Physique Avancée IV Semestre de printemps 2025

Semaine 9

17 avril 2025

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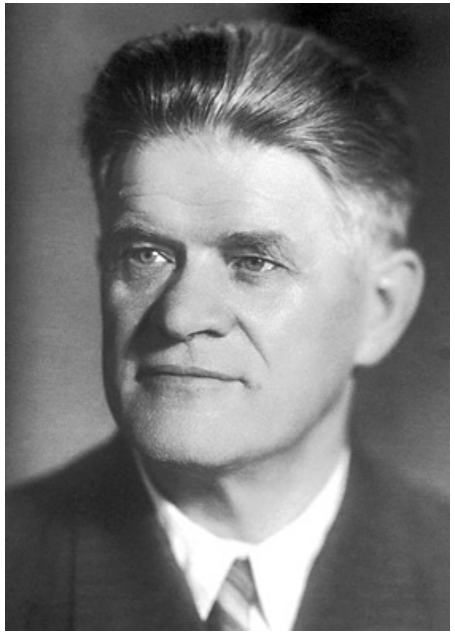
2.2.2 Milieux diélectriques anisotropes



Pavel Tcherenkov
(1904 - 1990)

Potentiel vecteur et scalaire

$$\nabla^2 \mathbf{A} - \frac{1}{c^2}\frac{\partial^2 \mathbf{A}}{\partial t^2} = -\mu_0 \mathbf{J}$$

$$\nabla^2 V - \frac{1}{c^2}\frac{\partial^2 V}{\partial t^2} = -\frac{\rho}{\epsilon}$$

$$\mathbf{E} = -\left(\nabla V + \frac{\partial \mathbf{A}}{\partial t}\right), \ \mathbf{B} = \nabla \times \mathbf{A}$$

Condition de Lorentz: $\nabla \cdot \mathbf{A} + \frac{1}{c^2}\frac{\partial V}{\partial t} = 0$

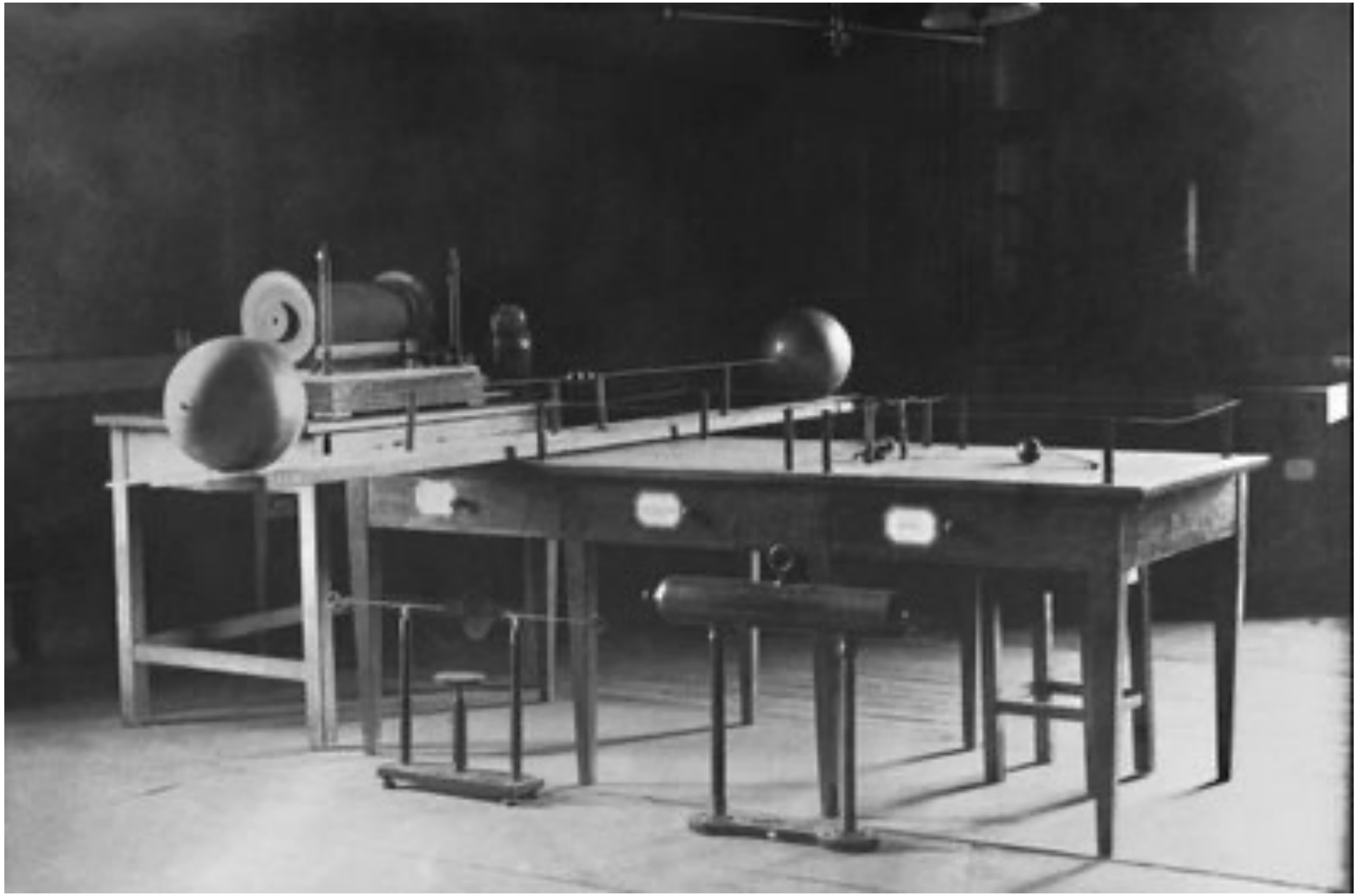
2.1.6.1 Les potentiels retardées

$$V(\mathbf{r},t) = \frac{1}{4\pi\epsilon_0}\int_\Omega \frac{\rho(\mathbf{r}',t-R/c)}{R}d\Omega$$

$$\mathbf{A}(\mathbf{r},t) = \frac{\mu_0}{4\pi}\int_\Omega \frac{\mathbf{J}(\mathbf{r}',t-R/c)}{R}d\Omega$$

$$R = \|\mathbf{r}-\mathbf{r}'\|$$

2.1.6.2 Oscillateur de Hertz



(ρ, θ, φ): Scalar function F; Vector field $\mathbf{f} = f_\rho \mathbf{e}_\rho + f_\theta \mathbf{e}_\theta + f_\varphi \mathbf{e}_\varphi$

- gradient : $\nabla F = \dfrac{\partial F}{\partial \rho}\mathbf{e}_\rho + \dfrac{1}{\rho \sin\varphi}\dfrac{\partial F}{\partial \theta}\mathbf{e}_\theta + \dfrac{1}{\rho}\dfrac{\partial F}{\partial \varphi}\mathbf{e}_\varphi$
- divergence : $\nabla \cdot \mathbf{f} = \dfrac{1}{\rho^2}\dfrac{\partial}{\partial \rho}(\rho^2 f_\rho) + \dfrac{1}{\rho}\sin\varphi \dfrac{\partial f_\theta}{\partial \theta} + \dfrac{1}{\rho \sin\varphi}\dfrac{\partial}{\partial \varphi}(\sin\varphi f_\theta)$
- curl : $\nabla \times \mathbf{f} = \dfrac{1}{\rho \sin\varphi}\left(\dfrac{\partial}{\partial \varphi}(\sin\varphi f_\theta) - \dfrac{\partial f_\varphi}{\partial \theta}\right)\mathbf{e}_\rho + \dfrac{1}{\rho}\left(\dfrac{\partial}{\partial \rho}(\rho f_\varphi) - \dfrac{\partial f_\rho}{\partial \varphi}\right)\mathbf{e}_\theta + \left(\dfrac{1}{\rho \sin\varphi}\dfrac{\partial f_\rho}{\partial \theta} - \dfrac{1}{\rho}\dfrac{\partial}{\partial \rho}(\rho f_\theta)\right)\mathbf{e}_\varphi$
- Laplacian : $\Delta F = \dfrac{1}{\rho^2}\dfrac{\partial}{\partial \rho}\left(\rho^2 \dfrac{\partial F}{\partial \rho}\right) + \dfrac{1}{\rho^2 \sin^2\varphi}\dfrac{\partial^2 F}{\partial \theta^2} + \dfrac{1}{\rho^2 \sin\varphi}\dfrac{\partial}{\partial \varphi}\left(\sin\varphi \dfrac{\partial F}{\partial \varphi}\right)$

2.2 Propagation des ondes électromagnétiques dans la matière

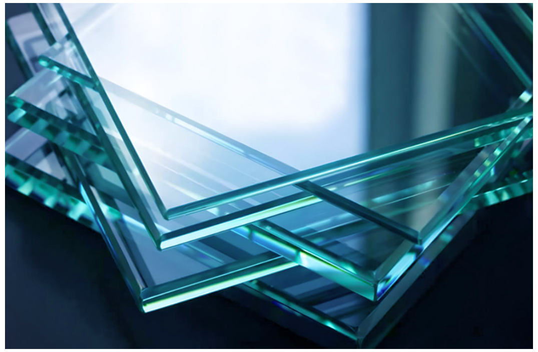
$$u = \sqrt{\frac{1}{\epsilon_0 \mu_0 \epsilon_r \mu_r}} = \frac{c}{\sqrt{\epsilon_r \mu_r}} = \frac{c}{n}$$

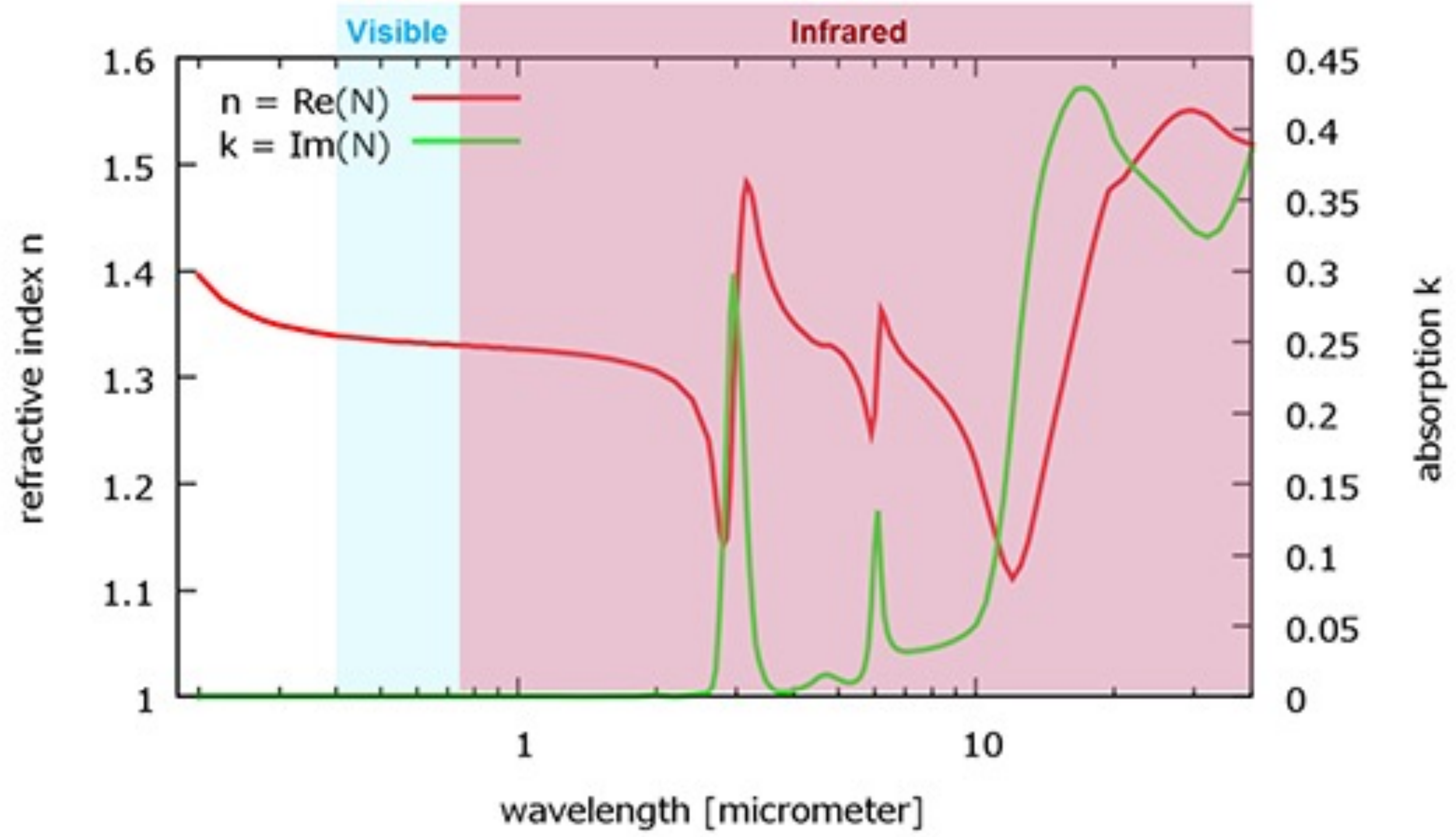
Materiaux	ϵ_r	μ_r
Eau	80	0.999992
Cuivre	∞	0.999994
Air	1	1.00000037
Bois	1.4 – 4.0	1.00000043
Diamant	5.7	0.99998
Saphir	~10	0.99999976

2.2.1 Milieux diélectriques isotropes

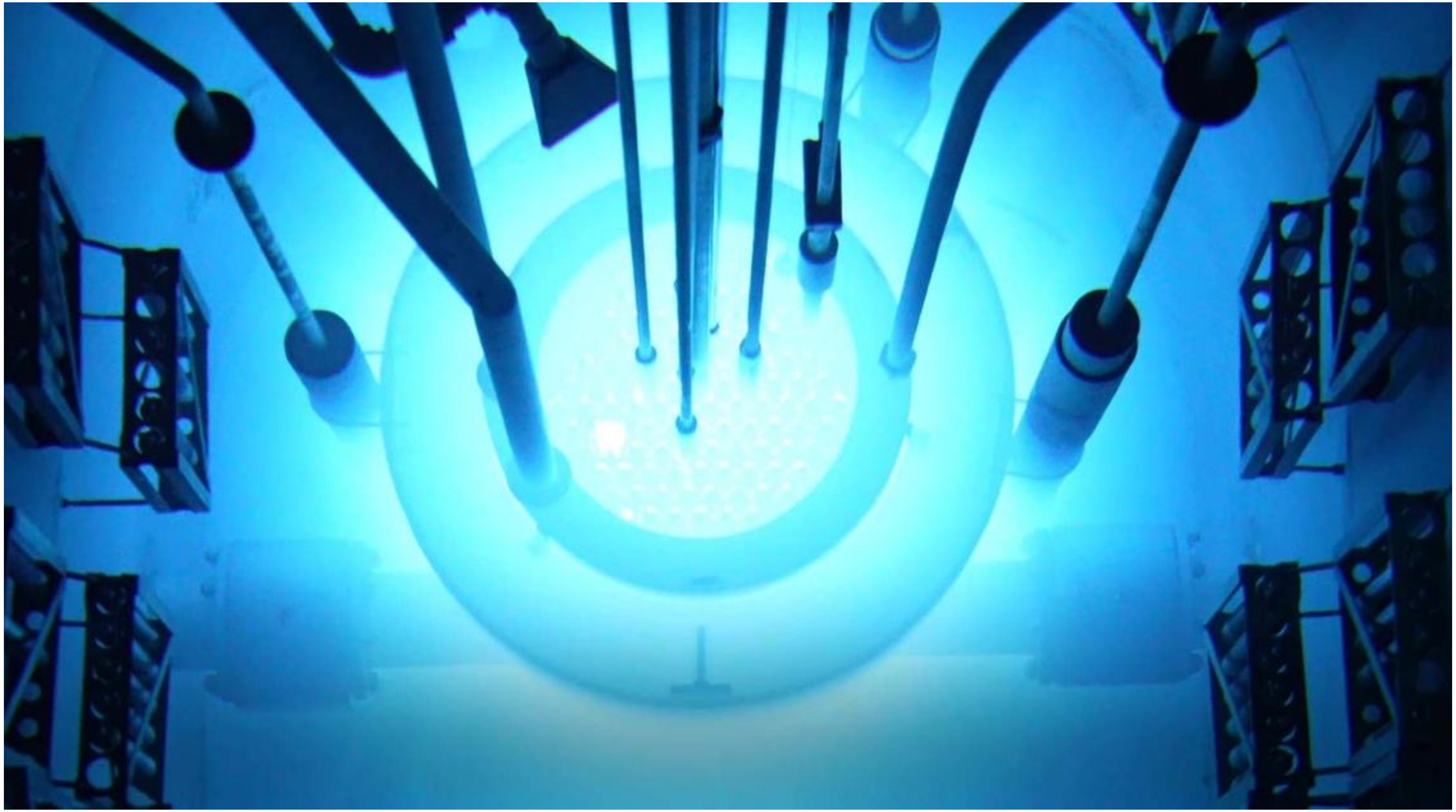
$$n \simeq \sqrt{\epsilon_r} \simeq 1 + \frac{N\alpha}{2\epsilon_0}$$

$$\alpha = \frac{e^2}{m_e} \sum_k \frac{f_k}{\omega_{0k}^2 - \omega^2 + i\gamma_k \omega}$$





Index de refraction de l’eau



Rayonnement de Tcherenkov