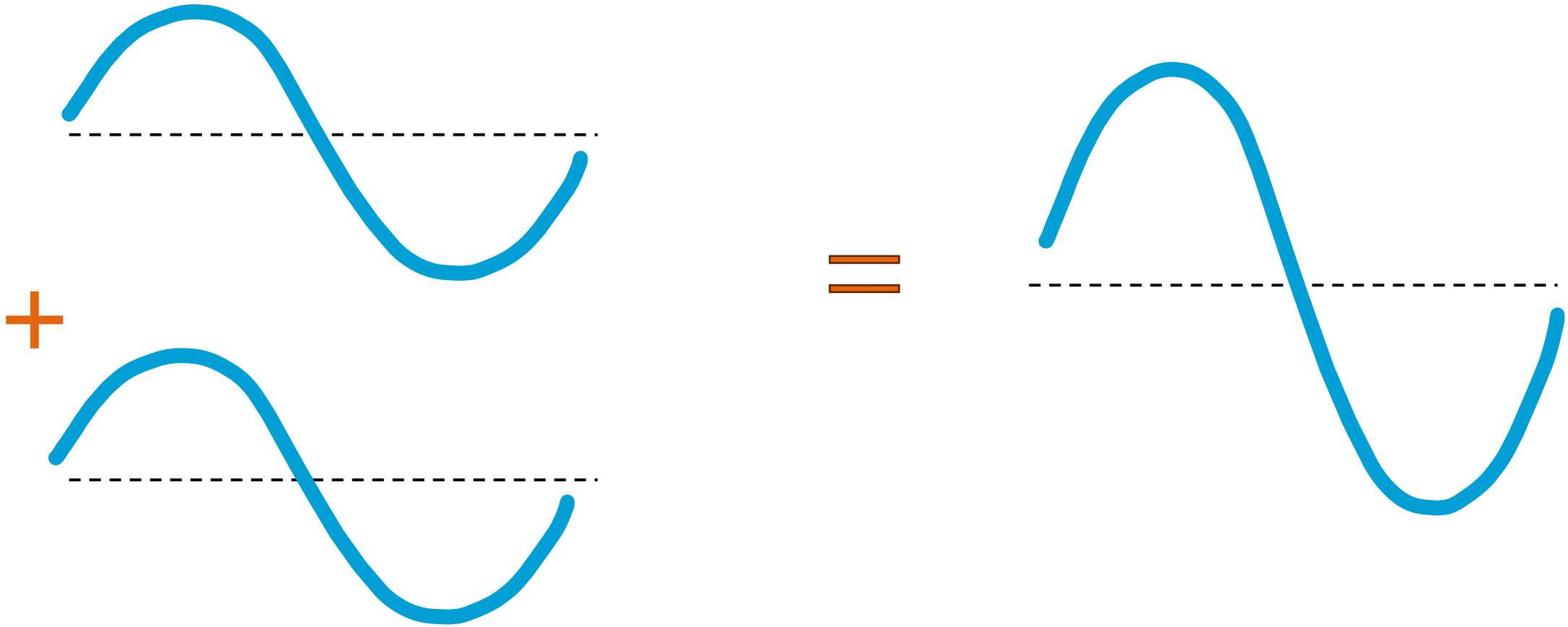


Monochromaticity

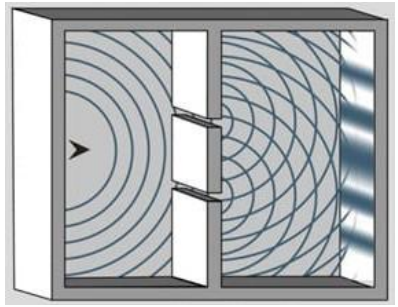
Polarization

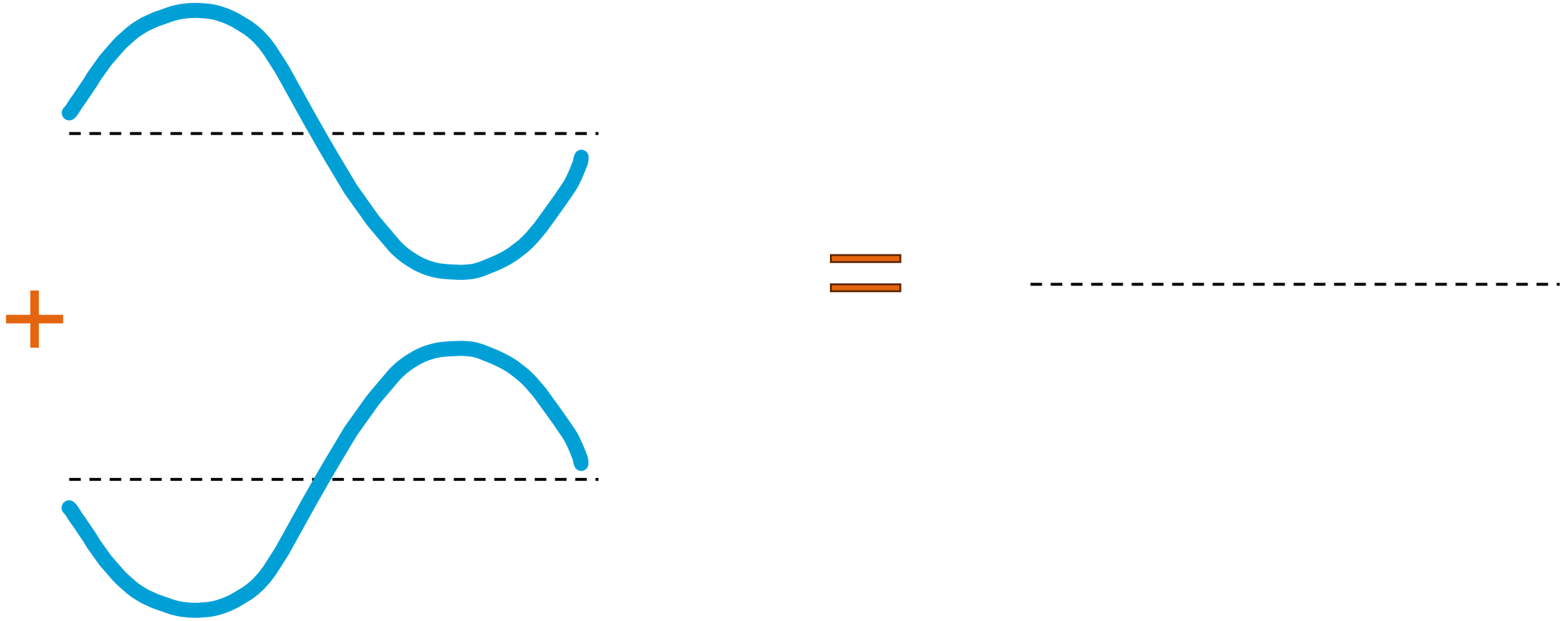
INTERFERENCE



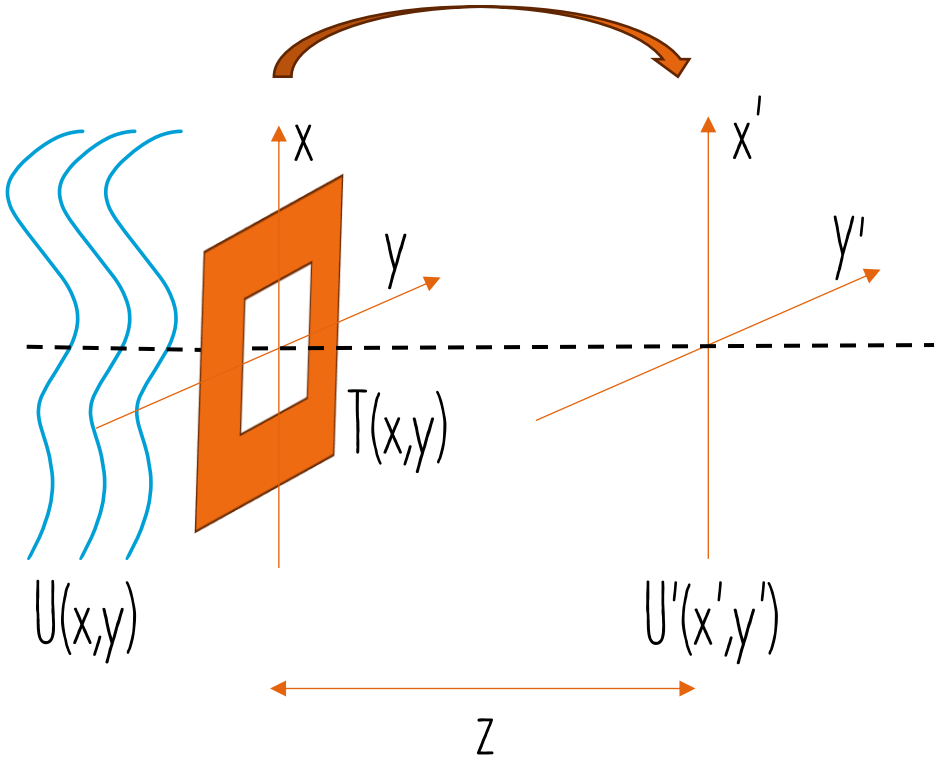


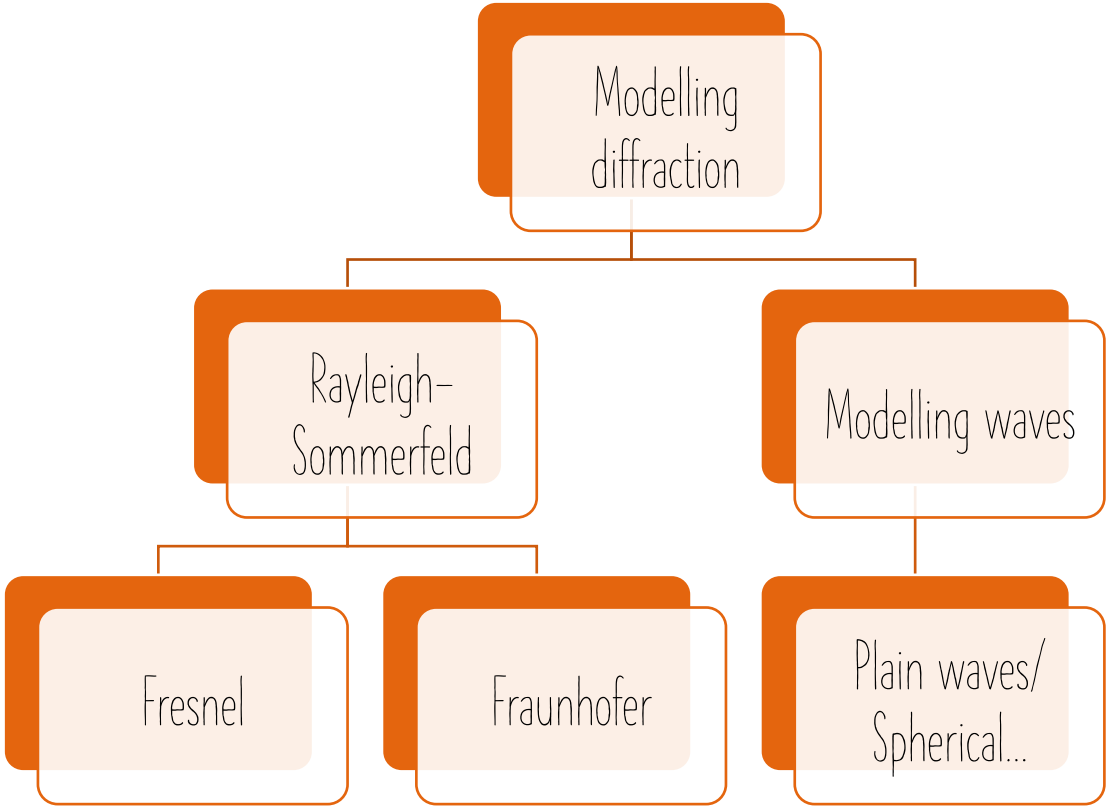
INTERFERENCE





LIGHT FIELD PROPAGATION IN FREE SPACE





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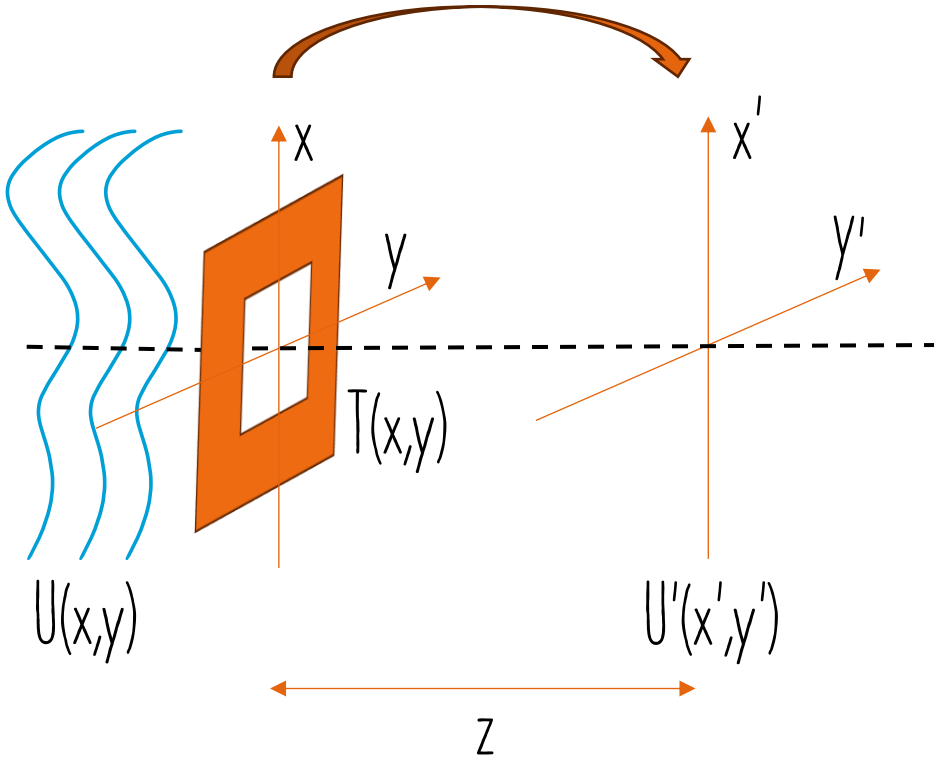

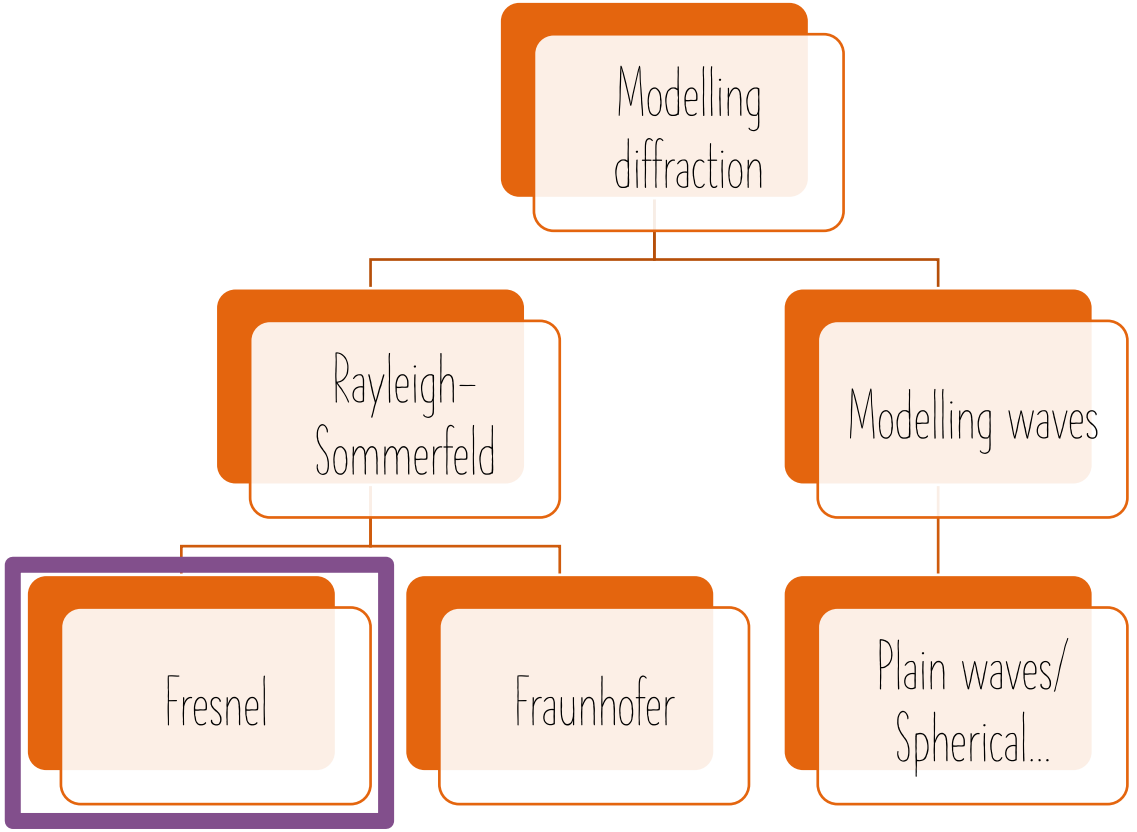

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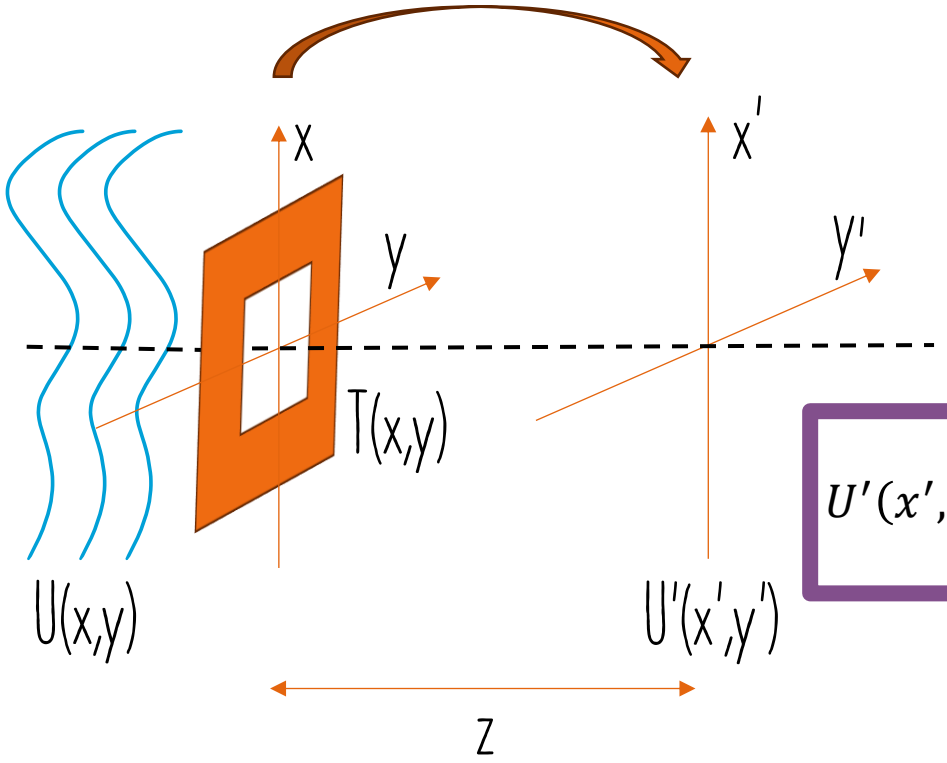
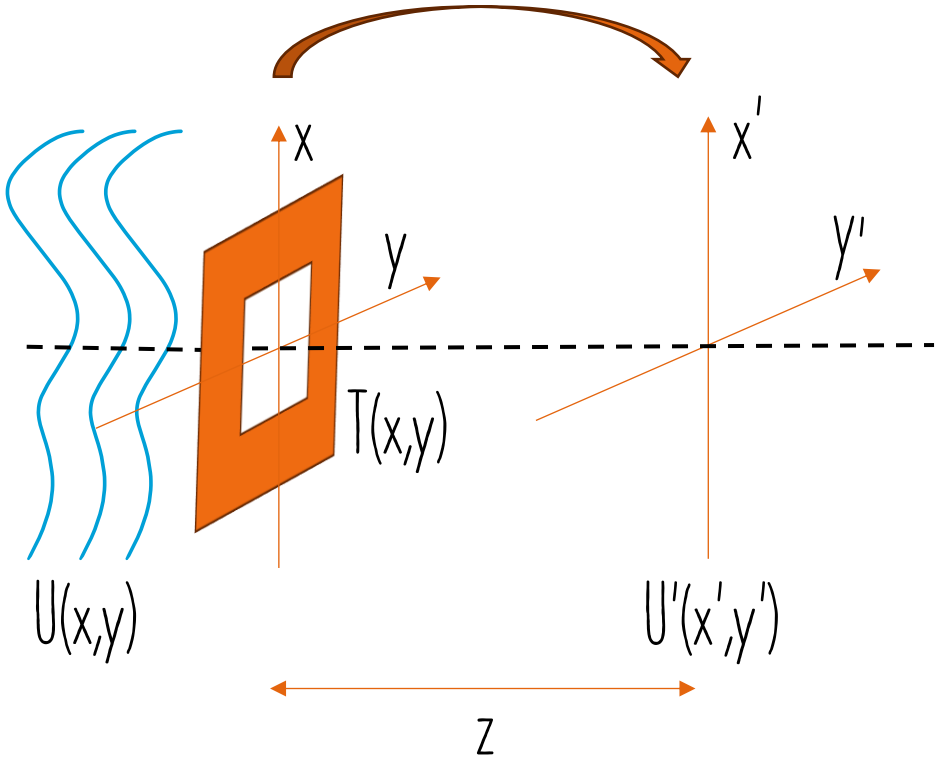


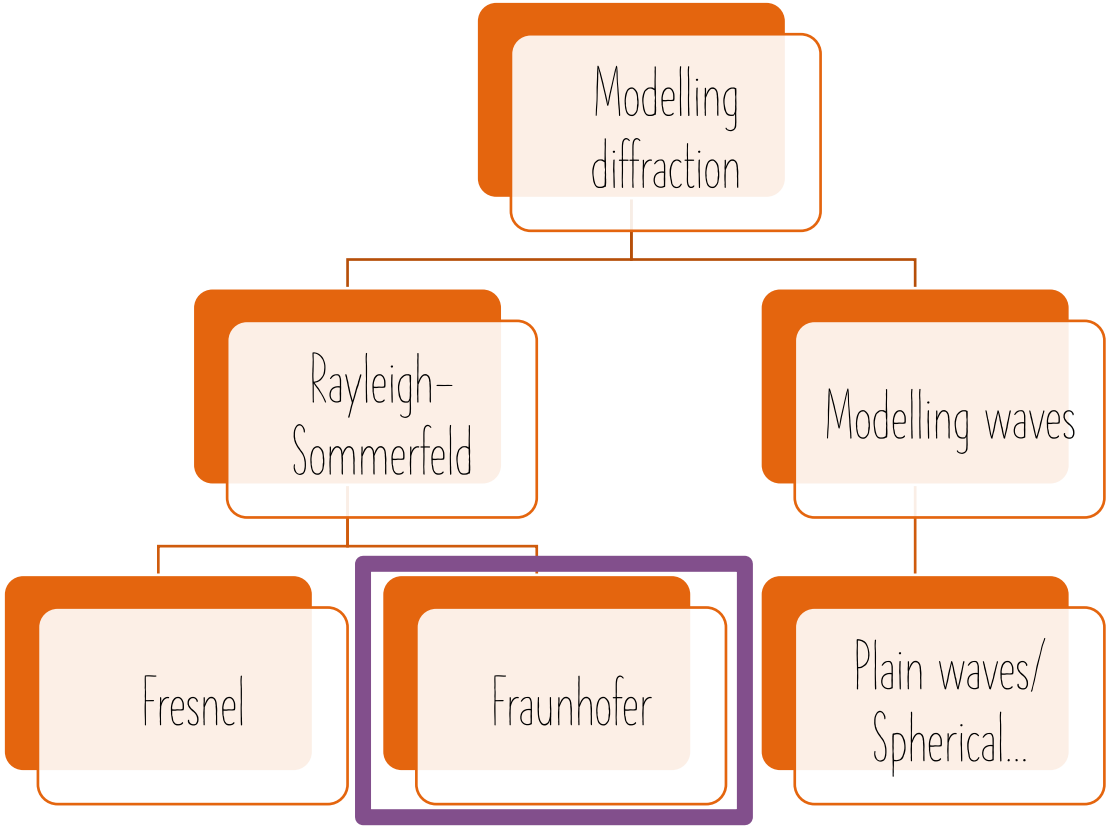
NEAR FIELD CONSTRICTIONS:

$$z^3 >> \frac{\pi}{4\lambda}\max[(x'-x)^2+(y^1-y)^2]$$

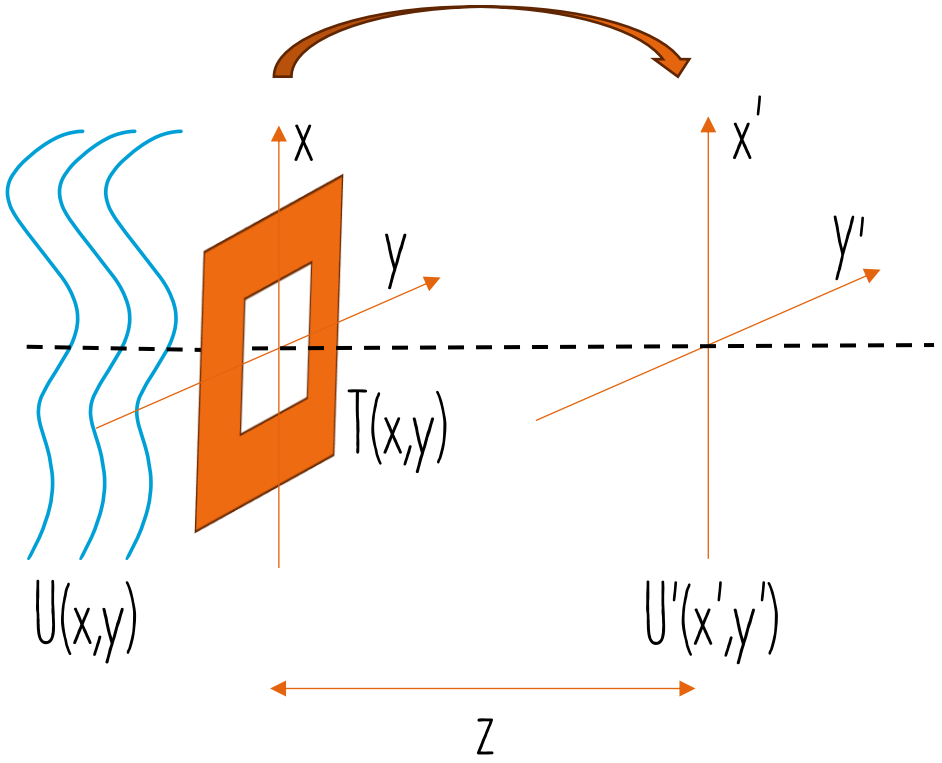
$$U'(x',y') = \frac{e^{ikz}}{i\lambda z} e^{\frac{ik}{2z}\left(x'^2+y'^2\right)} \iint_{\Sigma} U(x,y)T(x,y)e^{\frac{ik}{2z}(x^2+y^2)}\, e^{\frac{-i2\pi}{\lambda z}(xx'+yy')}dxdy$$

LIGHT FIELD PROPAGATION IN FREE SPACE





LIGHT FIELD PROPAGATION IN FREE SPACE

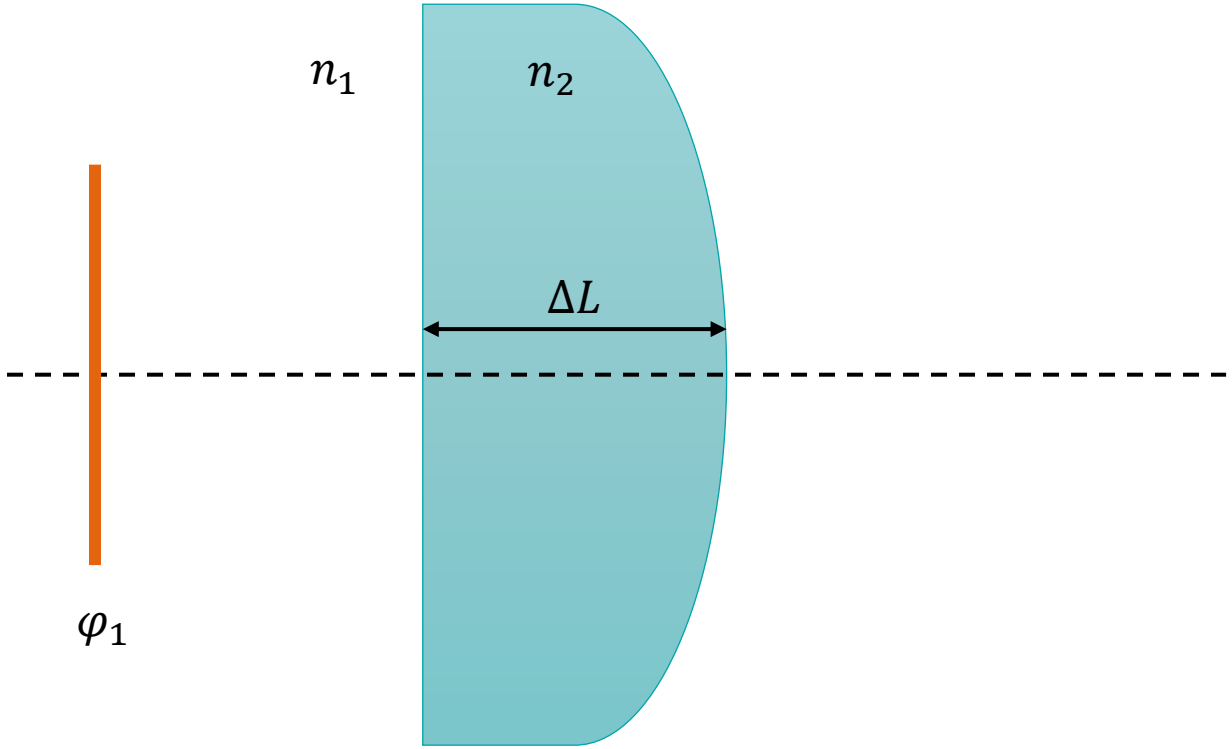


FAR FIELD CONSTRICTIONS:

$$z^3 >> \frac{\pi}{2\lambda}\max[x^2 + y^2]$$

$$U'(x',y') = \frac{e^{ikz}}{i\lambda z} e^{\frac{ik}{2z}\left(x'^2+y'^2\right)} \iint_{\Sigma} T(x,y)\, e^{\frac{-i2\pi}{\lambda z}(xx'+yy')}\, dxdy$$

WHEN THE OBSTACLE IS A PHASE OBJECT



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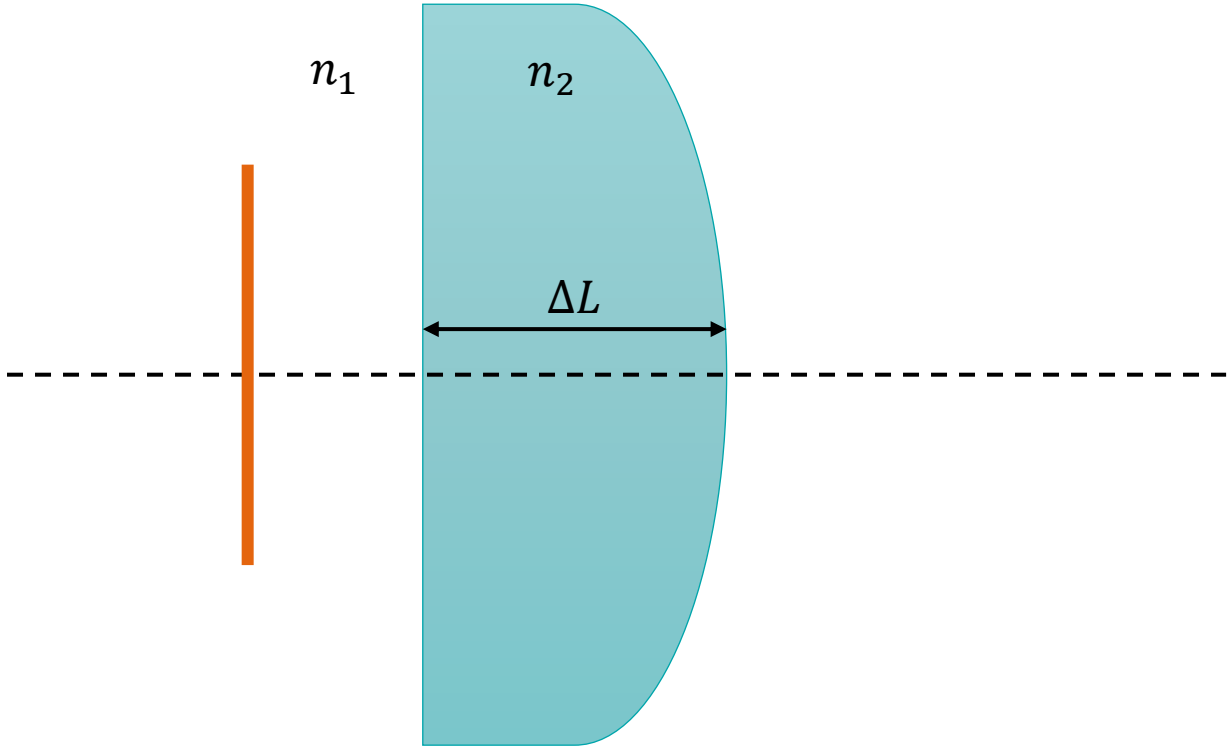

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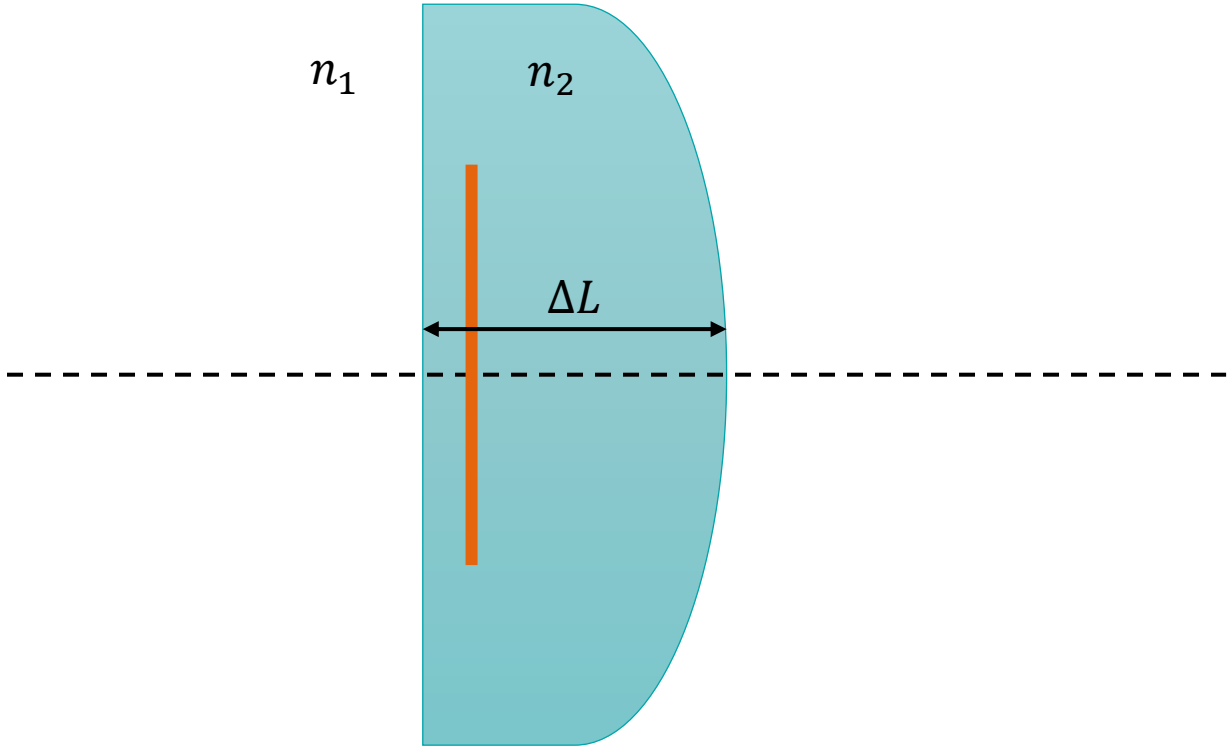

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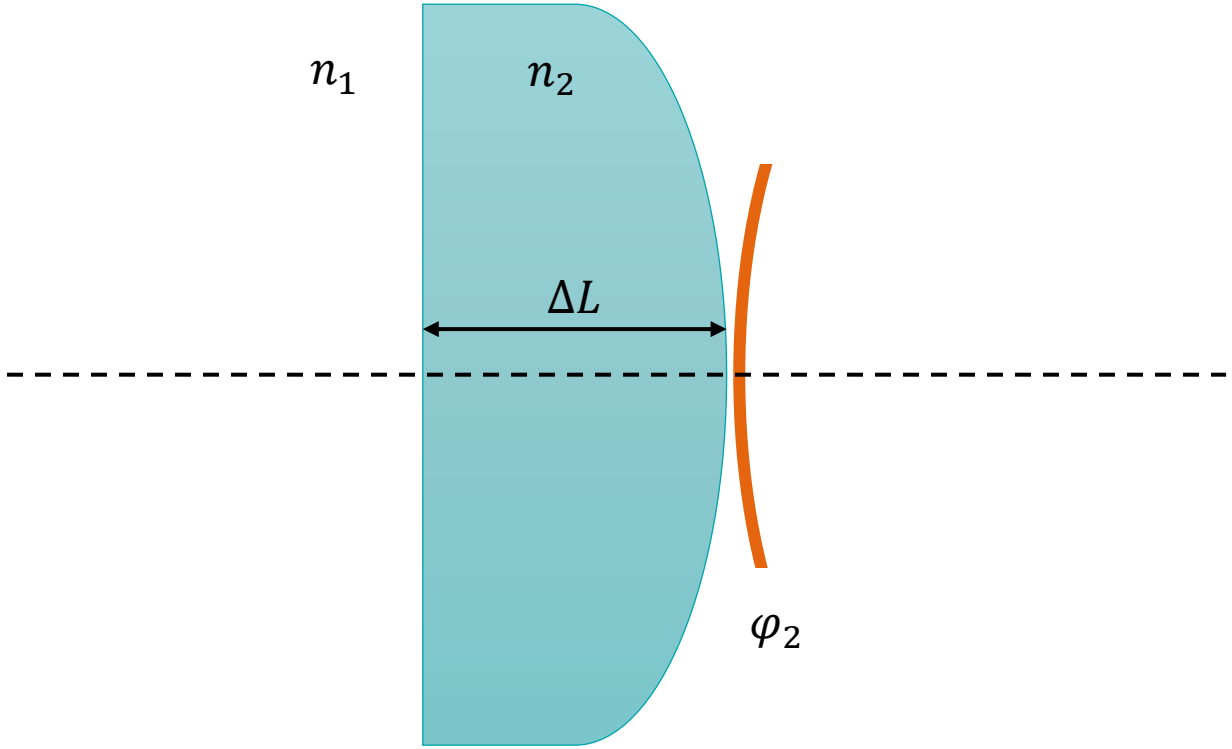

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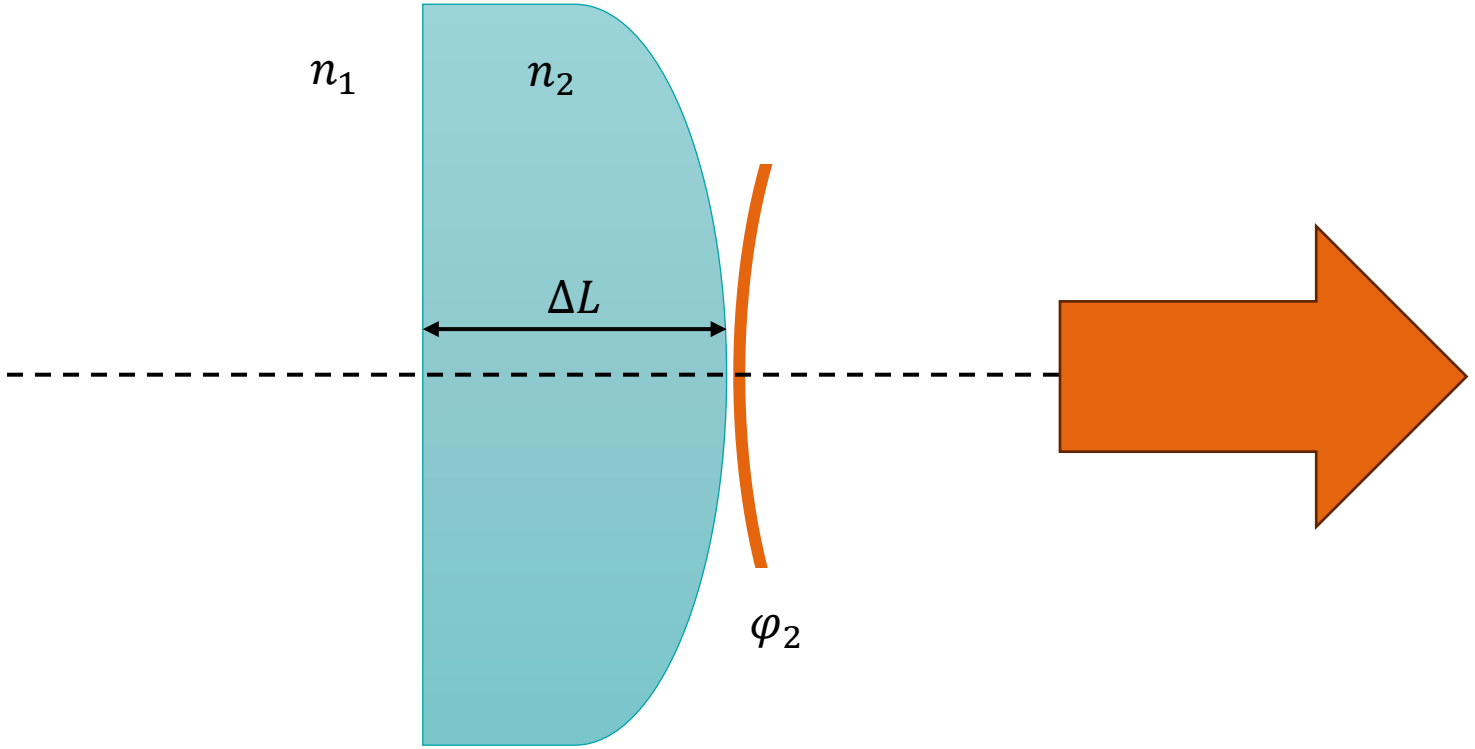
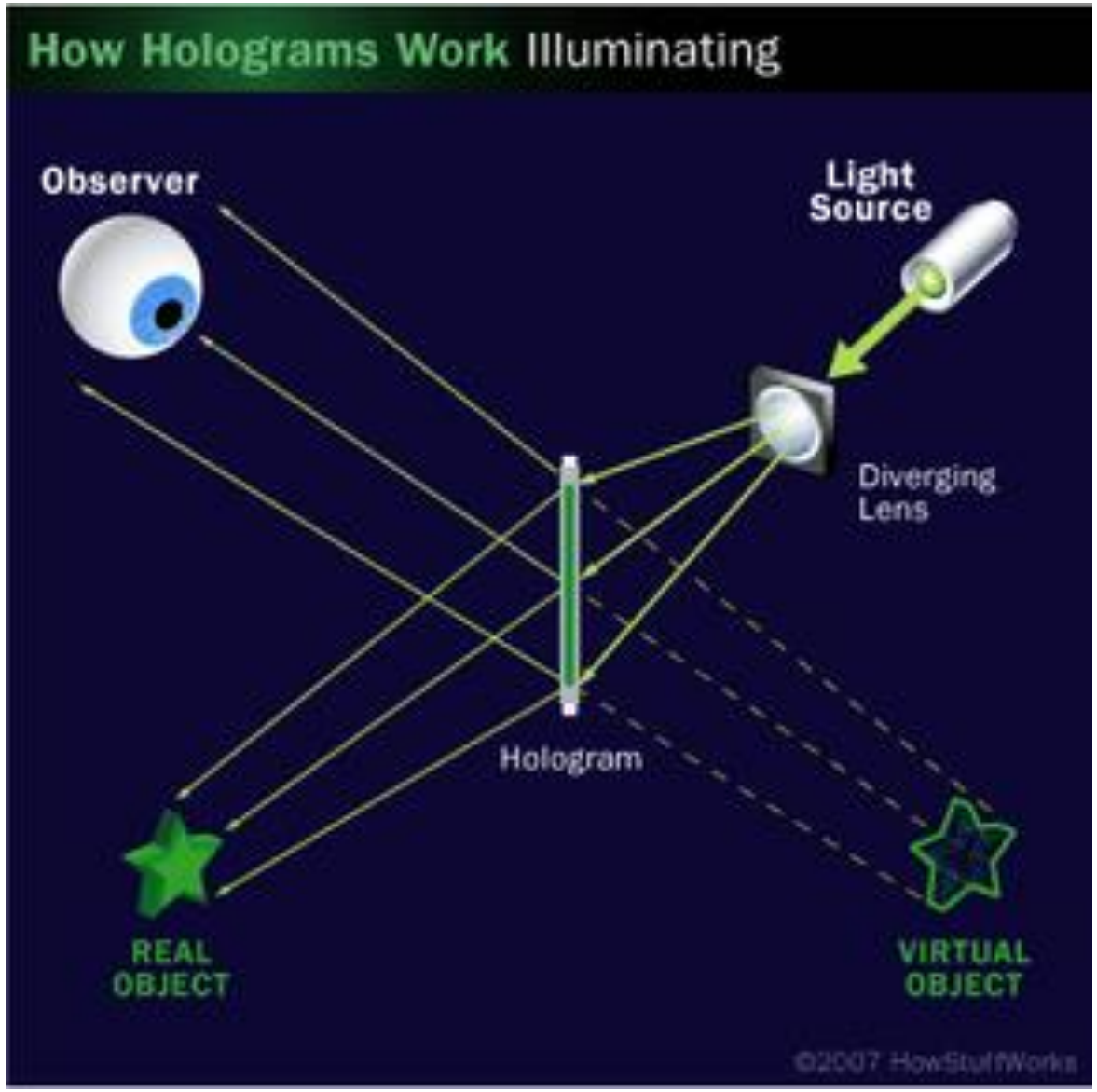


$$\Delta\varphi = \frac{2\pi}{\lambda} \cdot \Delta L \cdot \Delta n$$

WHAT DO WE SEE WHEN TAKING A HOLOGRAM?



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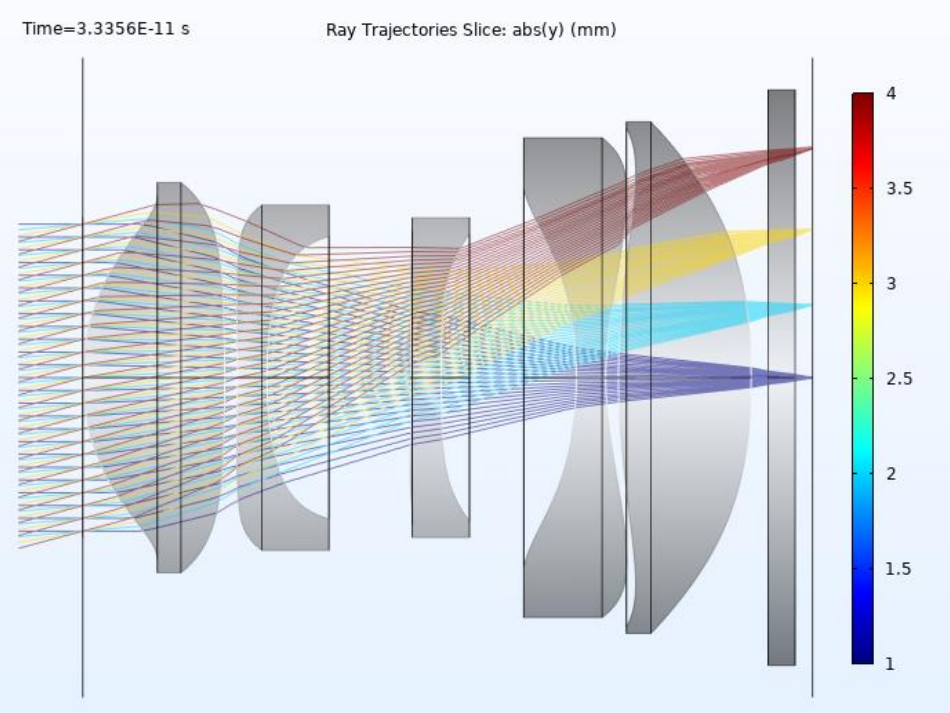
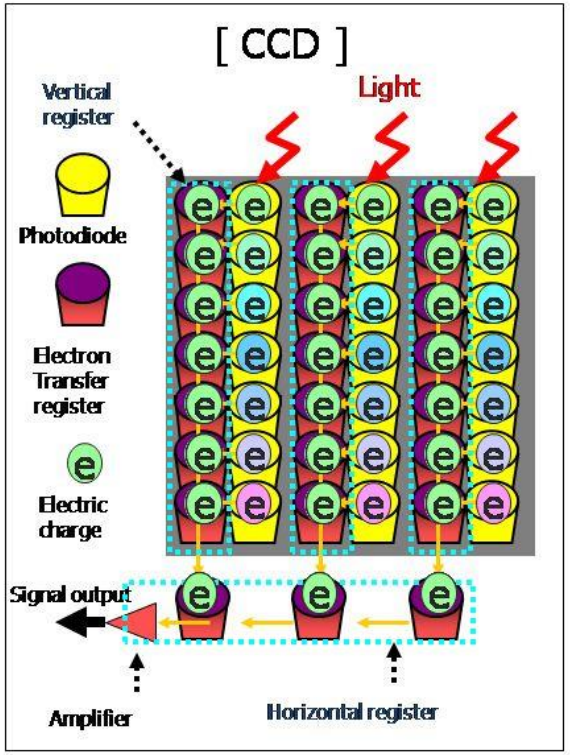
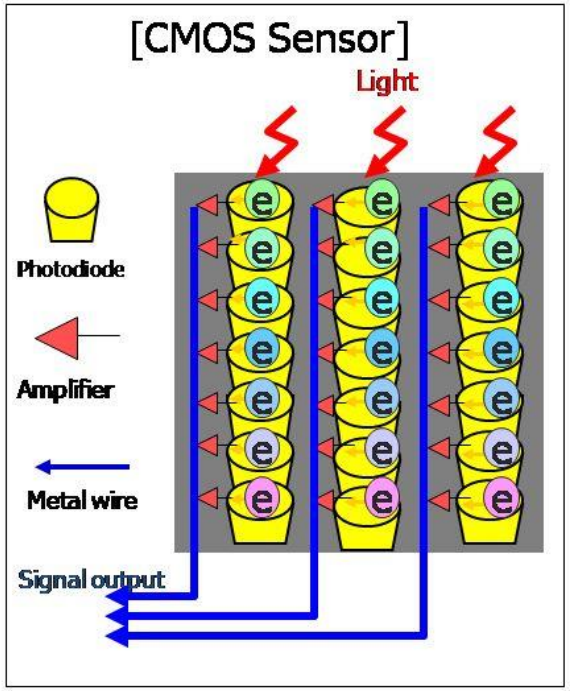
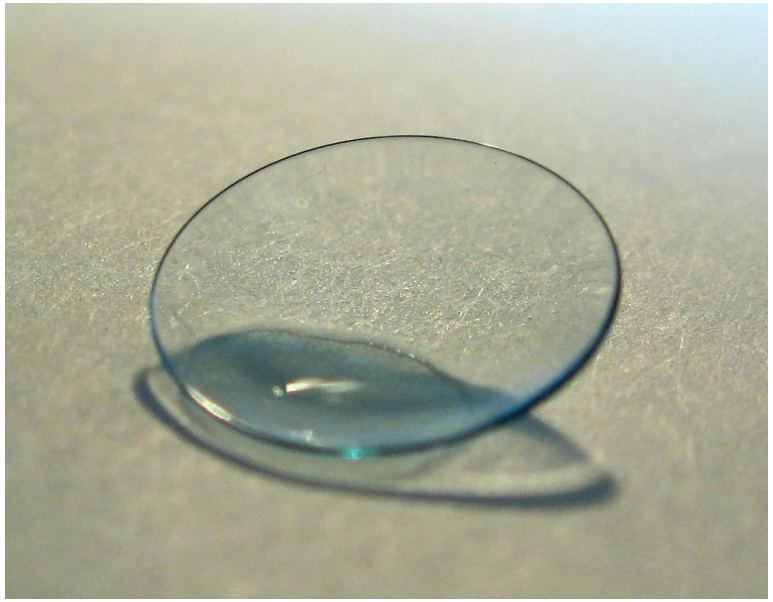
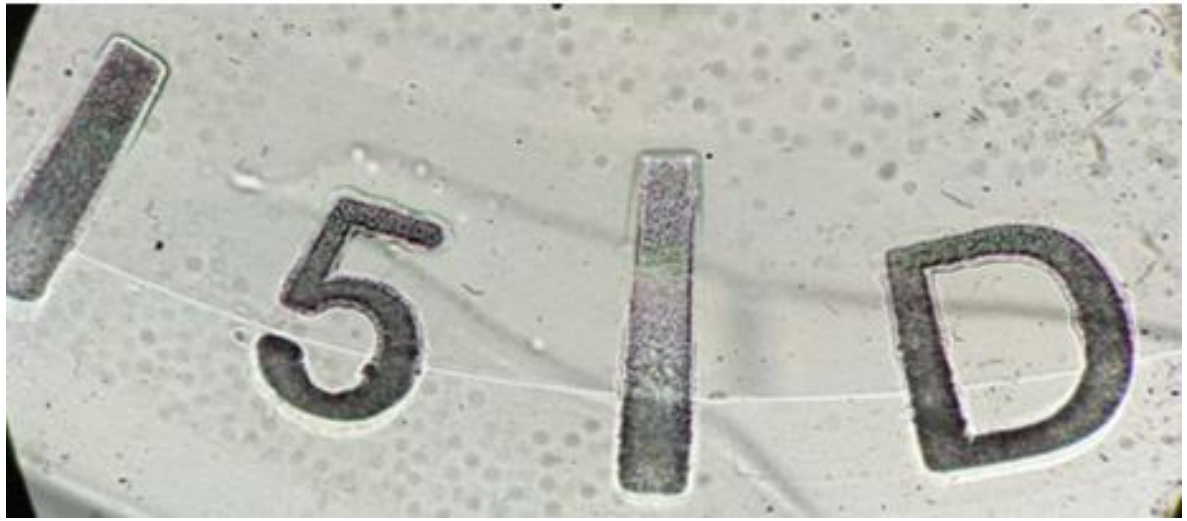






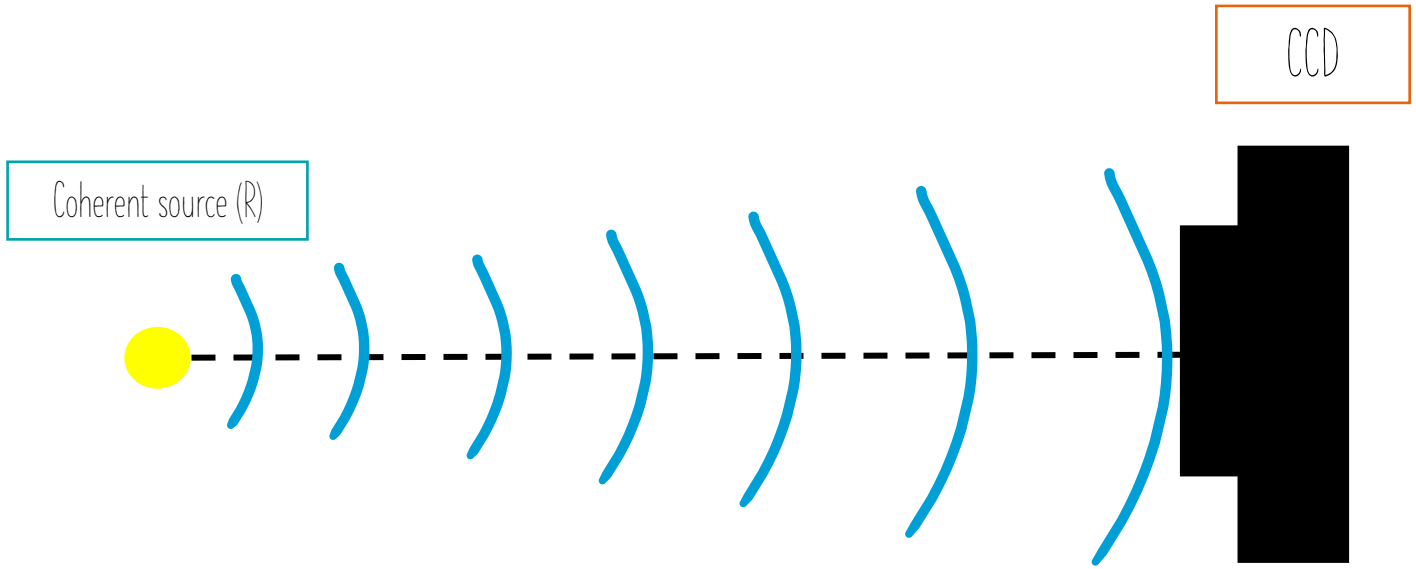
WHAT DO WE SEE THROUGH A PHOTOGRAPHY?



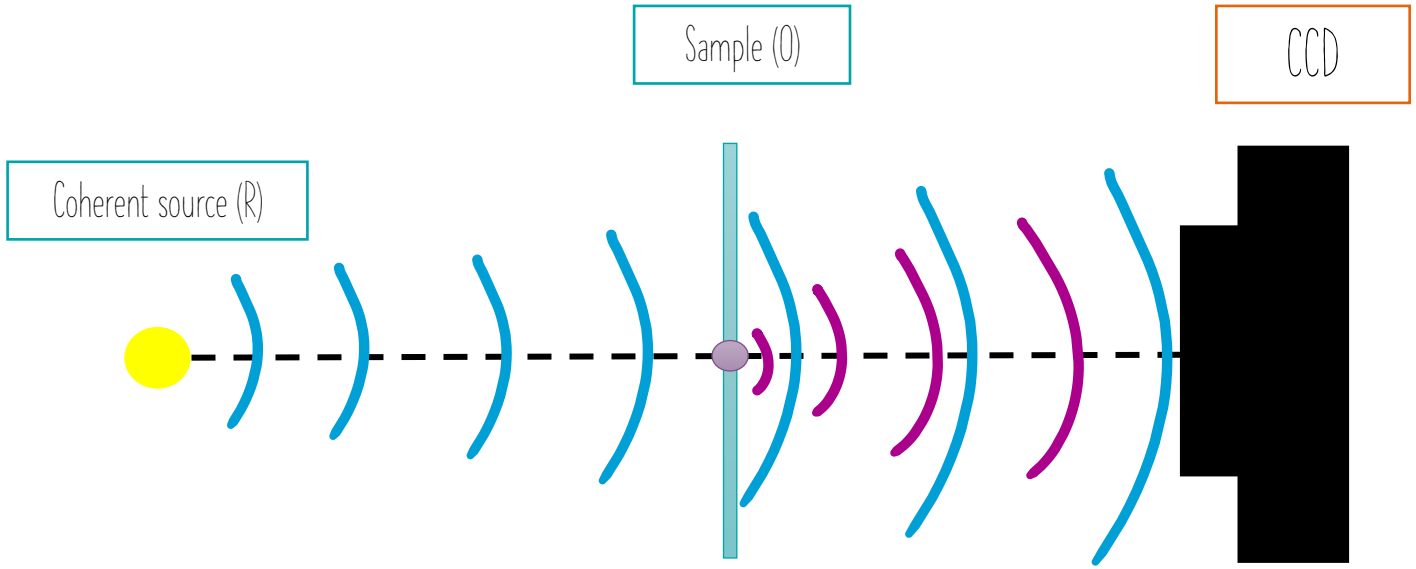


Vila-Andrés, R., Esteve-Taboada, J. J., & Micó, V. (2024). Soft Contact Lens Engraving Characterization by Wavefront Holoscopy. *Sensors*, *24*(11), 3492.

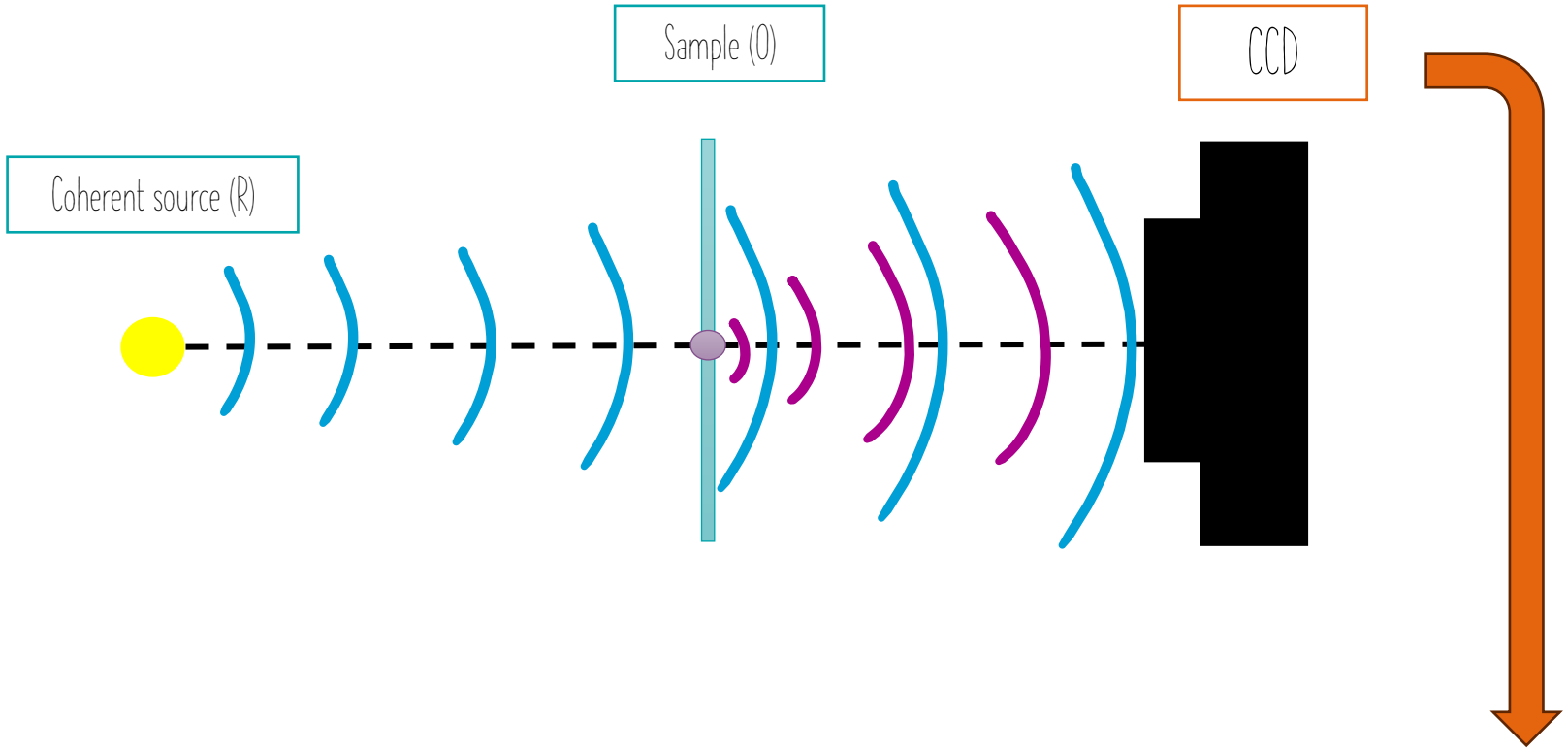
DIGITAL IN-LINE HOLOGRAPHY → CLASSIC ARRANGEMENT



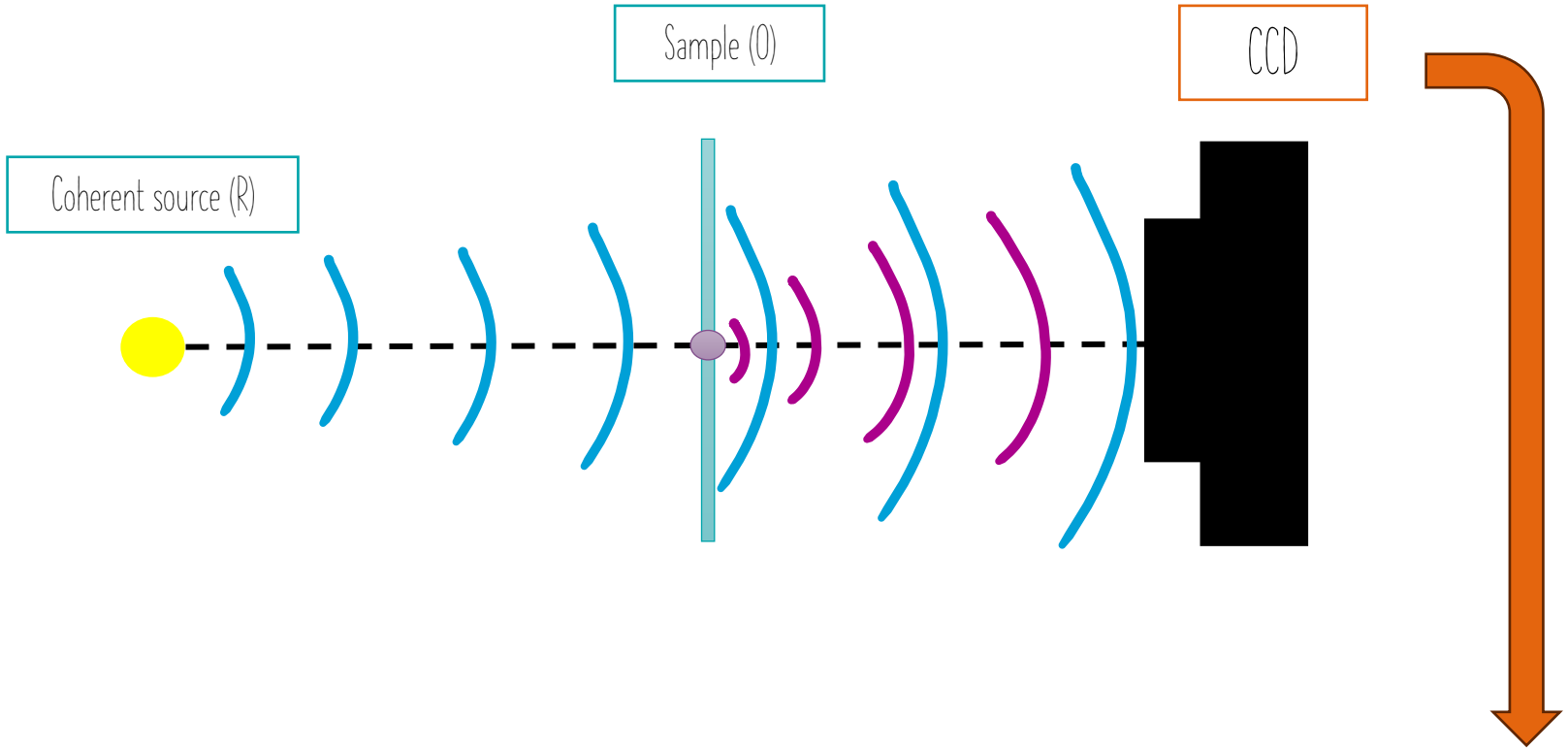
DIGITAL IN-LINE HOLOGRAPHY → CLASSIC ARRANGEMENT



DIGITAL IN-LINE HOLOGRAPHY → CLASSIC ARRANGEMENT

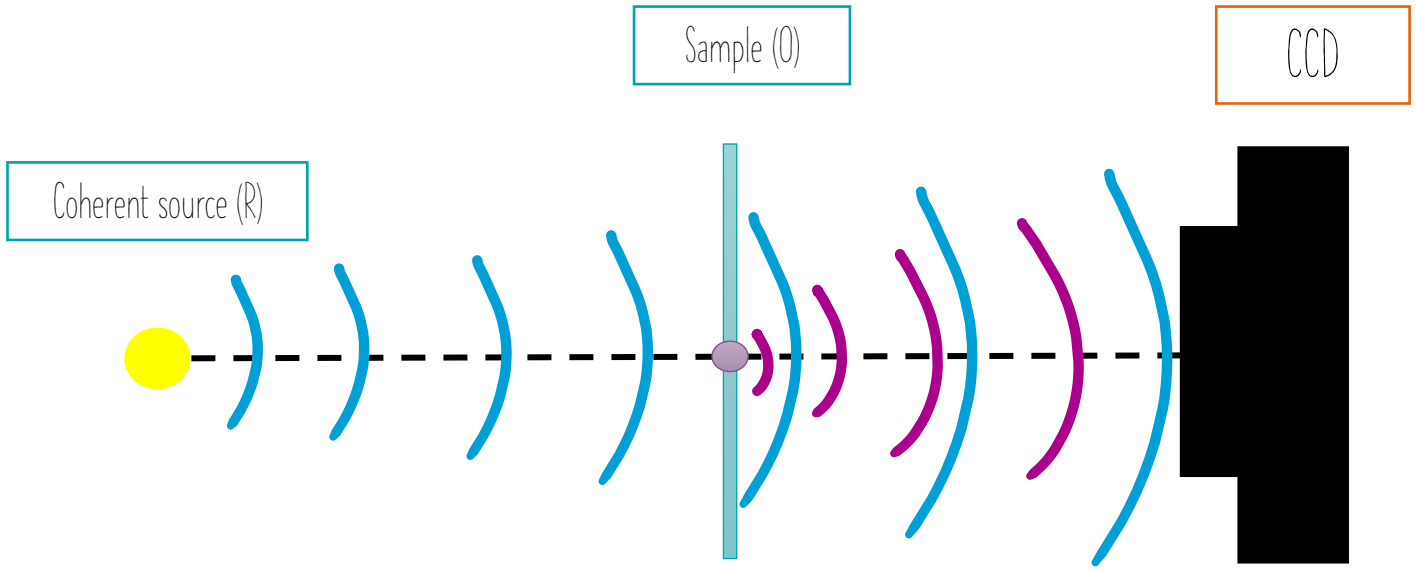


DIGITAL IN-LINE HOLOGRAPHY → CLASSIC ARRANGEMENT



$$|R + O|^2 = |R|^2 + |O|^2 + RO^* + R^*O$$

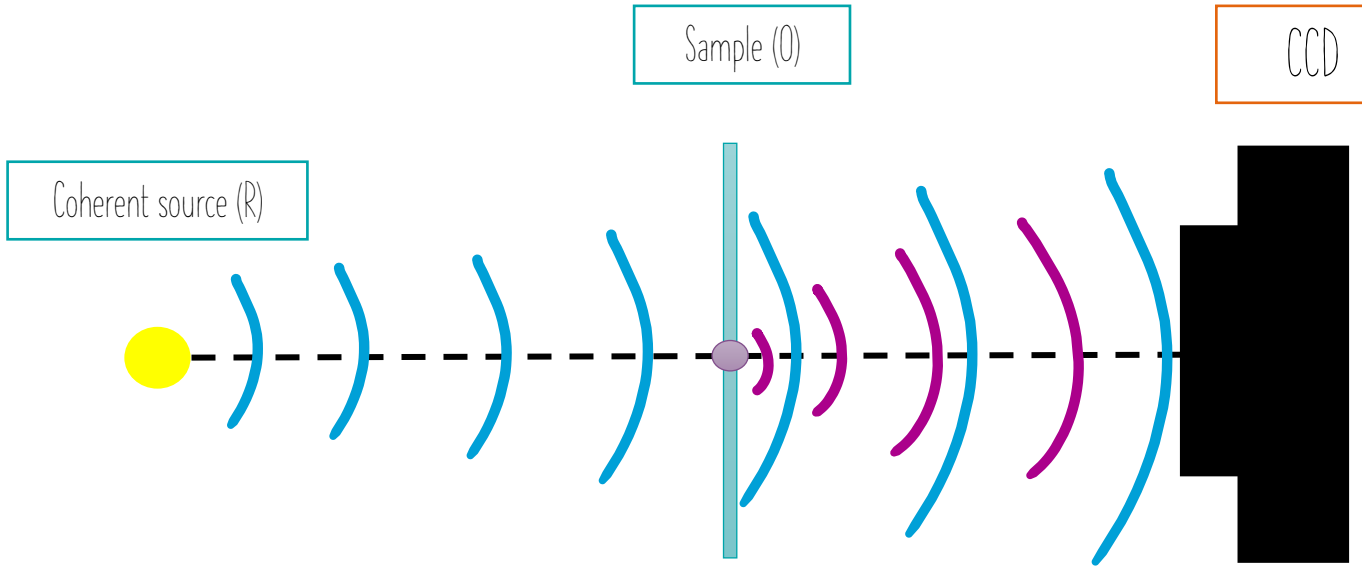
DIGITAL IN-LINE HOLOGRAPHY → CLASSIC ARRANGEMENT

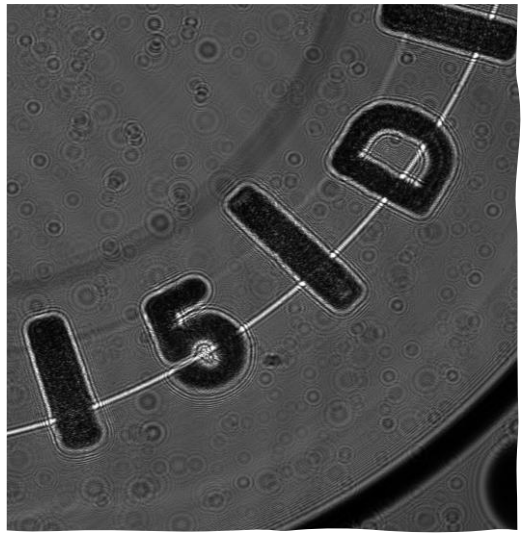


$$|R + O|^2 = |R|^2 + |O|^2 + RO^* + R^*O$$

WAIT... WHERE ARE THE LENSES?

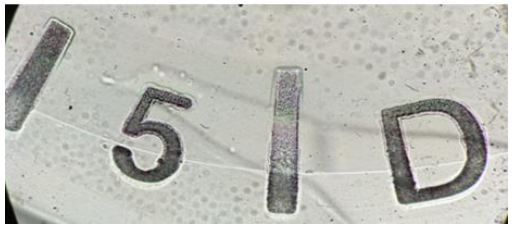
DIGITAL IN-LINE HOLOGRAPHY → CLASSIC ARRANGEMENT





$$|R + O|^2 = |R|^2 + |O|^2 + RO^* + R^*O$$

SO... WHAT IS HOLOGRAPHY FOR?



Conventional imaging

Holography

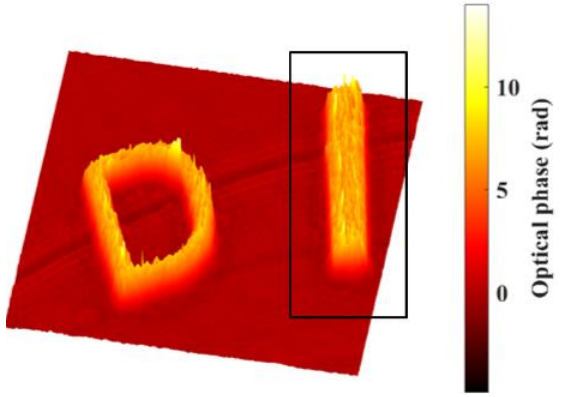
Intensity

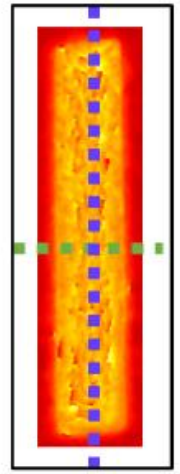
Incoherent light

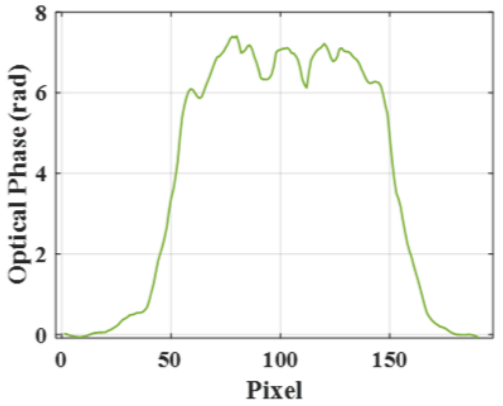
Intensity

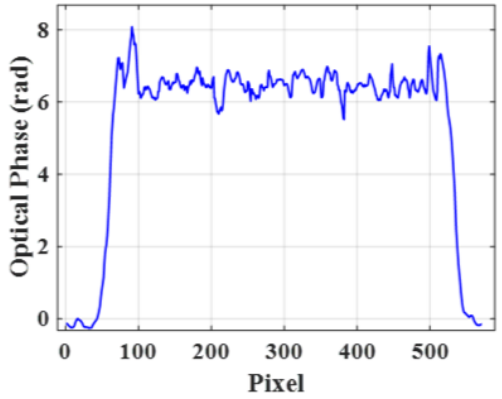
Phase

Coherent light









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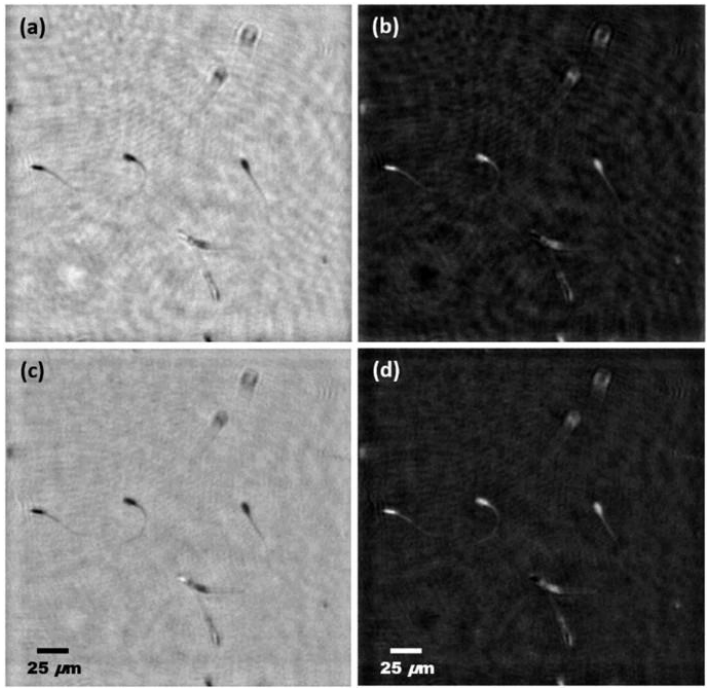
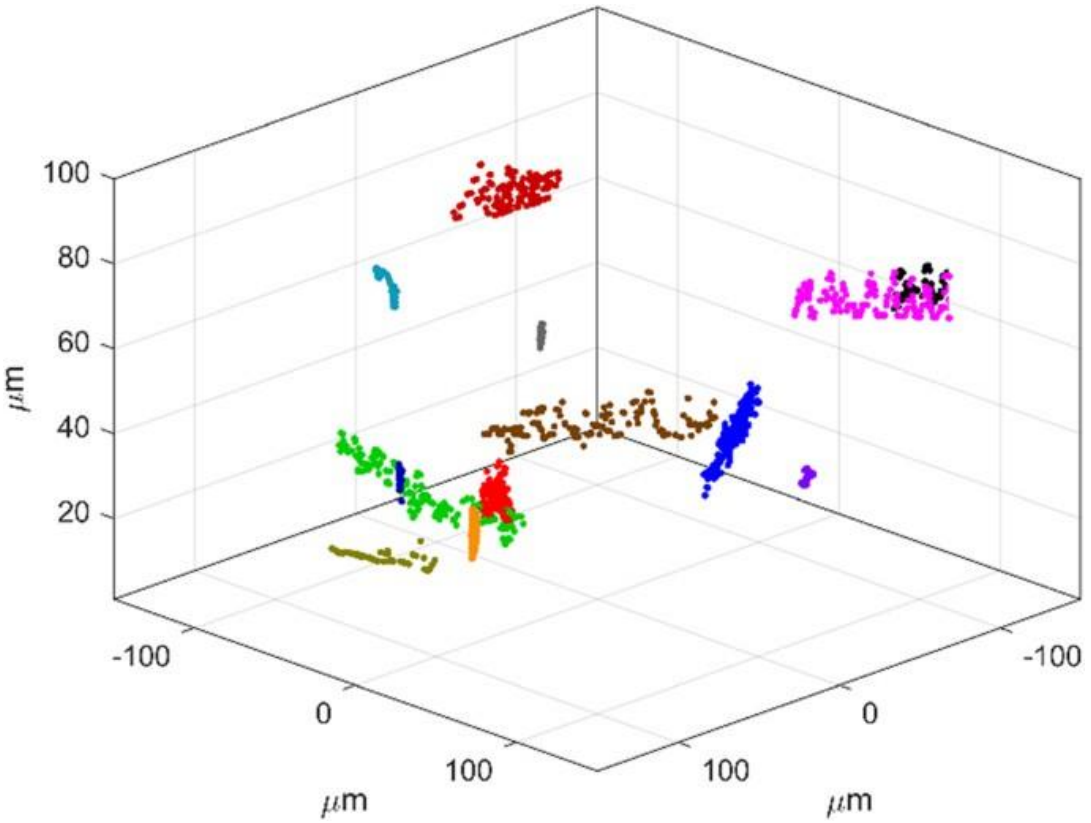
SOME OTHER EXAMPLES

- Biological applications: Cell visualization and tracking



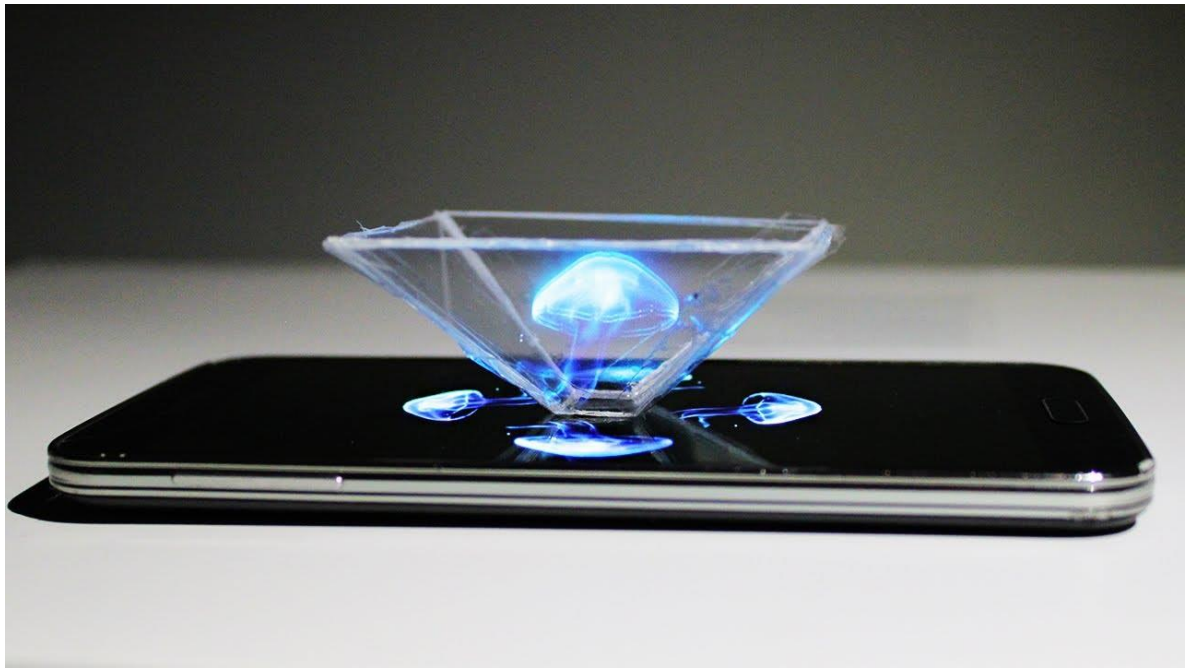


Sanz, M., Picazo-Bueno, J. Á., Granero, L., García, J., & Micó, V. (2017). Compact, cost-effective and field-portable microscope prototype based on MISHELF microscopy. *Scientific reports*, *7*(1), 43291.

DAILY LIFE: BANK NOTES

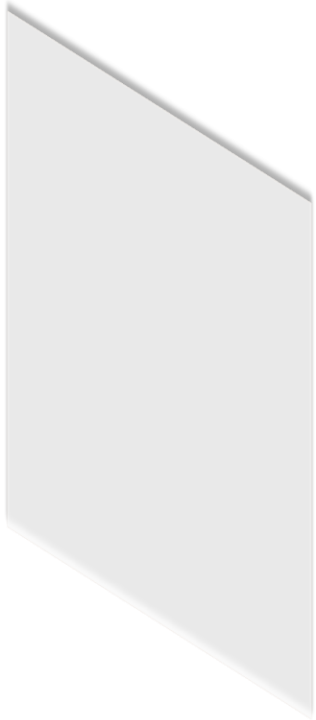
DAILY LIFE: PASSPORT AND IDENTITY CARDS

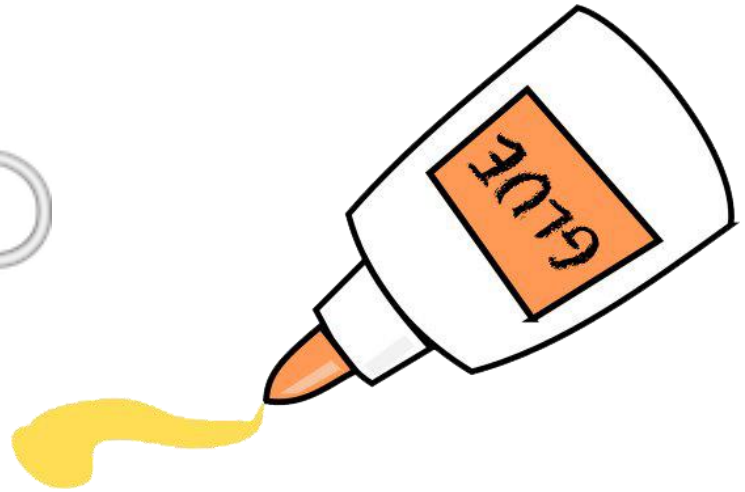
IS THIS A HOLOGRAM?



IS THIS A HOLOGRAM?

The answer is NO... But it is a funny experience to create at home!





HOLOGRAPHY: FROM PHYSICS TO DAILY LIFE

Rosa Vila Andrés

Sixth Physics Erasmus Summer School