

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

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## Lecture 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		

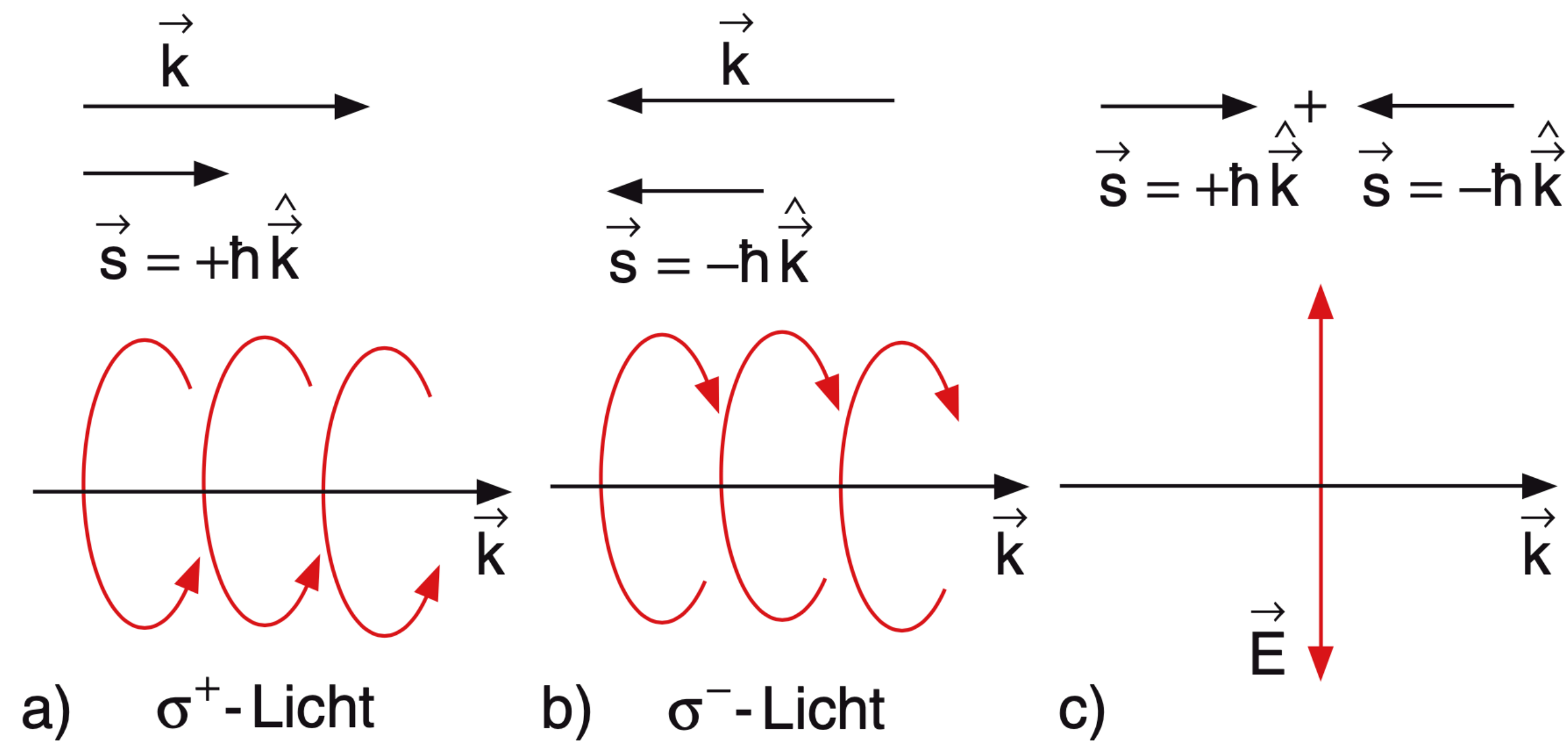
Exam: February 20, 2023, 9 am - 12 pm, 1 (one) DIN A4 page lettered

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

# Properties of photons

# Properties of photons - angular momentum

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# Properties of photons - gravity

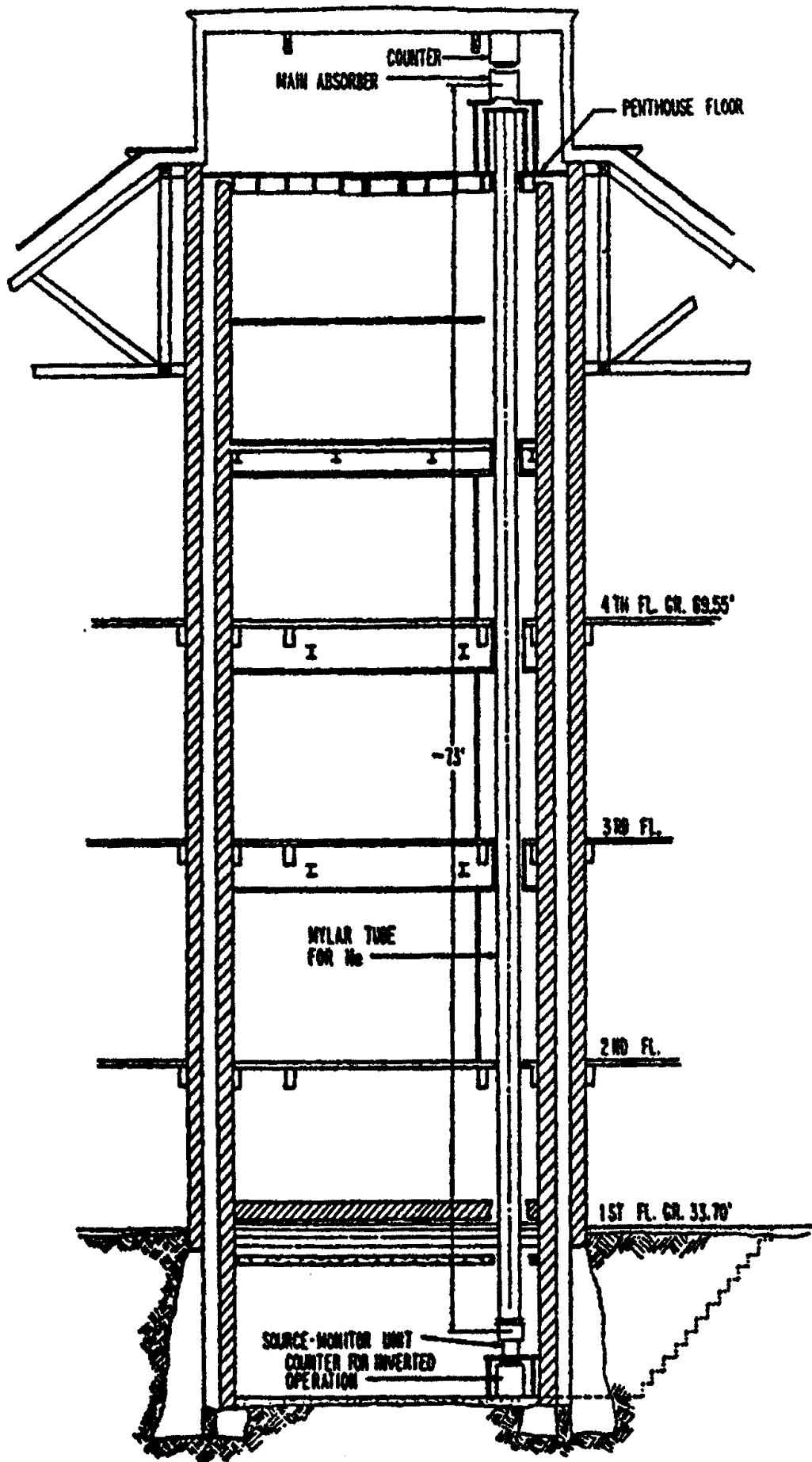
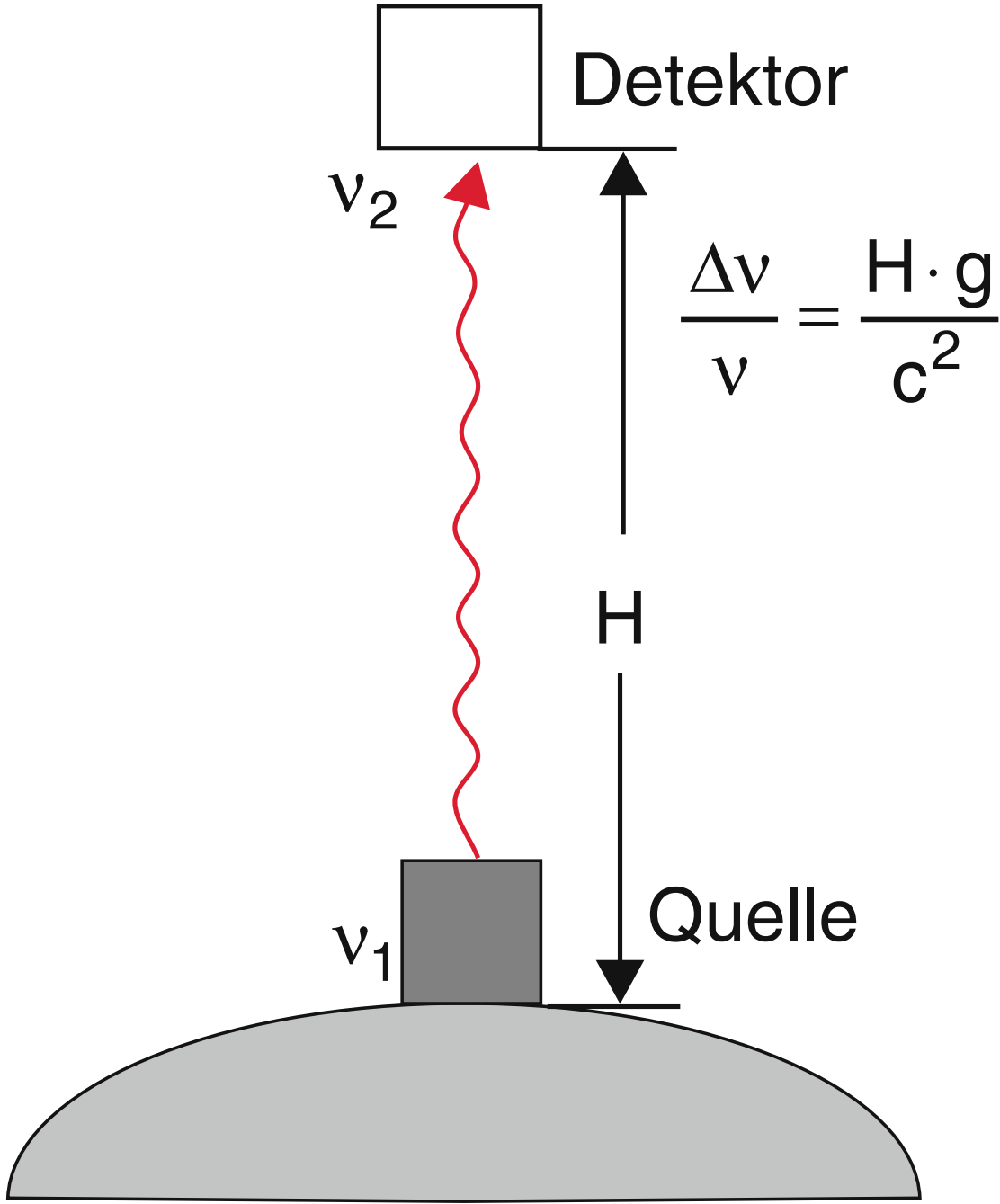


Fig. 4. Architectural sketch of the Jefferson Physical Laboratory tower showing the placement of the gravitational red-shift experiment running from the penthouse to the basement. Source: R. V. Pound and J. L. Snider, "Effect of Gravity" (ref. 23), p. B 792.

Pound & Rebka, Phys. Rev. Lett. 3, 440 (1959).

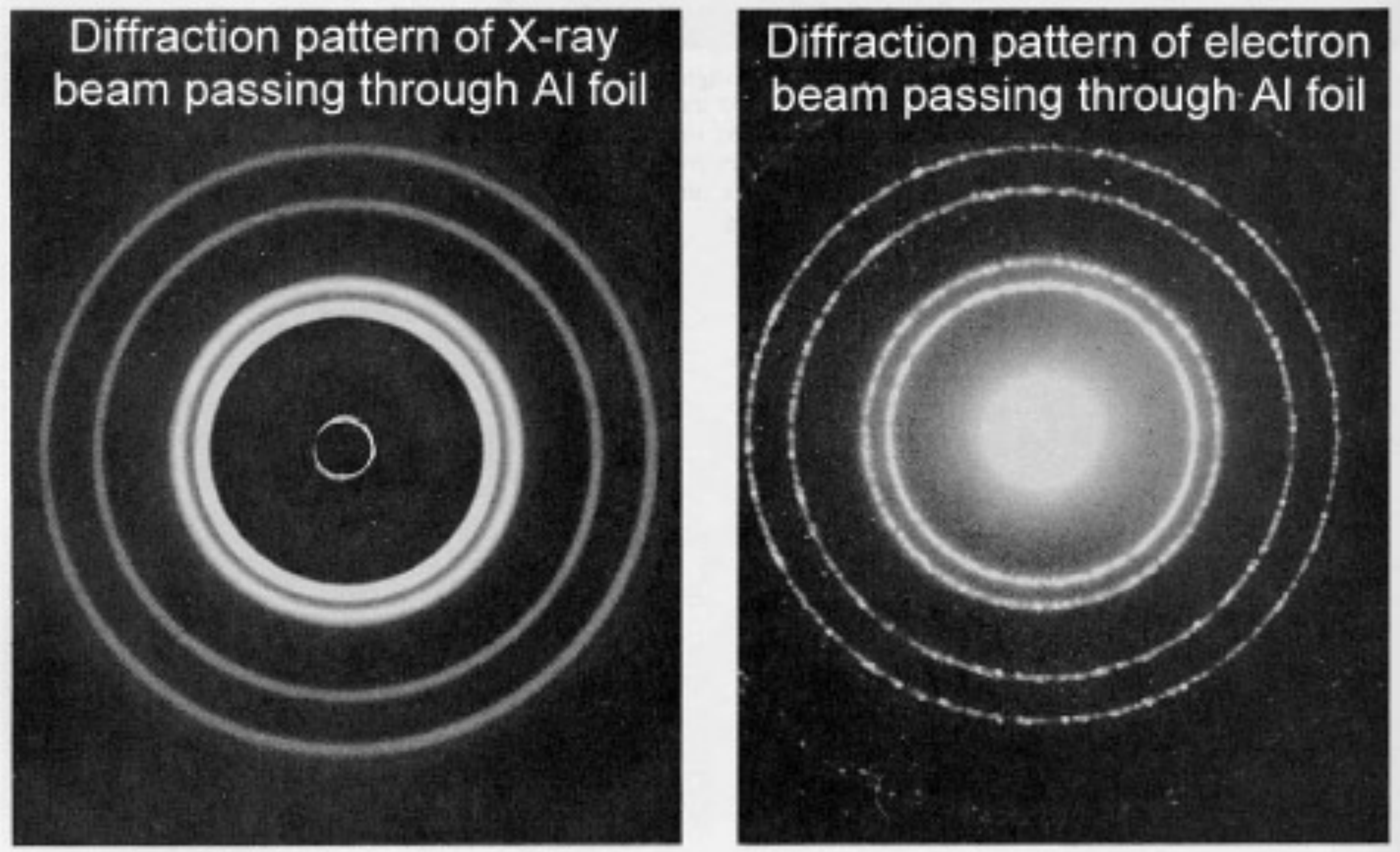


$$\frac{\Delta \nu}{\nu} = 2.5 \times 10^{-15}$$

Wave properties of corpuscles

# De Broglie wavelength - diffraction of light and electrons

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# Davisson Germer experiment

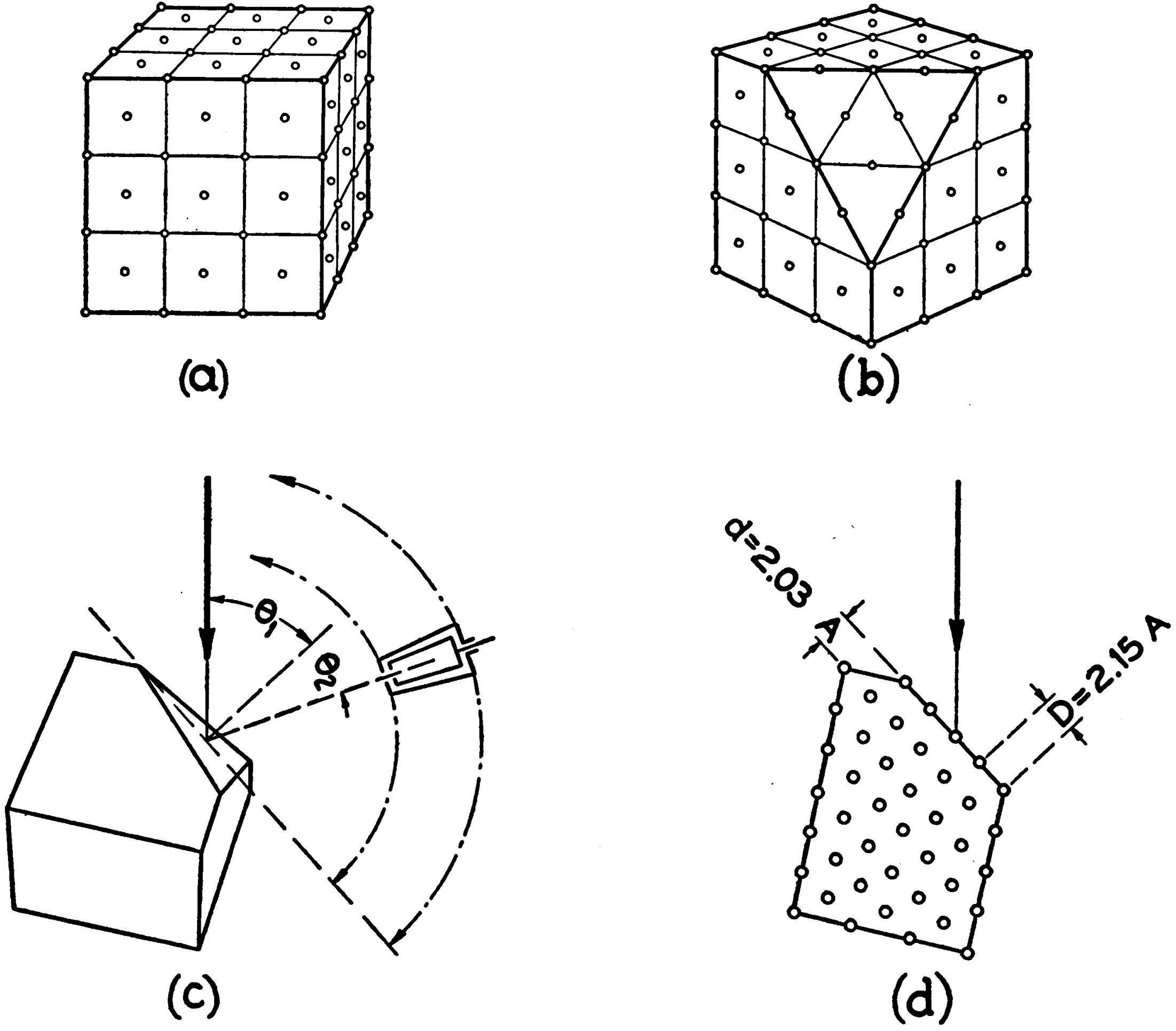
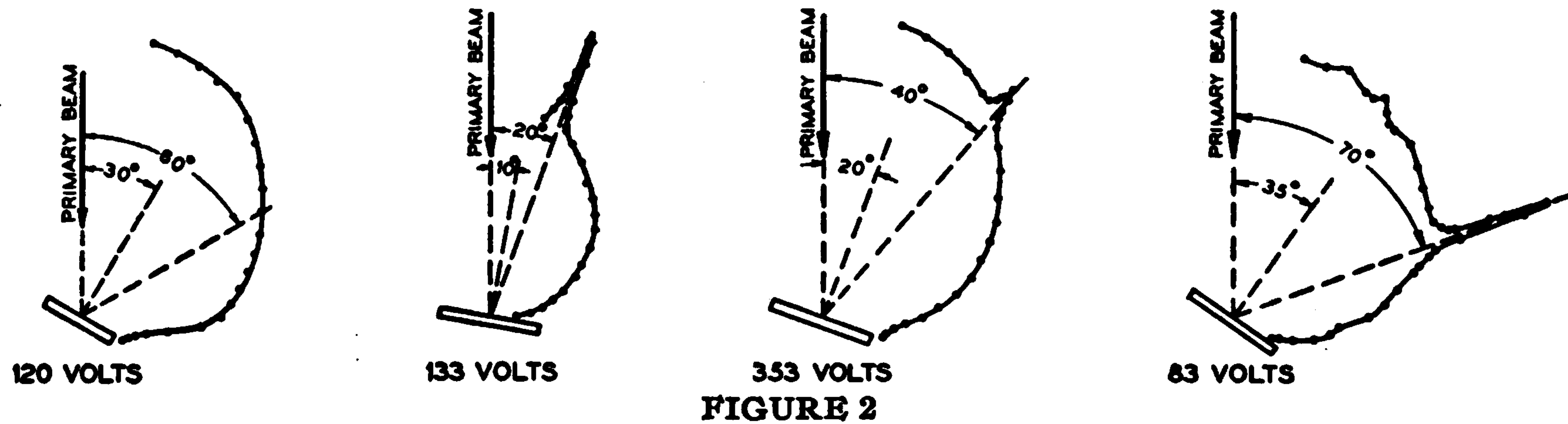


FIGURE 1  
Schematic diagrams indicating the experimental arrangement for measuring the reflection of electrons.



# Davisson Germer experiment

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**Distribution-in-angle of electrons of all speeds issuing from a [111] face of a nickel crystal for various angles of incidence and speeds of bombardment.**

# Davisson Germer experiment

Vol. 14, 1928

PHYSICS: DAVISSON AND GERMER

317

REFLECTION OF ELECTRONS BY A CRYSTAL OF NICKEL

By C. J. DAVISSON AND L. H. GERMER

BELL TELEPHONE LABORATORIES, INC., NEW YORK CITY

Communicated March 10, 1928

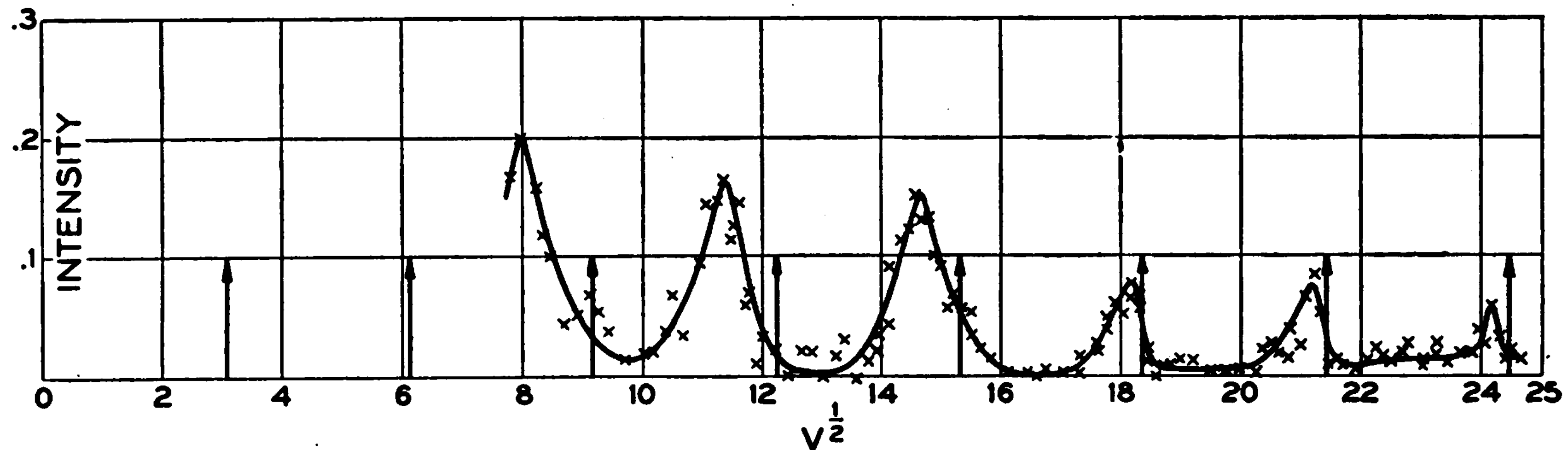
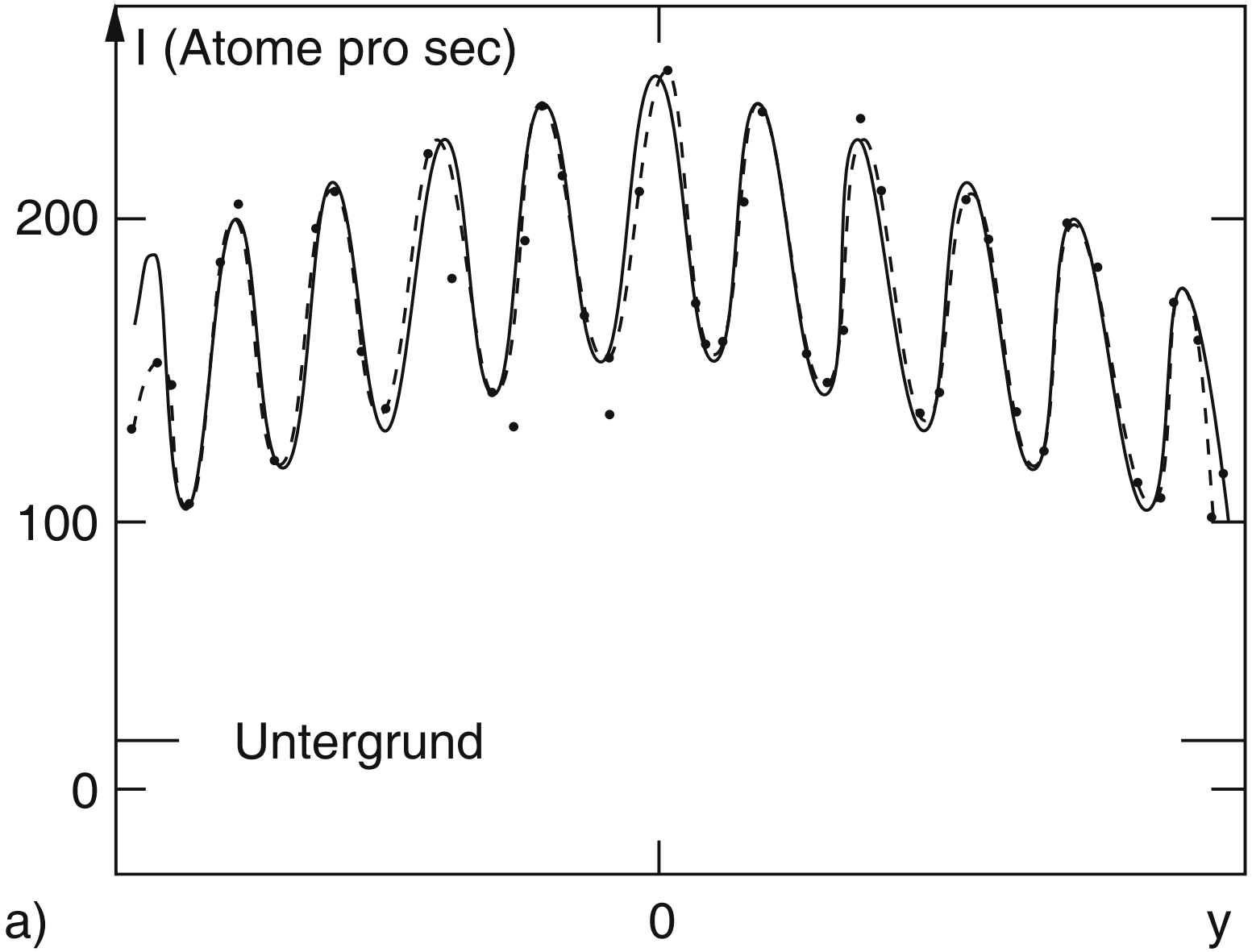
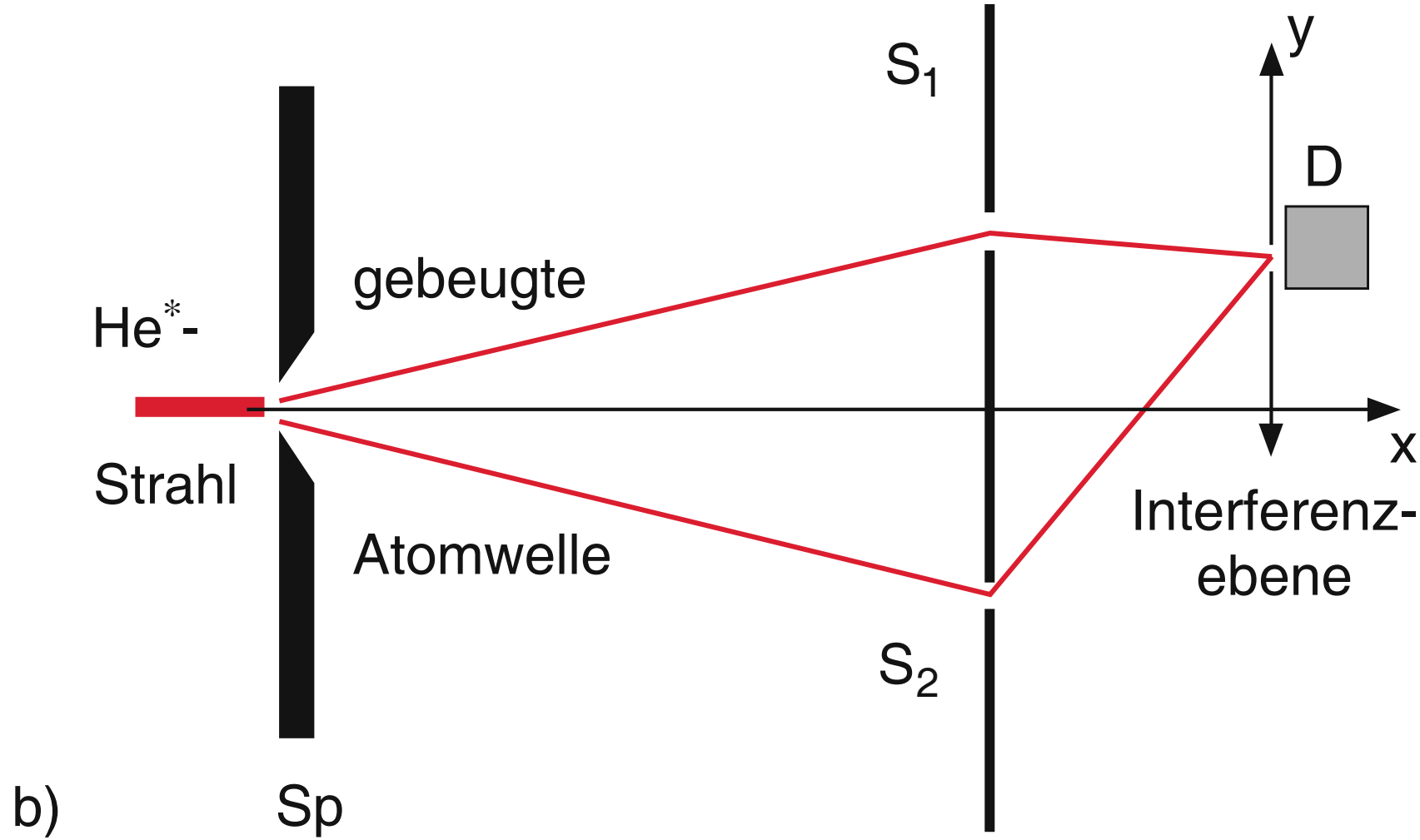


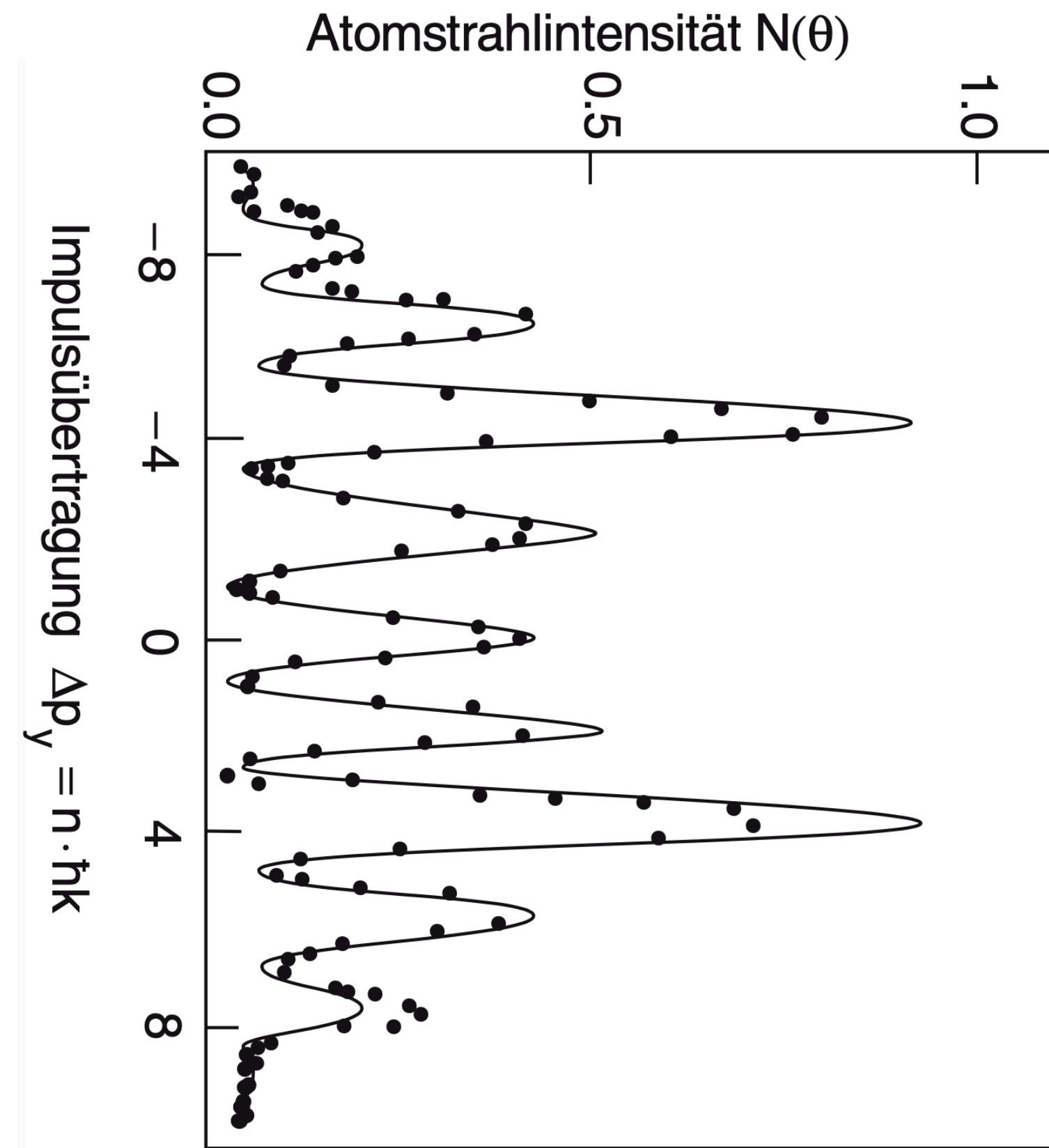
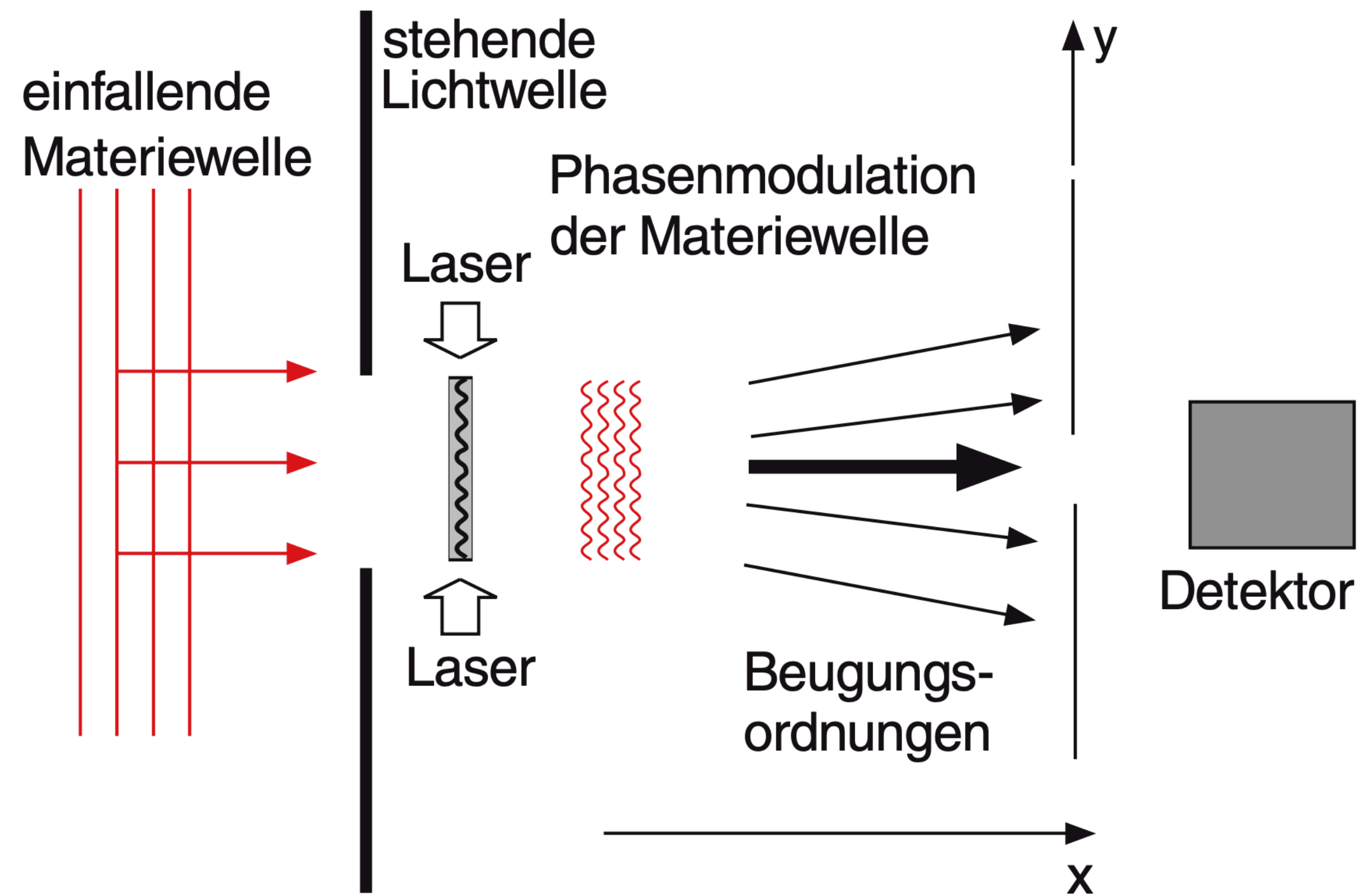
FIGURE 3

Variation of the intensity of the regularly reflected electron beam with bombarding potential, for  $10^\circ$  incidence—Intensity vs.  $V^{1/2}$ .

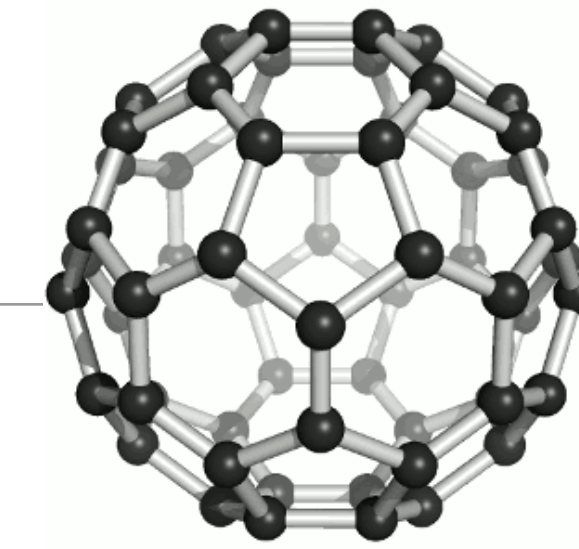
# Interference of atoms



# Interference of atoms



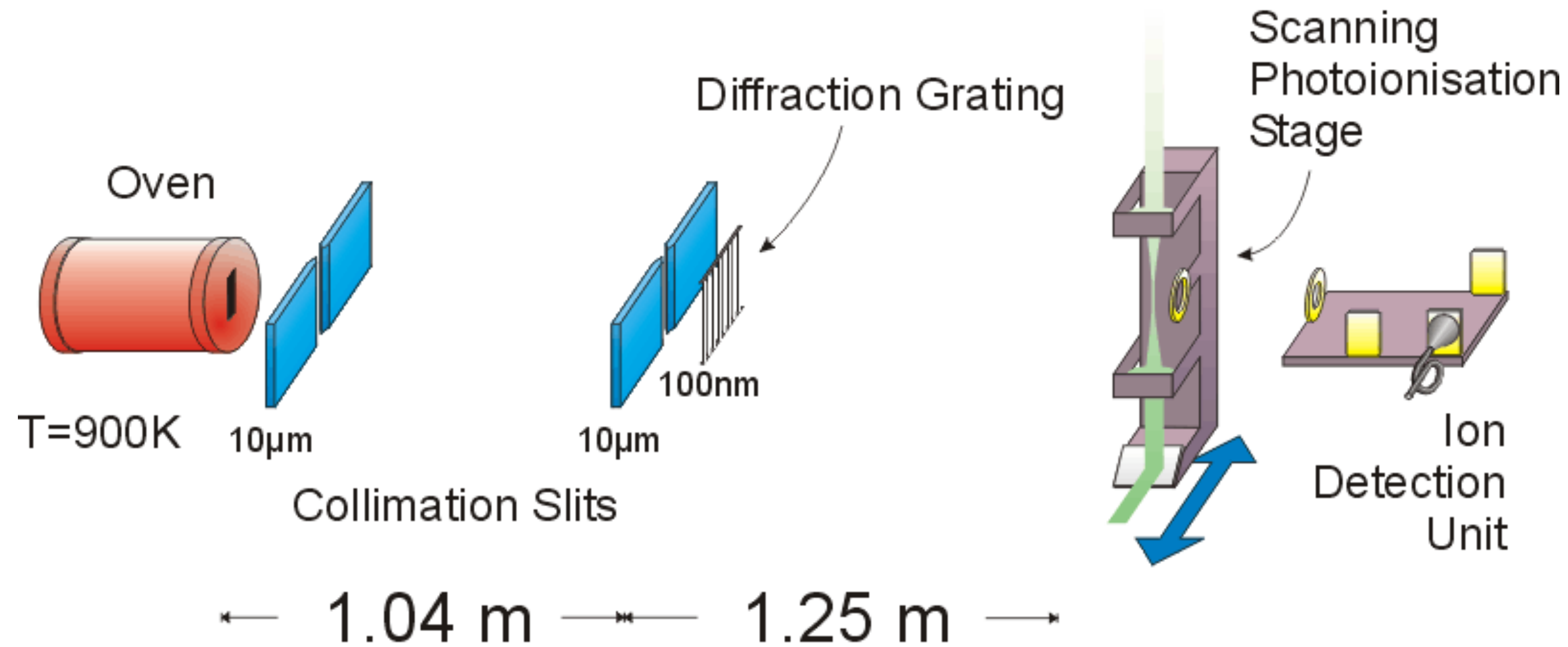
# Molecular interference - C<sub>60</sub>



## Wave-particle duality of C<sub>60</sub> molecules

Markus Arndt, Olaf Nairz, Julian Vos-Andreae, Claudia Keller,  
Gerbrand van der Zouw & Anton Zeilinger

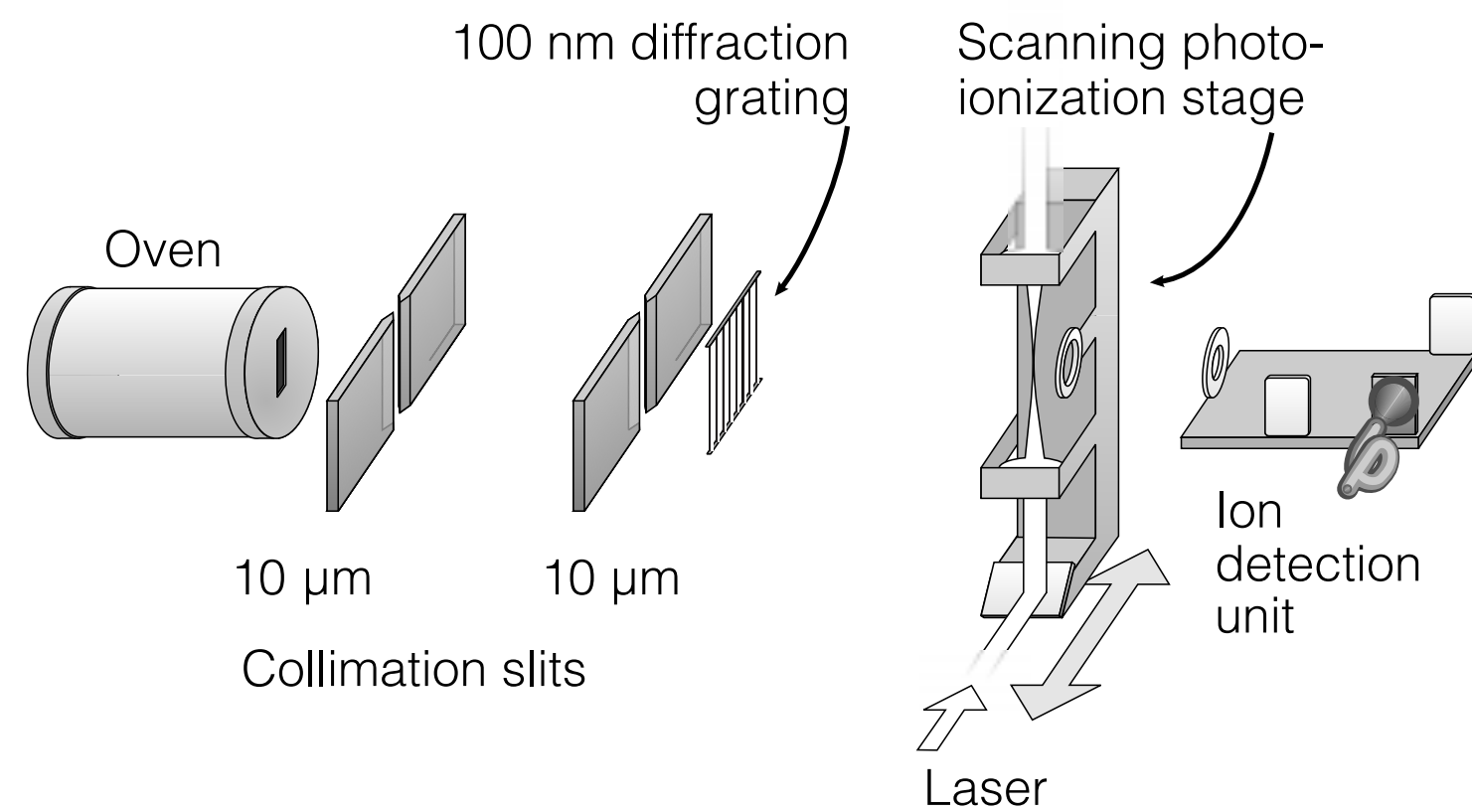
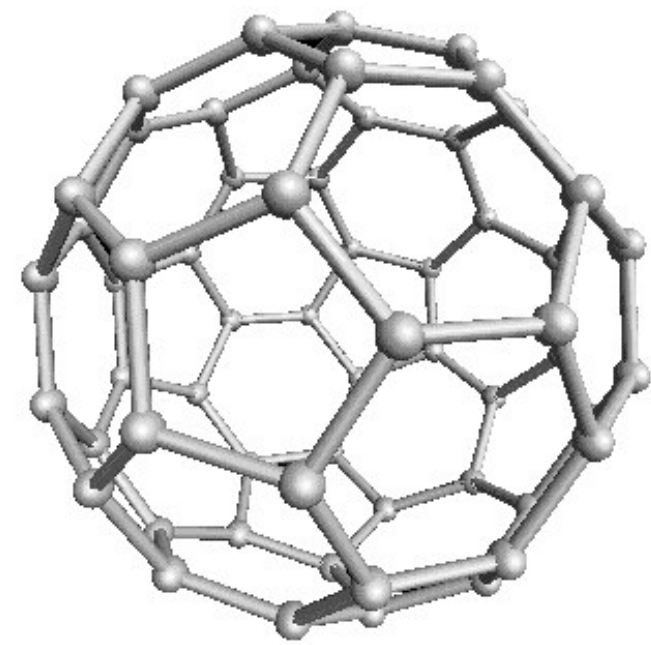
*Institut für Experimentalphysik, Universität Wien, Boltzmannngasse 5,  
A-1090 Wien, Austria*



Pressure  $\sim 5 \cdot 10^{-7}$  mbar

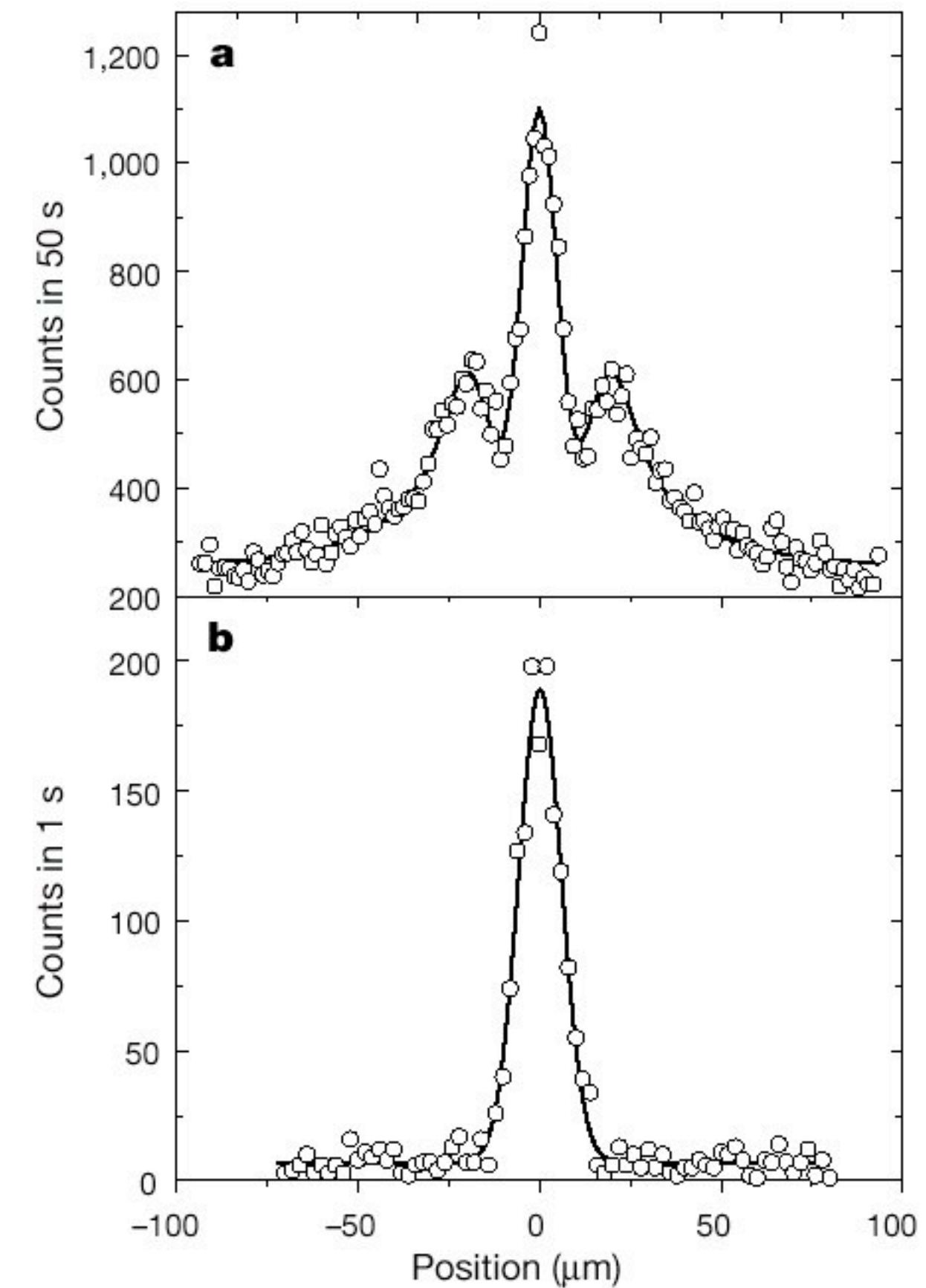
# Molecular interference

C<sub>60</sub> molecule



M.Arndt et al. Nature 401, 680 (1999).

diffraction of C<sub>60</sub> molecules on a grating

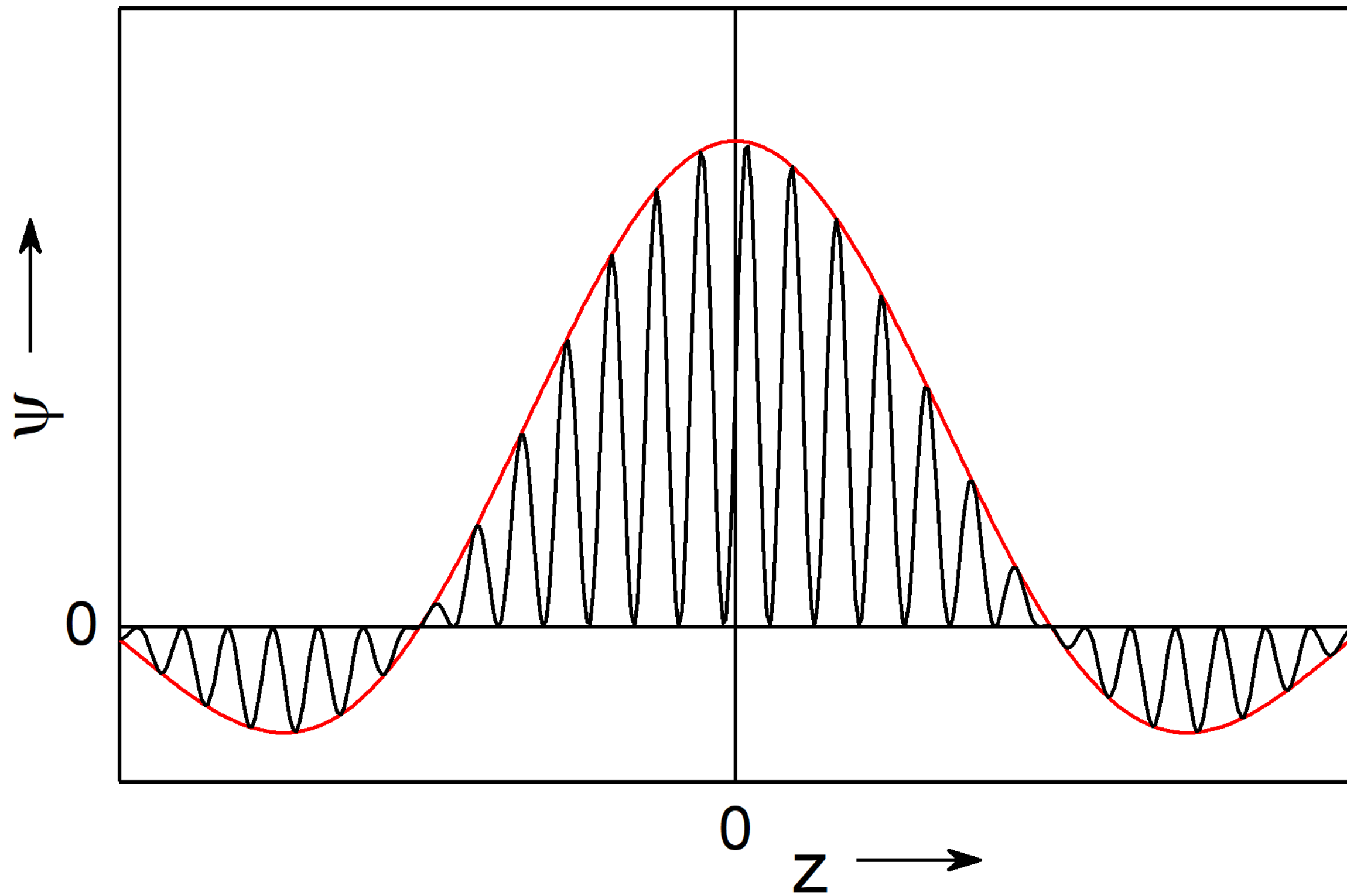


C<sub>60</sub> diffraction pattern

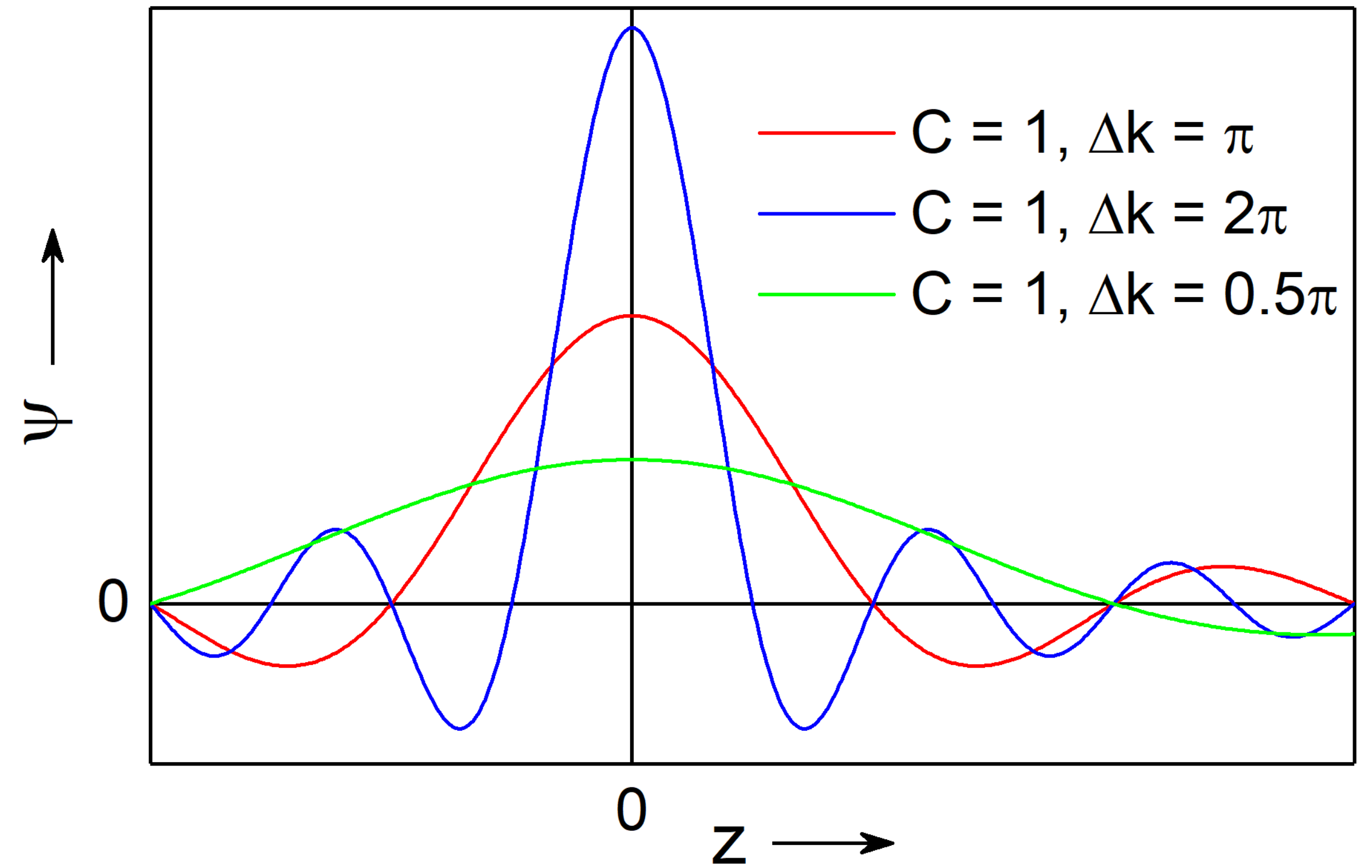
Beam profile without grating

Waves of matter

# Wave packet with constant amplitude



- Side lobes
- Negative values of  $\psi$

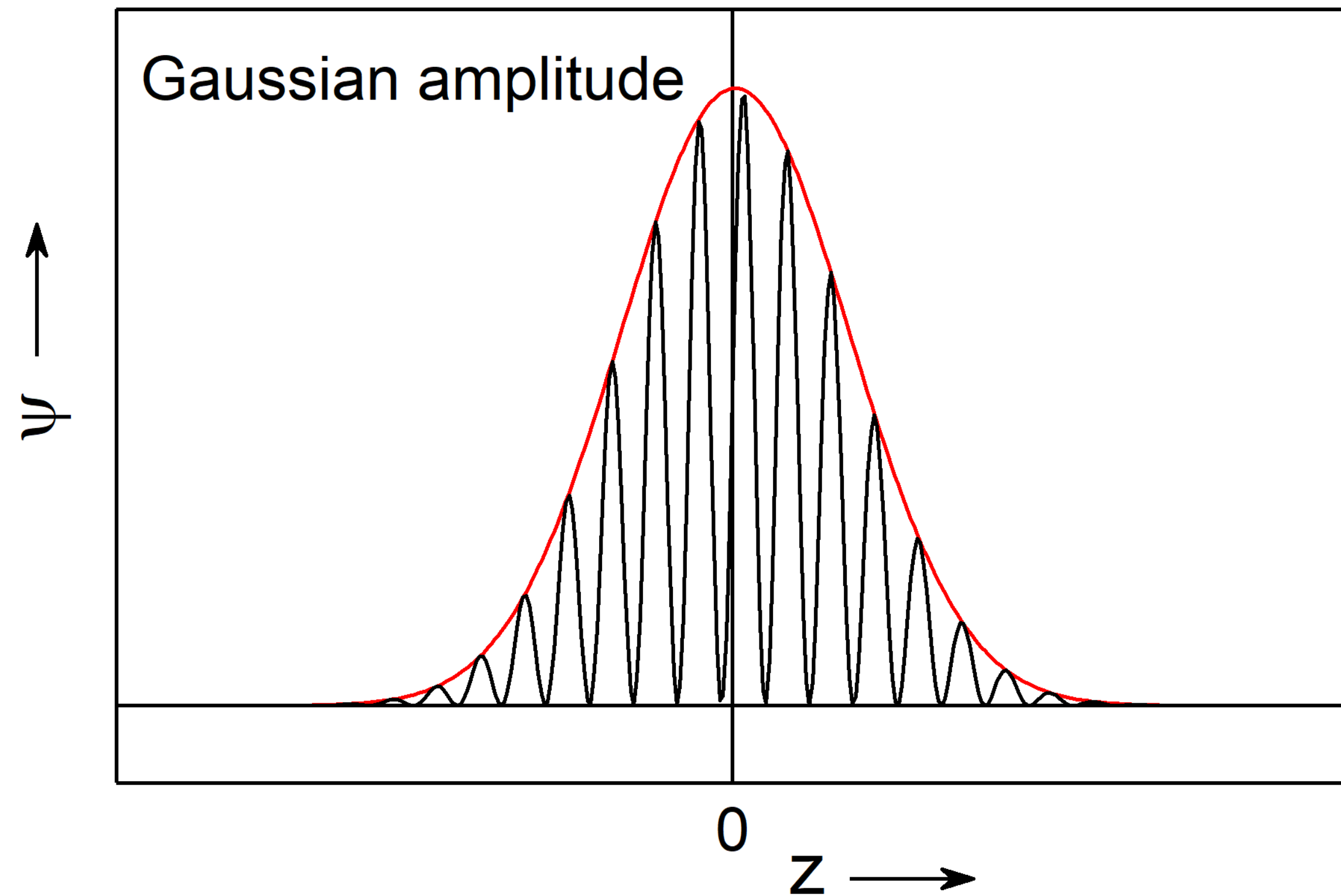


- The broader the interval  $\Delta k$ , the narrower the central maximum



# Wave packet with Gaussian amplitude

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- No side lobes
- No negative values of  $\psi$
- The broader the interval  $\Delta k$ , the narrower the central maximum