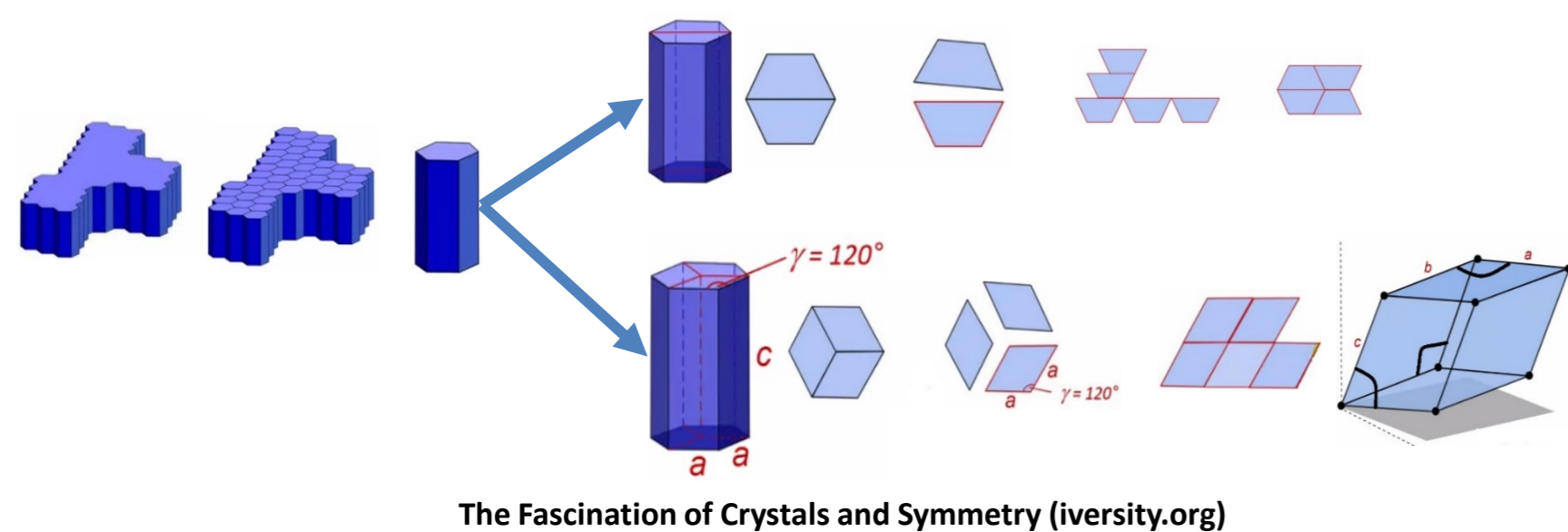


## Context

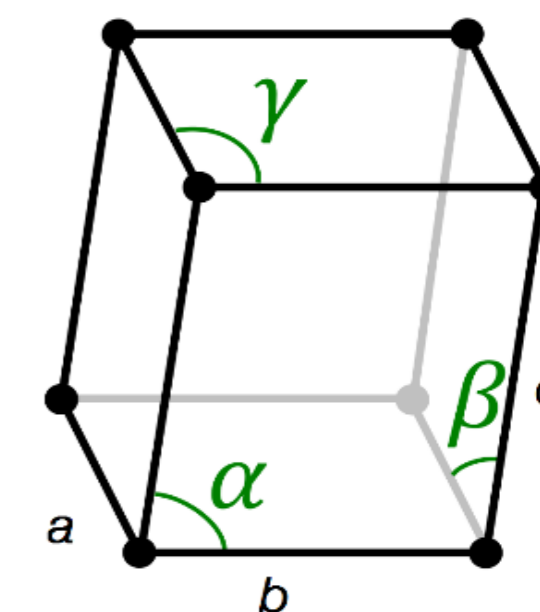
**Crystals** are solid materials which constitute atoms, molecules or ions with **periodic** arrangement extending in all three spatial dimensions.



The Fascination of Crystals and Symmetry (iversity.org)

Efficient use of **laser materials** requires full characterization of their **absorption** and **emission** properties. These properties can be described with **3-by-3** second rank linear **permittivity tensor**.

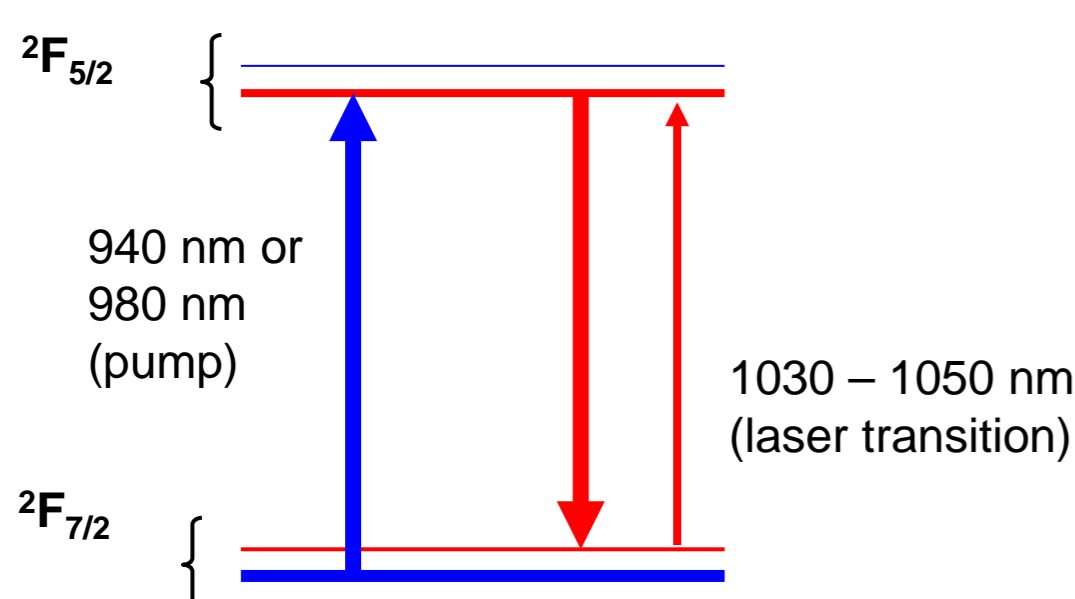
In the case of monoclinic crystals, the maximum values of absorption and fluorescence are not along the principal axes of the dielectric frame, but tilted at an angle with respect to one of the axes of dielectric frame.



## Ytterbium-doped laser materials

### Why Yb-doped materials?

- Absorption spectrum ⇒ direct diode-pumping
- Low quantum defect ⇒ high power operation
- Broad gain bandwidth ⇒ (ultra)short pulses



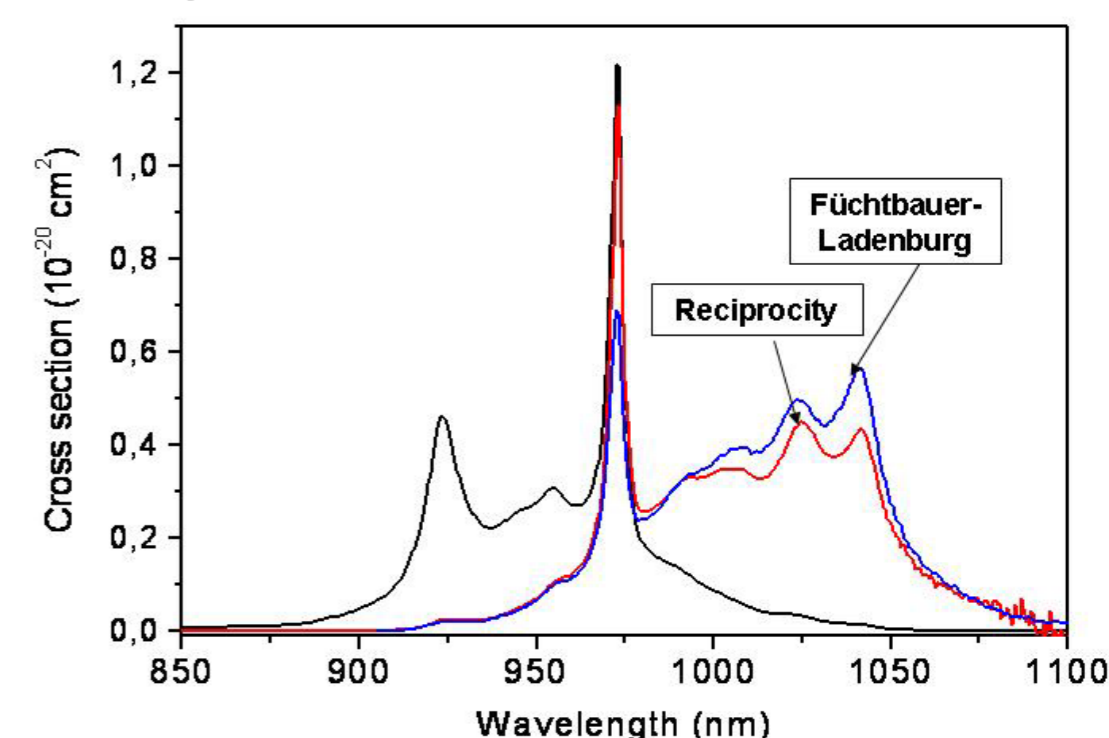
### However :

- Quasi - 3 - level structure
- reabsorption at lasing wavelength
- strong pumping necessary

Example: new borates of type: Li<sub>6</sub>(Gd<sub>(1-x)</sub>Y<sub>x</sub>)<sub>0.75</sub>Yb<sub>0.25</sub>(BO<sub>3</sub>)<sub>3</sub>



Absorption and emission cross sections of Yb:LYB  
→ **Typical signature** of Yb-doped materials



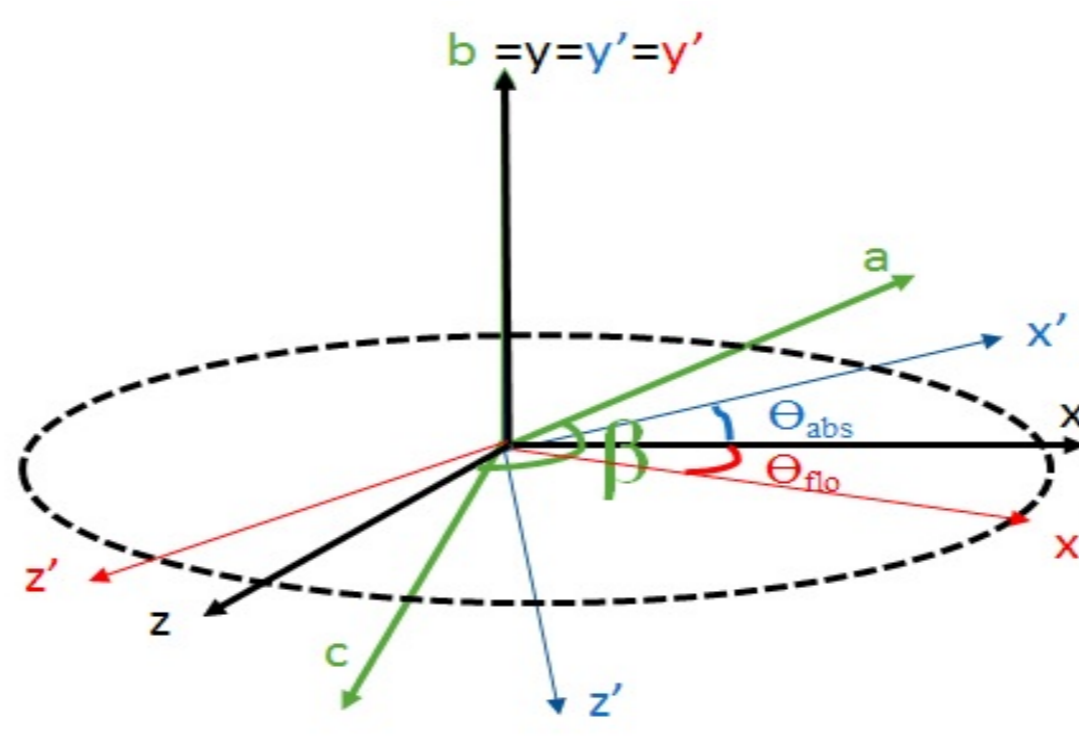
## Relationship between Crystallographic Axes and Relative Dielectric Permittivity Tensor

Monoclinic crystals : considering y//b

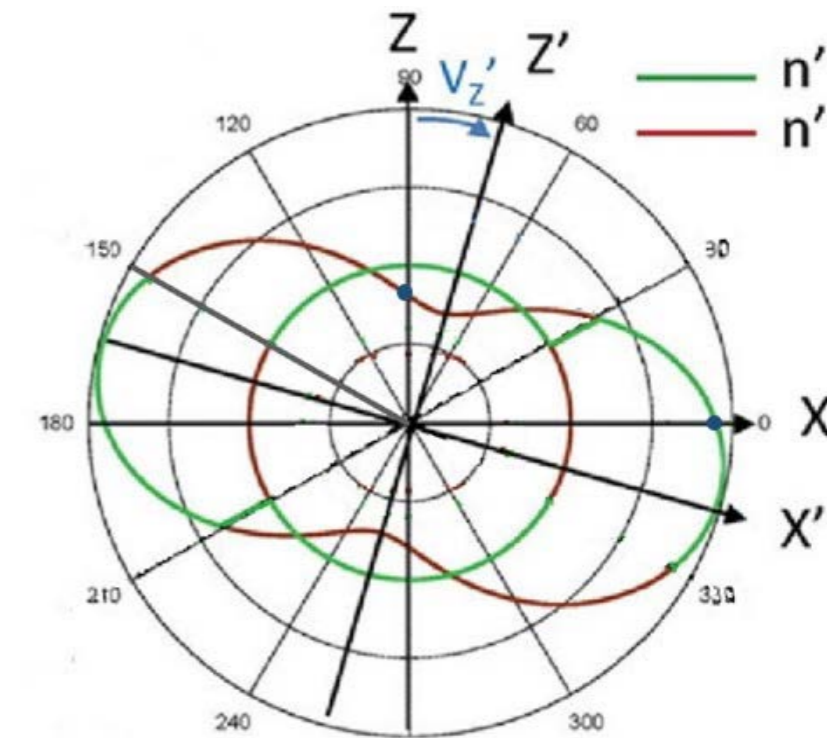
$$\bar{\epsilon}_r = \bar{\epsilon}_r(\omega) + j\bar{\epsilon}_r'' = \begin{bmatrix} \epsilon_{rxx} & 0 & 0 \\ 0 & \epsilon_{ryy} & 0 \\ 0 & 0 & \epsilon_{rzz} \end{bmatrix} + j \begin{bmatrix} \epsilon_{rxz}' & 0 & \epsilon_{rxz}'' \\ 0 & \epsilon_{ryy}' & 0 \\ \epsilon_{rxz}' & 0 & \epsilon_{rzz}'' \end{bmatrix}$$

diagonal (light splits and propagates the principal axis of the dielectric frame)

Off diagonal (rotation in xz plane)



(a, b, c)<sub>crystal</sub> ≠ (x, y, z)<sub>dielectric</sub> ≠ (x', y', z')<sub>absorption</sub> ≠ (x'', y'', z'')<sub>fluorescence</sub>

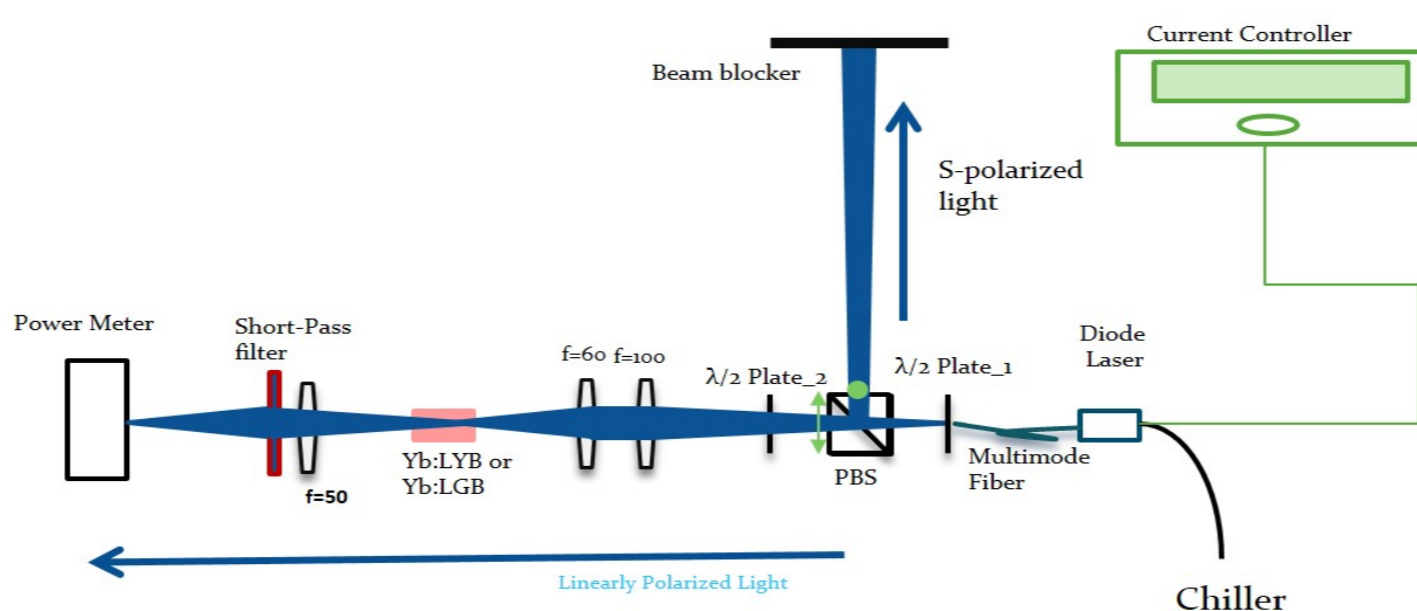


## Determination of « Good » Absorption Axis

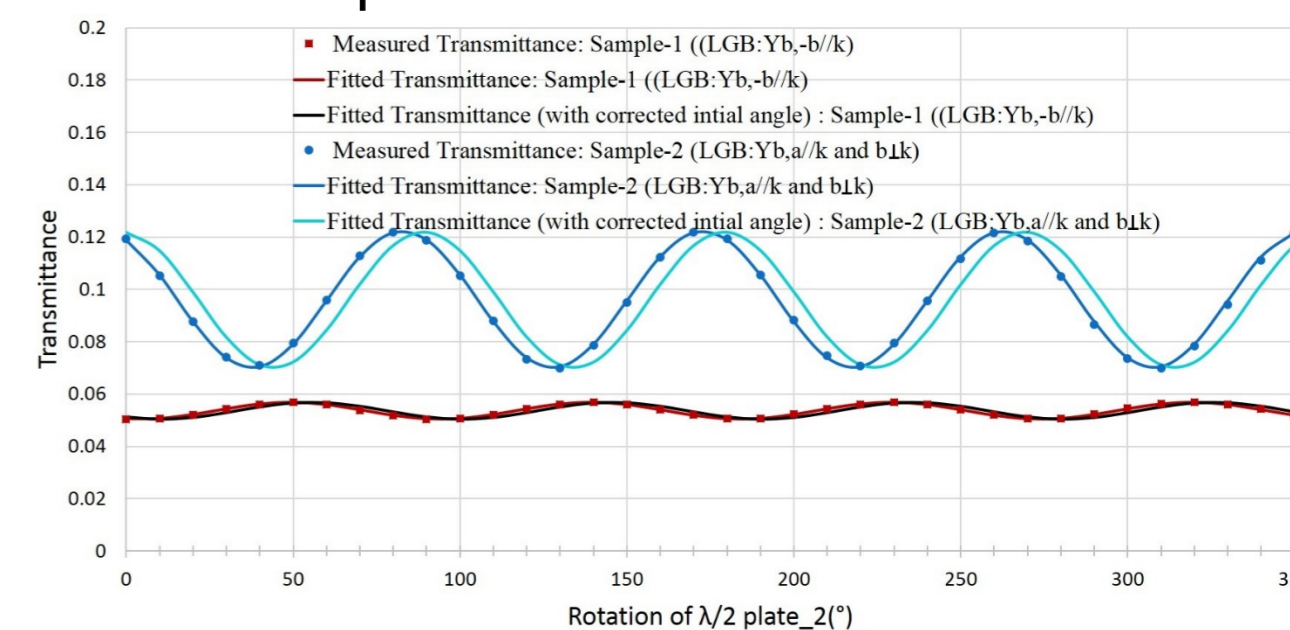
### Preparation of Samples:

Direction of Cut	LGB:Yb 22%	LYB:Yb 26%	Properties accessed
Face ⊥ b (i.e. b // k or -k)	Sample 1	Sample 3	$\epsilon'_{rxx}, \epsilon'_{rzz}$
Face // b with a or c // k or -k	Sample 2	Sample 4	$\epsilon'_{ryy}, \epsilon'_{rxz}$

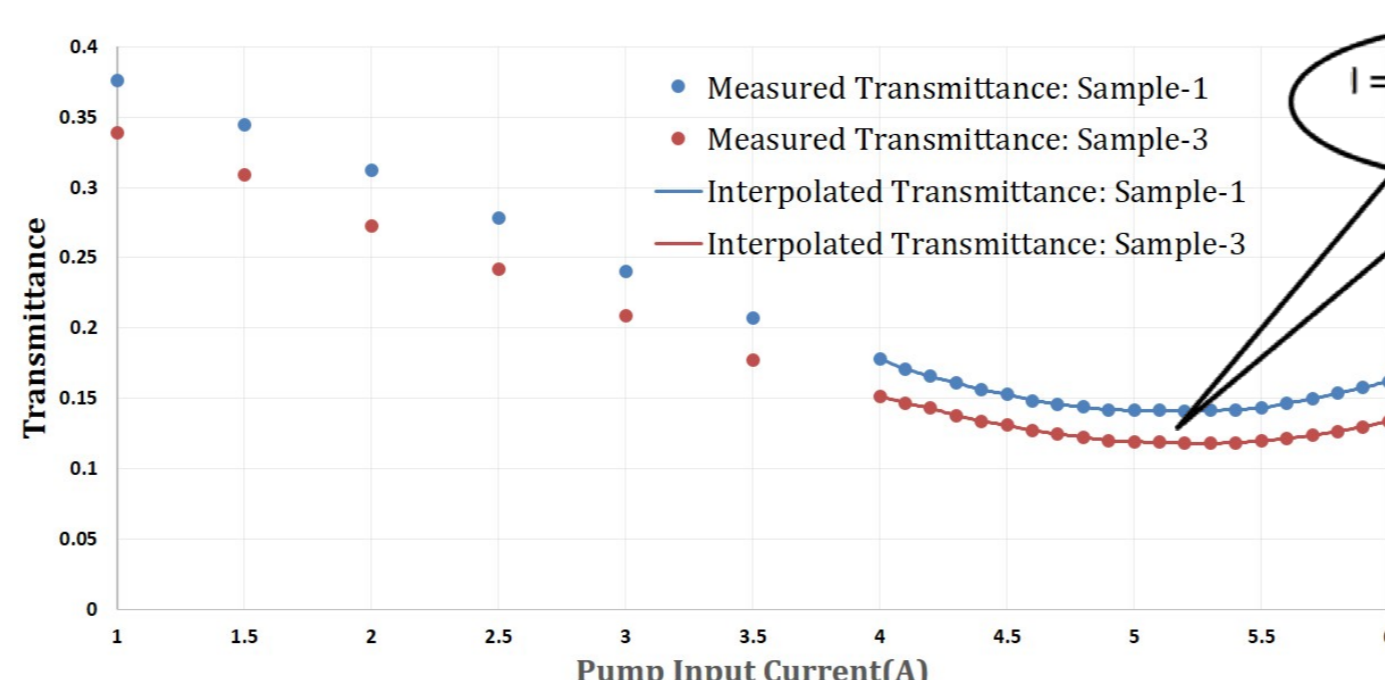
### Setup for polarization-dependent absorption measurement :



### Absorption Coefficient :



### Determination of Working point:



$$\alpha(\theta) = -\frac{1}{L} \ln \left[ \frac{T_{max} \cos^2[2(\theta - \theta_{initial, \lambda/2})] + T_{min} \sin^2[2(\theta - \theta_{initial, \lambda/2})]}{T^2} \right]$$

$$n'(\omega, \theta, \varphi) = \frac{\alpha(\omega, \theta, \varphi)L}{4\pi}$$

**Index Surfaces for the ordinary and extraordinary imaginary refractive indices!!!**