Métamatériaux à biréfringence extraordinaire pour le THz, le µonde et le visible

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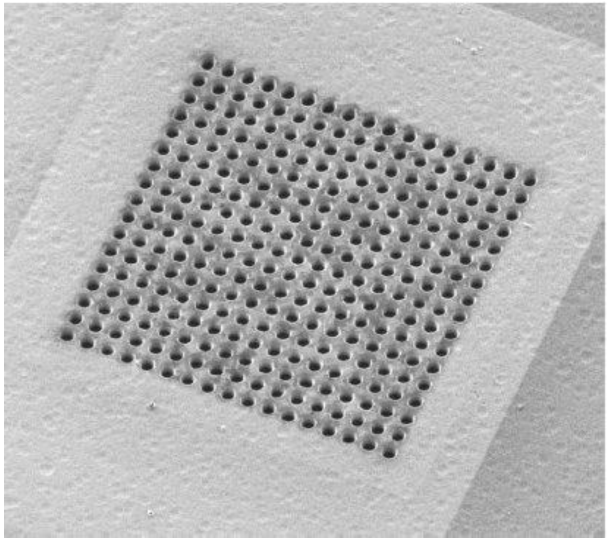
Université Mouloud Mammeri Tizi Ouzou, Algérie

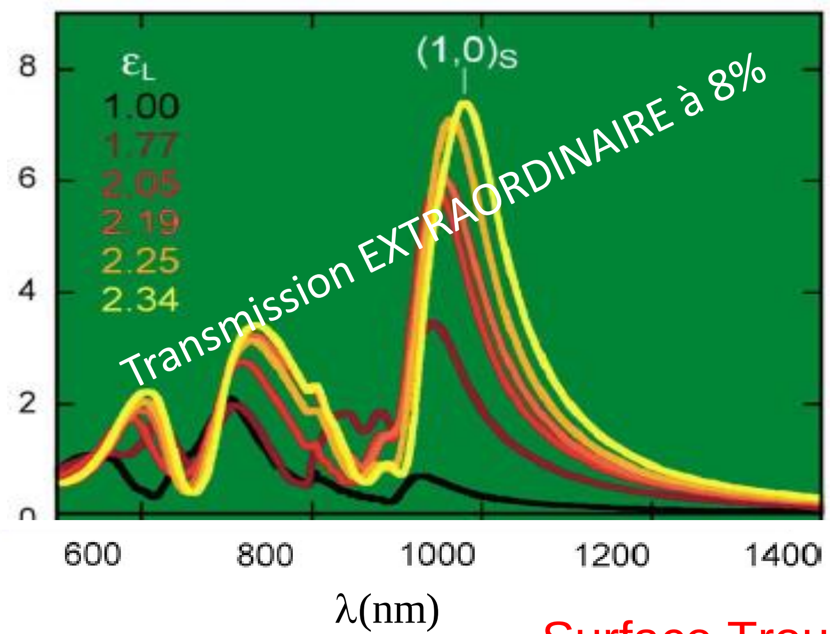
Contexte:

MÉTAMATÉRIAUX À TRANSMISSION EXTRAORDINAIRE

Réseaux d'ouvertures sub-λ dans un écran opaque avec transmission collective > somme des transmissions par chaque ouverture



Film en Or
Epaisseur : 250nm
Rayon : 100nm
Période : 600nm



$$\frac{\text{Surface Trous}}{\text{Surface totale}} = 8\%$$

T. Ebbesen *et al*, Nature 391, 667-69 (1998)
Phys. Rev. + JOSA + OC + …..

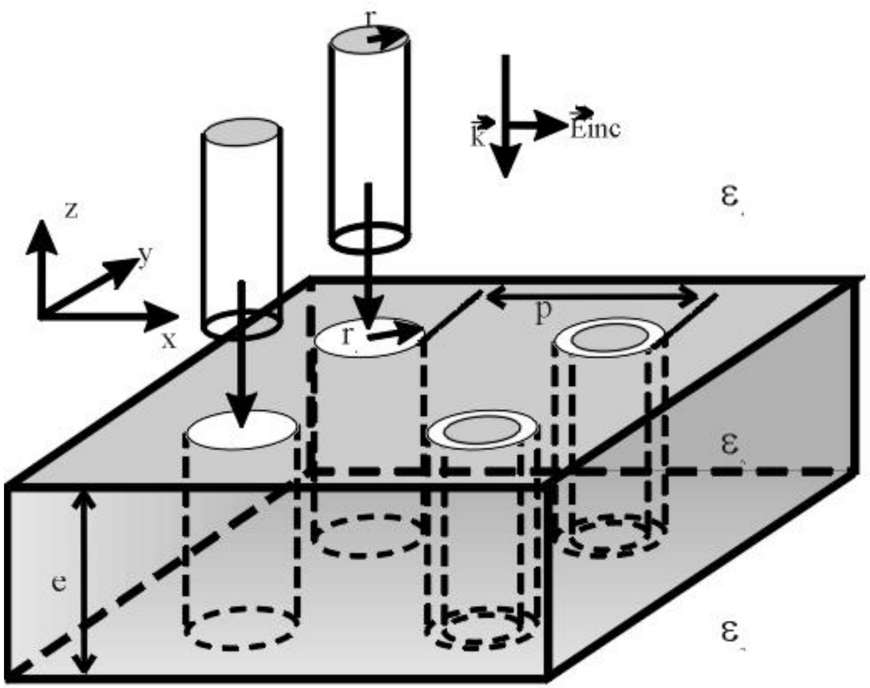
femto-st SCIENCES & TECHNOLOGIES

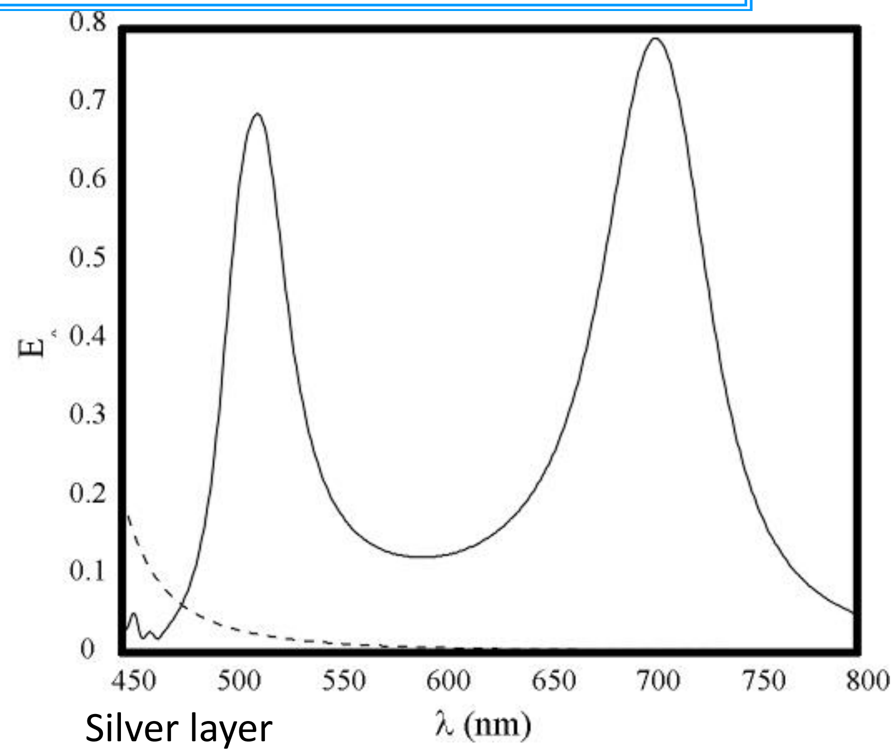
Contexte:

Ouvertures coaxiales!

Transmission by guided mode through the aperture

Because coaxial waveguide has a guided mode (TEM mode) without cutoff

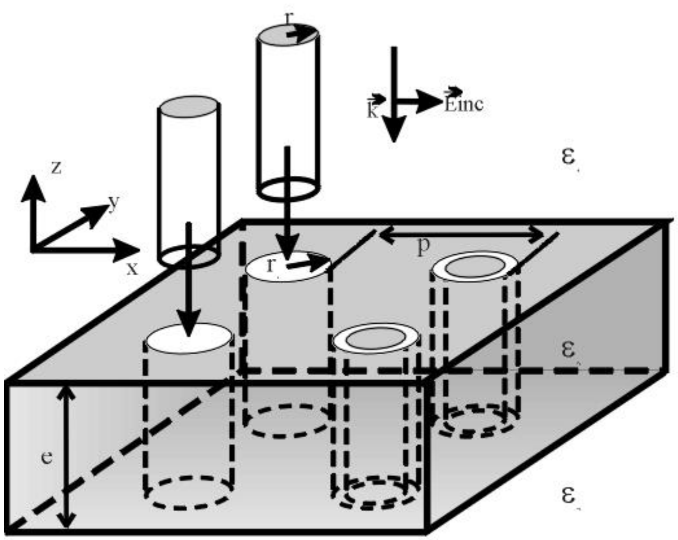


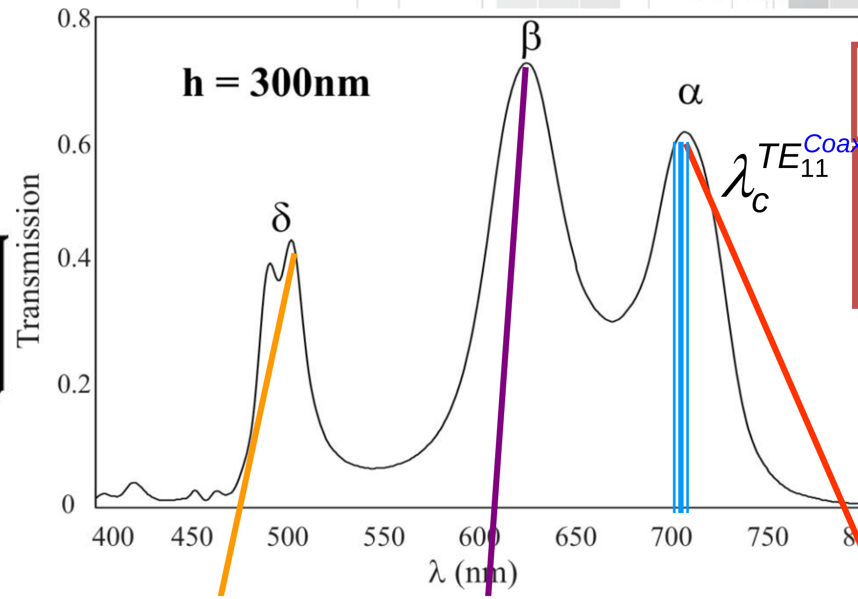


Silver layer
Thickness : 150nm
Inner radius Ri = 50nm
Outer radius Re= 75nm
Period : 300nm

F. Baida et D. Van Labeke, Opt.Commun., **209** (2002) 17-22.
A. Moreau et al., Opt. Express, **11** (2002) 1131-1136.
F. Baida et al., PRB, **67** (2003) 155314.
W. Fan et al., Phys. Rev. Lett. 94 (2005) 33902.

Contexte:





Peak $\alpha, \forall h$

Peaks $\beta, \delta, \ldots$

Fabry – Perot

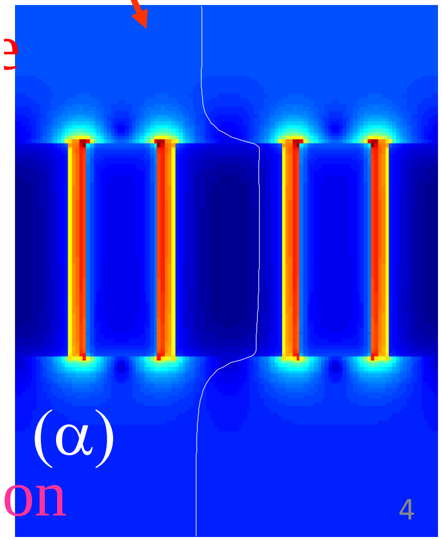
Silver structure

$\varepsilon_d = \varepsilon_l = 1$

a = 300 nm

Re=75nm

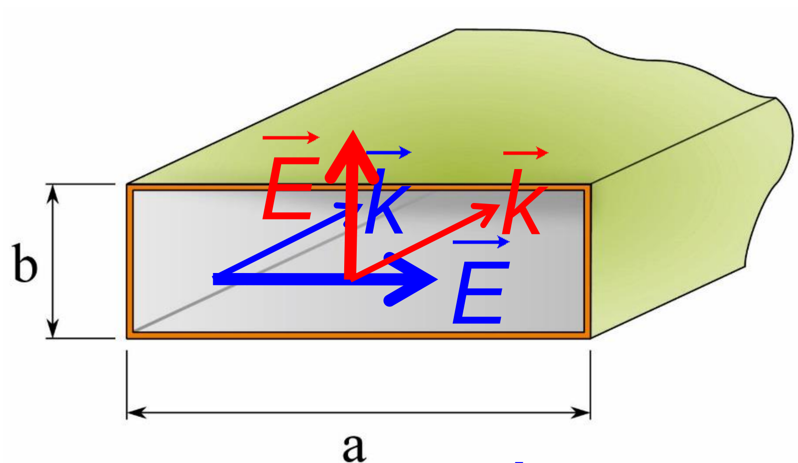
Ri=50nm



F. Baida et D. Van Labeke,
Opt. Communications 209 **(2002)** 17-22.

Motivation: THz pas d'absorption

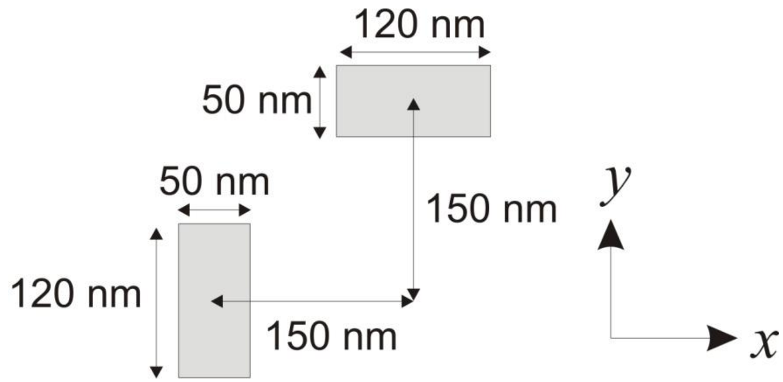
Thz and microwave metamaterials: anisotropic plates

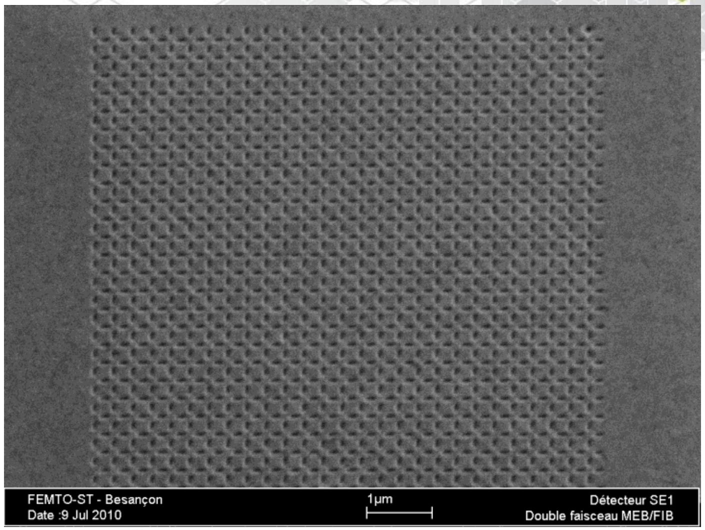


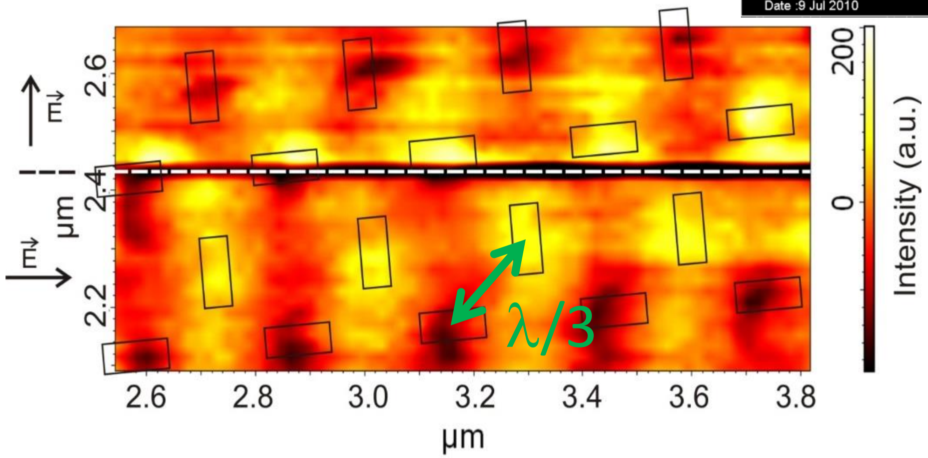
$$\lambda_c^{TM_{11}} = \frac{2ab}{\sqrt{a^2 + b^2}}$$

$$\lambda_c^{TE_{10}} = 2a > \lambda_c^{TM_{11}}$$

Adressage sub-λ (fab. & carac.)

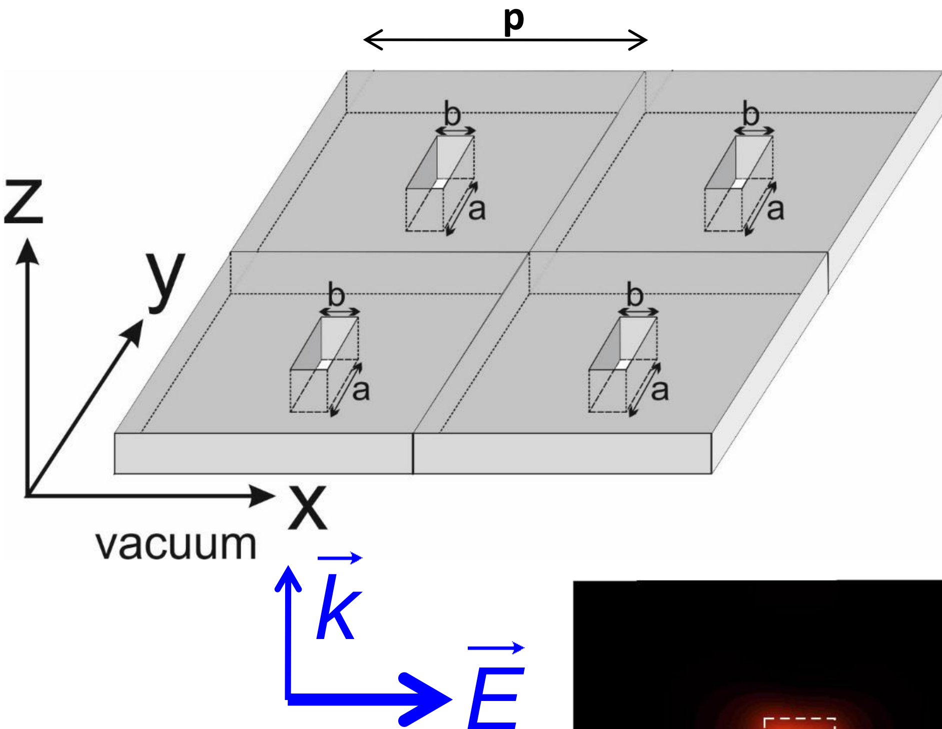


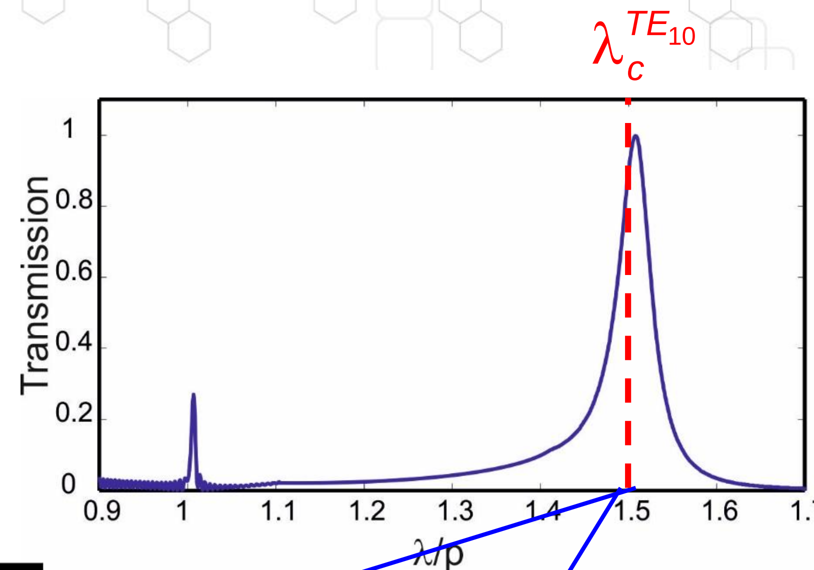


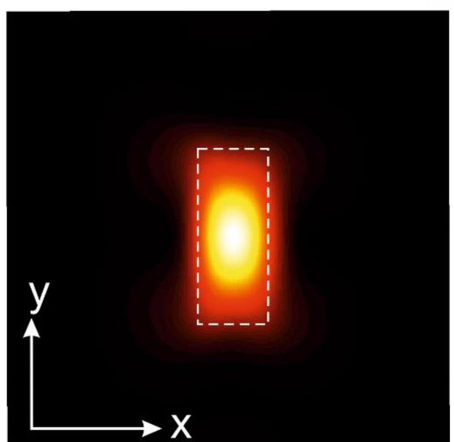


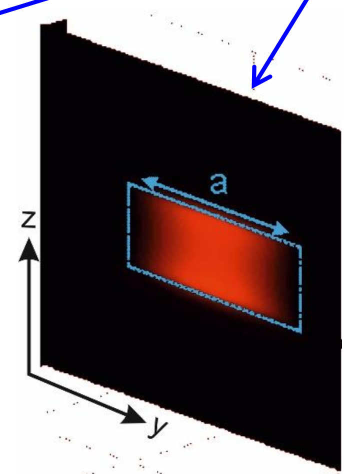
A. Ndao et al., Appl. Phys. B, 106 (2012) 857-862

Lames polarisantes



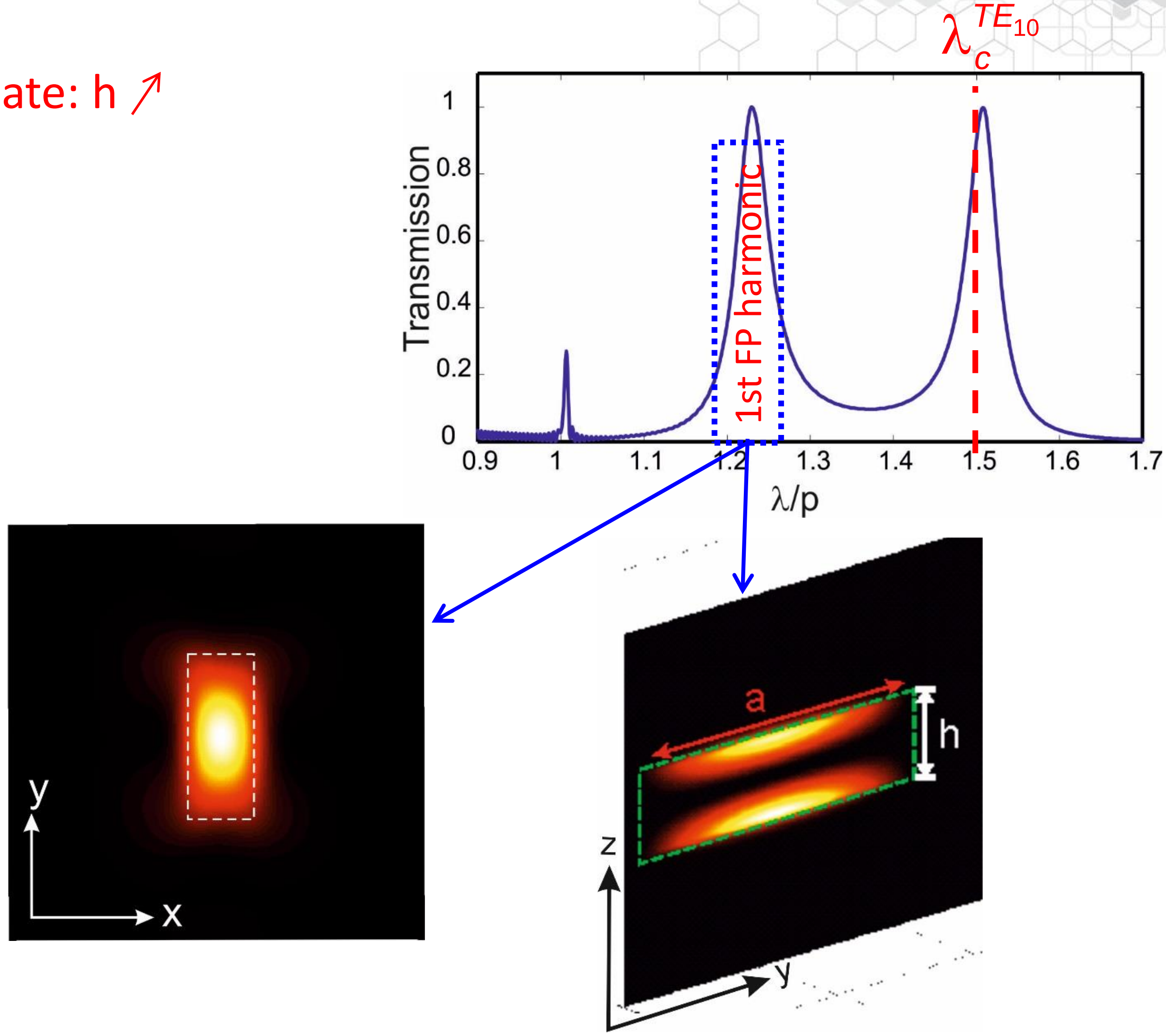




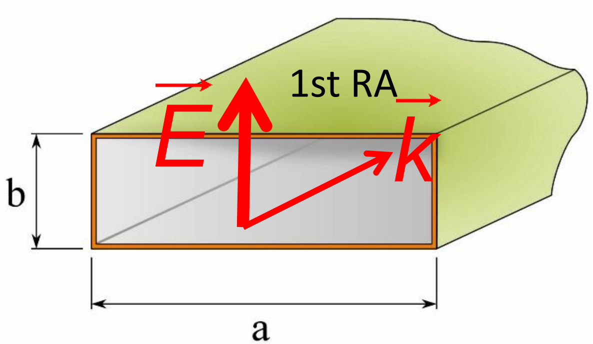


Lames polarisantes

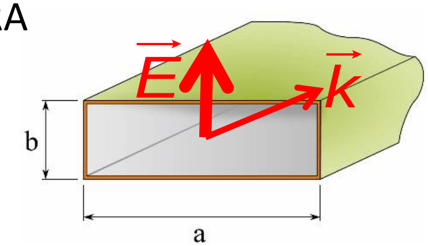
Thicker plate: h ↗

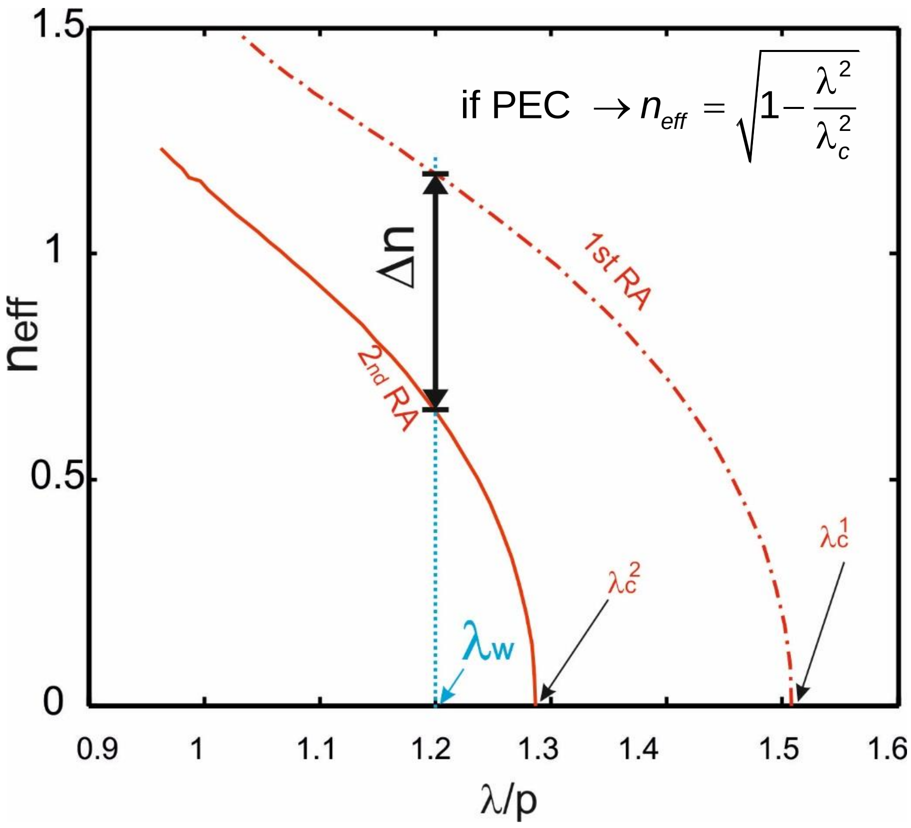


Anisotropie artificielle

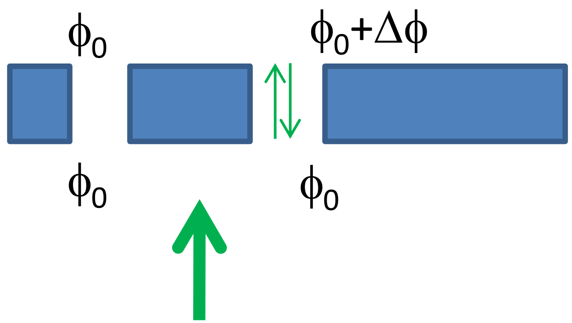


2nd RA



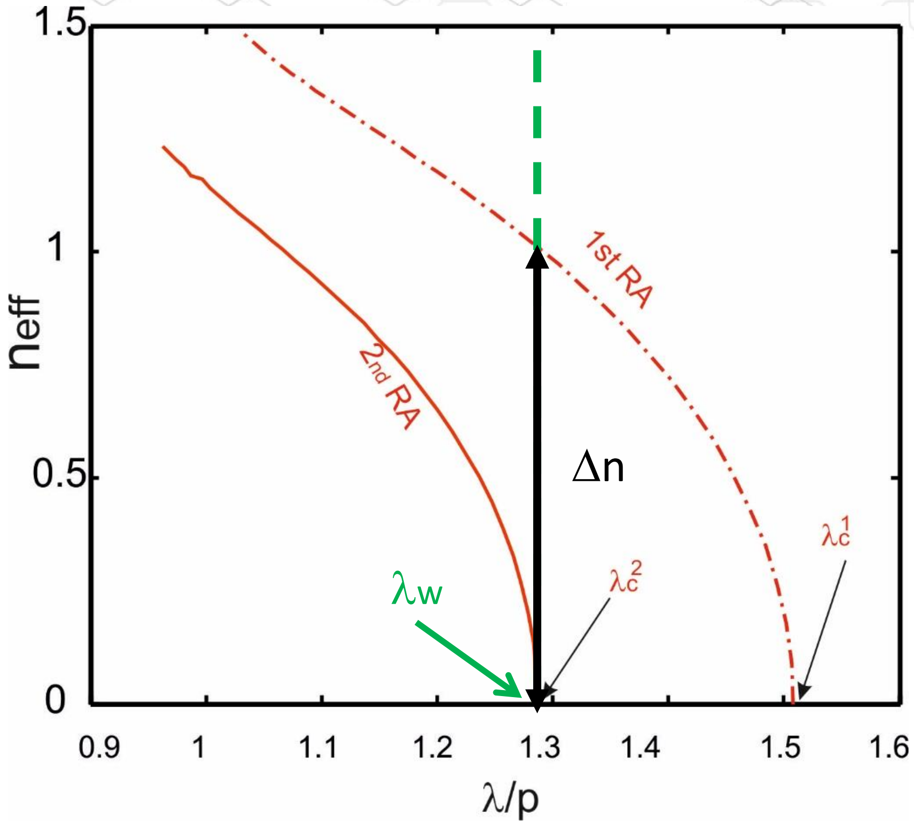


Anisotropie artificielle

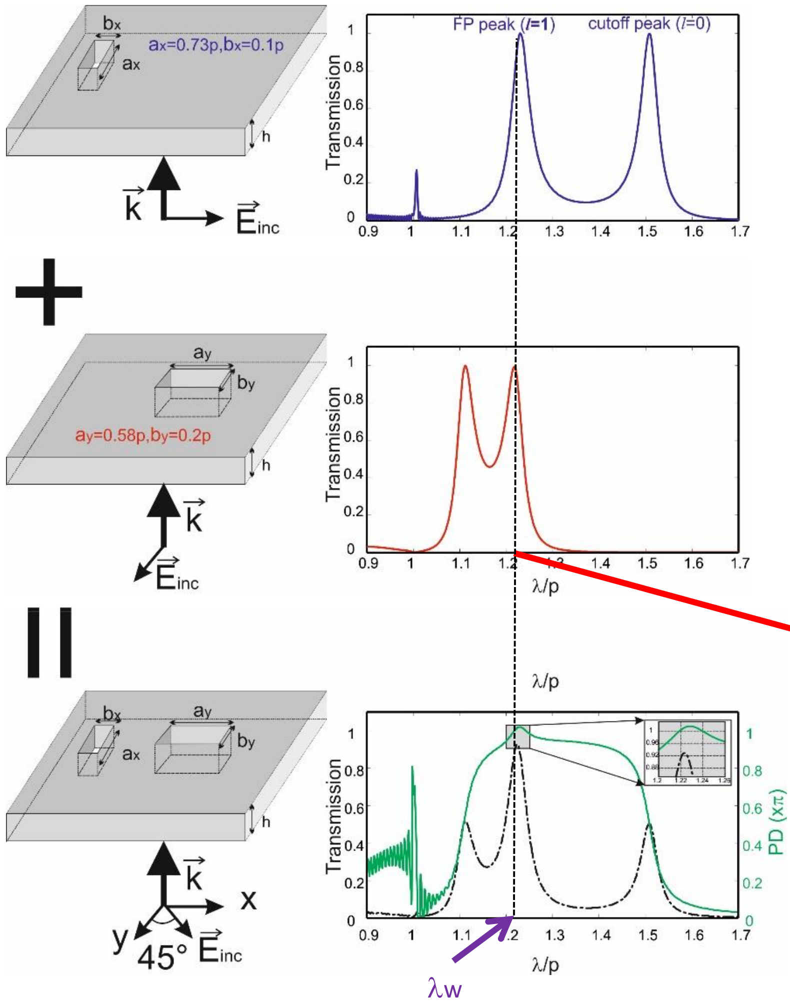


if $\lambda_w = \lambda_c^2 \rightarrow$ efficient transmission through the small aperture + Δn is max + efficient transmission through the large aperture $\rightarrow$ FP harmonic at λ_w

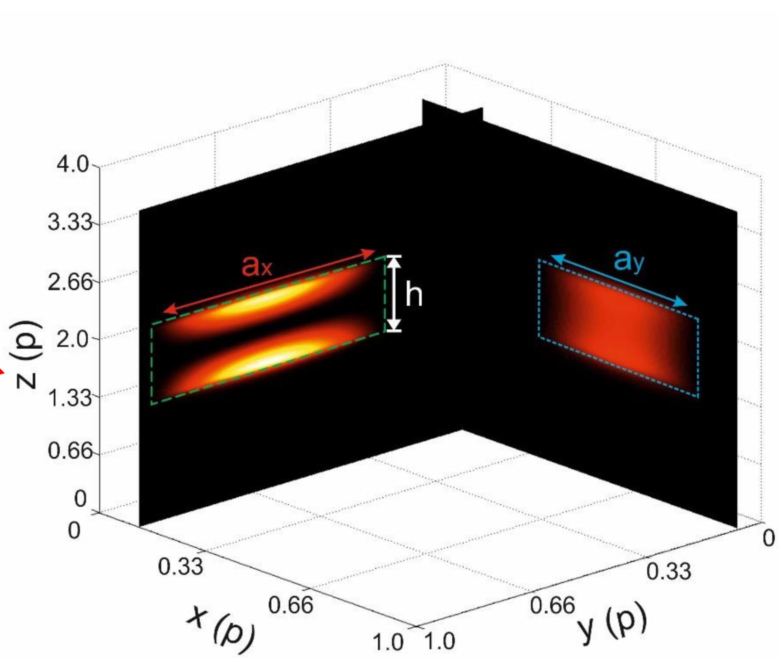
$$\Delta\phi = \frac{2\pi h \Delta n}{\lambda_w} = \pi$$



Lames $\lambda/2$ THz



half-wave plate with 92% transmission & $\Delta n=0.76$

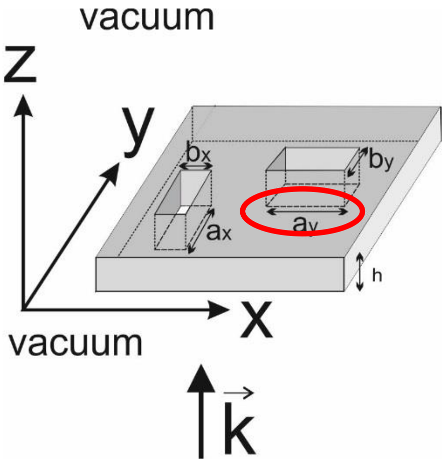


How to build quarter-wave plates ?

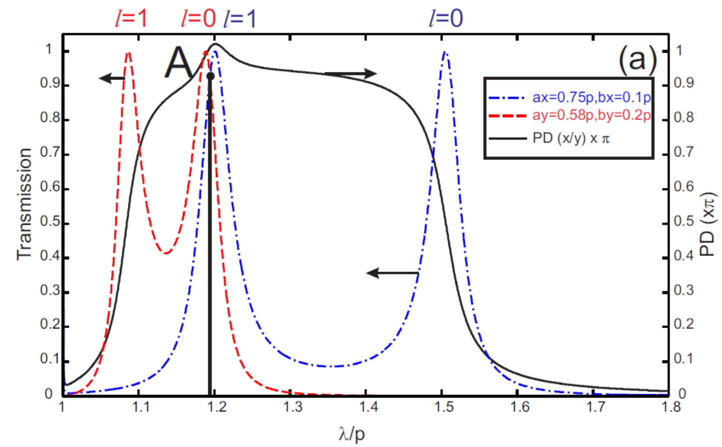
F. Baida et al., Phys. Rev. B , 84, 035107 (2011)

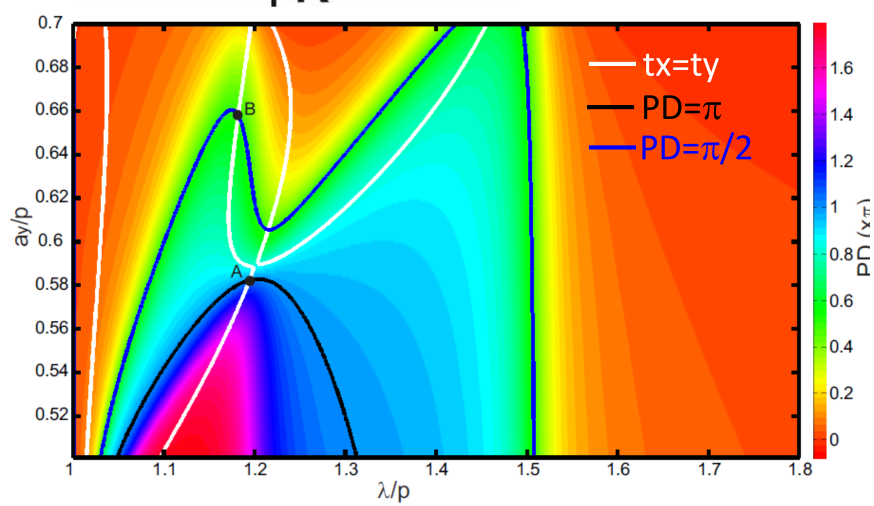
Lames λ/4 THz

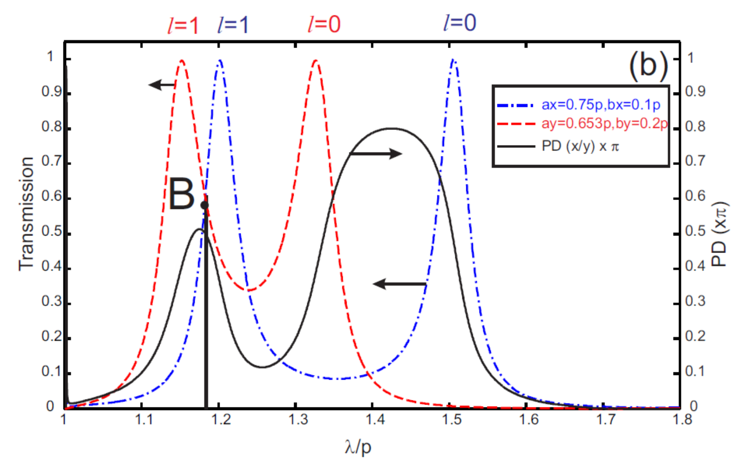
How to build quarter-wave plates ?



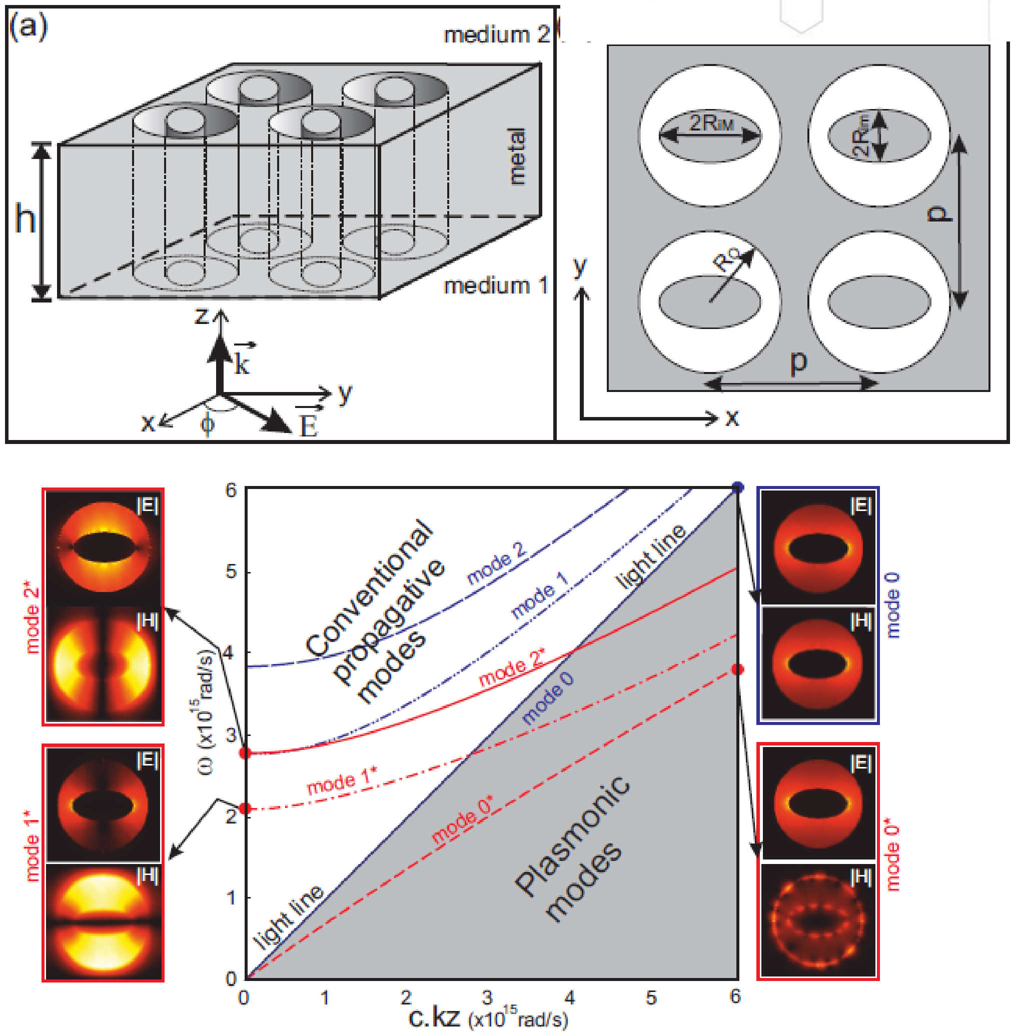
$$h = 0.8p$$
$$a_x = 0.75p$$
$$b_x = 0.1p$$
$$b_y = 0.2p$$



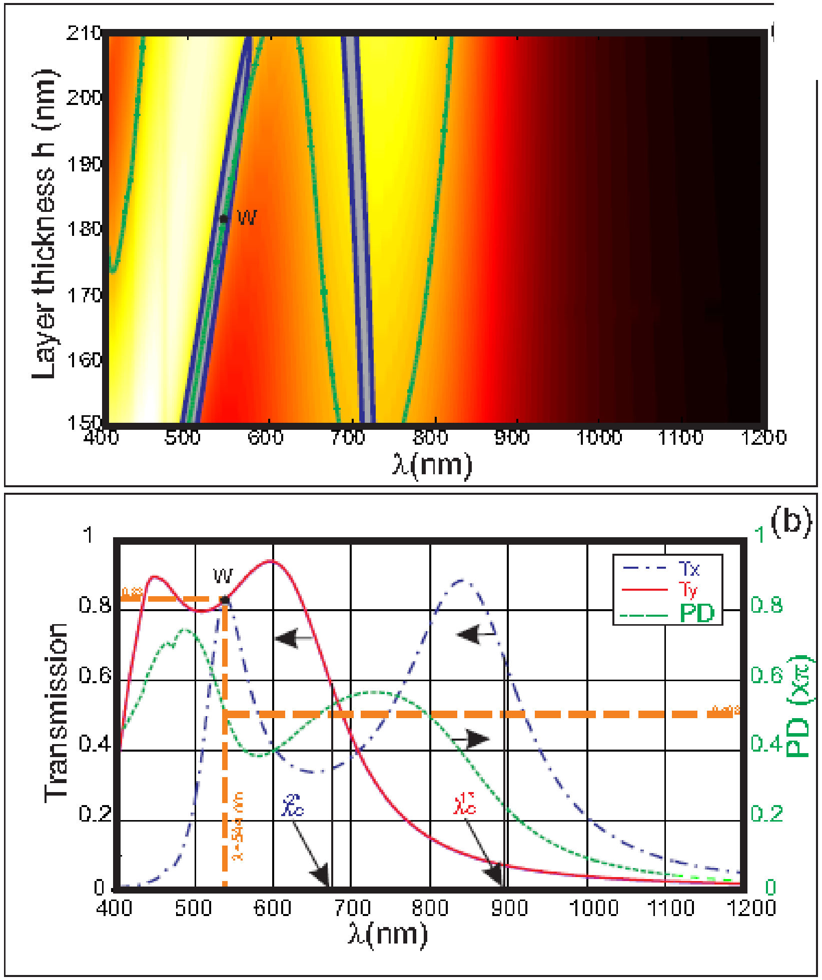




Lames $\lambda/4$ visible



Lames λ/4 visible



Transmission up to 83% in the visible range with realistic structure made in silver on glass substrate with $\Delta n=0.75$

J. Dahdah et al., Photonics Journal, IEEE , 4, 87-94, 2012

Miniature Plasmonic Wave Plates

I. nce
(Receiv uly 2008)

Linear birefringence, as implemented in wave plates, is a natural way to control the state of polarization of light. We report on a general method for designing miniature planar wave plates using surface plasmons. The resonant optical device considered here is a single circular aperture surrounded by an elliptical antenna grating. The difference between the short and long axis of each ellipsis introduces a phase shift on the surface plasmons which enables the realization of a quarter wave plate. Furthermore, the experimental results and the theoretical analysis show that the general procedure used does not influence the optical coherence of the polarization state and allows us to explore completely the surface of the unit Poincaré sphere by changing only the shape of the elliptical grating.

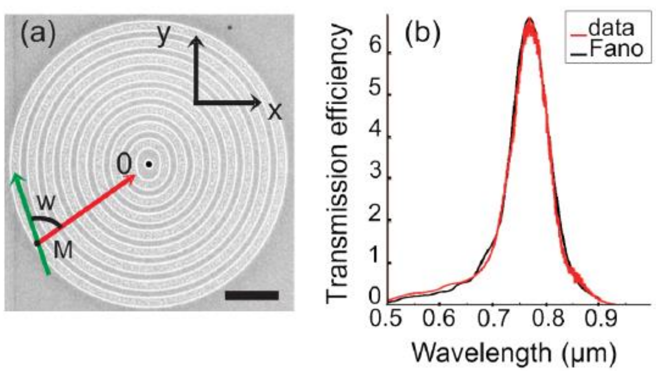


FIG. 1 (color). (a) Scanning electron microscopy image of the elliptical bull's eye structure. The scale bar is 2 μm long. The green arrow is an excited point dipole $\mathbf{P}_M$ located in **M**. SPP (red arrow) launched in **M** propagates along the radial direction **MO** to reach the hole located in **O**. w is the angle between **MO** and $\mathbf{P}_M$. (b) Comparison between the experimental white light transmission spectrum (red curve) associated with the structure shown in (a) and the theoretical prediction (black curve) obtained with the 2D dipoles model. The transmission scale is dimensionless and corresponds to the ratio between the transmitted and the incoming power at the level of the aperture.

$90° - \phi = 17.5°$ with the z axis. These predictions are directly consistent with the observations. Additionally, for a pure left circular input SOP, we experimentally obtain $\mathbf{S}^{\rm expt} = 0.1123\hat{\mathbf{x}} - 0.8984\hat{\mathbf{y}} + 0.3104\hat{\mathbf{z}}$ in agreement with the value deduced from $\mathcal{M}^{C_{2v}}$: $\mathbf{S}^{C_{2v}} = 0.1067\hat{\mathbf{x}} - 0.9272\hat{\mathbf{y}} + 0.2949\hat{\mathbf{z}}$.

To conclude, all this experimental and theoretical analysis demonstrates that we have a clear understanding of the SPP structure considered here. First, we have $\rho \simeq 1$ which implies that the system acts essentially as a birefringent medium with the Jones matrix

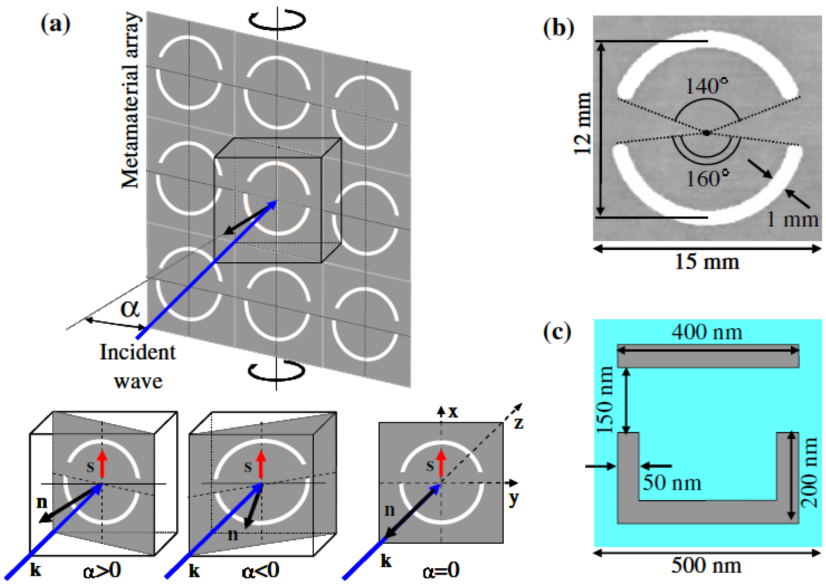
$$\mathcal{J} \simeq \begin{pmatrix} 1 & 0 \\ 0 & e^{i\phi} \end{pmatrix},$$

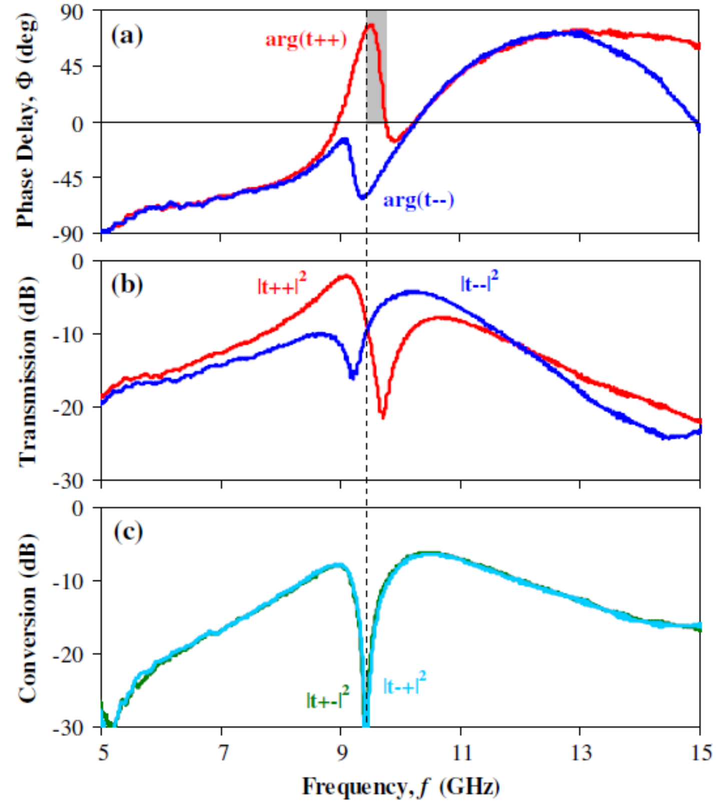
i.e., a wave plate. Second, the value obtained for ϕ shows that the system differs slightly from an ideal quarter wave plate for which $\phi = 90°$. From the point of view of the

Et les rotateurs ?? Chiralité

Metamaterials: Optical Activity without Chirality
E. Plum *et al.*, *Phys. Rev. Lett.*, **102, 113902 (2009).**

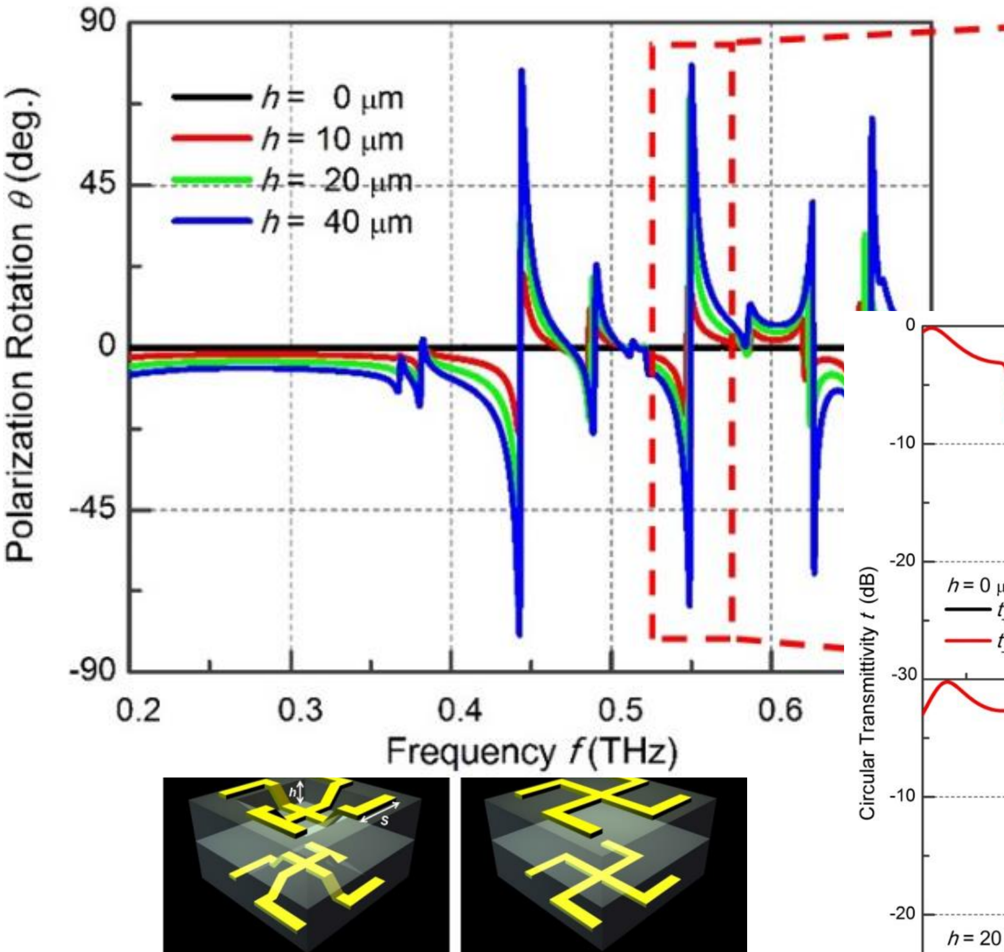
µondes – bandes C-X-Ku





Weak transmission, not tunable, …

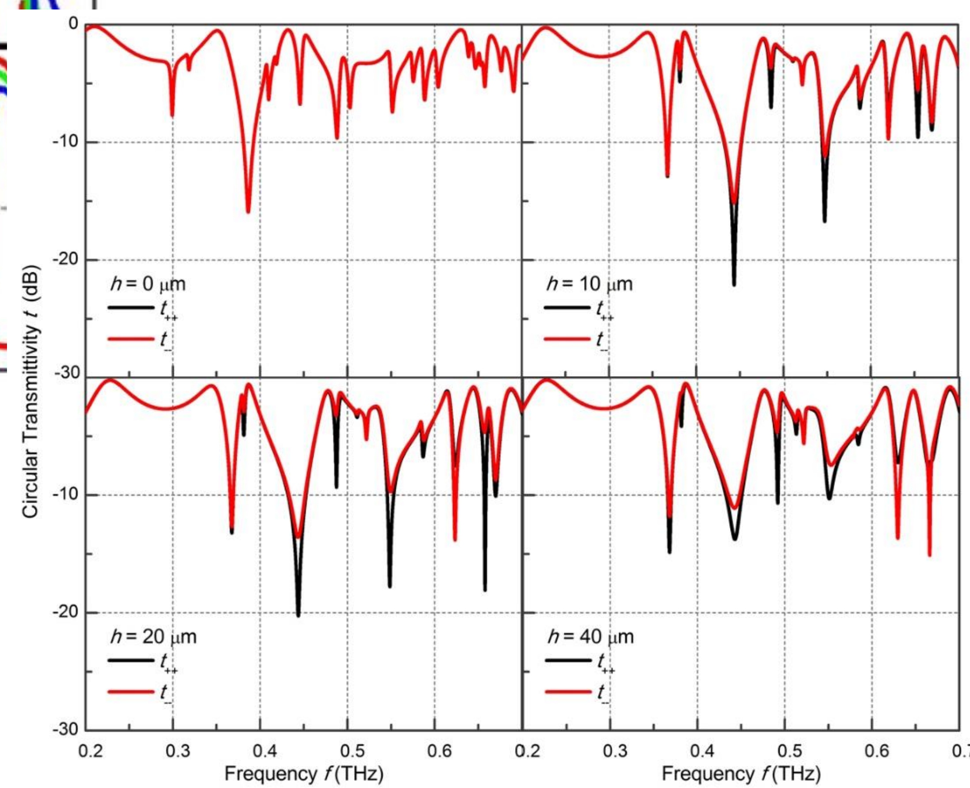
Et les rotateurs ?? Chiralité



(b) (c)

or

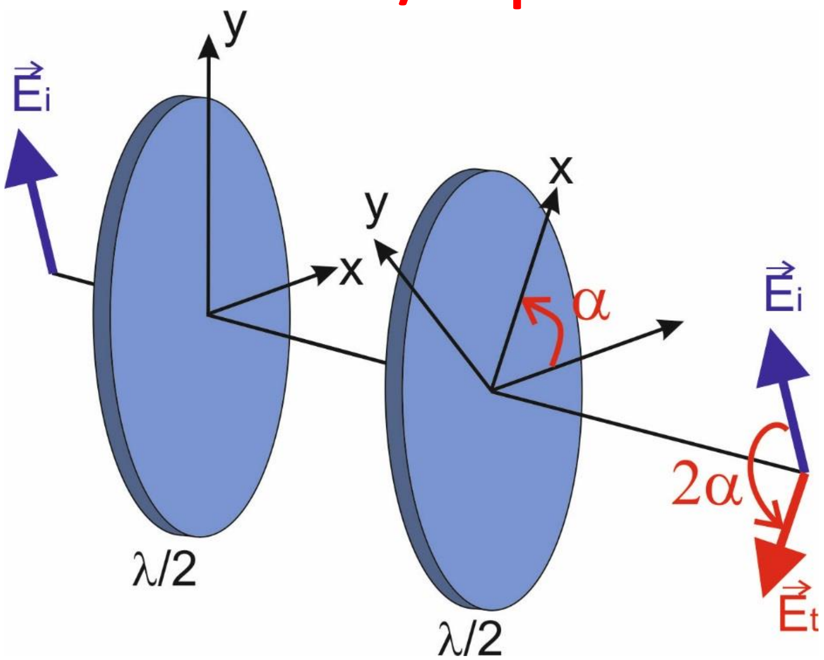
Thz

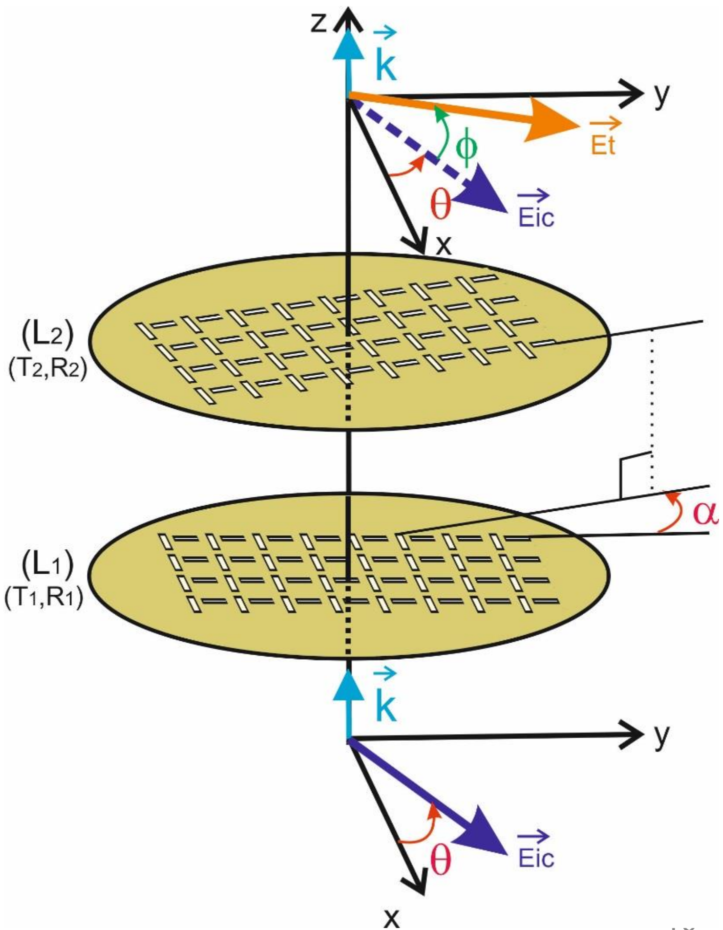


Rotateur optique

BUT: A well known property for opticiens:

2 λ/2 plates # optical rotator

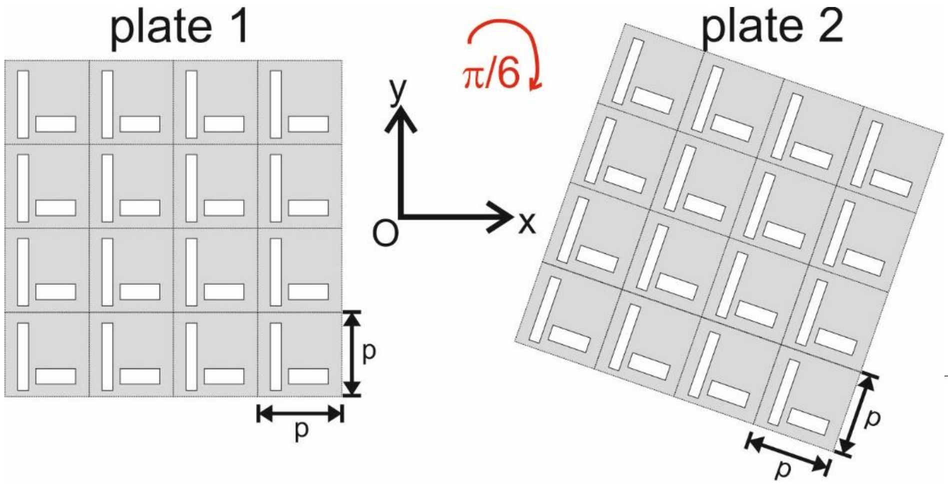


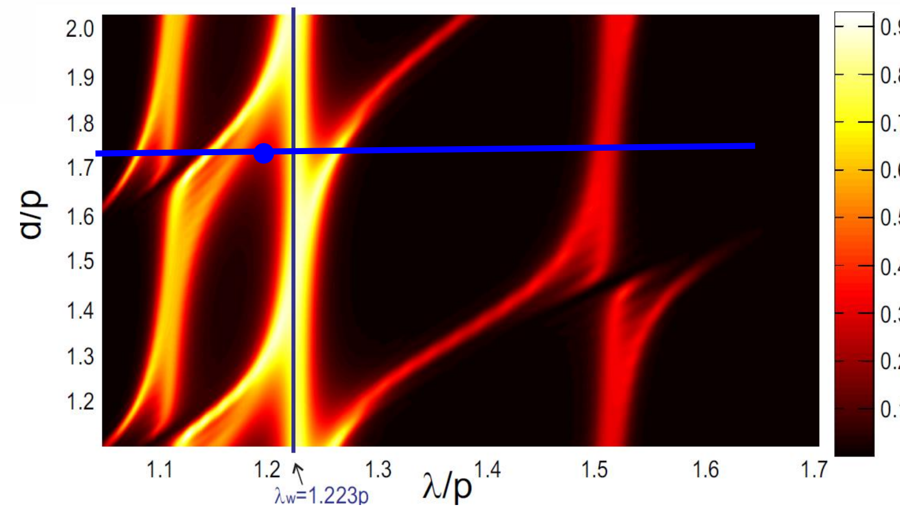


Large distance between the two plates

B) Thz and microwave metamaterials: Optical Activity

Modeling of the cascaded structures :

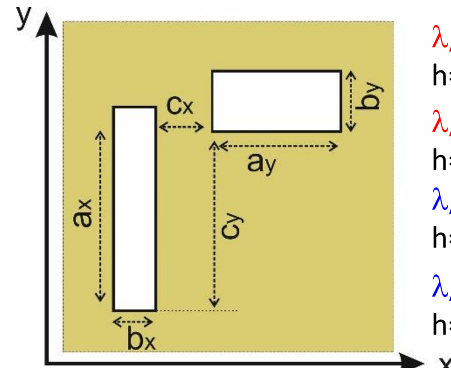


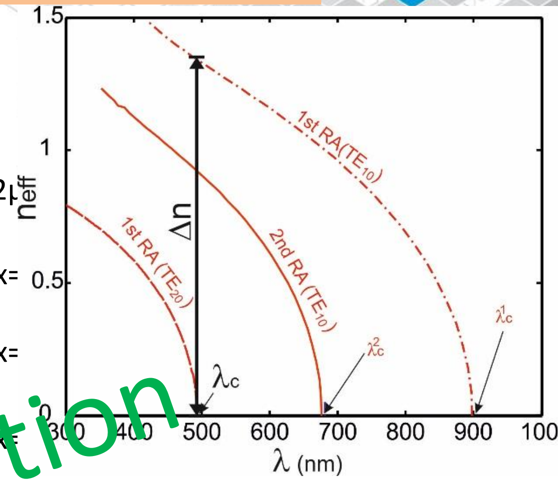


Transmission Jones matrix in the circular polarization basis

$$T(\lambda = 1.223p) = 0.9003 \begin{pmatrix} e^{-\frac{\pi}{3.08}i} & 0.0172e^{1.8639i} \\ 0.0174e^{2.0226i} & e^{\frac{\pi}{3.08}i} \end{pmatrix} \Rightarrow \text{rotation by } \pi/3.08 \text{ instead of } \pi/3$$

Catalogue de structures





$\lambda/2$ à f= 428GHz

h=475µm, p=572µm, ax=418µm, ay=332µm, bx=57.2µ … n

$\lambda/2$ à f= 625GHz

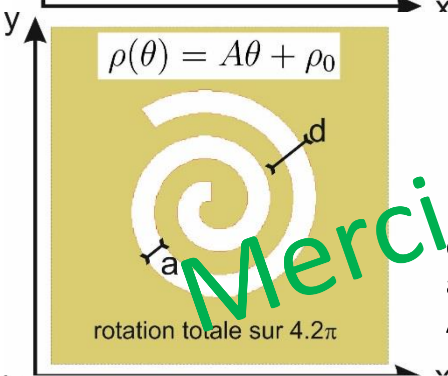
h=326µm, p=392,5µm, ax=286,5µm, ay=227,6µm, bx= … 5µm

$\lambda/4$ à f= 416GHz

h=475µm, p=593,5µm, ax=445,1µm, ay=359,4µm, bx= … ,2µm

$\lambda/4$ à f= 605GHz

h=326µm, p=407,5µm, ax=305,7µm, ay=246,8µm, bx= … ,0µm



Longueur d 'onde de travail : 651 µm,

fréquence 461GHz

h=326µm

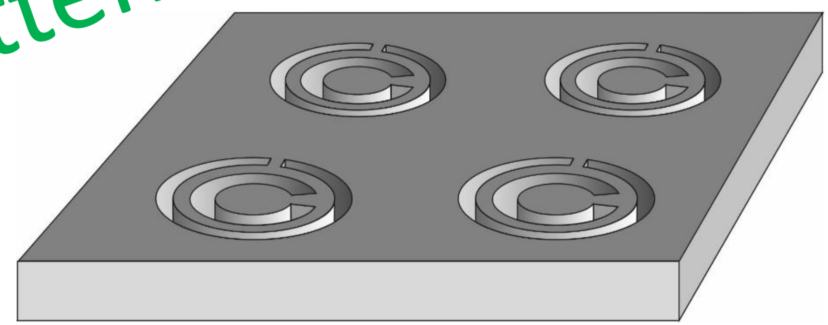
p=300µm

d=46µm

a=23µm

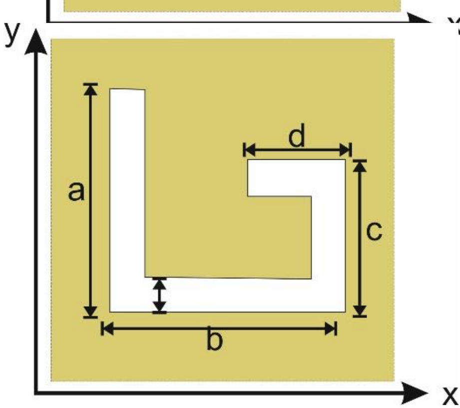
A=d/(2p)=7.32µm

Merci de votre attention



Structure à double C présentée en affiche ….

Δn=1,52



Longueur d 'onde de travail : ~520 µm,

fréquence 577GHz

h=326µm

p=300µm

a=80µm

b=80µm

c=60µm

d=40µm

w=20µm