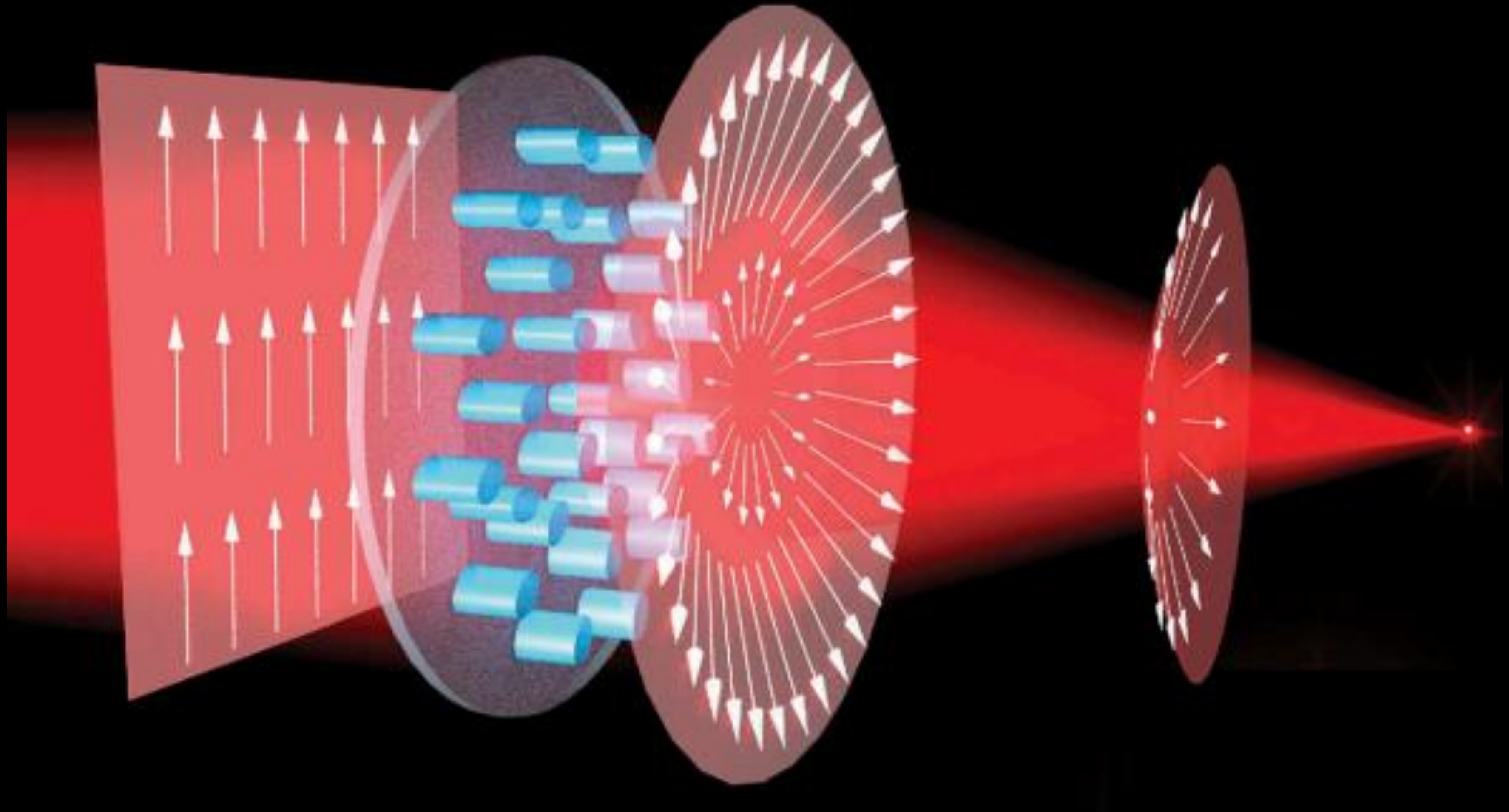
Le nuove sfide della multifocalità: aspetti fisici

Massimo Gurioli (UNIFI)



Meta-optics per IOL multifocali
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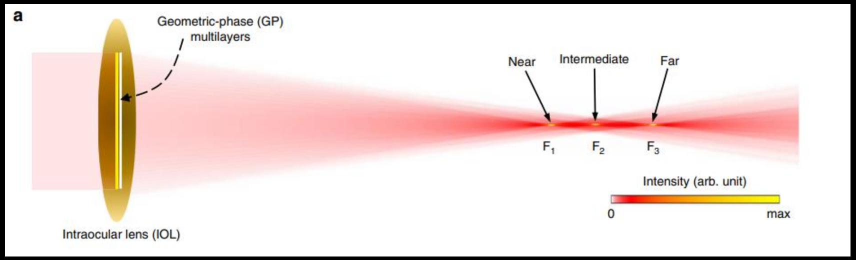
Geometric-phase intraocular lenses with multifocality

Seungmin Lee[1], Gayeon Park[1], Seonho Kim[1], Yeonghwa Ryu[1], Jae Woong Yoon[1], Ho Sik Hwang[2], In Seok Song[3], Chang Sun Lee[4] and Seok Ho Song[1,5]



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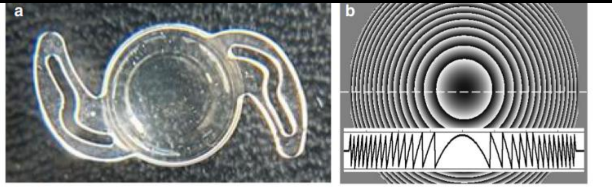

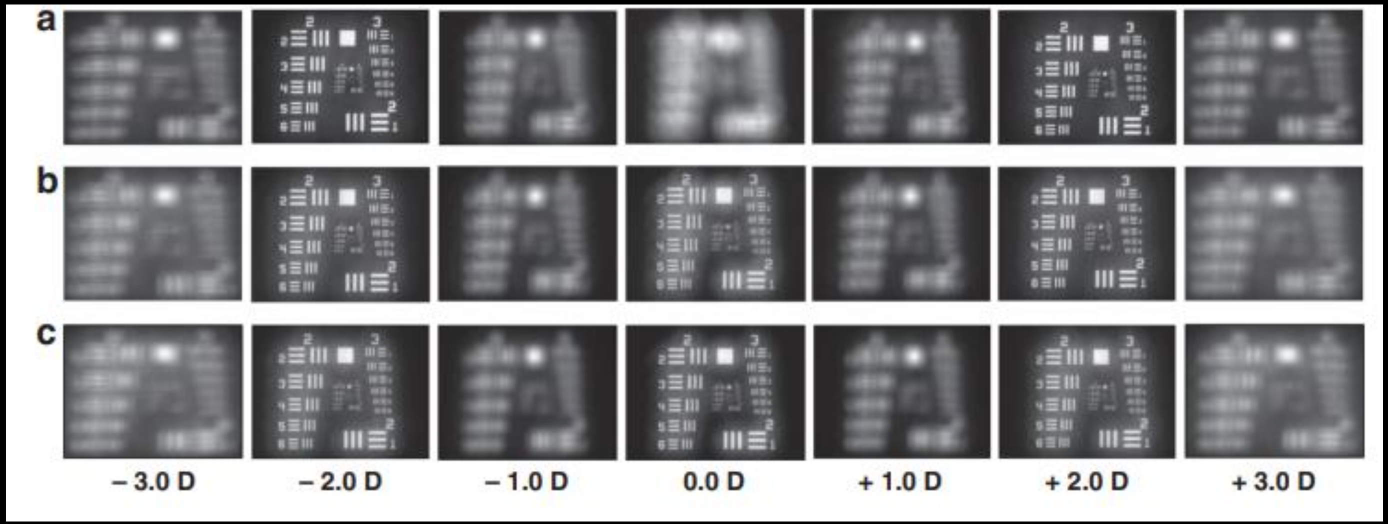

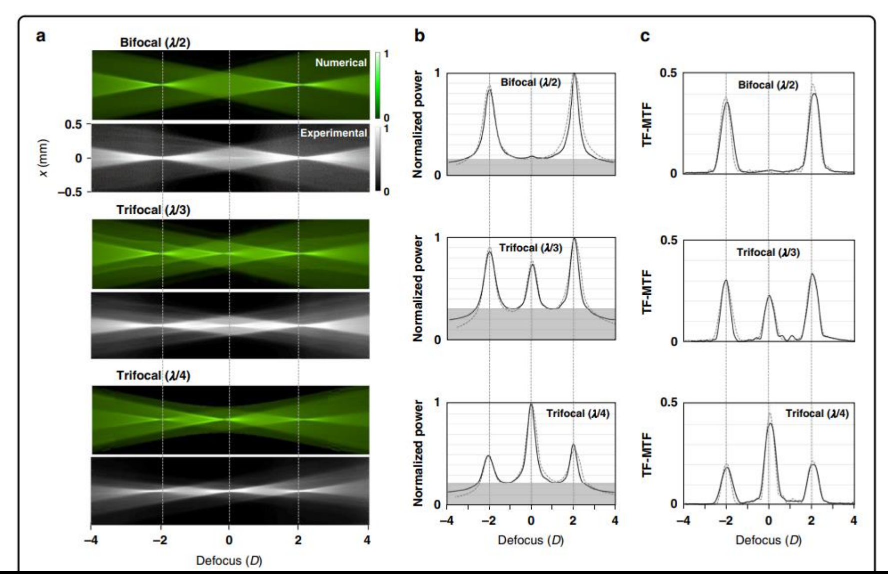

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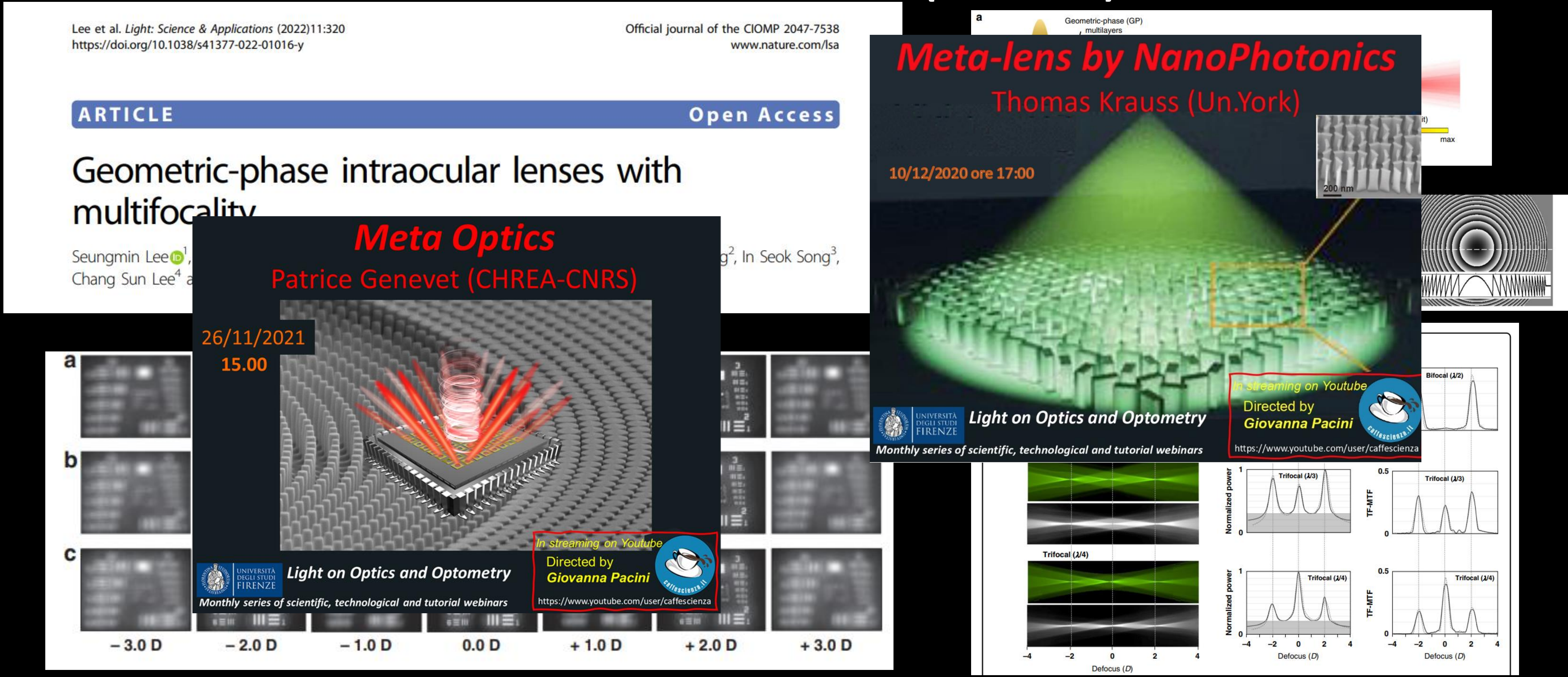
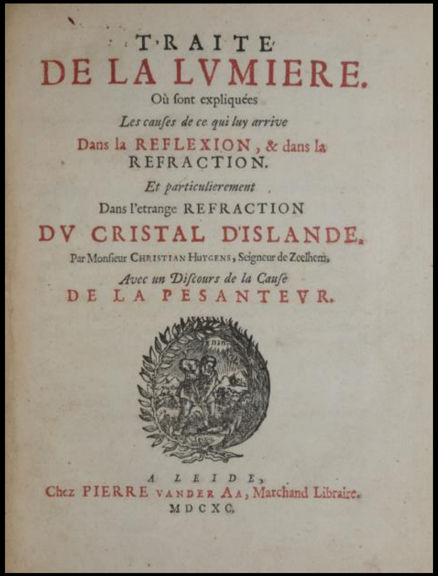
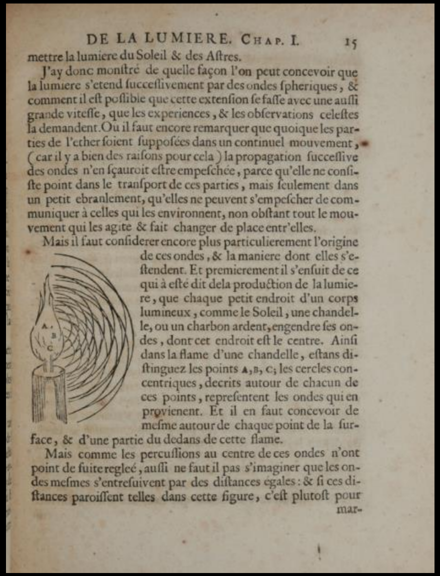


Aspetti fisici di GP-IOL *via* principio di Huygens


T·RAITE
DE LA LVMIERE.
Où ſont expliquées
Les cauſes de ce qui luy arrive
Dans la REFLEXION, & dans la
REFRACTION.
Et particulierement
Dans l'etrange REFRACTION
DV CRISTAL D'ISLANDE.
Par Monſieur CHRISTIAN HUYGENS, Seigneur de Zeelhem,
Avec un Diſcours de la Cauſe
DE LA PESANTEVR.

A LEIDE,
Chez PIERRE VANDER AA, Marchand Libraire.
MDCXC.


DE LA LUMIERE. CHAP. I. 15

mettre la lumiere du Soleil & des Aſtres.

J'ay donc monſtré de quelle façon l'on peut concevoir que la lumiere s'etend ſucceſſivement par des ondes ſpheriques, & comment il eſt poſſible que cette extenſion ſe faſſe avec une auſſi grande viteſſe, que les experiences, & les obſervations celeſtes la demandent. Ou il faut encore remarquer que quoique les parties de l'ether ſoient ſuppoſées dans un continuel mouvement, (car il y a bien des raiſons pour cela) la propagation ſucceſſive des ondes n'en ſçauroit eſtre empeſchée, parce qu'elle ne conſiſte point dans le tranſport de ces parties, mais ſeulement dans un petit ebranlement, qu'elles ne peuvent s'empeſcher de communiquer à celles qui les environnent, non obſtant tout le mouvement qui les agite & fait changer de place entr'elles.

Mais il faut conſiderer encore plus particulierement l'origine de ces ondes, & la maniere dont elles s'eſtendent. Et premierement il s'enſuit de ce qui à eſté dit de la production de la lumiere, que chaque petit endroit d'un corps lumineux, comme le Soleil, une chandelle, ou un charbon ardent, engendre ſes ondes, dont cet endroit eſt le centre. Ainſi dans la flame d'une chandelle, eſtans diſtinguez les points A, B, C; les cercles concentriques, decrits autour de chacun de ces points, repreſentent les ondes qui en provienent. Et il en faut concevoir de meſme autour de chaque point de la ſurface, & d'une partie du dedans de cette flame.

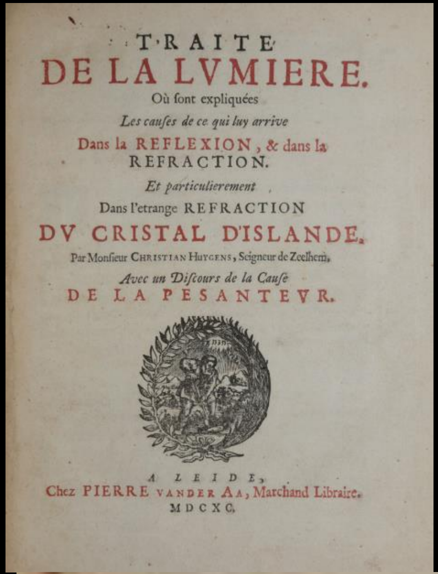
Mais comme les percuſſions au centre de ces ondes n'ont point de ſuite reglée, auſſi ne faut il pas s'imaginer que les ondes meſmes s'entreſuivent par des diſtances egales: & ſi ces diſtances paroiſſent telles dans cette figure, c'eſt plutoſt pour mar-

1678
Principio di Huygens

Luce come somma di

Ondelettes (Français)
Wavelets (English)

Principio di Huygens


TRAITE
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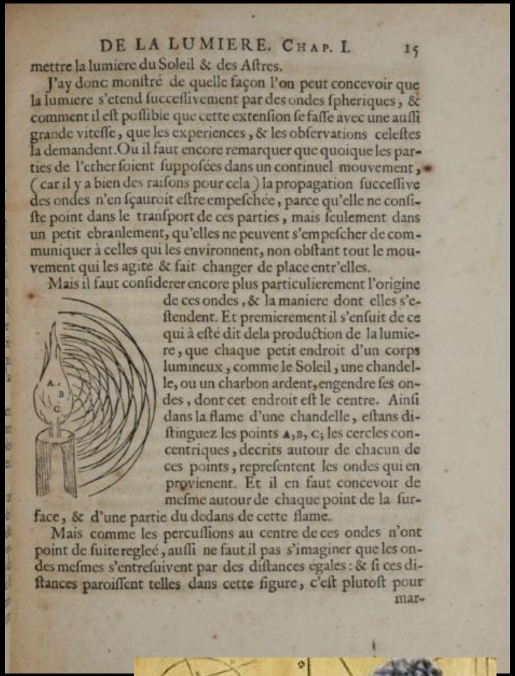
DE LA LUMIERE. CHAP. I. 15

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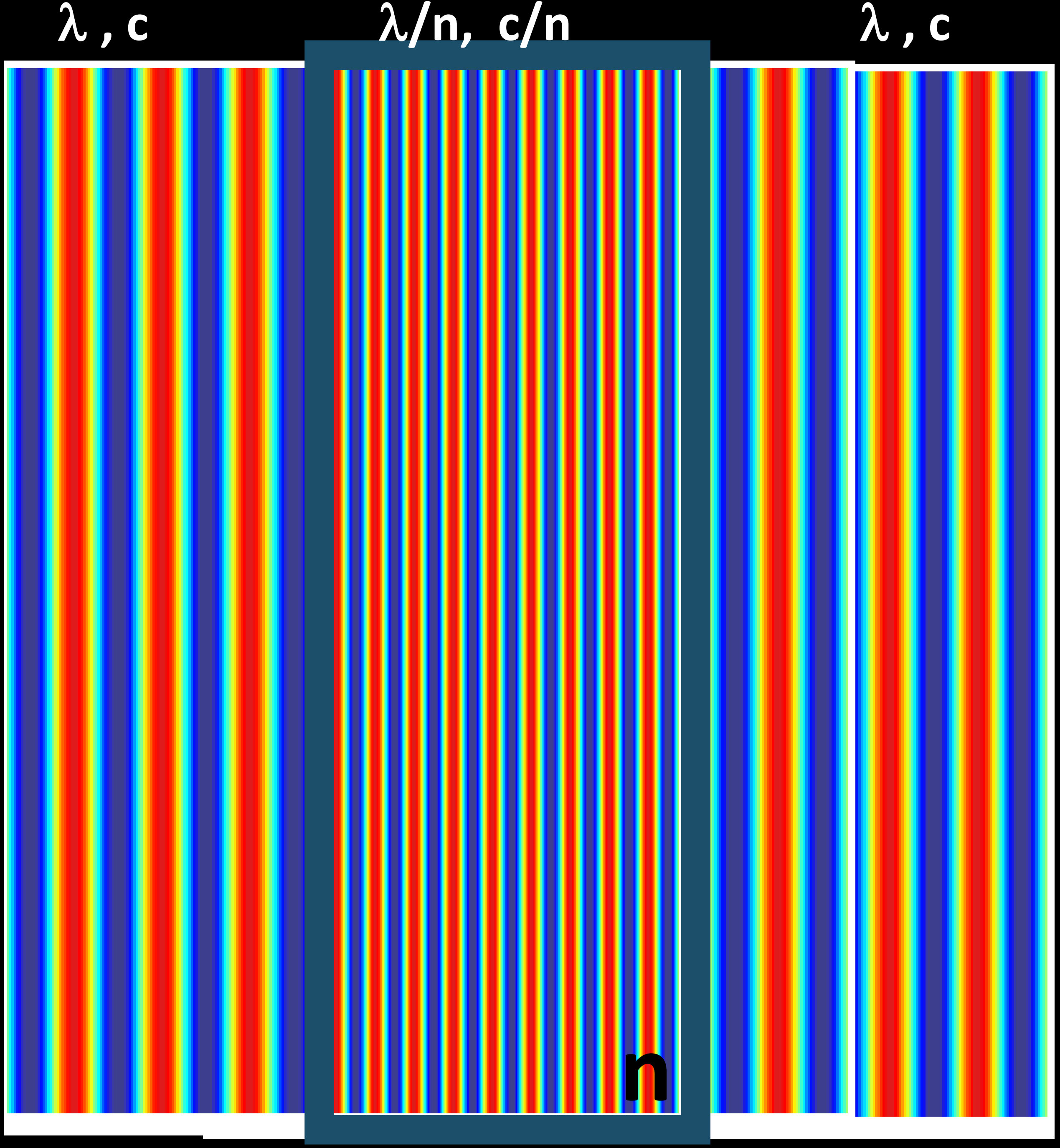
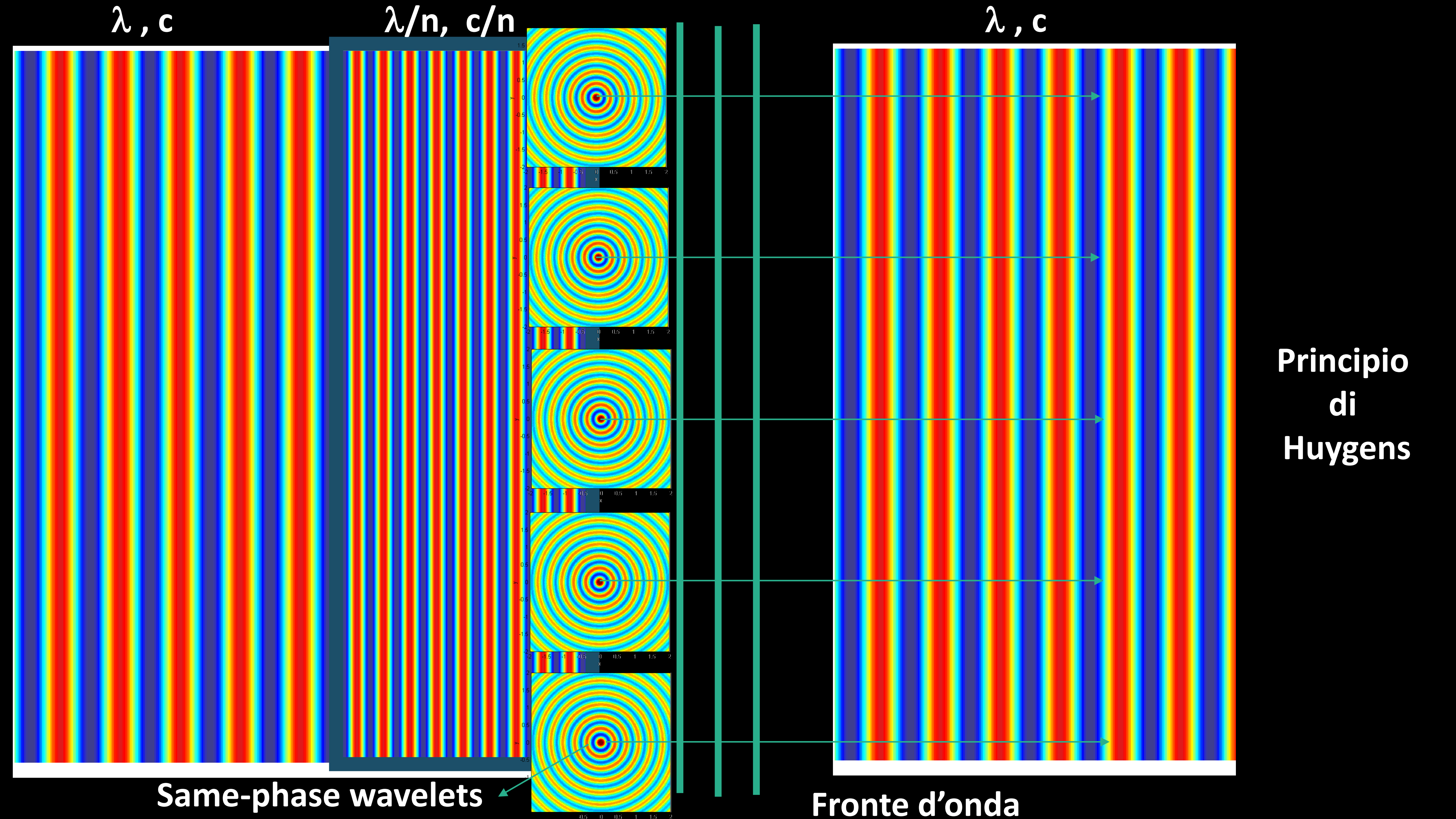
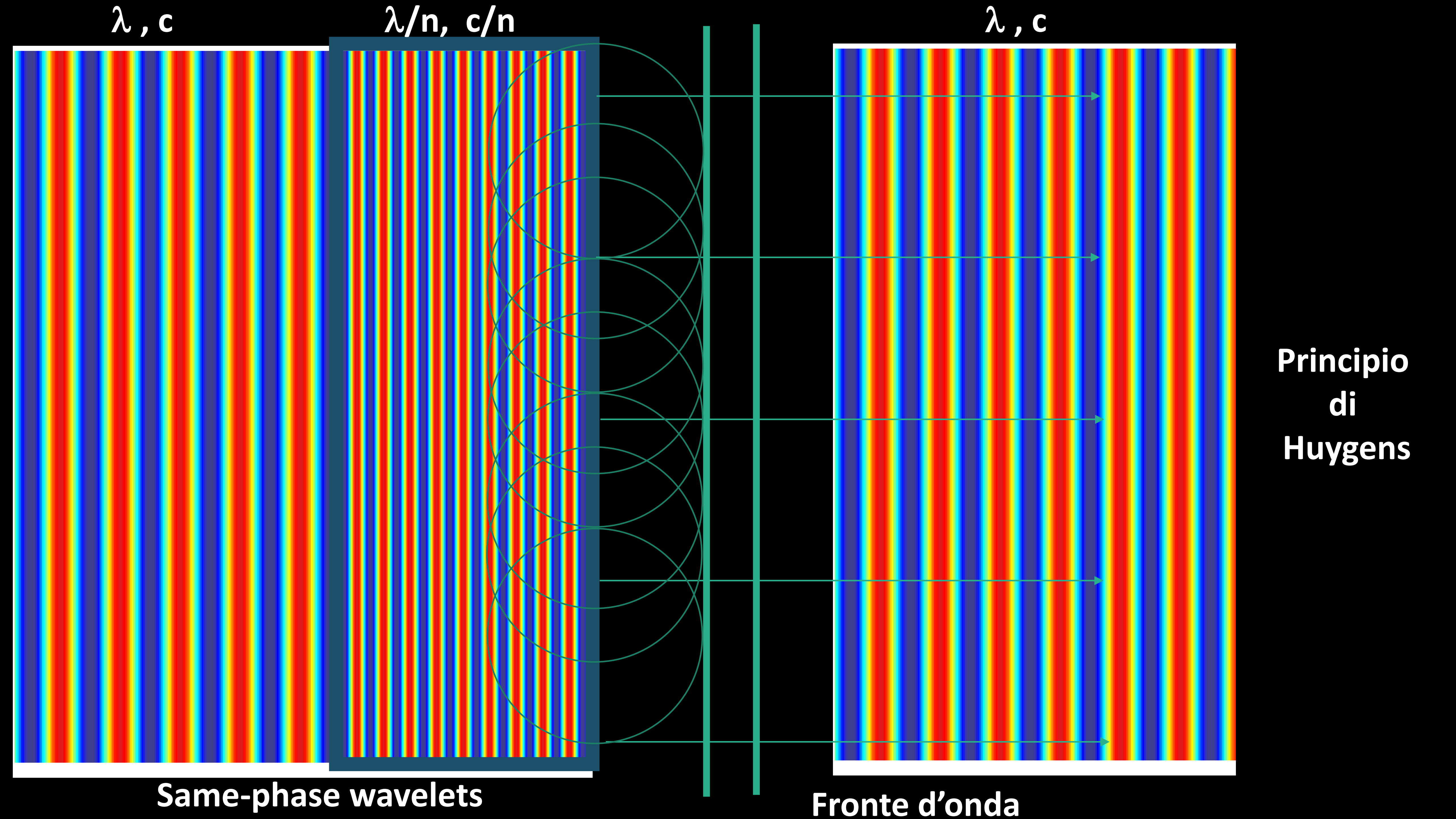
Luce come somma di

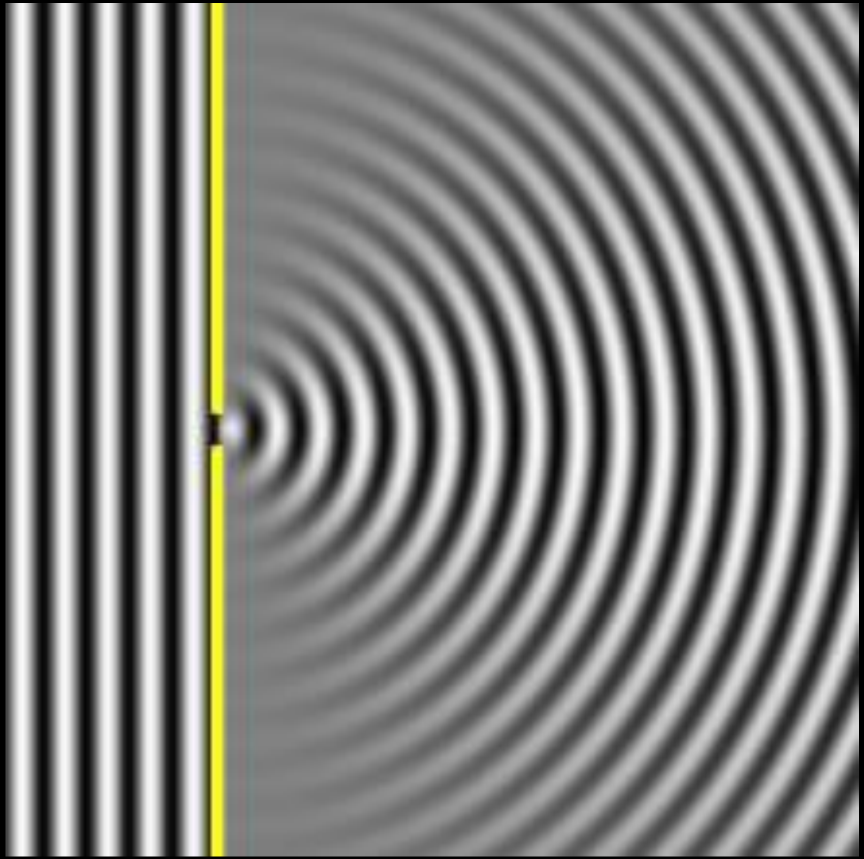
Ondelettes (FR)
Wavelets (UK)

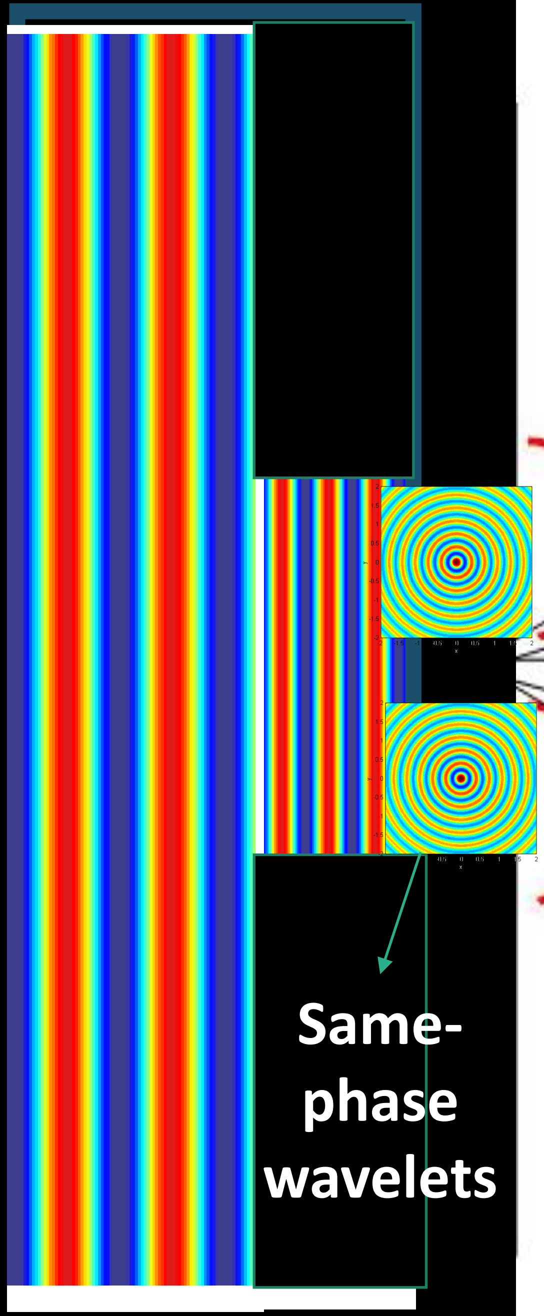


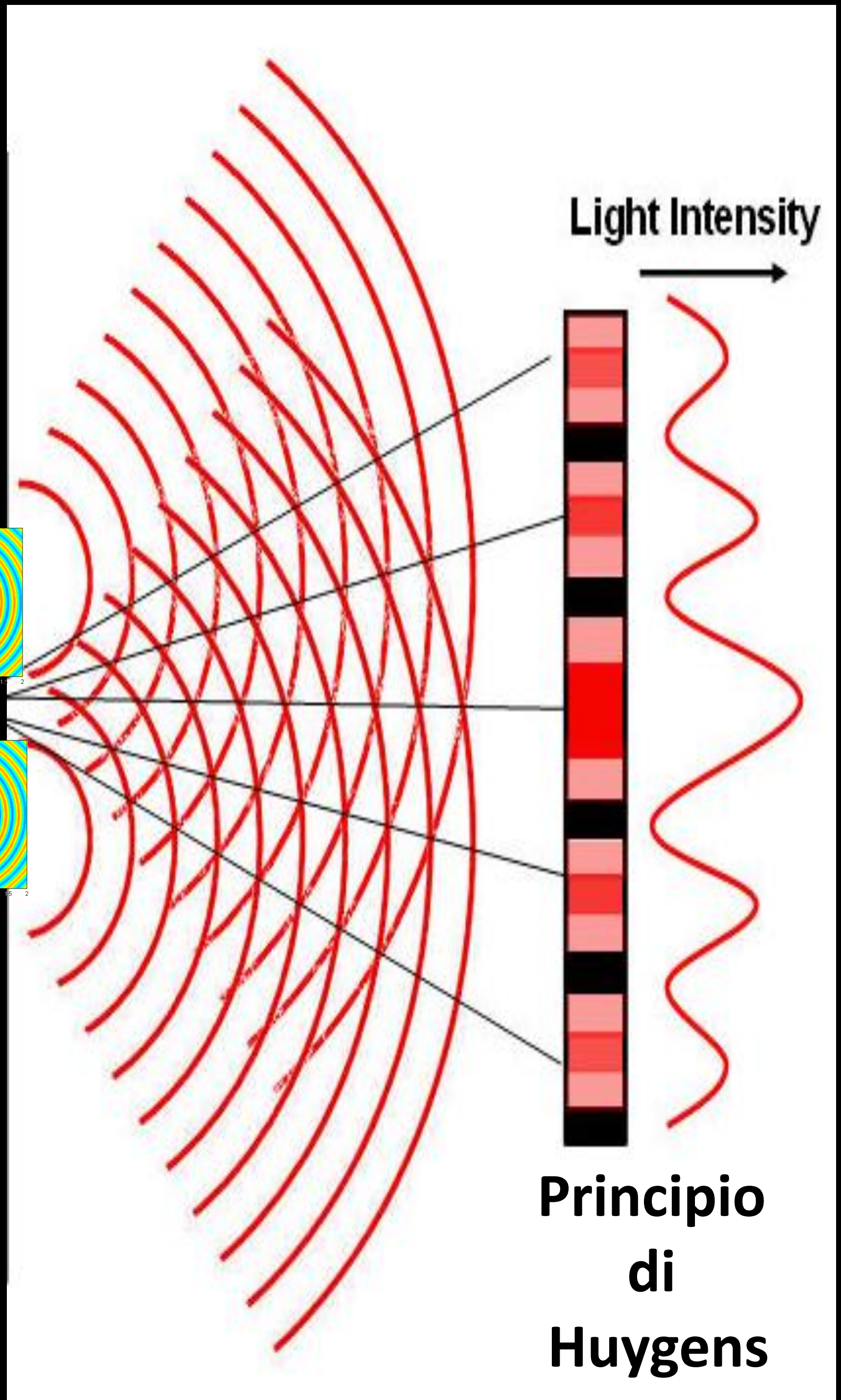

λ , c
λ/n, c/n
λ , c
Principio
di
Huygens
Same-phase wavelets
Fronte d’onda


λ , c
λ/n, c/n
λ , c
Principio
di
Huygens
Same-phase wavelets
Fronte d'onda

Diffrazione

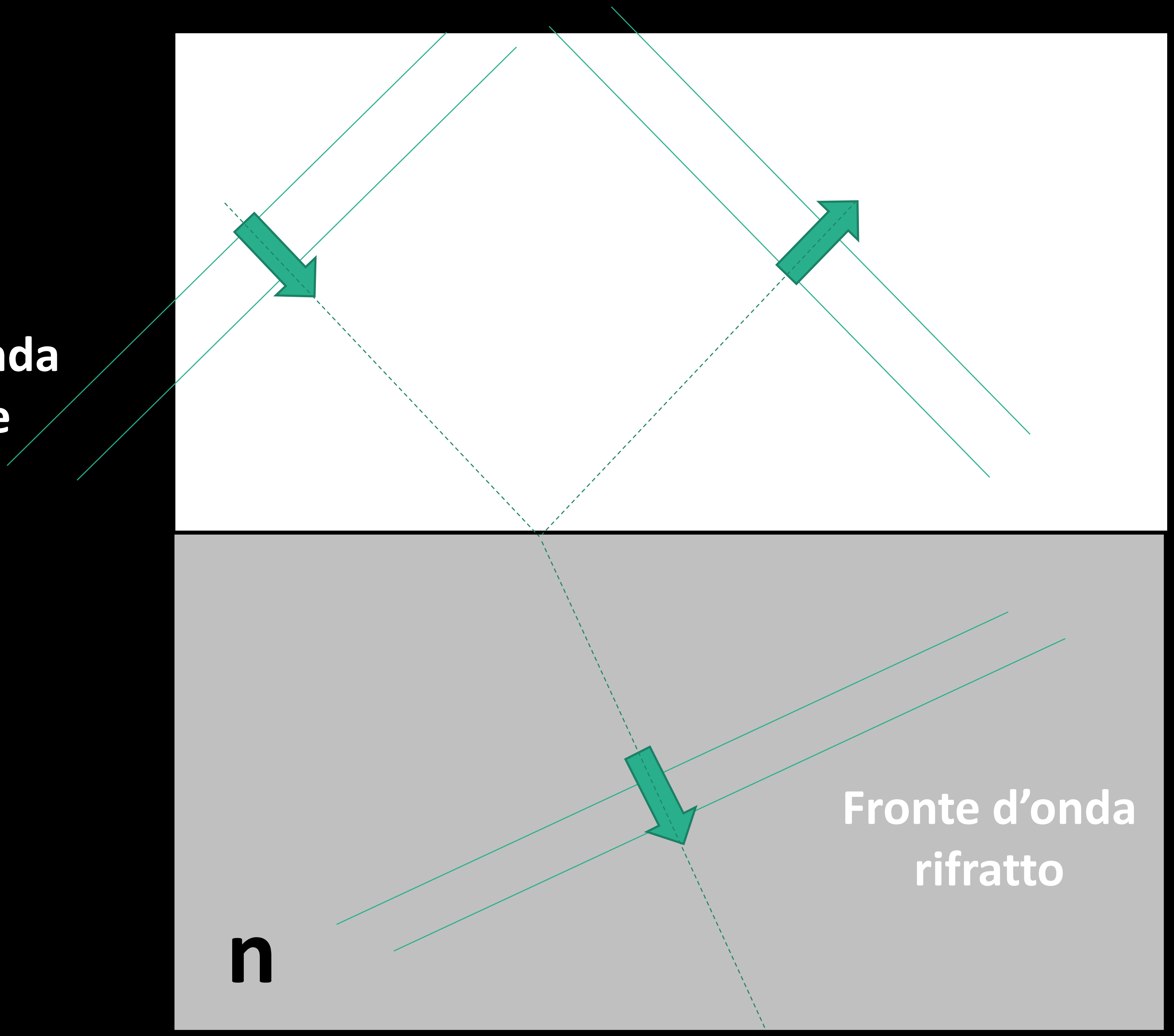






Riflessione
e
Rifrazione

Principio
di
Huygens

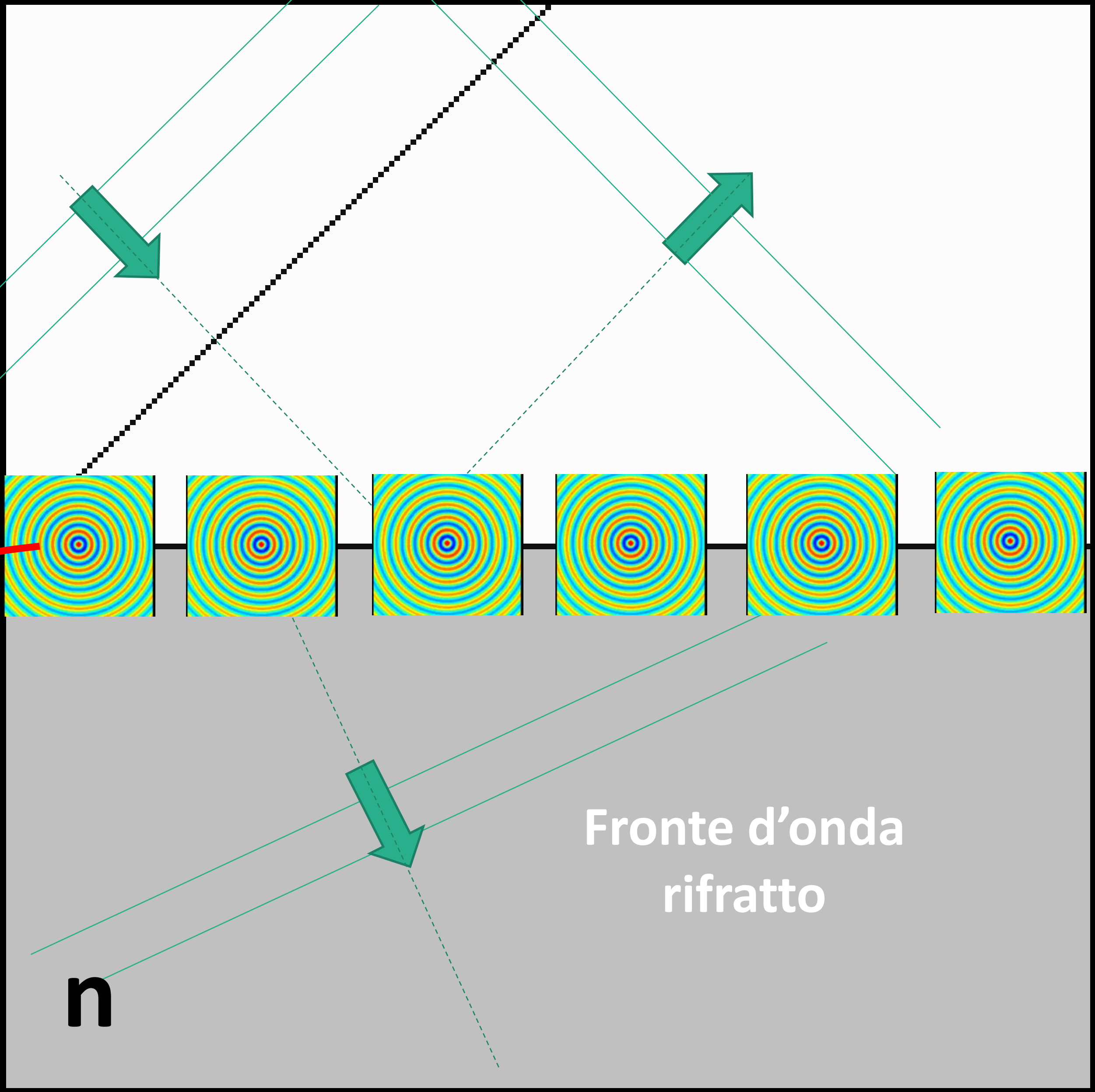


Riflessione
e
Rifrazione

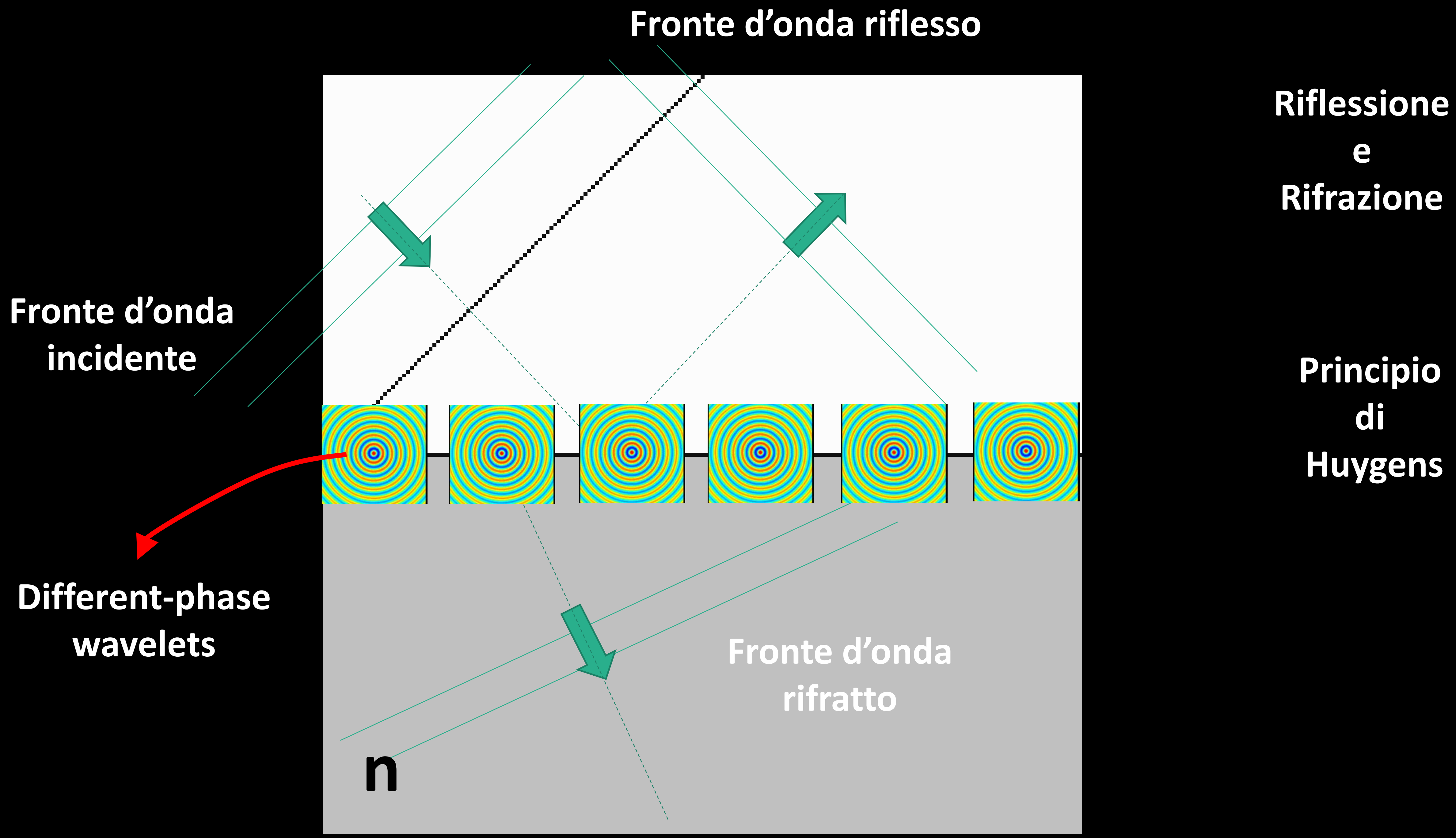
Principio
di
Huygens

Fronte d’onda riflesso

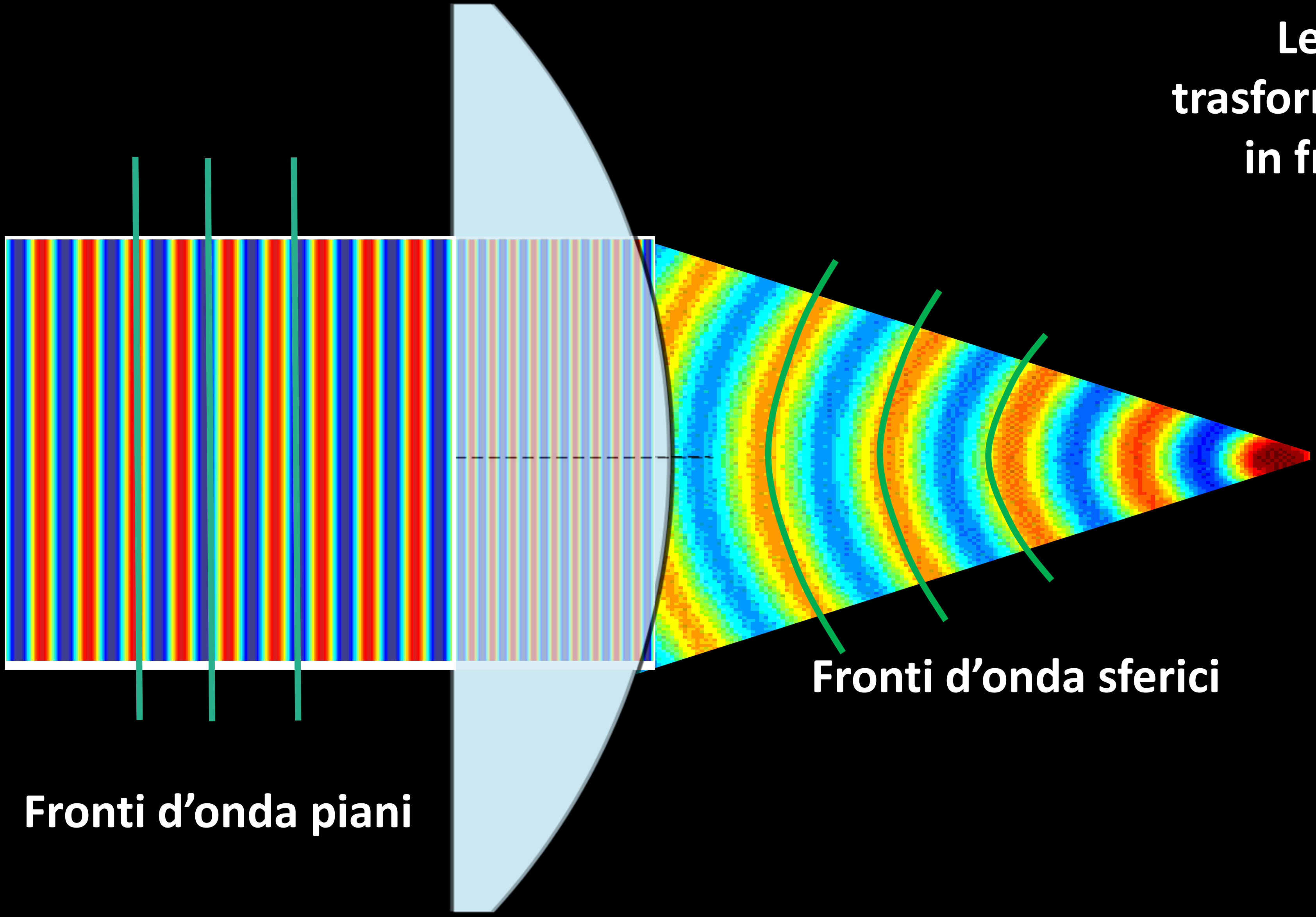
Fronte d’onda incidente

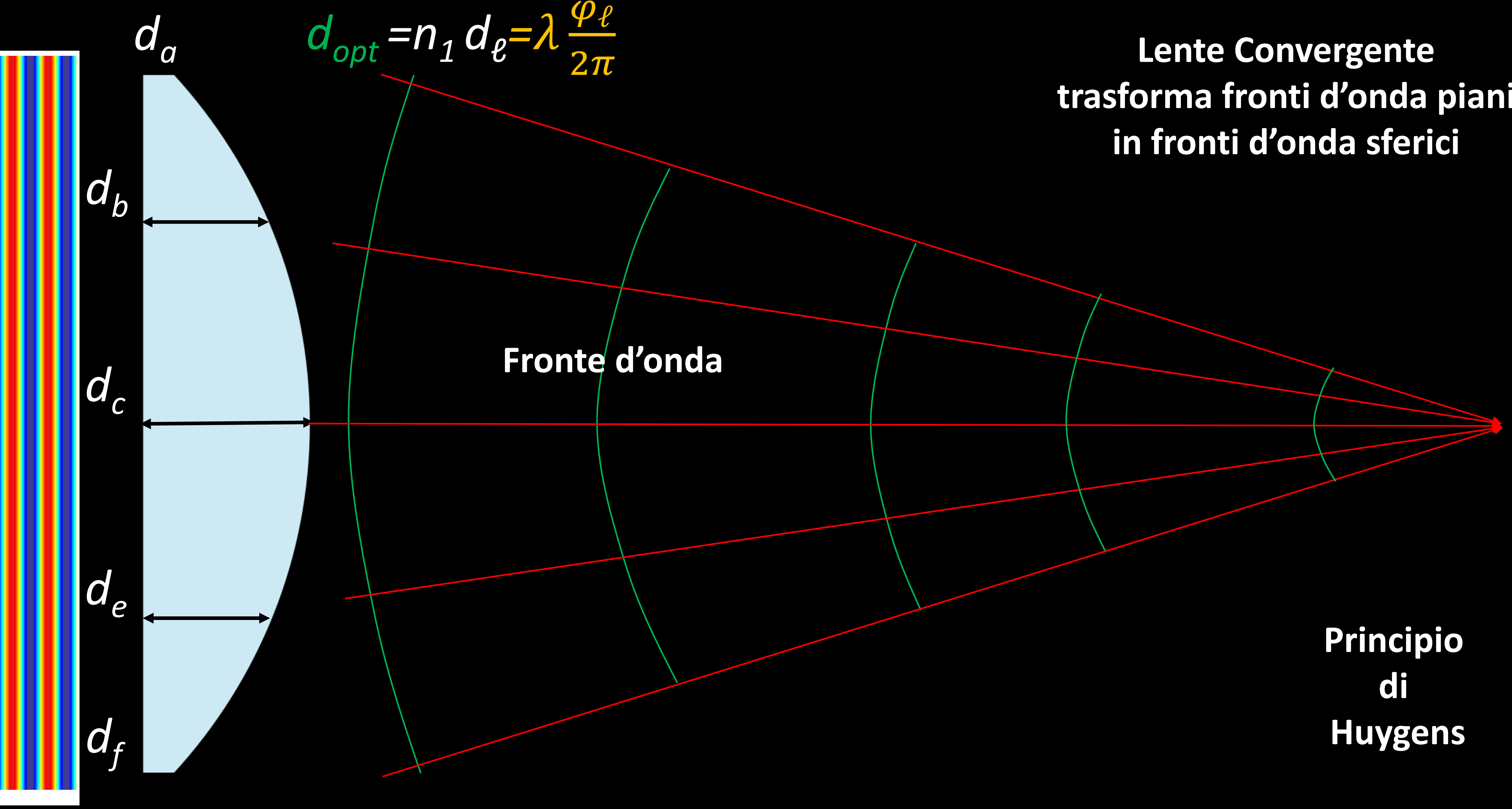


Different-phase wavelets


Fronte d'onda riflesso
Riflessione
e
Rifrazione
Fronte d'onda
incidente
Principio
di
Huygens
Different-phase
wavelets
Fronte d'onda
rifratto
n

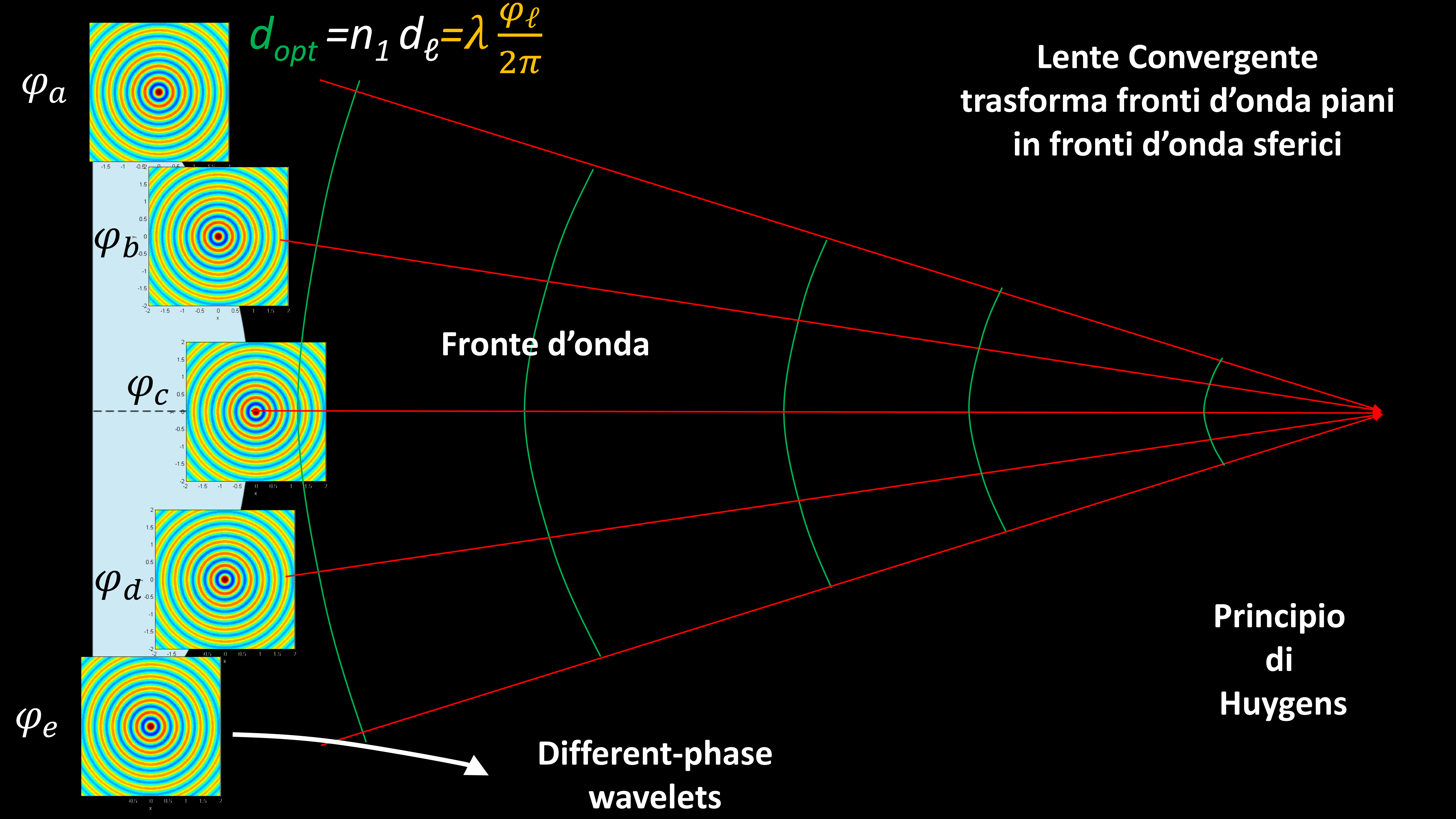
Lente Convergente
trasforma fronti d’onda piani
in fronti d’onda sferici





**Lente Convergente
trasforma fronti d’onda piani
in fronti d’onda sferici**

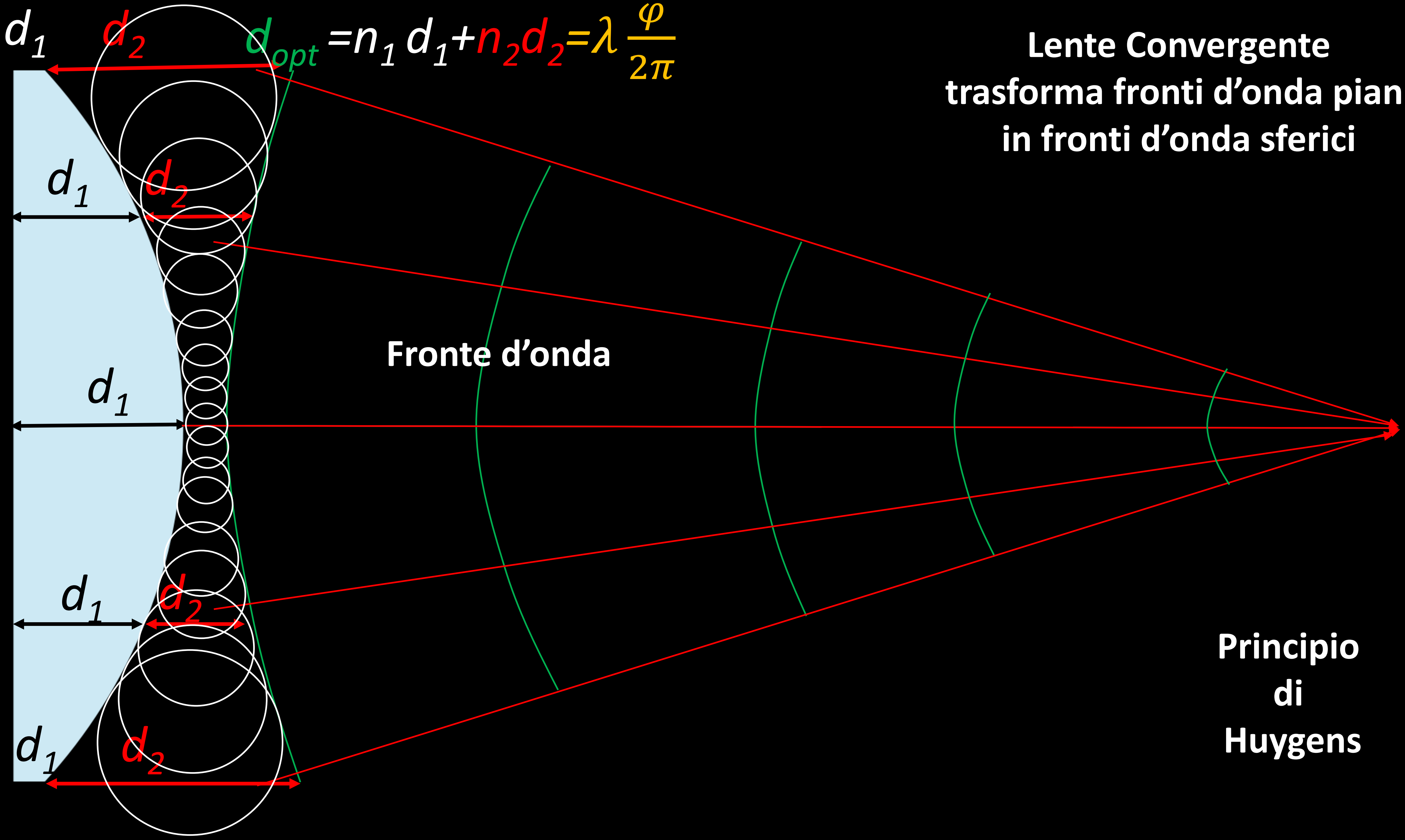
**Principio
di
Huygens**

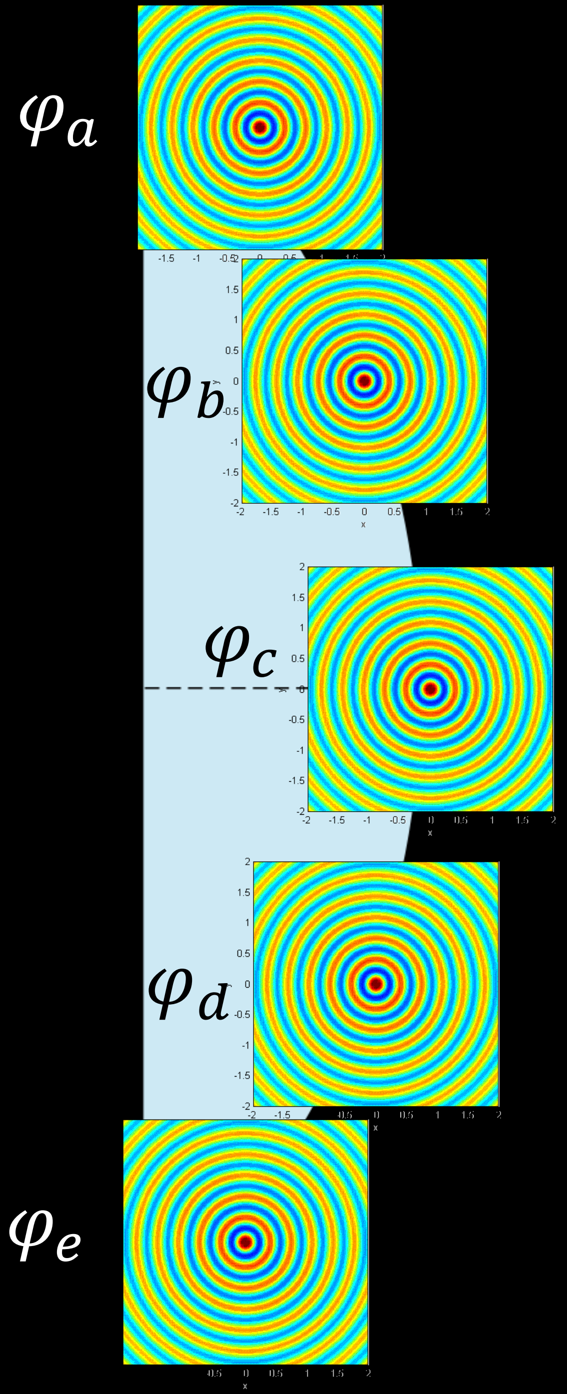


$d_{opt} = n_1 d_\ell = \lambda \frac{\varphi_\ell}{2\pi}$
Lente Convergente
trasforma fronti d'onda piani
in fronti d'onda sferici
φ_a
φ_b
φ_c
φ_d
φ_e
Fronte d'onda
Principio
di
Huygens
Different-phase
wavelets

Lente Convergente trasforma fronti d'onda piani in fronti d'onda sferici

$d_{opt} = n_1 d_1 + n_2 d_2 = \lambda \frac{\varphi}{2\pi}$



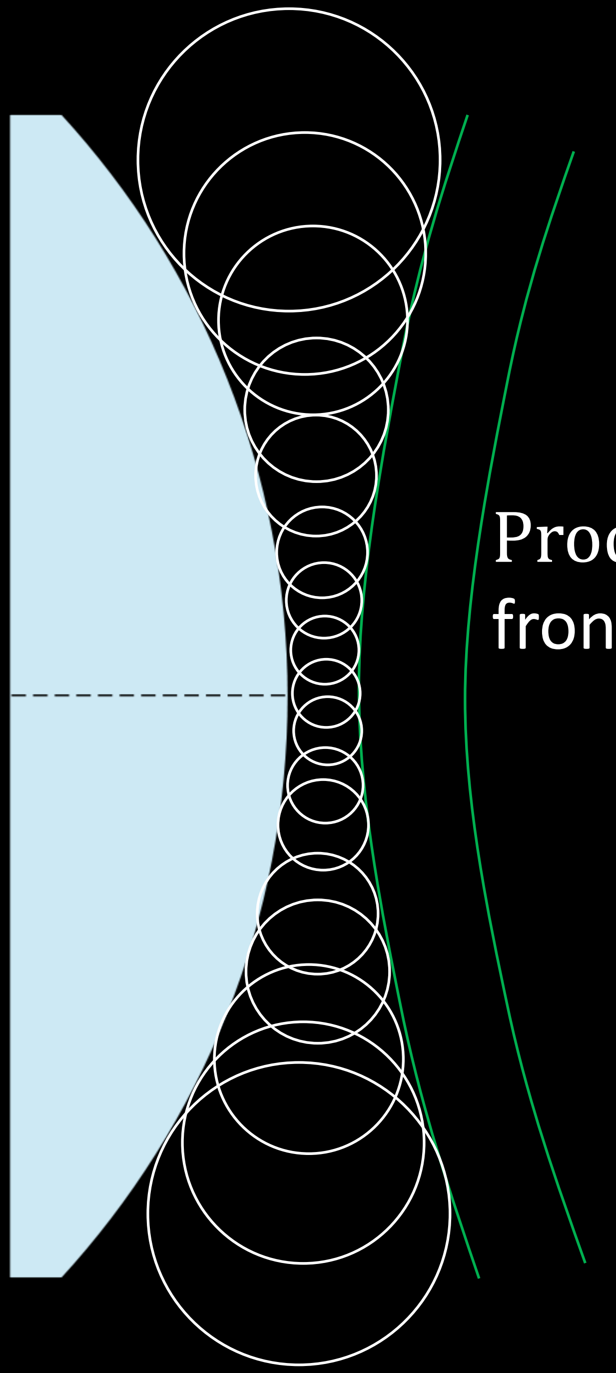


Lente Convergente

+

Principio di Huygens

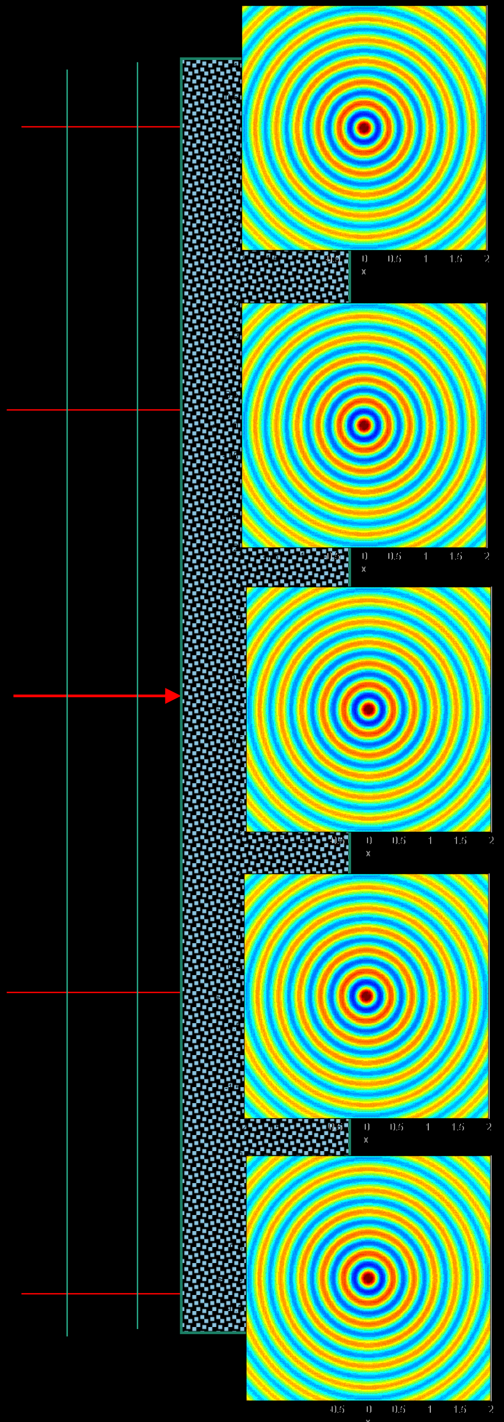
Somma di Wavelets con φ modulato sulla superficie della lente concava



La modulazione di φ è data da

forma della lente

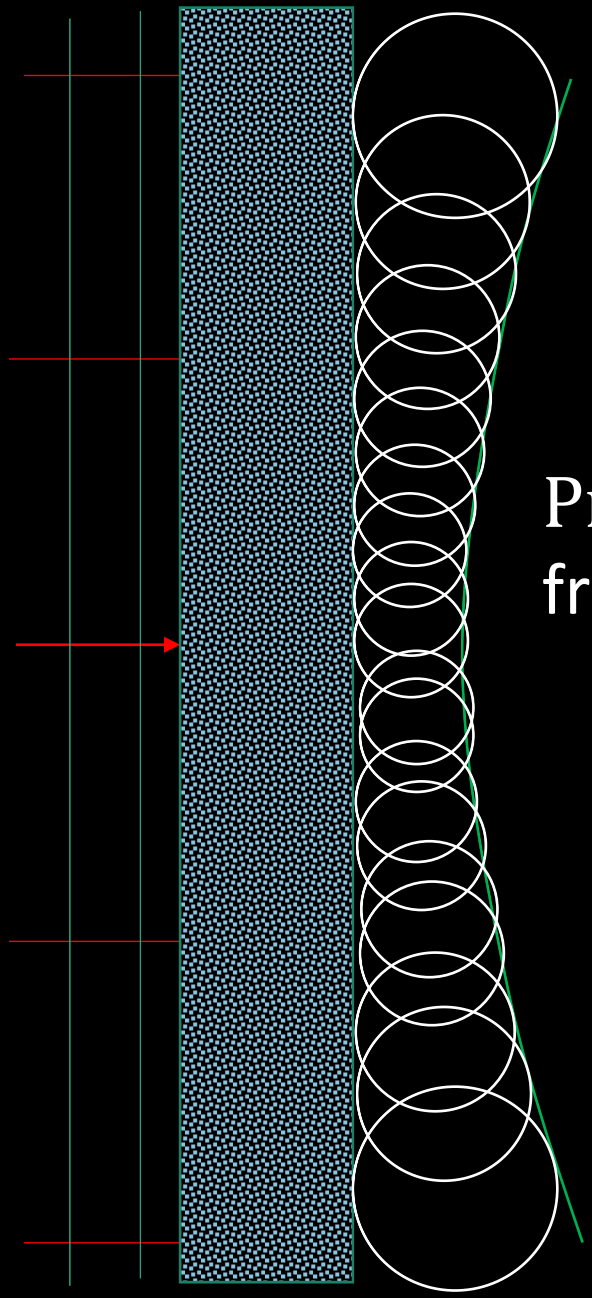
Lente Convergente a superficie piana



La modulazione di φ è data da

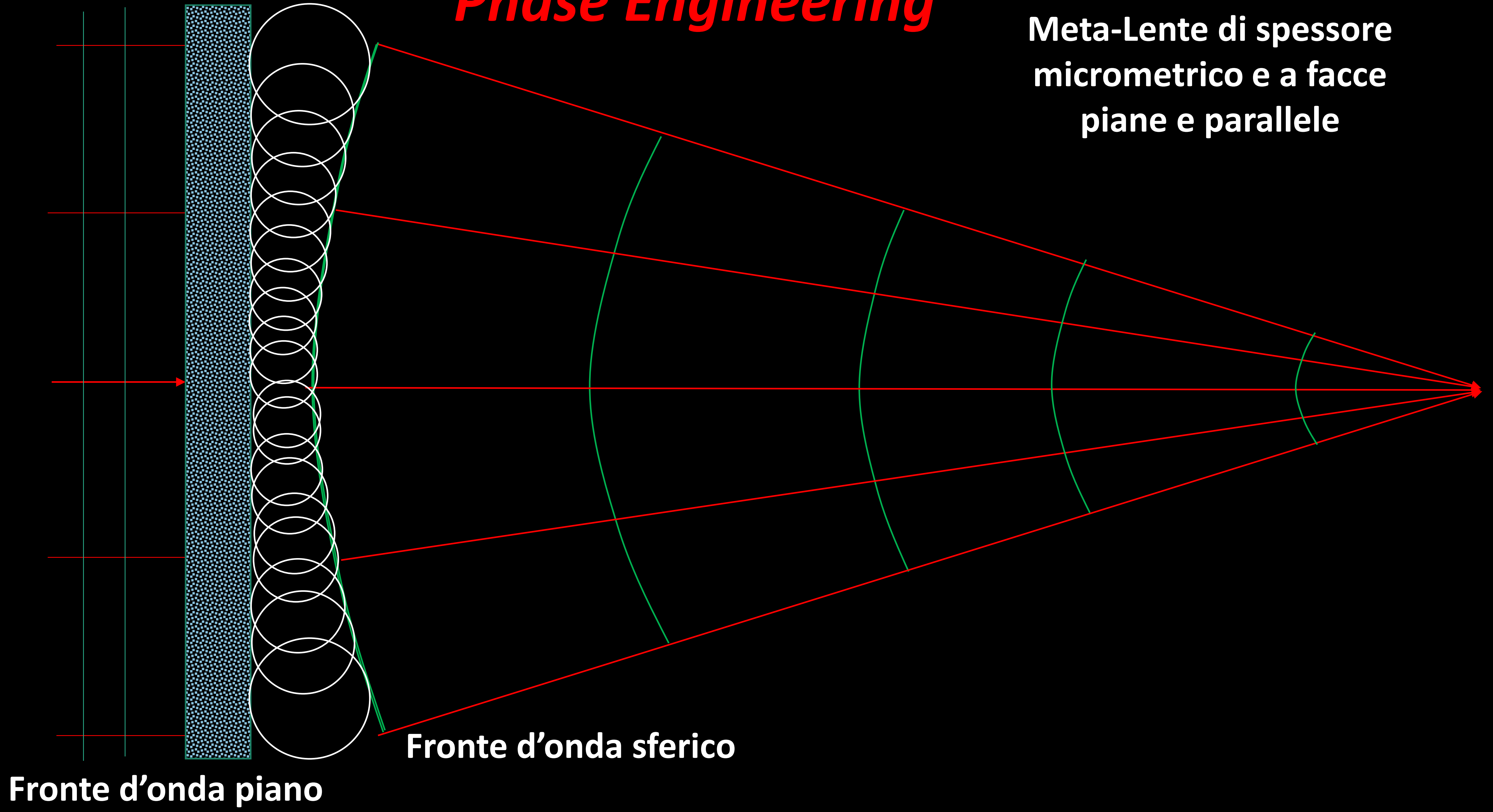
Phase engineering

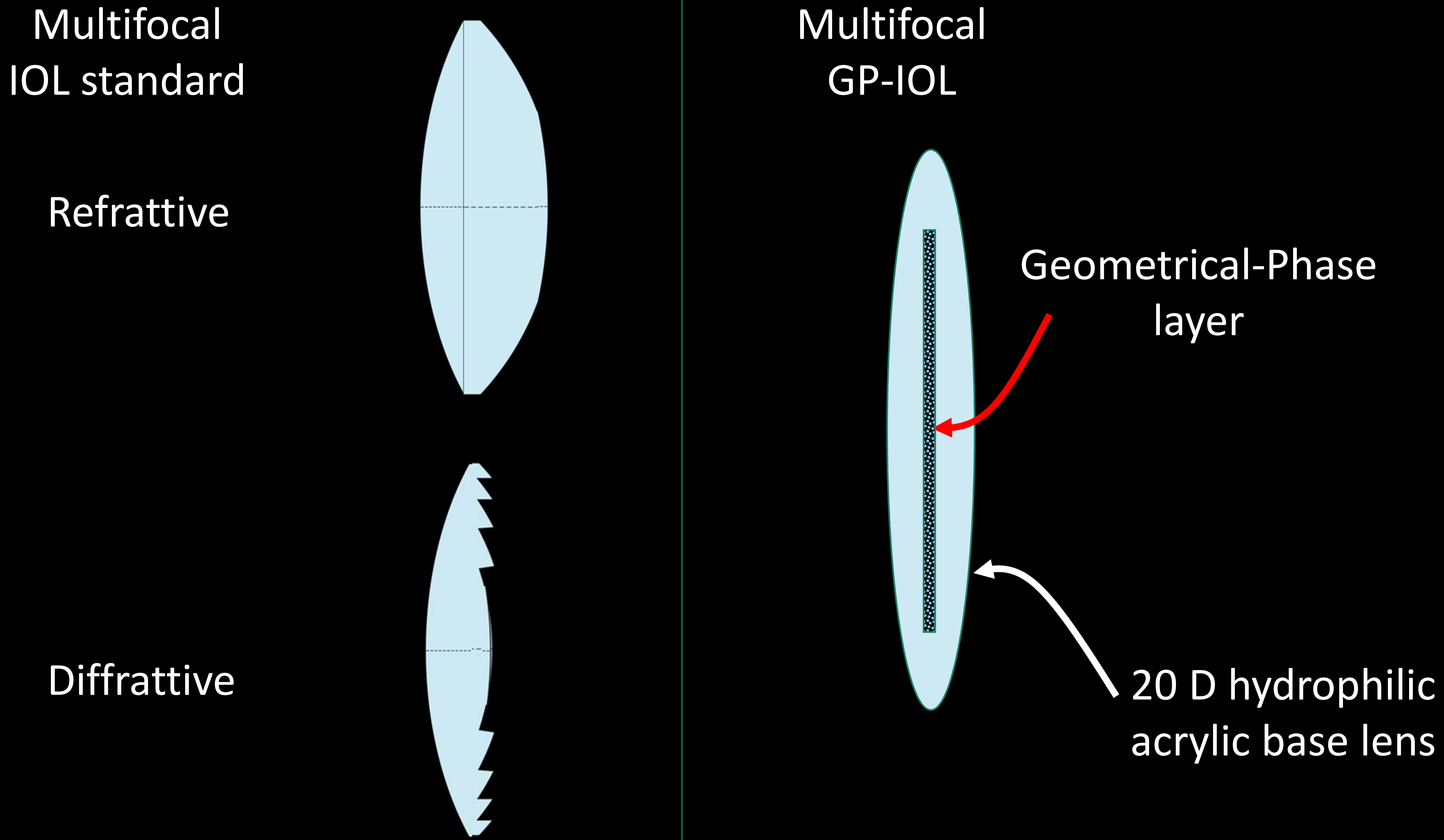
Somma di Wavelets con φ modulato **opportunamente**



Produce un fronte sferico

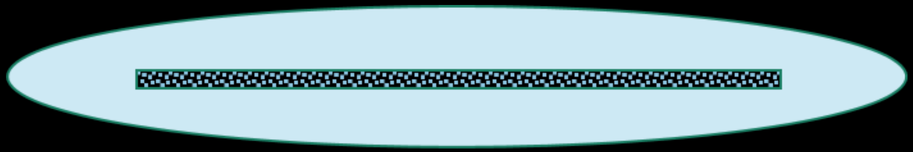
Phase Engineering

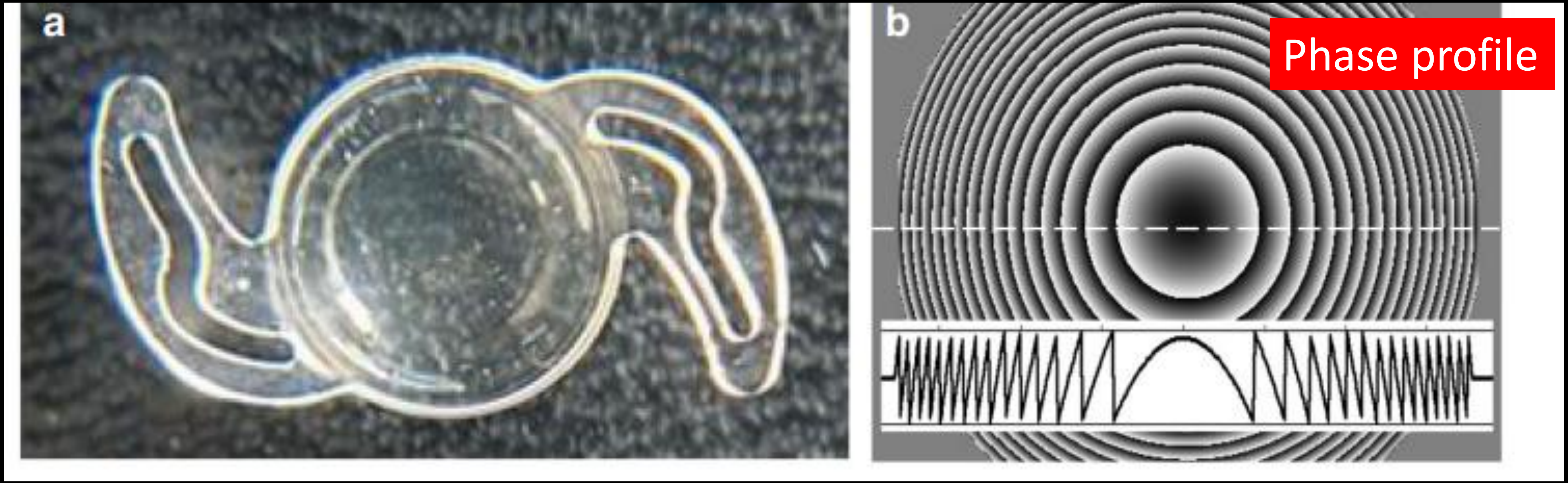



Multifocal
IOL standard
Refrattive
Diffrattive
Multifocal
GP-IOL
Geometrical-Phase
layer
20 D hydrophilic
acrylic base lens

Multifocal GP-IOL con salto di fase non accompagnato da scalini alla superficie

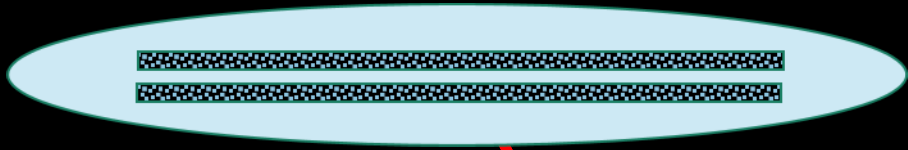
GP-IOL



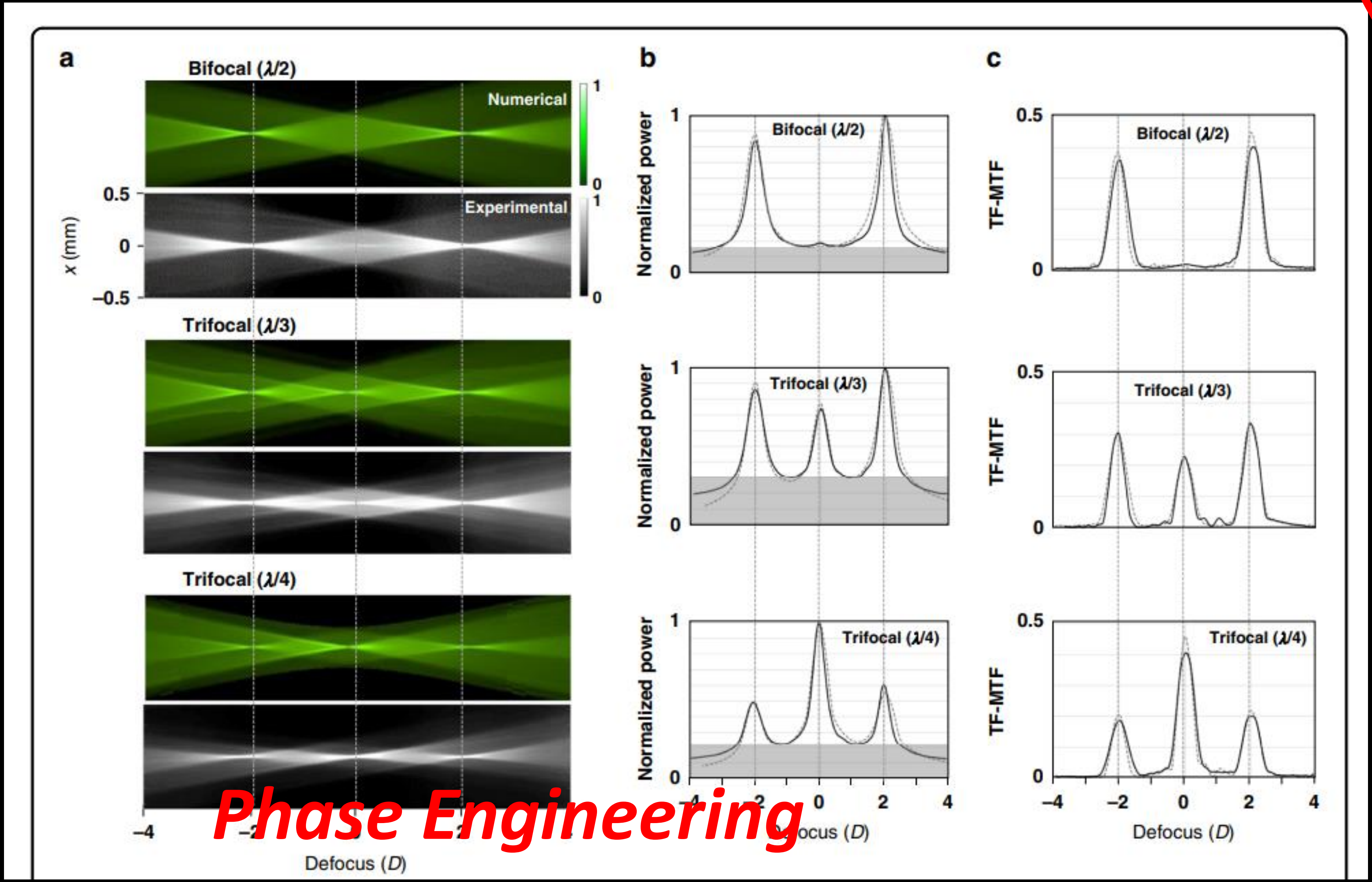


Diffractive IOL

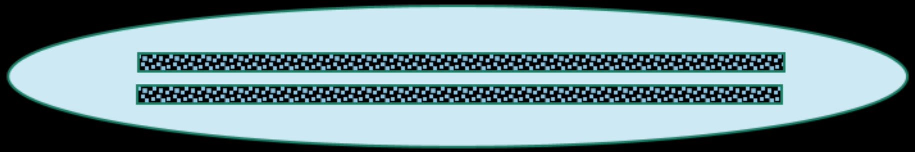
GP- IOL permettono design «arbitrari»



GP multilayer



GP-IOL permettono design «arbitrari»



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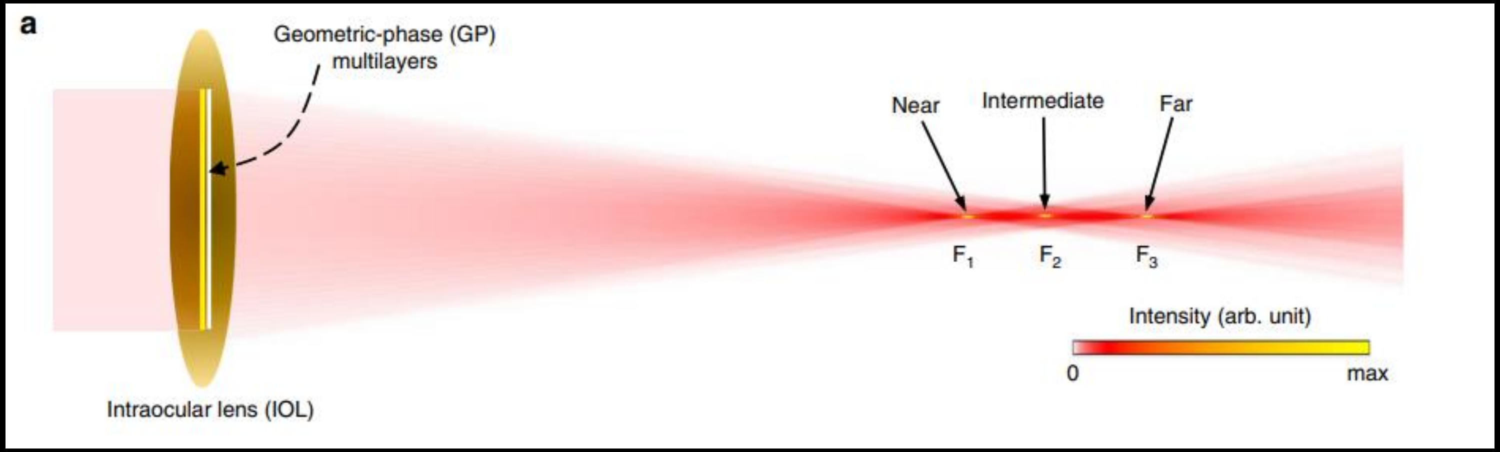
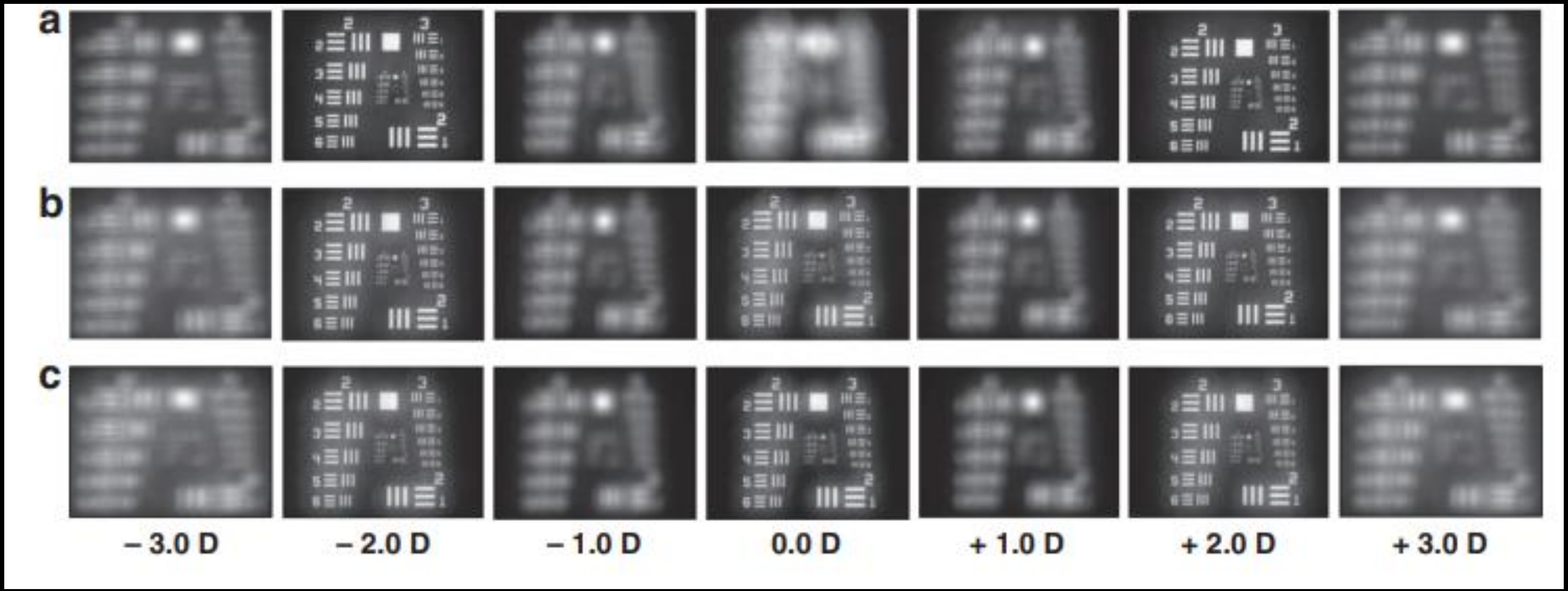
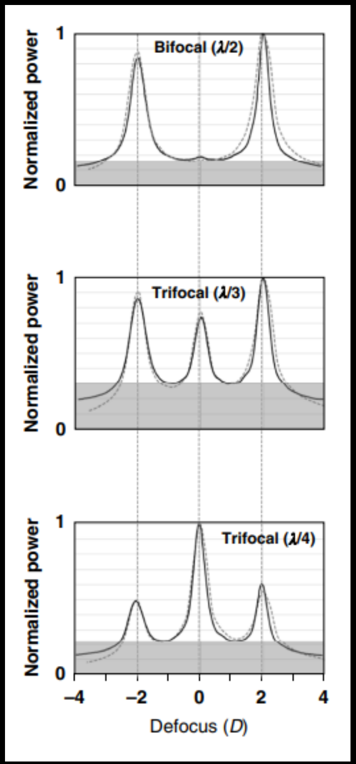






EDOF IOL with GP multilayer

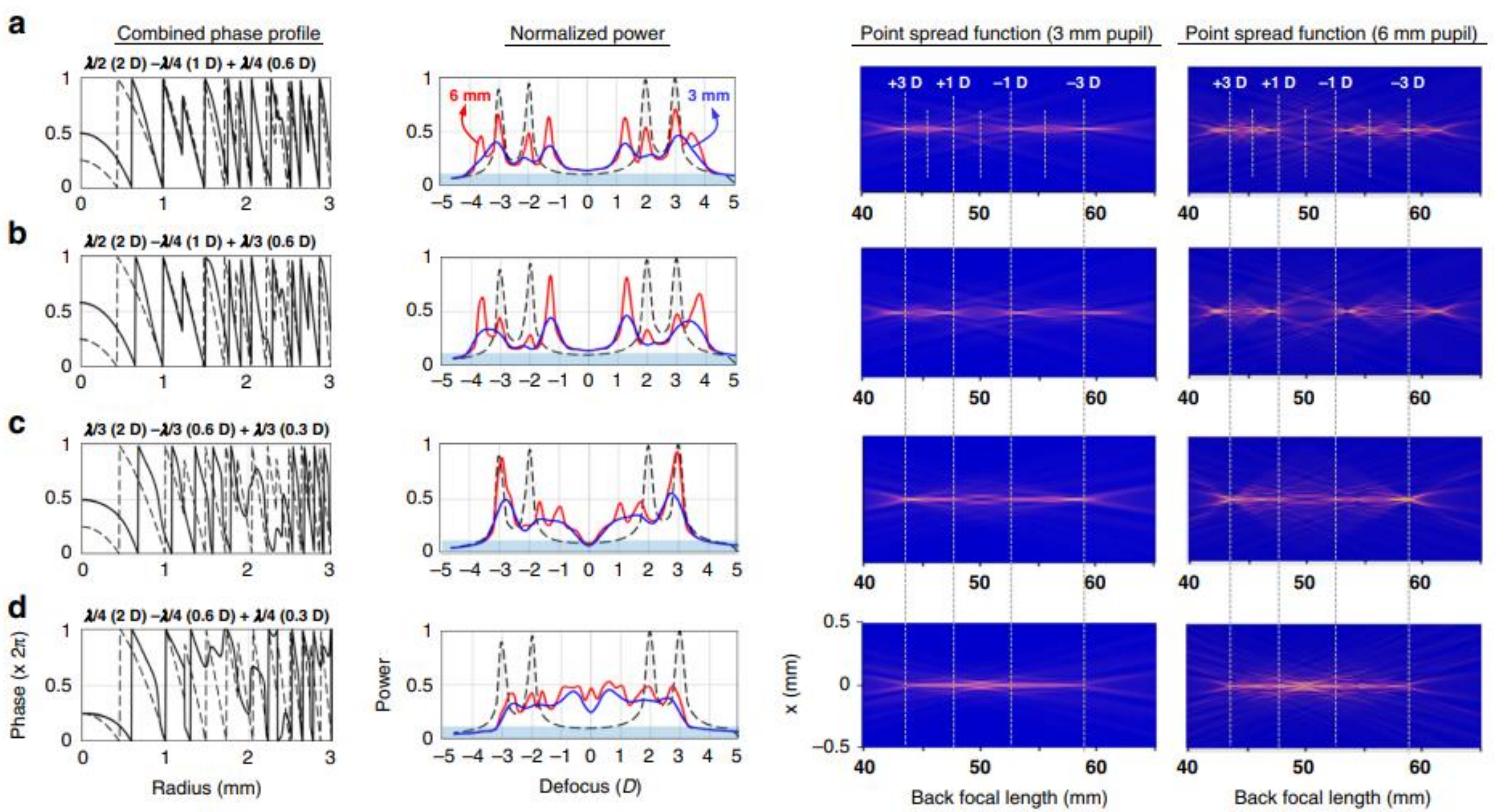


Fig. 8 EDoF GP IOLs. Triple-layered GP IOLs stacked in order of λ/2 (2 D)−λ/4 (1 D)+λ/4 (0.6 D) (**a**), λ/2 (2 D)−λ/4 (1 D)+λ/3 (0.6 D) (**b**), λ/3 (2 D)−λ/3 (0.6 D)+λ/3 (0.3 D) (**c**), and λ/4 (2 D)−λ/4 (0.6 D)+λ/4 (0.3 D) (**d**), where the '*x* (*y*)' notation represents the OPR (add power) of the stacked GP layers. The dashed black curves in the combined phase profile and the normalized power diagrams are those for the double-layered GP IOL of λ/2 (2 D)−λ/4 (1 D) (Fig. 7d) for comparison. The red and blue curves of normalized power correspond to the use of pupil diameters of 6 and 3 mm, respectively, and the blue lower area is the background caused by the halo effect. The point spread functions are displayed on equal scales of 0 to 4 color brightness, and the 50 mm back focal length of the IOLs means 0.0 D position

Confronto luce diffusa fra IOL diffrattiva e GP-IOL

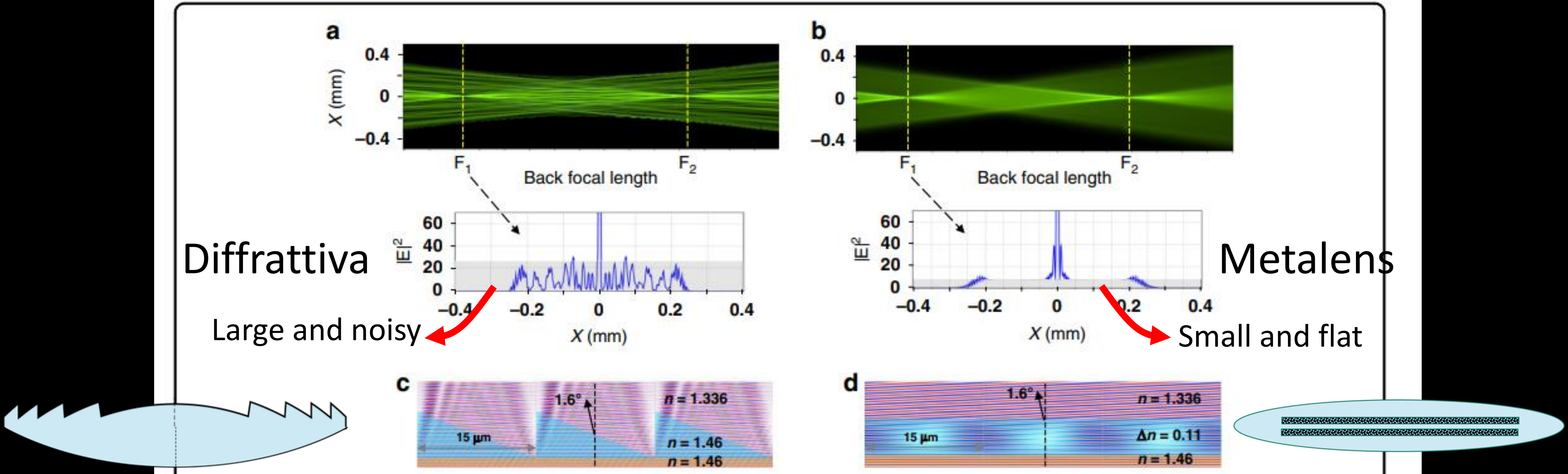


Fig. 2 Comparison of light scattering from conventional diffractive IOL and GP IOL for a coherent beam incidence. a, **b** Through-focus point spread functions of diffractive and GP bifocal IOLs, respectively. The defocus distance between F_1 and F_2 is 4 D. The point spread functions on F_1 focal plane along the *x*-axis are compared bellow. **c**, **d** Propagation of planewave normally incident from the bottom through a diffractive sawtooth profile and uniformly thick GP film (blue areas), respectively. After passing through the phase modulation layer, the GP film produces very uniform wavefronts while the incident beam is deflected at a certain angle of 1.6° in both cases

Claims di riduzione di

- dysphotopsia such as halo, blur, haze, glare, starbursts…
- posterior capsule opacification by epithelial-cell at «roughness»

Qualche dettaglio sulla nanofabbricazione

Cristalli liquidi birifrangenti su 10x10 μm reticoli di linee con nanoimprinting

Fuochi diversi per le due polarizzazioni circolari

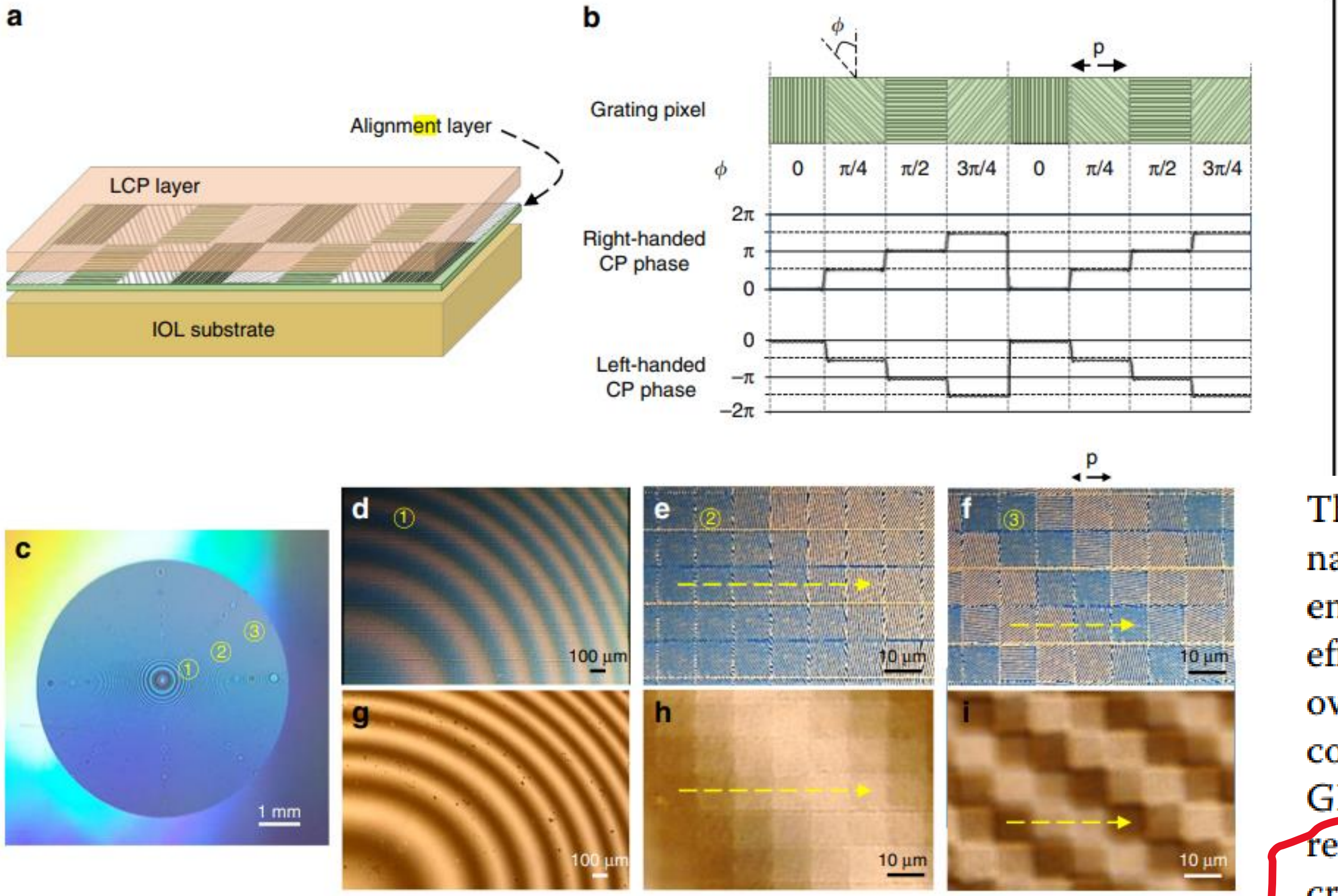
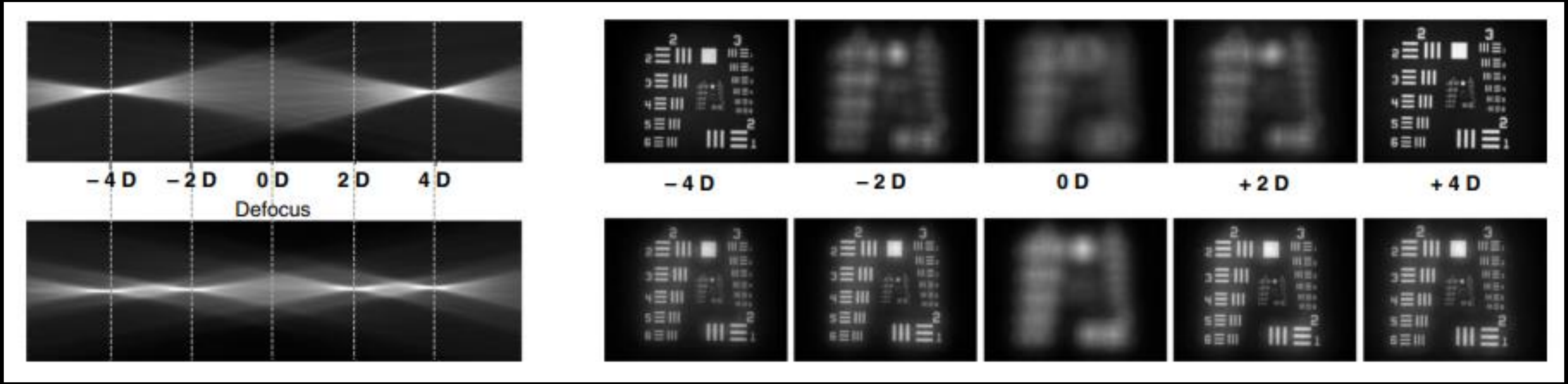
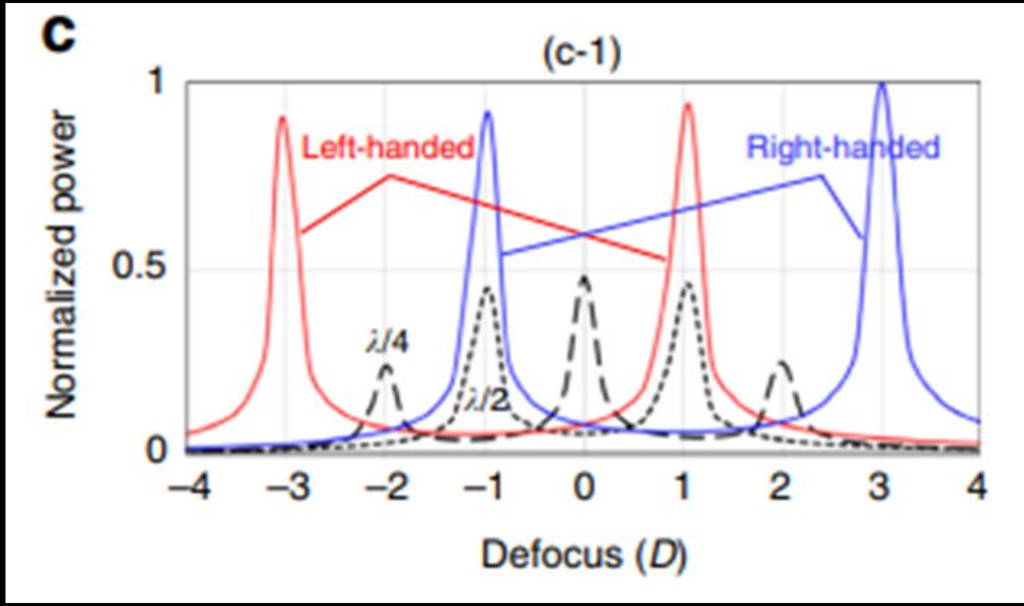


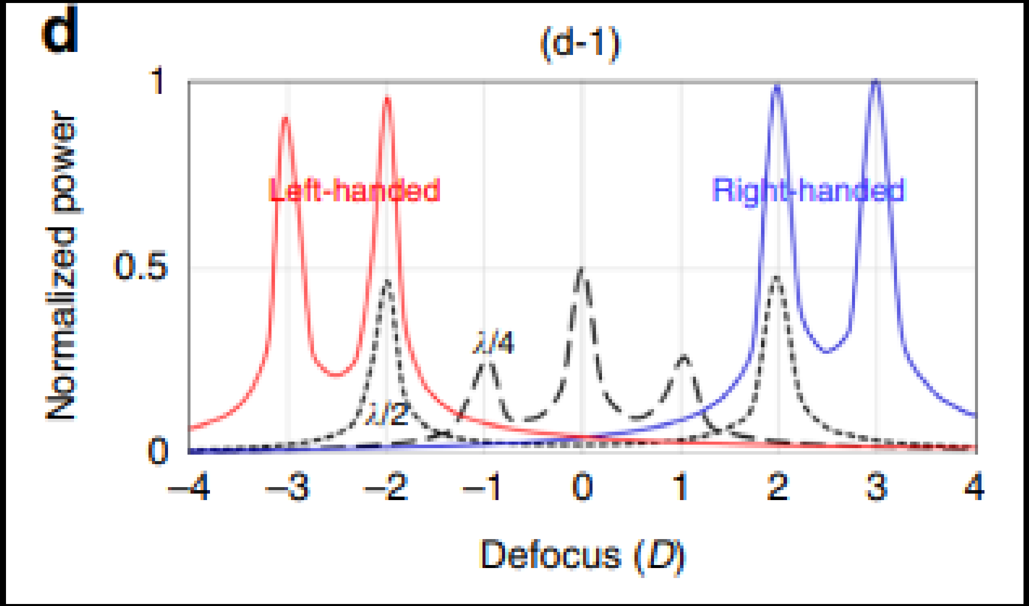
Fig. 4 Fabrication of GP layers. a Birefringent LCP layer spin-coated onto alignment layer of nanopatterned surface imprinted on IOL substrate. **b** The nanopatterned surface composed of square grating pixels with discrete corrugation angles (ϕ) and constant width ($p = 10\,\mu$m), and the corresponding GP modulation (2ϕ) for right-handed CP and left-handed CP incidences. **c** Photograph of the microtextured grating pixels fabricated on a silicon wafer. **d–f** Photographs of the square grating pixels at the positions of ①, ②, and ③ marked in (**c**), respectively. **g–i** Measured polarizing optical micrographs of the aligned LCP layer under crossed polarizers at the regions respective to (**d–f**). The brightness represents the geometric-phase distribution normalized by 2π

Thin anisotropic films are continuous down to sub-nanometer scale and can be deposited in multiple layers, ensuring clear, haze-less optics without compromising efficiency and transmittance[37,38]. This is advantageous over the discontinuous surface corrugations of most conventional IOLs. In the proposed MF and EDOF IOLs, GP layers with spatially variant anisotropy axes can be realized using nanostructured metasurfaces[33,39] or liquid crystal polymers[40,41]. UV-curable liquid crystal polymers (LCP) are particularly attractive because they can be foldable and made at low cost[42,43].

Warning: sono polarizzate

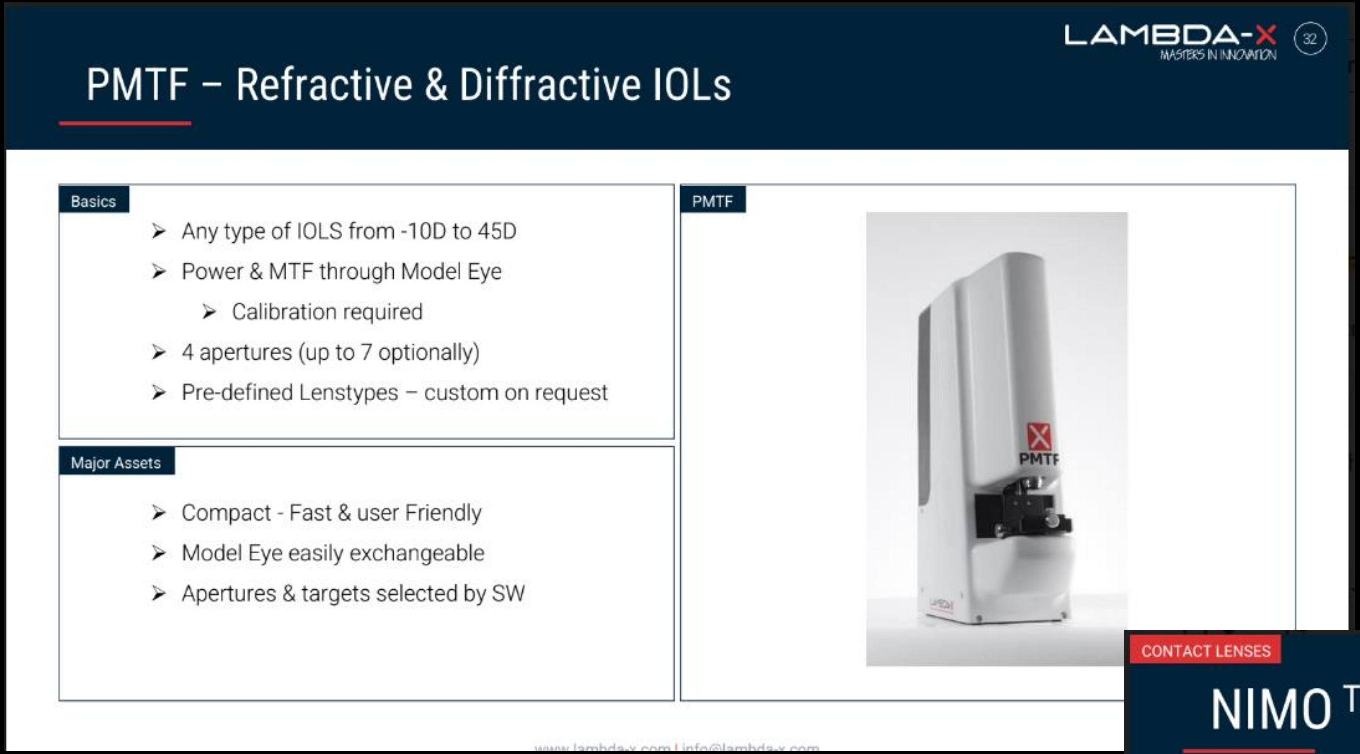


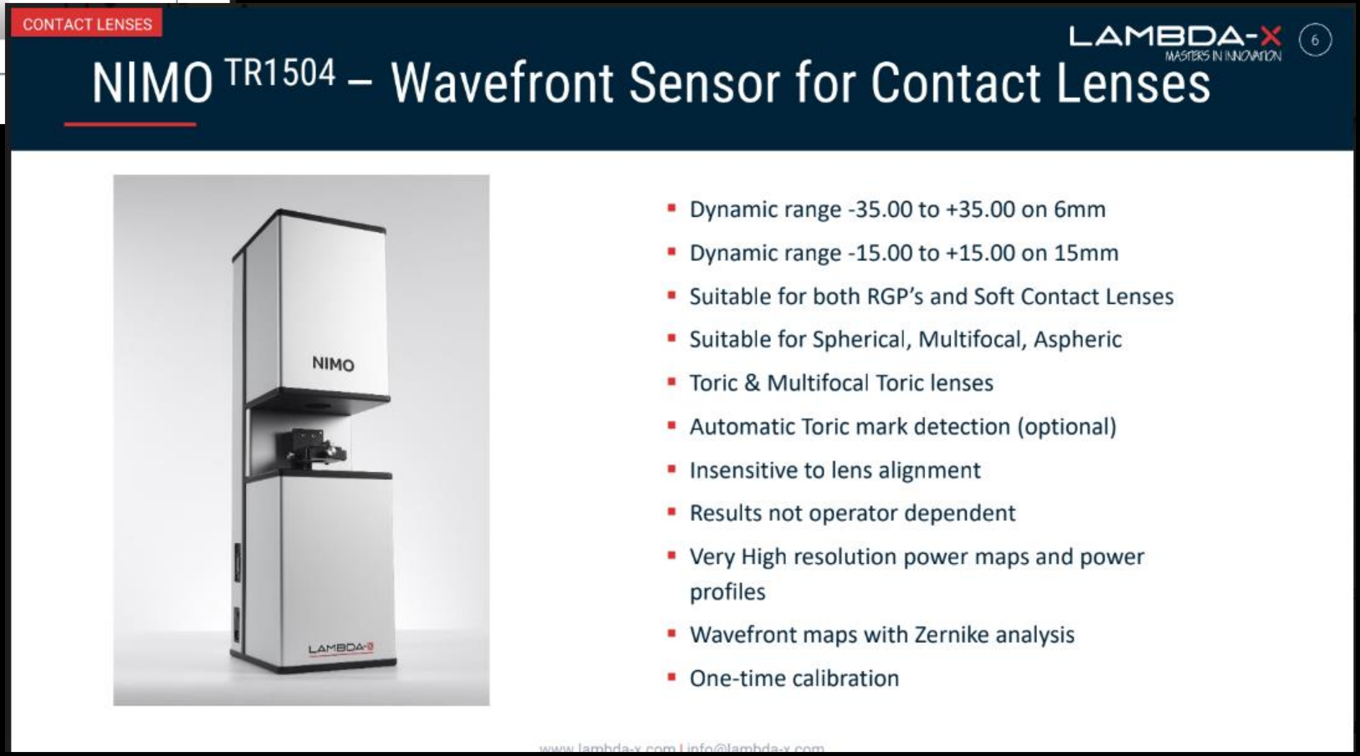


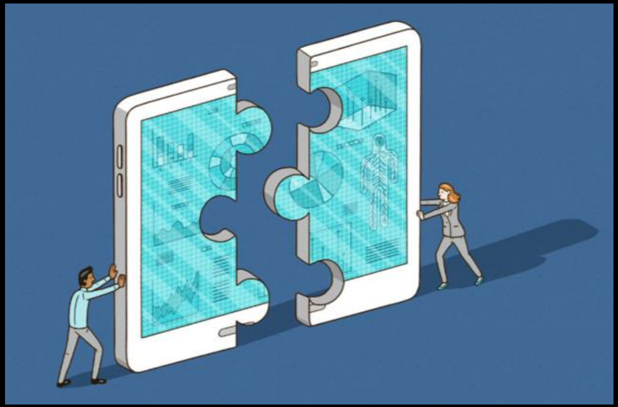


Slides @ massimo.gurioli@unifi.it

Nuovi acquisti @ UNIFI





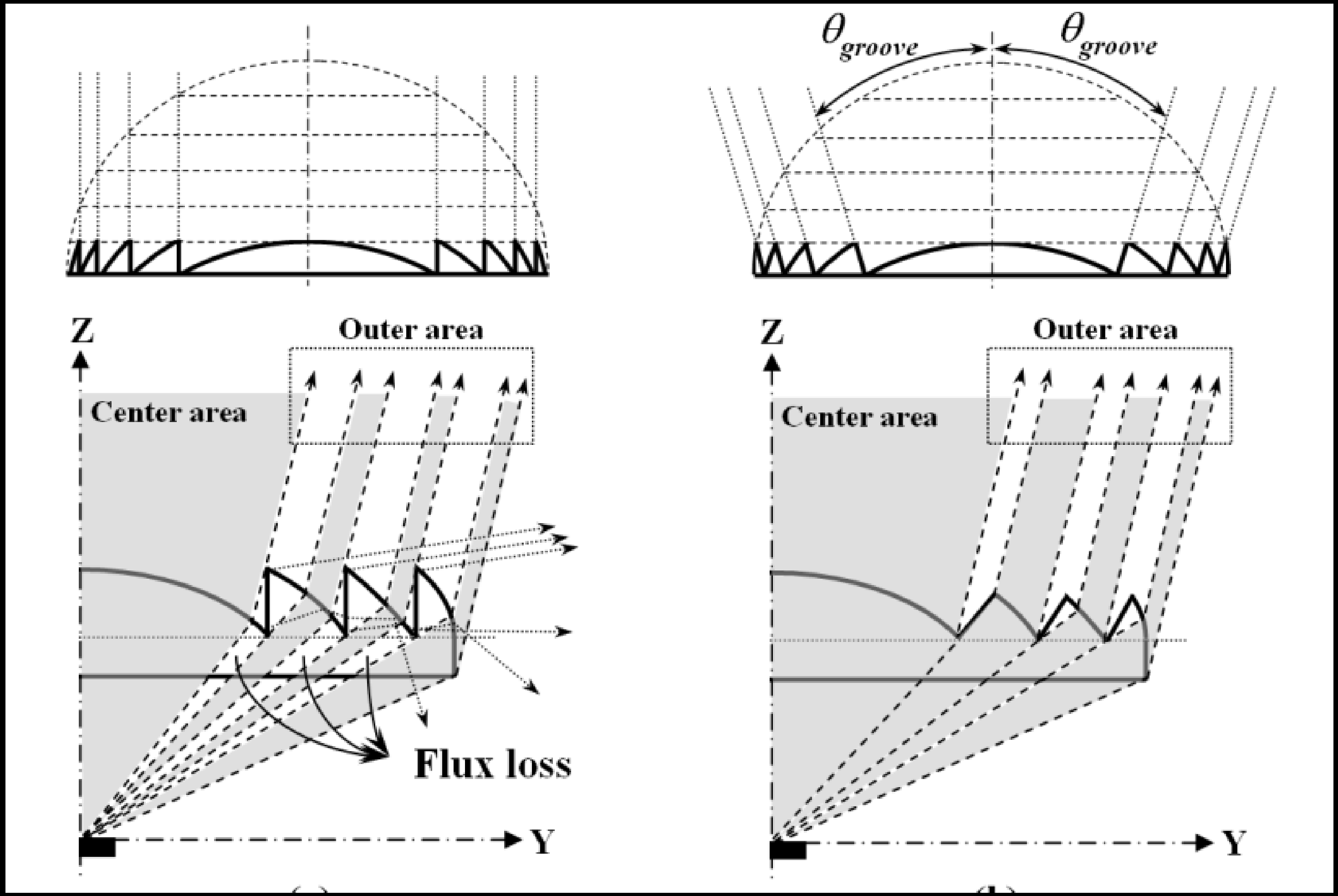


Auspichiamo collaborazioni

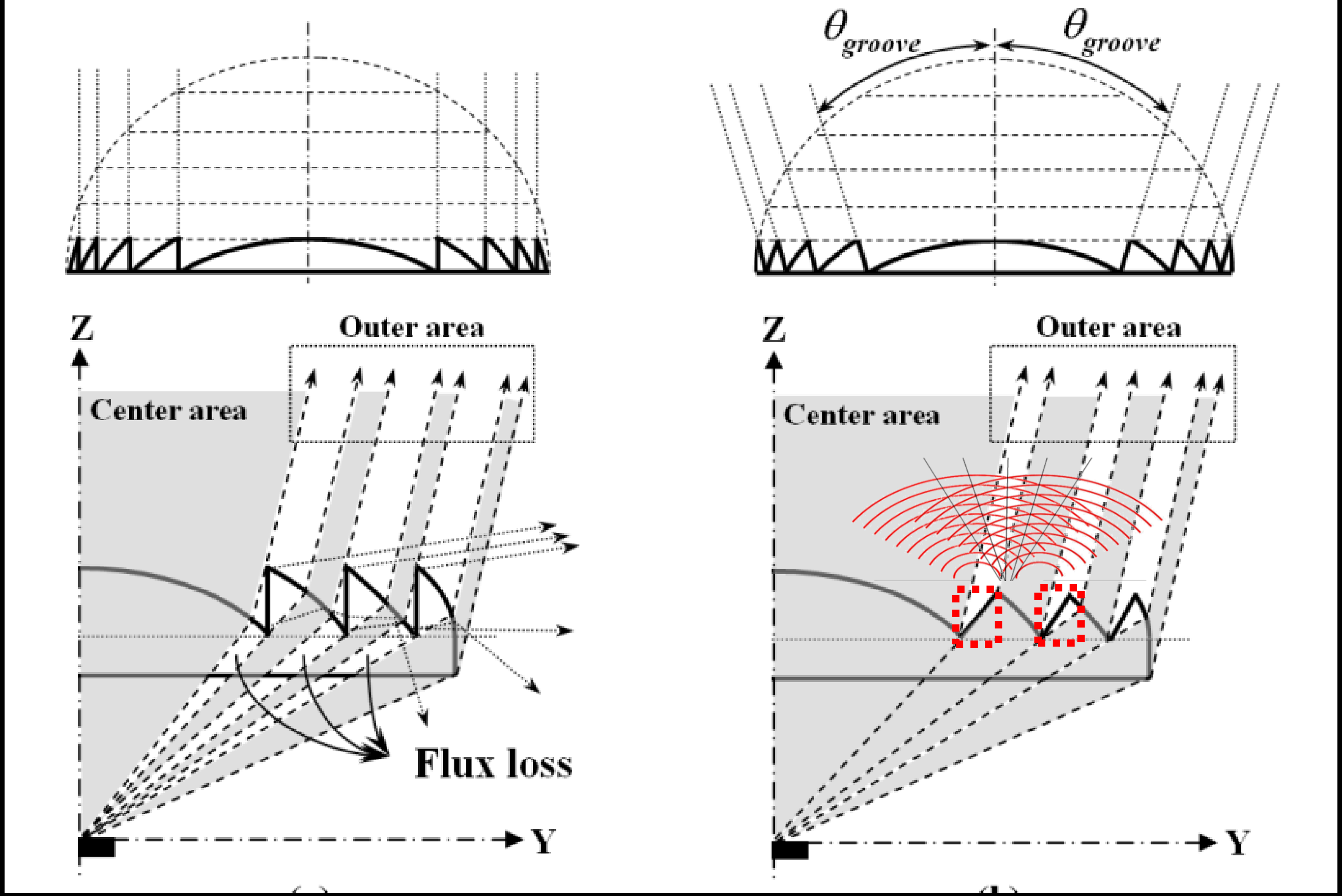
Le nuove sfide della multifocalità: aspetti fisici

Massimo Gurioli (UNIFI)

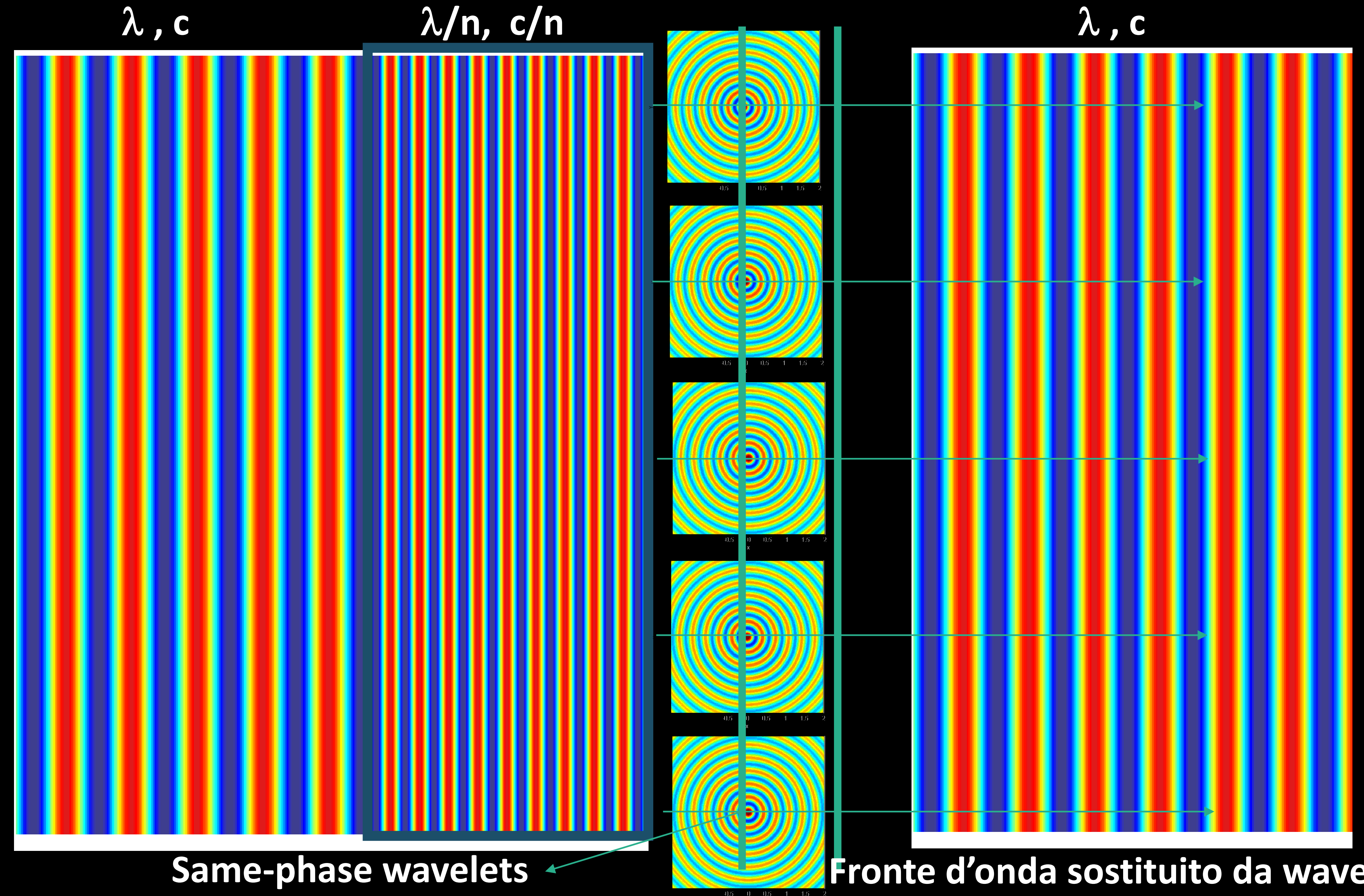
Halo in multifocali diffrattive



Halo in multifocali diffrattive



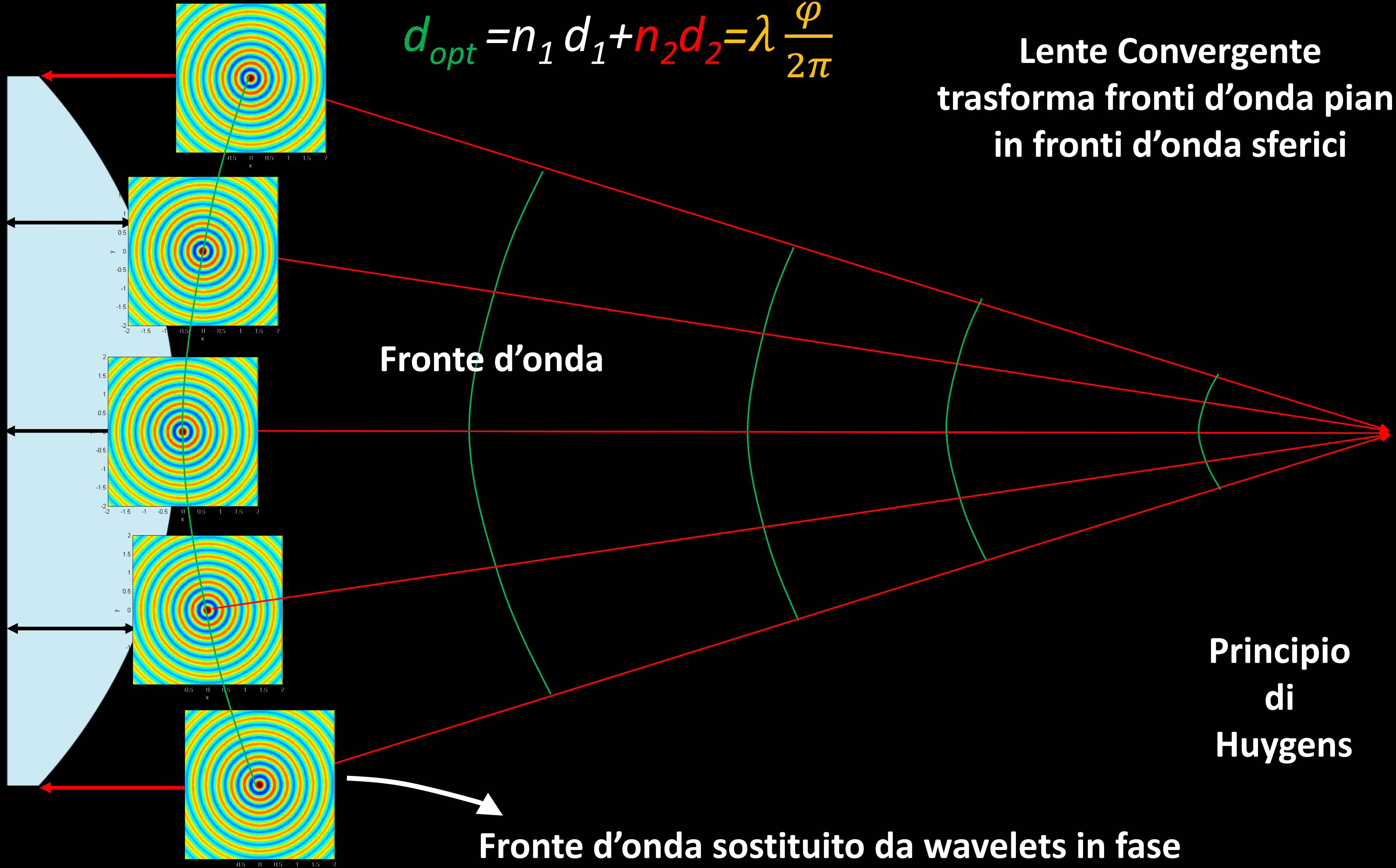
Diffrattive



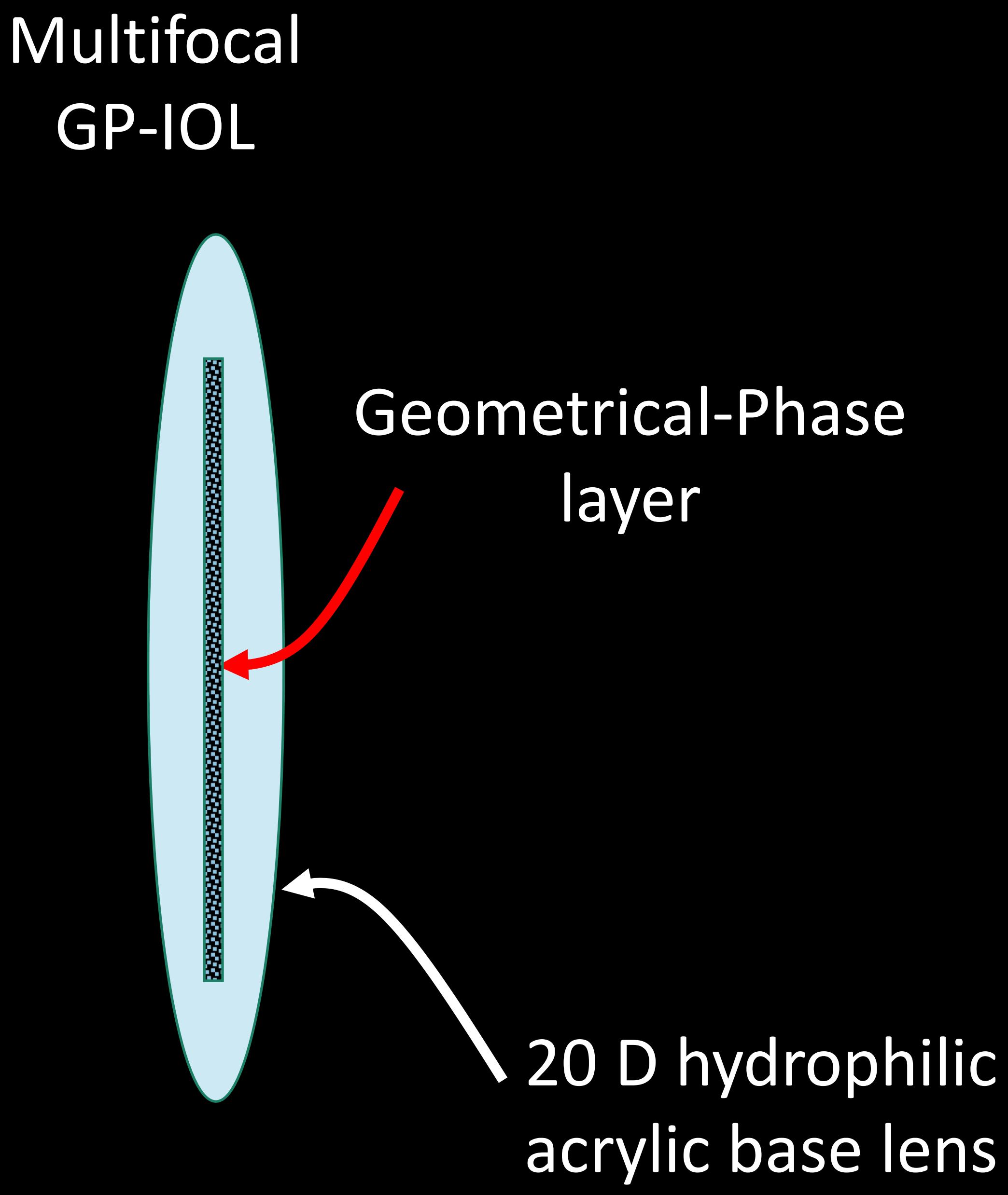
Principio di Huygens

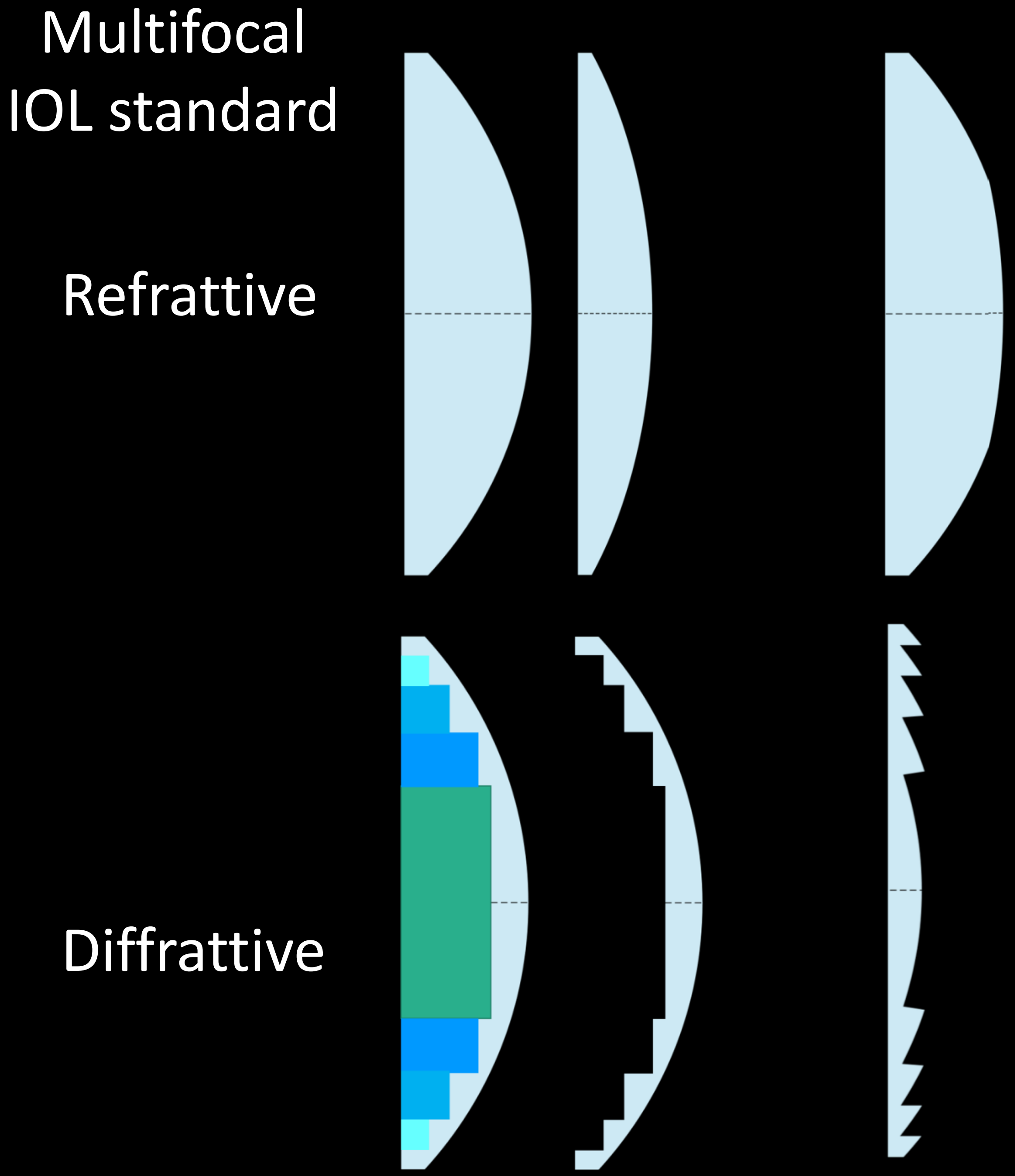
$$d_{opt} = n_1 d_1 + n_2 d_2 = \lambda \frac{\varphi}{2\pi}$$

Lente Convergente trasforma fronti d'onda piani in fronti d'onda sferici



Principio di Huygens


Multifocal
GP-IOL
Geometrical-Phase
layer
20 D hydrophilic
acrylic base lens


Multifocal
IOL standard
Refrattive
Diffrattive