Experimental Physics 3 - Em-Waves,Optics, Quantum mechanics

Lecture 25

Prof. Dr. Frank Cichos
WS 2022/23

Some dates in January and February

Mo	Tu	We	Th	Fr	Sa	Su
						1
2	3	4	5	6	7	8
9	10	11	12 Submission sheet 11	13	14	15
16	17	18	19 Submission mock exam	20	21	22
23	24	25	26 Submission sheet 12	27	28	29
30	31 Last Tuesday seminar	1	2 Last Thursday seminar Last lecture	3		

Exam: February 20, 2023, 9 am - 12 pm, 1 (one) DIN A4 page lettered

Re-exam: March 27, 2023, 9 am - 12 pm

Heisenberg’s uncertainty relation

Recap - Heisenberg's uncertainty principle, mathematical base

Original form by Heisenberg: $\Delta x \cdot \Delta p \approx \hbar$

Mathematical base: **Fourier transform and Cauchy-Schwarz unequality**

Let $f(x) \in L^2(\mathbb{R})$ be the wave function of a free particle and $\hat{f}(u)$ the Fourier transform of $f(x)$

Probability density that particle is at position x: $\dfrac{\left|f(x)\right|^2}{||f||_2}$, variance in x: $\sigma_x^2 = \dfrac{1}{||f||_2} \int \left(x - x_0\right)^2 \left|f(x)\right|^2 \mathrm{d}x$

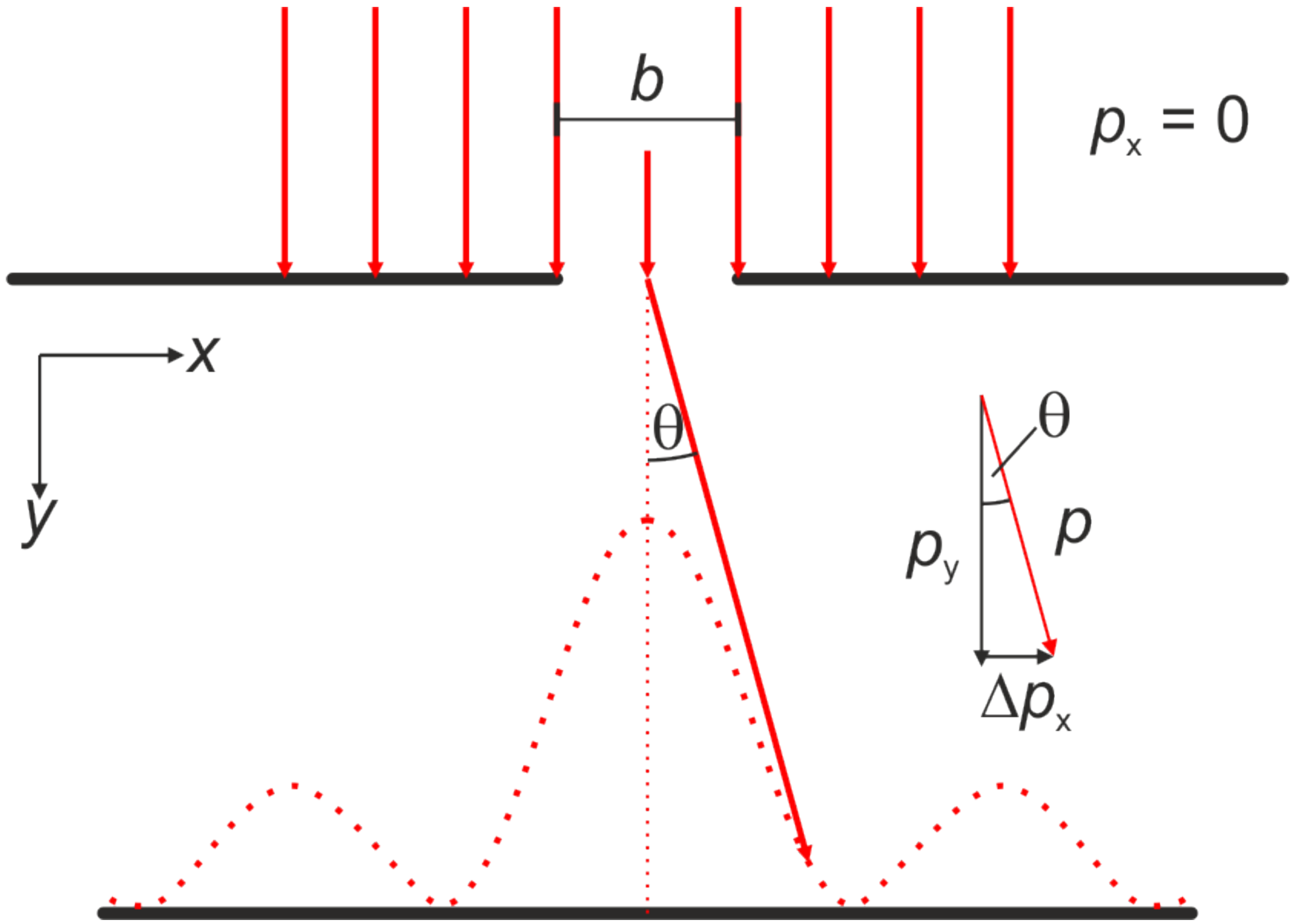
that momentum is equal to p: $\dfrac{\left|\hat{f}(p)\right|^2}{2\pi\,||f||_2}$, variance in p: $\sigma_p^2 = \dfrac{1}{2\pi\,||f||_2} \int \left(p - p_0\right)^2 \left|\hat{f}(p)\right|^2 \mathrm{d}x$

Theorem: $\left(\int (x-a)^2 \left|f(x)\right|^2 \mathrm{d}x\right)\left(\int \left(u-b\right)^2 \left|\hat{f}(u)\right|^2 \mathrm{d}x\right) \geq \dfrac{\pi}{2}\left(\int \left|f(x)\right|^2 \mathrm{d}x\right)^2$

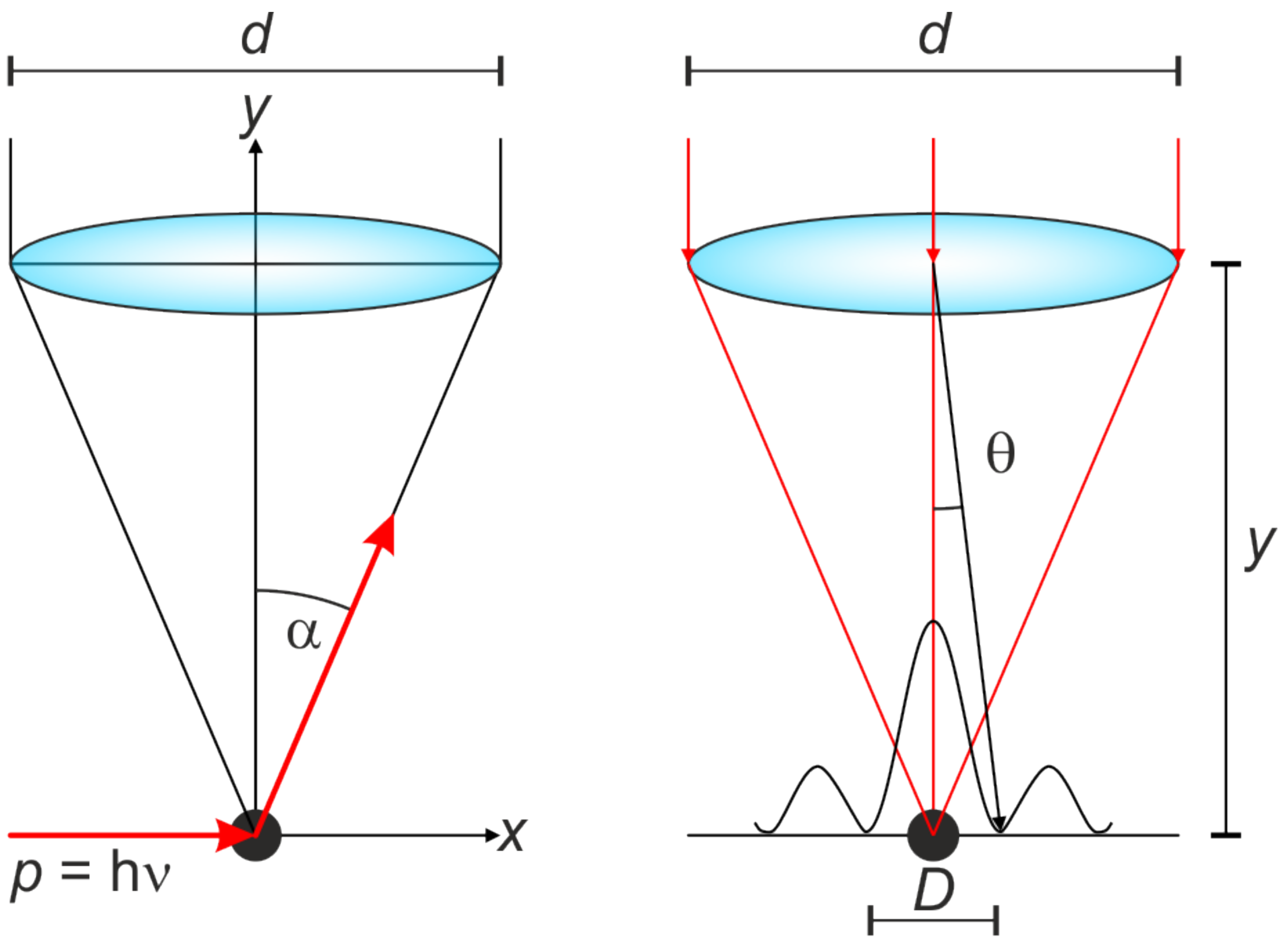
Result $\sigma_x \cdot \sigma_p \geq \dfrac{1}{4}$ (and factor $\hbar$ in addition)

http://math.uchicago.edu/~may/REU2021/REUPapers/Dubey.pdf
https://www.ams.org/journals/bull/2021-58-02/S0273-0979-2021-01715-0/viewer/

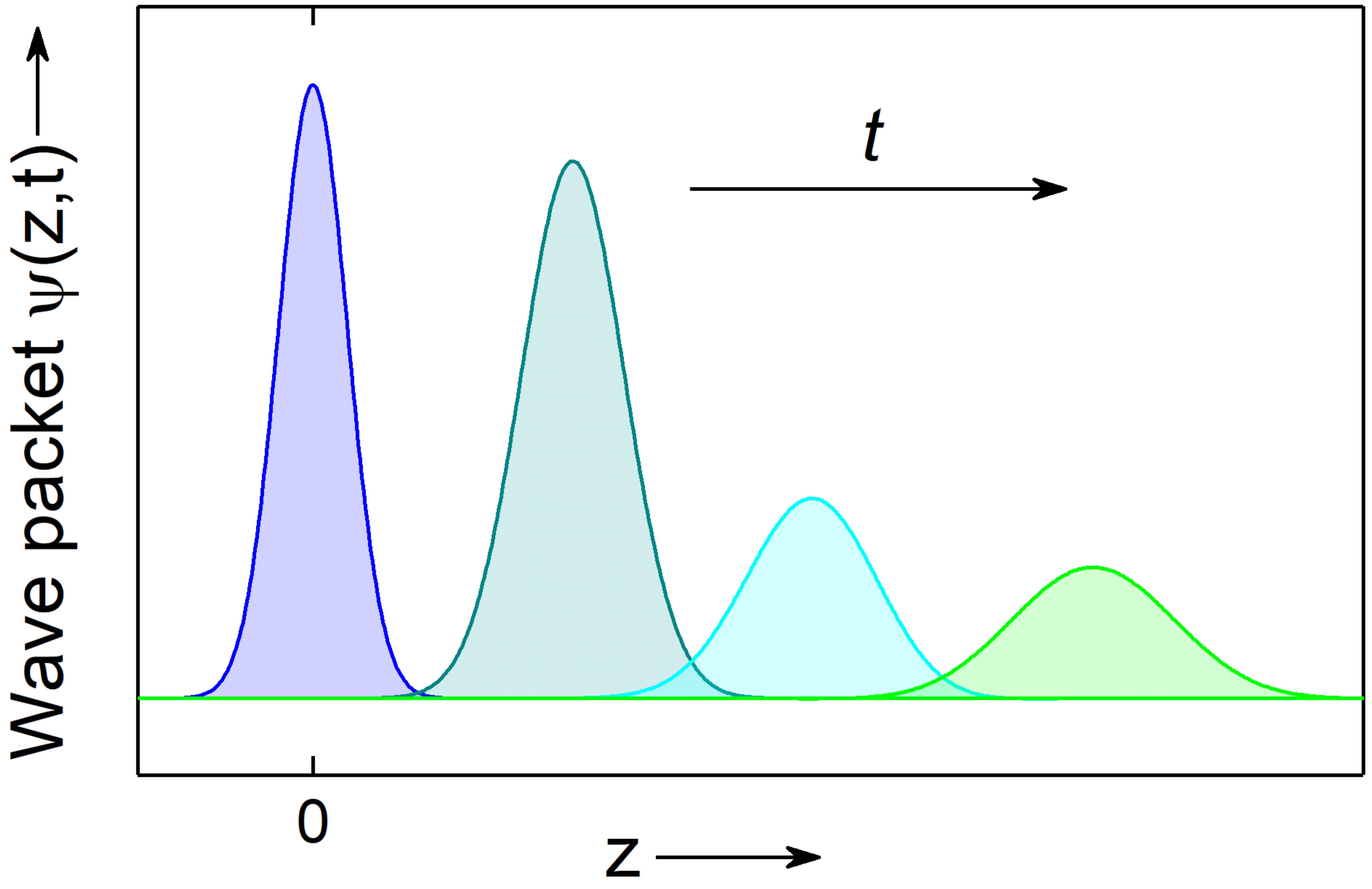
Recap - Heisenberg's uncertainty principle, electron in a single slit



Recap - Heisenberg’s uncertainty principle, photon scattering

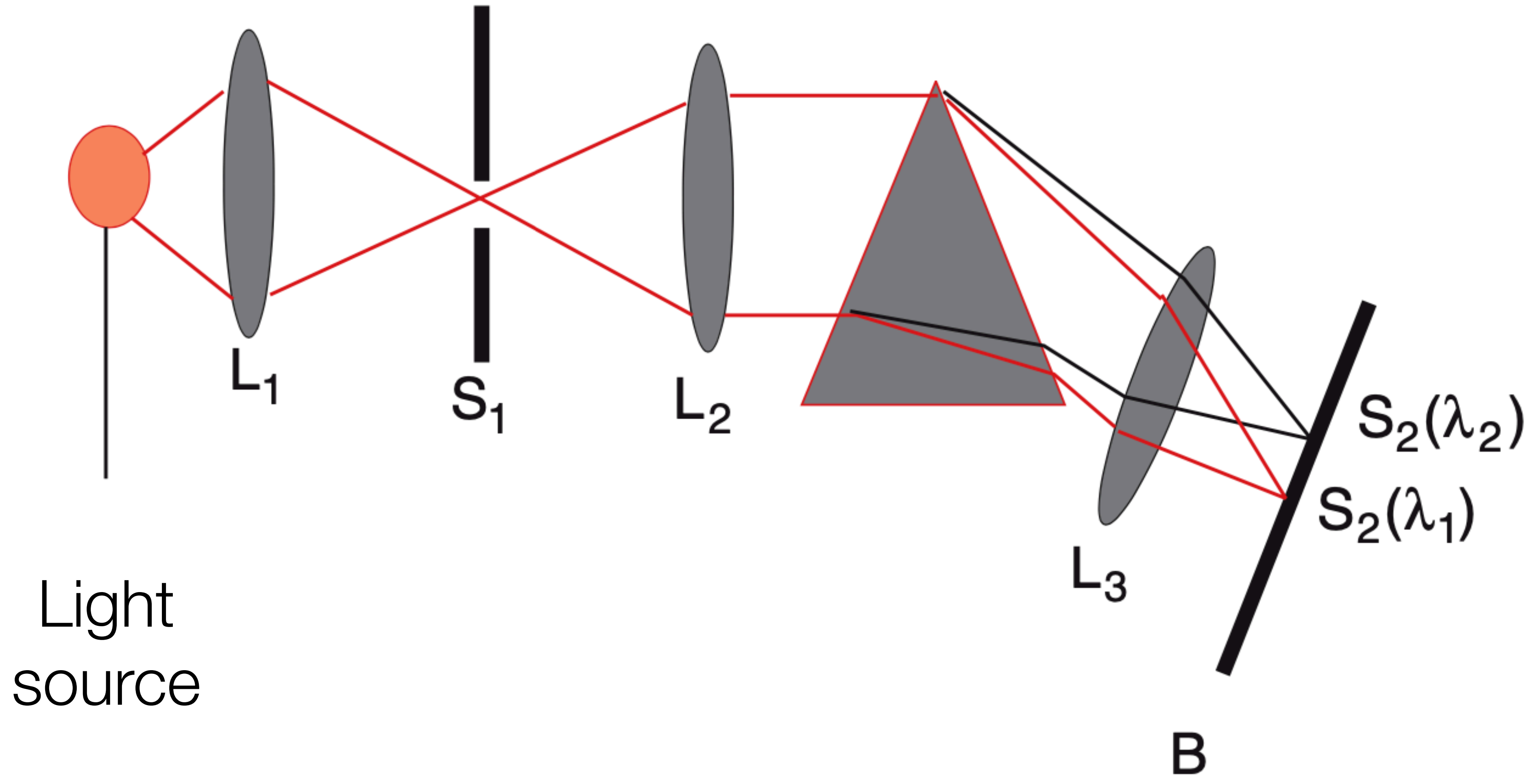


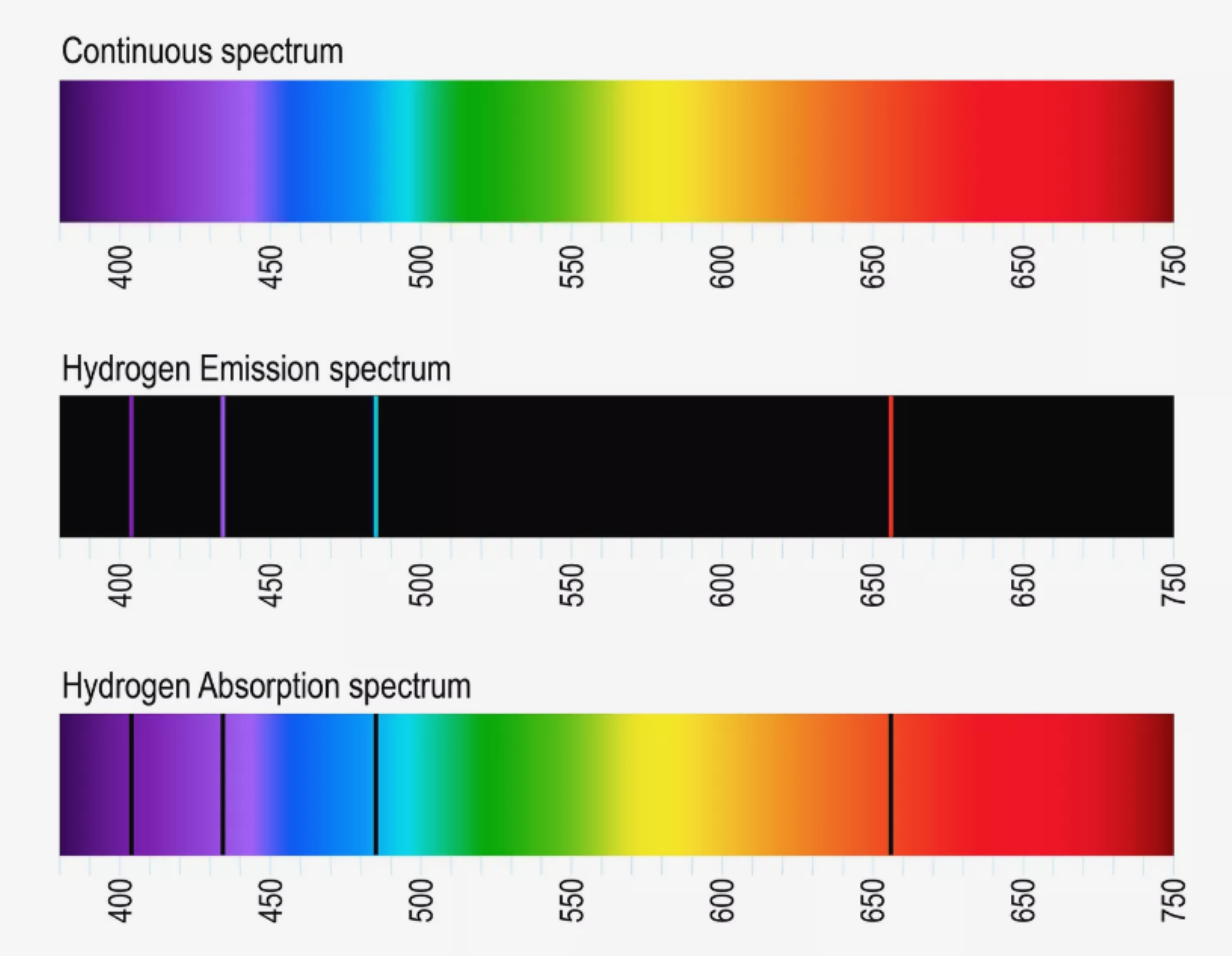
Recap - wave packet spreading



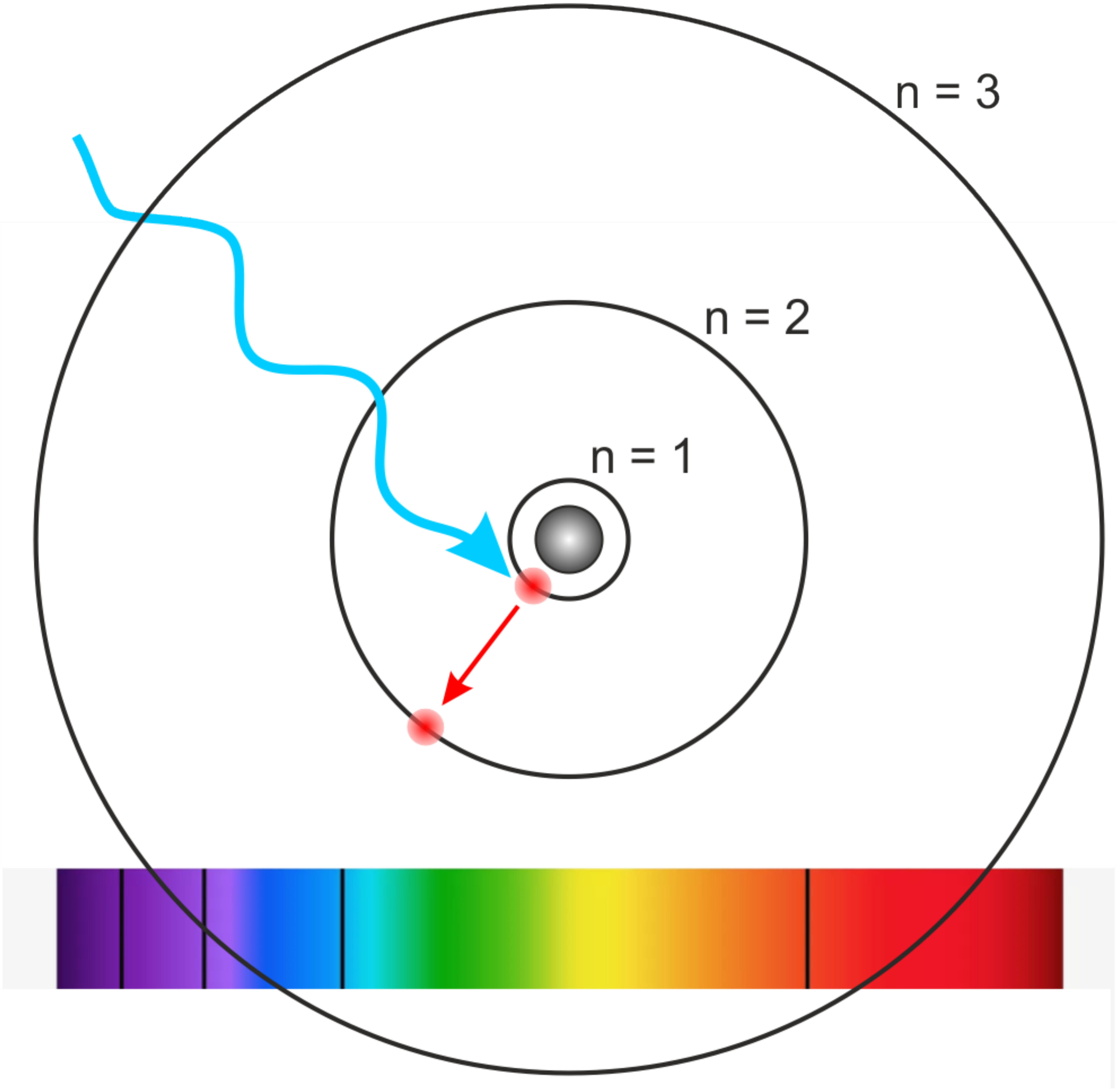
The Bohr model

Bohr model - line spectra

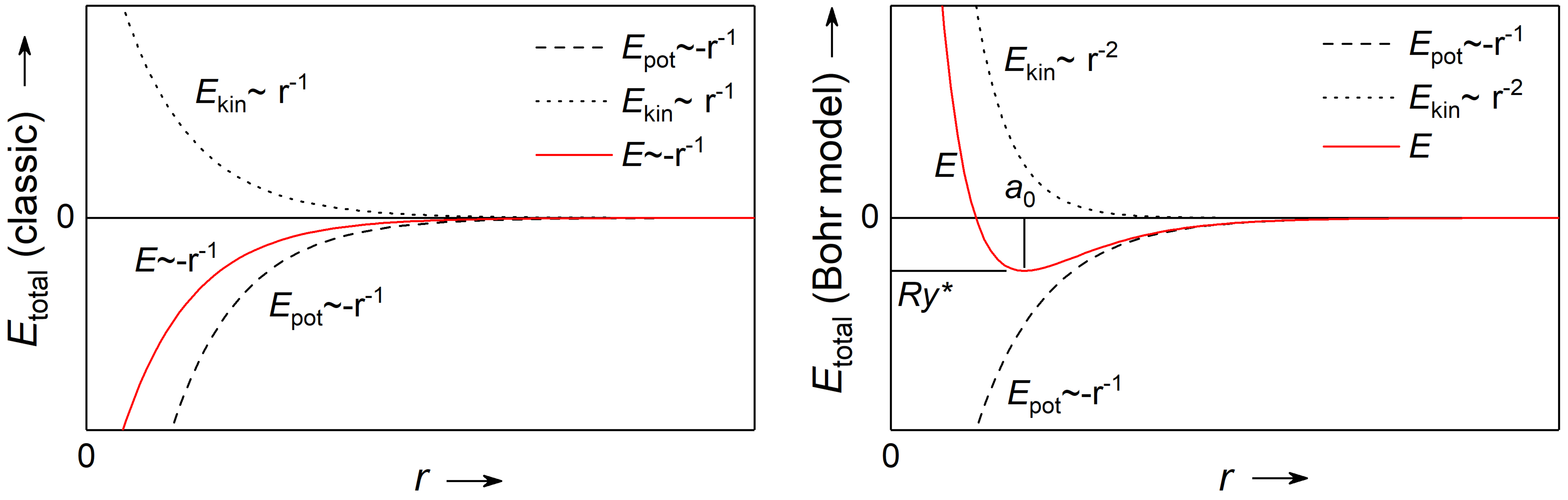




Bohr model - line spectra due to absorption and emission

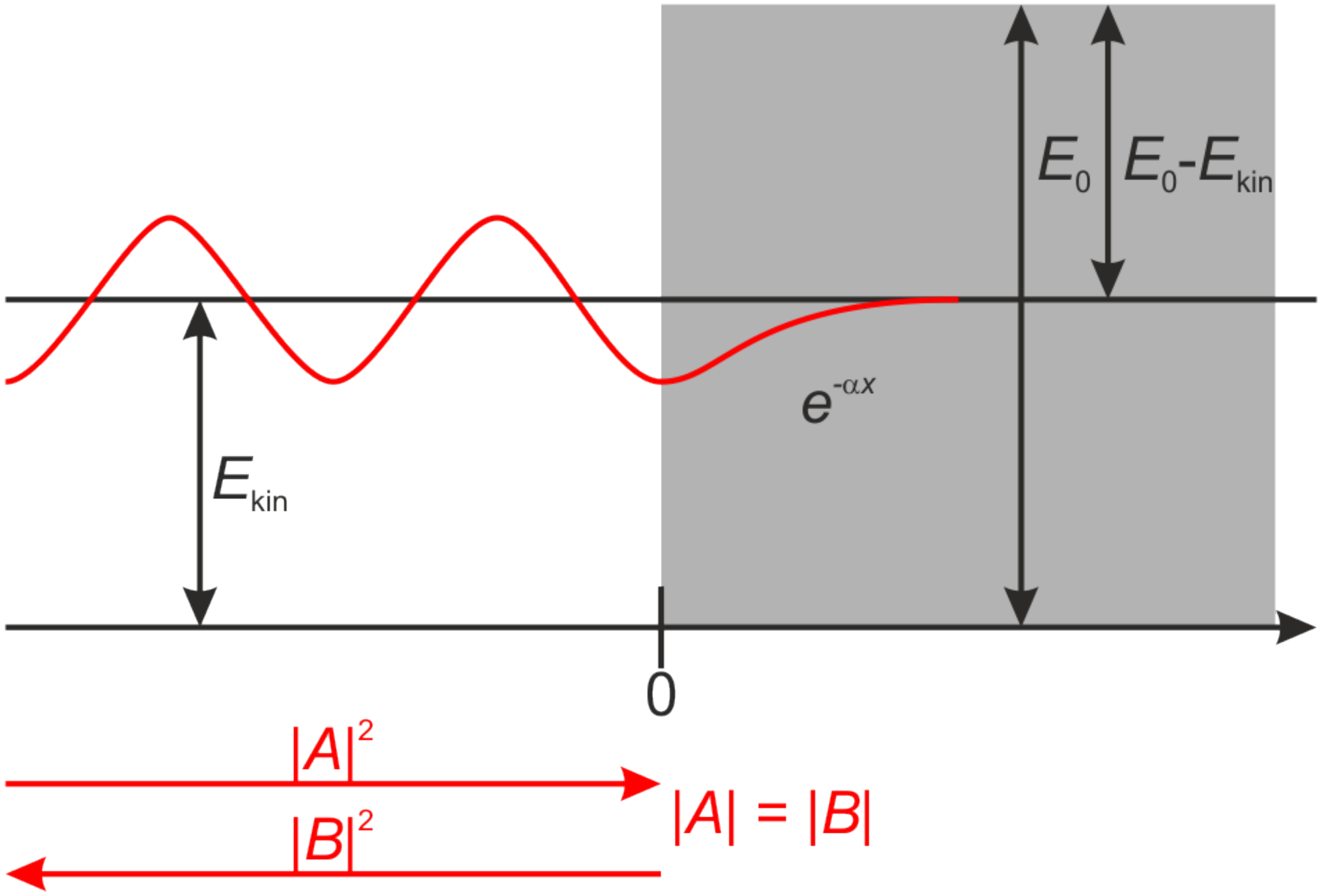


Bohr model - stable electron radius



The Schrödinger equation

Schrödinger equation - potential barrier $E < E_0$



Schrödinger equation - potential barrier $E < E_0$