The Flattened Pyramid Sensitivity

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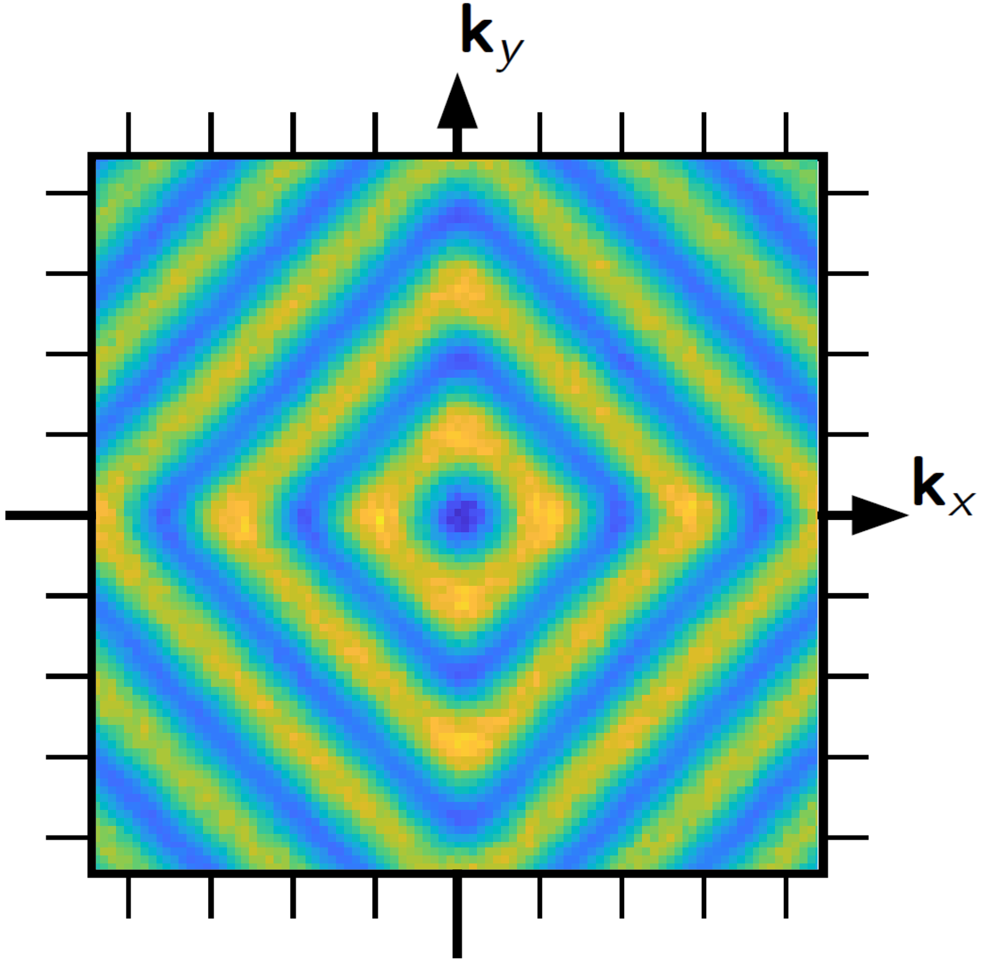
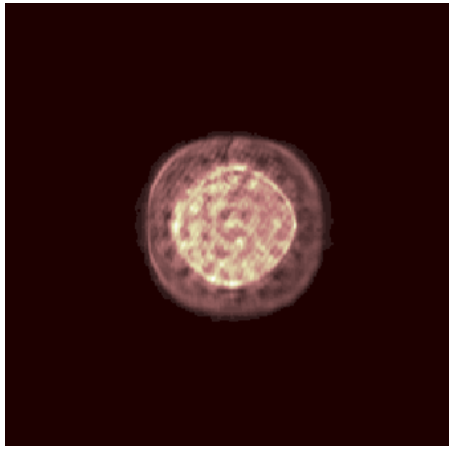
WFS workshop, Firenze – October 29, 2019

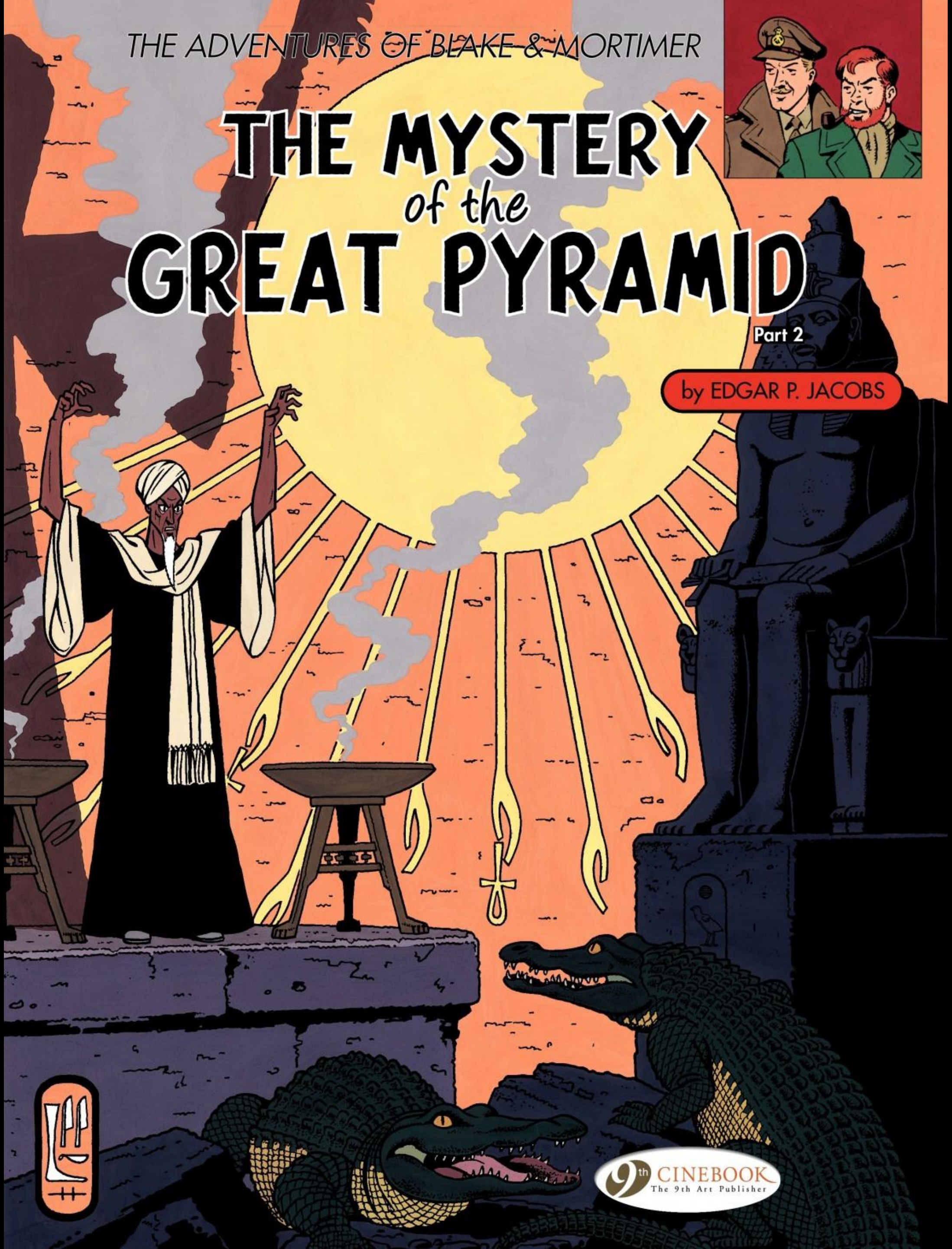
Objective of the presentation



Experimental
Spatial frequencies Sensitivity
Of the
Flattened Pyramid WFS



P. Janin-Potiron


THE ADVENTURES OF BLAKE & MORTIMER
THE MYSTERY of the GREAT PYRAMID
Part 2
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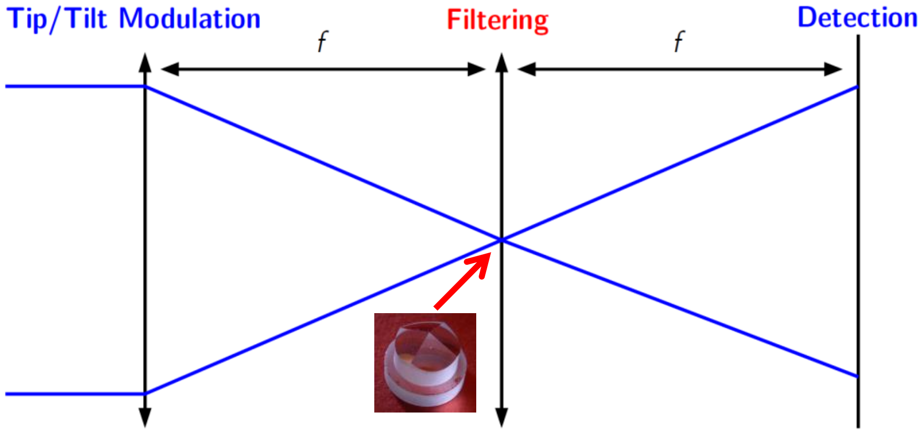
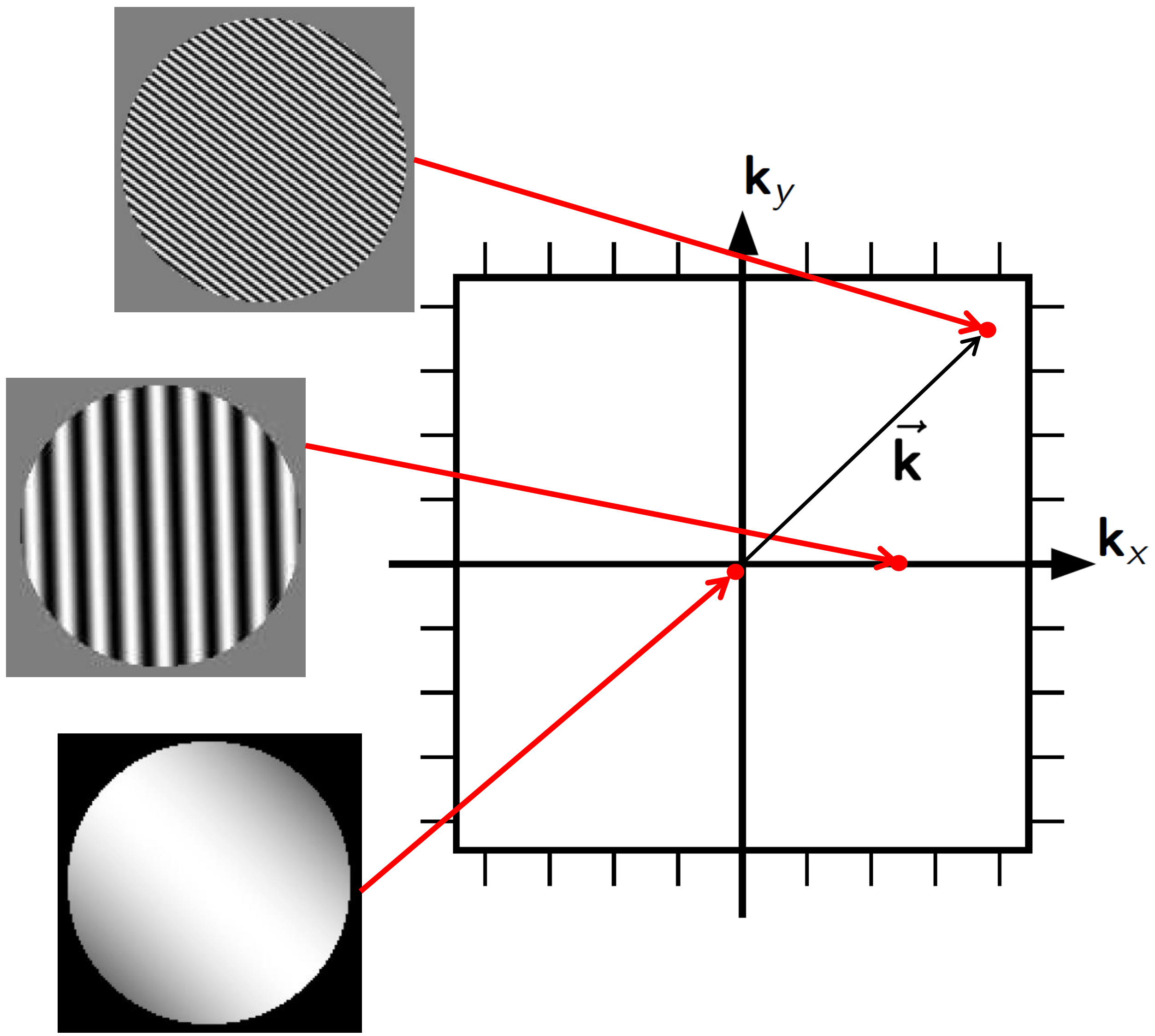
Spatial frequencies sensitivity



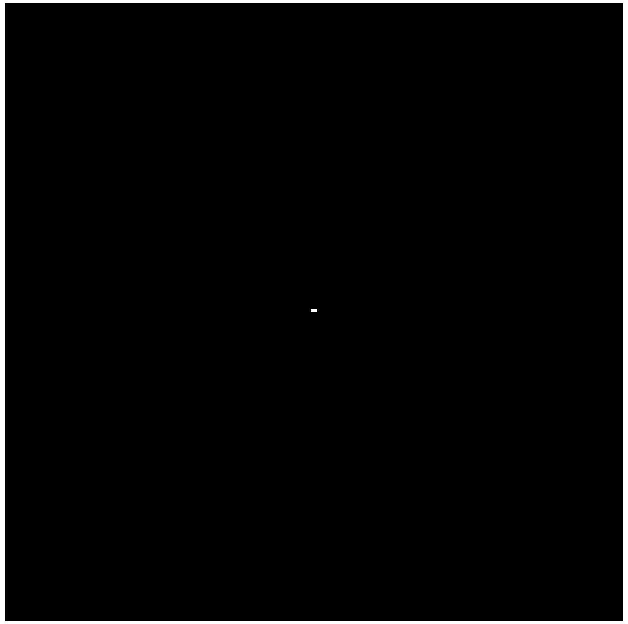
$$\text{Sensitivity} = \frac{||\text{WFS output}||}{||\text{Input phase}||}$$

Fourier basis

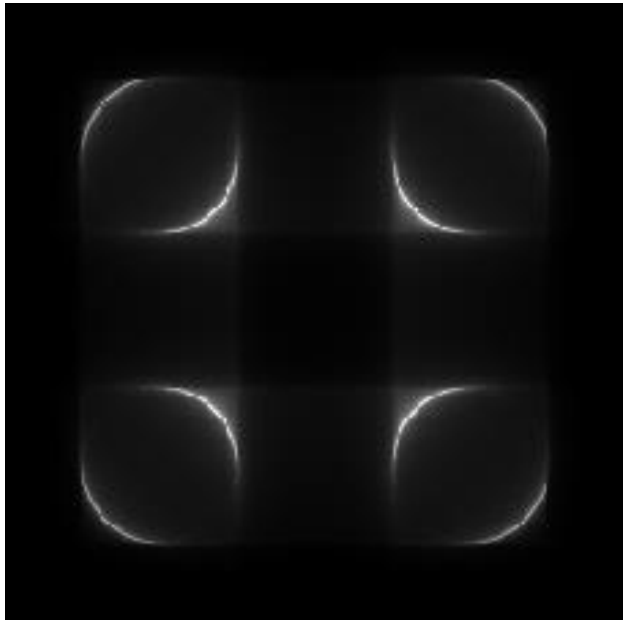
$$\cos\left(\frac{2\pi}{\lambda}\vec{\mathbf{k}}.\vec{\mathbf{r}}\right) \quad \sin\left(\frac{2\pi}{\lambda}\vec{\mathbf{k}}.\vec{\mathbf{r}}\right)$$



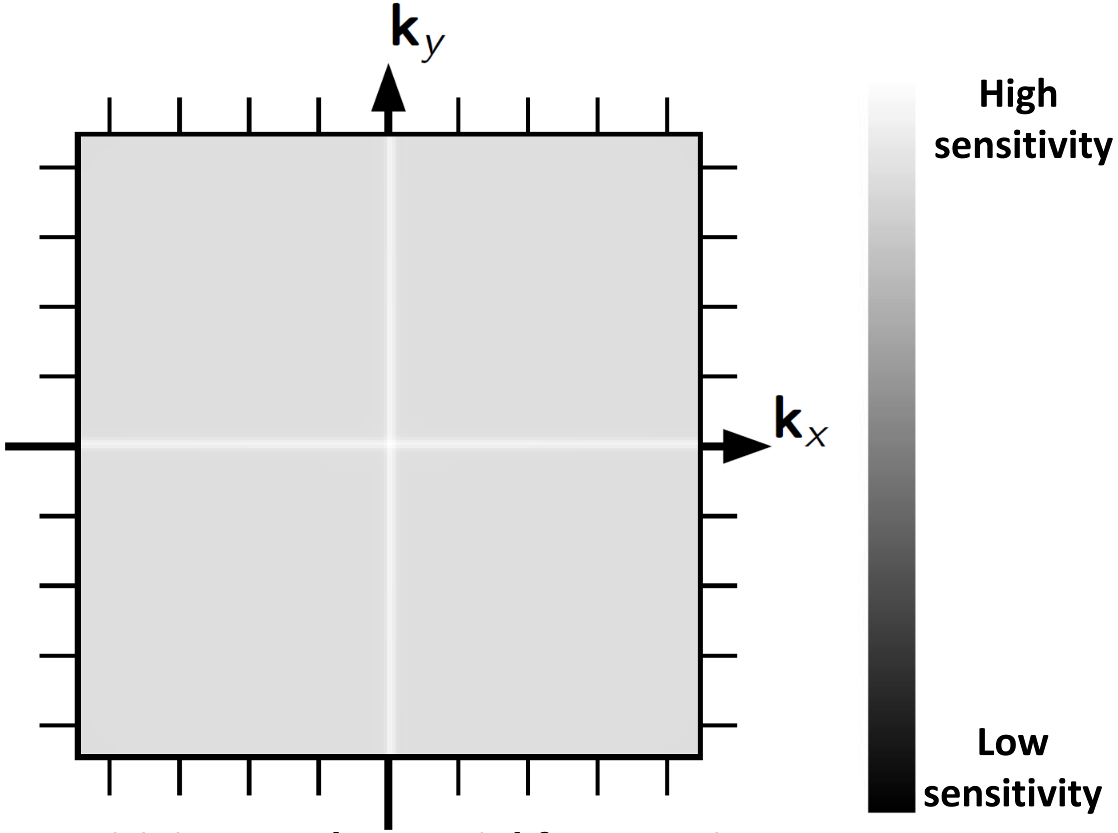
Impact of the modulation radius



Modulation path



Reference intensity



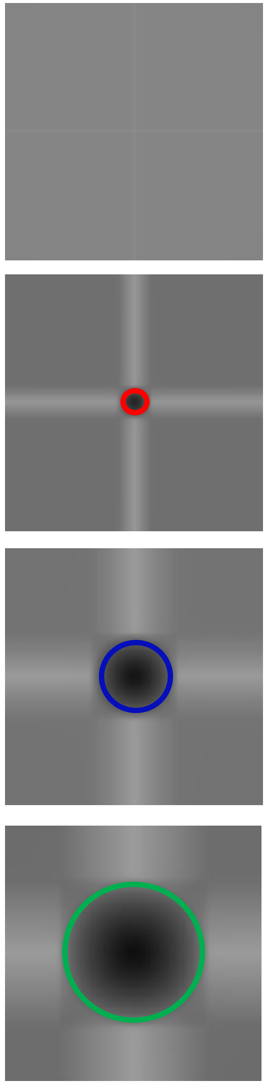
Sensitivity wrt the spatial frequencies

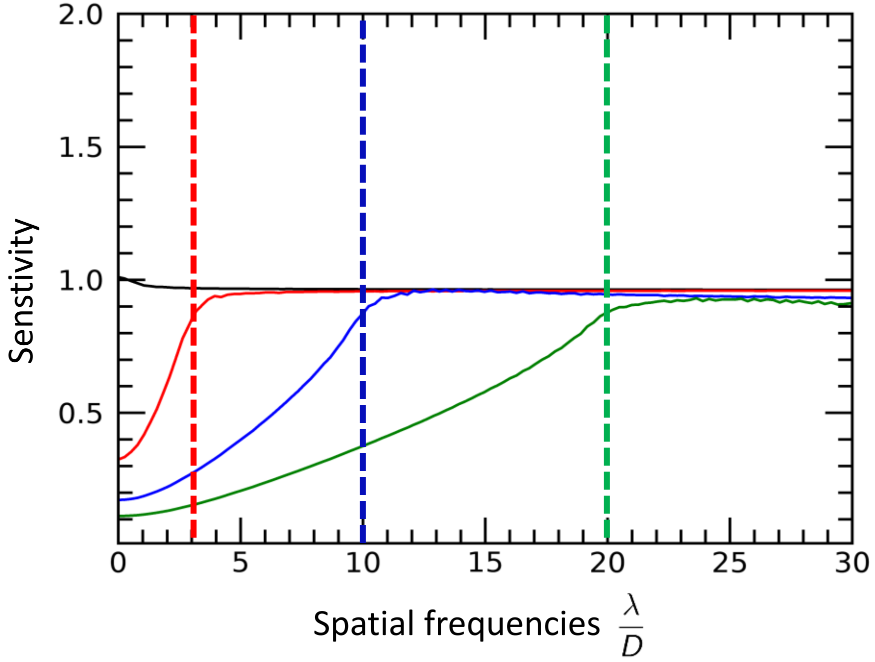
$$r = 0\frac{\lambda}{D}$$

$$r = 3\frac{\lambda}{D}$$

$$r = 10\frac{\lambda}{D}$$

$$r = 20\frac{\lambda}{D}$$





Why ?

$$\Xi_{\mathrm{PY}}(u) = \frac{1}{\pi}\mathrm{FT}\left(p.v.\frac{\sin(\alpha_\lambda x)}{\alpha_\lambda x^2}\right)$$
$$= \begin{cases} -\mathrm{i}\,\mathrm{sgn}(u) & \text{for } |u| > \frac{\alpha}{\lambda}, \\ -\frac{\mathrm{i}\lambda}{\alpha}u & \text{for } |u| < \frac{\alpha}{\lambda}. \end{cases}$$

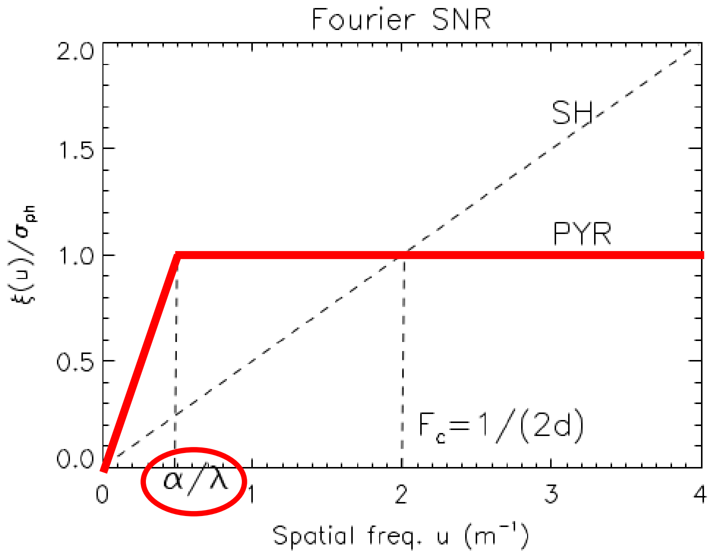


Fig. 3. Fourier SNR curves for the SHS with quad-cells (dashed line) and for the Pyramid sensor (solid line). Sub-aperture size $d = 0.25$ m.

Vérinaud 2004

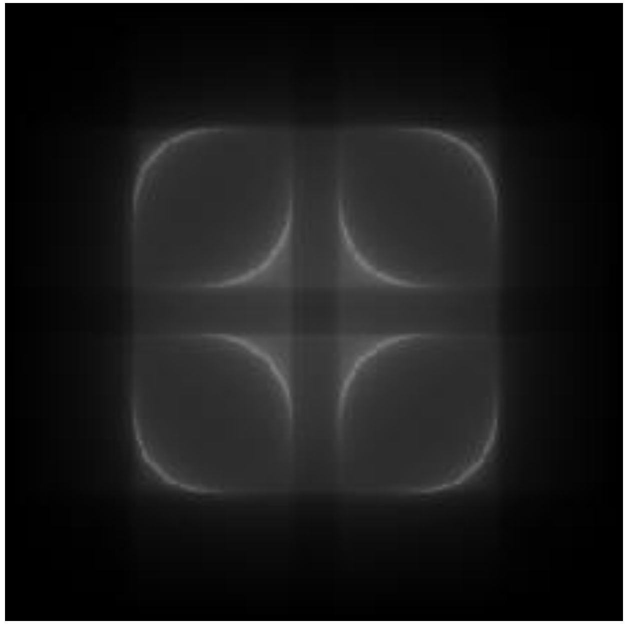
Two regimes:

- -LF: slope sensor
- -HF: phase sensor

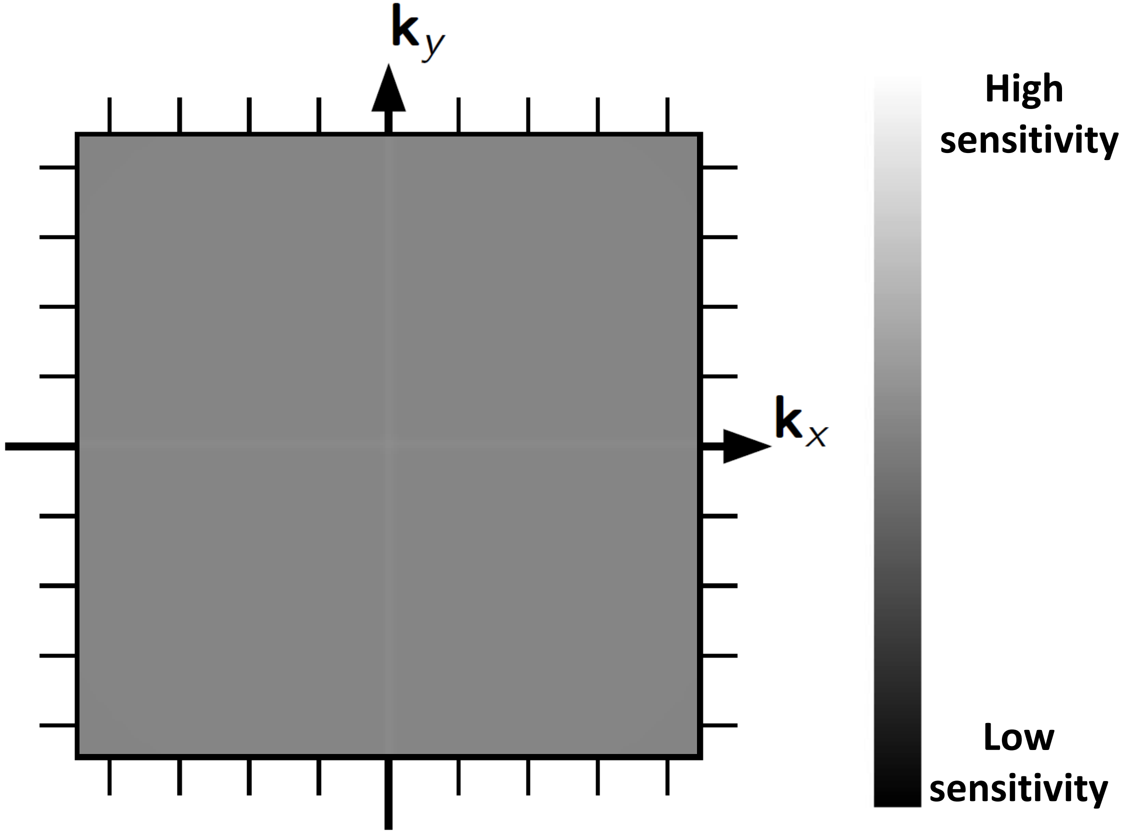
Modulation radius = transition frequency

What remains to understand…

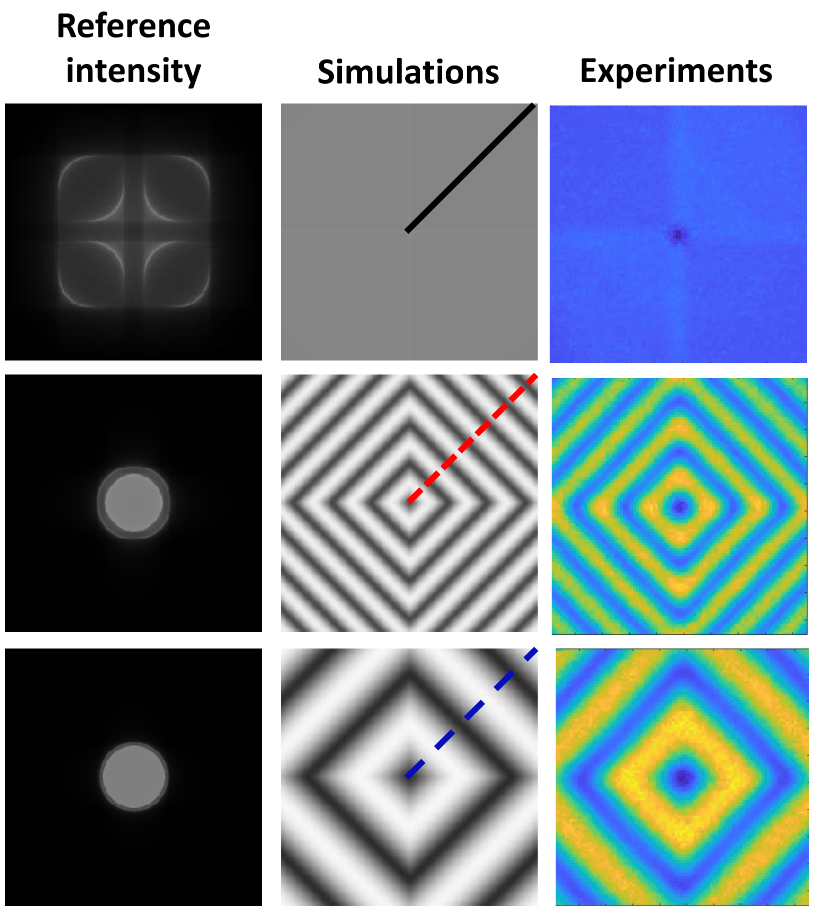
Impact of the pyramid angle

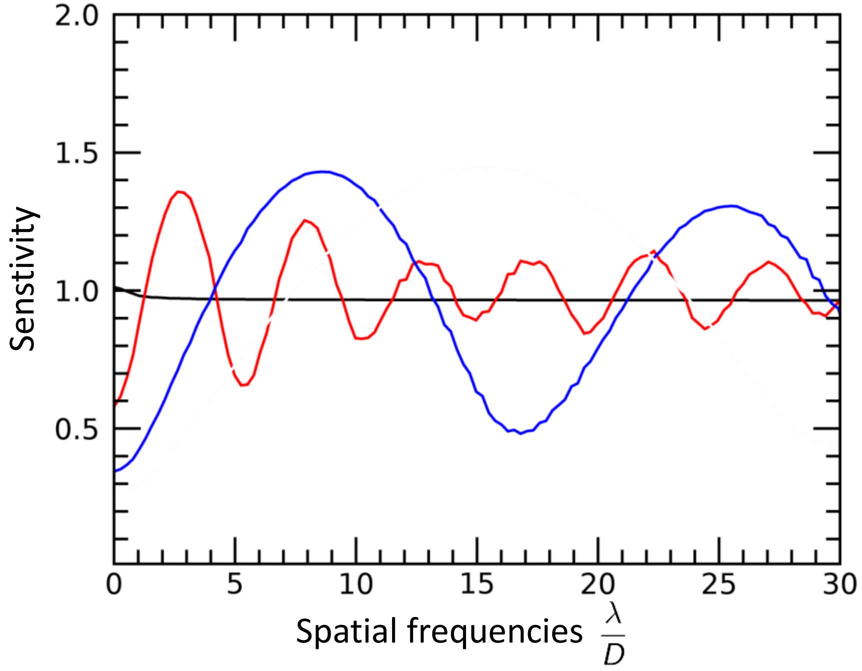


Reference intensity



Sensitivity wrt the spatial frequencies



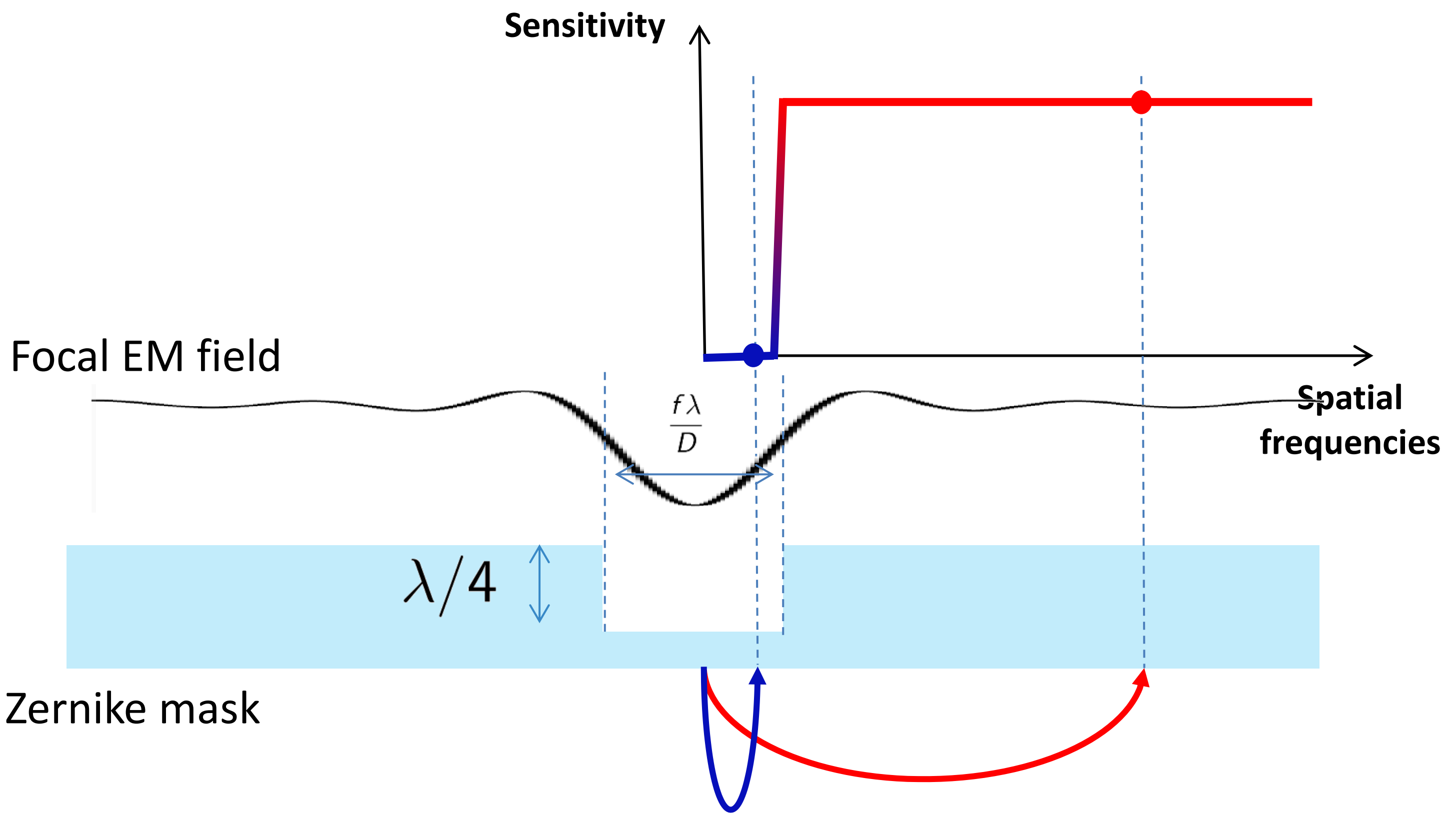


Oscillations ? Period(angle) ?

Sensitivity peaks ?

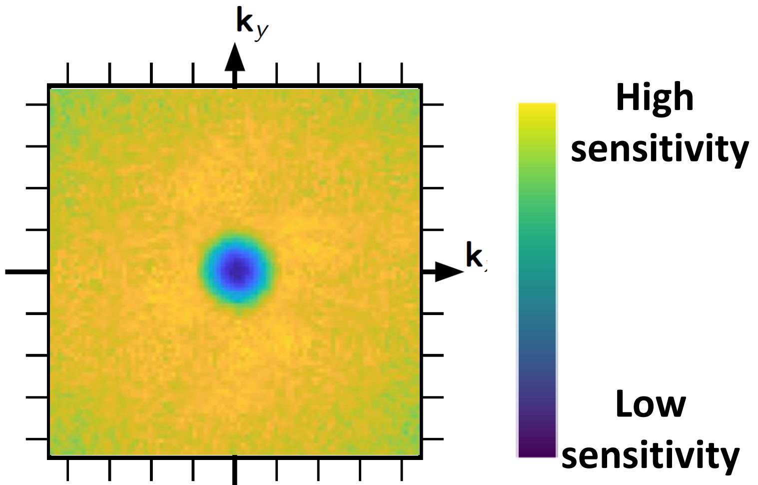
Why constant sensitivity for the classical ?

Help from another Fourier filtering WFS



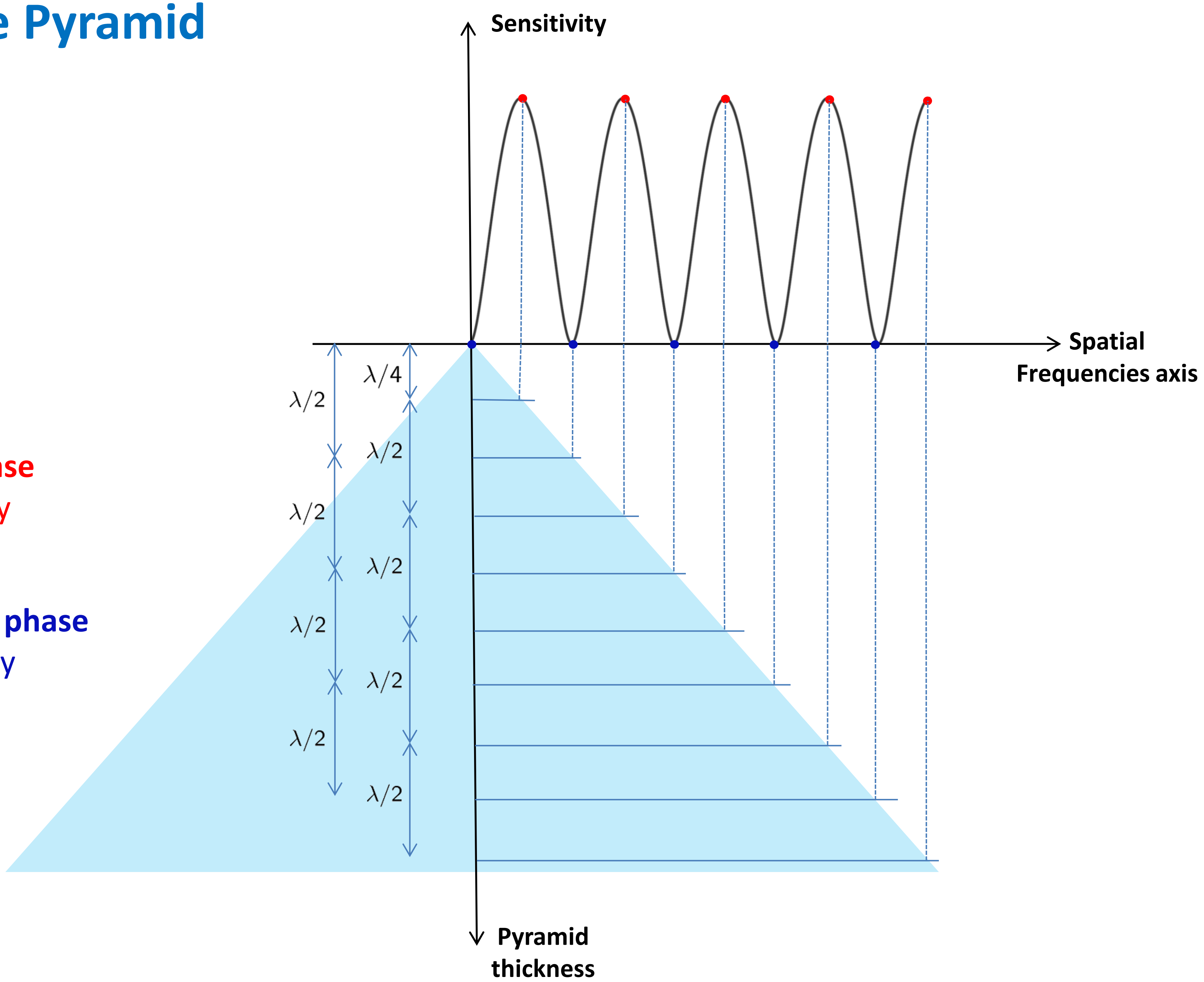
Quadrature of phase
-> Constructive interference
-> High sensitivity

Phase/Opposition of phase
-> No/destructive interference
-> Low sensitivity



Zernike sensitivity
wrt the **spatial frequencies**

Application to the Pyramid



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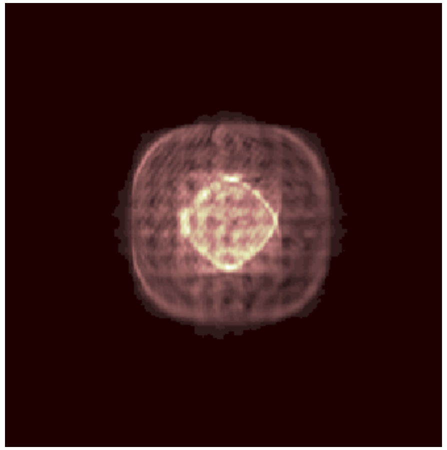
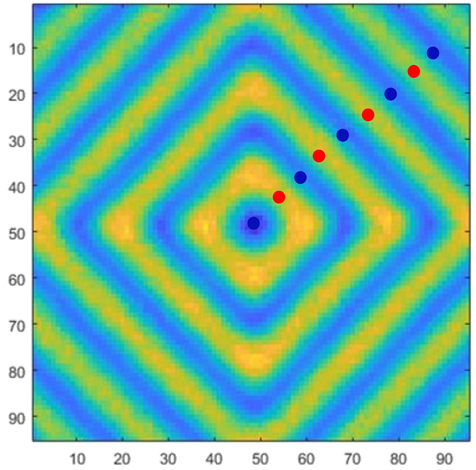
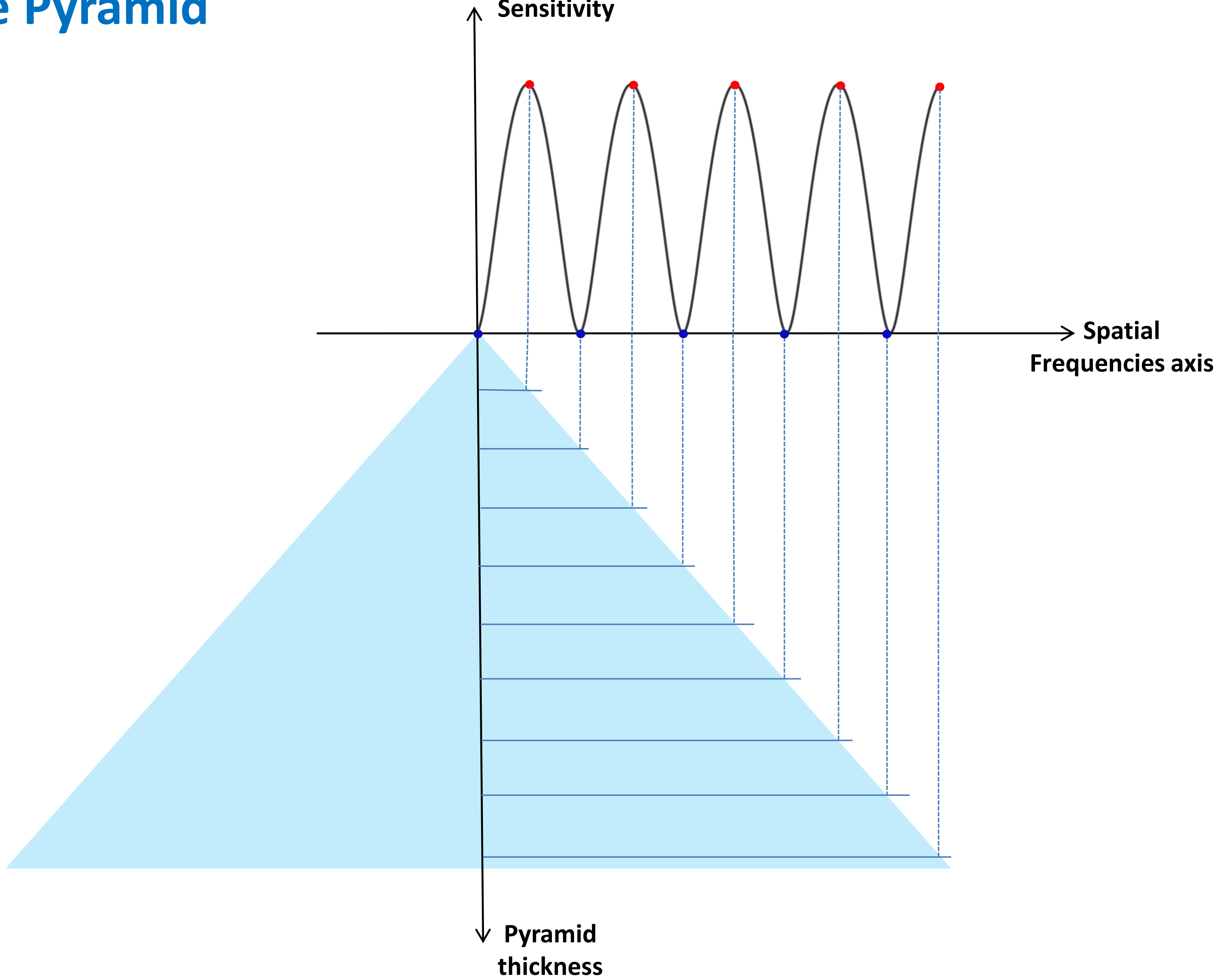
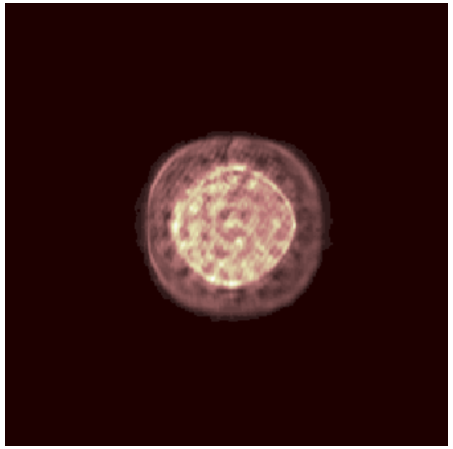
Application to the Pyramid

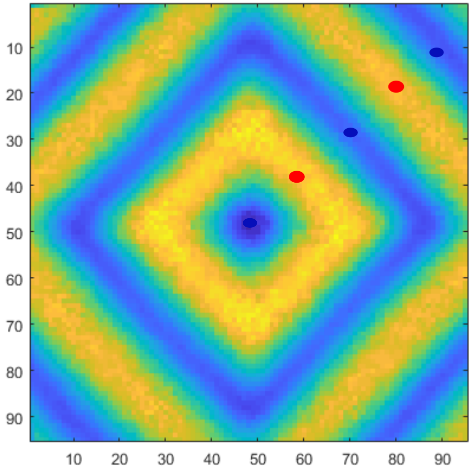


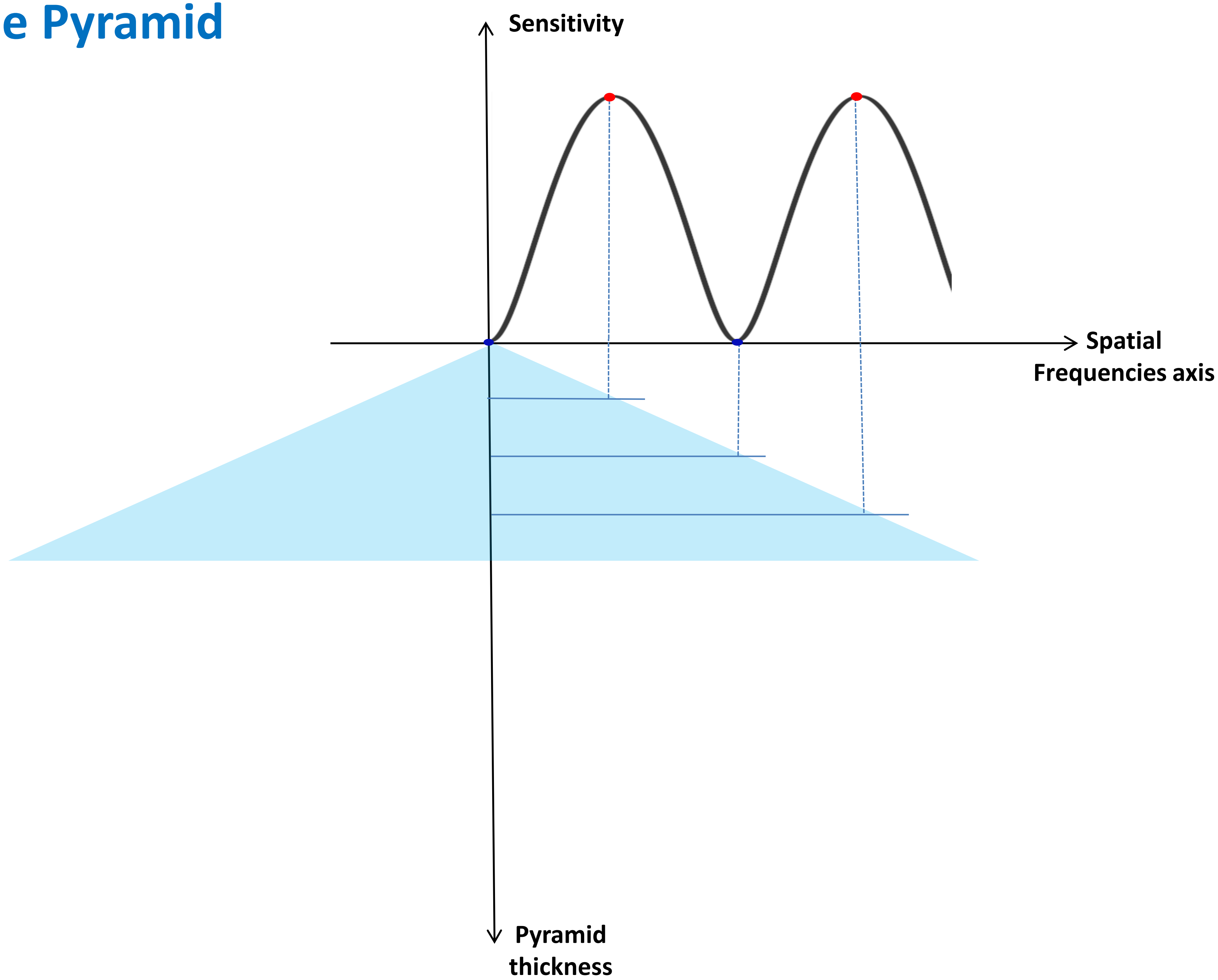




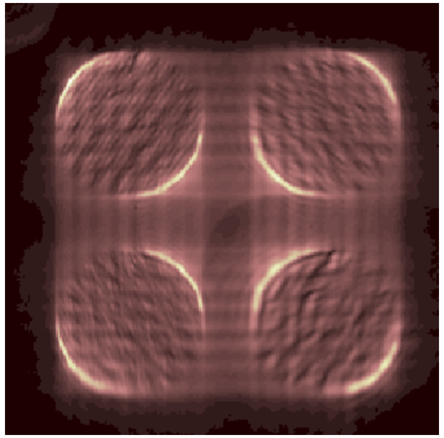
Application to the Pyramid

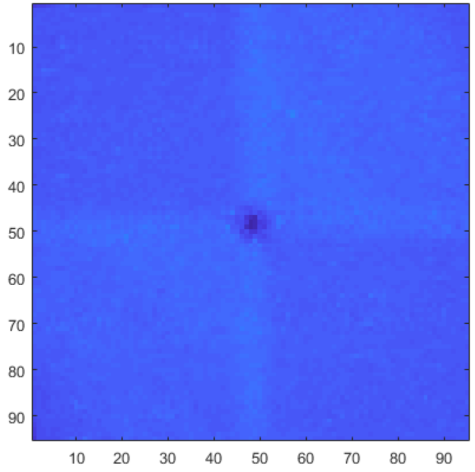


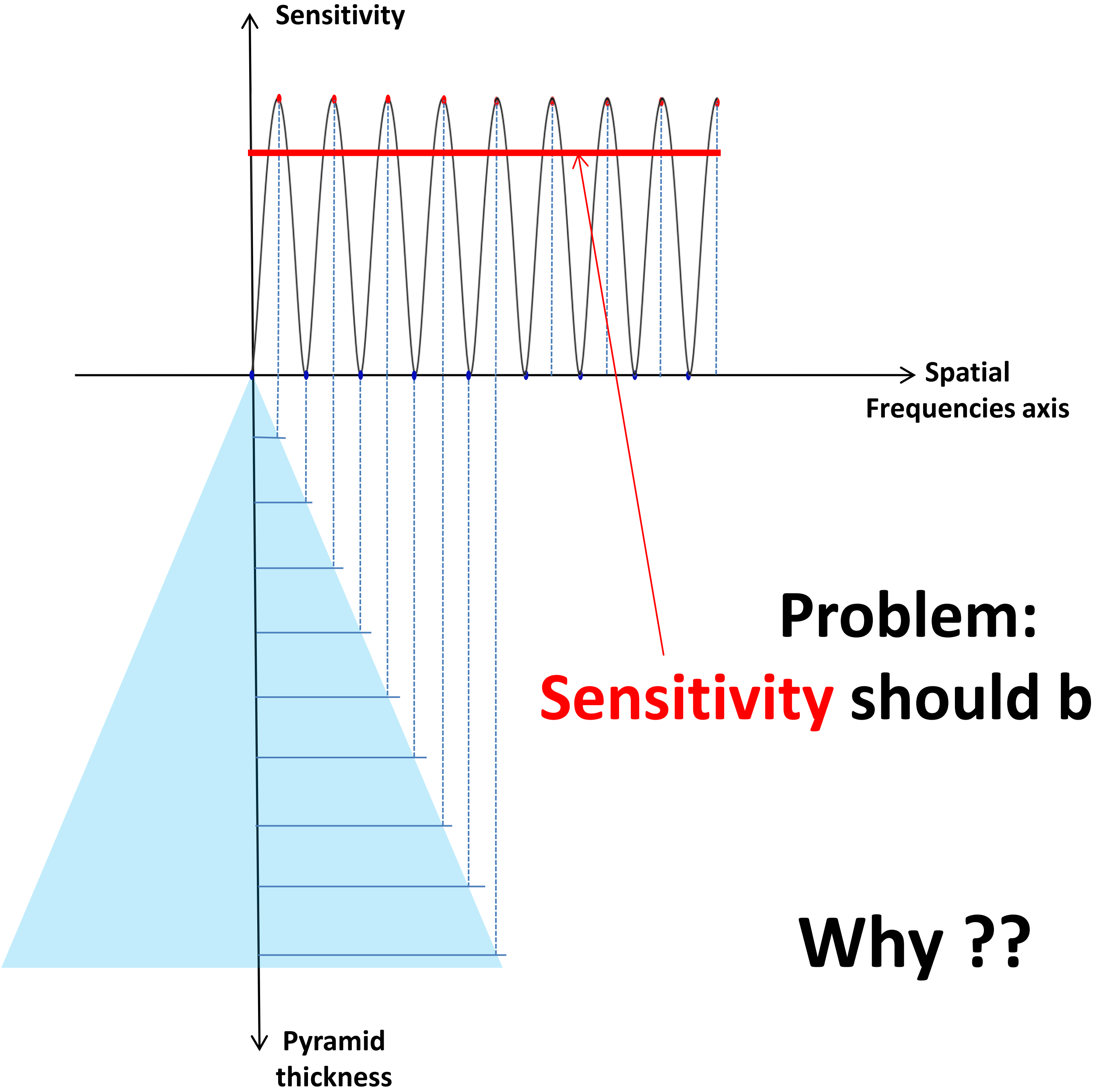




Application to the Pyramid







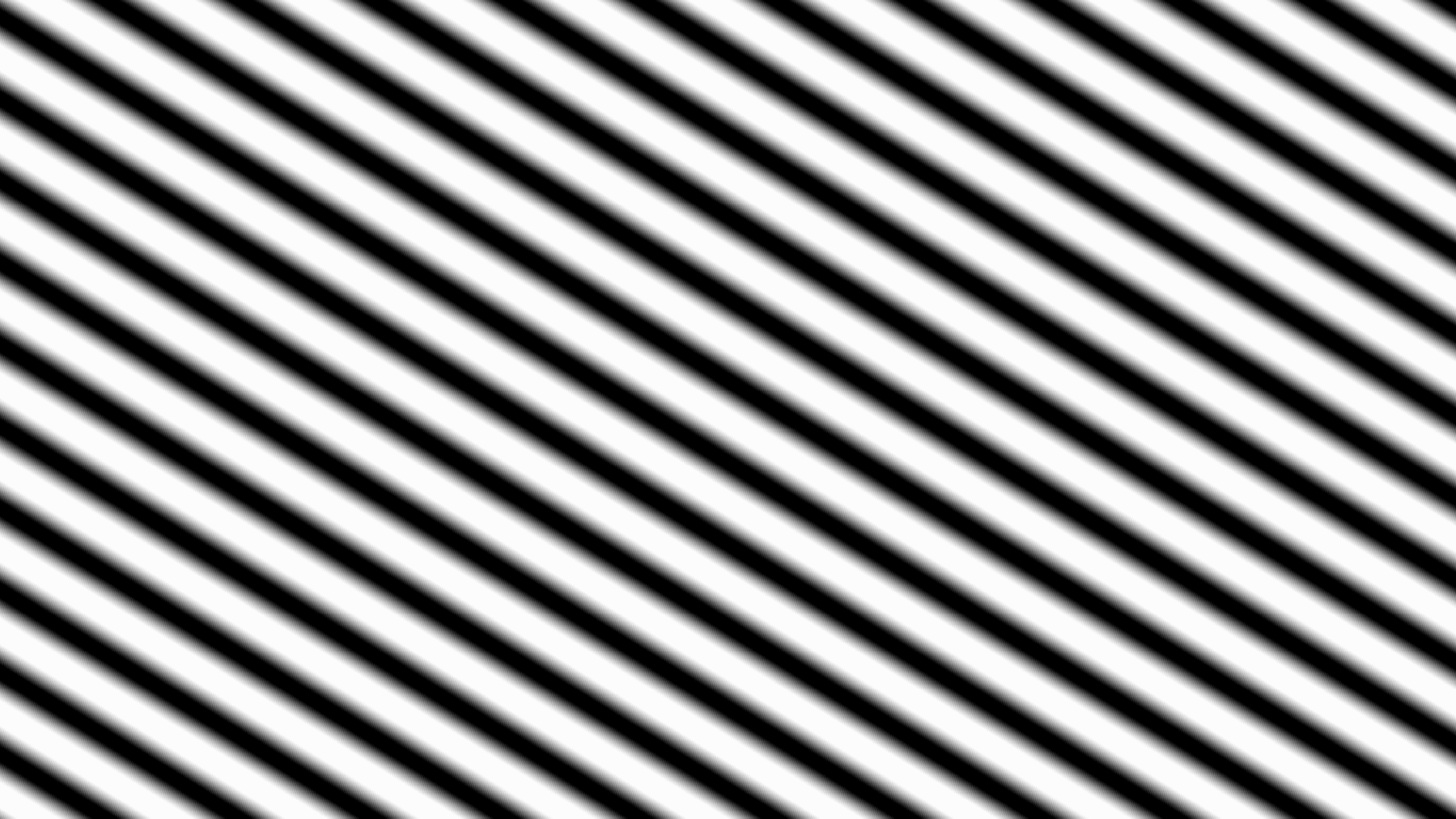
Problem:

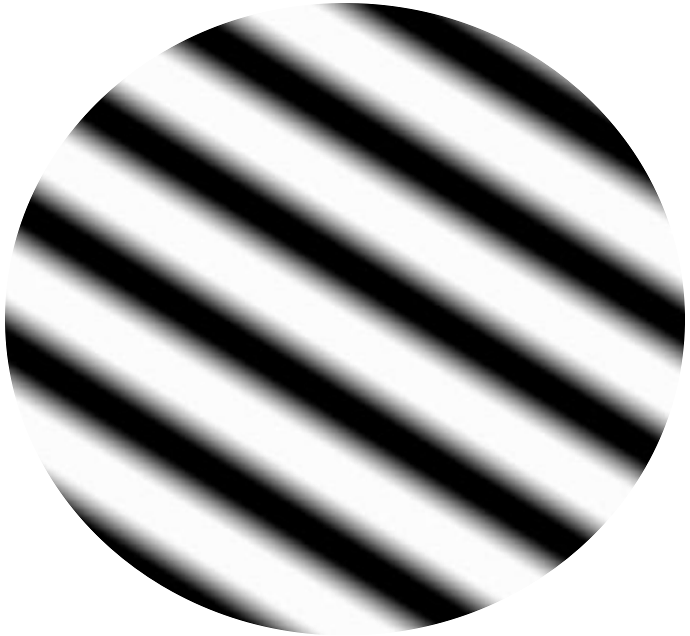
Sensitivity should be flat !

Why ??

Because…

(Sorry for the next slide…)

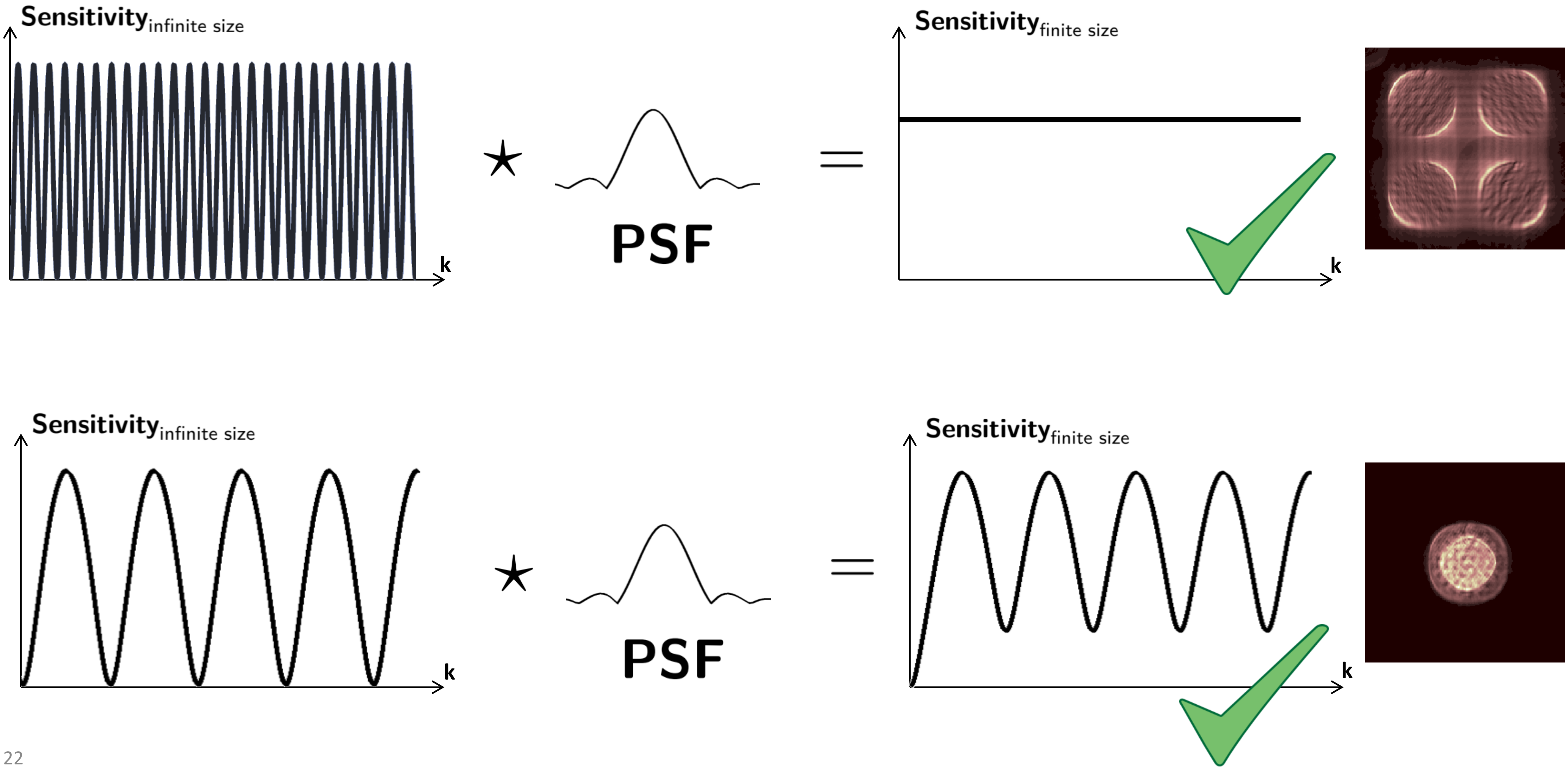




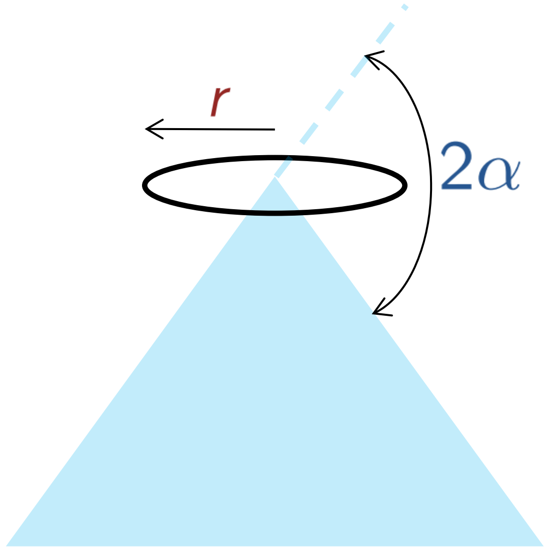
We have to take into account the finite size of the pupil !

-> Not pure spatial frequencies ! $\mathbb{I}_P(\vec{\mathbf{r}}) \cos\left(\frac{2\pi}{\lambda}\vec{\mathbf{k}}.\vec{\mathbf{r}}\right)$

$$\textbf{Sensitivity}_{\text{infinite size}} \star \textbf{PSF} = \textbf{Sensitivity}_{\text{finite size}}$$


Sensitivity$_{\text{infinite size}}$
k
PSF
Sensitivity$_{\text{finite size}}$
k
Sensitivity$_{\text{infinite size}}$
k
PSF
Sensitivity$_{\text{finite size}}$
k

Analytical formula
of the sensitivity



Oscillations

$$\textbf{Period} = \frac{2\pi}{\alpha}$$

$$\textbf{Sensitivity}_{\text{infinite size}}(\mathbf{k}) = \begin{cases} \frac{\mathbf{k}}{r}\left|\sin(\alpha\mathbf{k})\right| & \mathbf{k} \leq r \\ \left|\sin(\alpha\mathbf{k}) + \mathrm{sinc}(\alpha r)\sin[(r-\mathbf{k})\alpha]\right| & \mathbf{k} > r \end{cases}$$

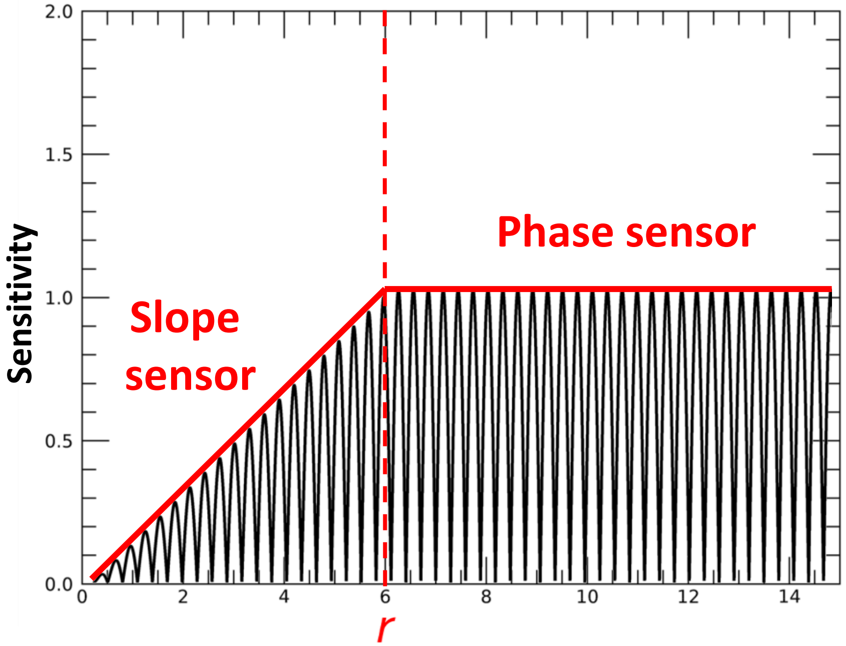
Two regimes

Slope/phase

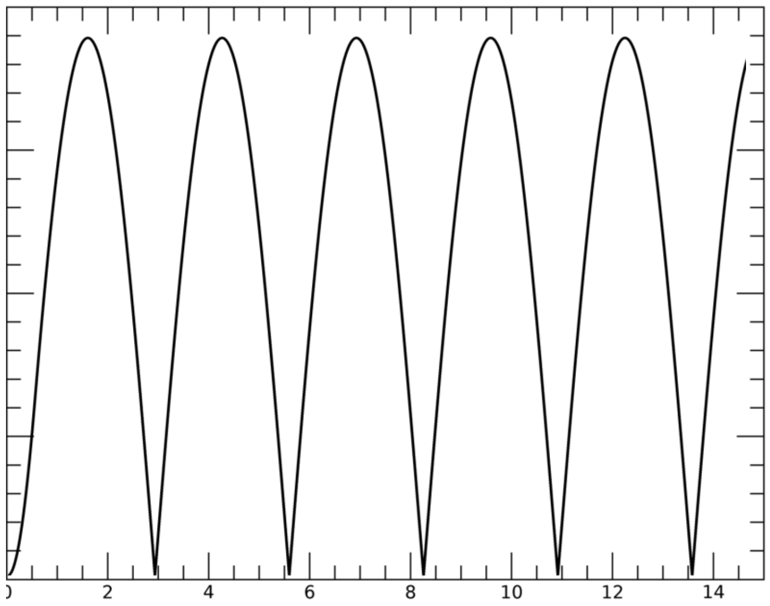
Flattened Pyramid term !

Non negligible if αr << 1 → **Enhanced sensitivity !**

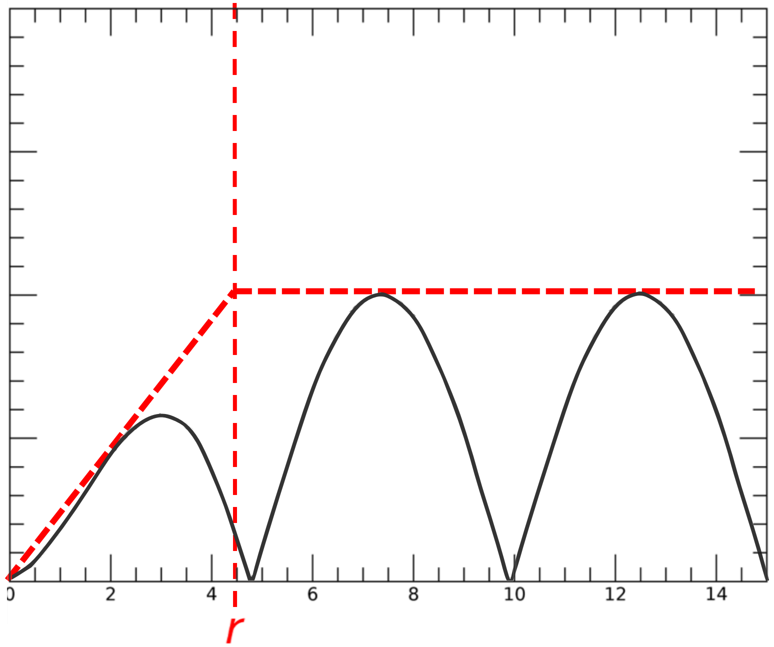
Classical modulated PWFS



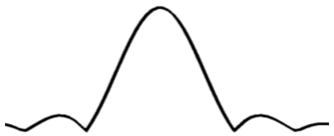
Flattened PWFS



Flattened & modulated PWFS



Do not forget to ★



PSF

Conclusion

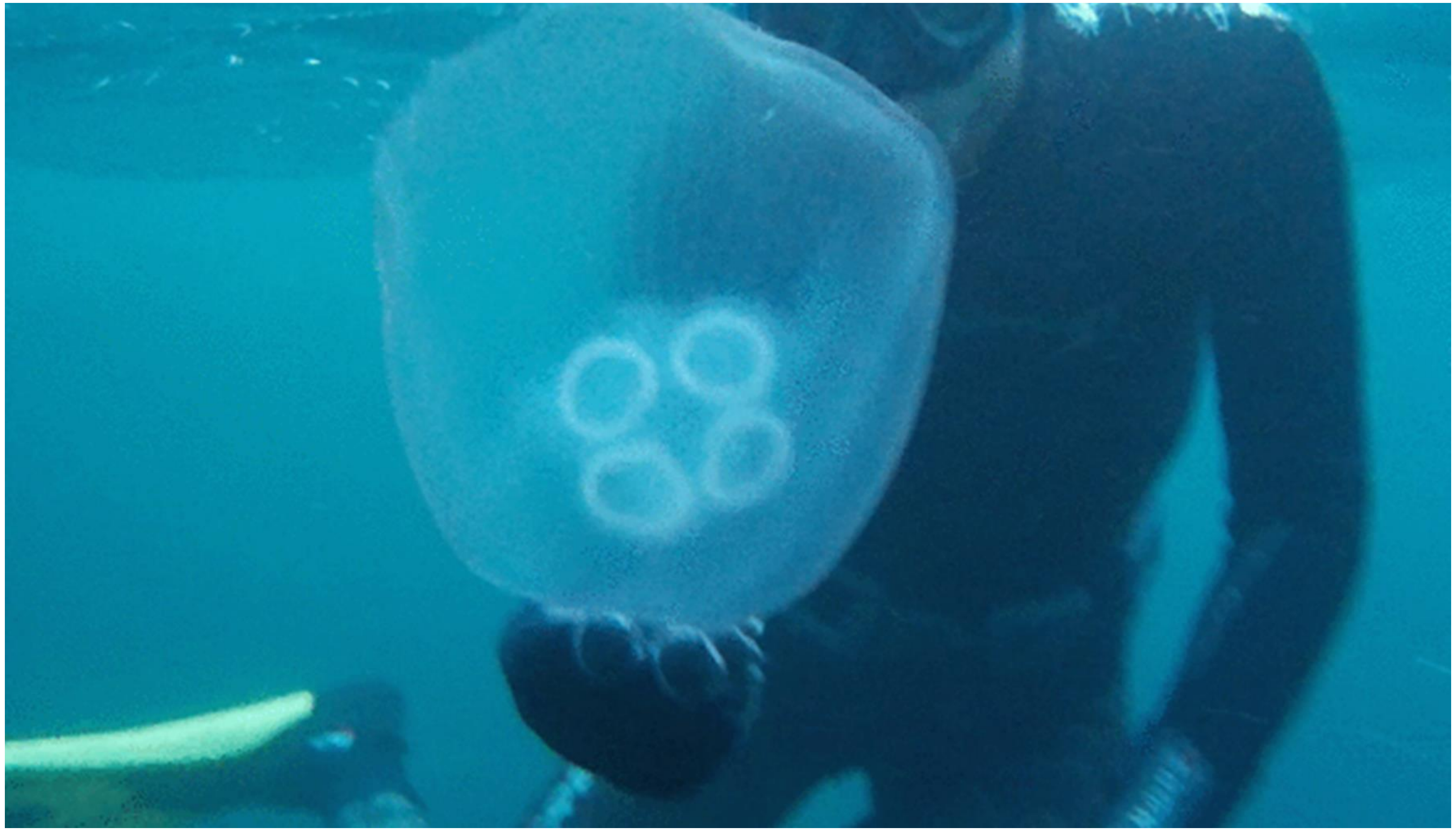
A new way to understand the Pyramid sensitivity

Major role of the constructive/destructive interference

Analytical formula(**modulation & angle**)

-> Explains the oscillations !

Flattened Pyramid: ready to be used !



Picture: *Cédric Taïssir Héritier*

***Aurelia aurita* jellyfish**

or 4-sided Pyramid ?

Thank you for your attention