Channeling 2014
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Similarity between Synchrotron radiation and photons escaping from a bent optical fiber

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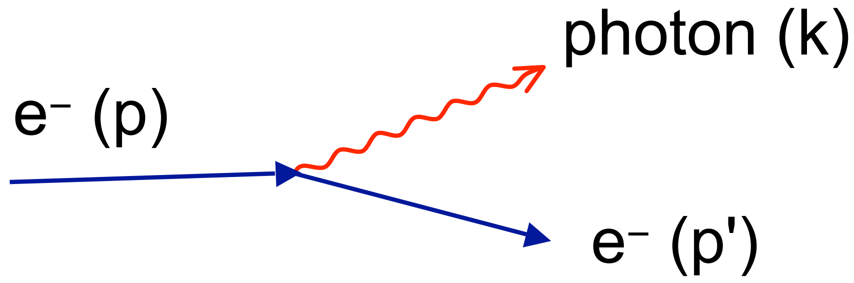
Synchrotron case

The reaction :

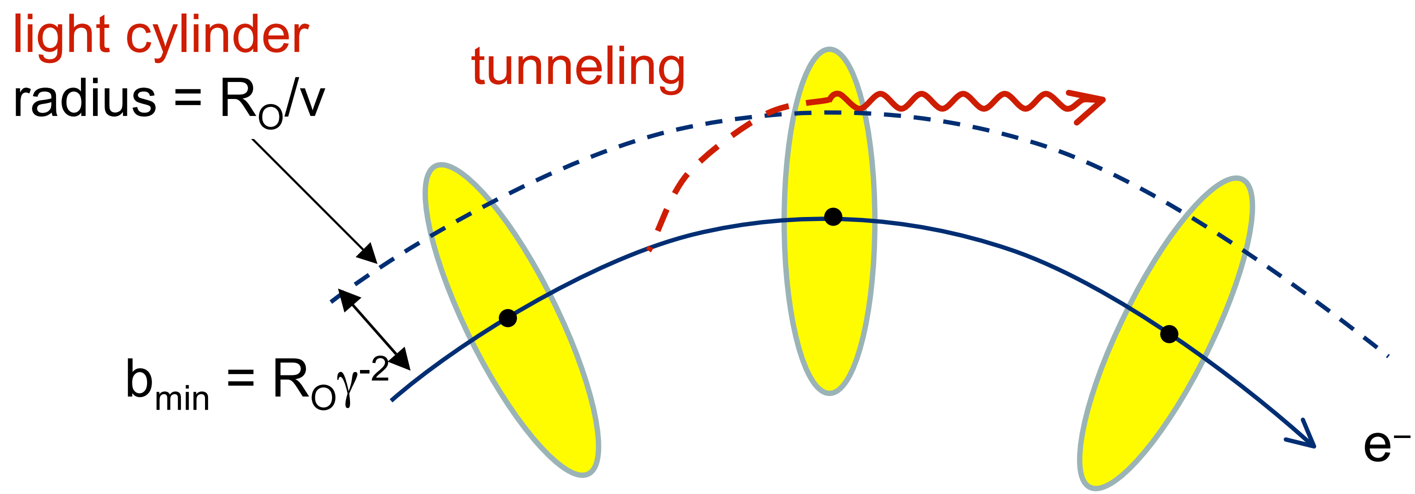


is kinematically forbidden
*as a **local*** process between ***classical particles***,

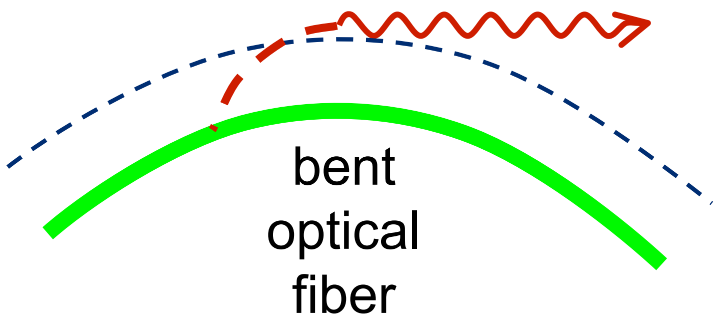
but it can occur via a quantum **tunnelling effect**.

Impact parameter point of view

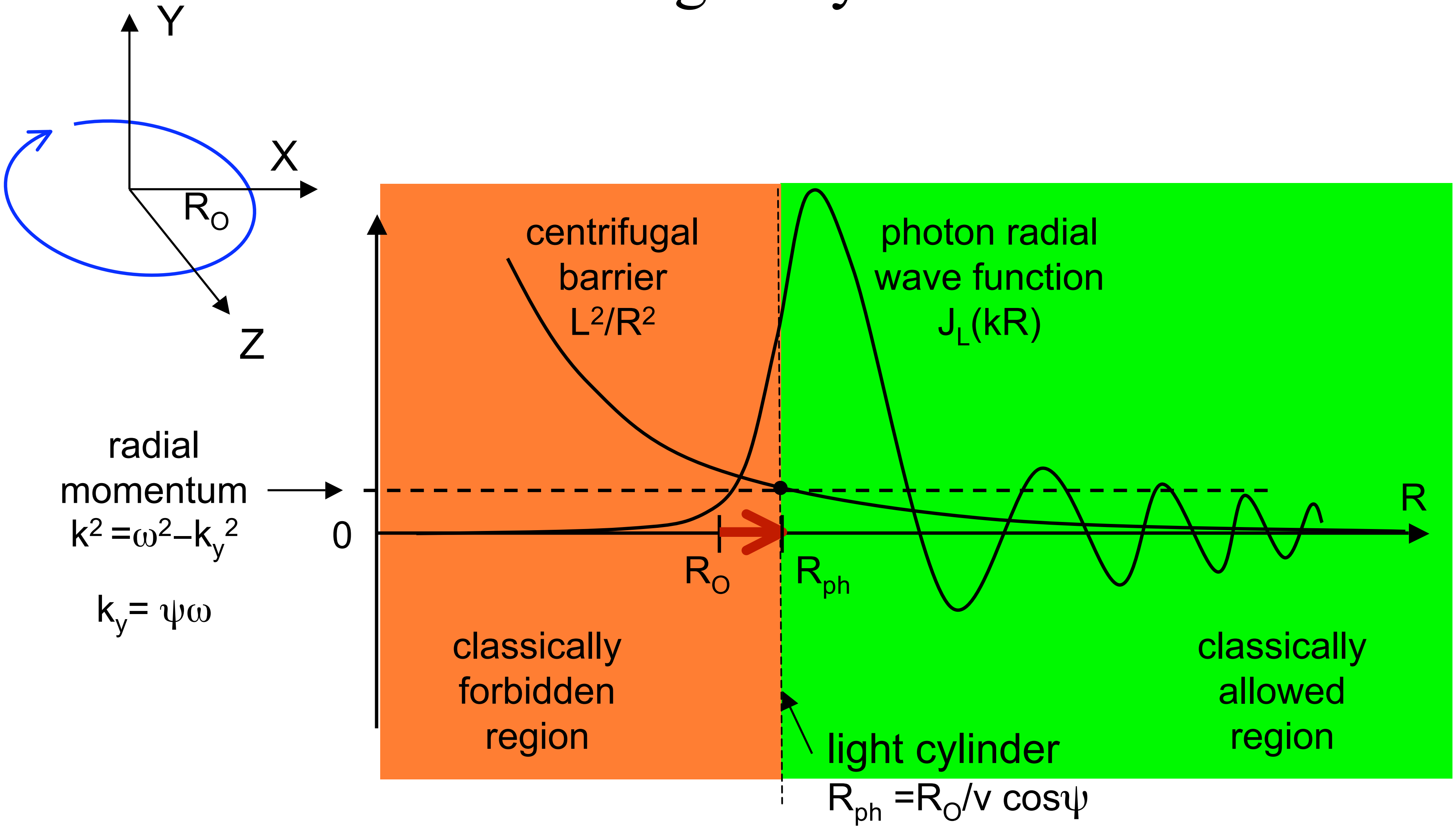
Synchrotron radiation ~ **slow leakage** of the Coulomb field



Analogy :



Wave tunnelling in Synchrotron Radiation

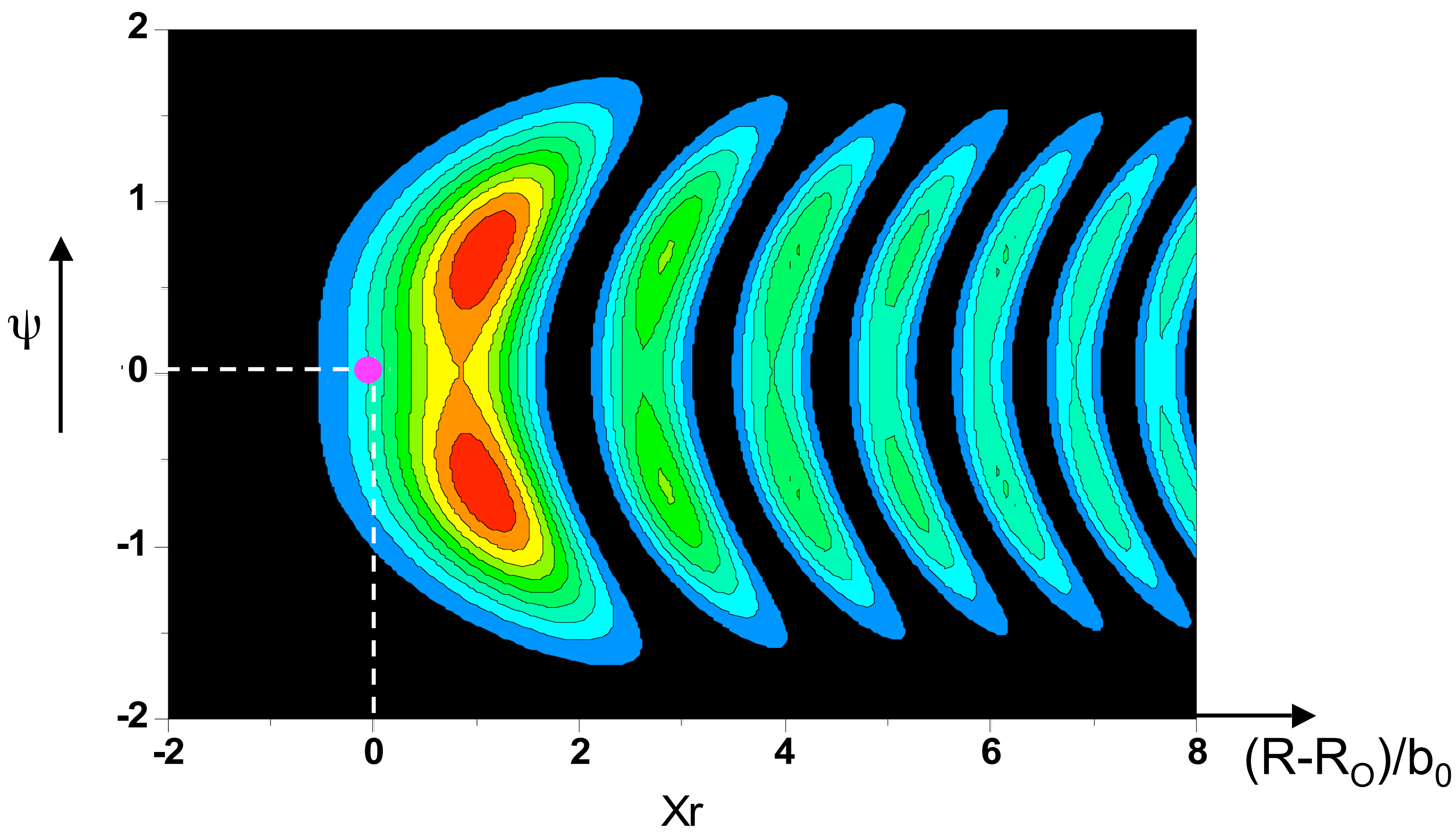


$J_L(kR) \sim$ Airy function $(R_{ph} - R)$

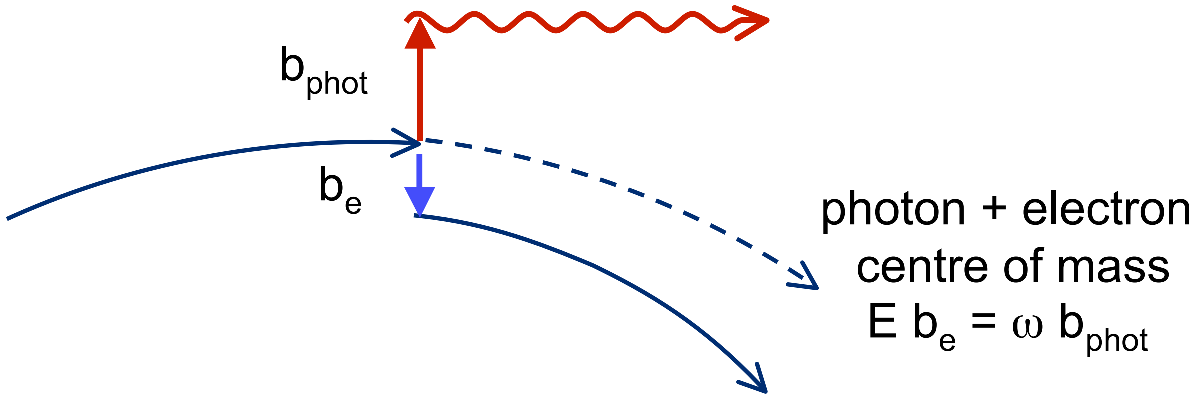
$\sim \exp\{ -(\omega/\omega_c)(1 + \gamma^2\psi^2)^{3/2}/3 \} \leftarrow$ tunnelling factor $\qquad \omega_c = \gamma^3 / R_O$

Horizontal Profile of Synchrotron Radiation

[X. A. and C. Ray (2006)]

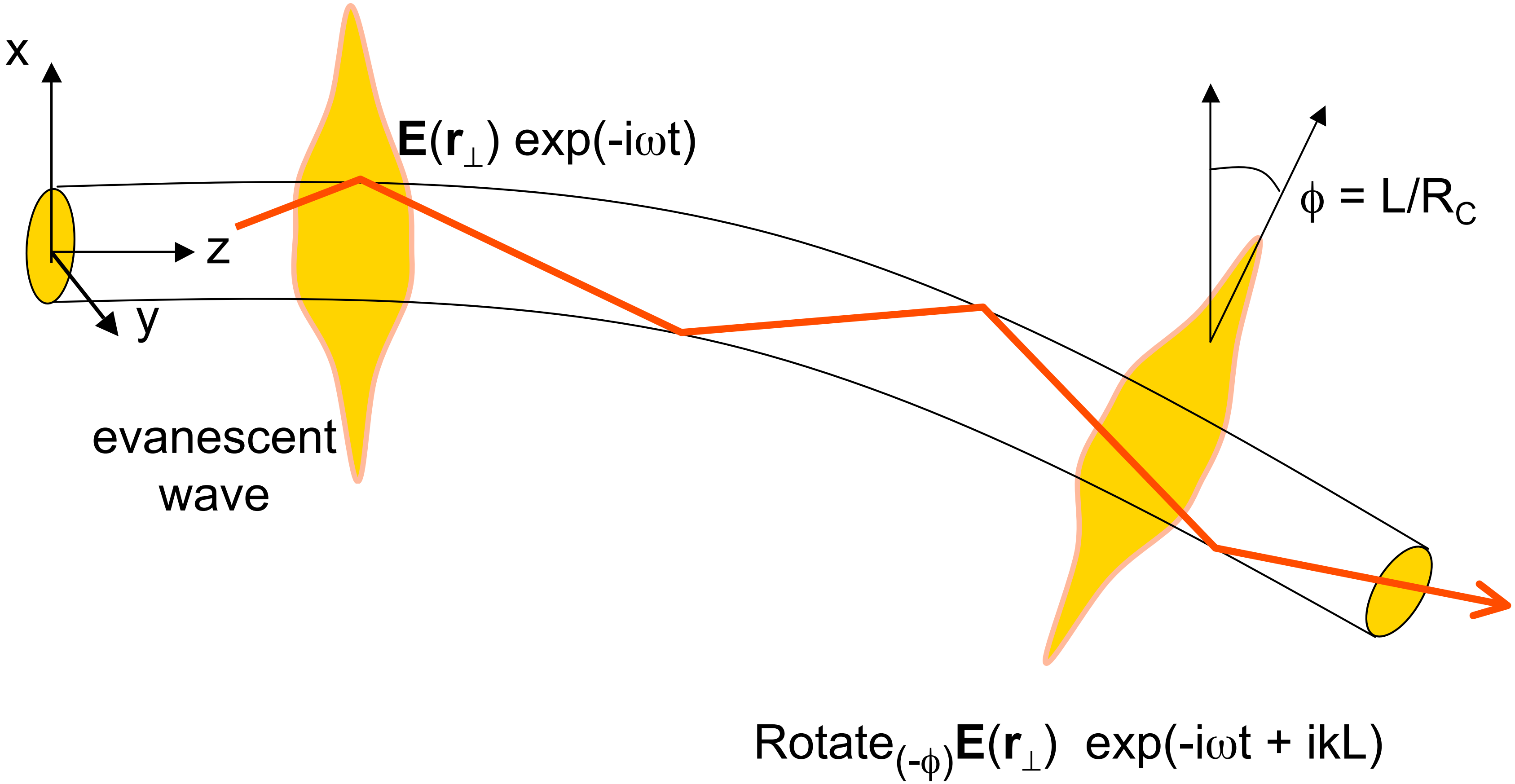


Side slipping

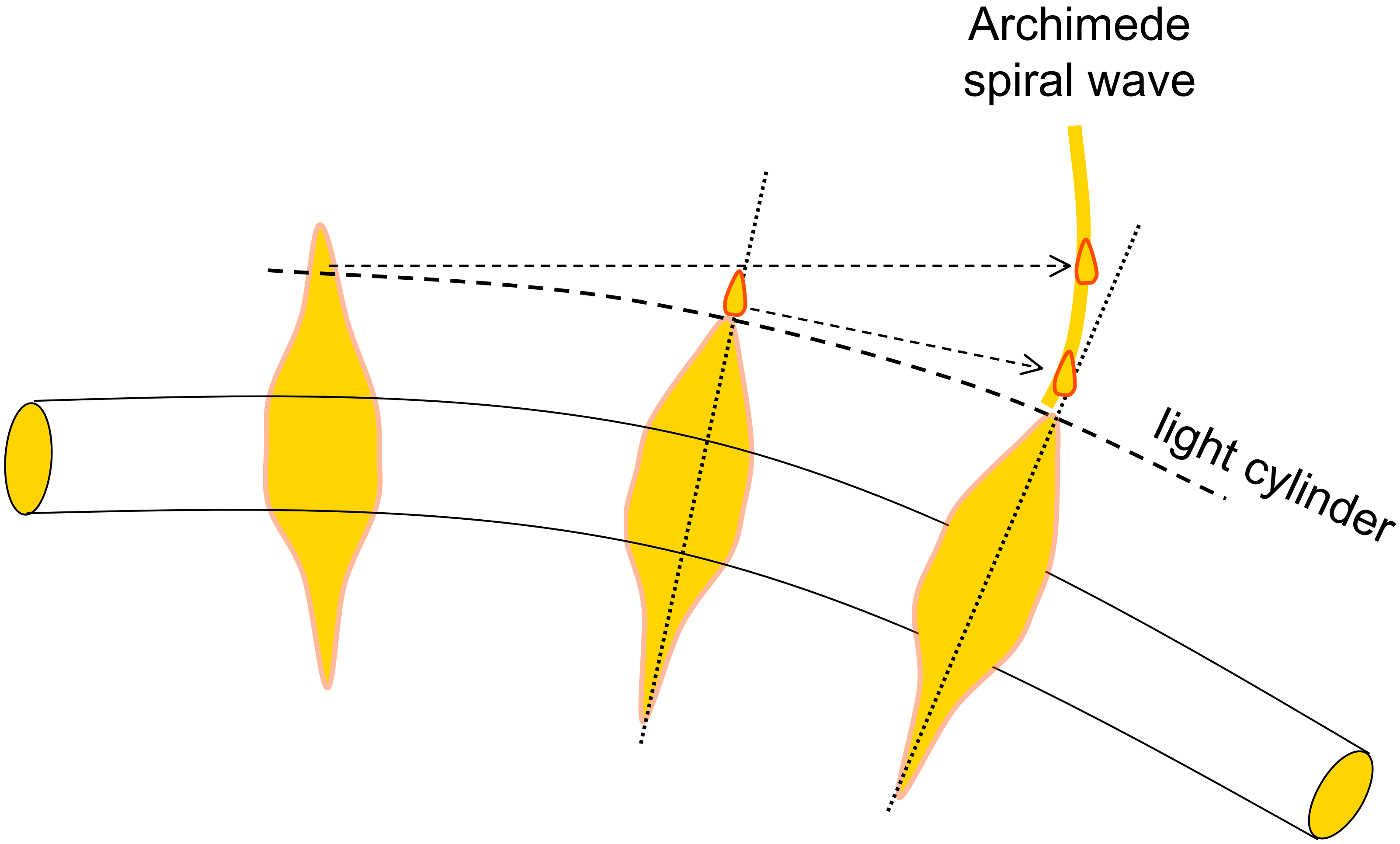


- $b_e \sim \lambda_C = 400$ fm
- Side-slipping is responsible for the d^3X/dt^3 term of the Abraham-Lorentz equation

The field in a bent fiber



Escape of the field

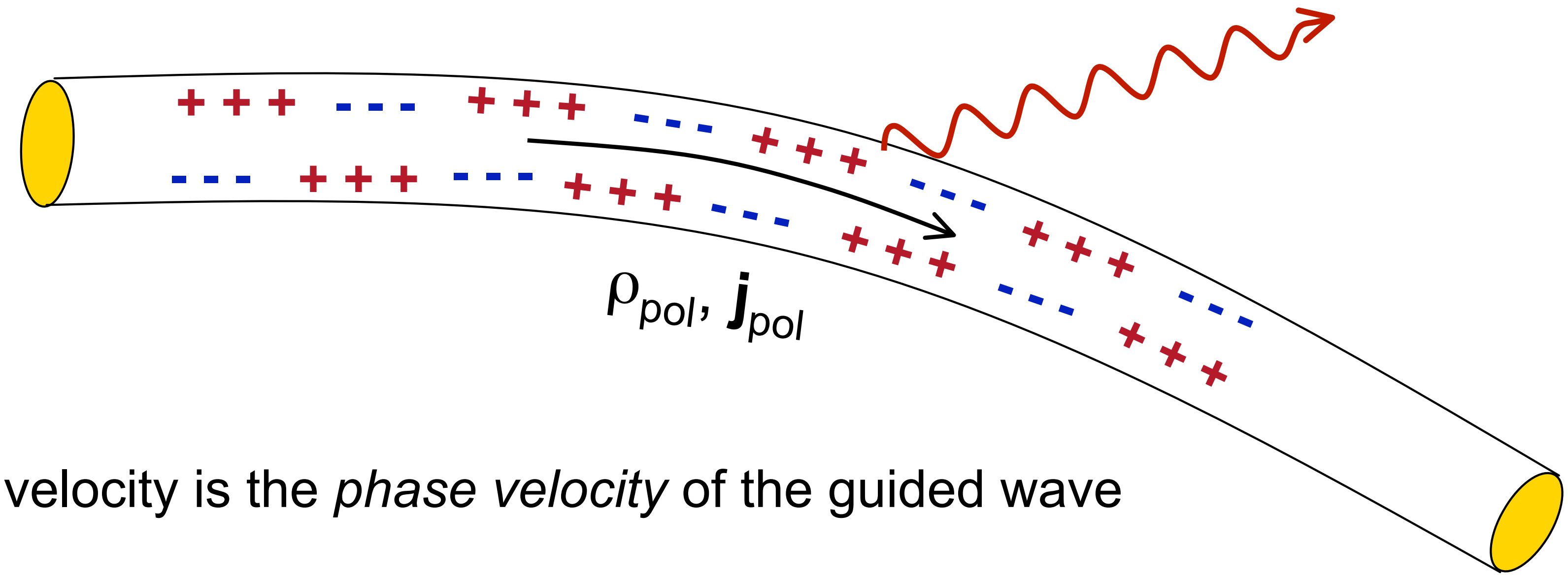


Mathematical treatment

Volume Current Method [M. Kuznetsov and H. Haus ; White] : the wave inside the fiber produces a polarization 4-current

$$j^{\mu}_{pol} = (\rho_{pol}, \mathbf{j}_{pol}) \; ; \qquad \rho_{pol} = \nabla \mathbf{E} \; ; \qquad \mathbf{j}_{pol} = \nabla\times\mathbf{B} - \partial_t \mathbf{E}$$

One assumes that ρ_{pol} and $\mathbf{j}_{pol}$ are *nearly the same as in a straight fiber*. This 4-current follows the bends of the fiber ⇒ it radiates a kind of Synchrotron Radiation.



The velocity is the *phase velocity* of the guided wave

Analytical results - momentum space

For a narrow fiber, $v_{phase} = \omega/k$ is close to 1. The escaping light is collimated as SR at $\gamma >> 1$

Notations: $\theta_0 = (kR_O)^{-1/3}$; $\xi = (1/v - \cos\psi) / \theta_0^2$; $A(\xi) = 2^{4/3} \pi \, \mathrm{Ai}(2^{1/3} \xi)$

Synchrotron Radition :

$$\mathbf{E}(k) = e \, \theta_0 R_O \{ - i\theta_0 \, A'(\xi) \, \mathbf{e}_{horiz} + \psi \, A(\xi) \, \mathbf{e}_{vert} \}$$

Optical Fiber : - replace e by f_z

- add 2 other terms : $- \theta_0 R_O \, A(\xi) \, [f_x \, \mathbf{e}_{horiz} + f_y \, \mathbf{e}_{vert}]$

$\mathbf{f}$ = 2-dim Fourrier transform of $\mathbf{j}_{pol}(x,y)$ with argument $(0,k_y)$

Analytical results - impact parameter space

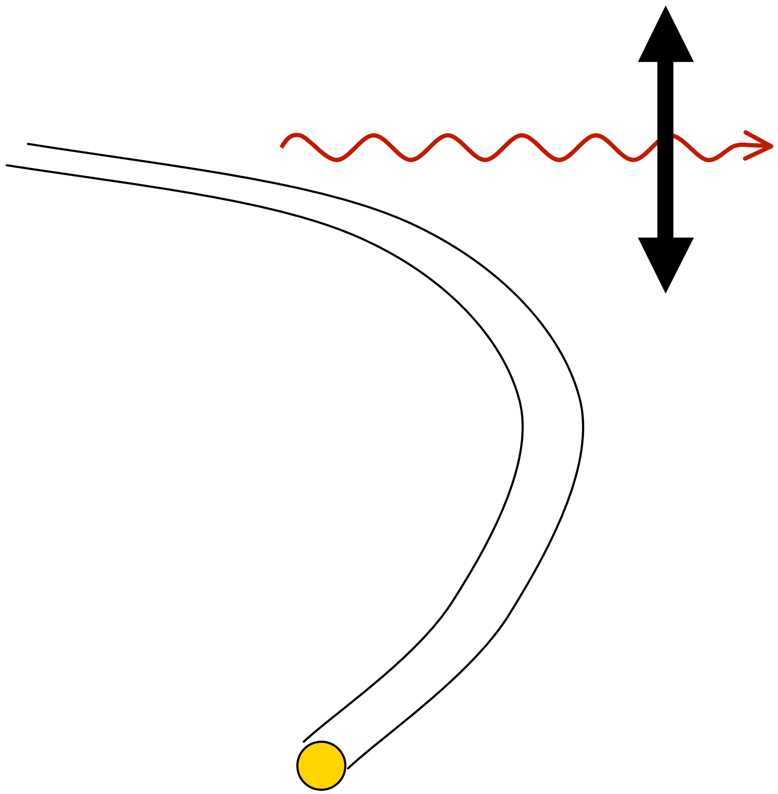
Synchrotron Radiation

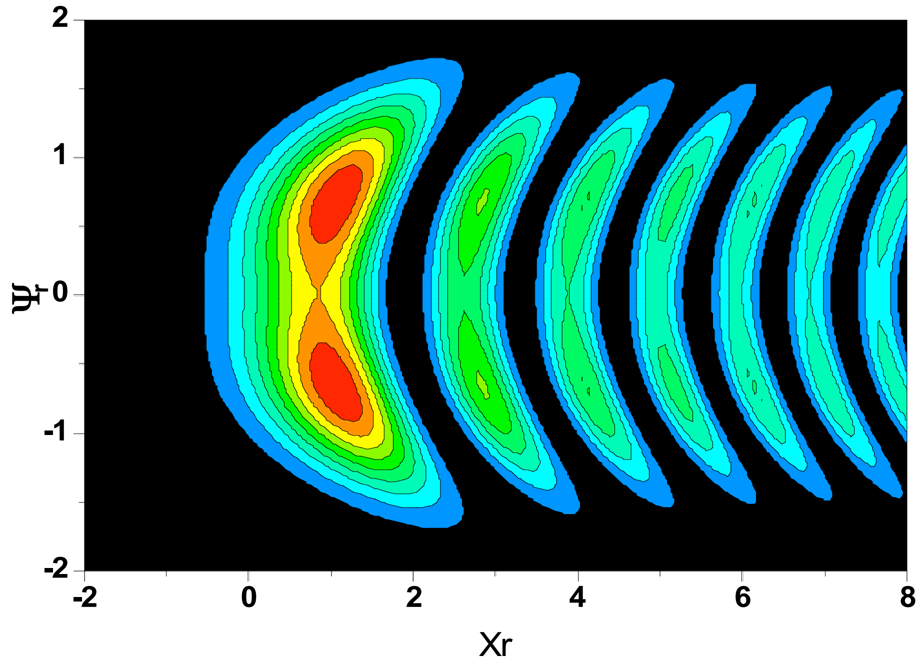
$$dW/(dx, d\psi, d\omega) = (\omega\theta_0^2/2\pi) \quad A^2(\xi) \quad dW/(d\phi, d\psi, d\omega)$$

Optical Fiber

$$dW/(dx, d\psi, dt) = (\omega\theta_0^2/2\pi) \quad A^2(\xi) \quad dW/(d\phi, d\psi, dt)$$

Expected from a optical fiber experiment





Conclusion

- Bent fibers can be used to understand and test properties of Synchrotron Radiation.
- They have at least a pedagogical interest.

Thank you for your attention !