Title: Interpretation of Quantum Theory: Lecture 15

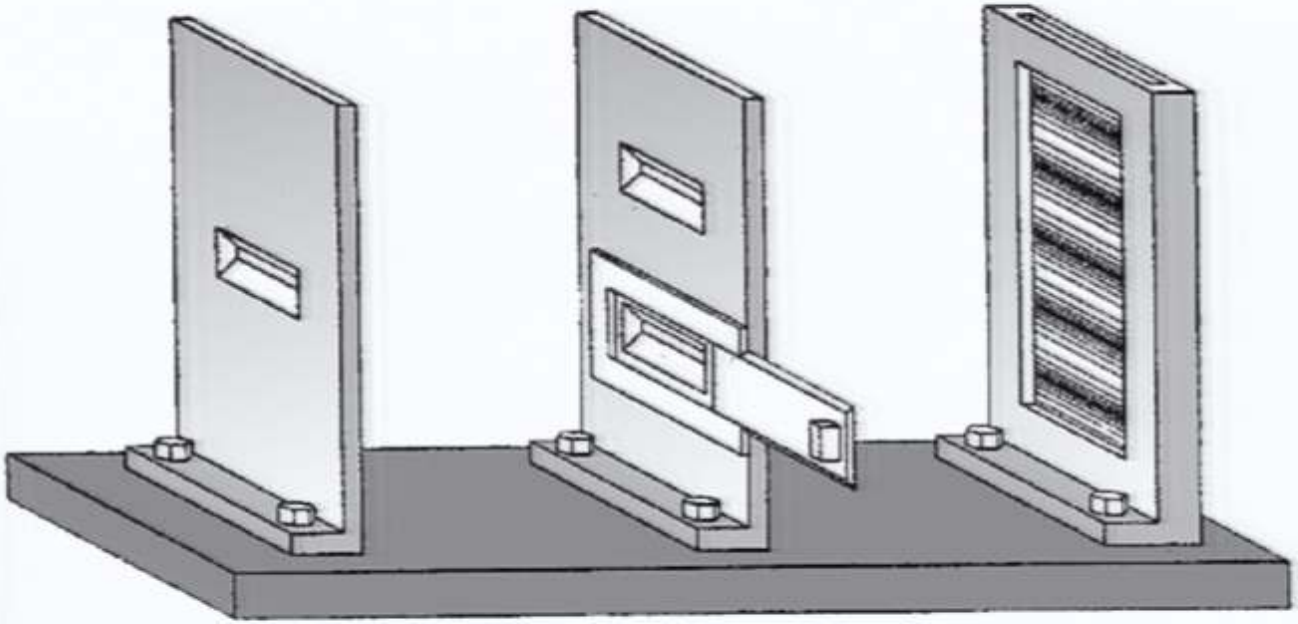
Date: Mar 01, 2005 02:15 PM

URL: http://pirsa.org/05030079

Abstract:

Double Slit Interference

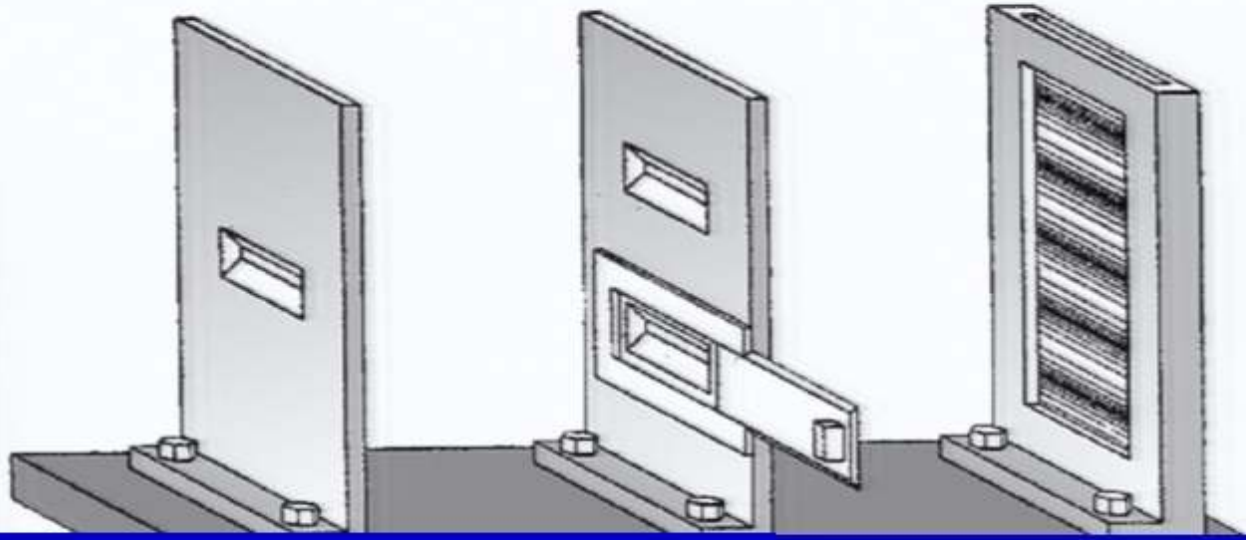
Superposition



Bohr-Einstein Dialogue

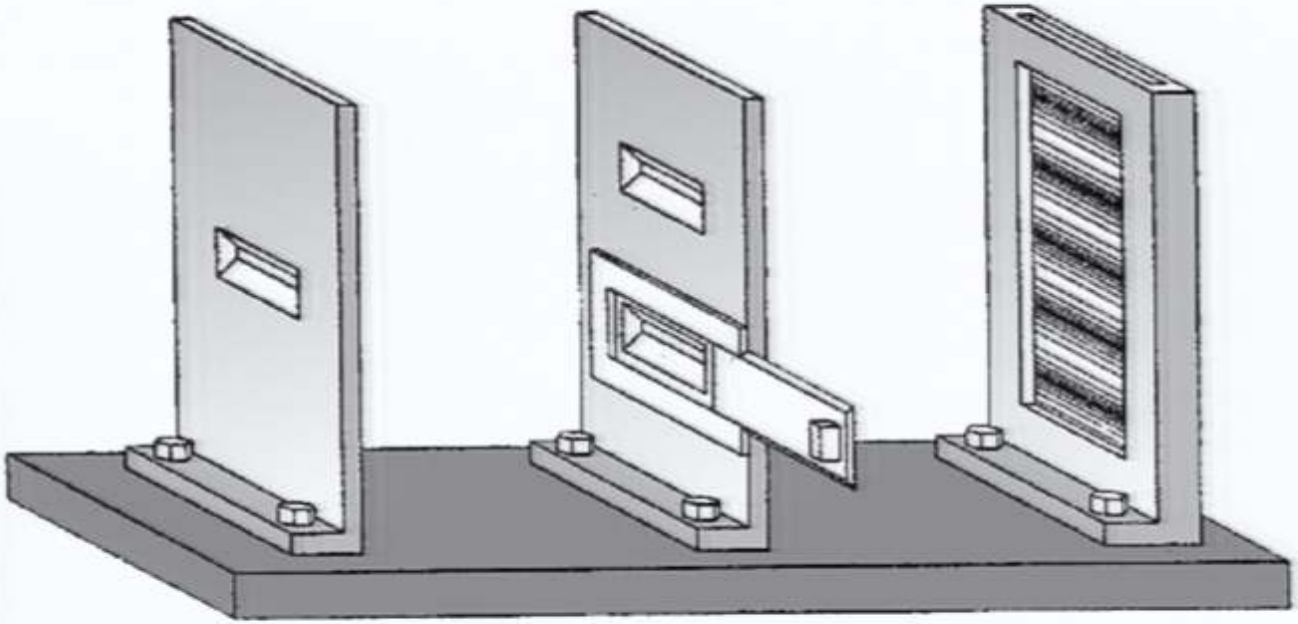
Double Slit Interference

Superposition



Double Slit Interference

Superposition



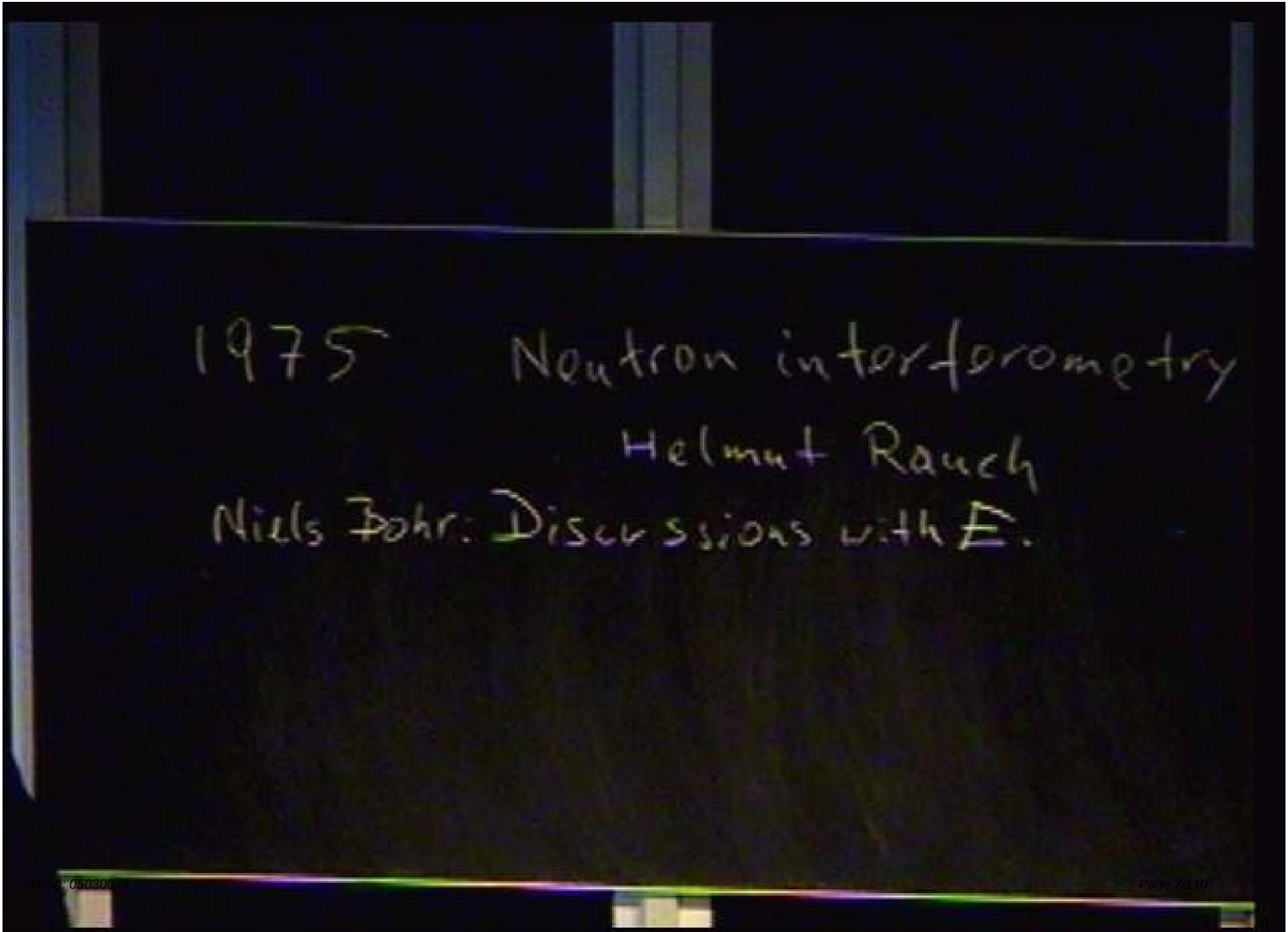
Bohr-Einstein Dialogue

After all, physics is an experimental science

Asher Peres

1975 Neutron interferometry

Helmut Rauch


1975 Neutron interferometry
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Niels Bohr: Discussions with E.

1975 Neutron interferometry

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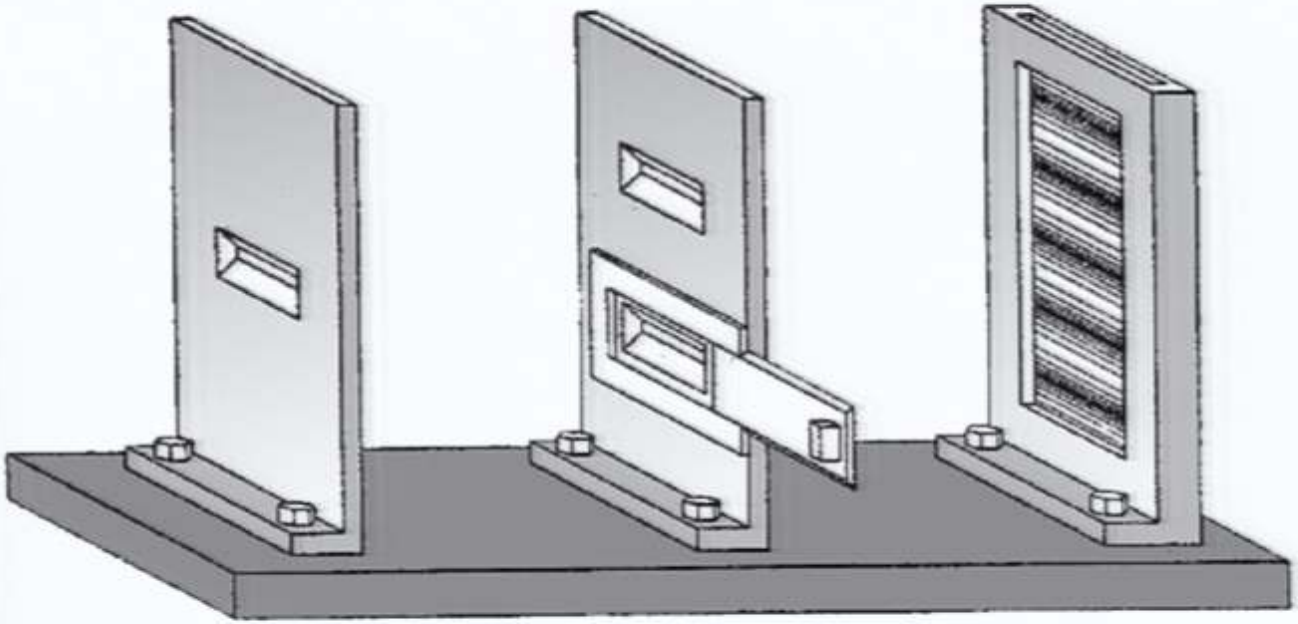
Schilpp

Albert Einstein

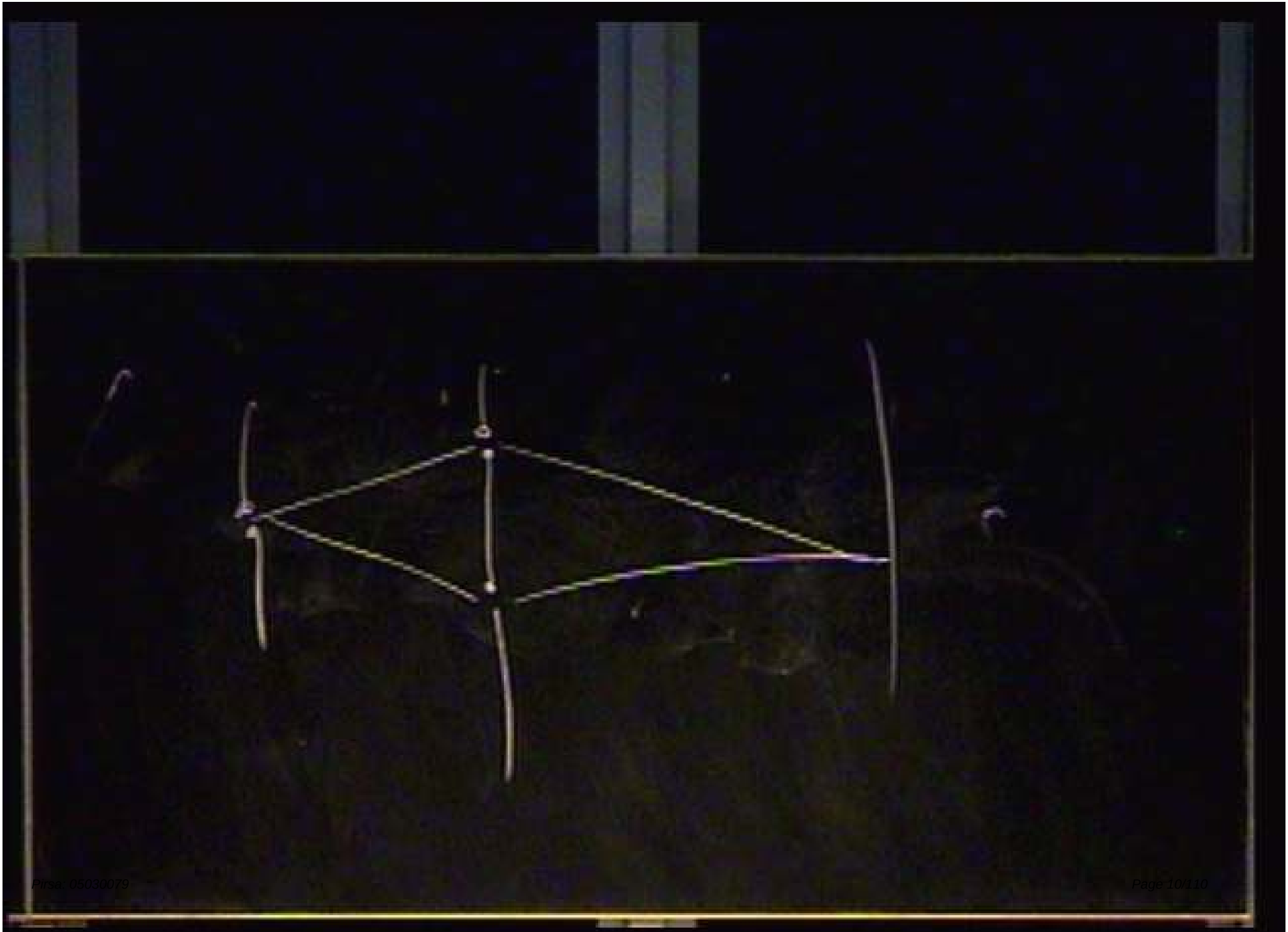
Philosopher-Scientist

Double Slit Interference

Superposition



Bohr-Einstein Dialogue

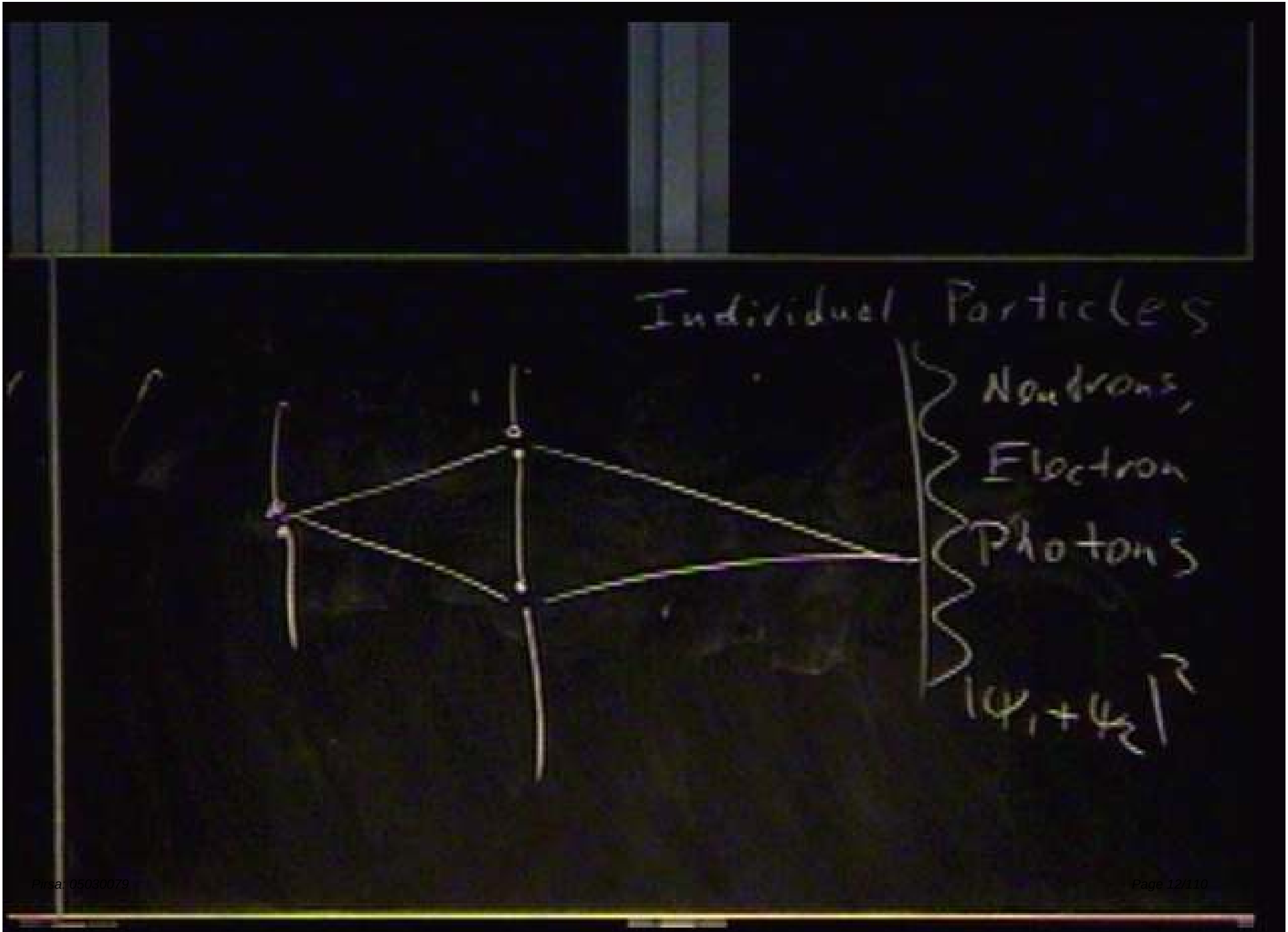


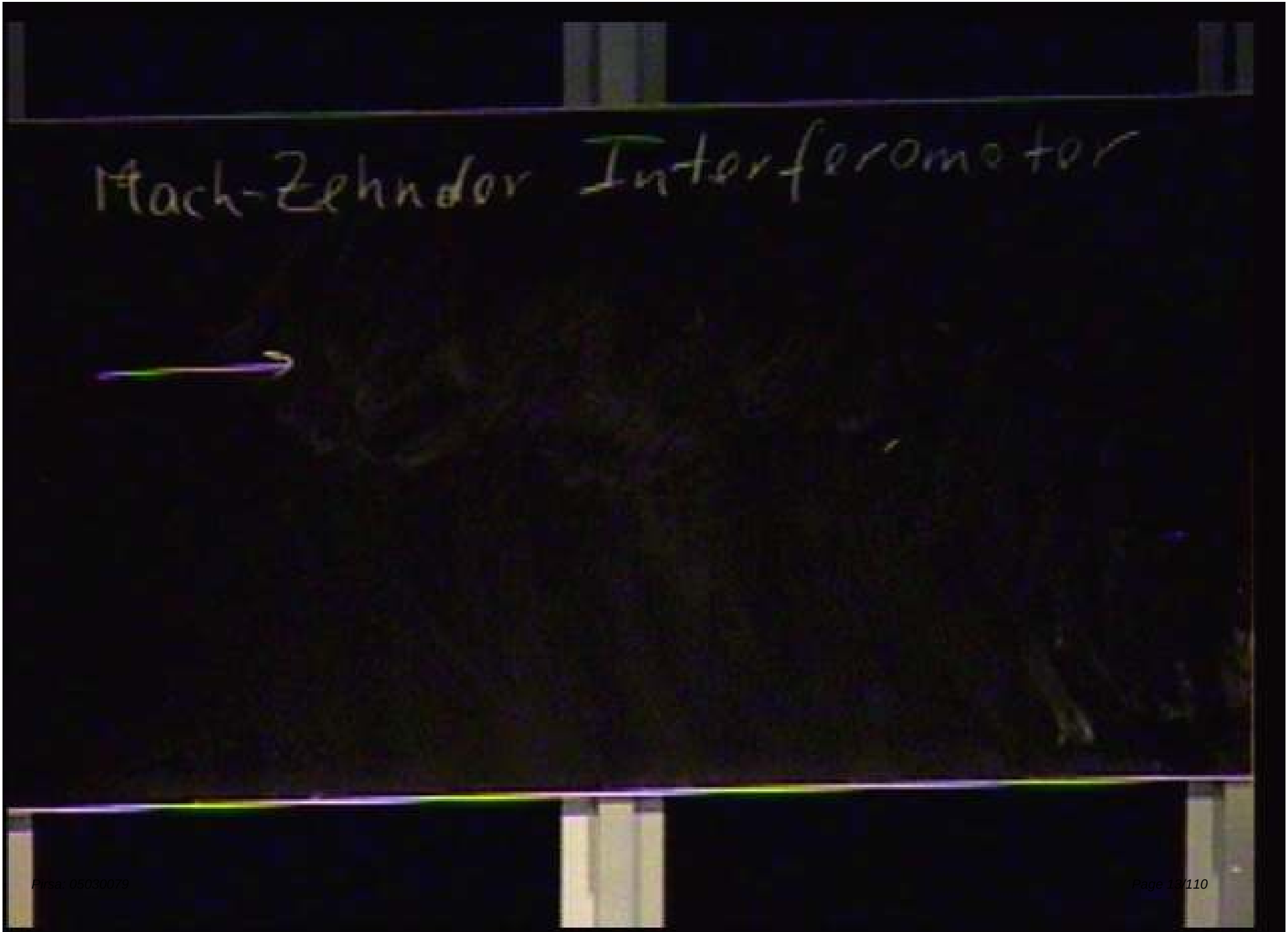
Individual Particles

Neutrons,

Electron

Photons


Individual Particles
Neutrons,
Electron
Photons
$|\psi_1 + \psi_2|^2$

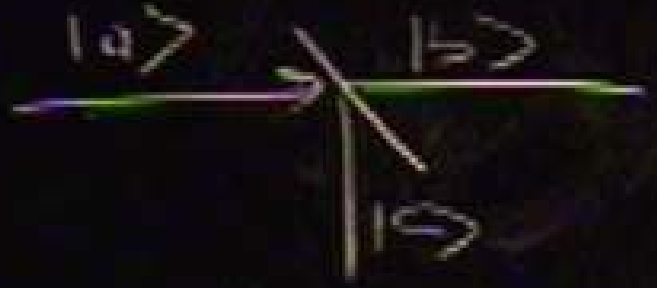

Mach-Zehnder Interferometer

Mach-Zehnder Interferometer

Mach-Zehnder Interferometer

$|a\rangle \Rightarrow \frac{1}{\sqrt{2}}(|b\rangle + i|c\rangle)$

Coherent Superposition



Mach-Zehnder Interferometer

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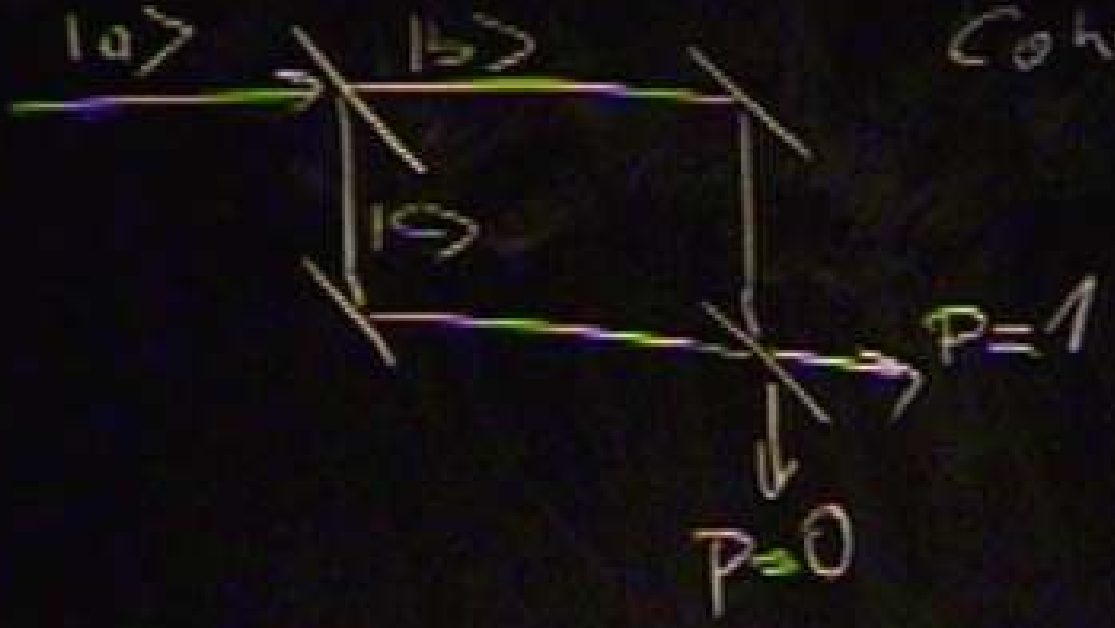
Coherent Superposition



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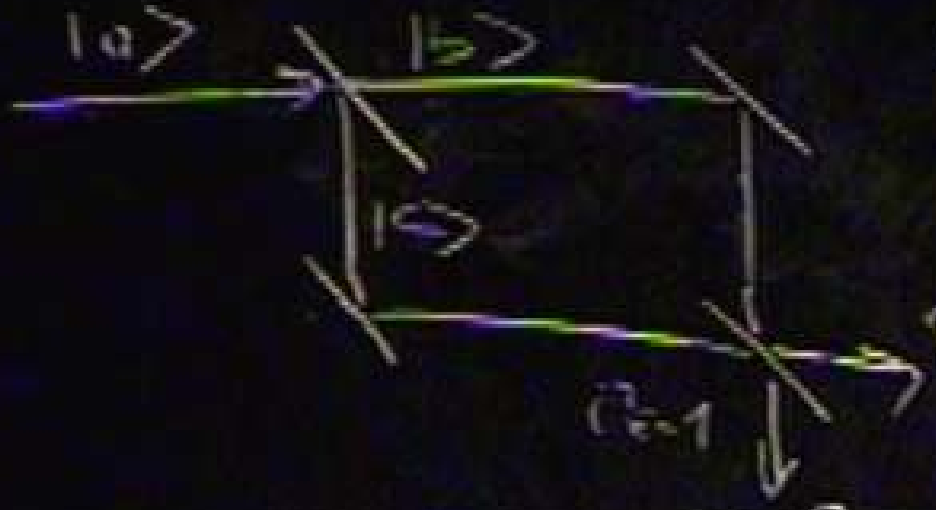
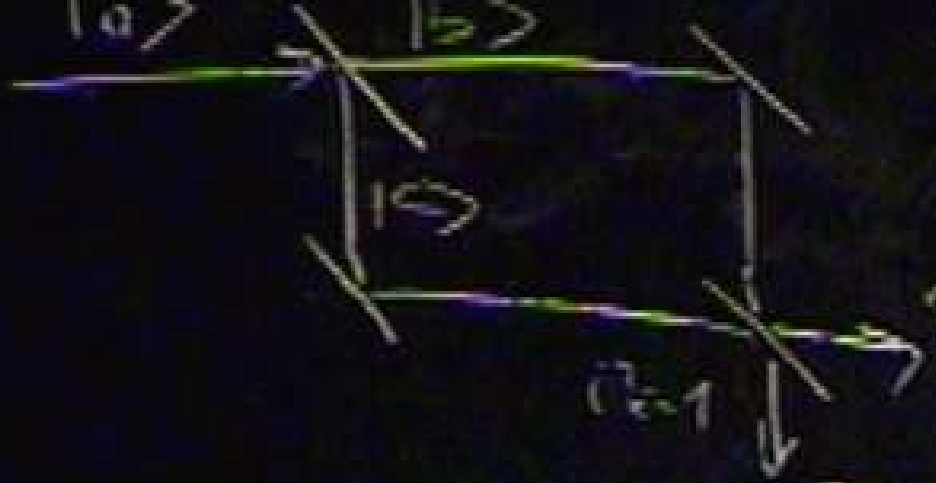


Destructive Interference

Mach-Zehnder Interferometer

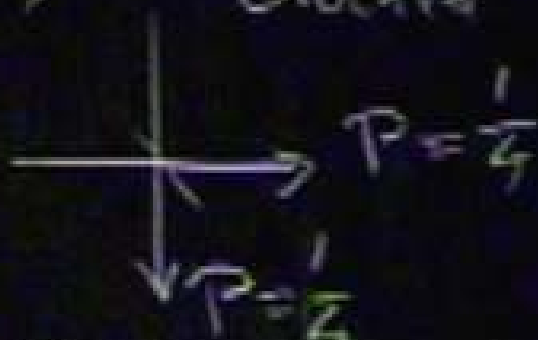
$|a\rangle \rightarrow \frac{1}{\sqrt{2}}(|b\rangle + i|c\rangle)$

Coherent Superposition



Destructive Interference

One beam blocked



Elitzur-Vaidman
ca. 1990

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Superbomb: 1 Photon triggers it

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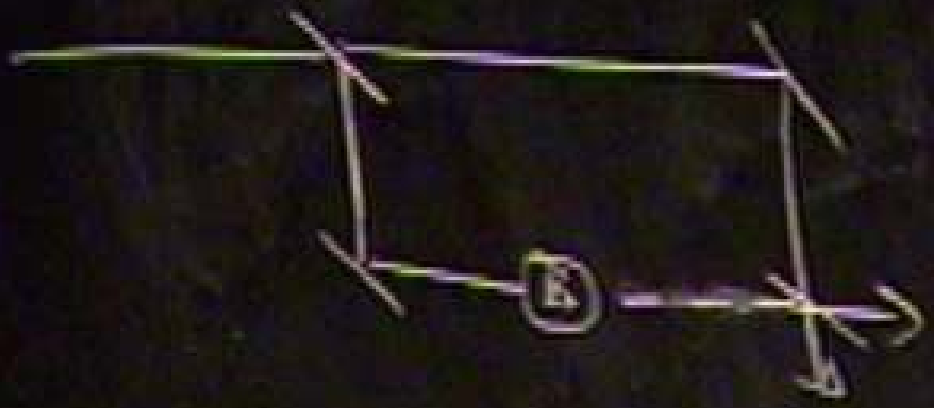

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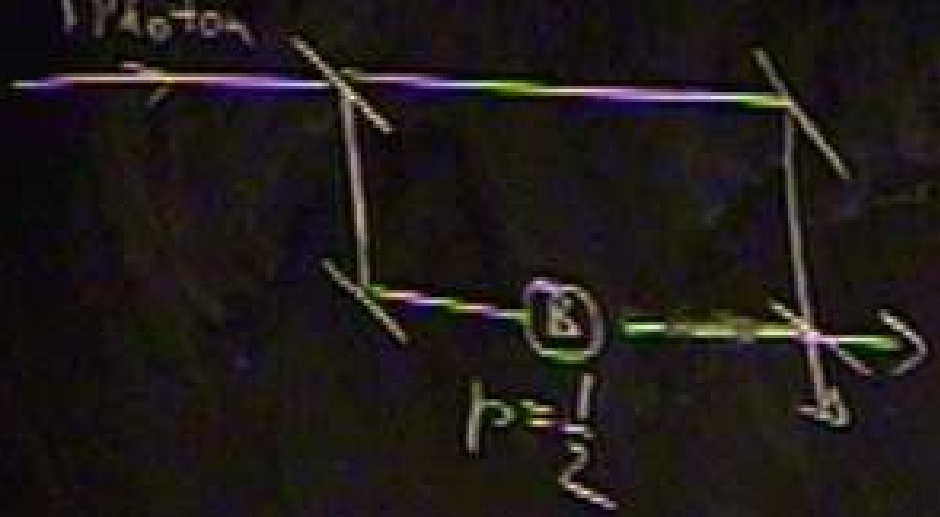

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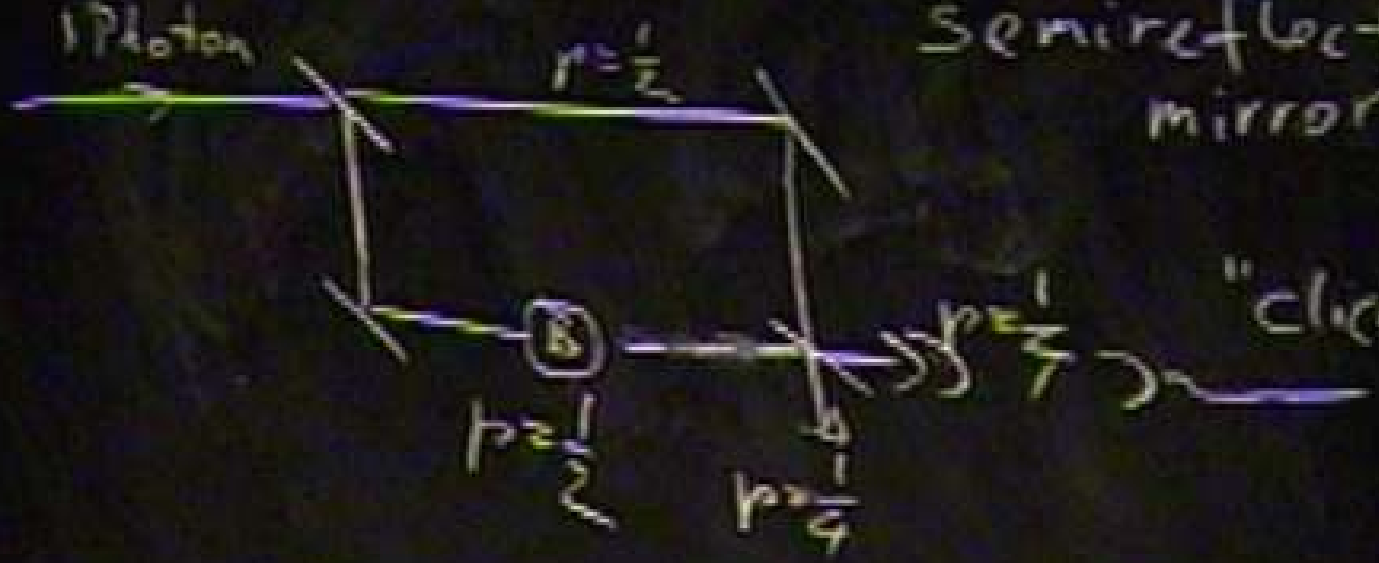


Neutron interferometry

Helmut Rauch

r. Discussions with E.

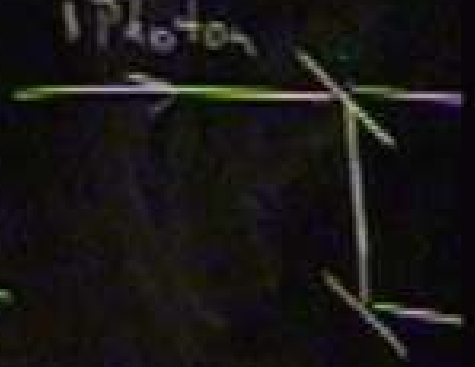
ert Einstein

Philosopher-Scientist

Elitzur-

Superb

1 Photon



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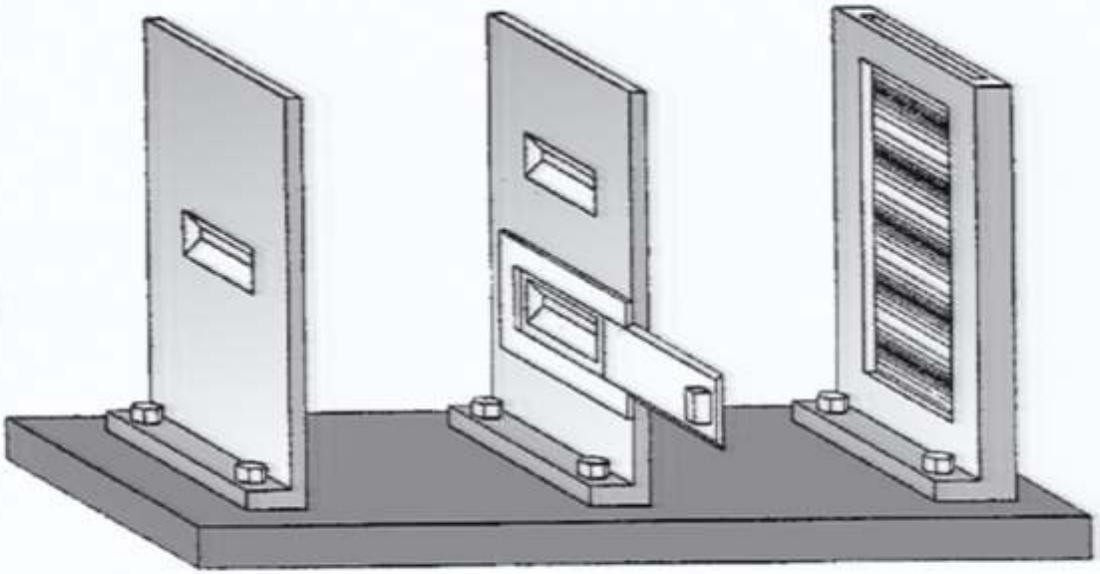
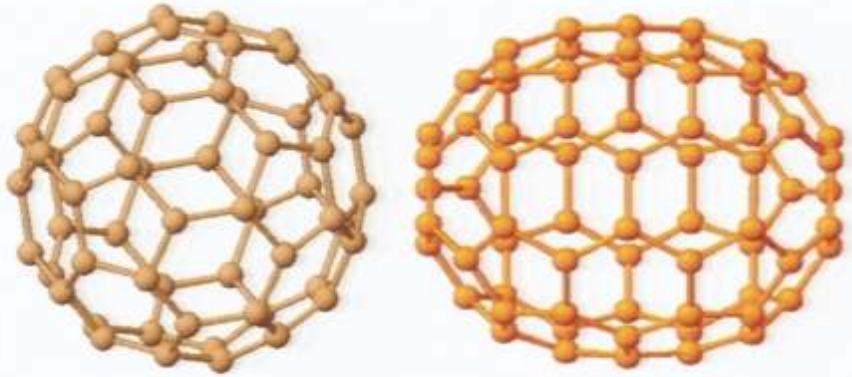
Matter-Wave Interferences

- Electrons, Neutrons, Atoms, Small Molecules
  .....





C_{60} C_{70}

Matter-Wave Interferences

- Electrons, Neutrons, Atoms, Small Molecules
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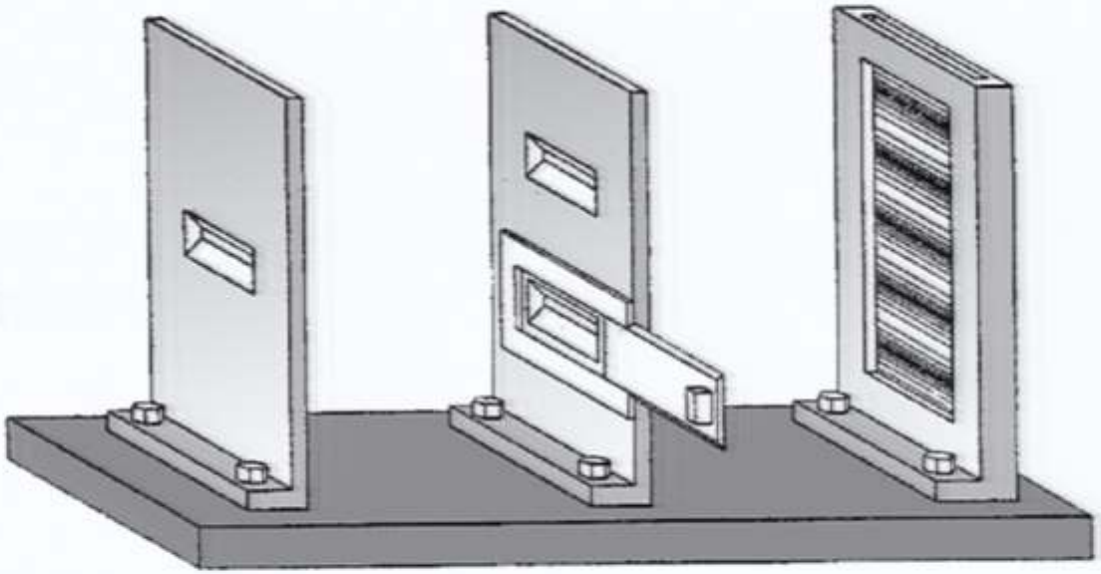
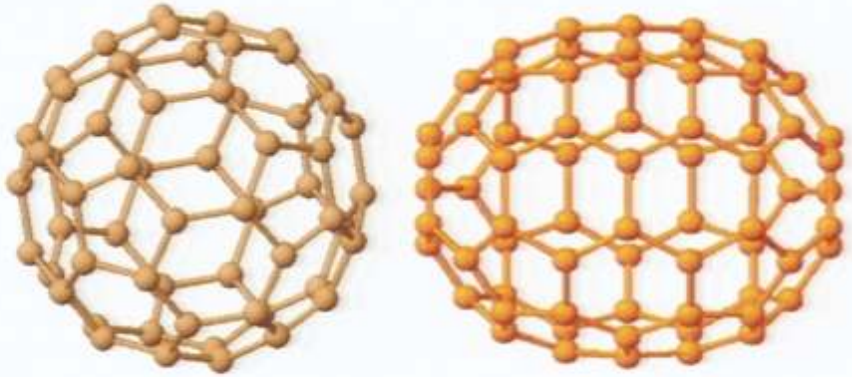


- Is there a Limit?

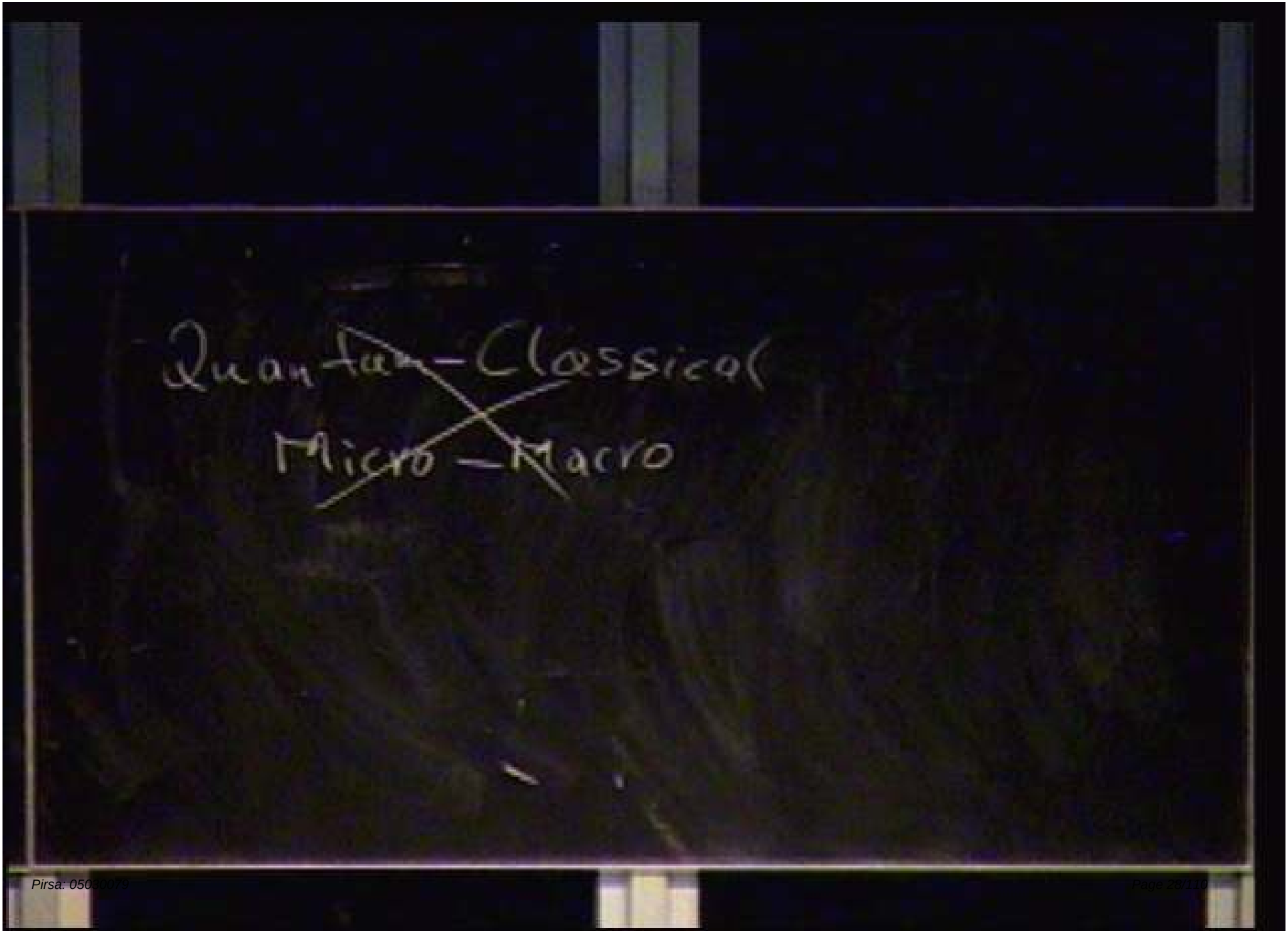
  Mass? Complexity? Temperature?

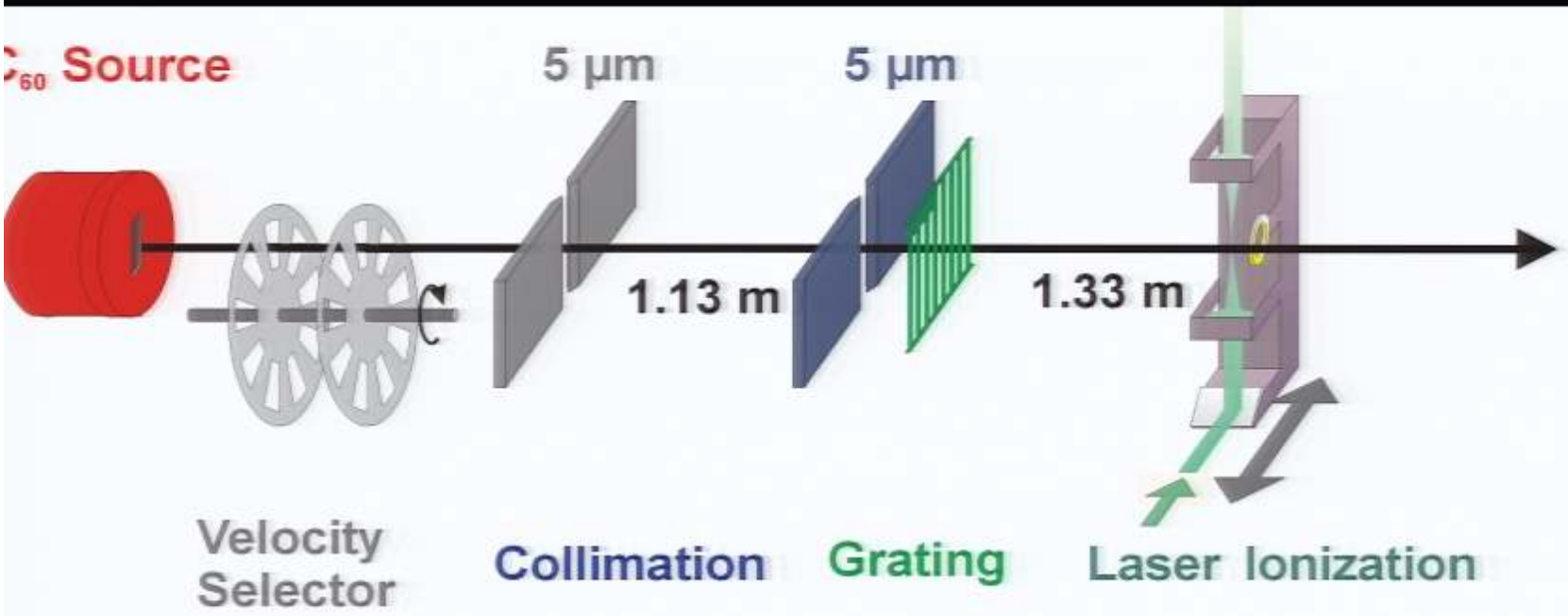


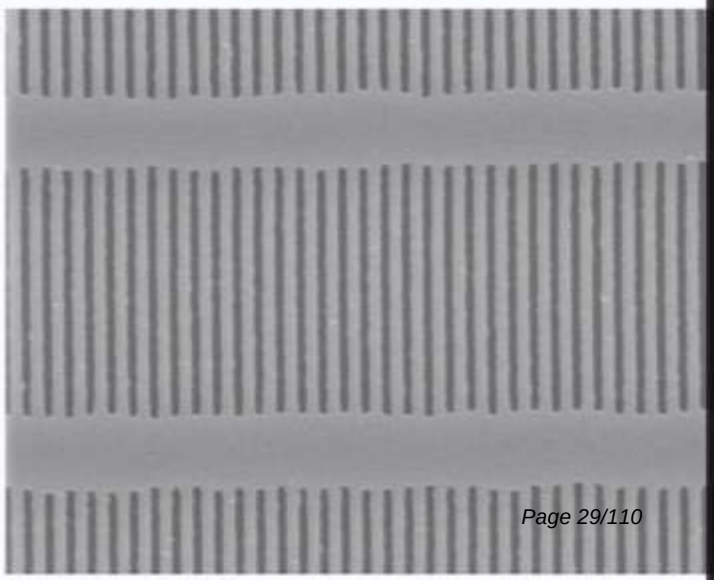
C_{60} C_{70}

Quantum-Classical

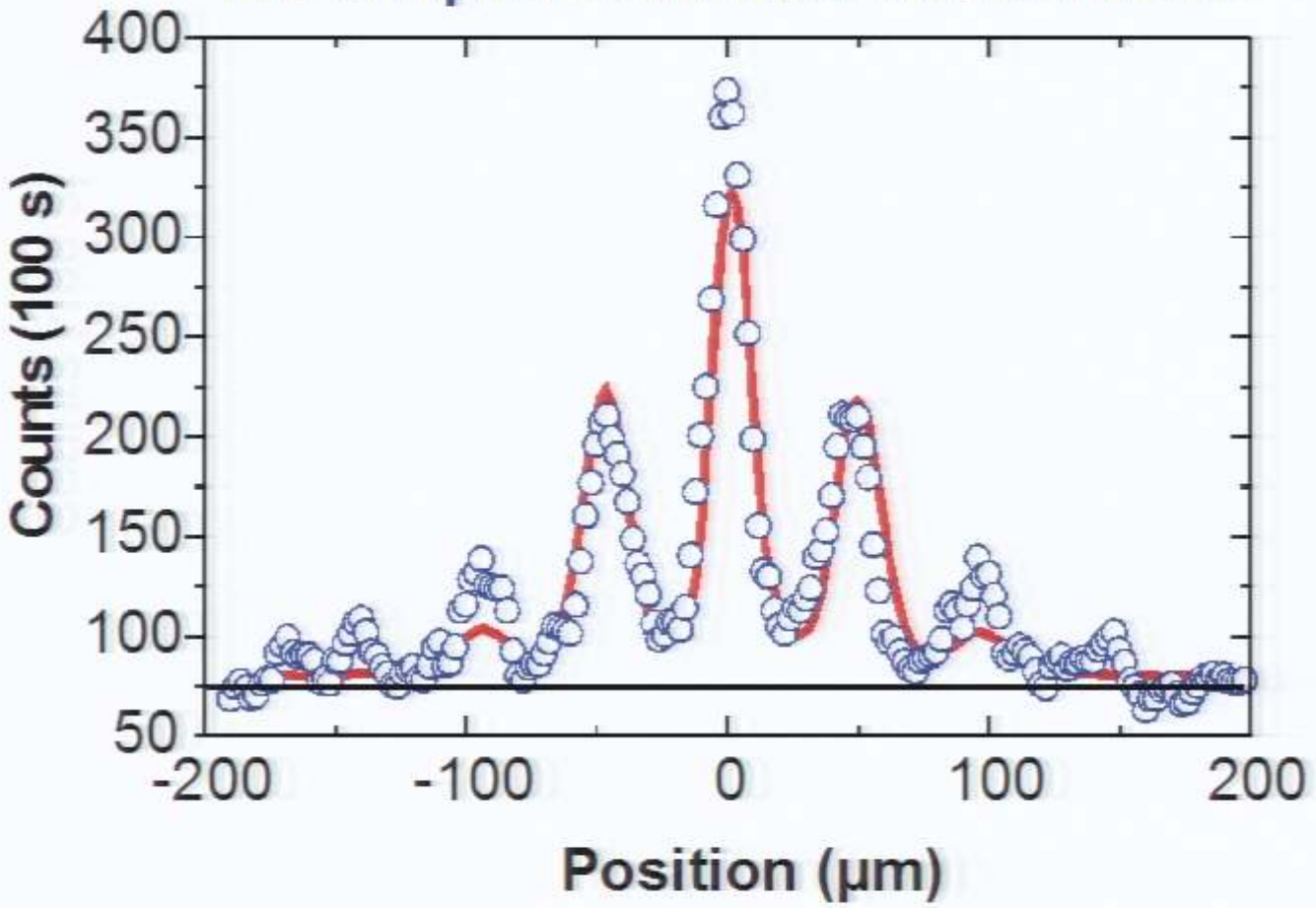
Micro-Macro


Quantum - Classical
Micro - Macro

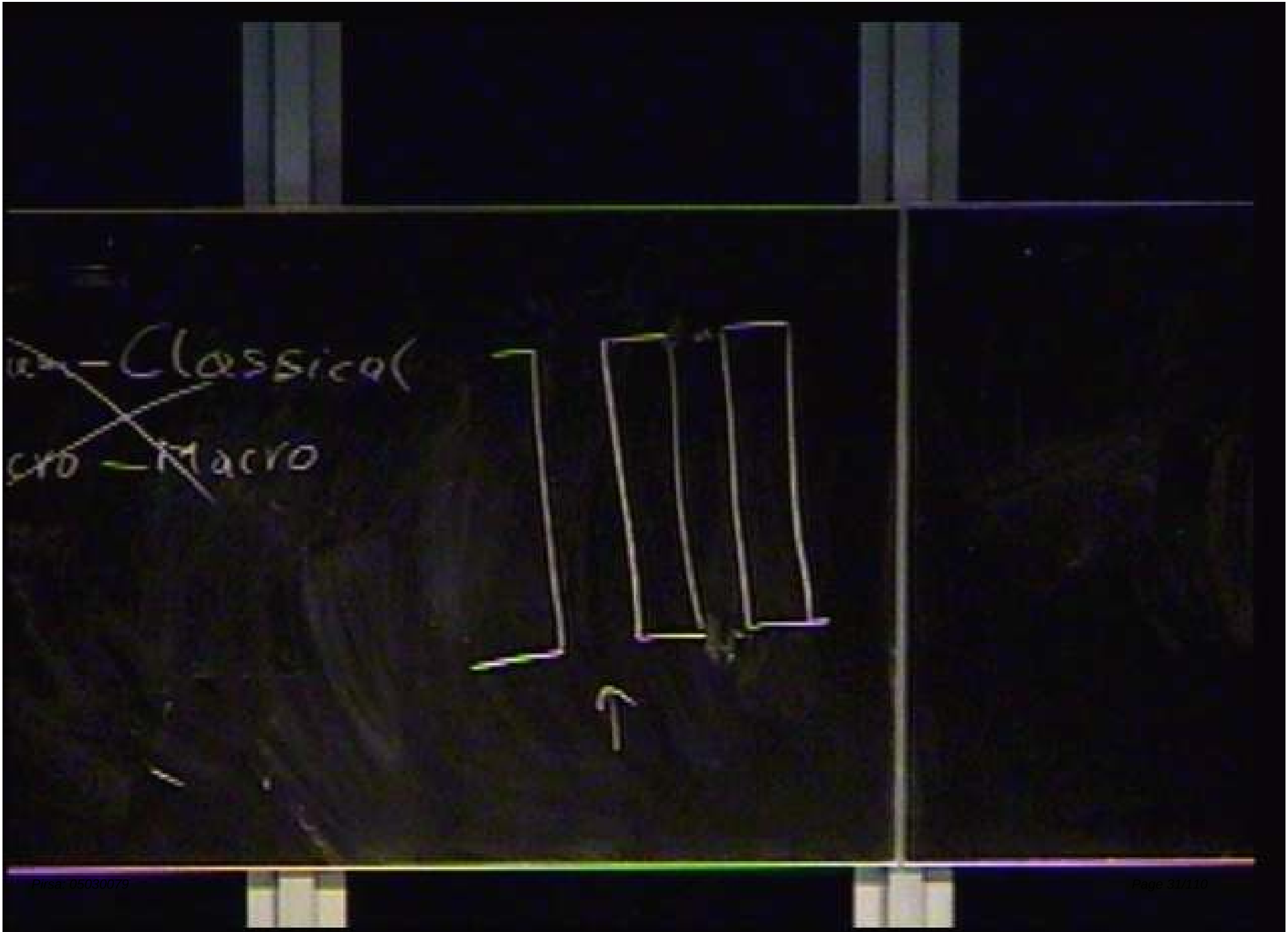

C_{60} Source
5 µm
5 µm
1.13 m
1.33 m
Velocity Selector
Collimation
Grating
Laser Ionization



Fit: simple Fraunhofer wave model



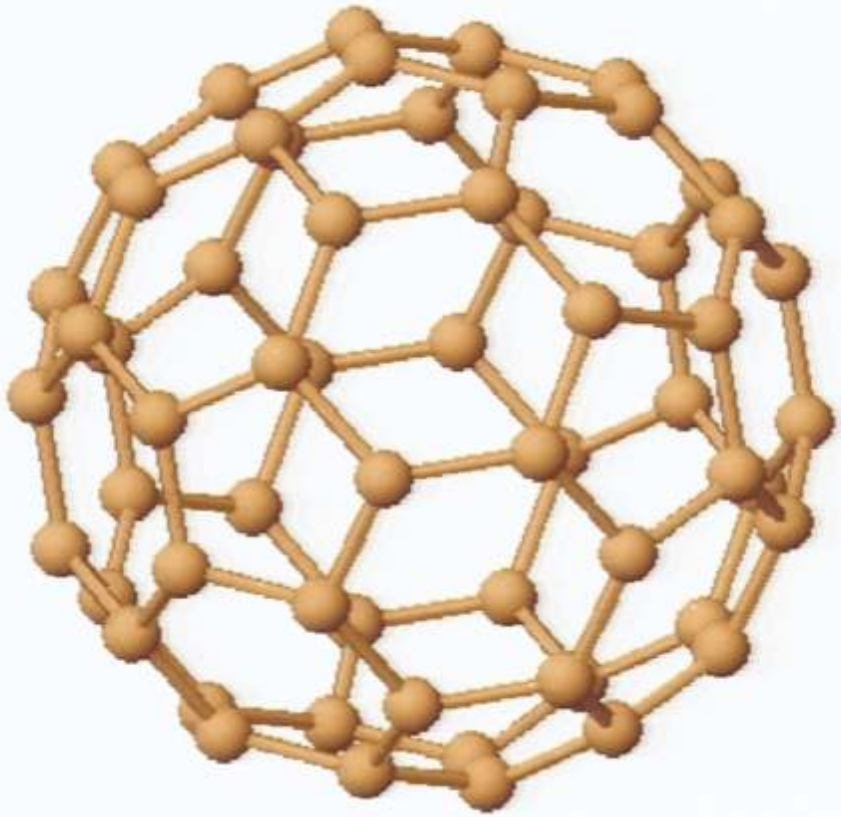
Van der Waals Force
Casimir Interaction


- Classico(
cro - Macro

The Scale

T ≈ 900 K

$\lambda_{deBroglie} \approx 3 \cdot 10^{-12}$ m
$= 3 \cdot 10^{-2}$ Å



λ_{dB}

Diameter:
$D \approx 10^{-9}$ m = 10 Å

$\lambda_{dB} \ll D$

Coherence Length:
2 - 5 λ_{dB} !

The Scale

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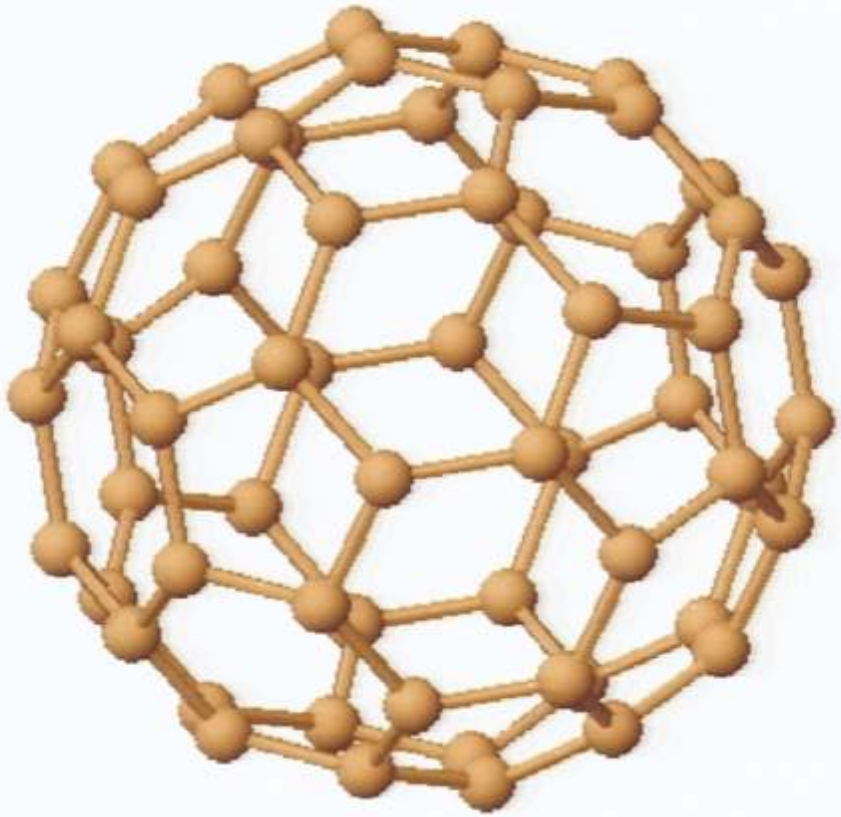

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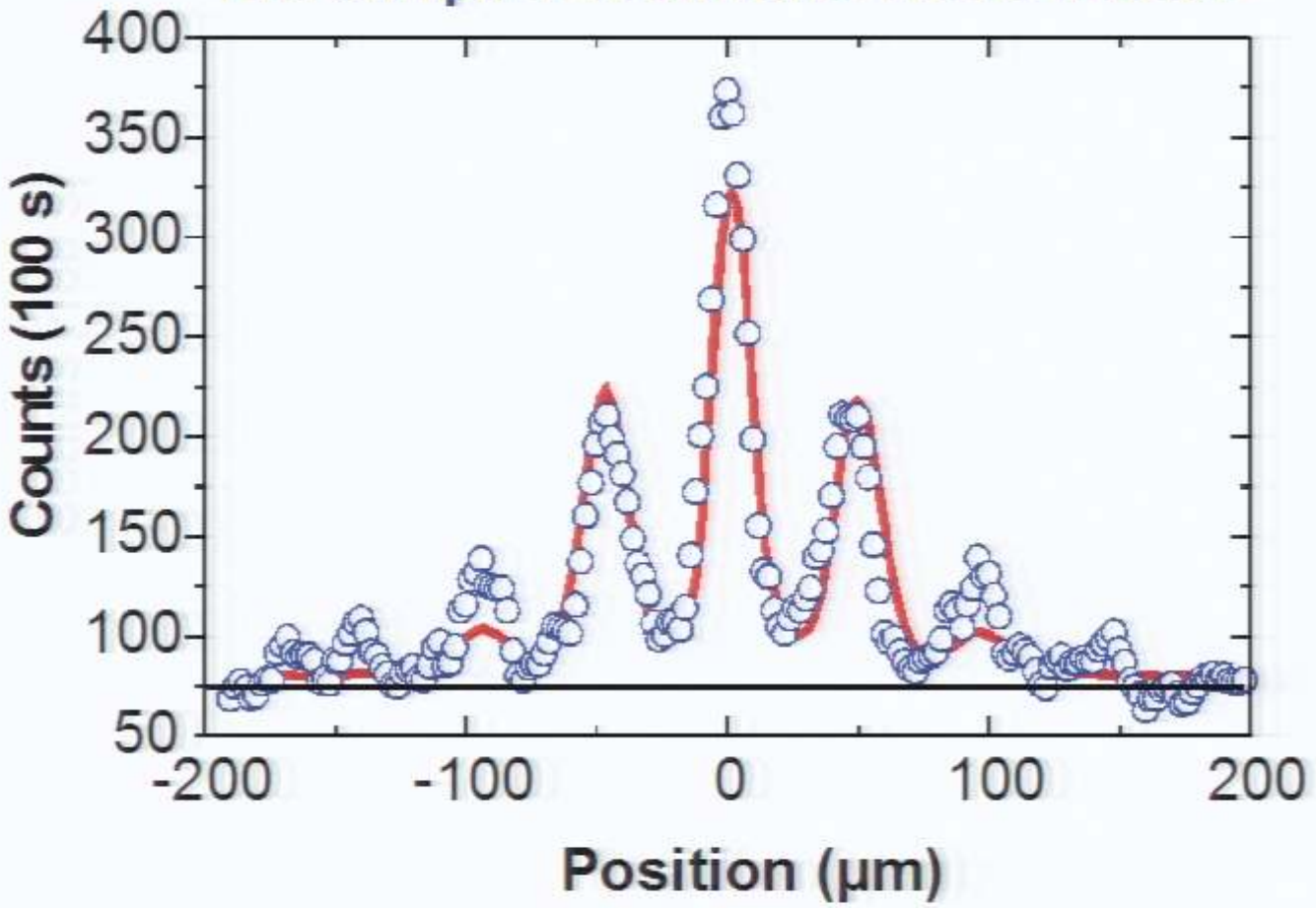
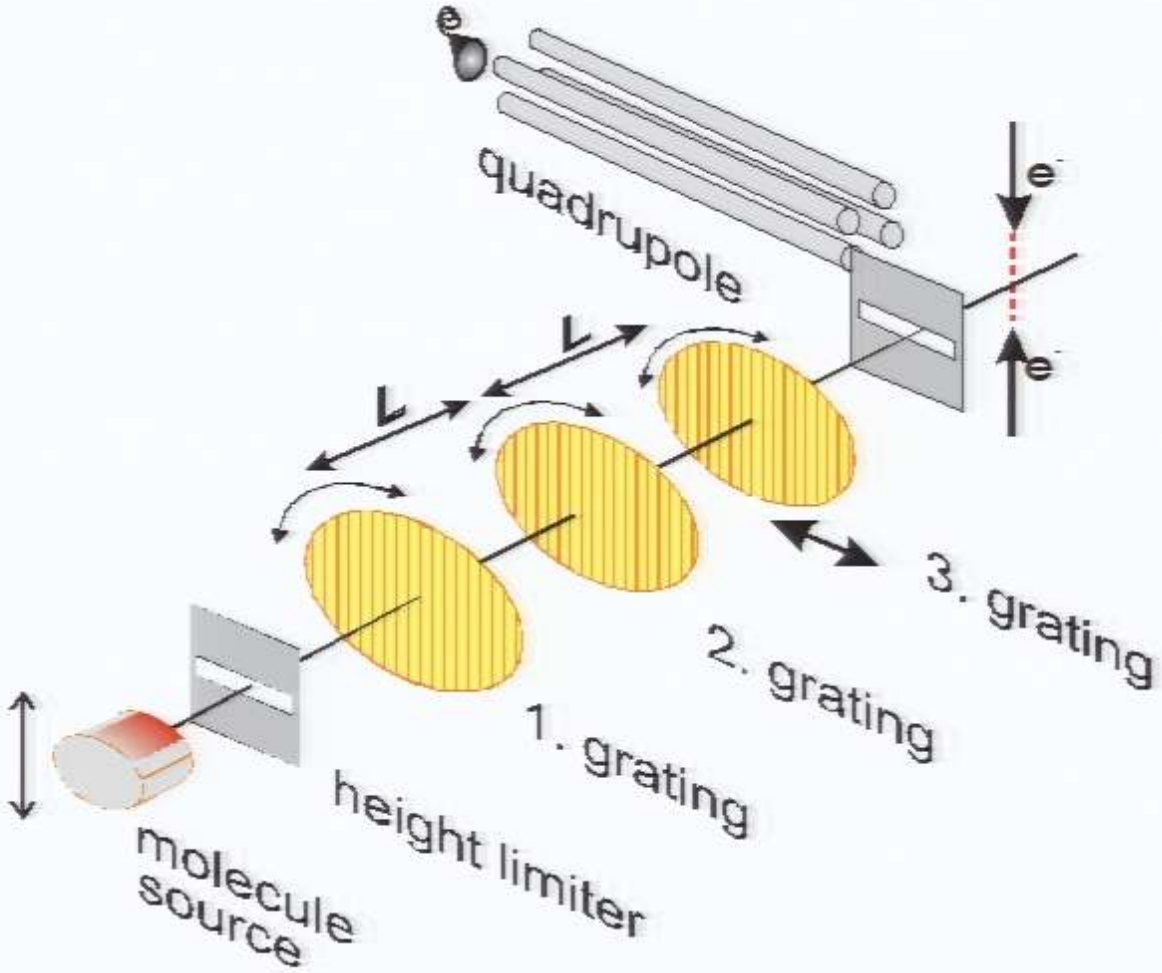


Van der Waals Force
Casimir Interaction

Talbot-Lau (near field) Interferometry with Macromolecules



L. Hackermüller, S. Uttenthaler, K. Hornberger, E. Reiger, B. Brezger, A. Zeilinger and M. Arndt, Phys. Rev. Lett 91, 90408 (2003).

Linearity at 2m

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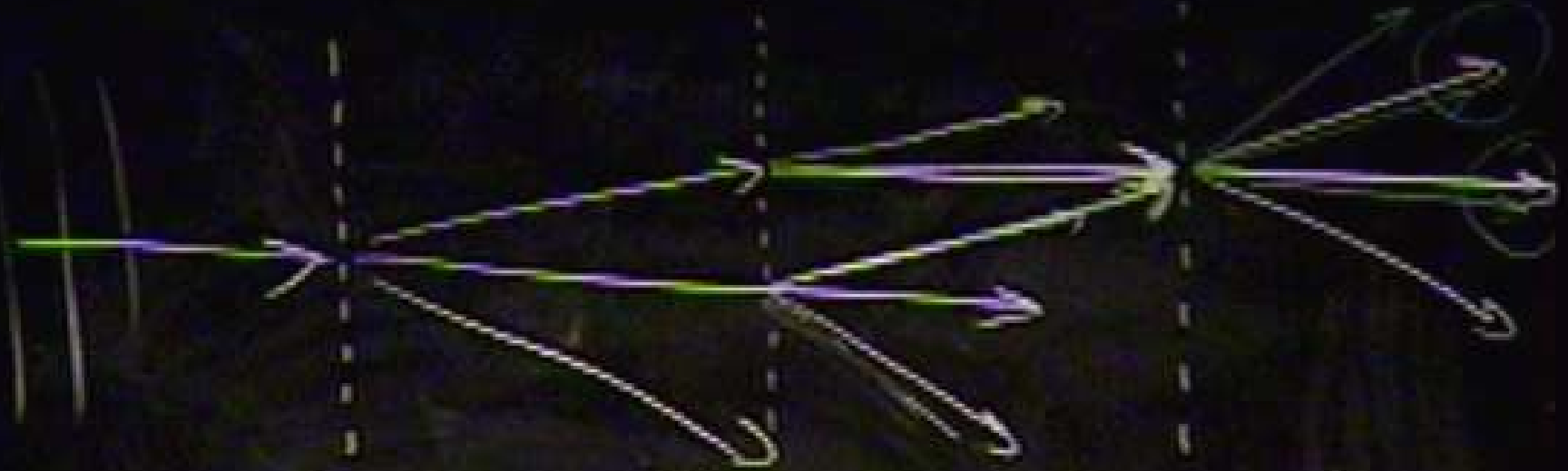
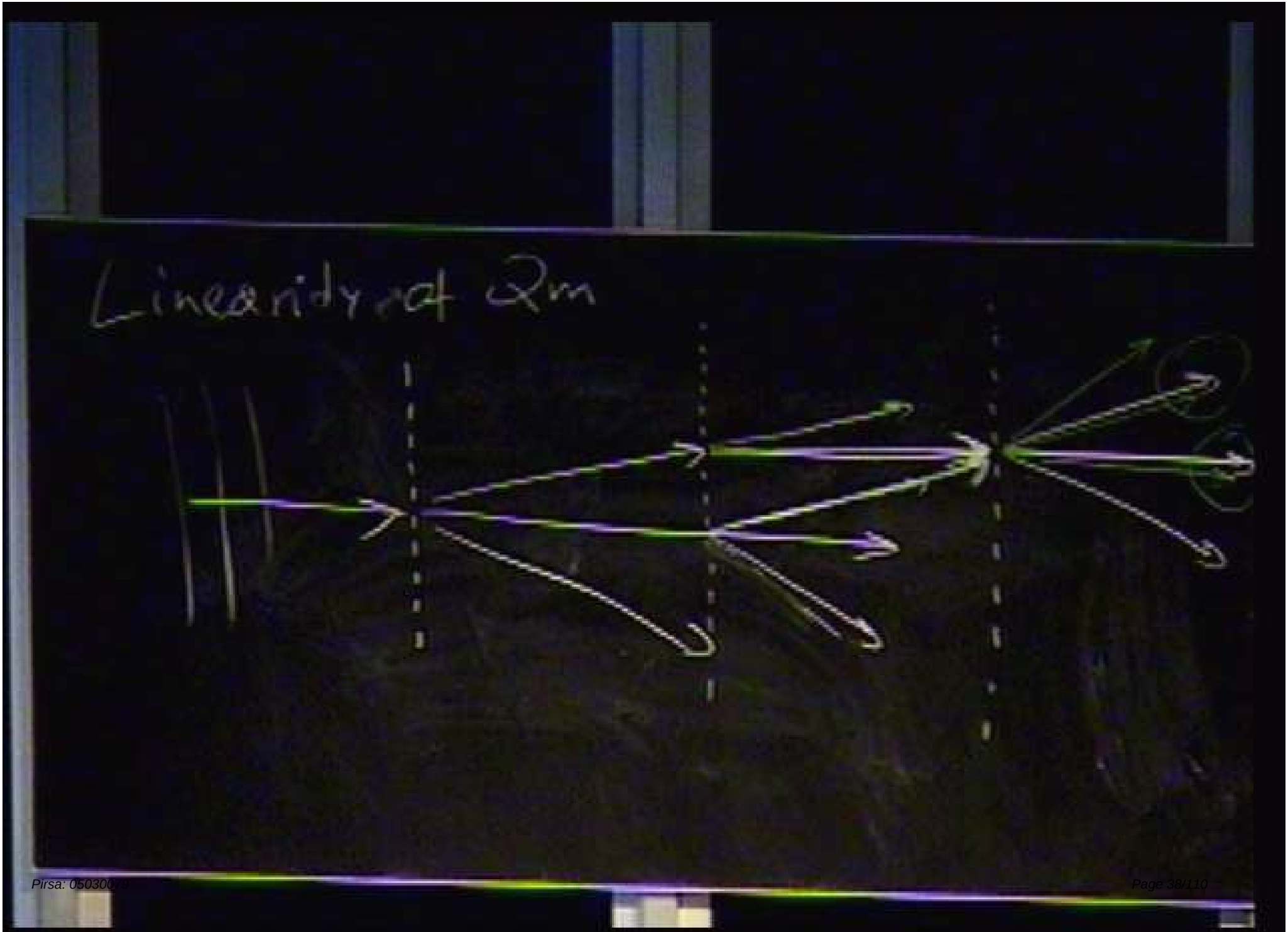
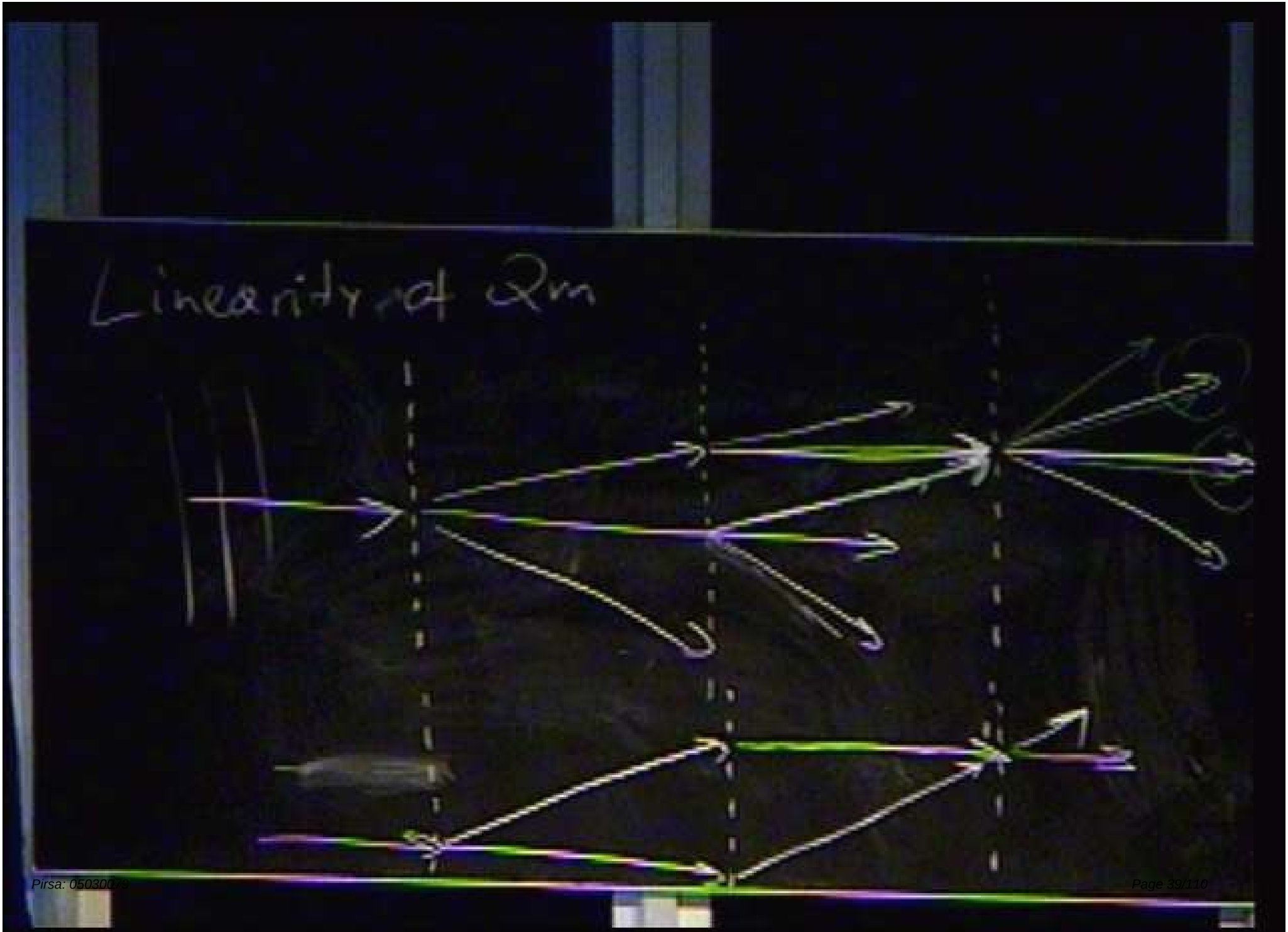


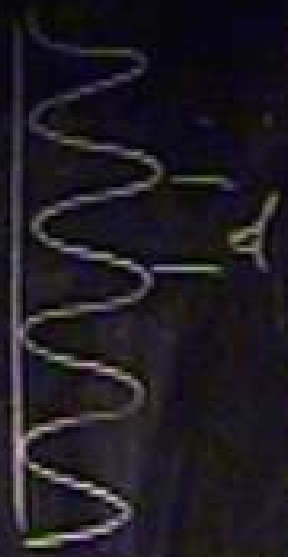

Linearity at 2m


Linearity at 2m

Linearity at Qm
$\lambda = \frac{h}{Mv}$
$\theta = \frac{\lambda}{d}$

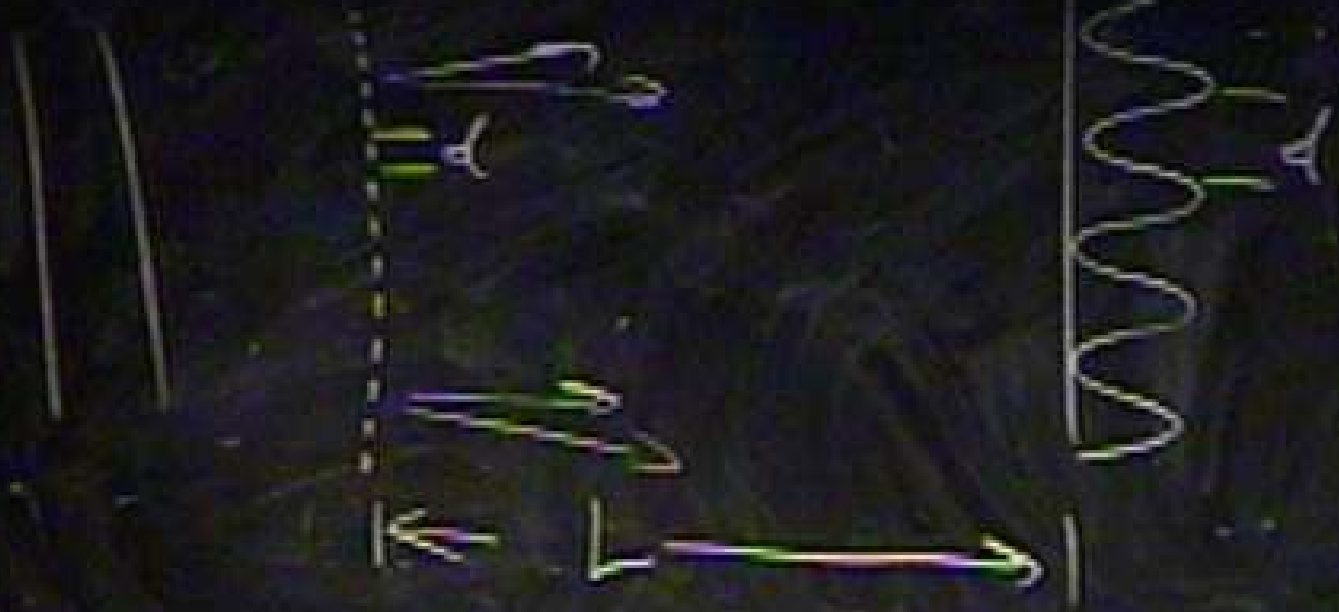
Talbot - Effekt

Talbot - Effekt



Talbot - Effekt

$$L = \frac{d^2}{\lambda}$$

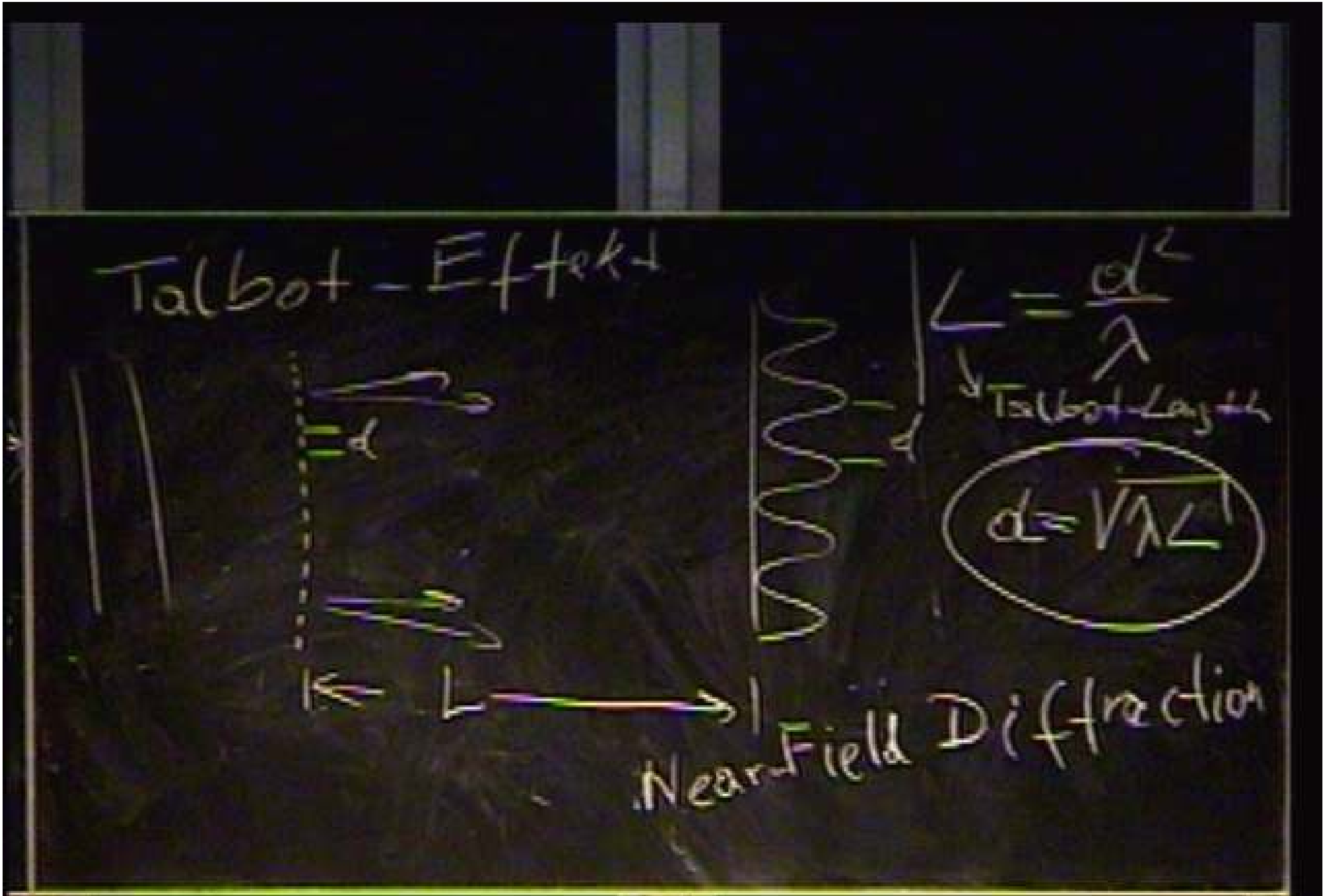


Talbot-Effekt

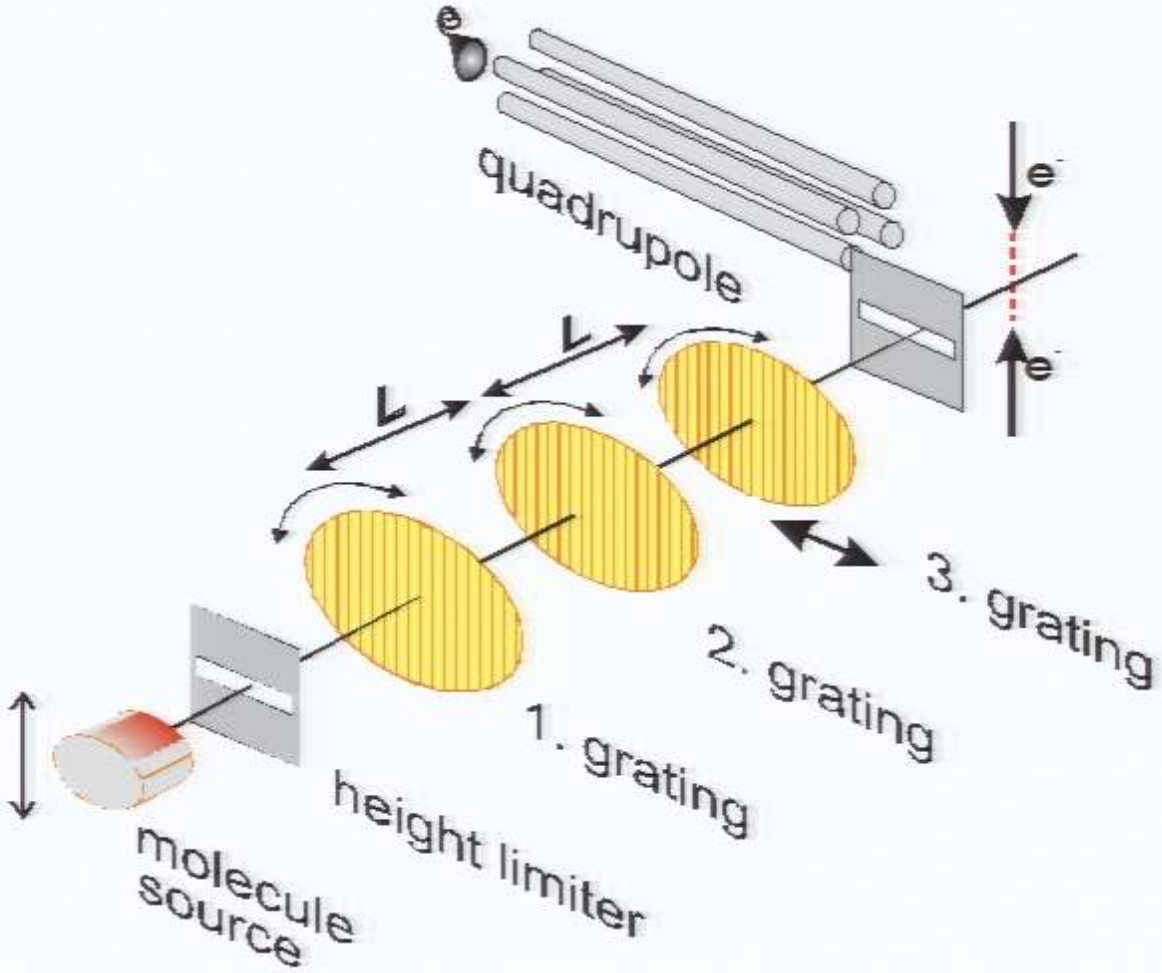
$$L = \frac{d^2}{\lambda}$$

↓ Talbot-Länge

$$d = \sqrt{\lambda L}$$


Talbot - Effekt
d
L
$L = \frac{d^2}{\lambda}$
Talbot-Länge
$d = \sqrt{\lambda L}$
Near-Field Diffraction

Talbot-Lau (near field) Interferometry with Macromolecules



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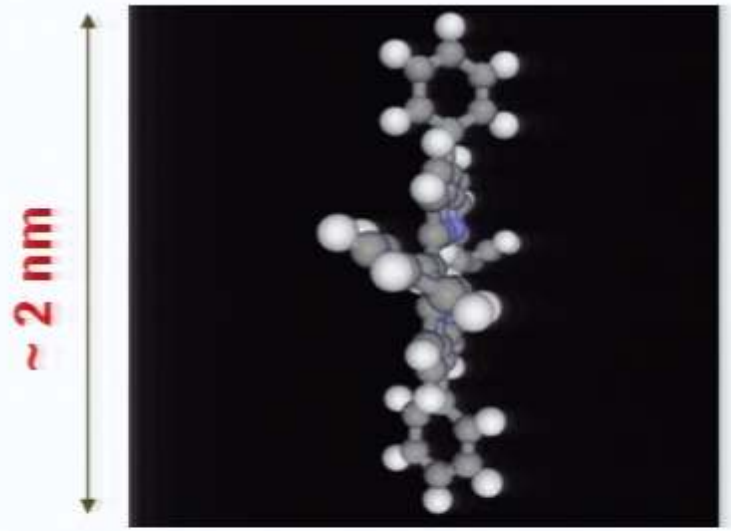
A „Color of Life“

nterferometry with
'orphyrin



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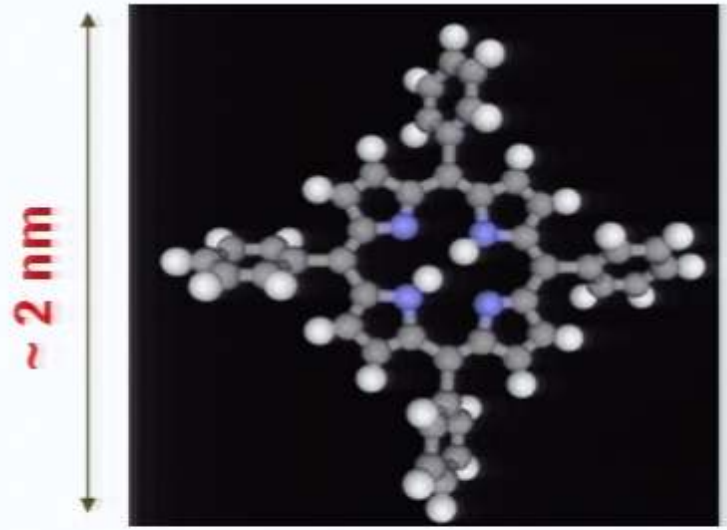

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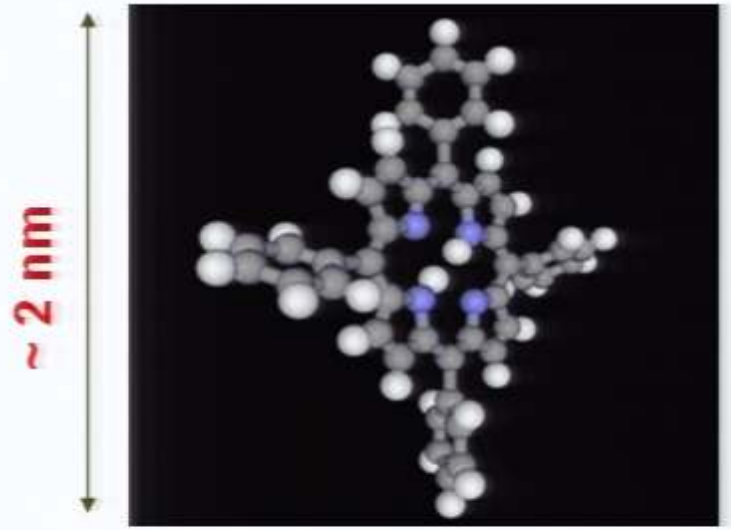

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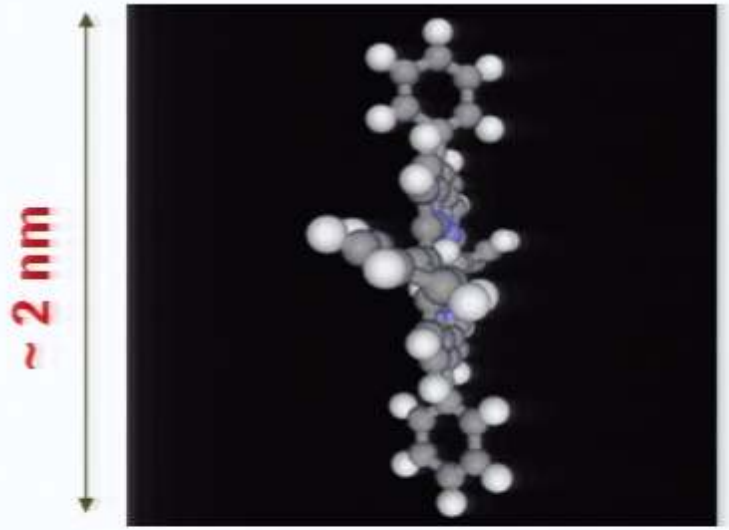

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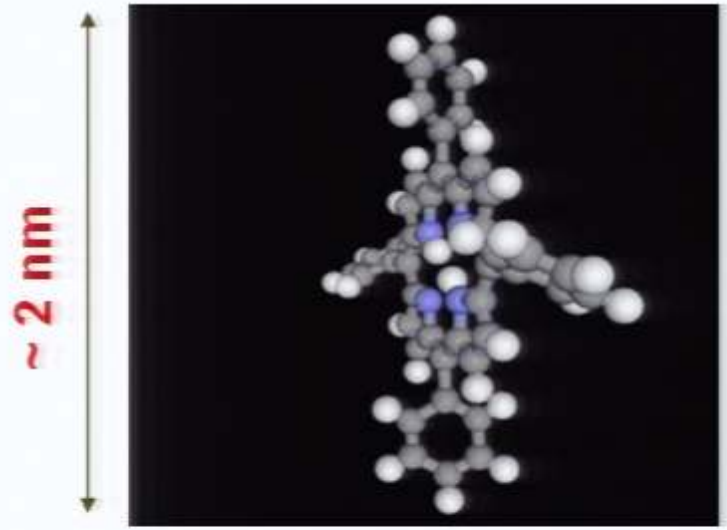

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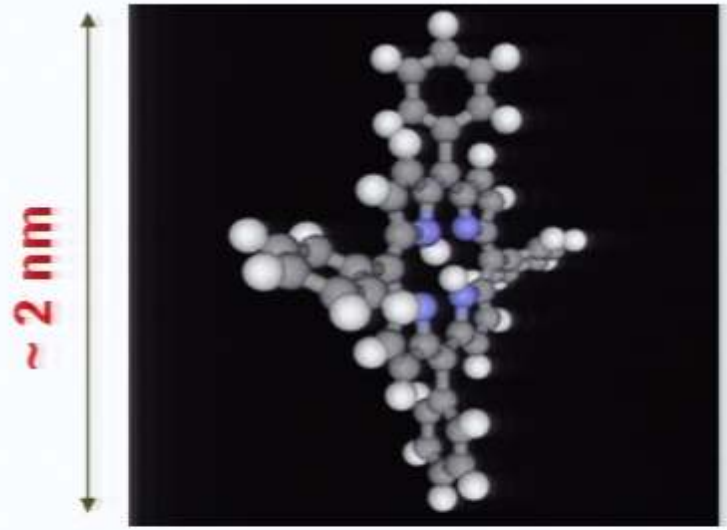

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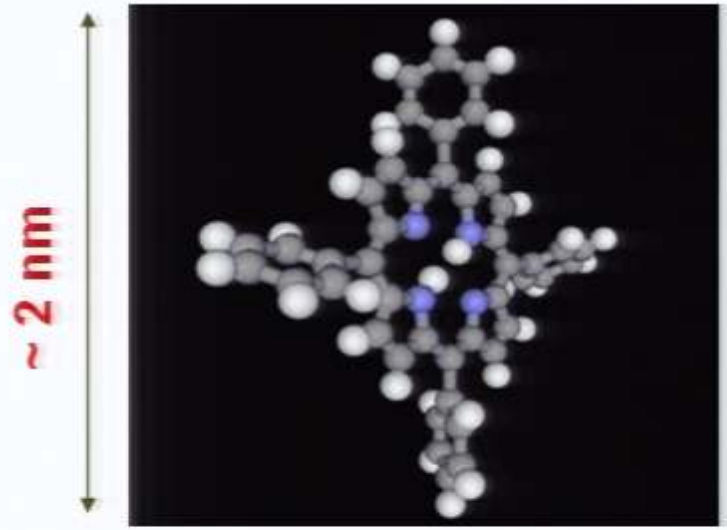

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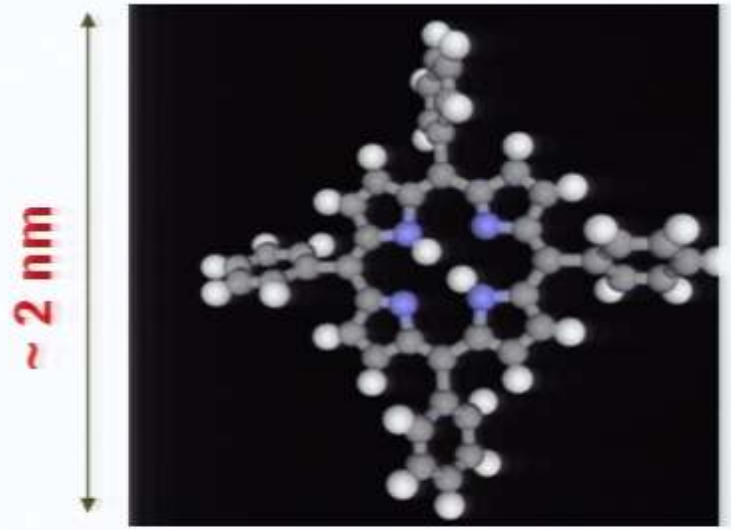
nterferometry with
'orphyrin



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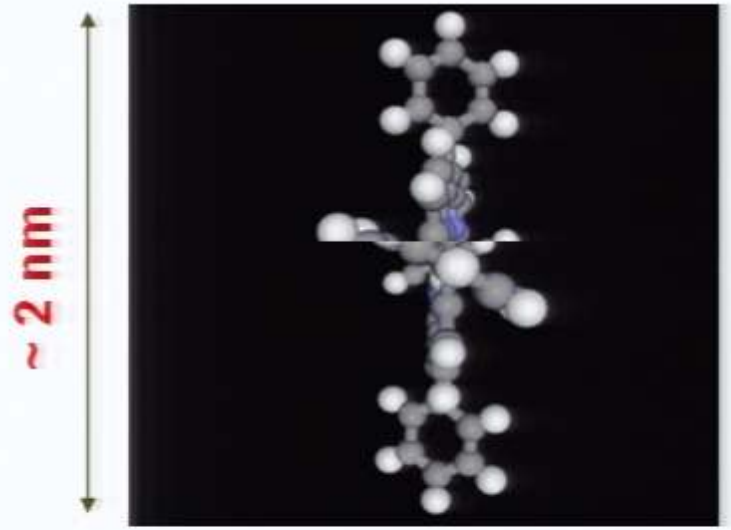

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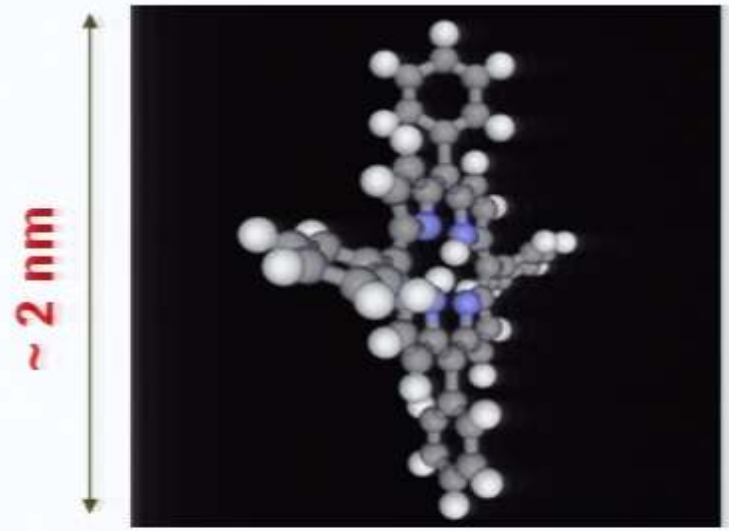
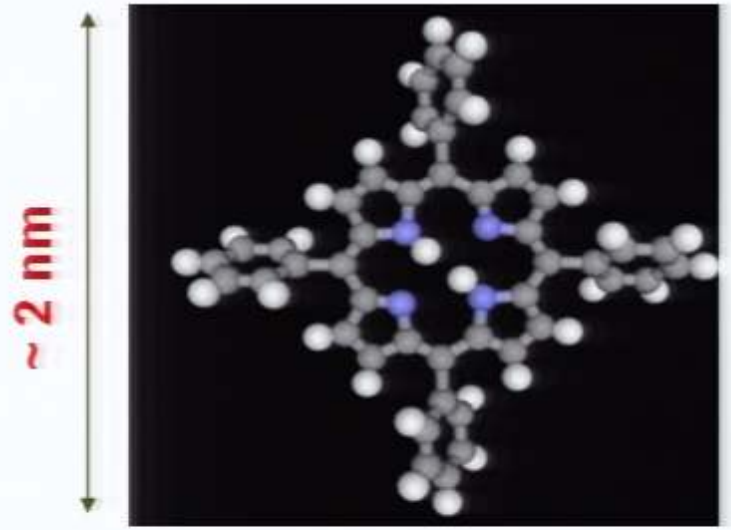
nterferometry with
'orphyrin



A „Color of Life“

nterferometry with
'orphyrin



A „Color of Life“

nterferometry with
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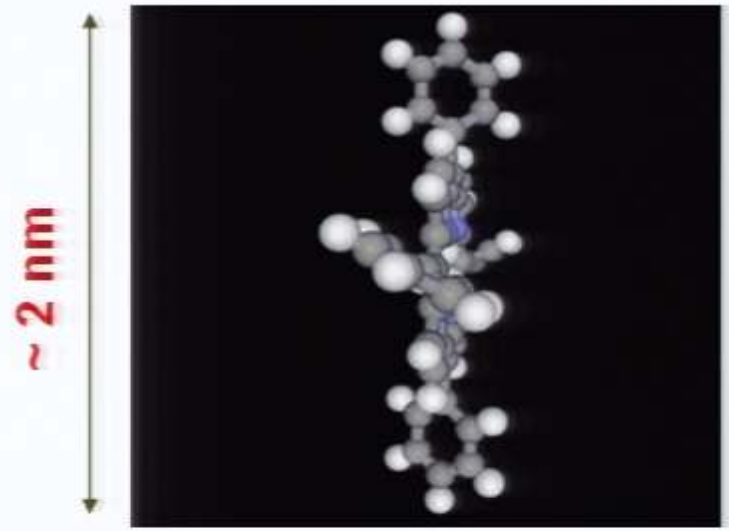

A „Color of Life“

nterferometry with
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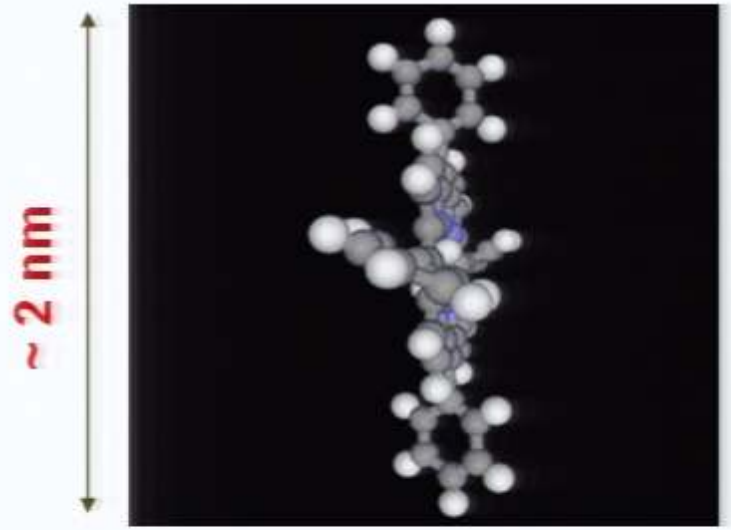

A „Color of Life“

nterferometry with
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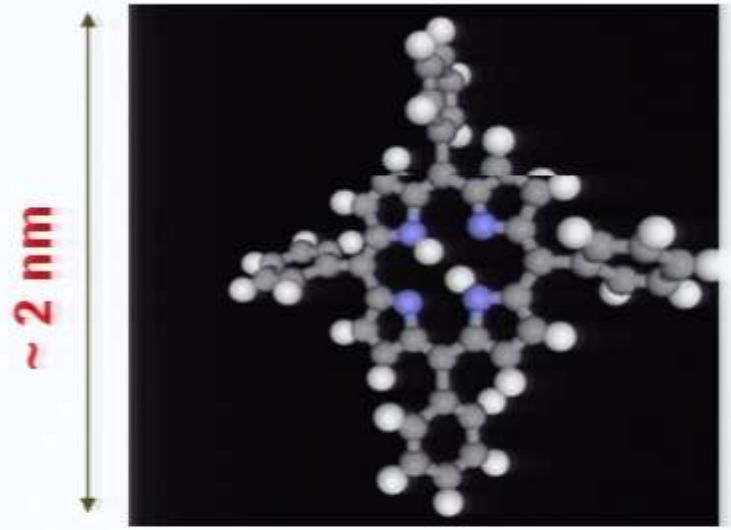

A „Color of Life“

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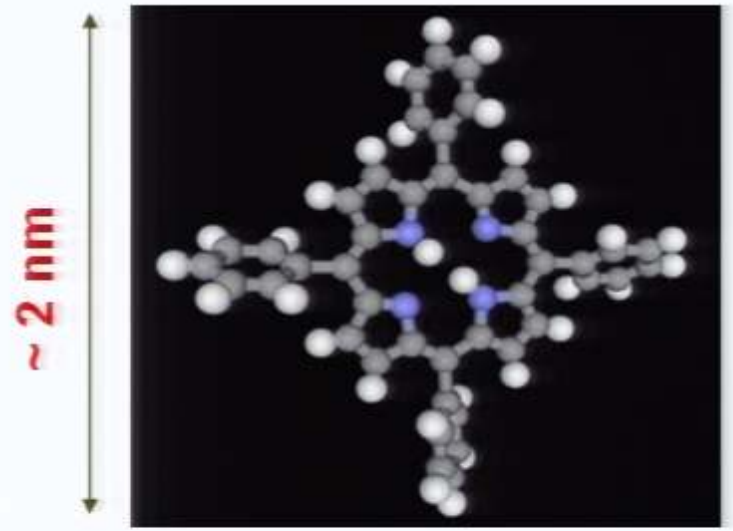

A „Color of Life“

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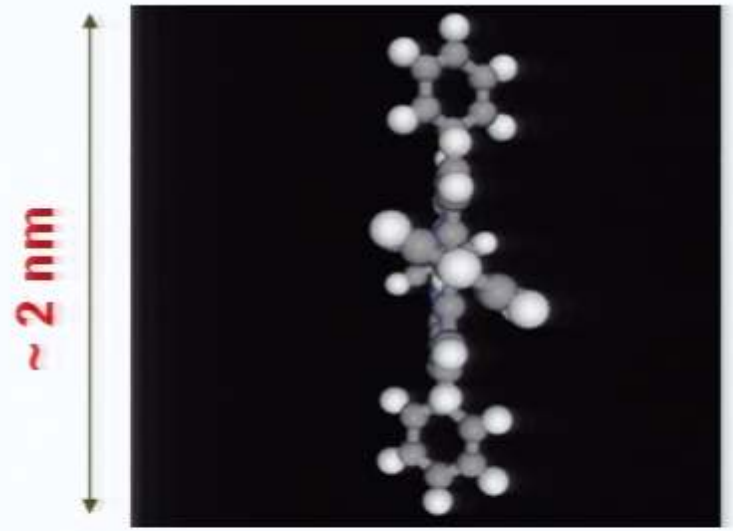
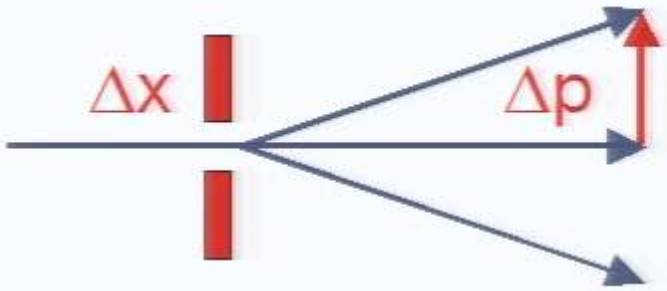


Heisenberg Uncertainty for Macromolecules

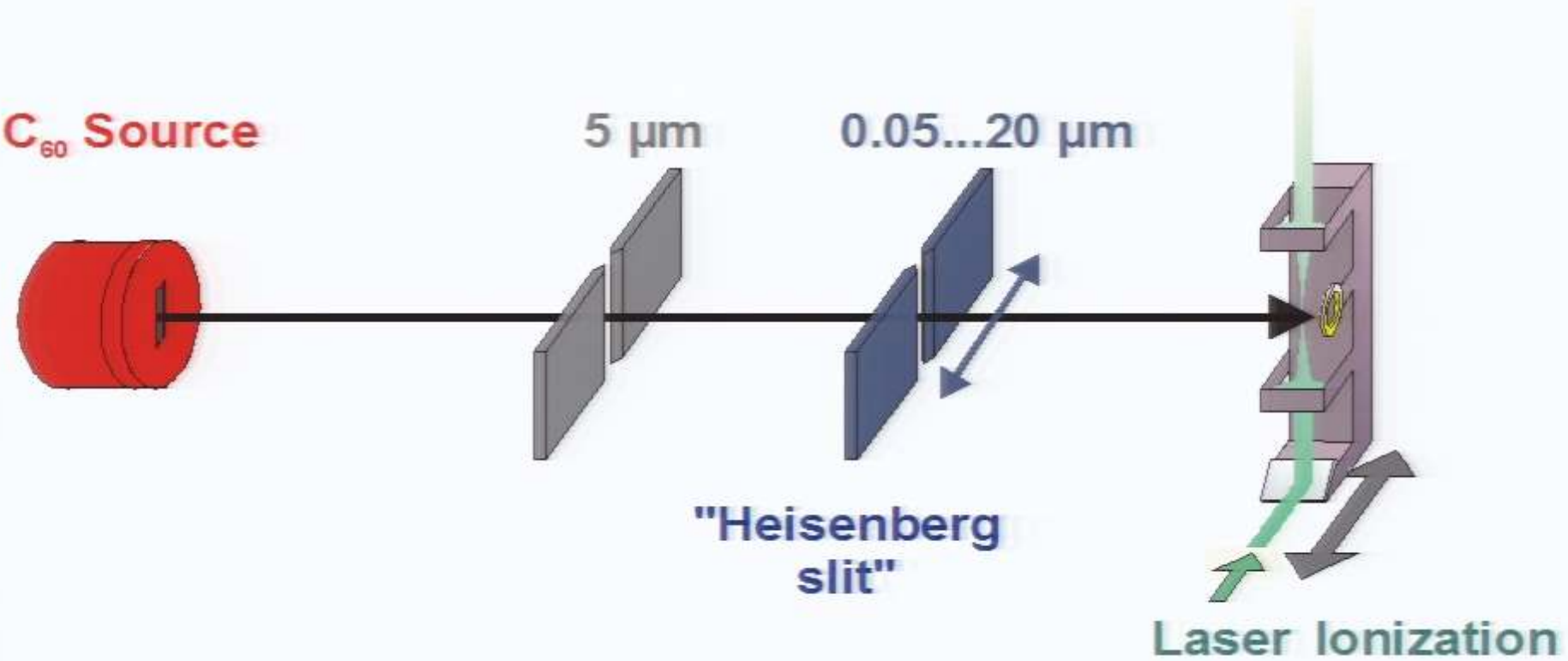
- Measurement by Diffraction at a Narrow Slit
- Prepares Coherent Wave Fronts



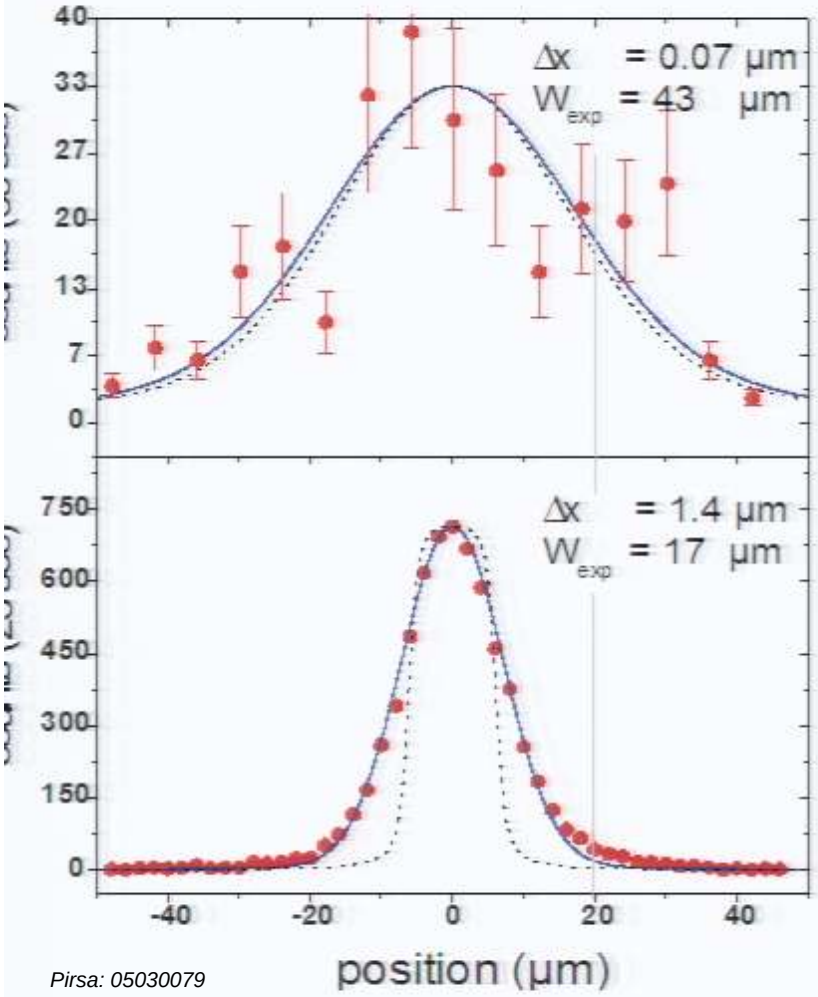
$$\Delta x \cdot \Delta p \geq \frac{\hbar}{2}$$

$$\Delta x \cdot \Delta p \gtrsim \hbar$$

Heisenberg Experiment



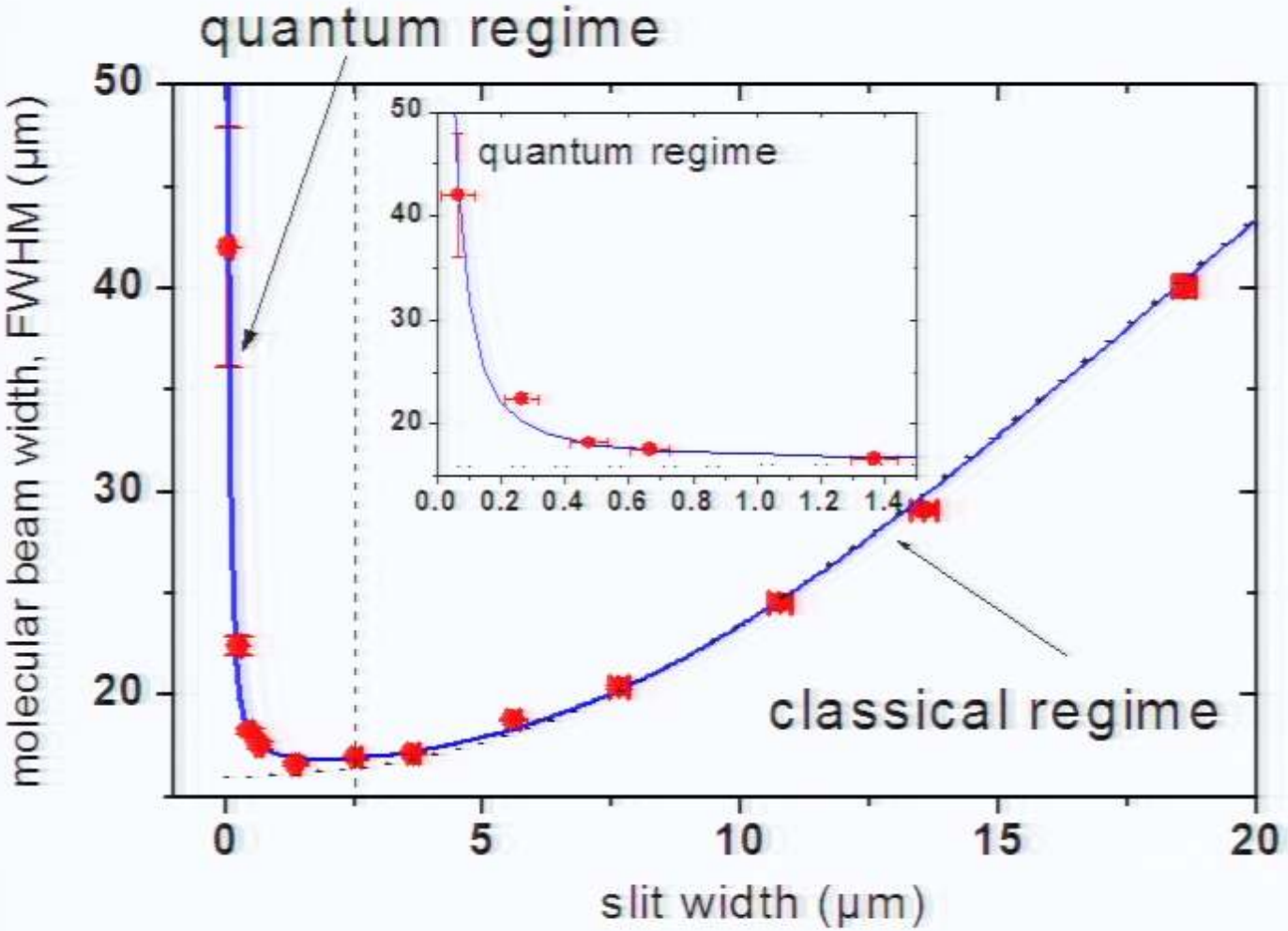
Experimental Results



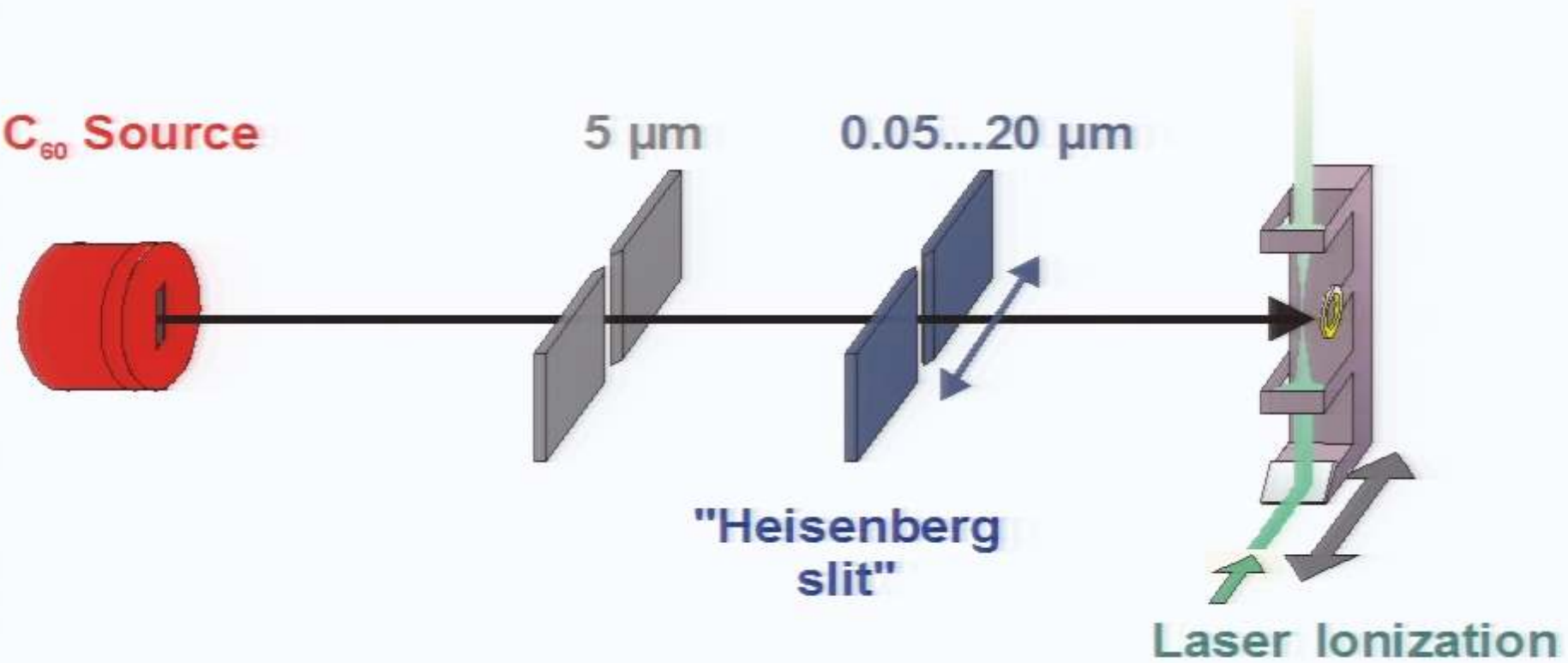
Smaller Slit Width

Larger Momentum Spread

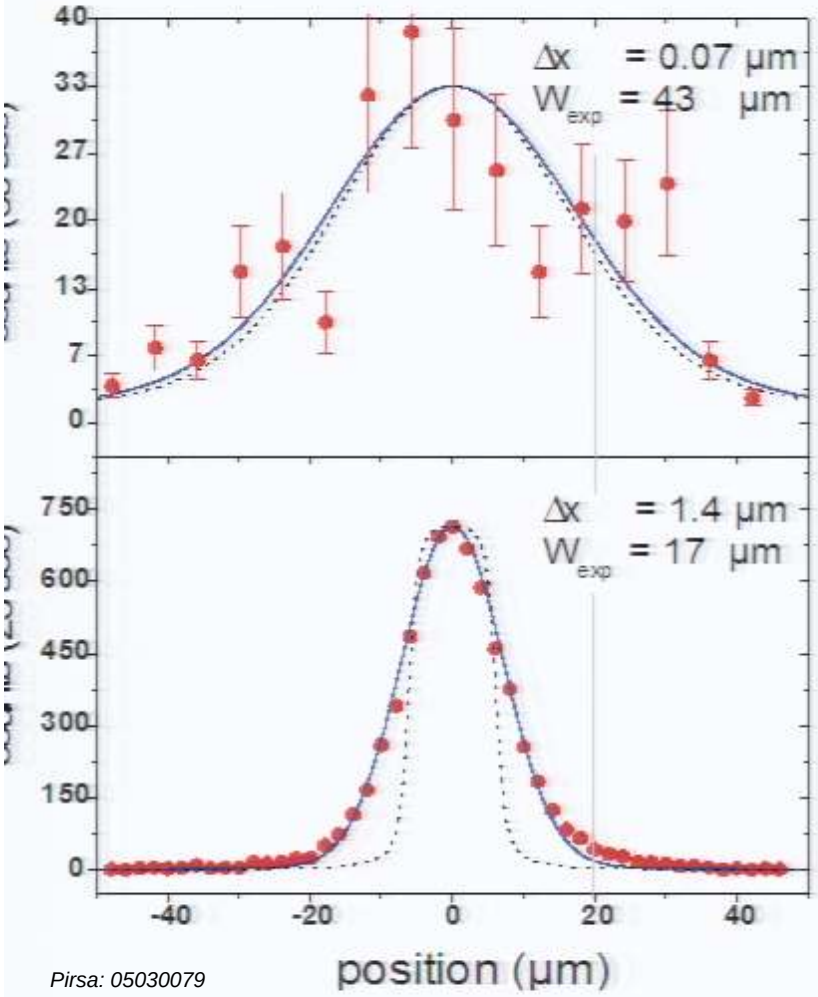
Experimental Results



Heisenberg Experiment



Experimental Results



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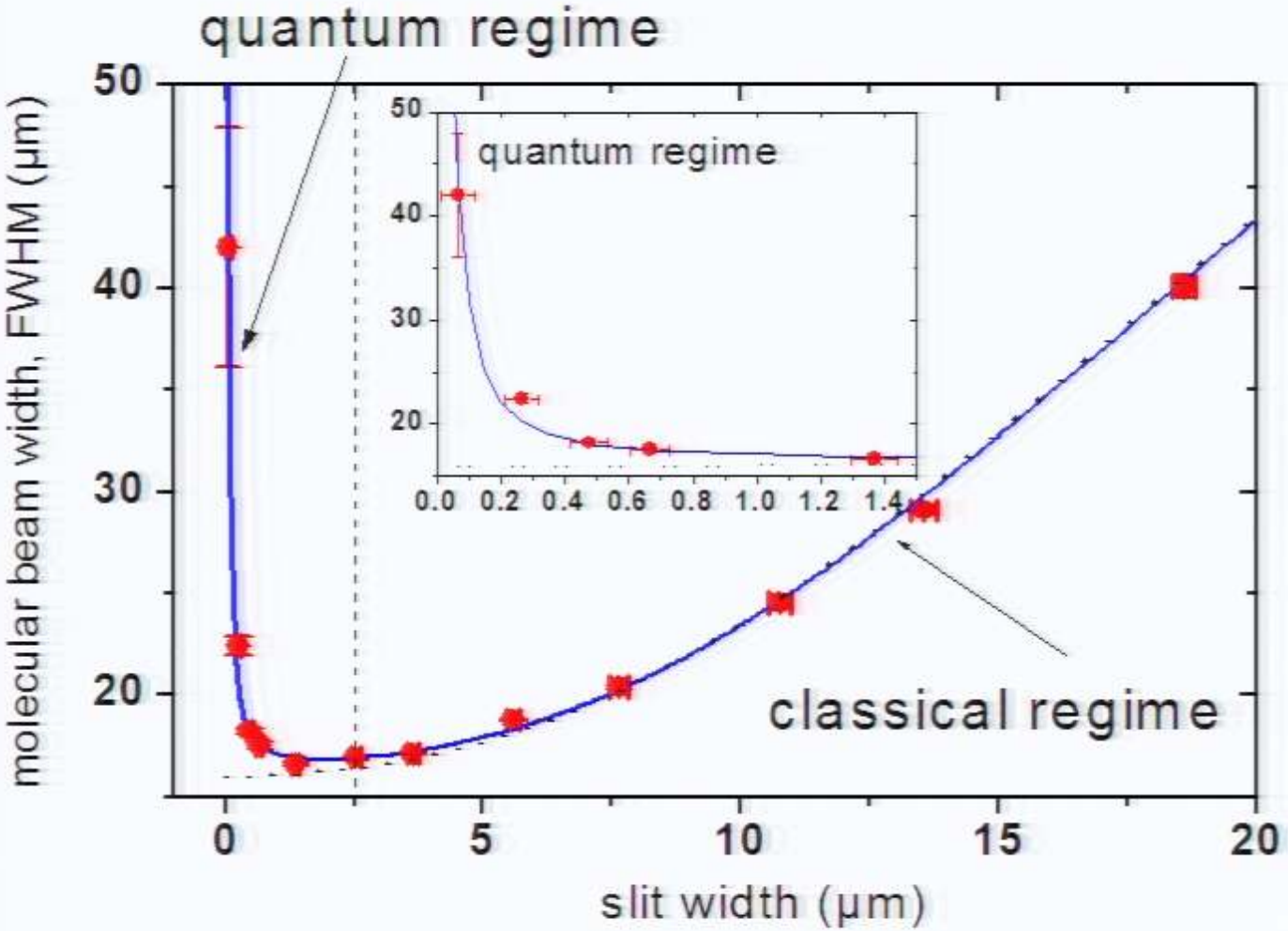
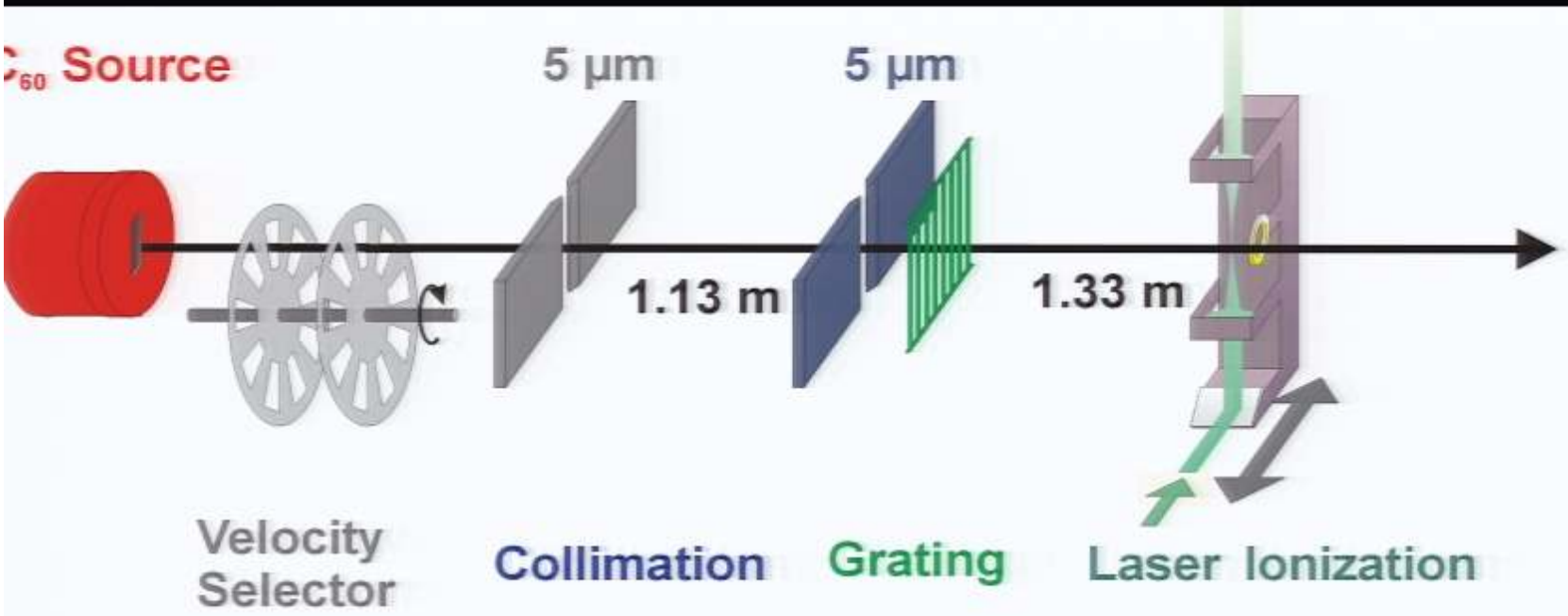
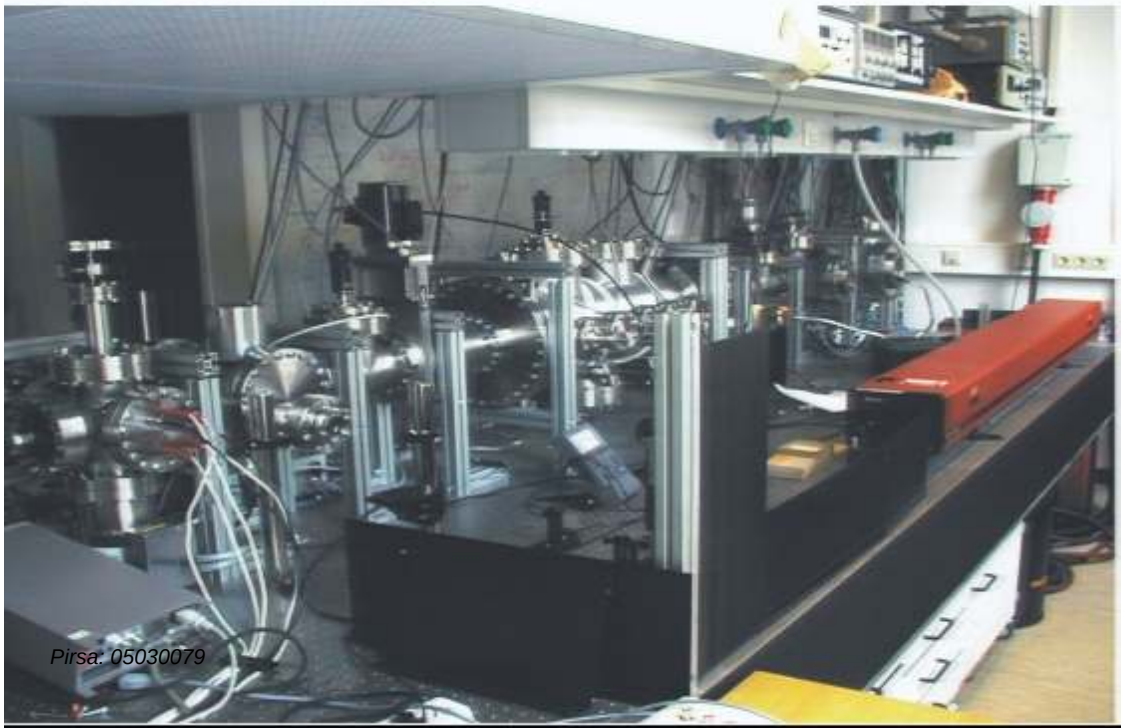
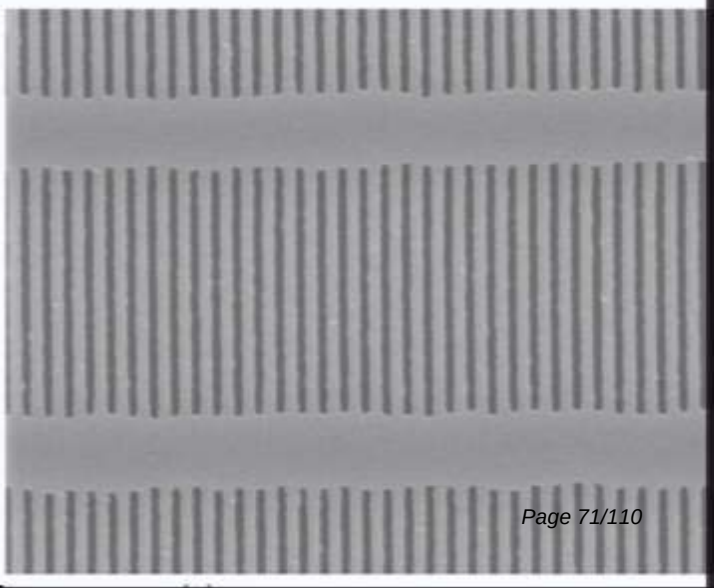



C_{60} Source
5 µm
5 µm
1.13 m
1.33 m
Velocity Selector
Collimation
Grating
Laser Ionization

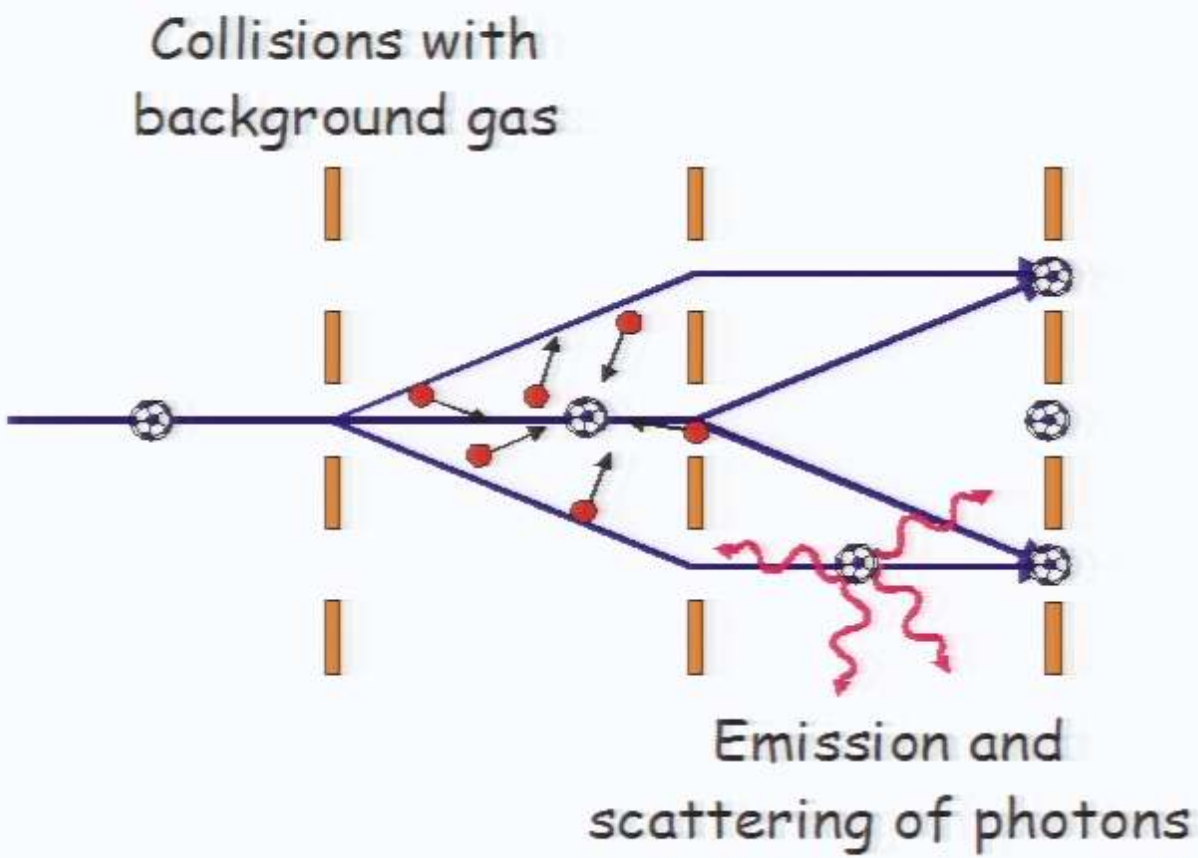




Where is the Limit ?

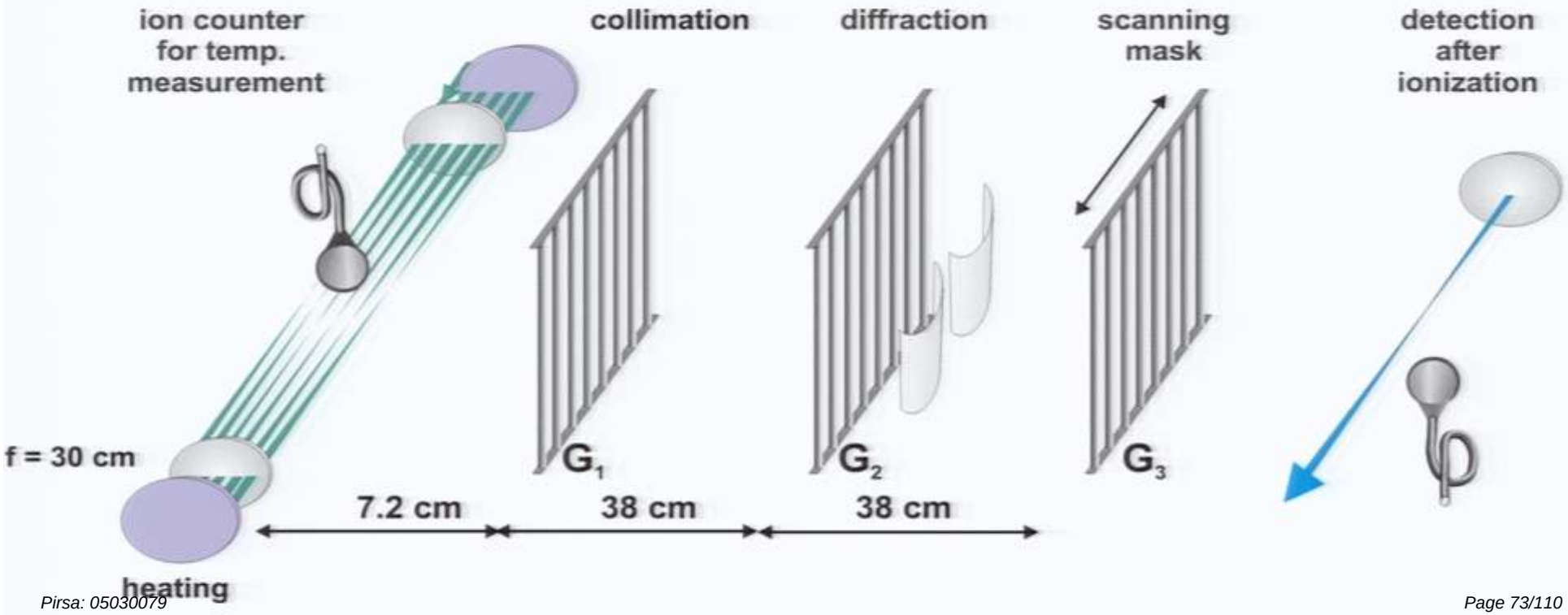
Collisional or Thermal Decoherence

Transition to Classical Dynamics



Decoherence by Emission of Thermal Radiation

Where are the Boundaries of the Quantum World?



Decoherence by Emission of Thermal Radiation

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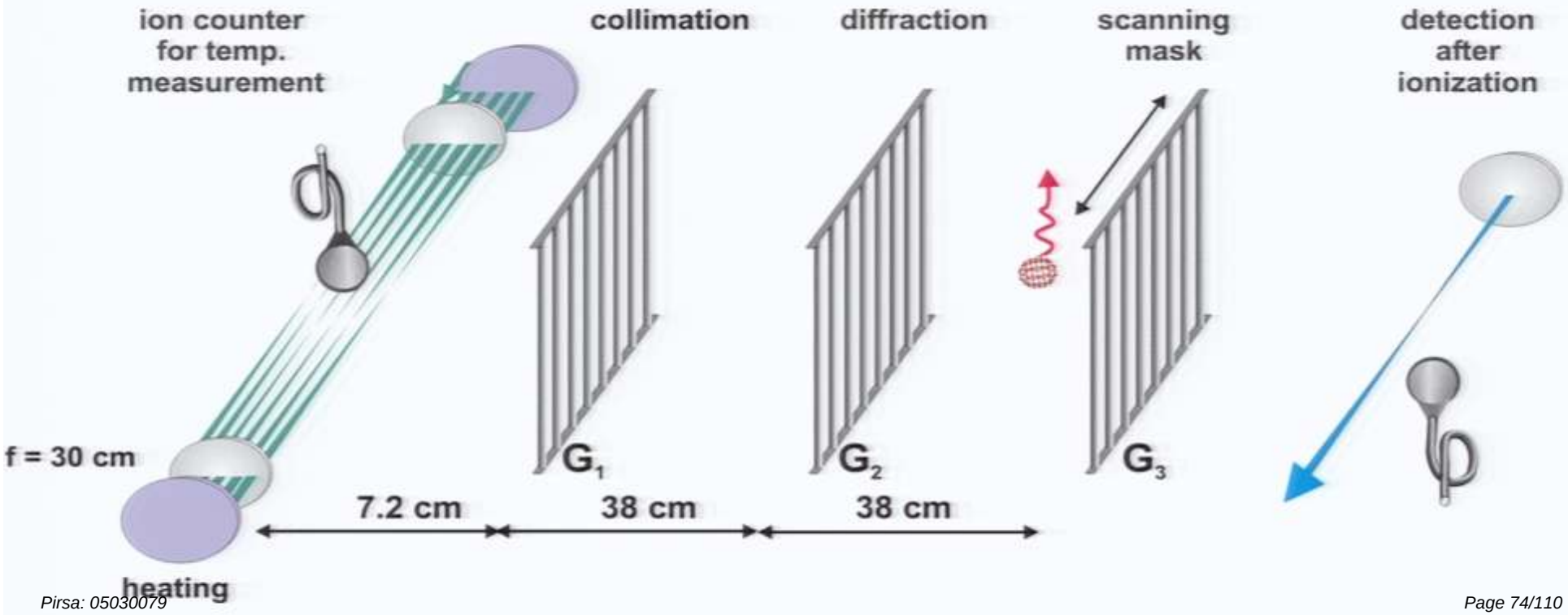

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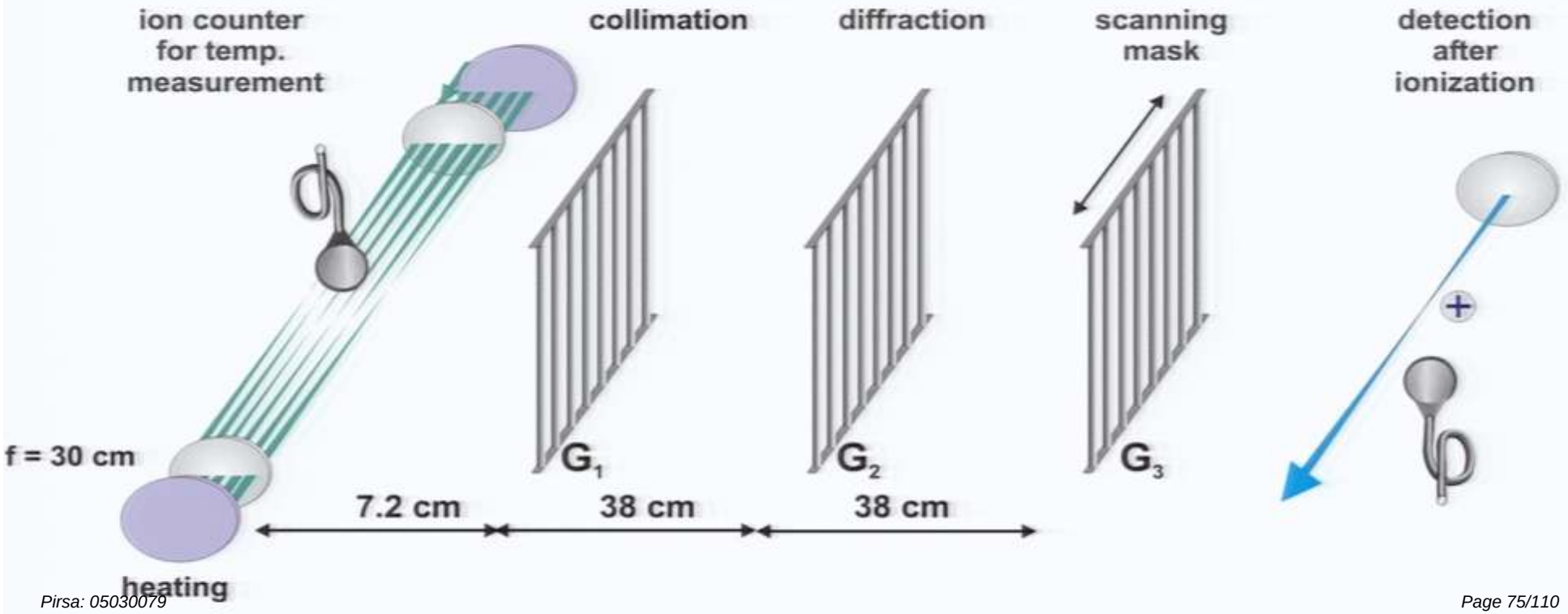

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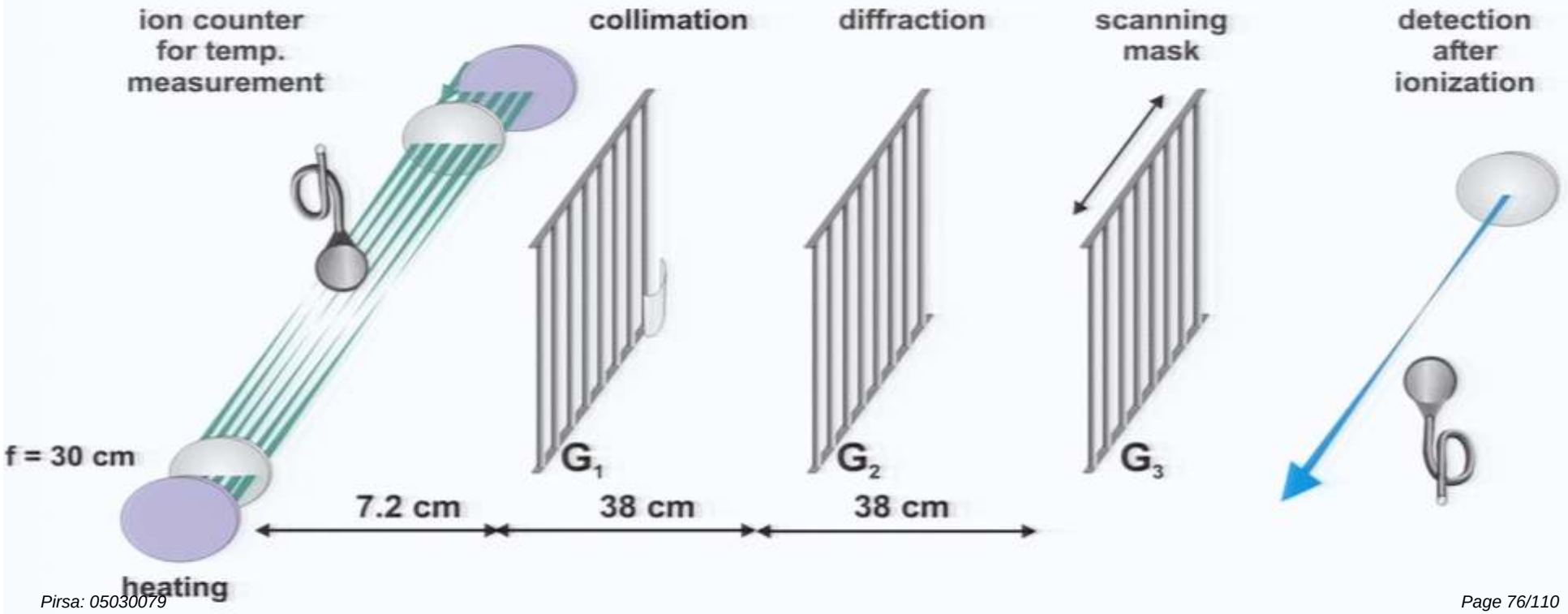

Decoherence by Emission of Thermal Radiation

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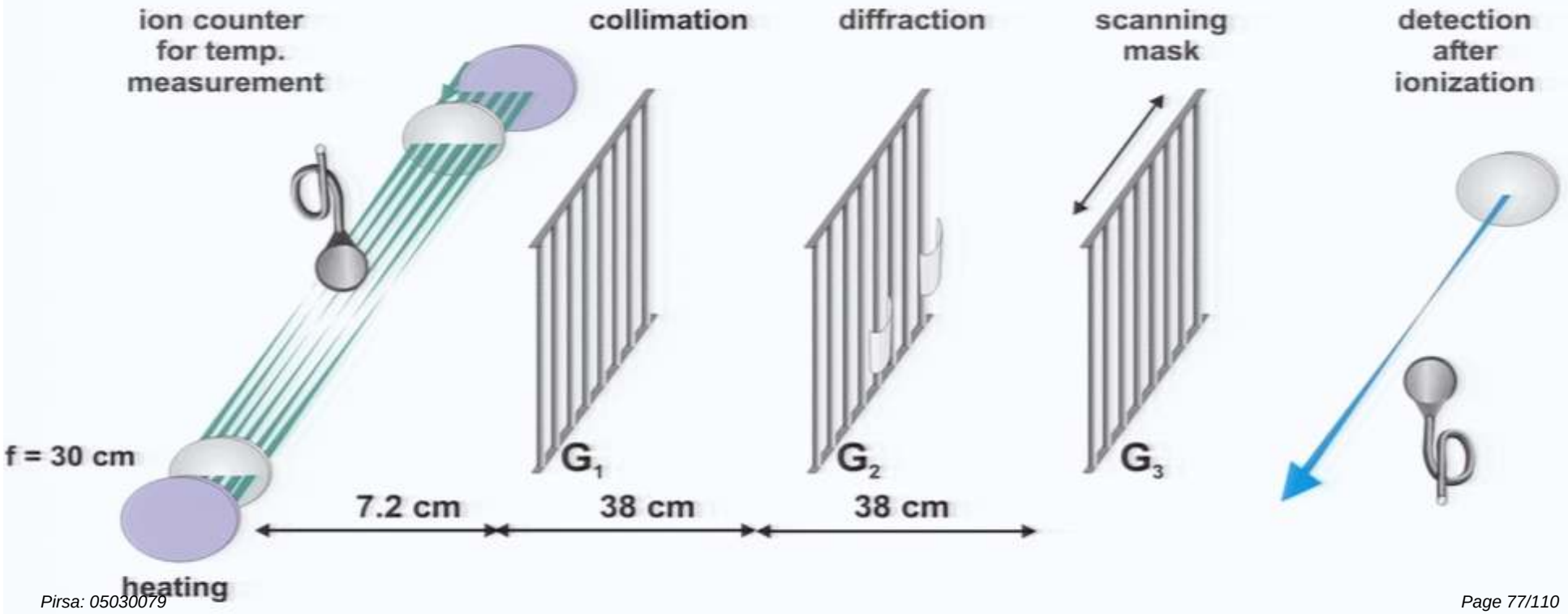

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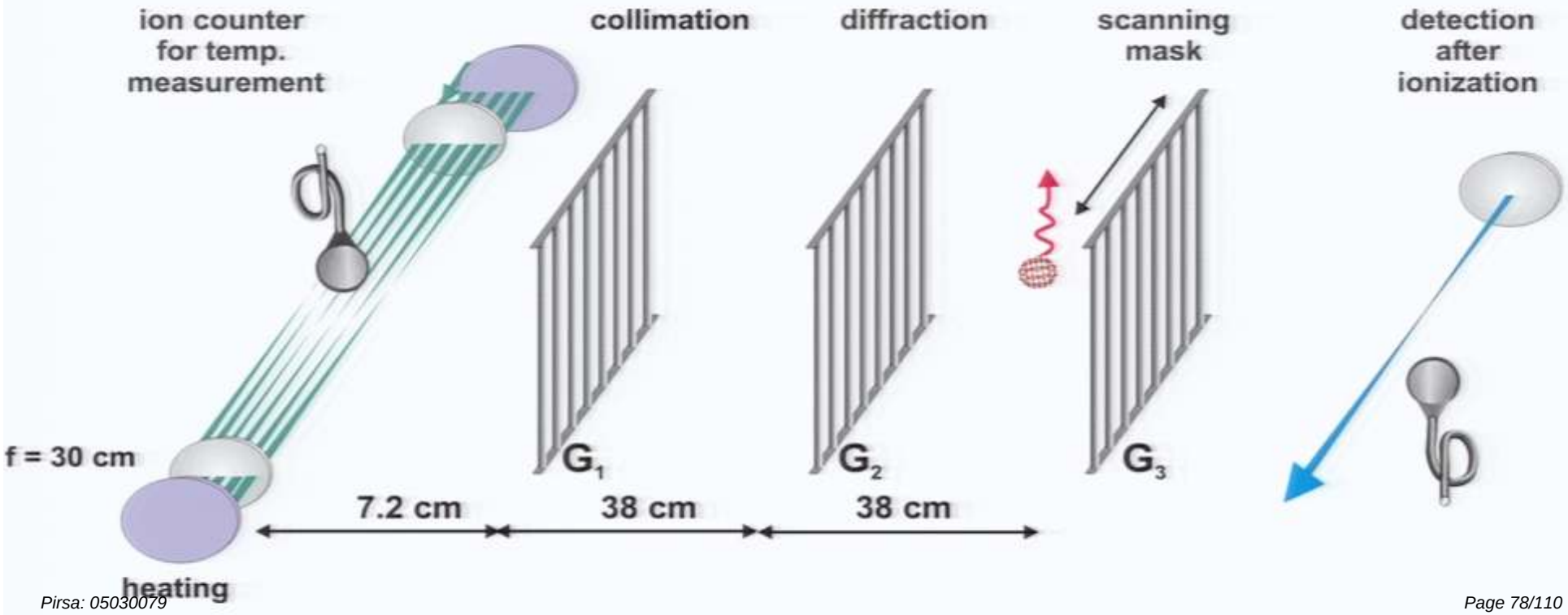

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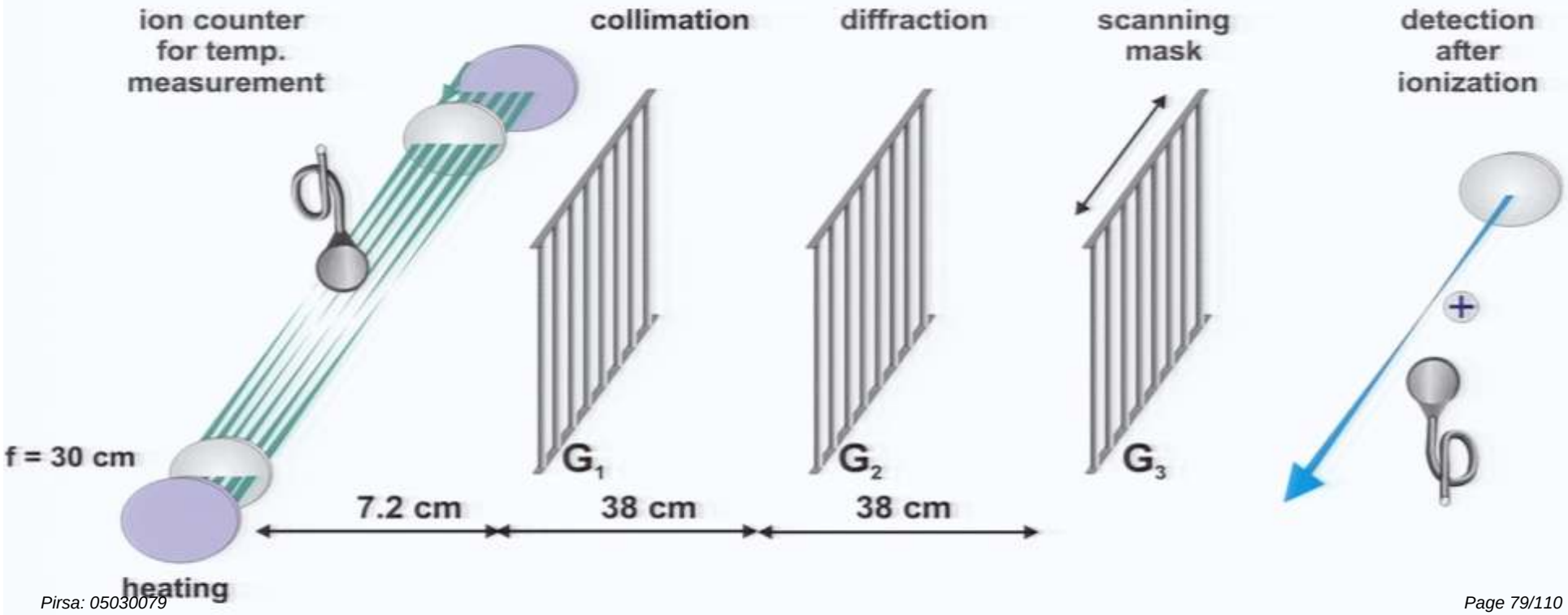
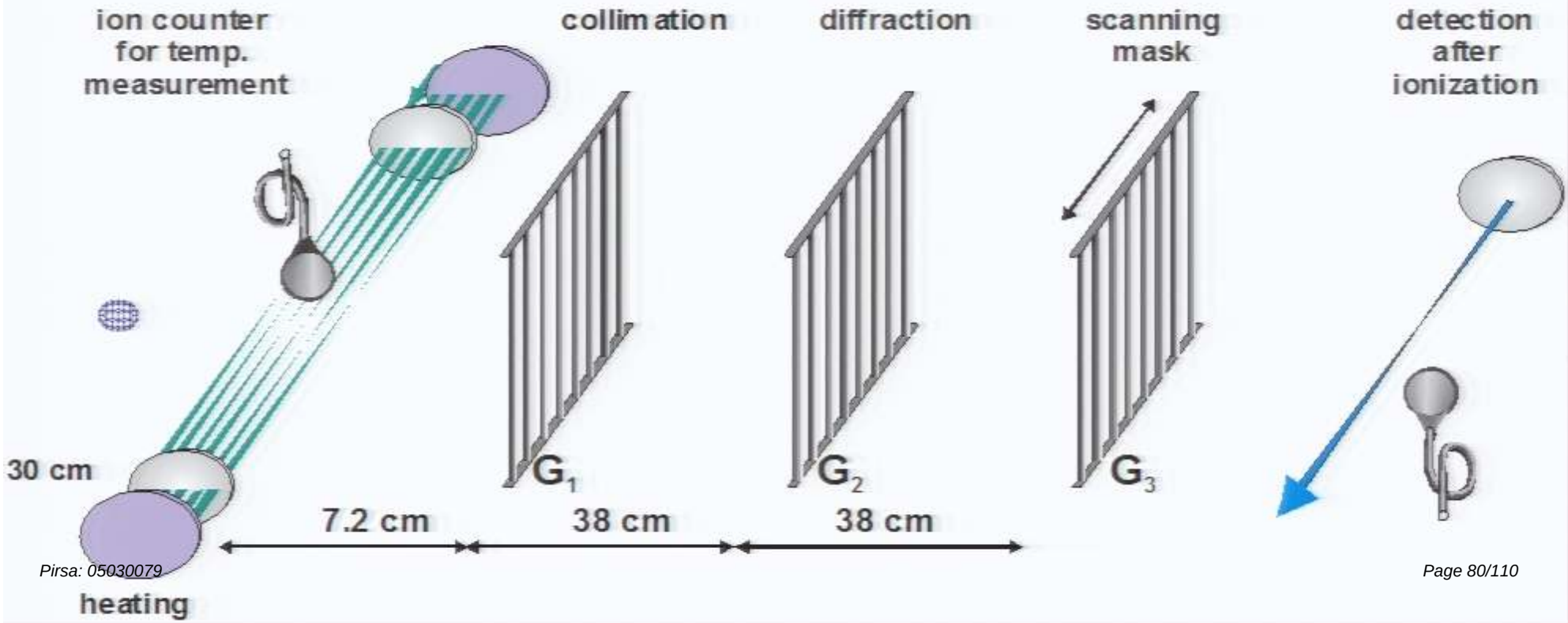
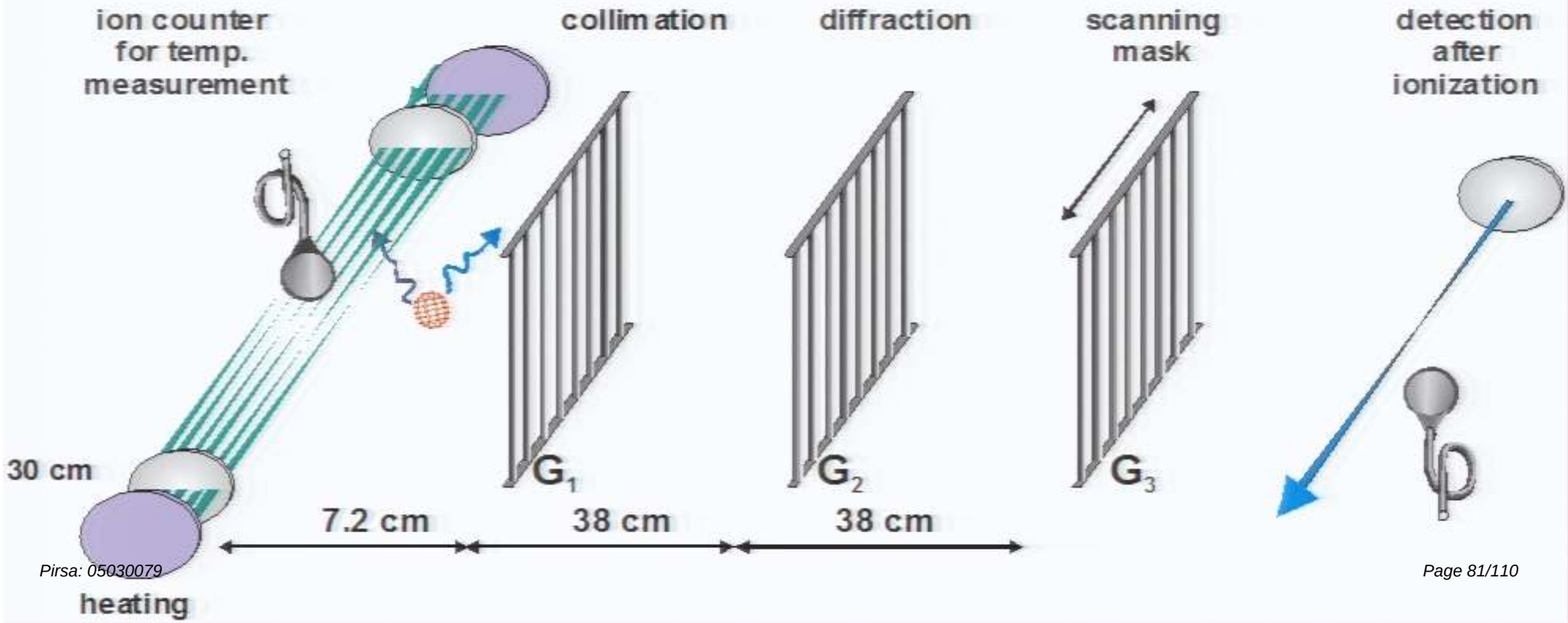



ion counter
for temp.
measurement
collimation
diffraction
scanning
mask
detection
after
ionization
30 cm
G1
G2
G3
7.2 cm
38 cm
38 cm
heating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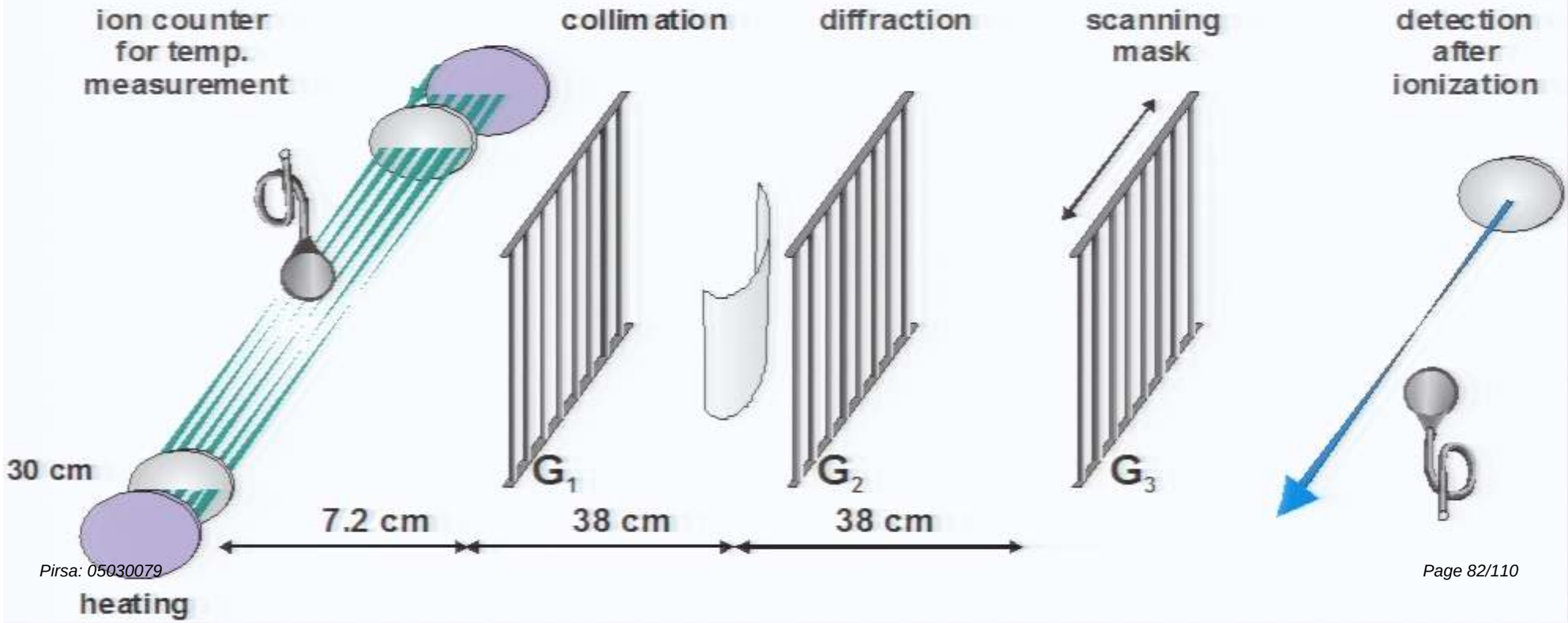
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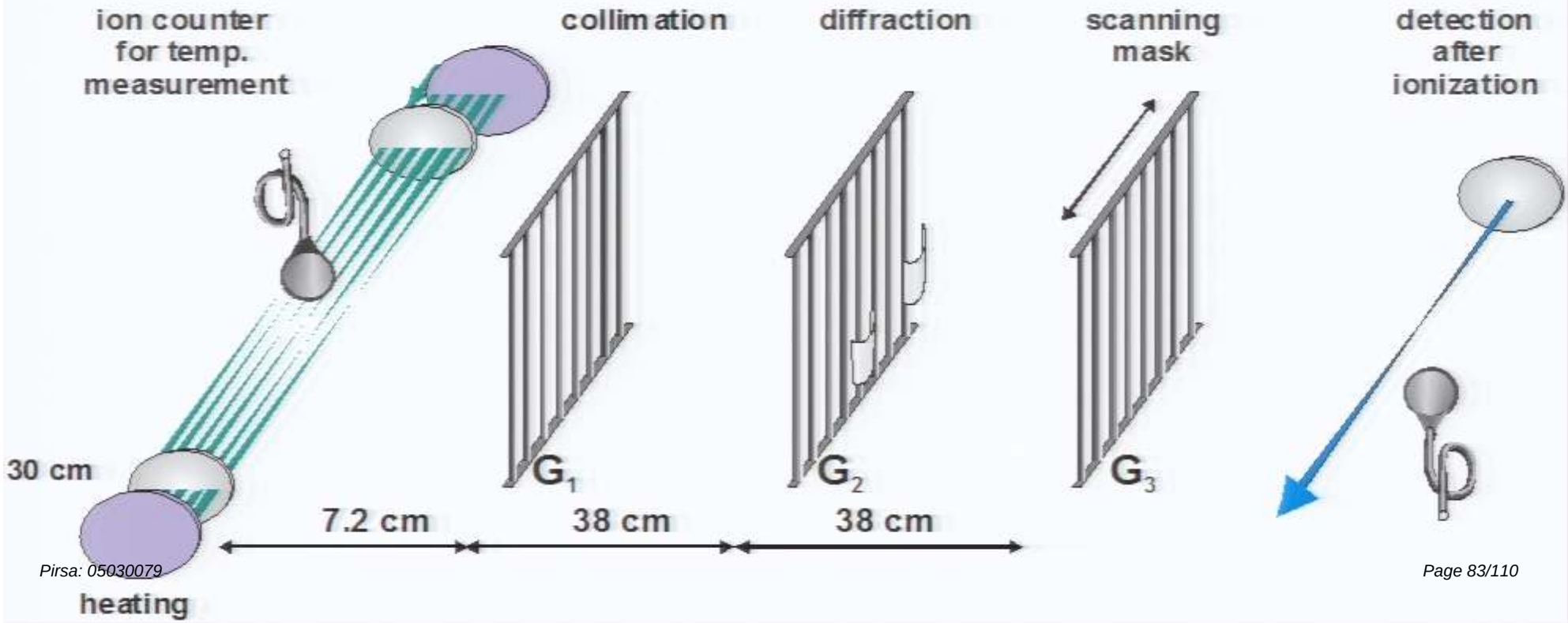
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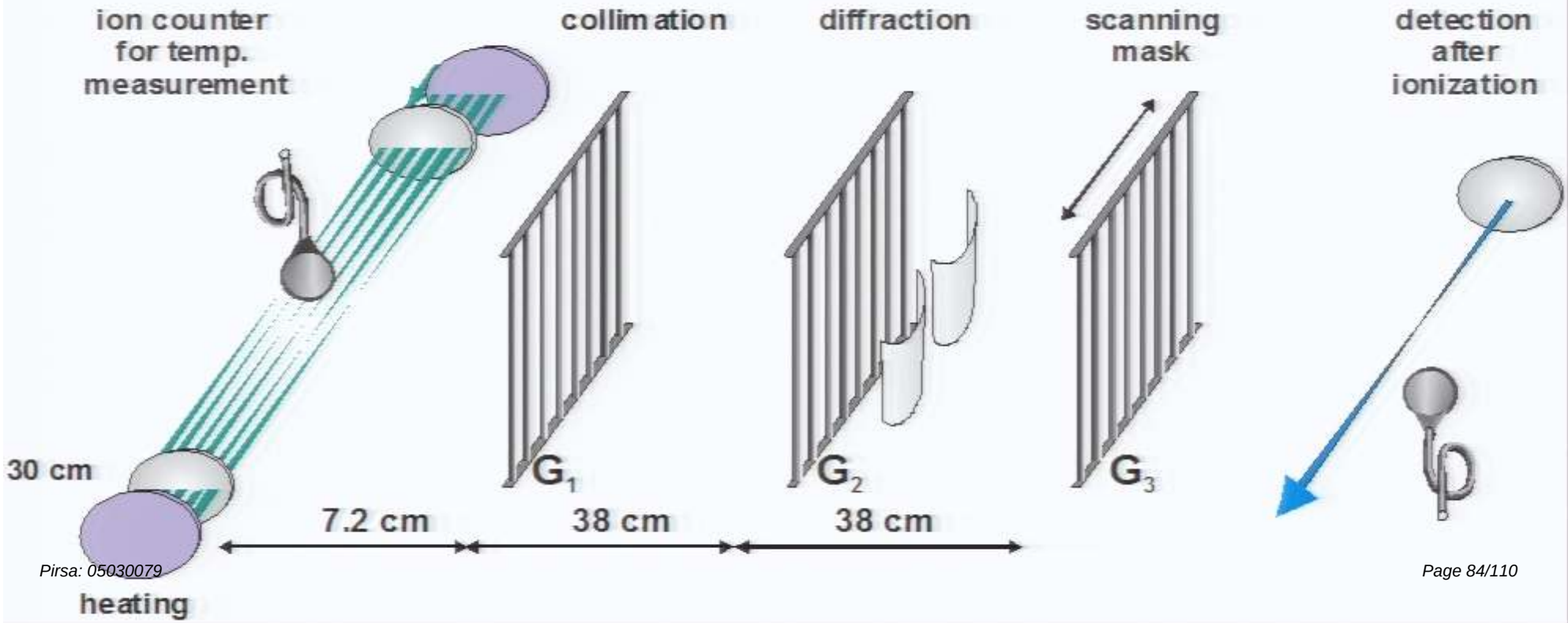
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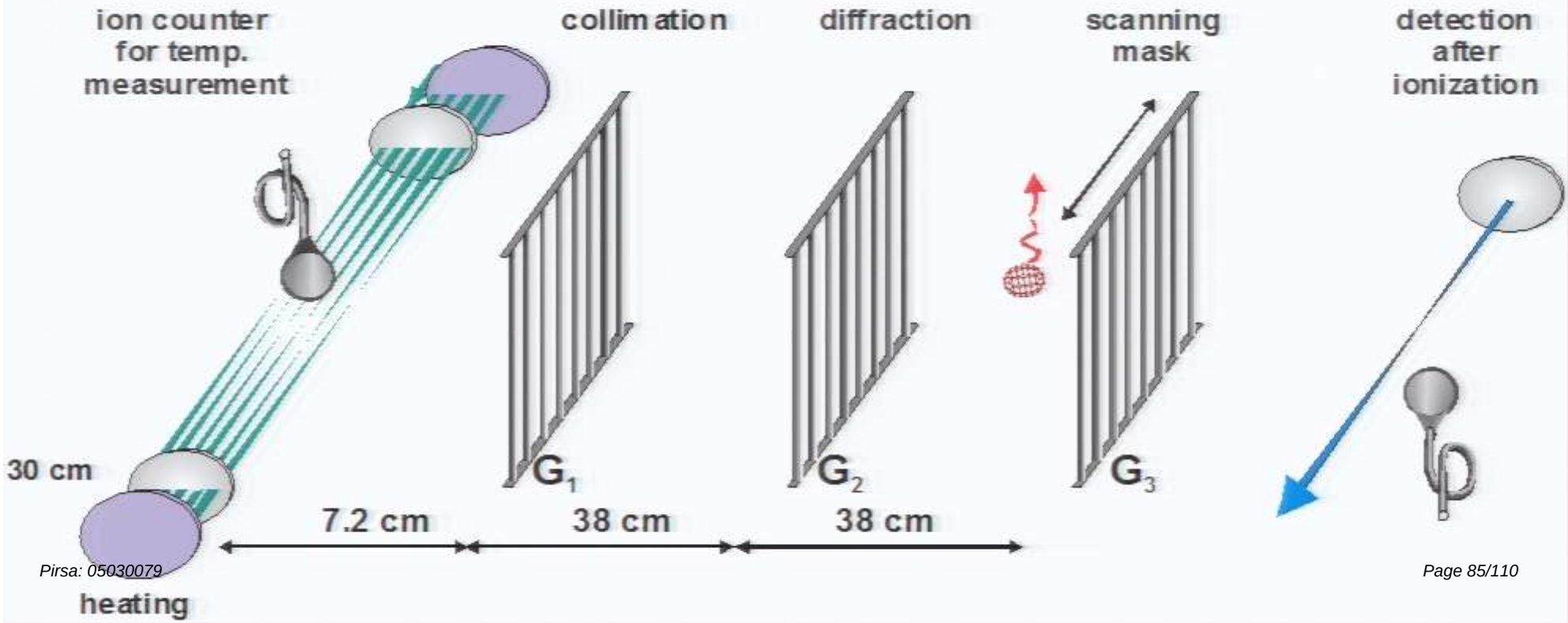
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Decoherence by Emission of Thermal Radiation

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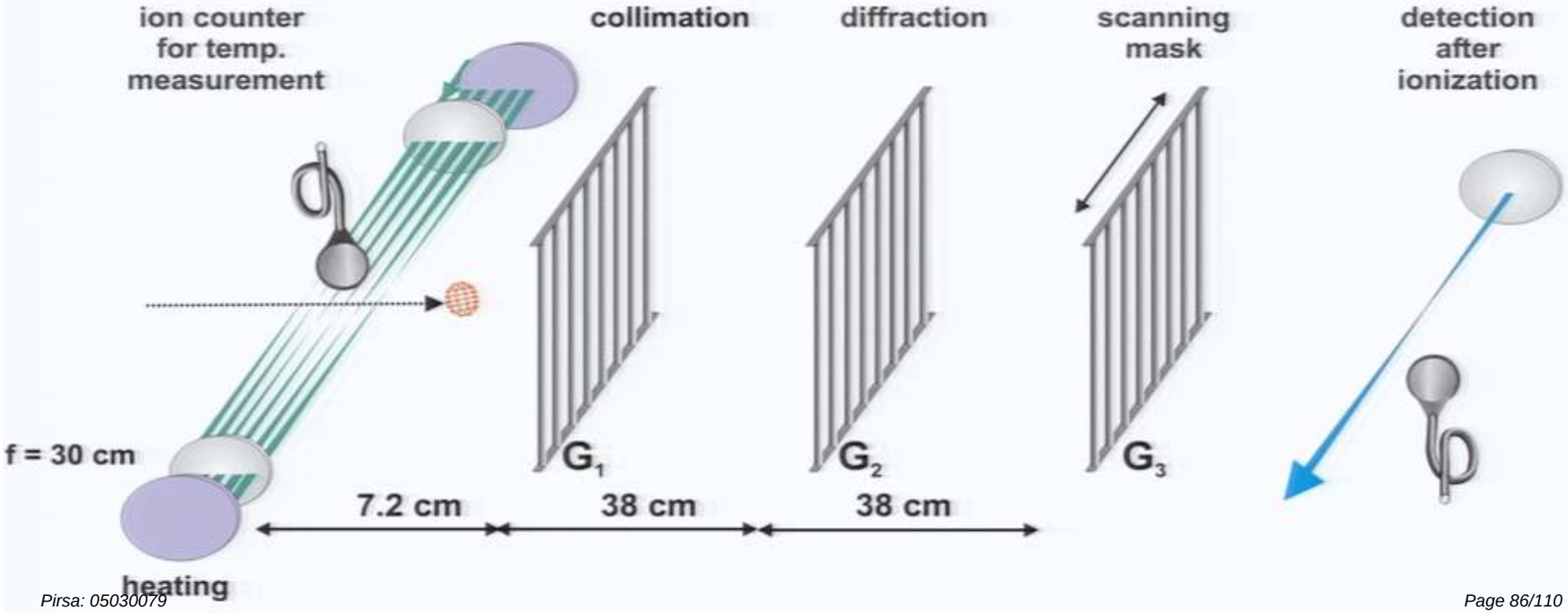
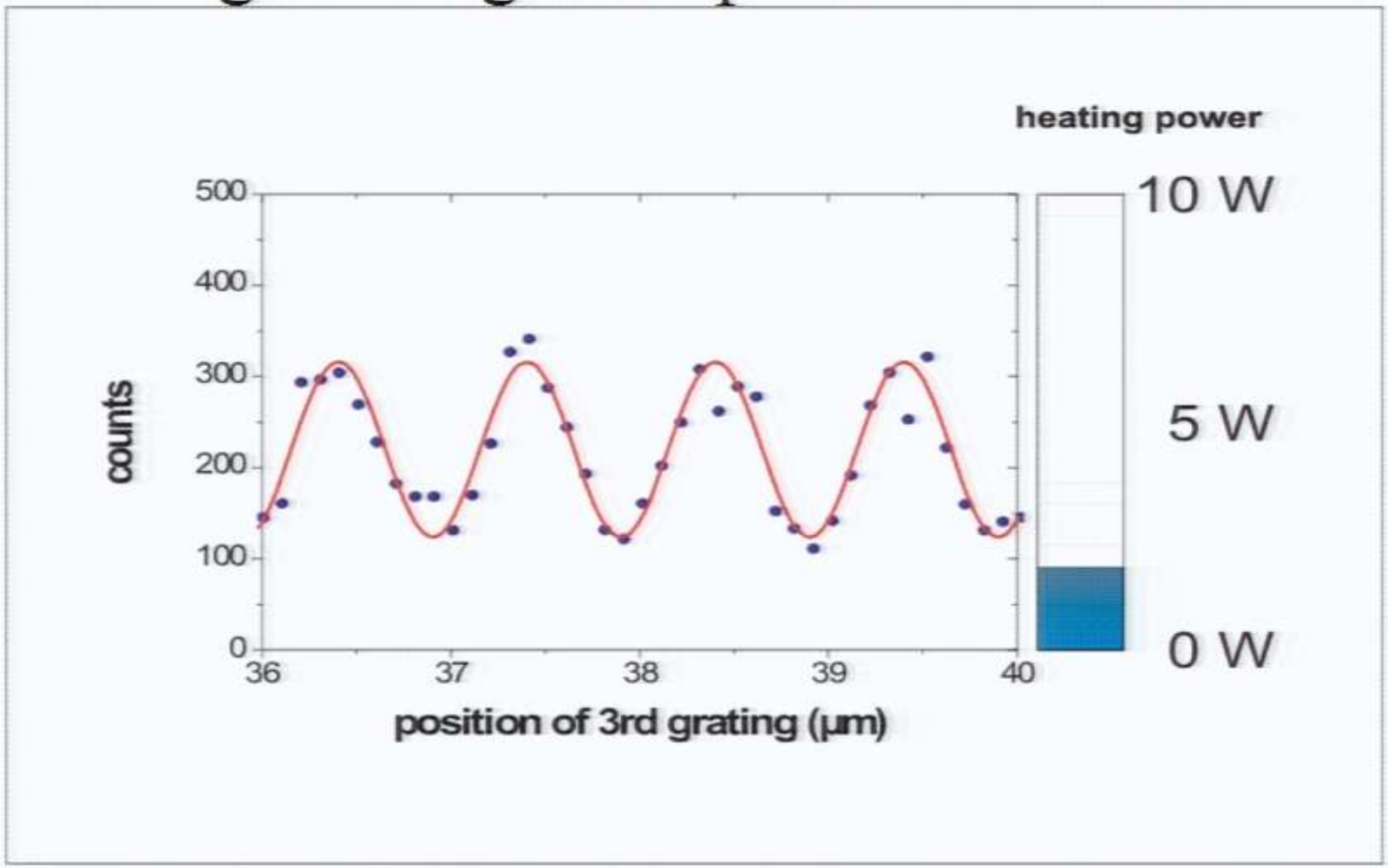
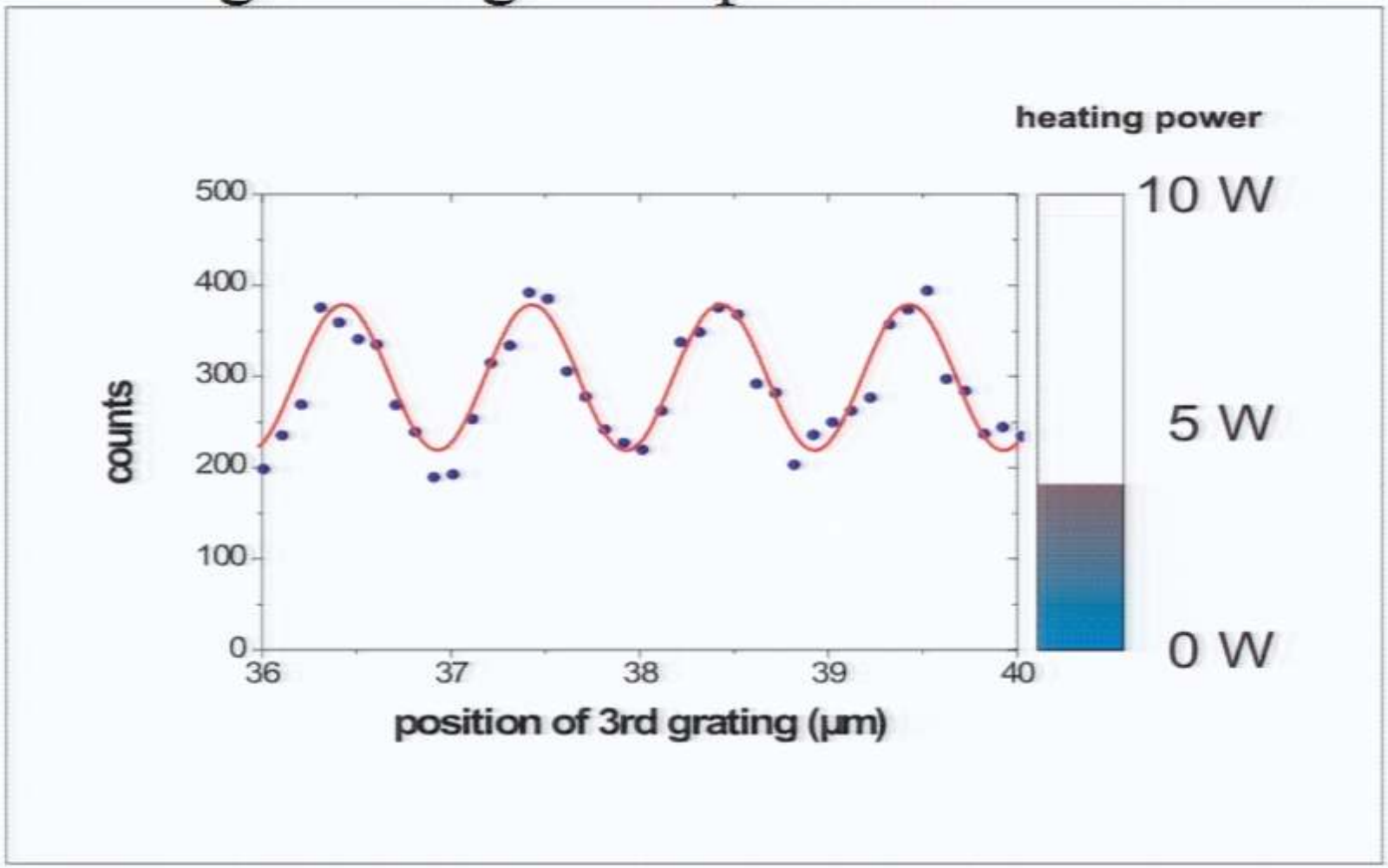


Interference patterns for
Increasing heating laser power



Interference patterns for Increasing heating laser power



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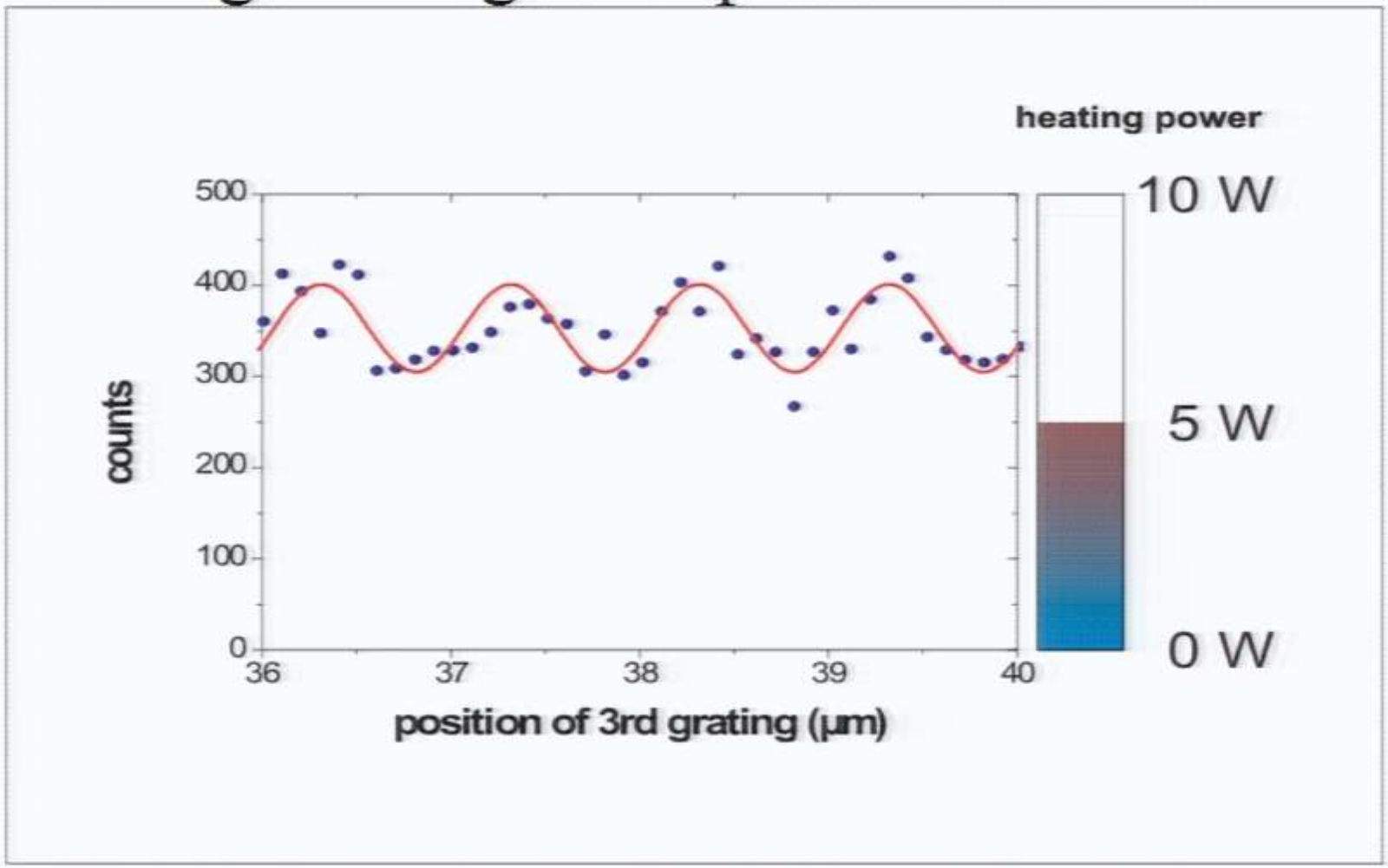

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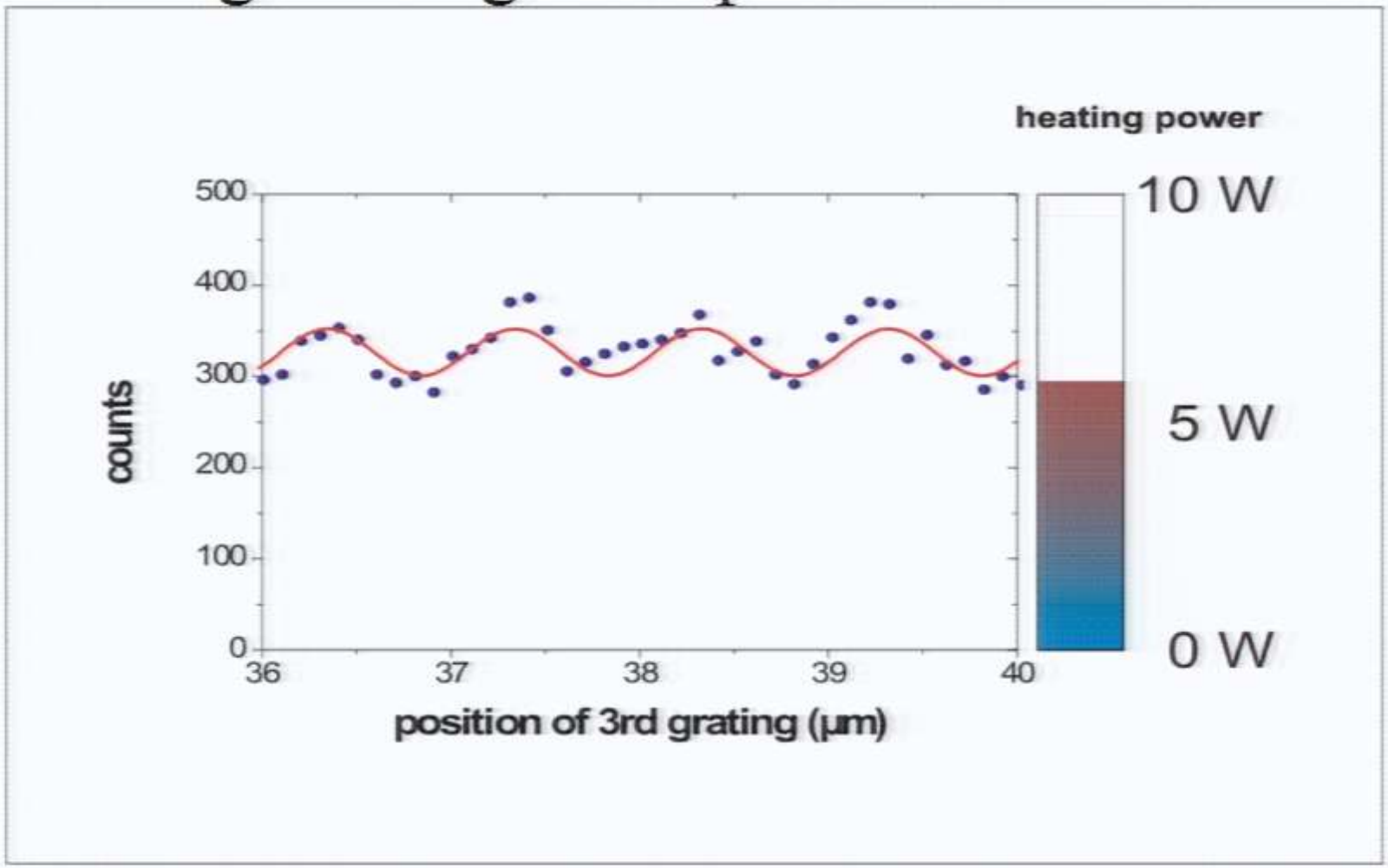

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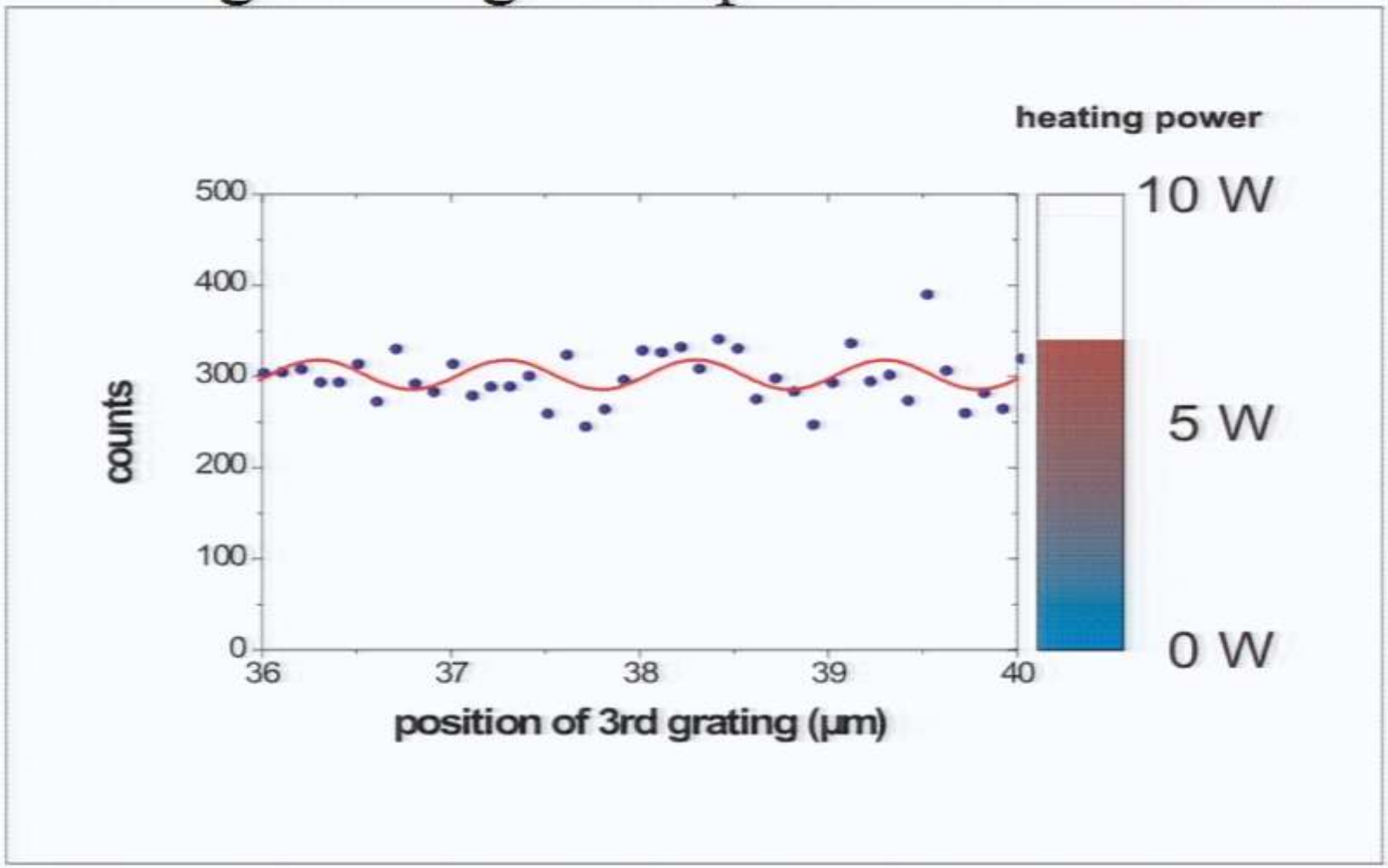

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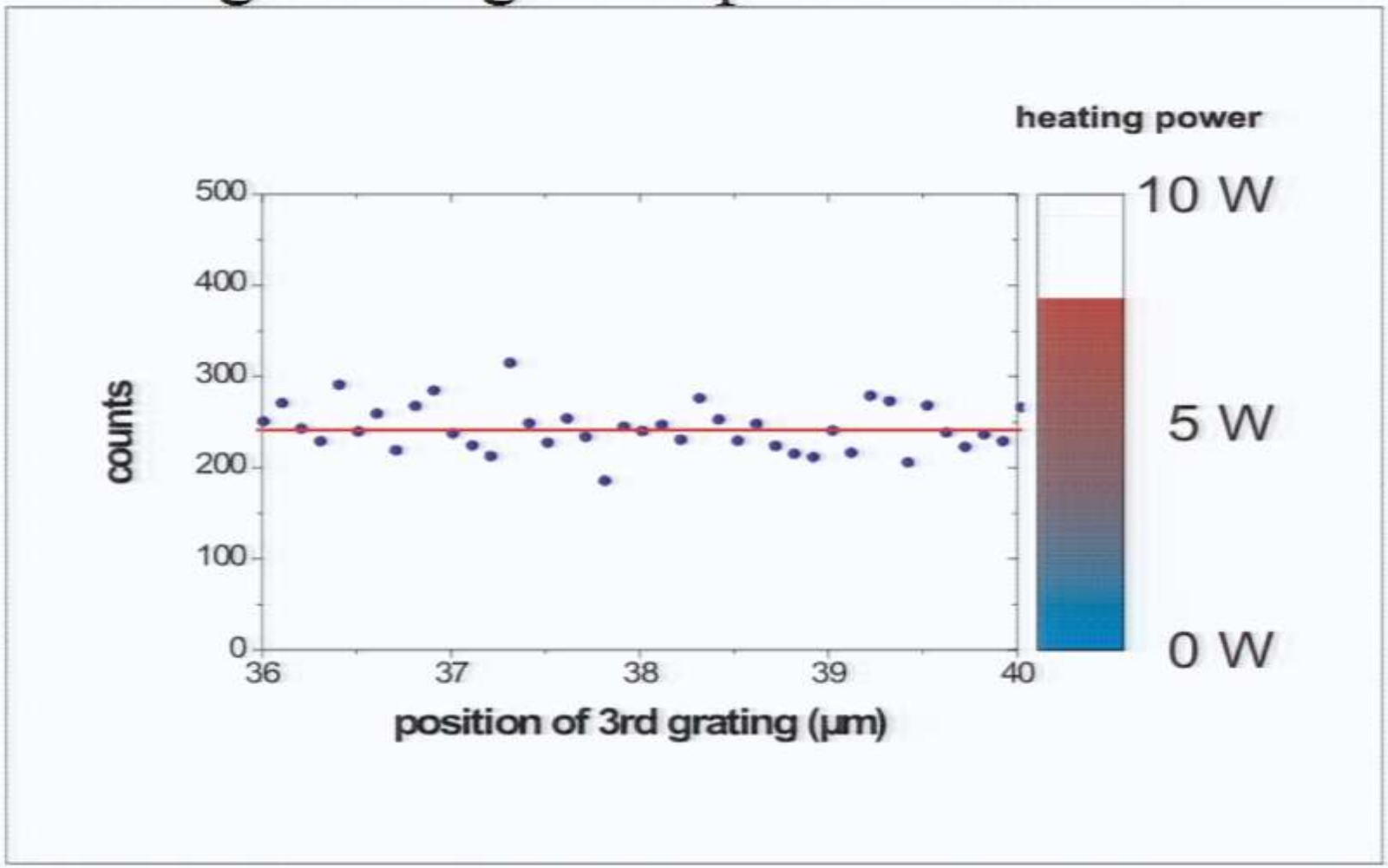

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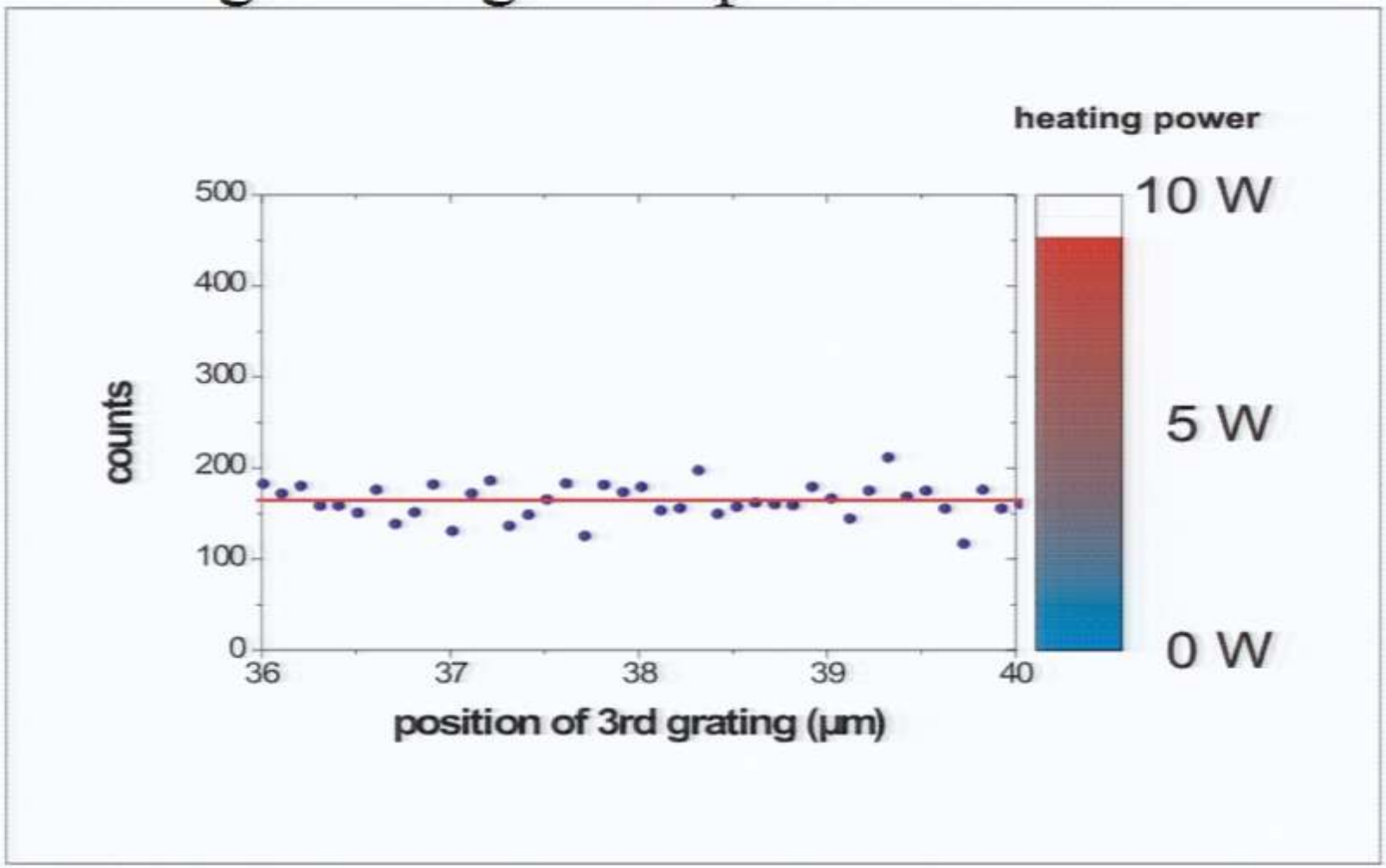

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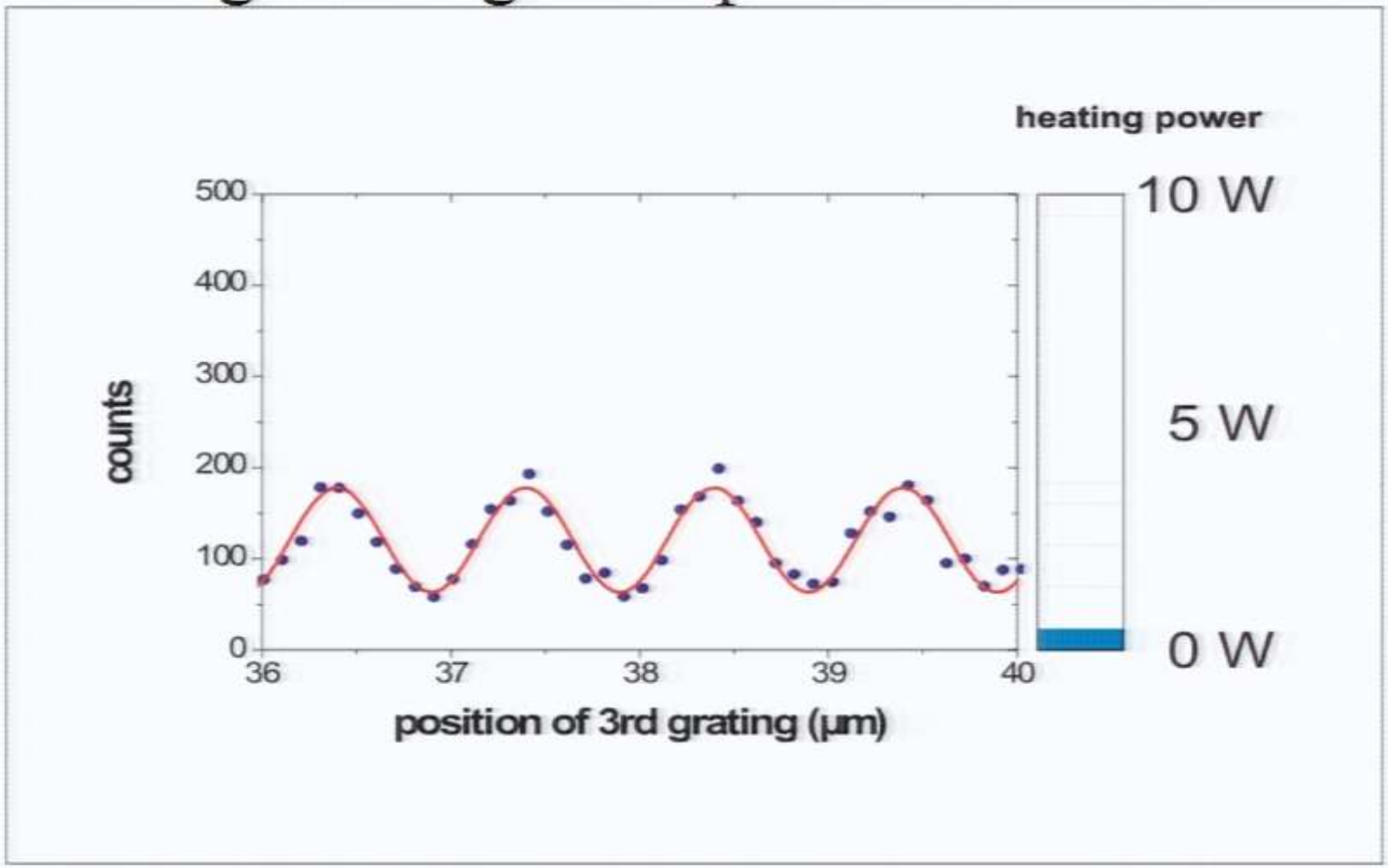

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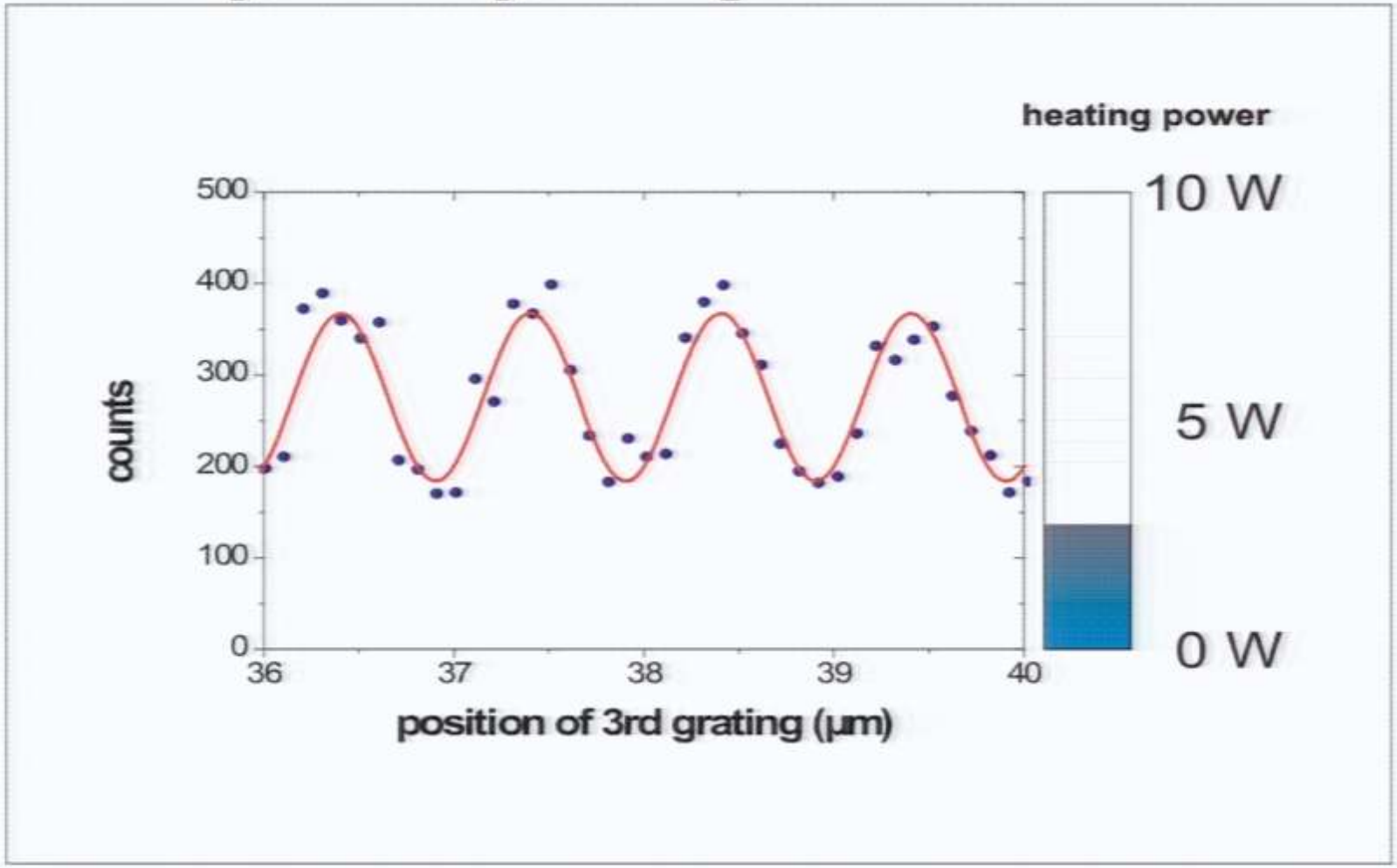

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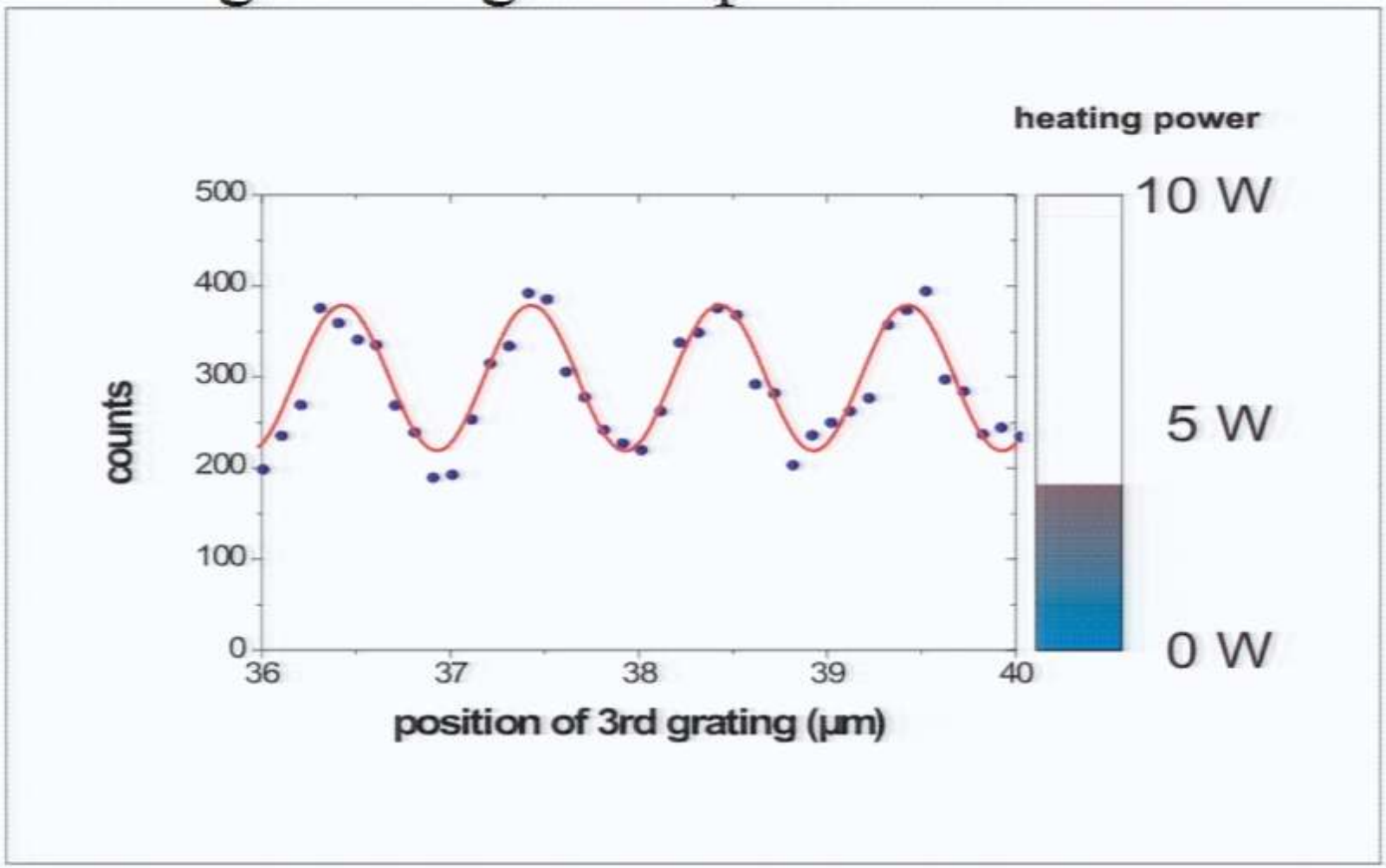

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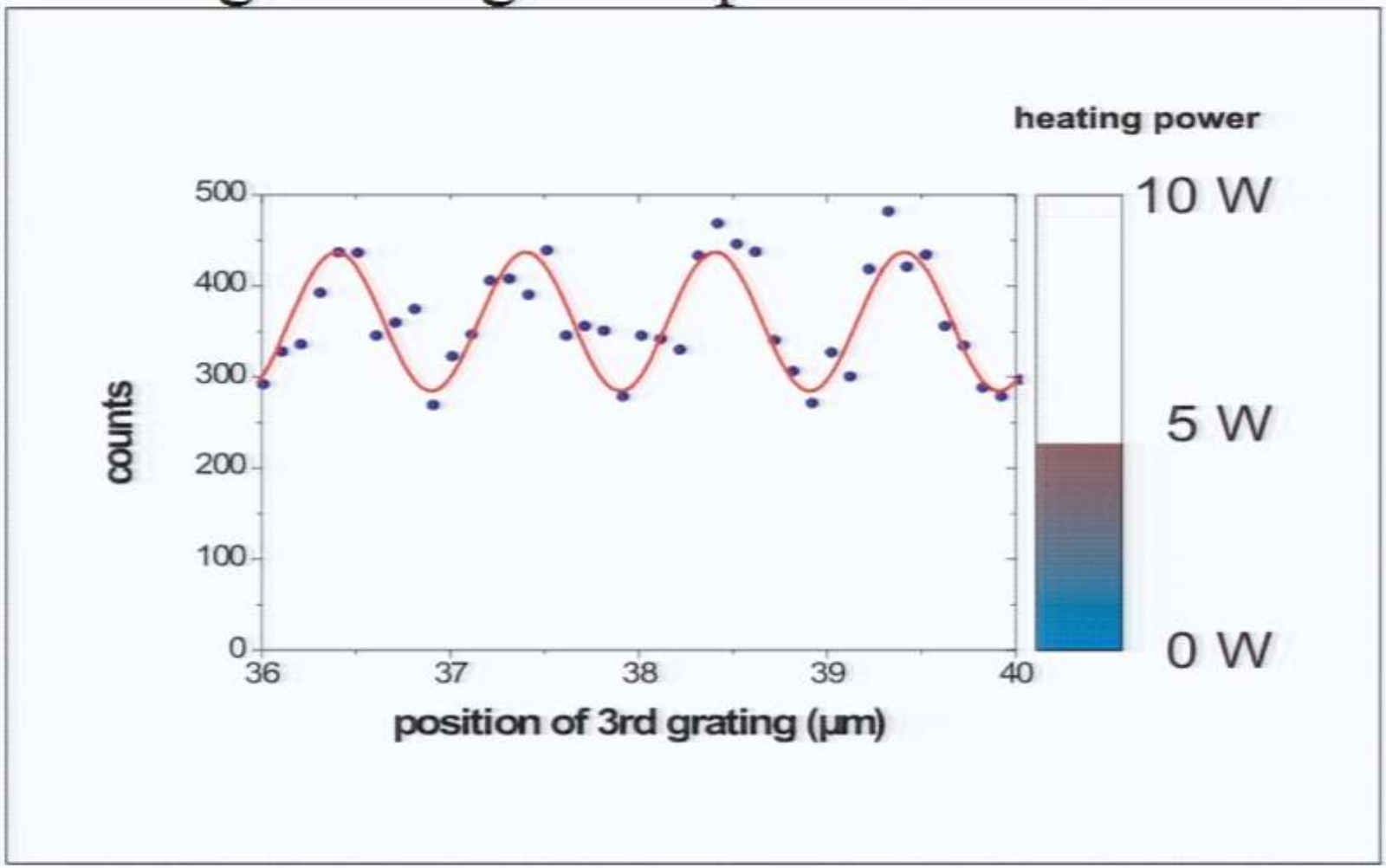

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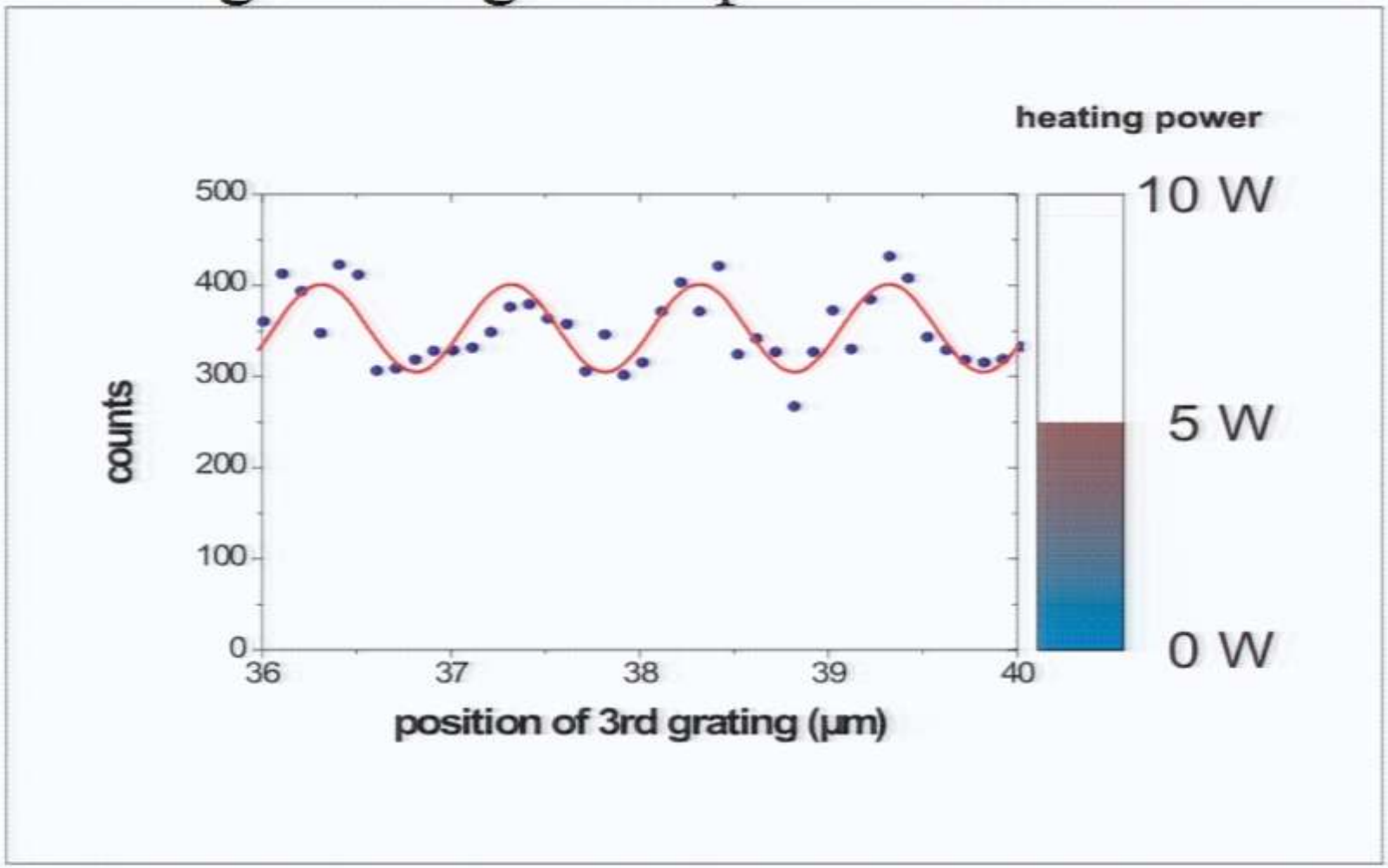

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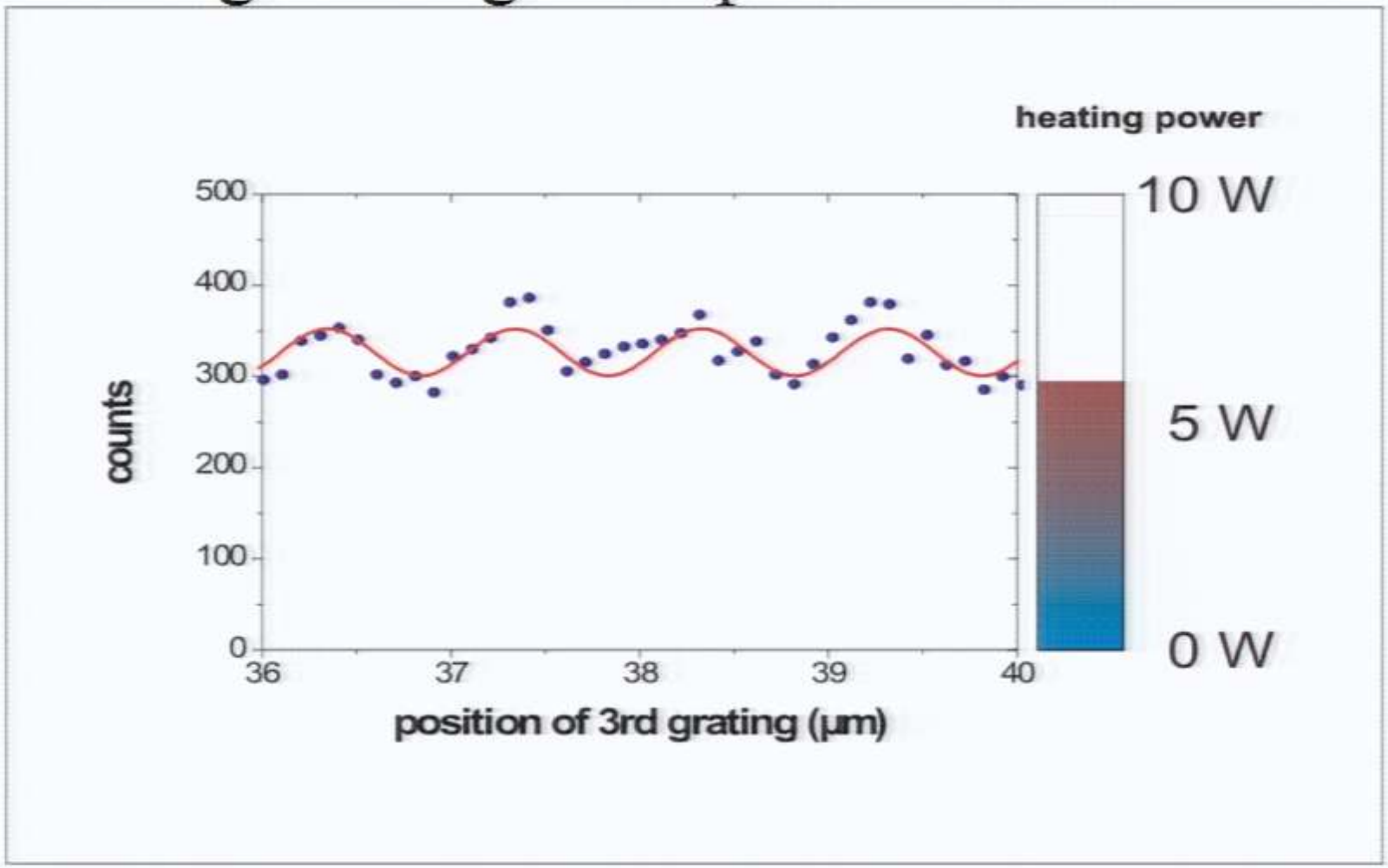

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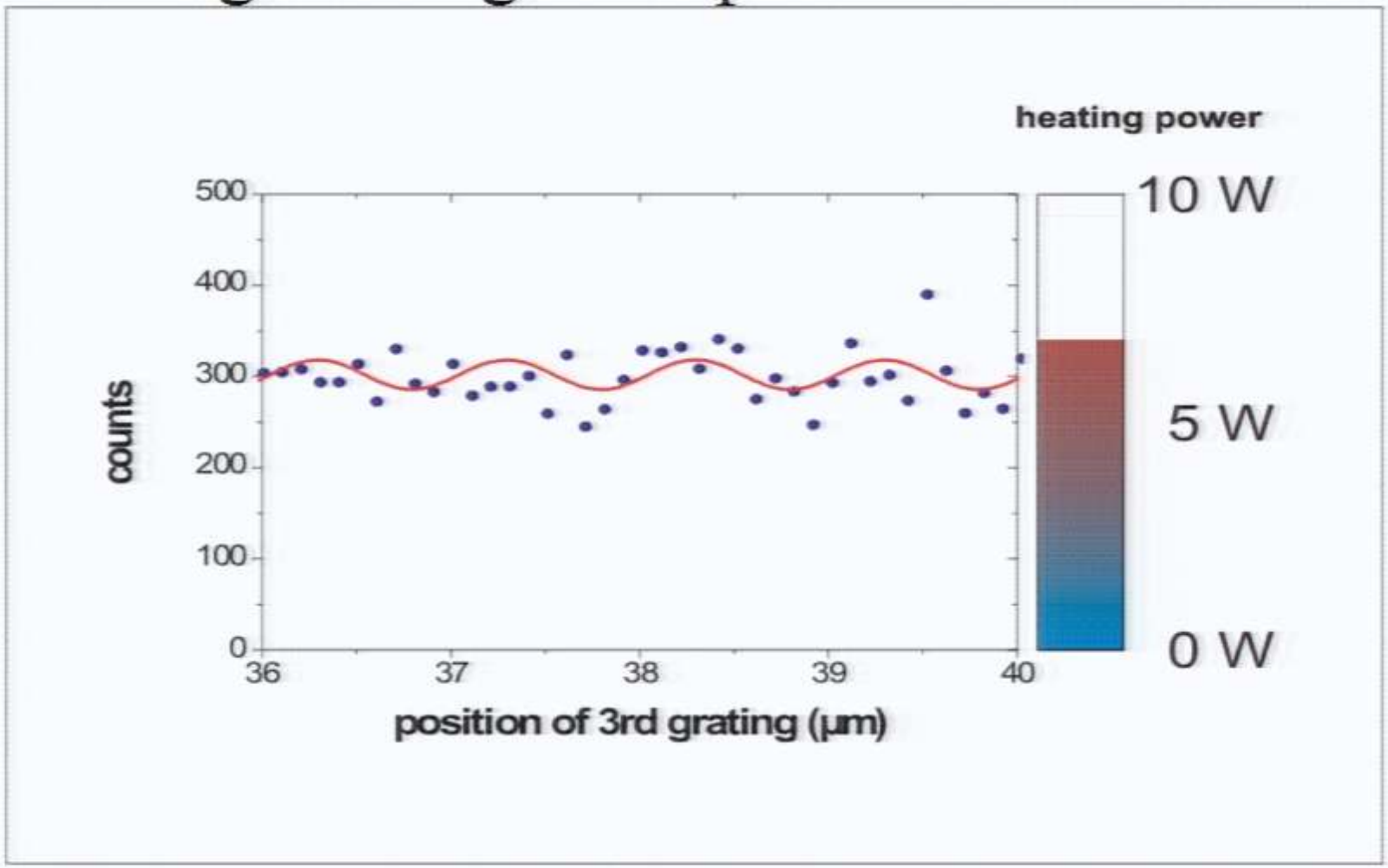

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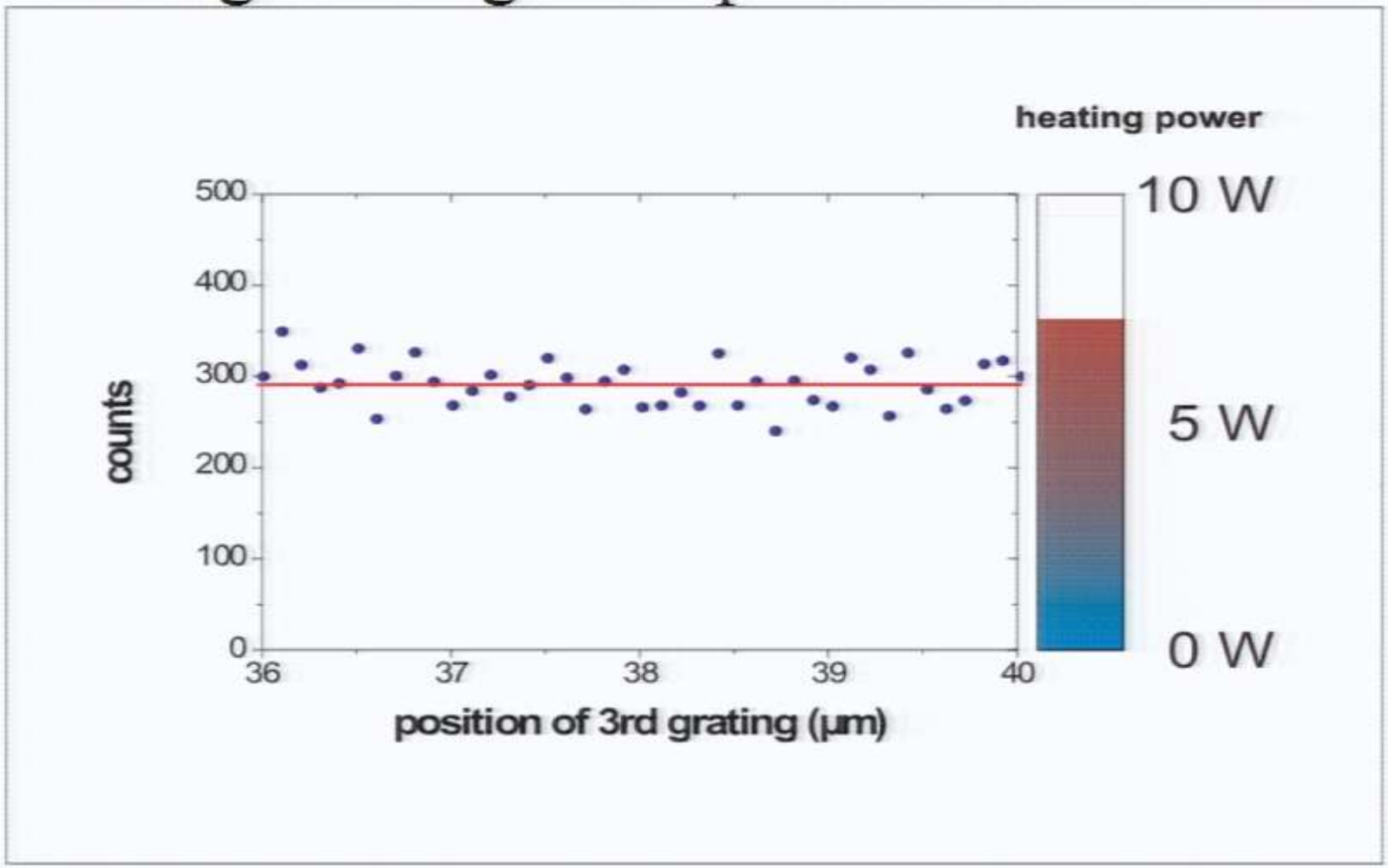

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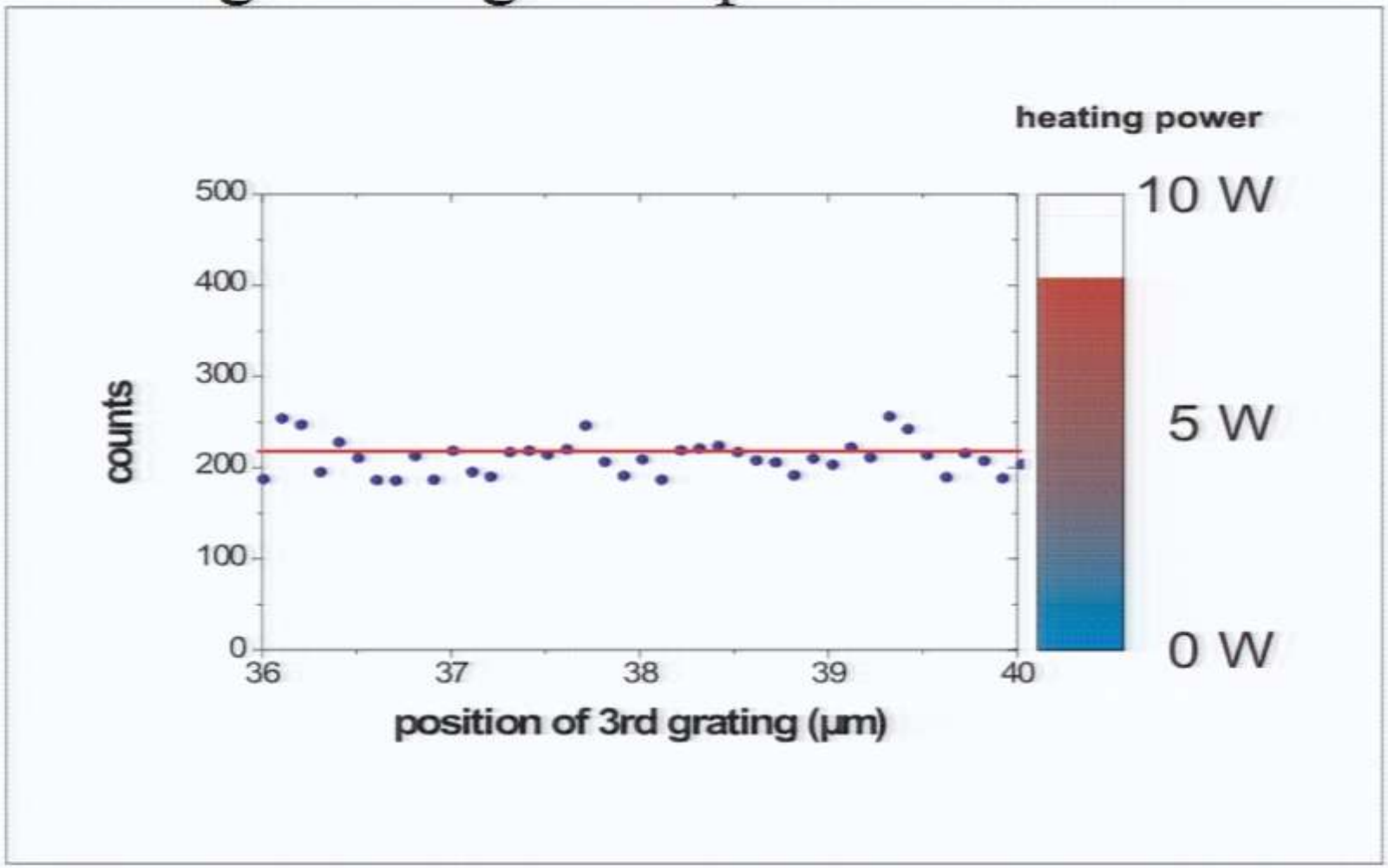

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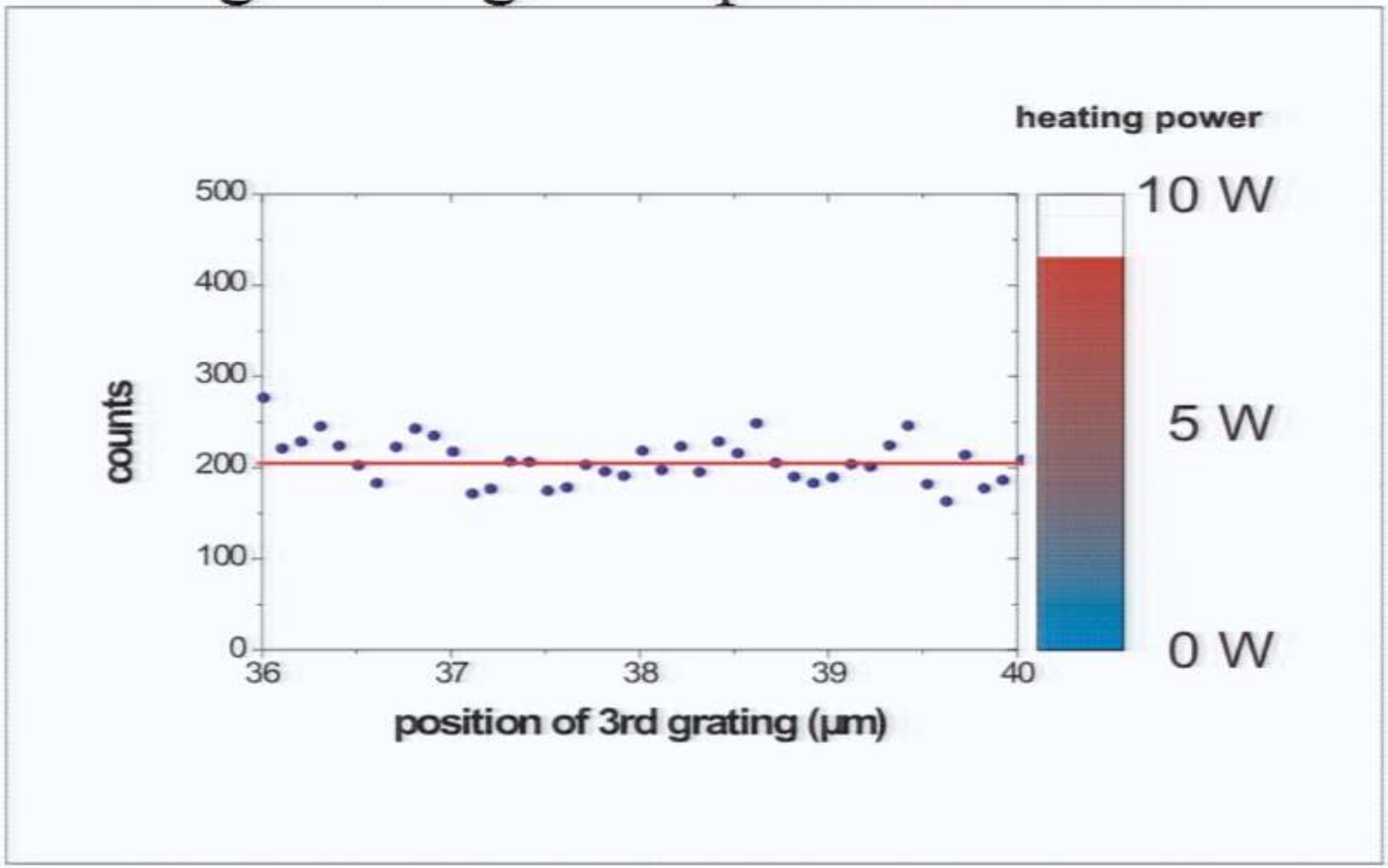
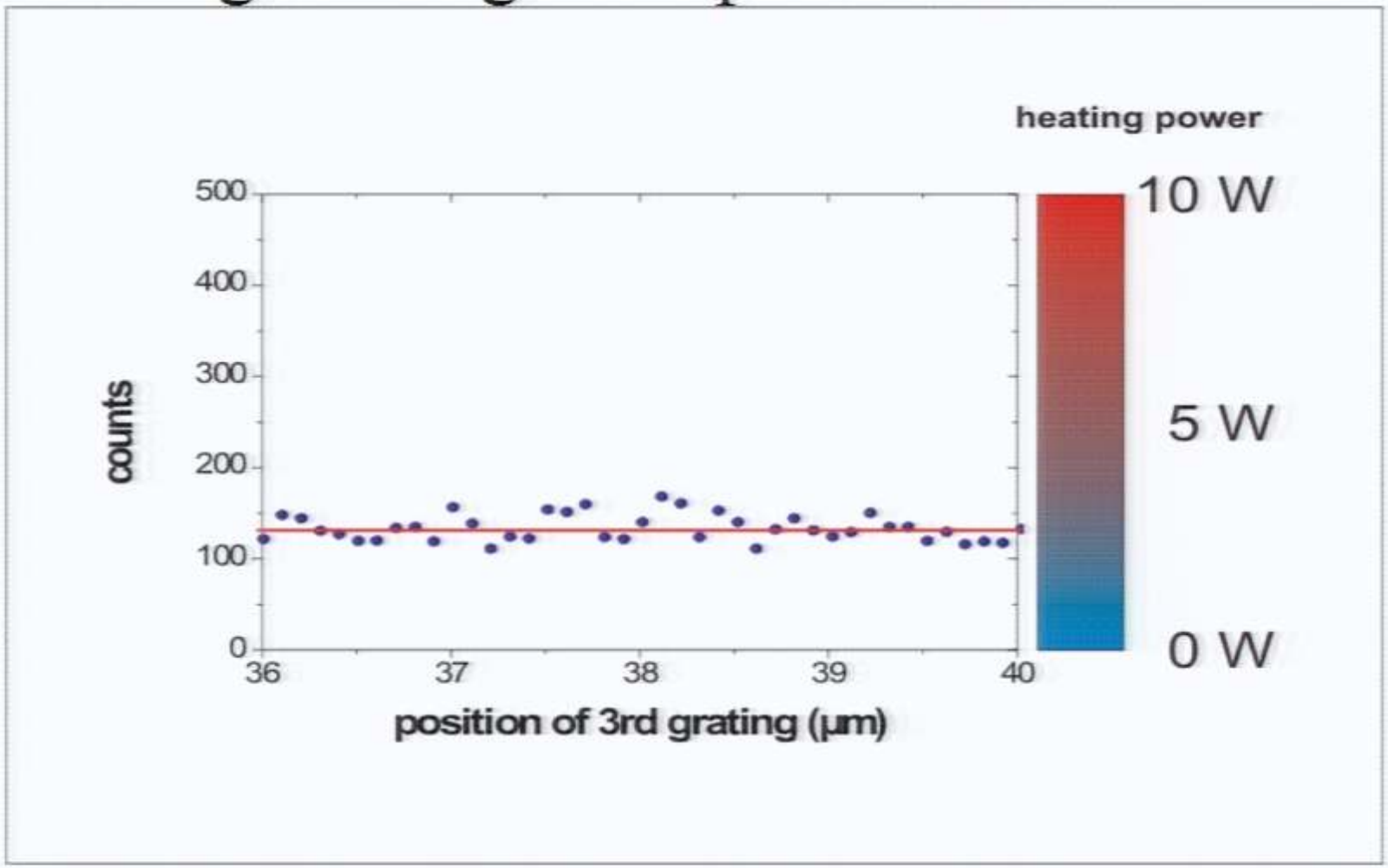


Interference patterns for Increasing heating laser power



Interference patterns for
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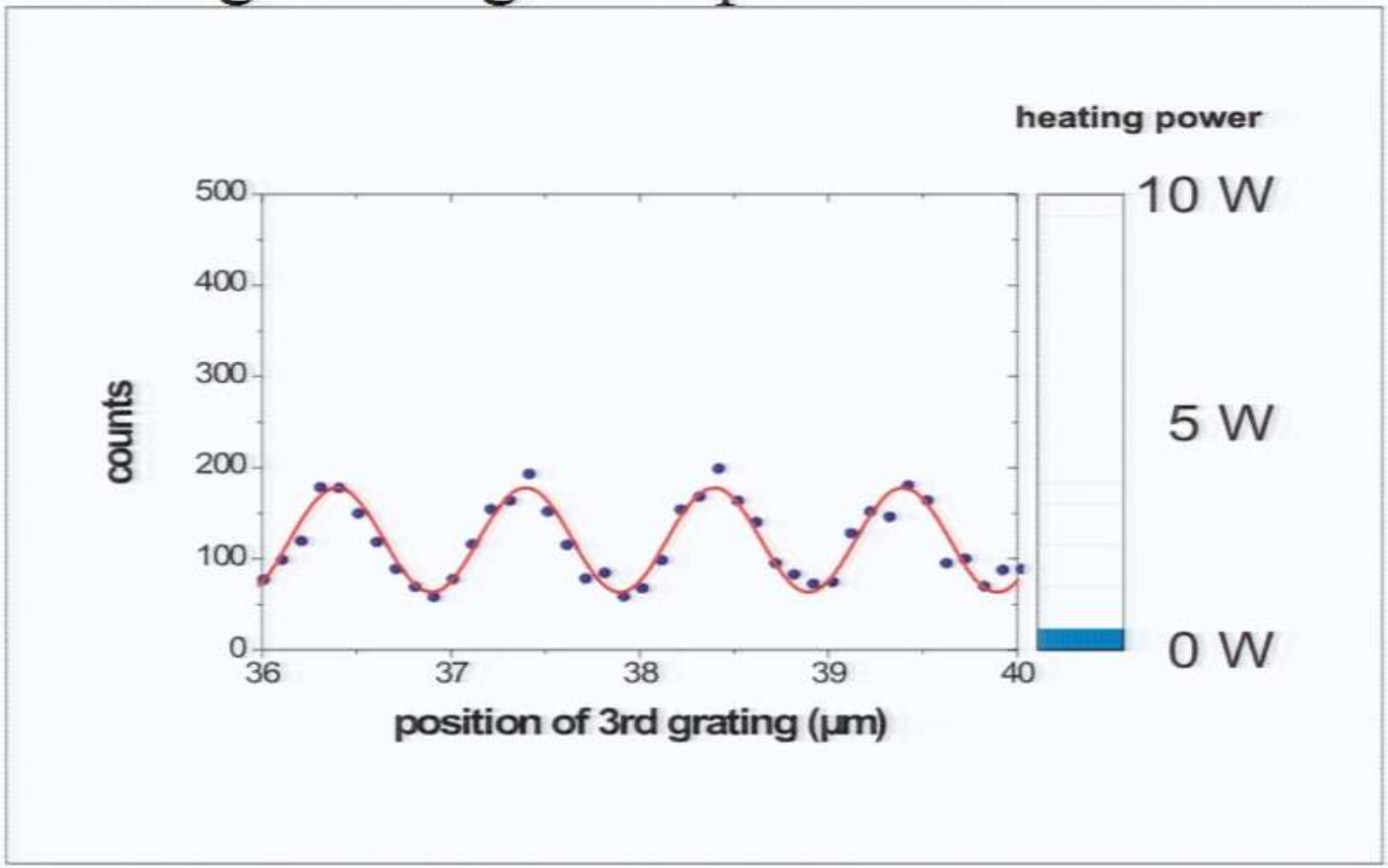
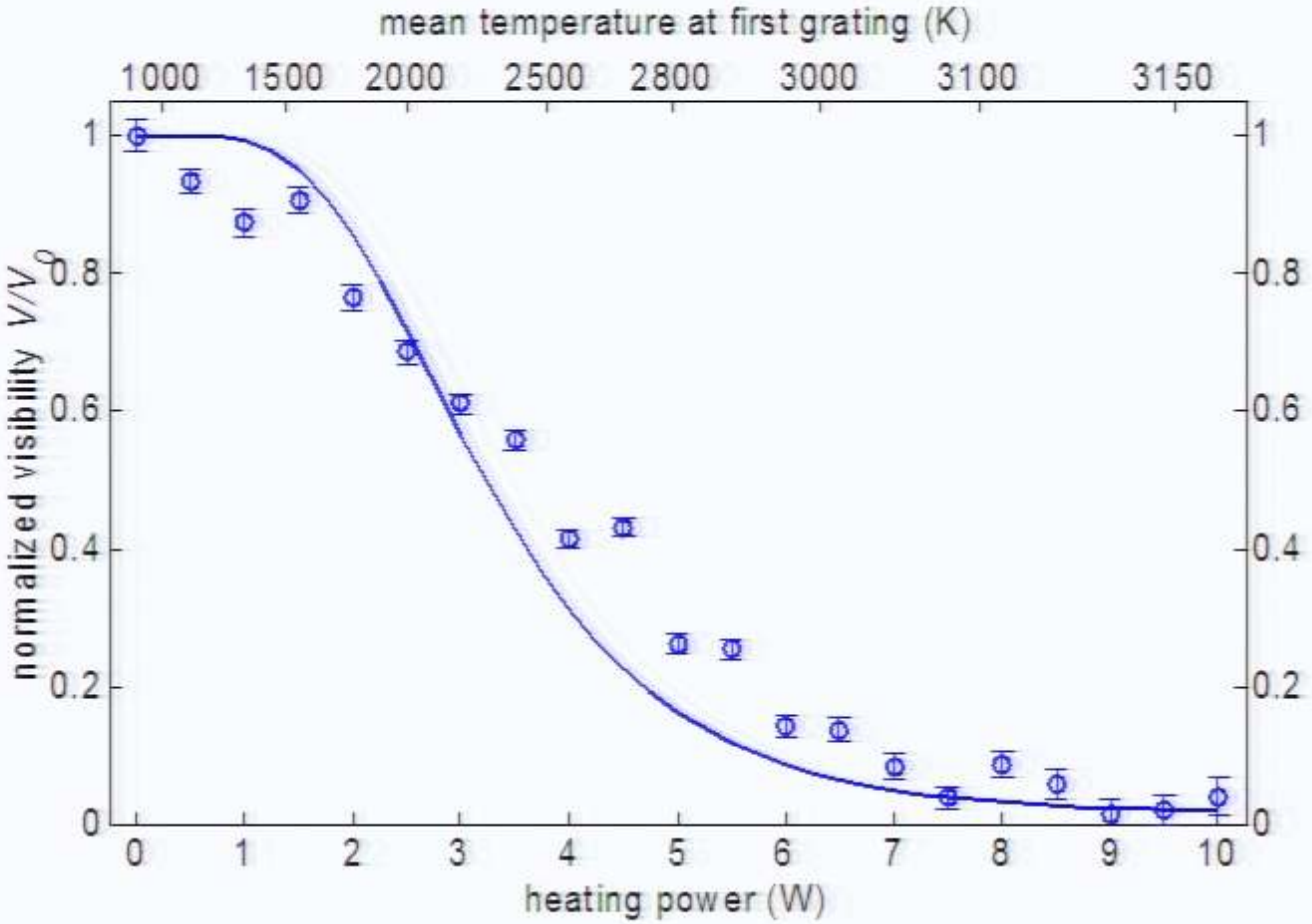


Thermal Decoherence of C_{70}

Comparison between Experiment & Theory



. Hackermüller, K. Hornberger, B. Brezger,
nton Zeilinger, Markus Arndt: Nature (in press)

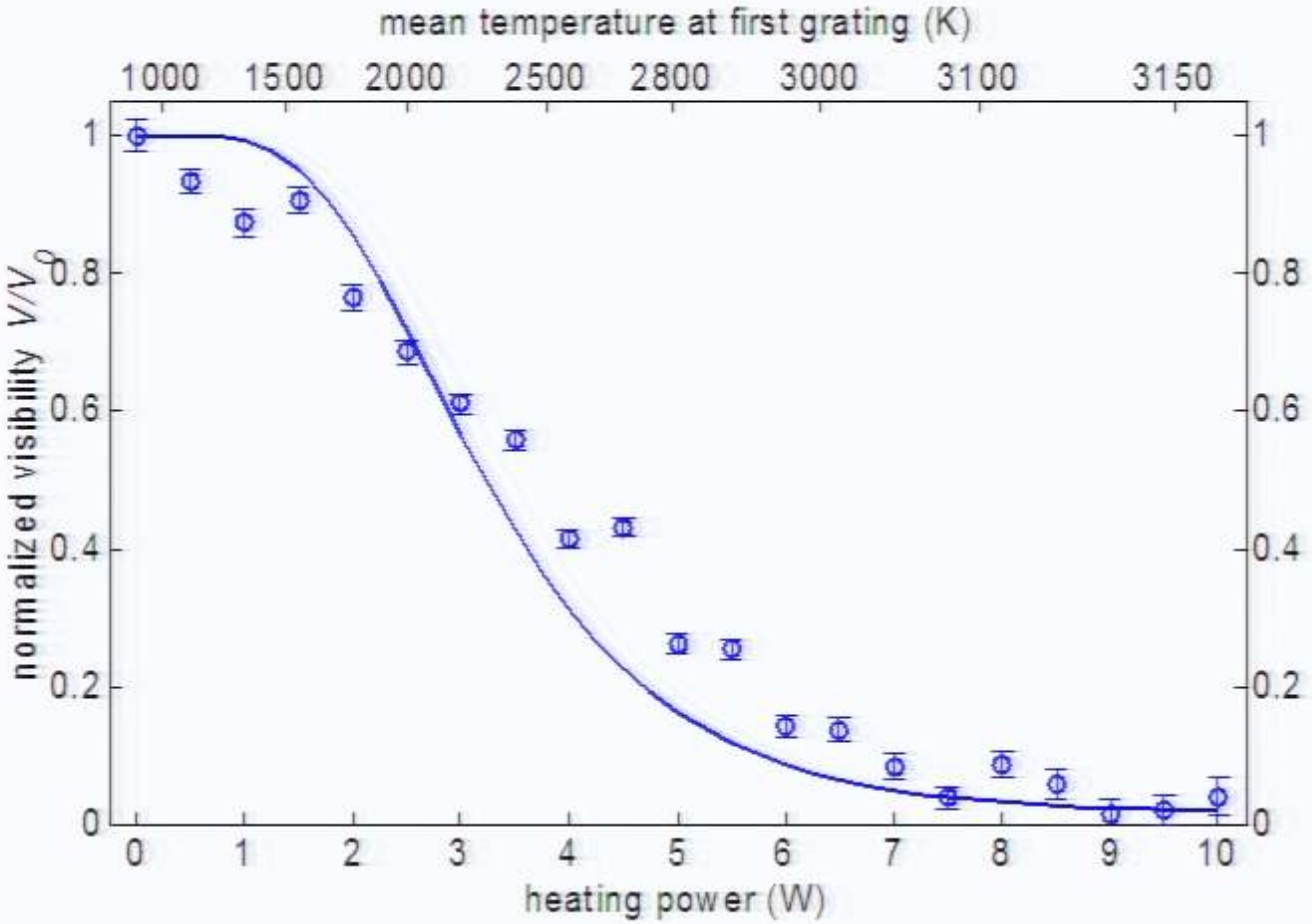
v = 200 m/s, 16 heating beams

$\Delta x \cdot \Delta p \geq \frac{\hbar}{2}$ $\quad \Delta x \cdot \Delta p \gtrsim \hbar$

$$V = \frac{I_{max} - I_{min}}{I_{max} + I_{min}}$$

Thermal Decoherence of C_{70}

Comparison between Experiment & Theory



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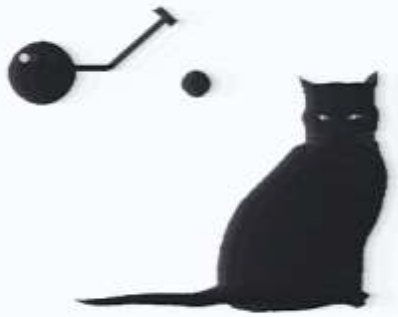
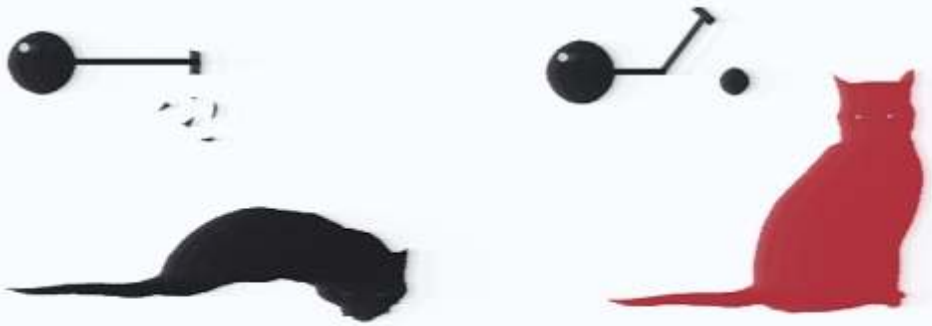
Schrödinger´s Cat



tot oder lebend



quantenmechanische Superposition

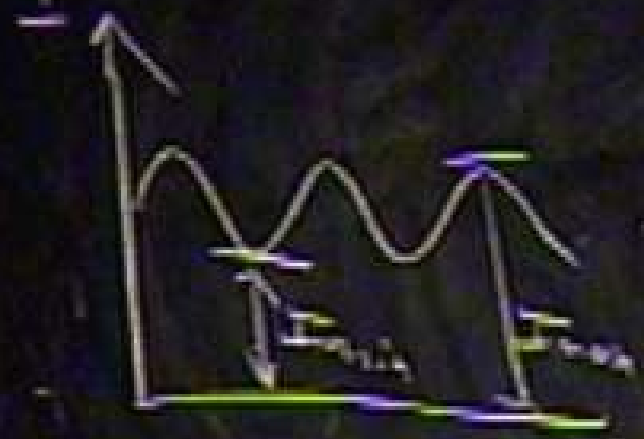
One can even set up quite ridiculous cases. A
at is penned up in a steel chamber, along
ith the following device (which must be
cured against direct interference by the
at): in a Geiger counter there is a tiny bit of
adioactive substance, *so* small, that *perhaps*
the course of the hour one of the atoms
ecays, but also, with equal probability,
erhaps none; if it happens, the counter tube
scharges and through a relay releases a
ammer which shatters a small flask of
ydrocyanic acid. If one has left this entire
stem to itself for an hour, one would say
at the cat still lives *if* meanwhile no atom
as decayed. The psi-function of the entire
stem would express this by having in it the
ving and dead cat (pardon the expression)
ixed or smeared out in equal parts."

$\Delta x \cdot \Delta p \geq \frac{\hbar}{2}$

$\Delta x \cdot \Delta p \gtrsim \hbar$

10^{-7} amu

$T \lesssim 300K$



$V = \frac{I_{max} - I_{min}}{I_{max} + I_{min}}$