

Title: Interpretation of Quantum Theory: Lecture 15

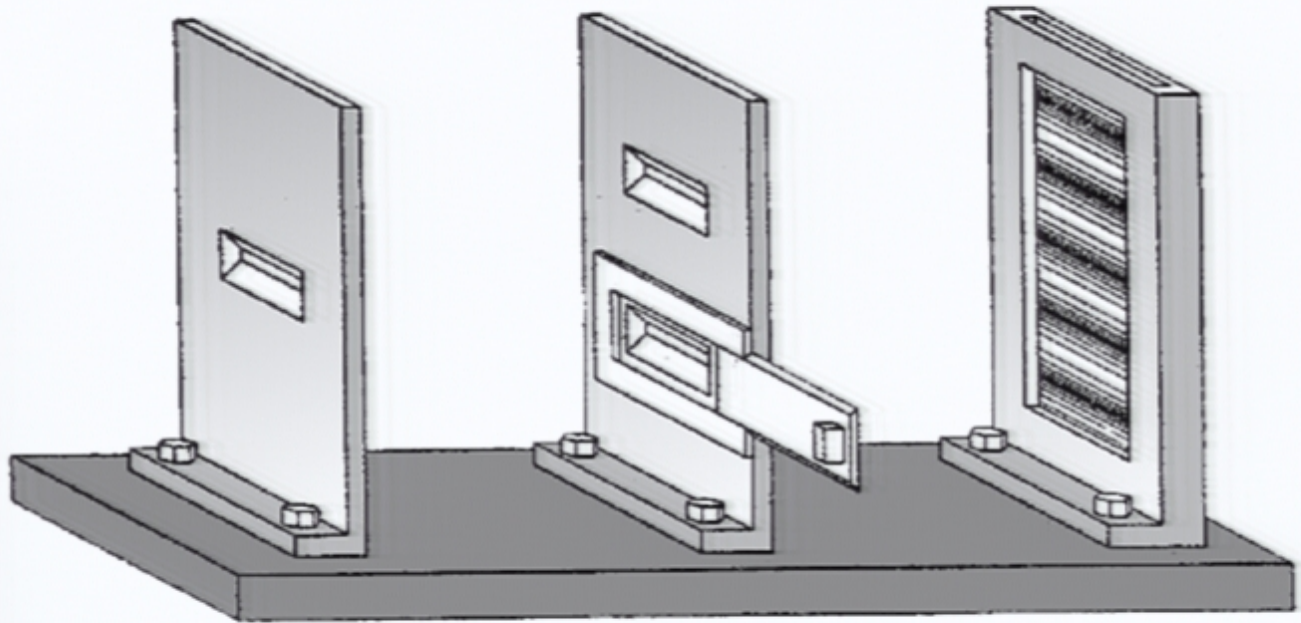
Date: Mar 01, 2005 02:15 PM

URL: <http://pirsa.org/05030079>

Abstract:

Double Slit Interference

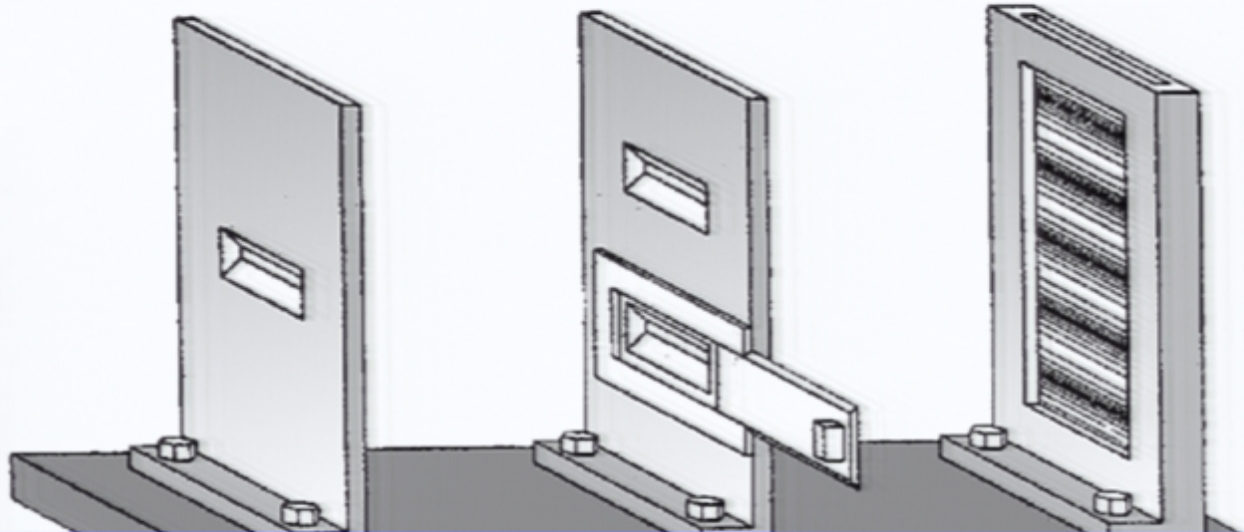
Superposition



Bohr-Einstein Dialogue

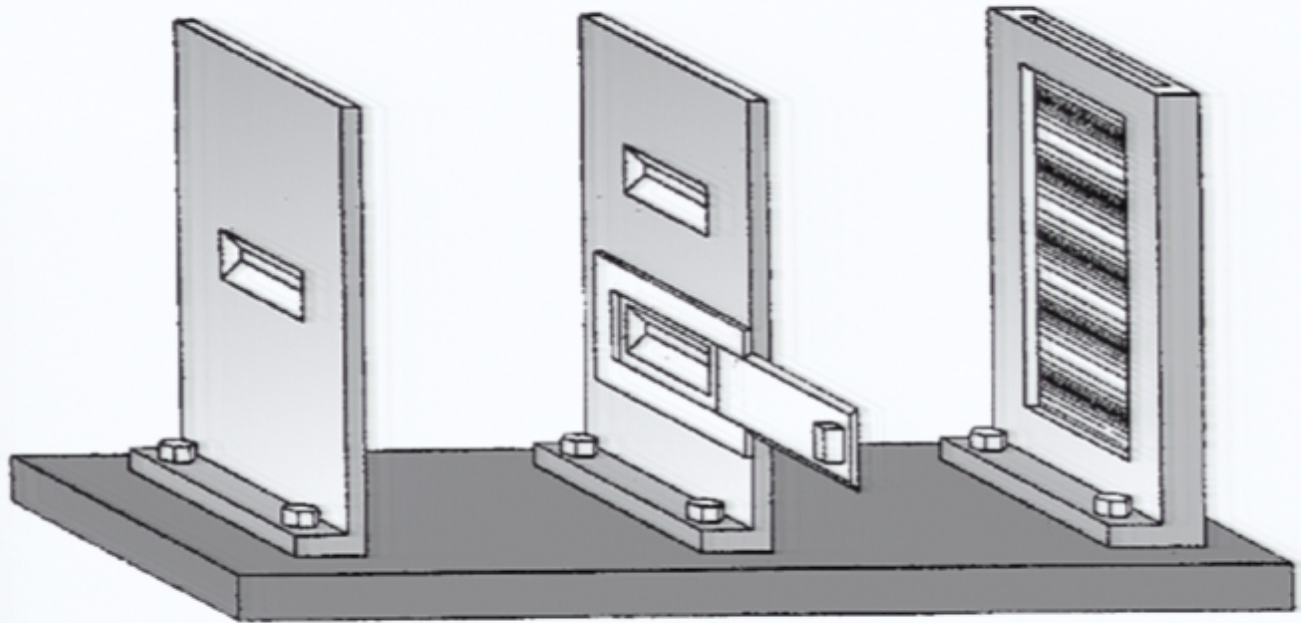
Double Slit Interference

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
Helmut Rauch
Niels Bohr: Discussions with E.

1975 Neutron interferometry

Helmut Rauch

Niels Bohr: Discussions with E.

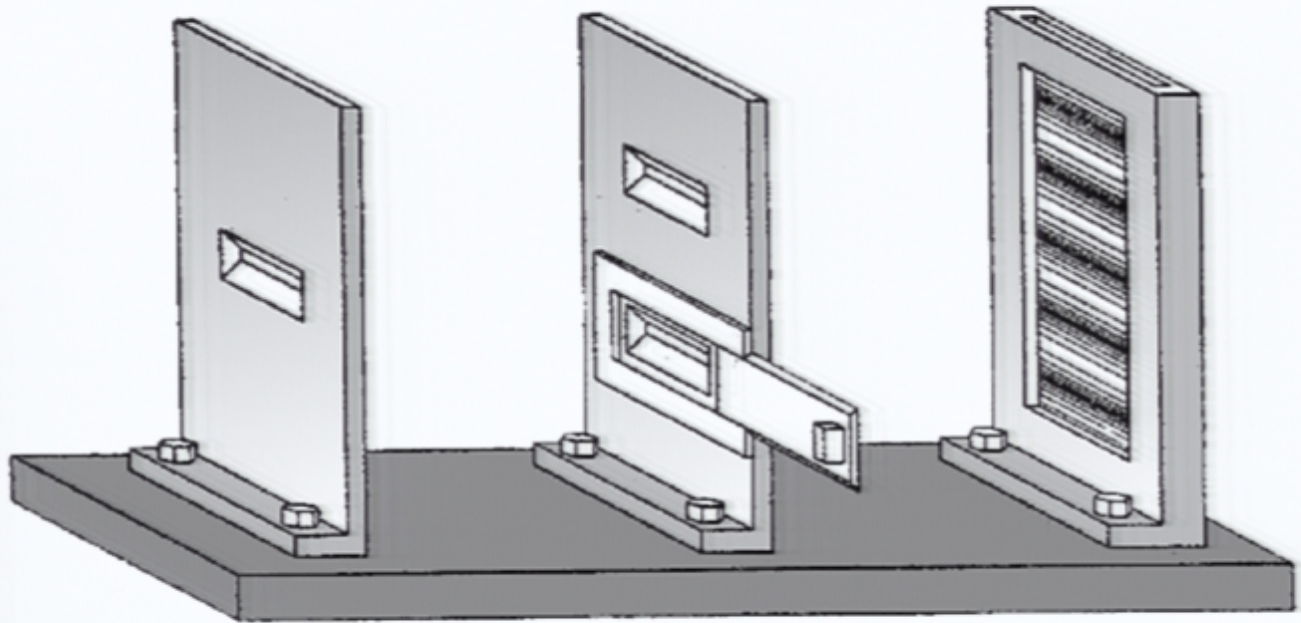
Schilpp

Albert Einstein

Philosopher-Scientist

Double Slit Interference

Superposition

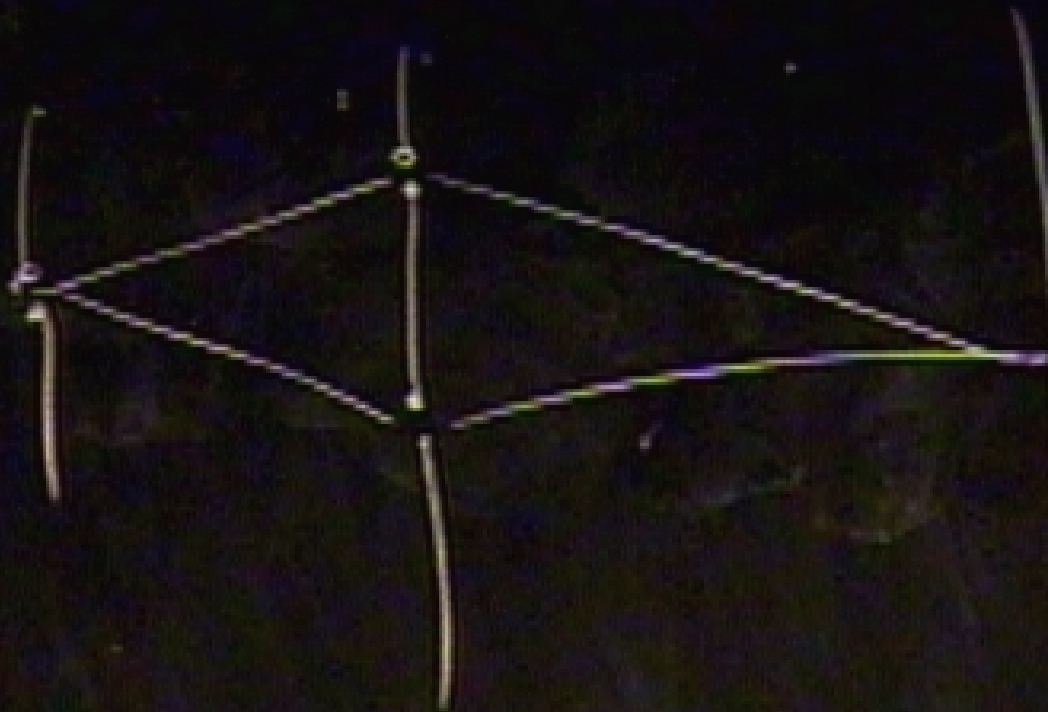


Bohr-Einstein Dialogue

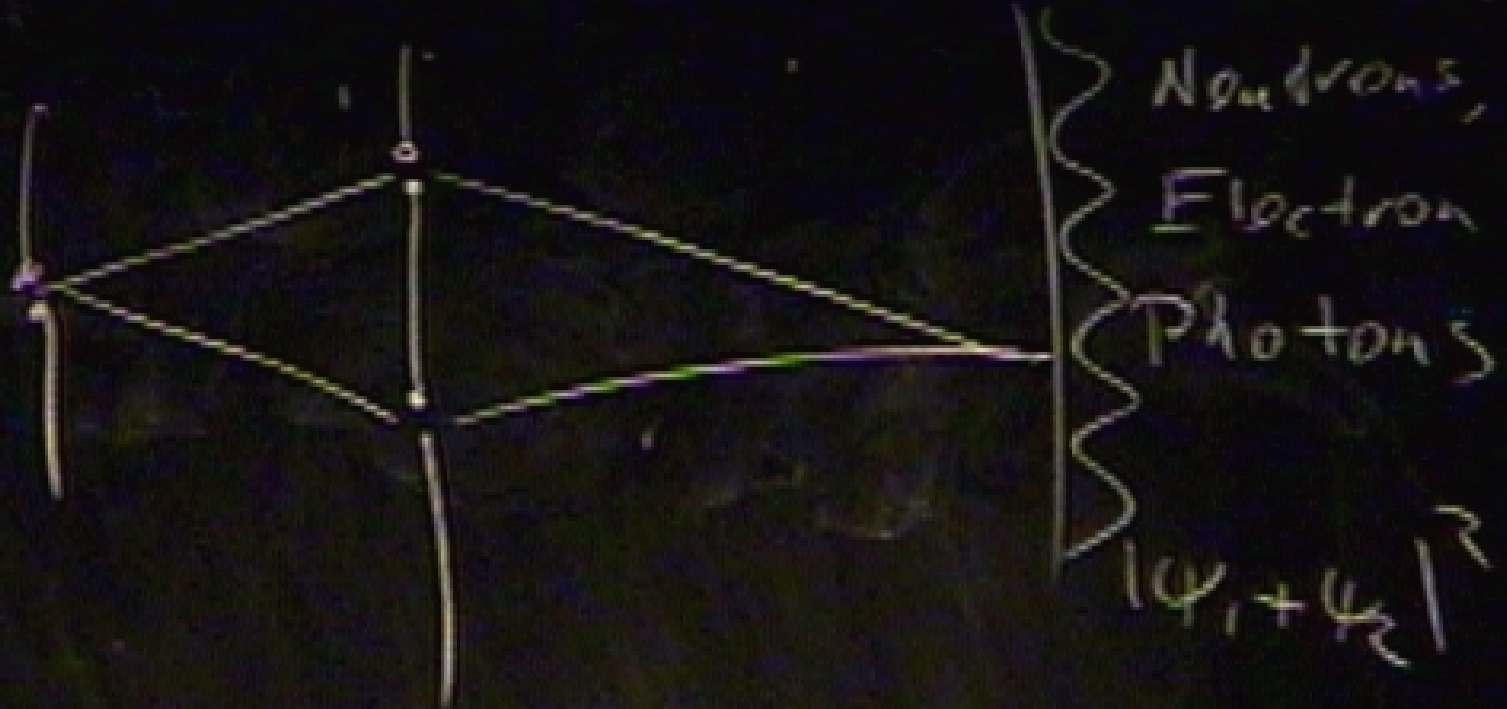


Individual Particles

Neutrons,
Electron
Photons



Individual Particles



Mach-Zehnder Interferometer



Mach-Zehnder Interferometer



Mach-Zehnder Interferometer

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

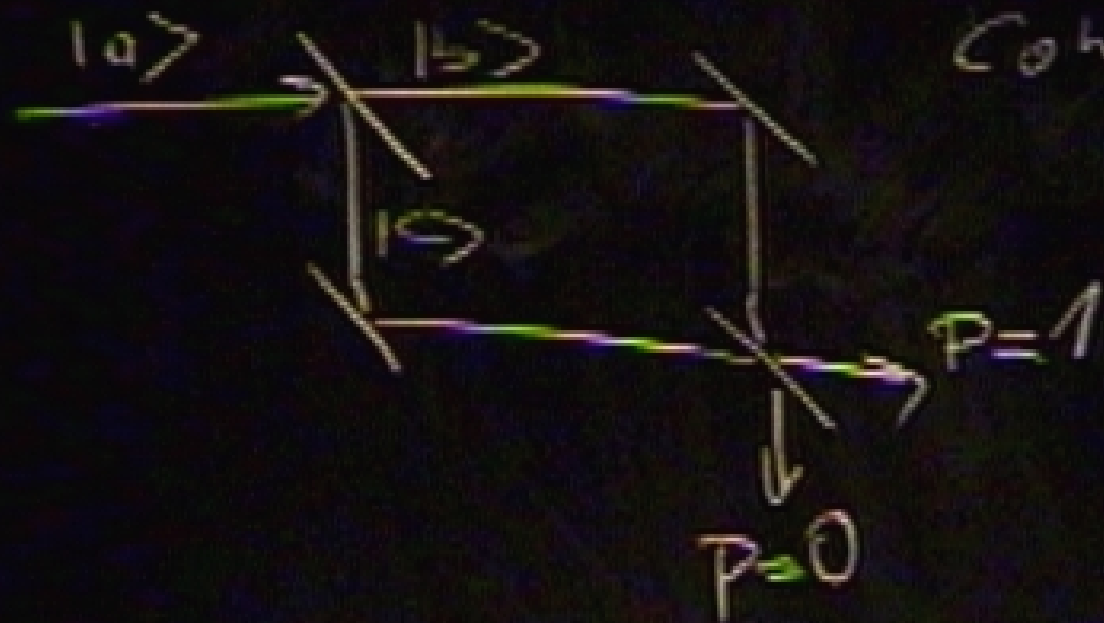
Cohherent Superposition



Mach-Zehnder Interferometer

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

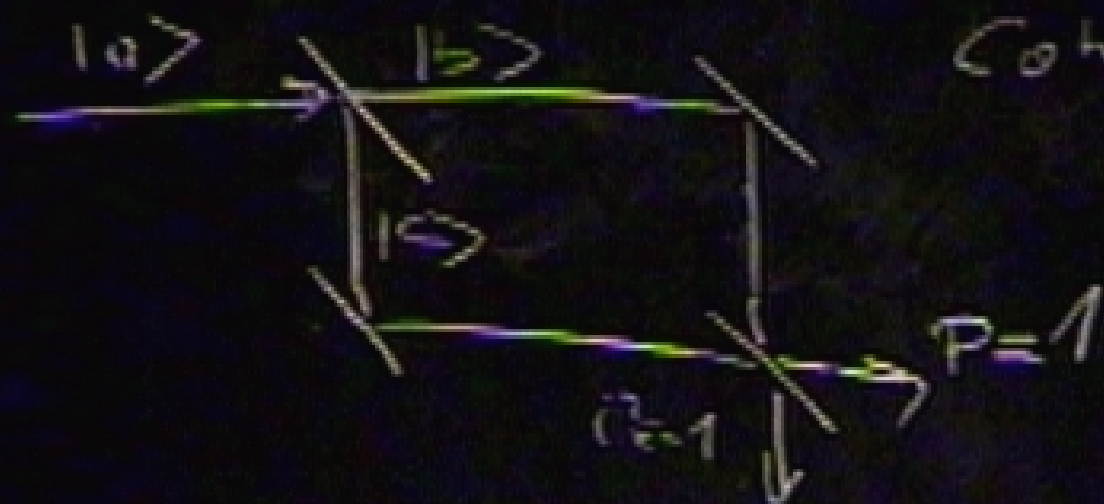
Cohorent Superposition



Mach-Zehnder Interferometer

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

Cohherent Superposition



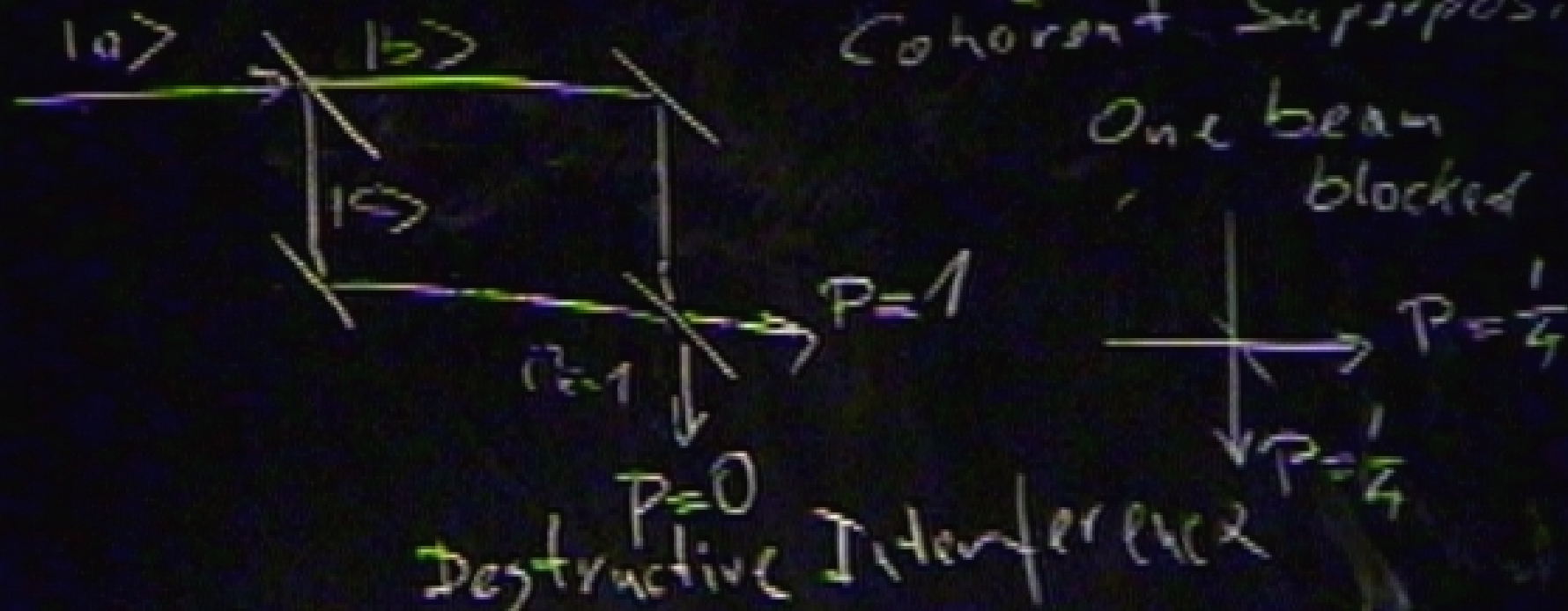
$P=0$
Destructive Interference

Mach-Zehnder Interferometer

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

Cohorent + Superposition

One beam
blocked



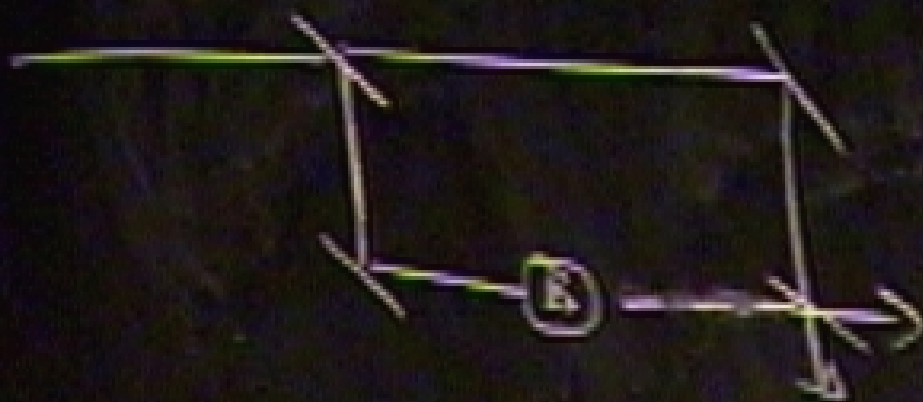
Elitzer-Vridman
ca. 1990

Elitzur-Vaidman
ca. 1990

Superbomb: 1 Photon triggers it

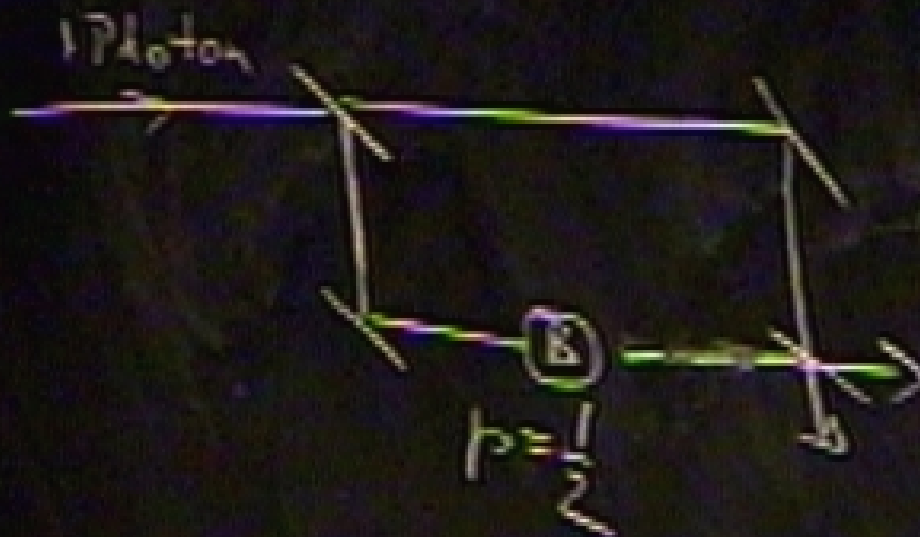
Elitzur-Vaidman
ca. 1990

Superbomb: 1 Photon triggers it



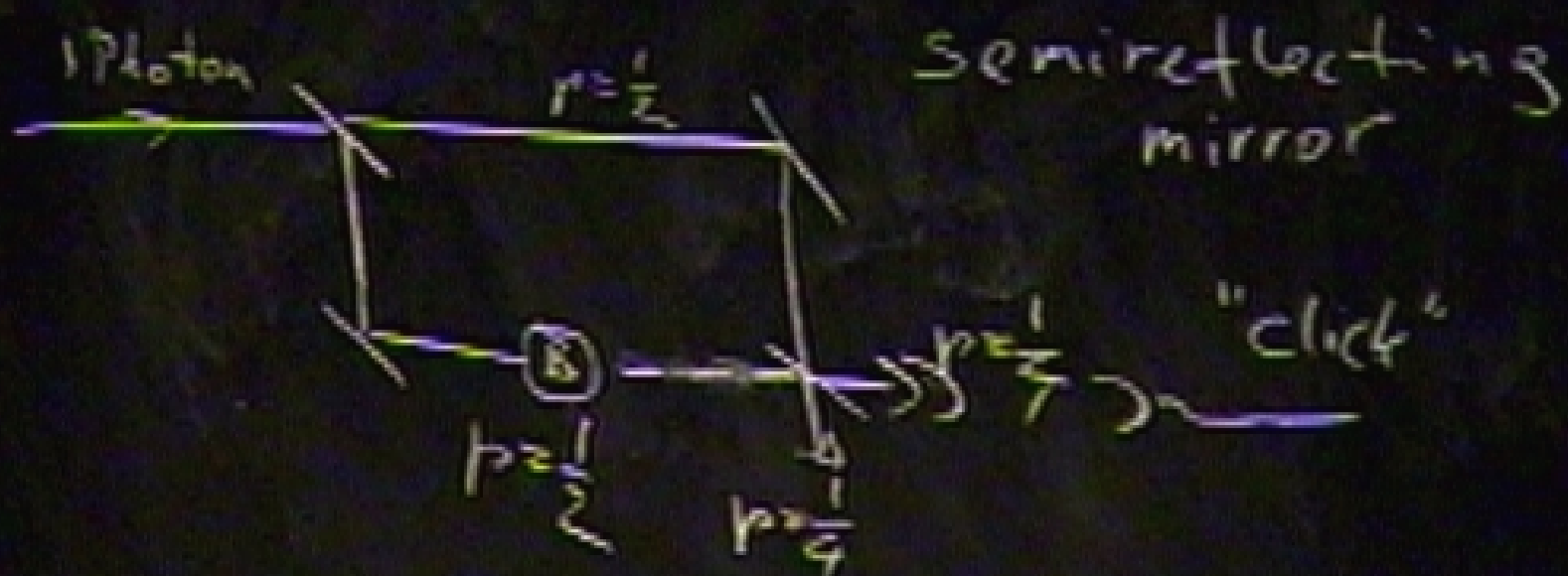
Eltzer-Vaidman
ca. 1990

Superbombs. 1 Photon triggers it



Elitzur-Vaidman
ca. 1990

Superbomb: 1 Photon triggers it



Neutron interferometry

Helmut Rauch

r: Discussions with E.

Albert Einstein
Philosopher-Scientist

Kwiat
Weinfurter
Kasevich

Elitzur-1

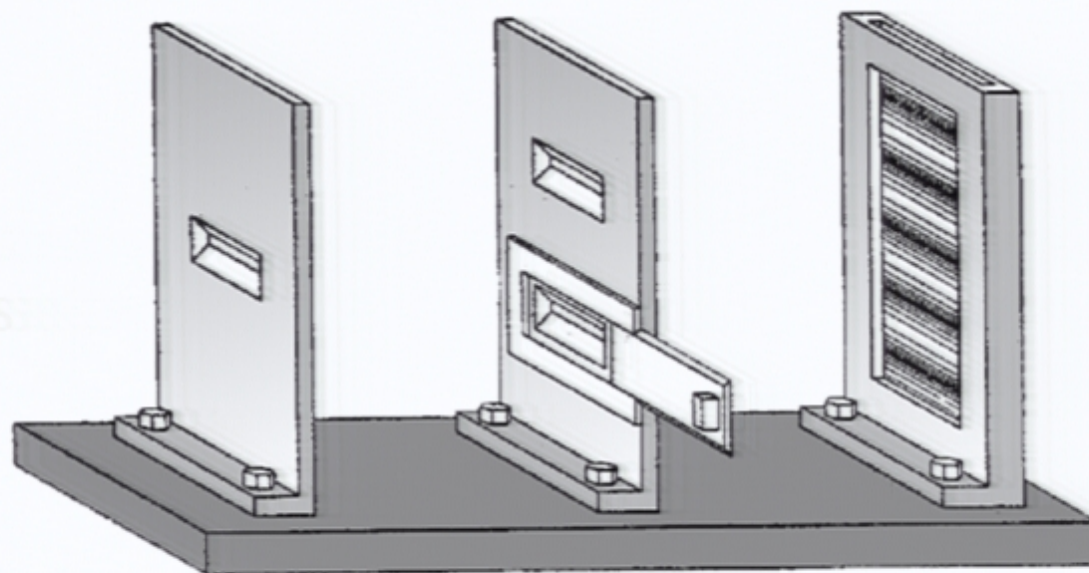
Superb



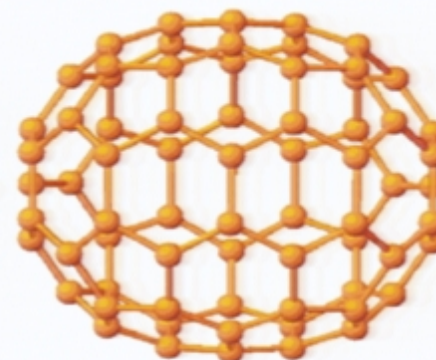
Matter-Wave Interferences

- Electrons, Neutrons, Atoms, Small Molecules

.....



C₆₀



C₇₀

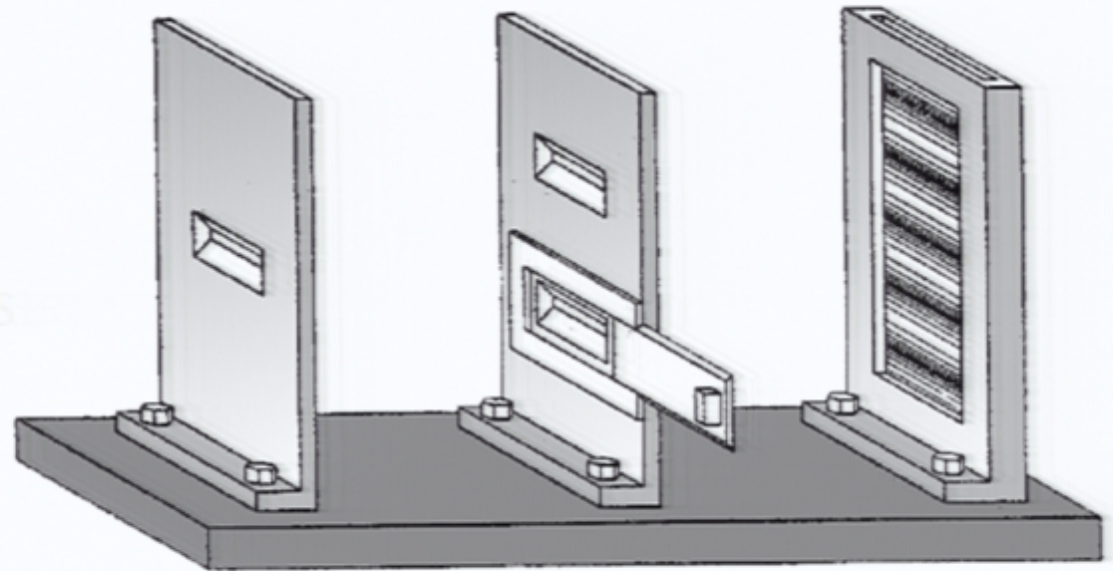
Matter-Wave Interferences

- Electrons, Neutrons, Atoms, Small Molecules

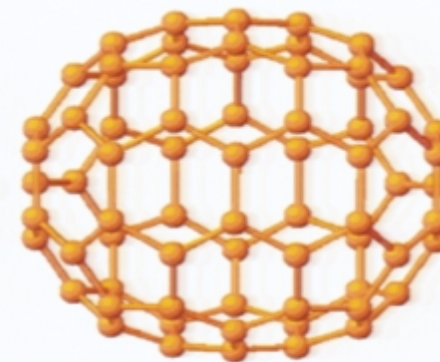
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- Is there a Limit?

Mass? Complexity?
Temperature?



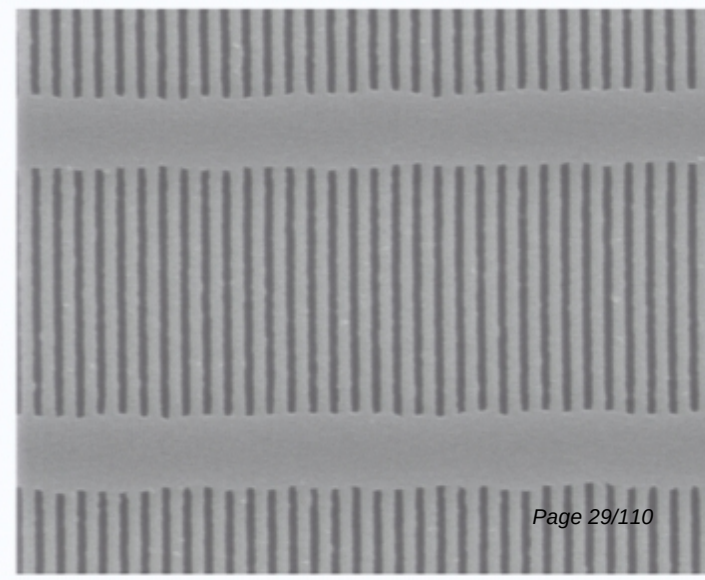
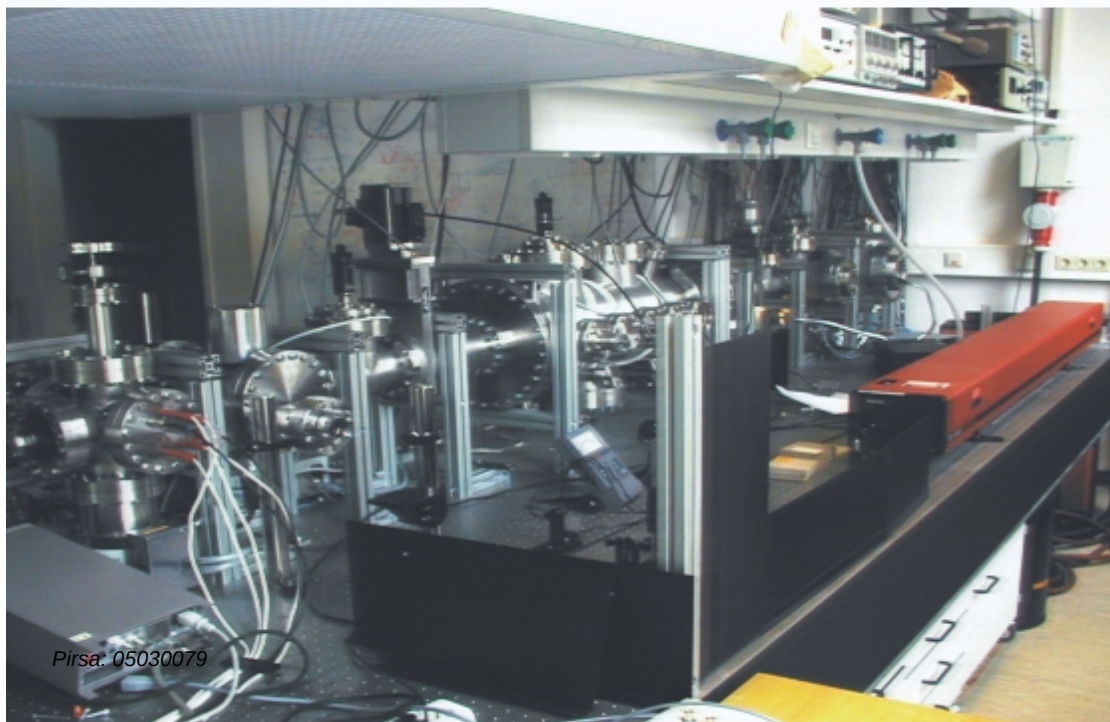
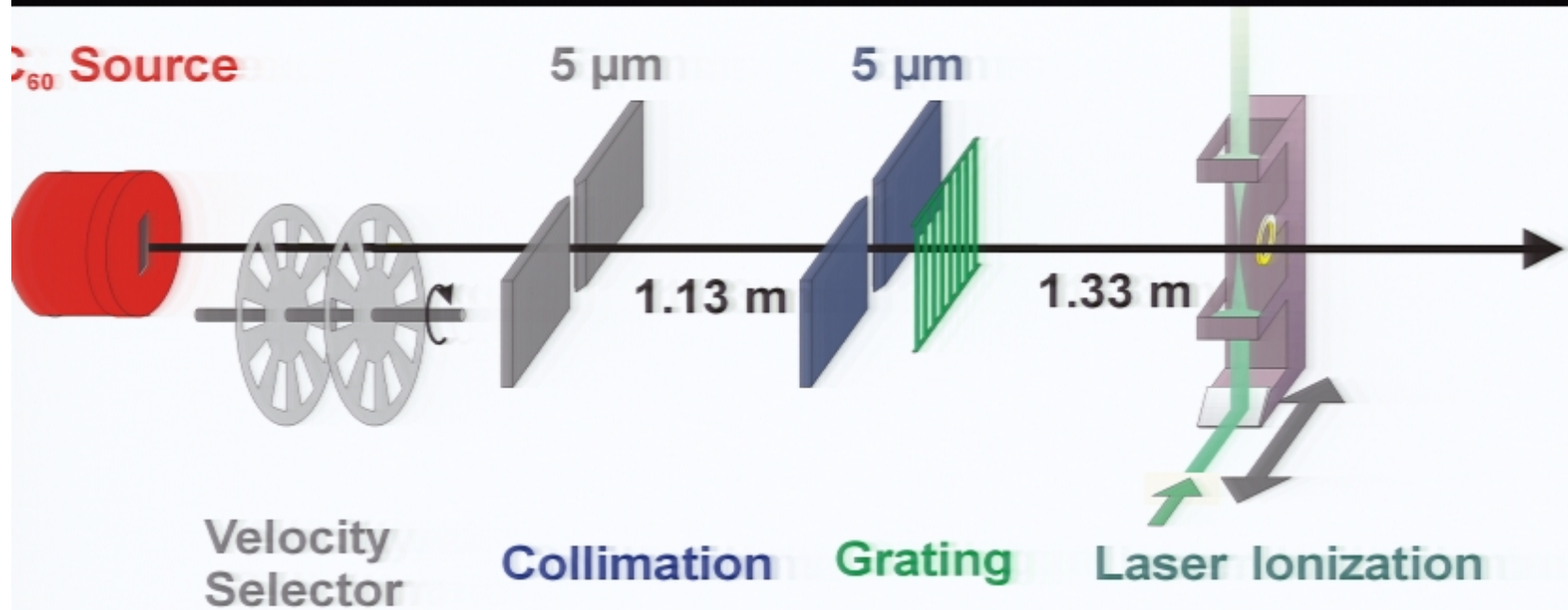
C₆₀

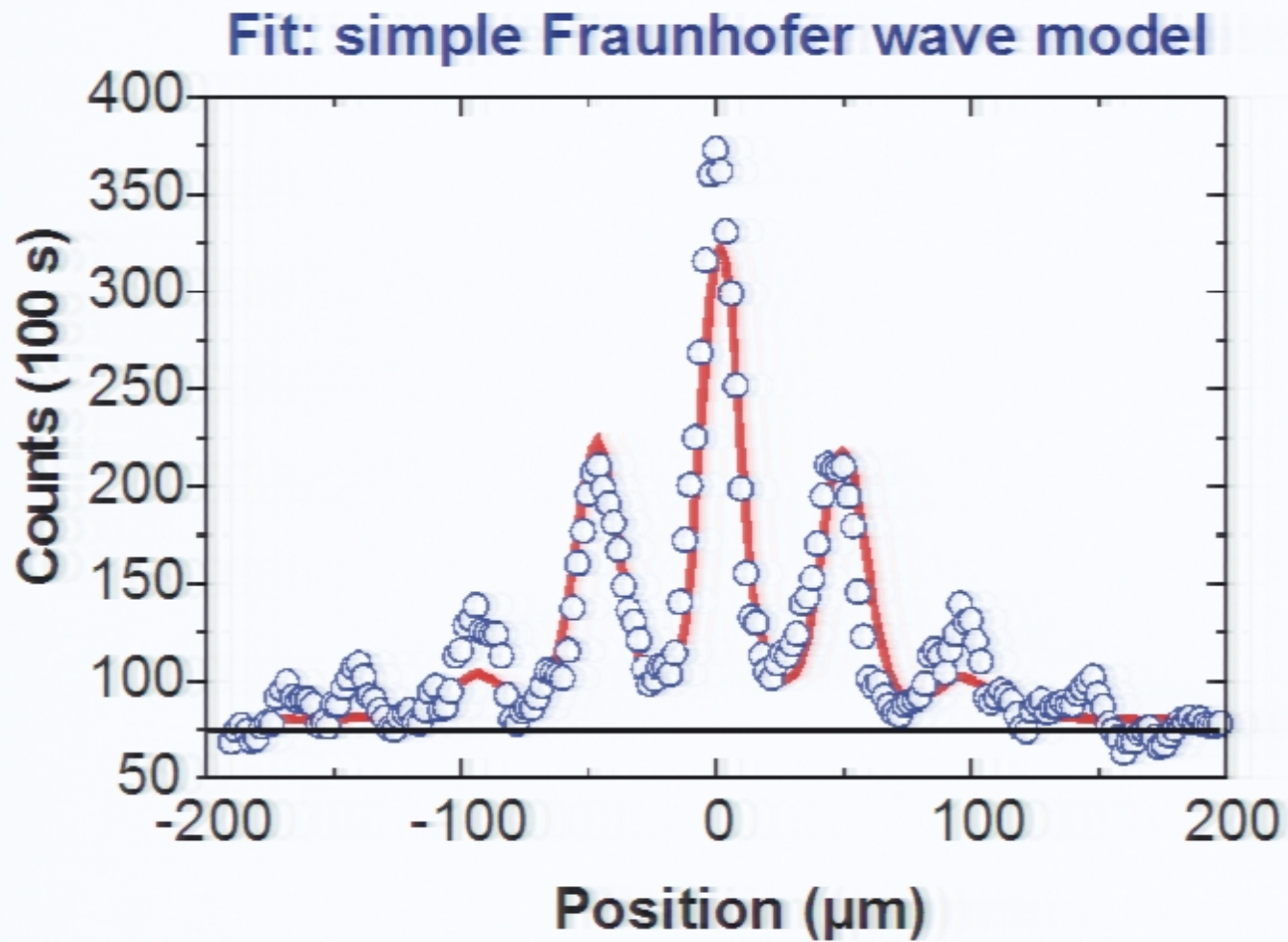


C₇₀

Quantum-Classical
Micro-Macro

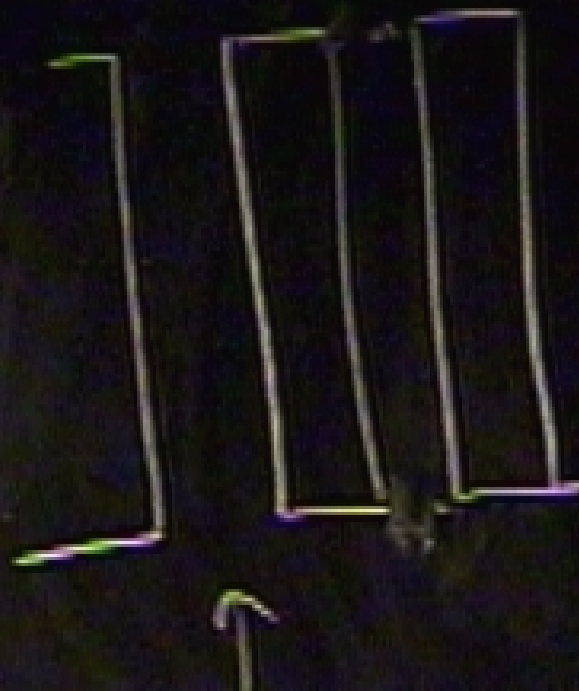
~~Quantum - Classical~~
~~Micro - Macro~~





Van der Waals Force
Casimir Interaction

~~Macro - Classical~~
~~Macro - Macro~~



$$T \approx 900 \text{ K}$$

The Scale

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

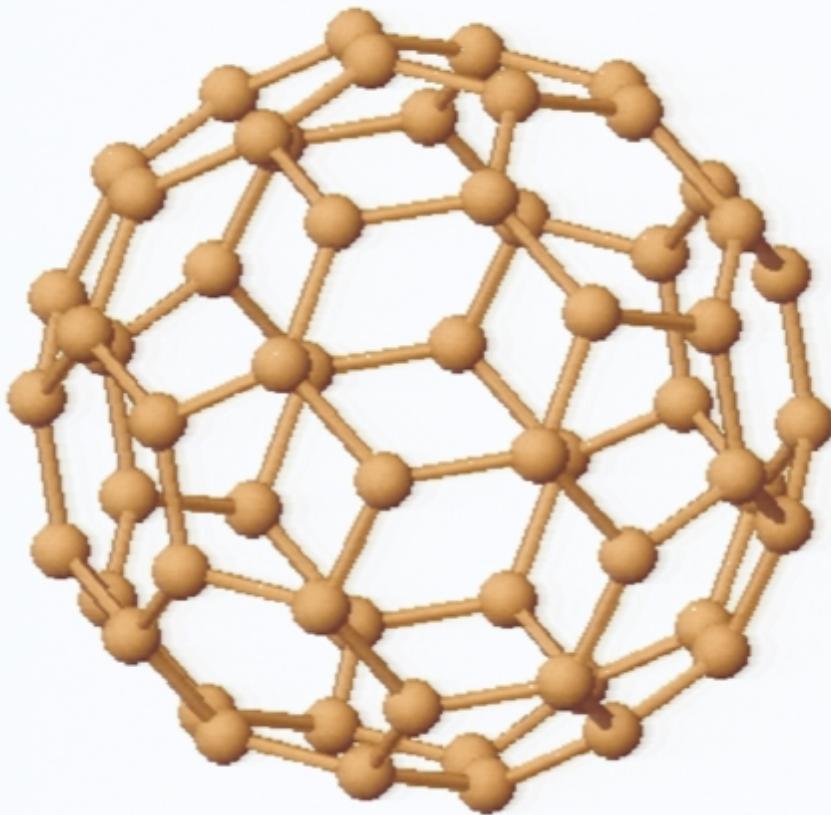
Diameter:

$$D \approx 10^{-9} \text{ m} = 10 \text{ \AA}$$

$$\lambda_{\text{dB}} \ll D$$

Coherence Length:

$$2 - 5 \lambda_{\text{dB}} !$$



$$T \approx 900 \text{ K}$$

The Scale

$$\begin{aligned}\lambda_{\text{deBroglie}} &\approx 3 \cdot 10^{-12} \text{ m} \\ &= 3 \cdot 10^{-2} \text{ \AA}\end{aligned}$$

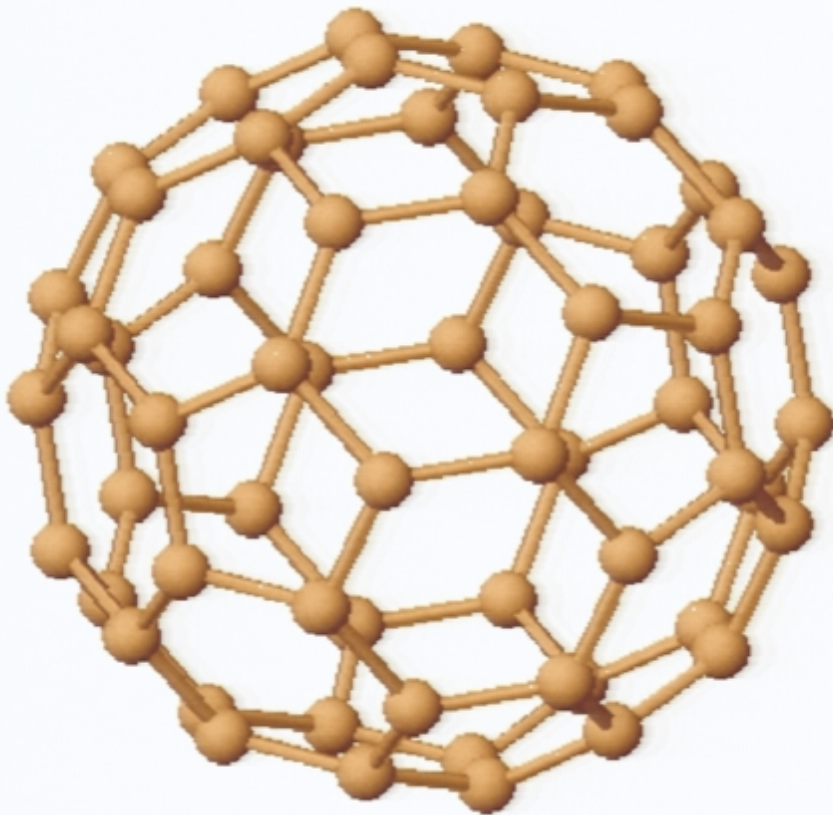
Diameter:

$$D \approx 10^{-9} \text{ m} = 10 \text{ \AA}$$

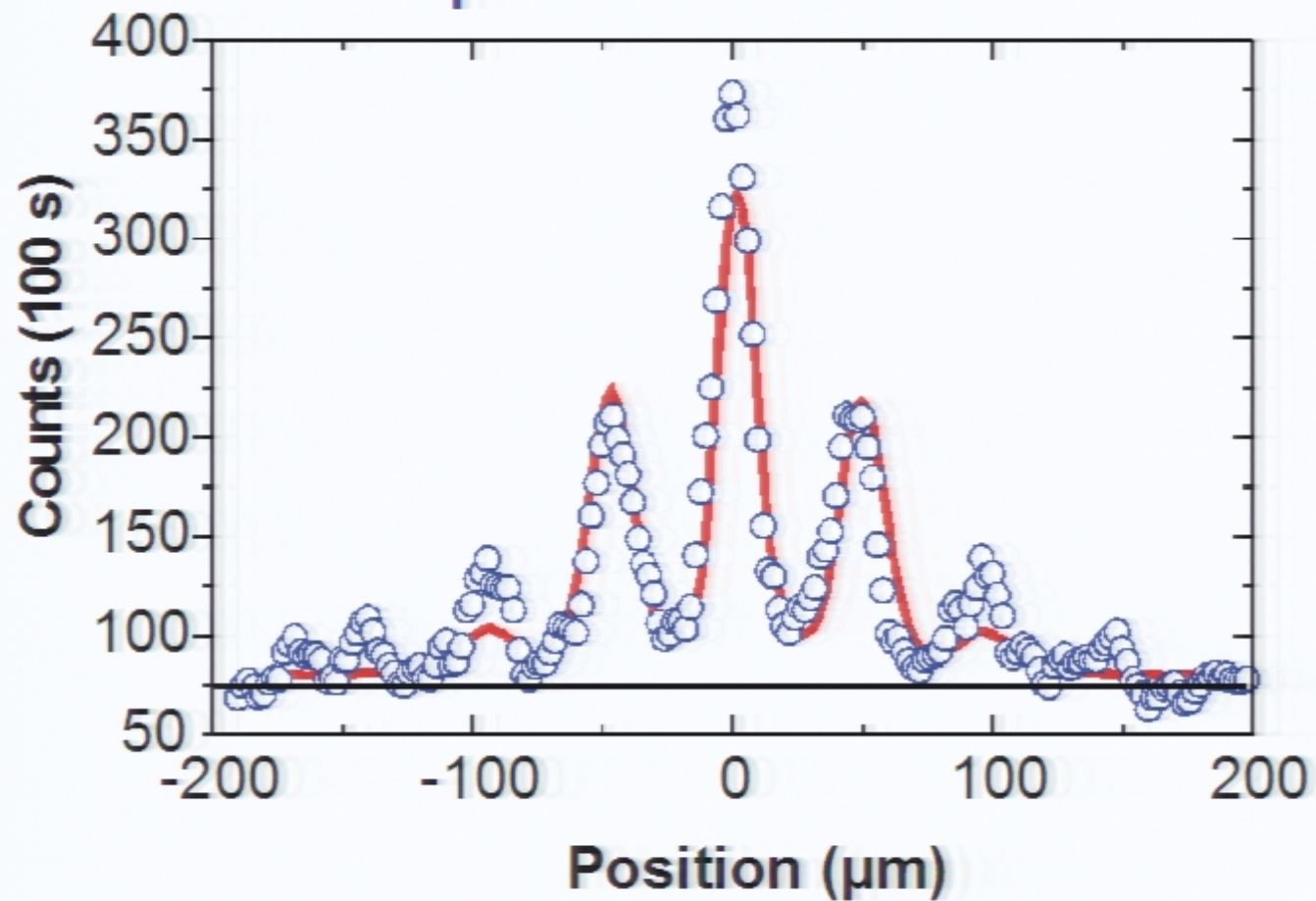
$$\lambda_{\text{dB}} \ll D$$

Coherence Length:

$$2 - 5 \lambda_{\text{dB}} !$$

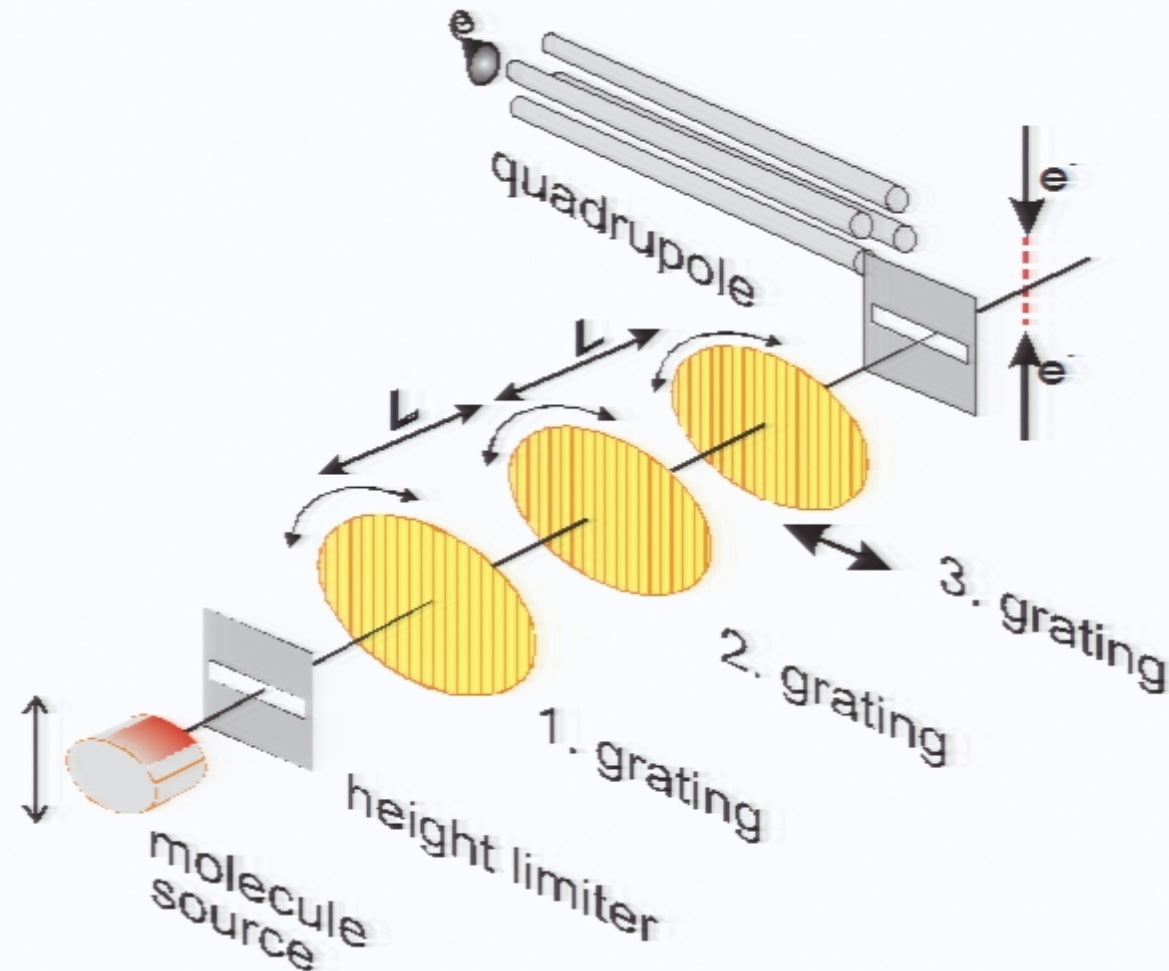


Fit: simple Fraunhofer wave model



Van der Waals Force
Casimir Interaction

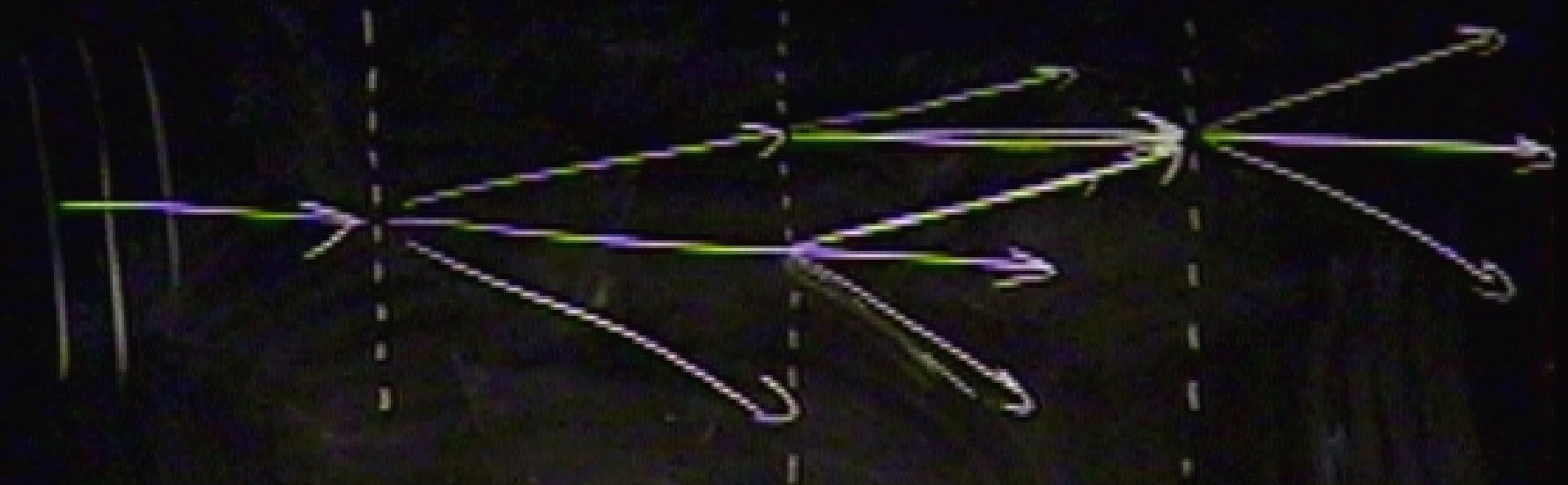
Albot-Lau (near field) Interferometry with Macromolecules



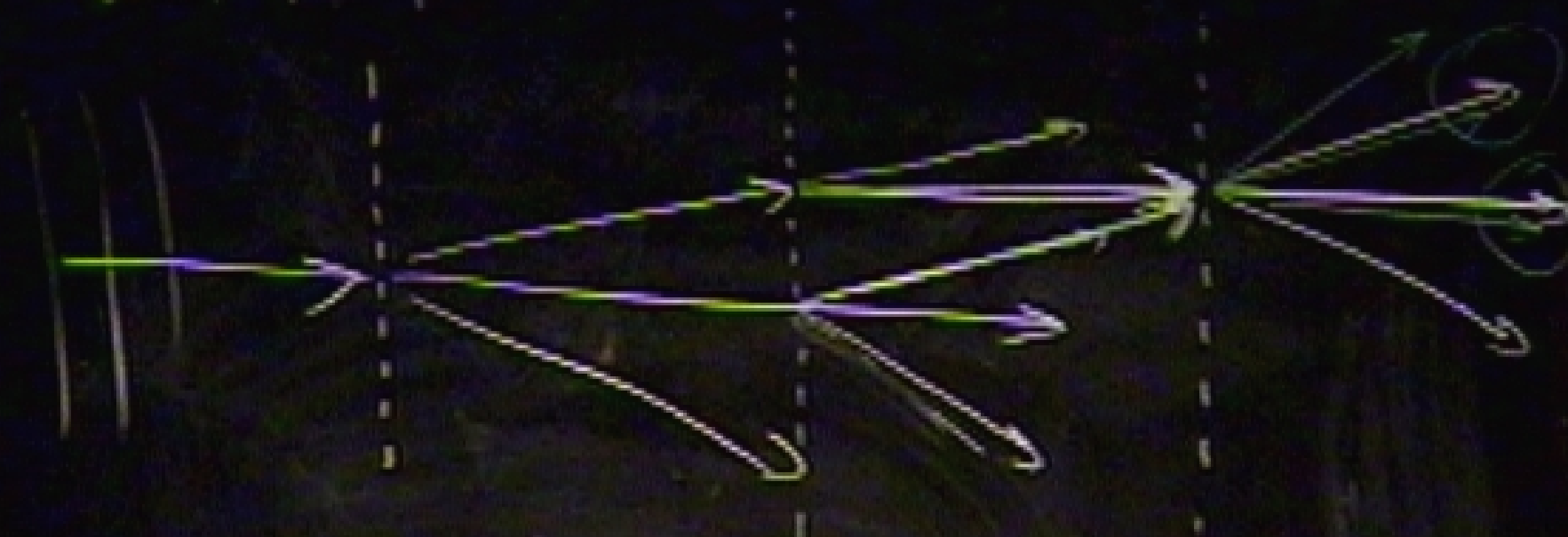
L. Hackermüller, S. Uttenthaler, K. Hornberger, E. Reiger, B. Brezger, A. Zeilinger and M. Arndt,

Pirsa: 05030079
Phys. Rev. Lett 91, 90408 (2003).

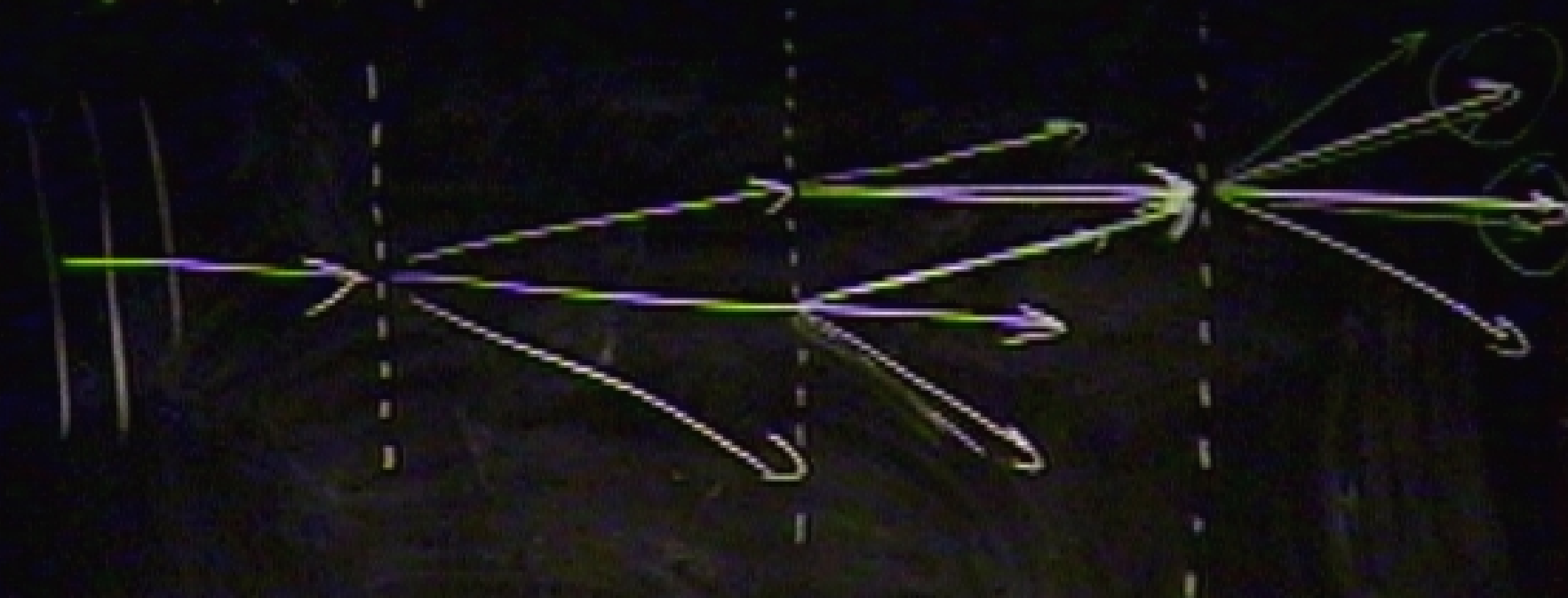
Linearity of $\mathbb{R}^m$



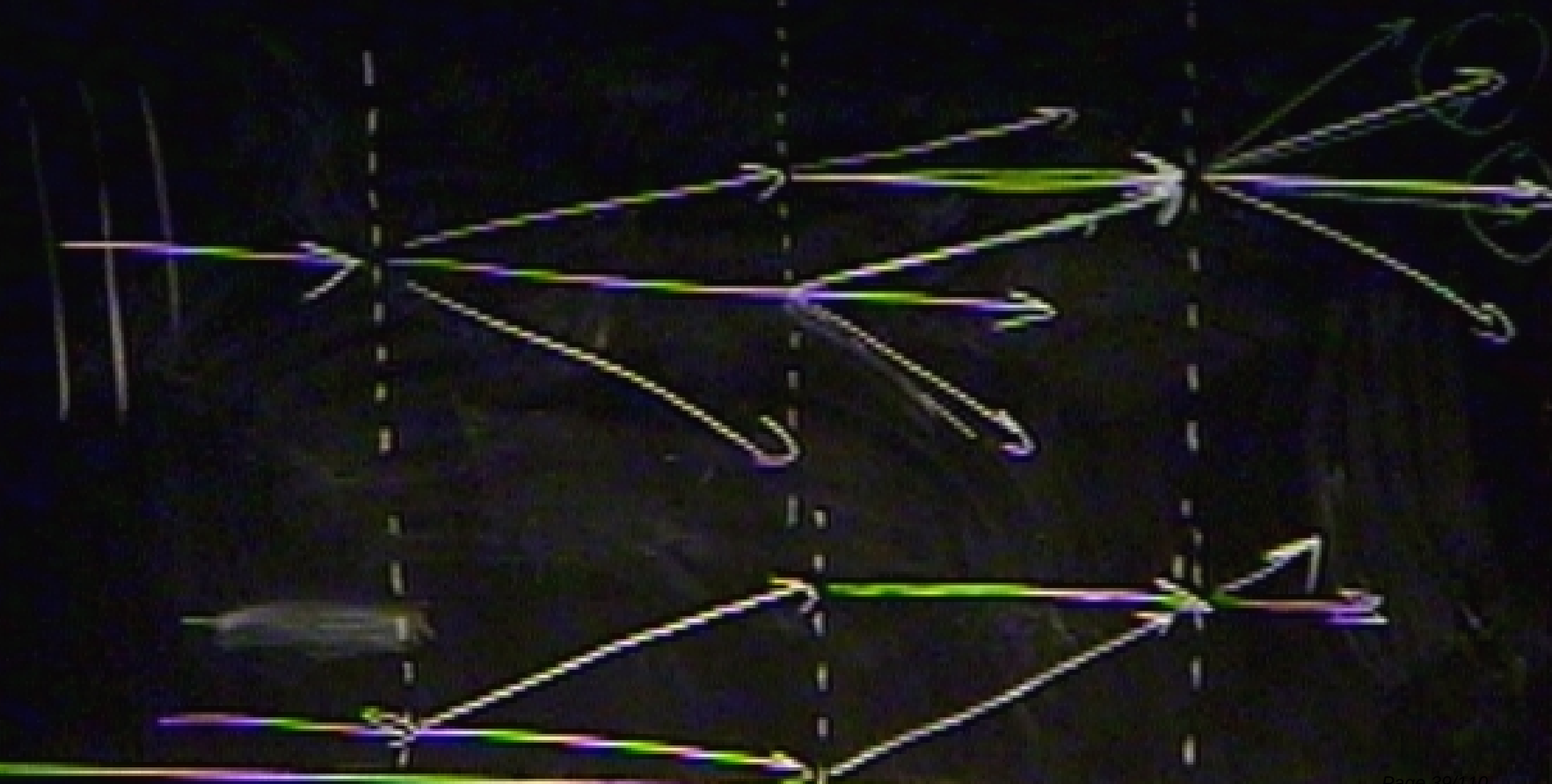
Linearity of $\mathbb{R}^m$



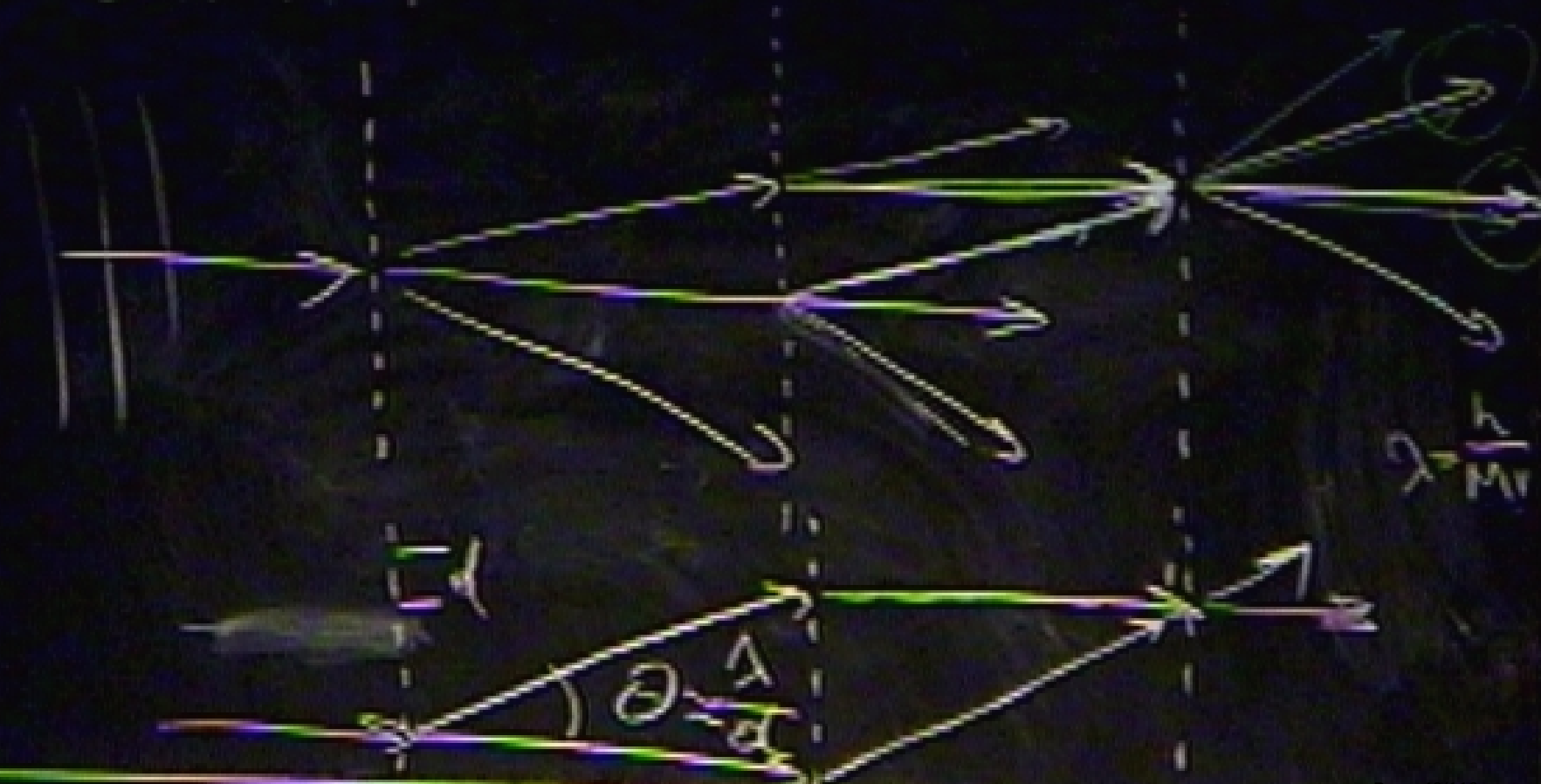
Linearity of $\mathbb{R}^m$



Linearity of $\mathbb{R}^n$



Linearity of $\mathcal{Q}_m$



Talbot - Effekt

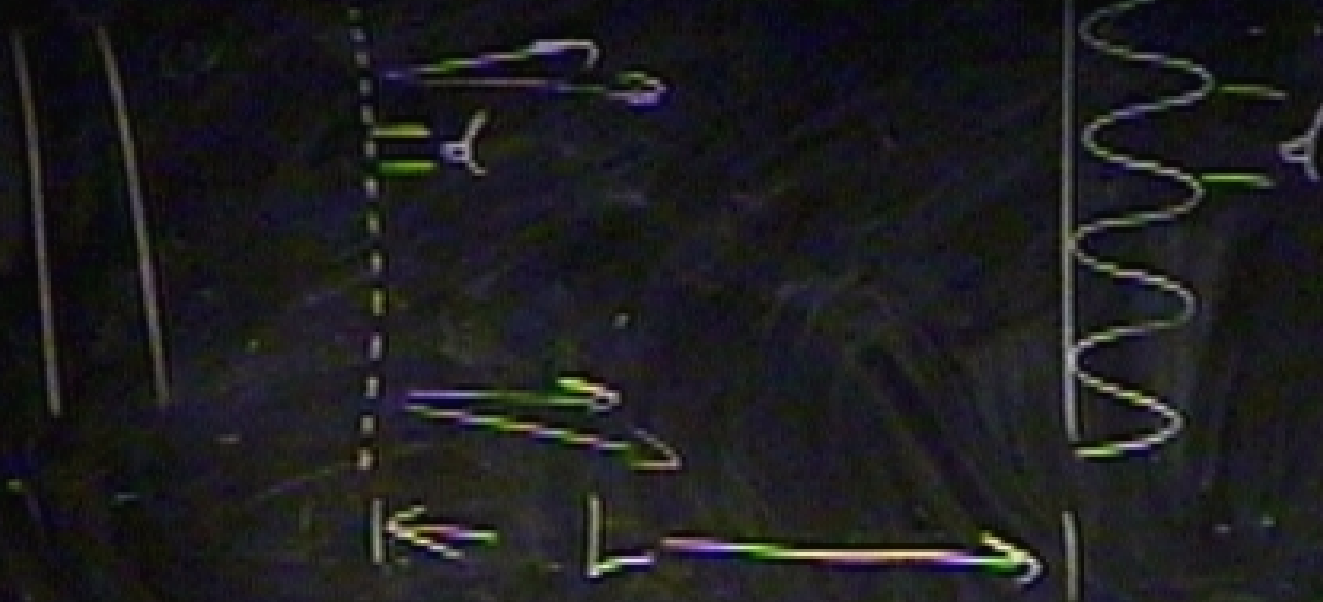


Talbot - Efteki



Talbot - Eftek

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



Talbot - Eftekl

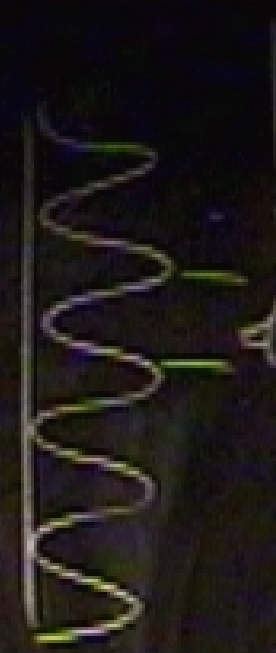


$$L = \frac{d^2}{\lambda}$$

Talbot-Langth

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

Talbot - Effekt



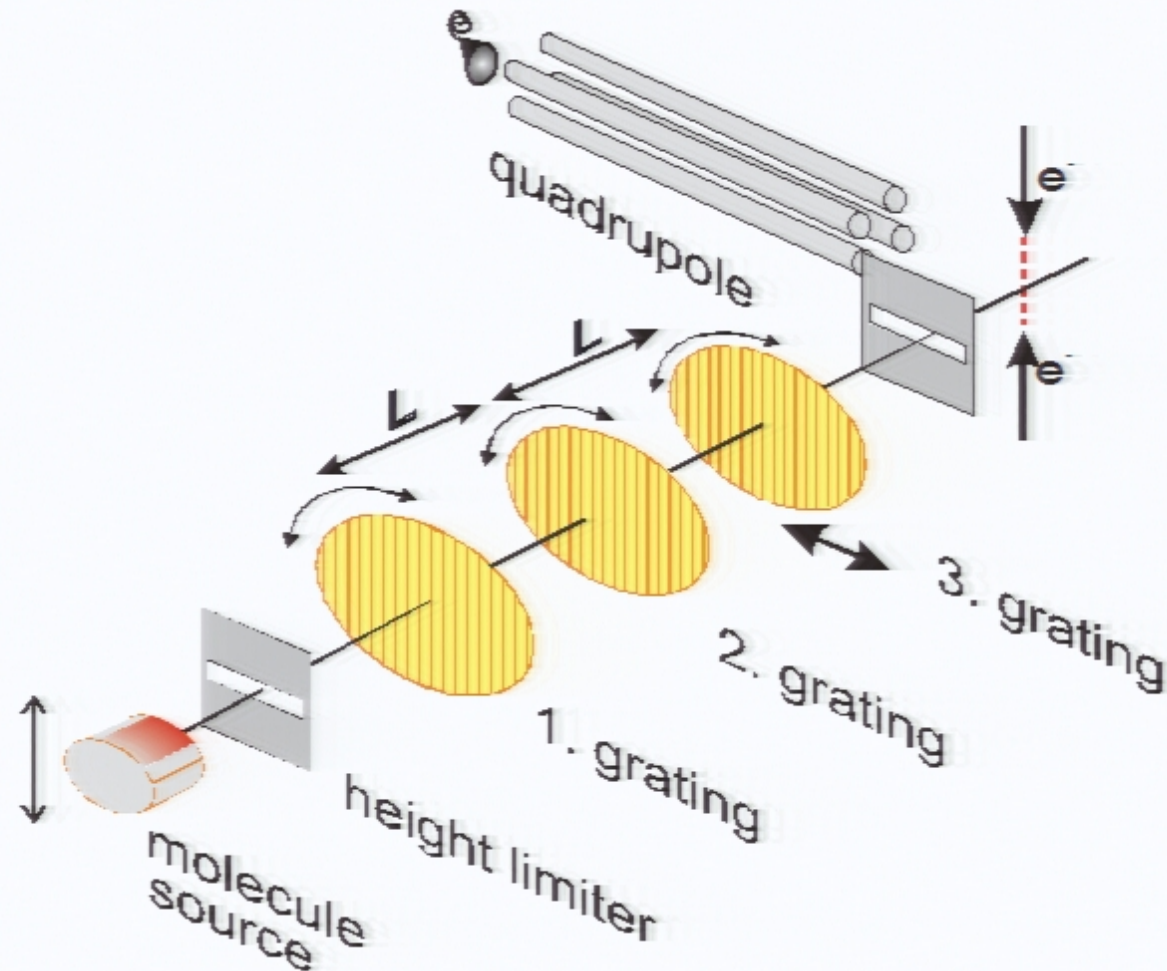
$$L = \frac{d^2}{\lambda}$$

Talbot-Longth

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

Near-Field Diffraction

Albot-Lau (near field) Interferometry with Macromolecules

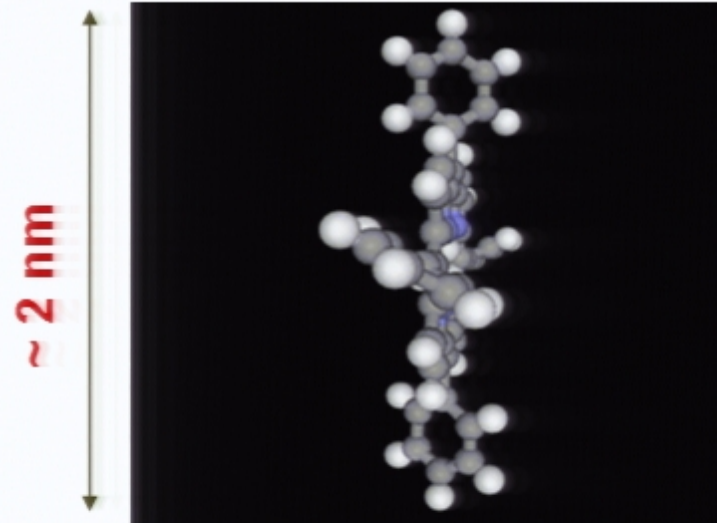


L. Hackermüller, S. Uttenthaler, K. Hornberger, E. Reiger, B. Brezger, A. Zeilinger and M. Arndt,

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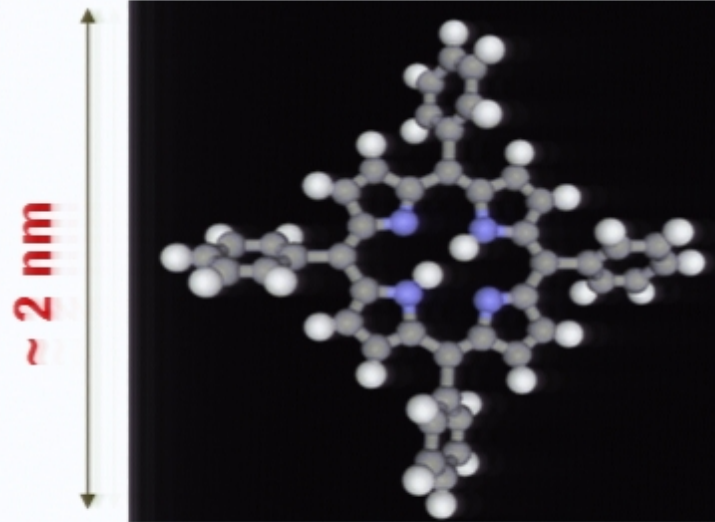
A „Color of Life“

Interferometry with
Porphyrin



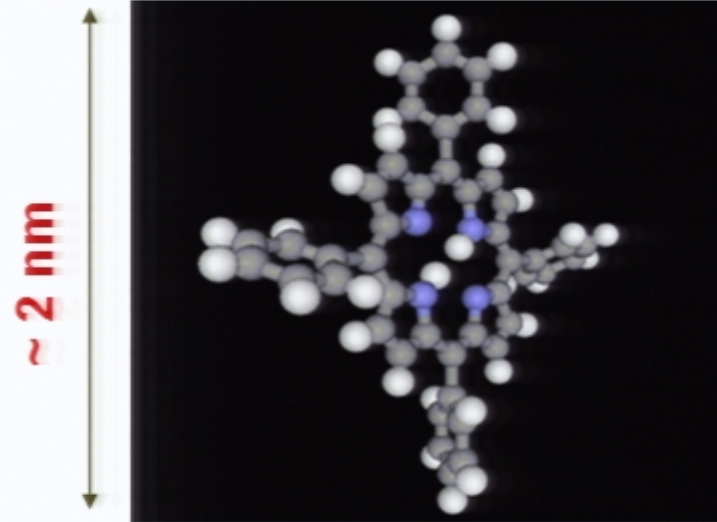
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Interferometry with
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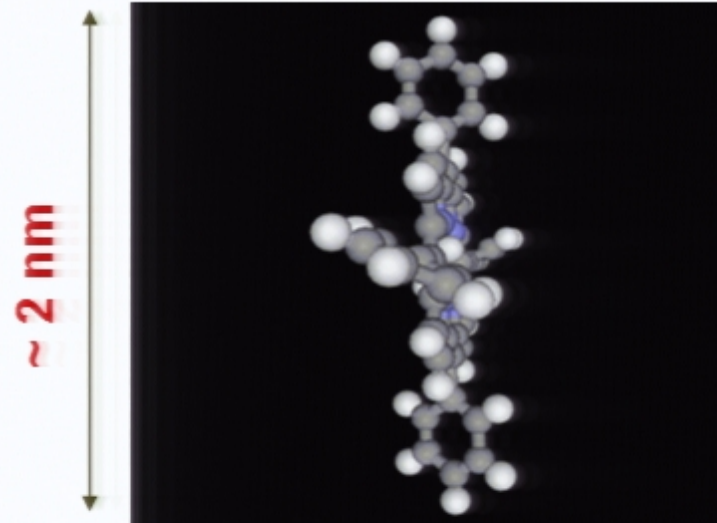
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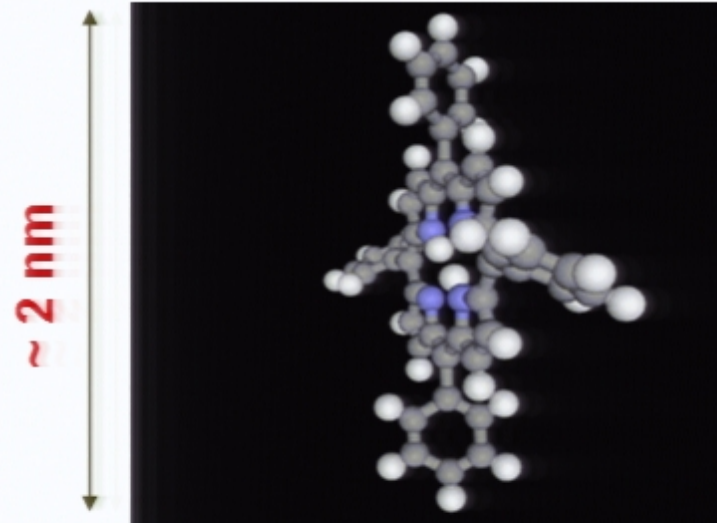
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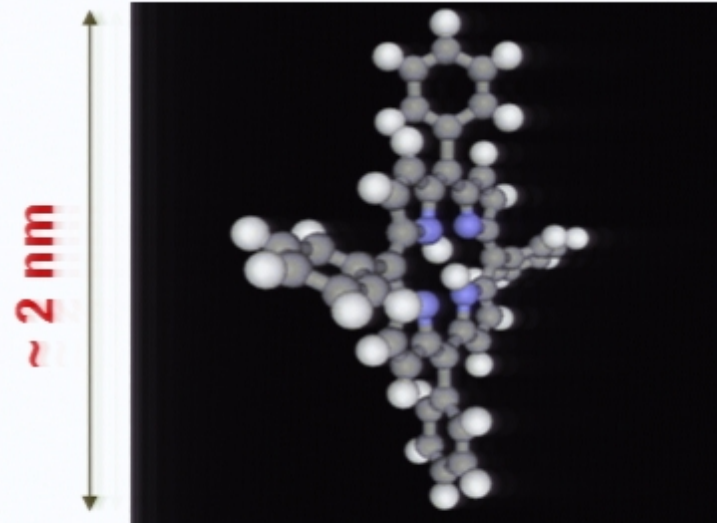
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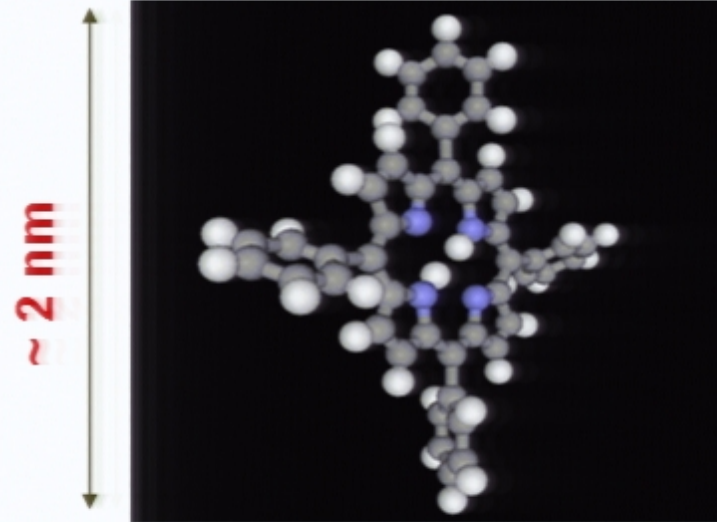
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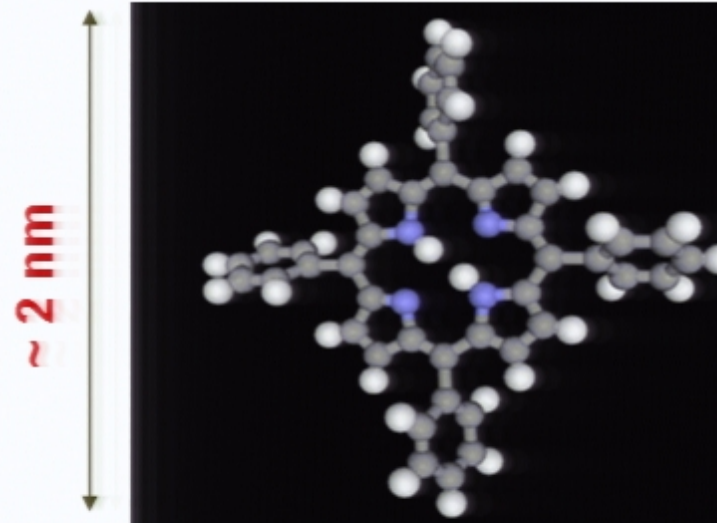
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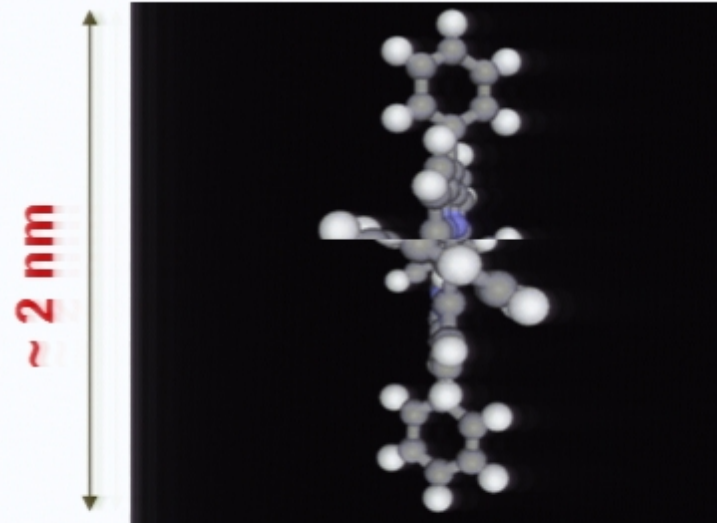
A „Color of Life“

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Porphyrin



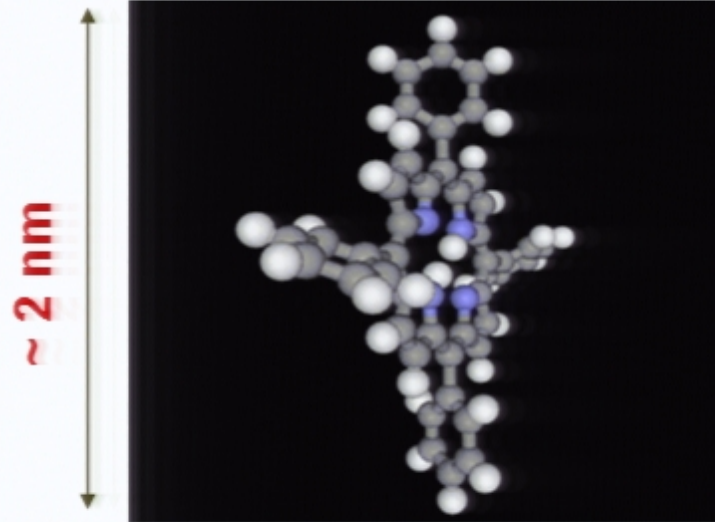
A „Color of Life“

Interferometry with
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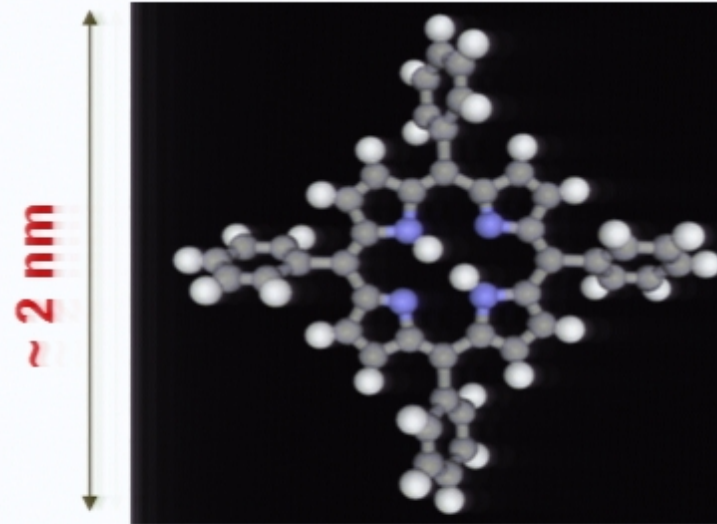
A „Color of Life“

Interferometry with
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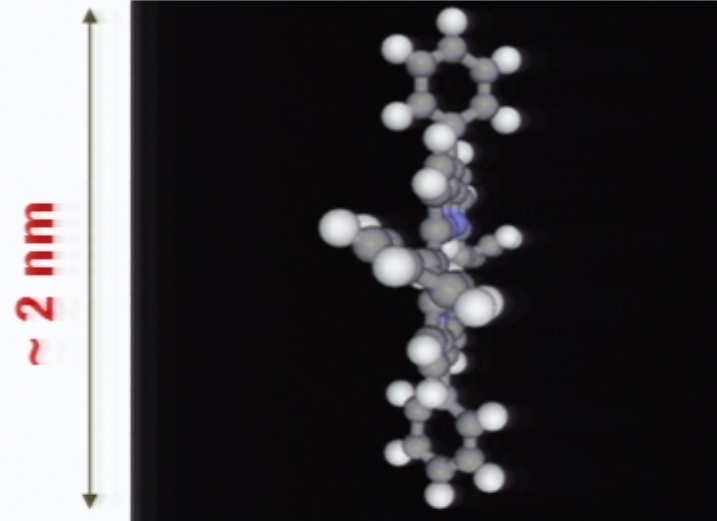
A „Color of Life“

Interferometry with
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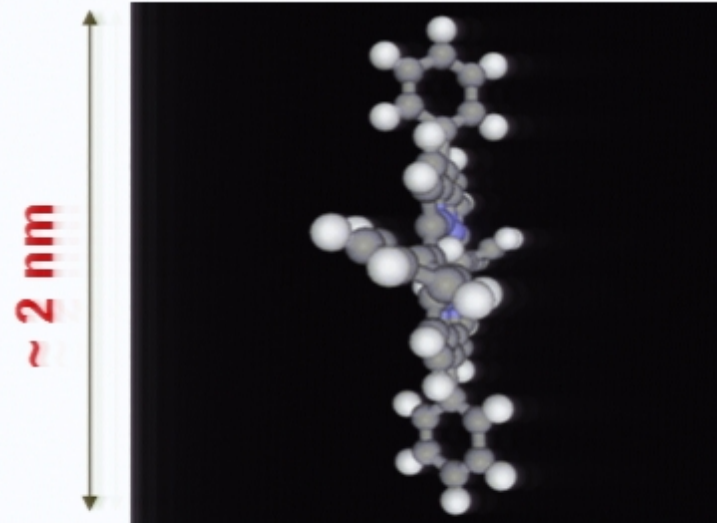
A „Color of Life“

Interferometry with
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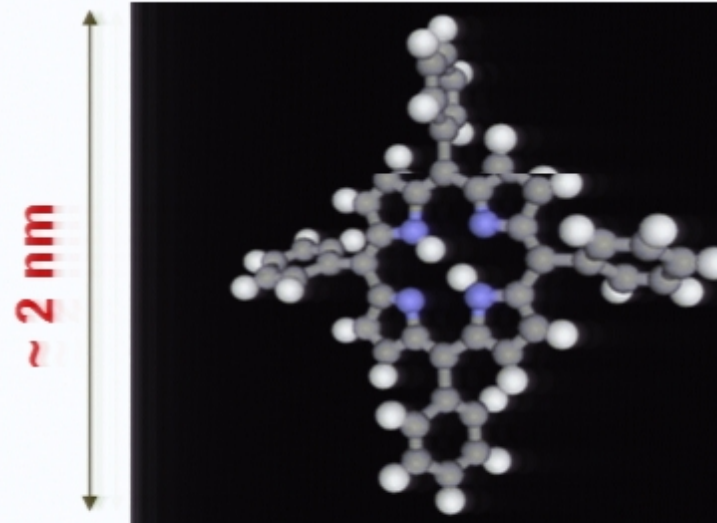
A „Color of Life“

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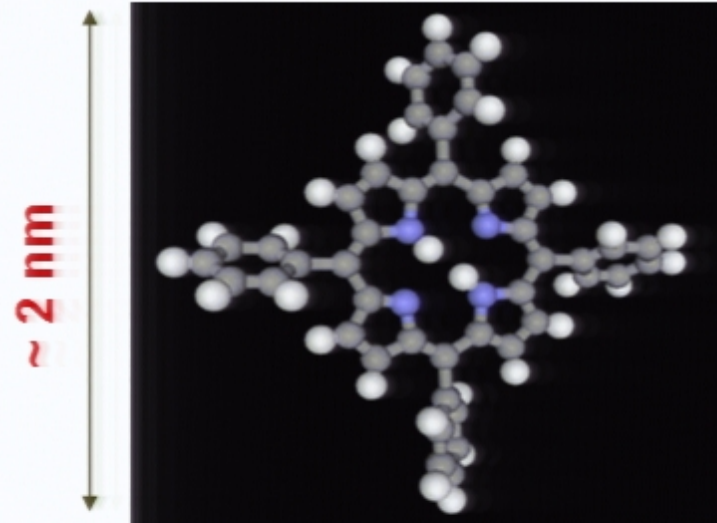
A „Color of Life“

Interferometry with
Porphyrin



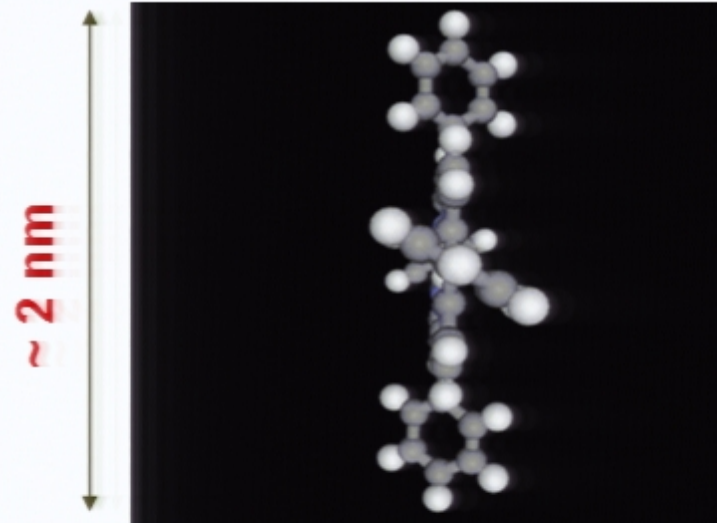
A „Color of Life“

Interferometry with
Porphyrin



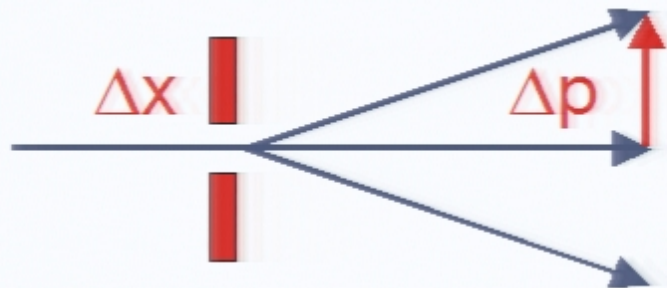
A „Color of Life“

Interferometry with
Porphyrin



Heisenberg Uncertainty for Macromolecules

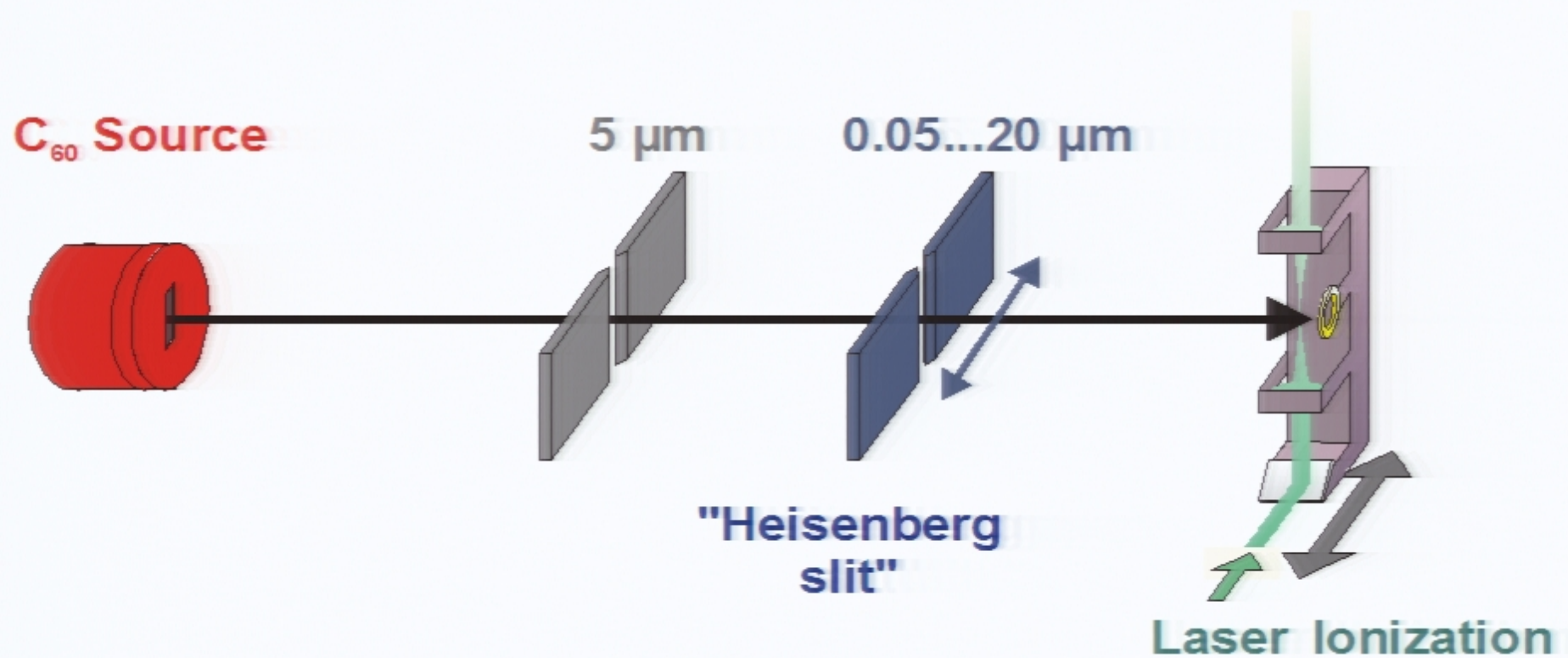
- Measurement by Diffraction at a Narrow Slit
- Prepares Coherent Wave Fronts



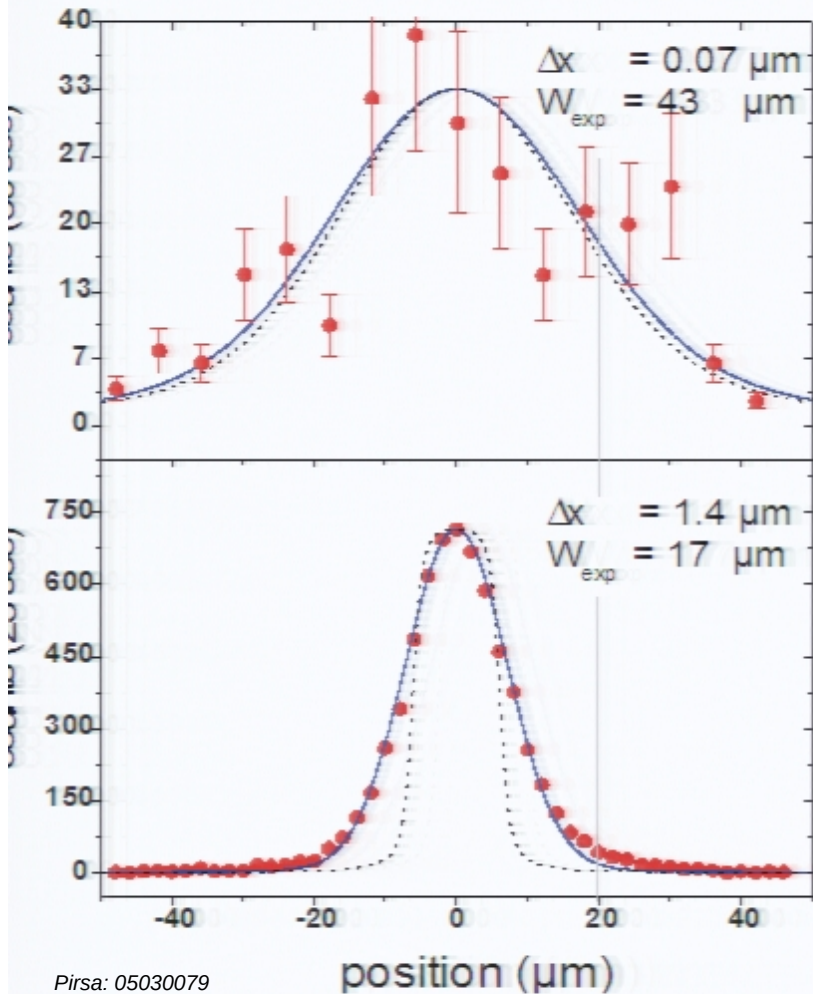
$$\Delta x \cdot \Delta p \geq \frac{h}{2}$$

$$\Delta x \cdot \Delta p \gtrsim h$$

Heisenberg Experiment



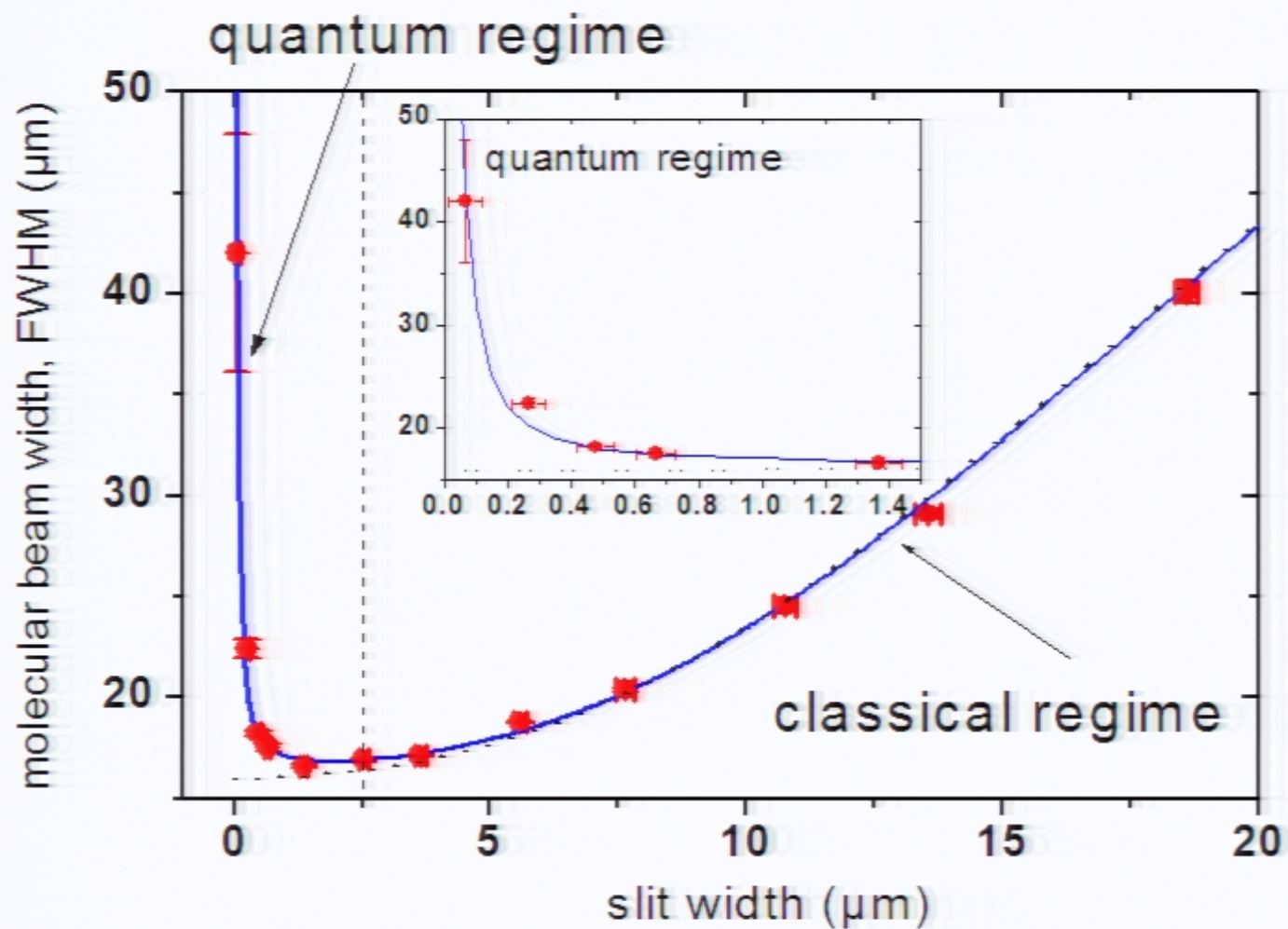
Experimental Results



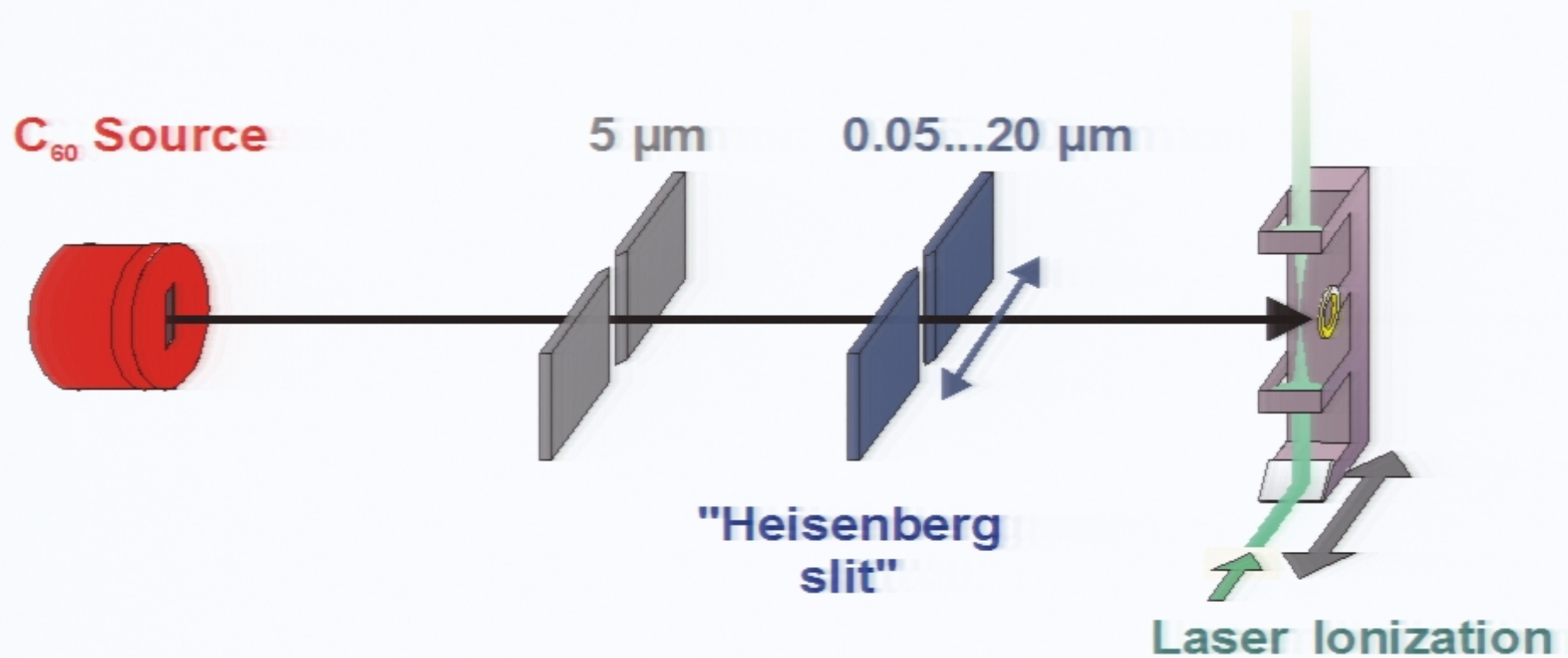
Smaller Slit Width

Larger Momentum Spread

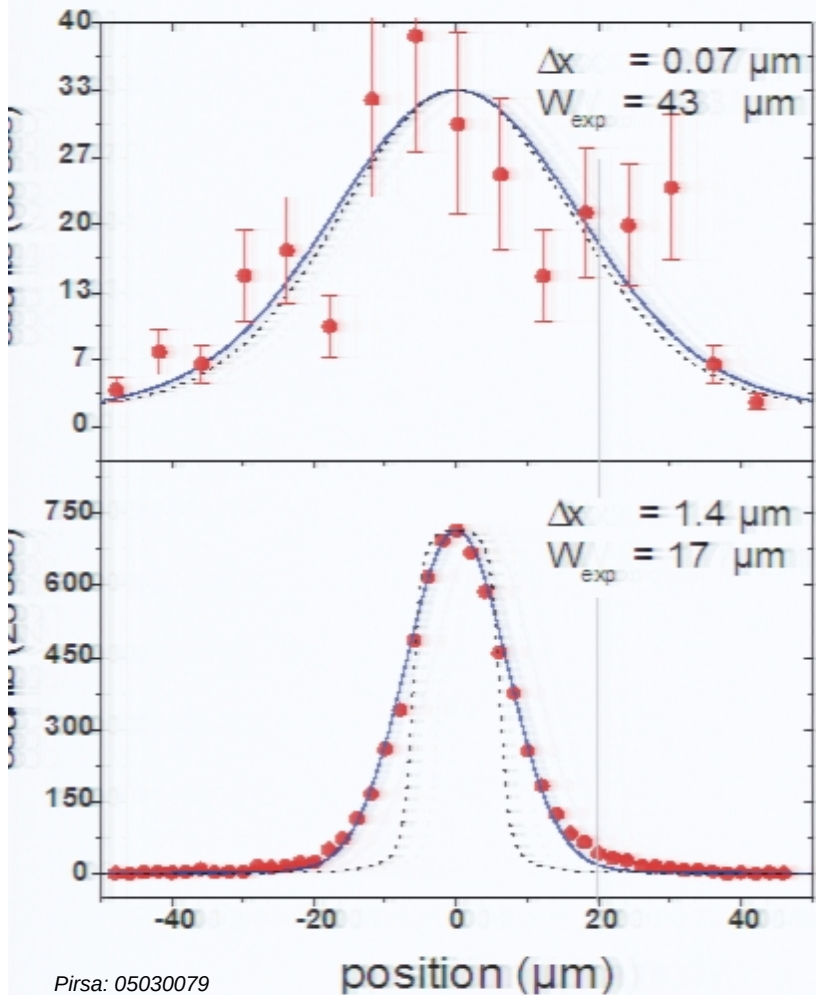
Experimental Results



Heisenberg Experiment



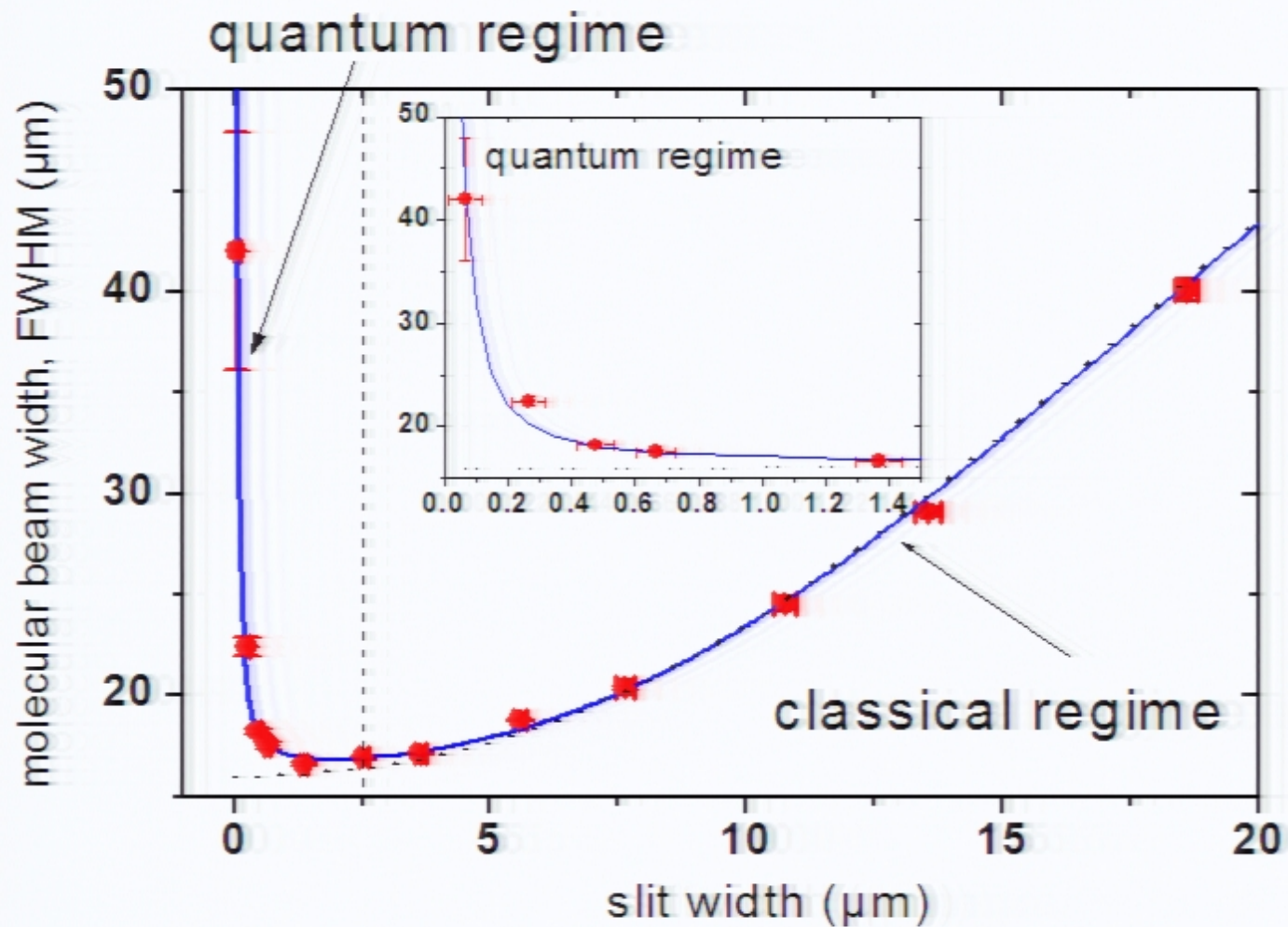
Experimental Results

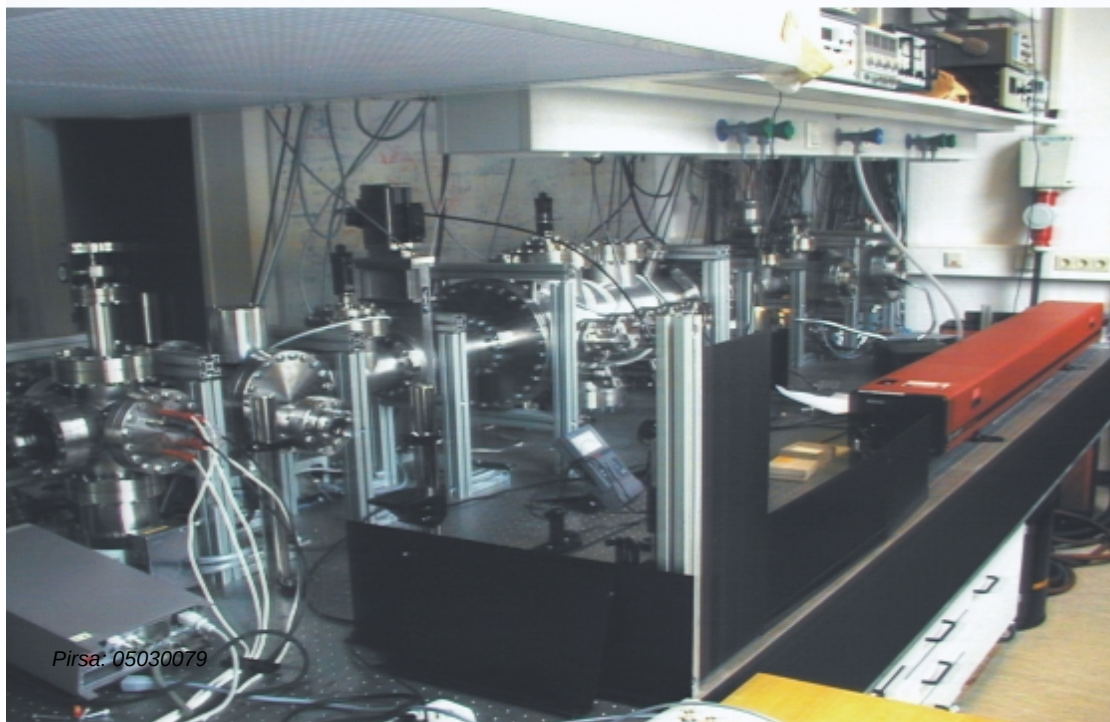
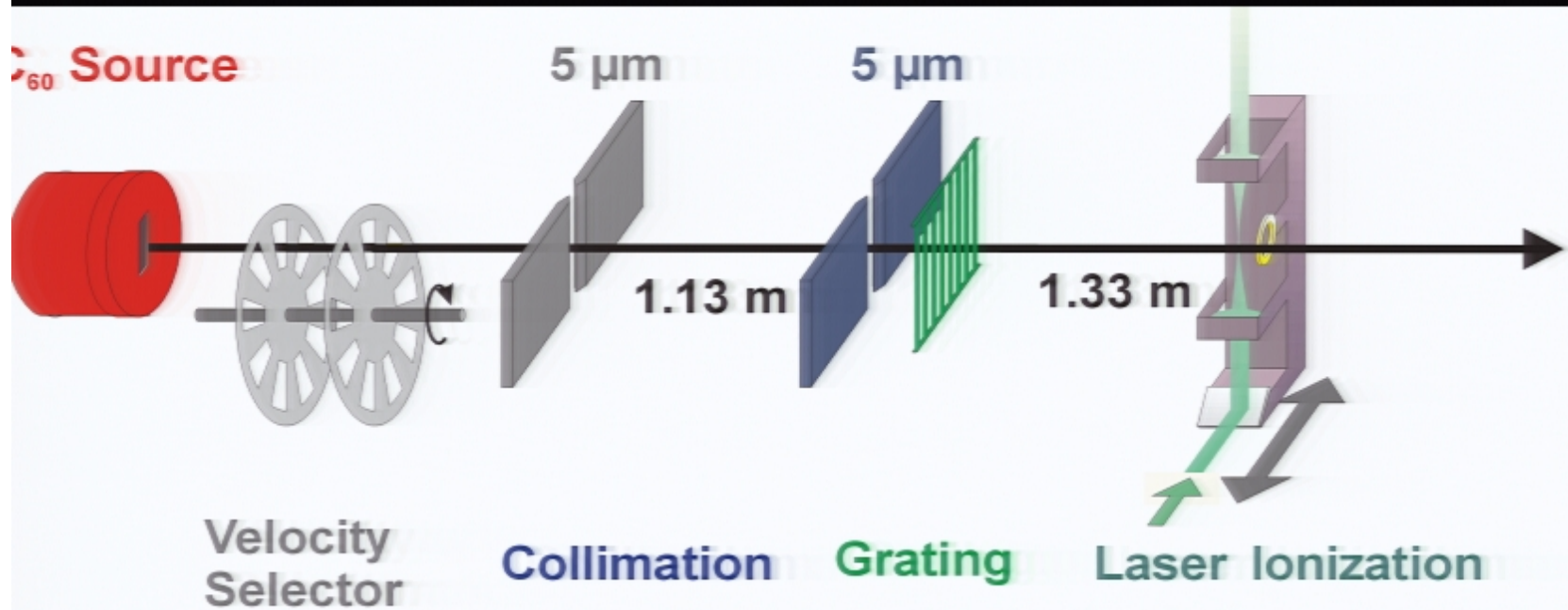


Smaller Slit Width

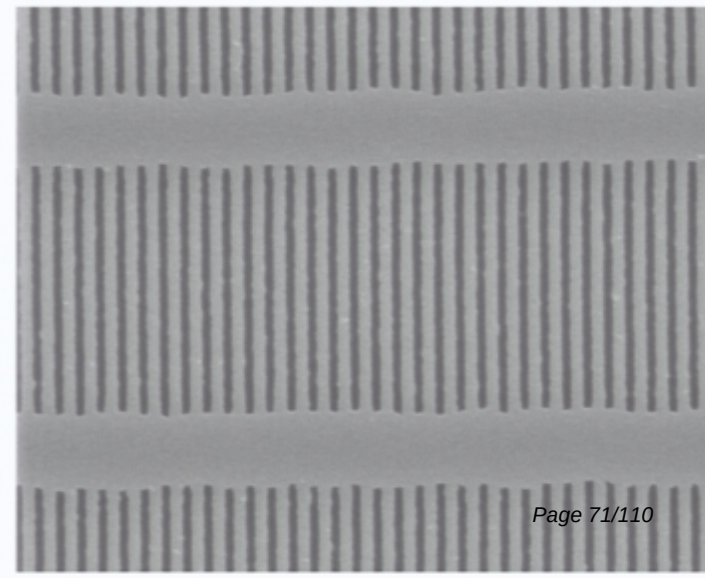
Larger Momentum Spread

Experimental Results





Pirsa: 05030079

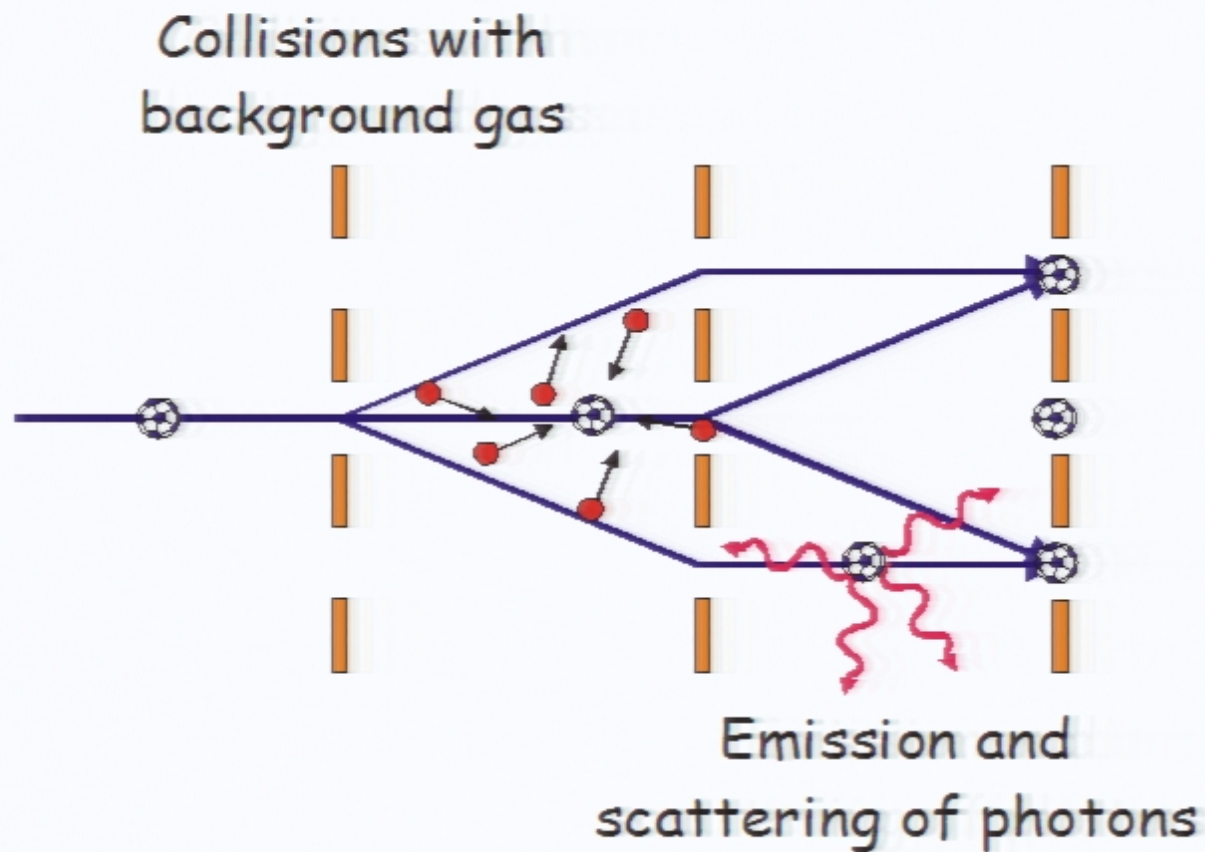


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Where is the Limit ?

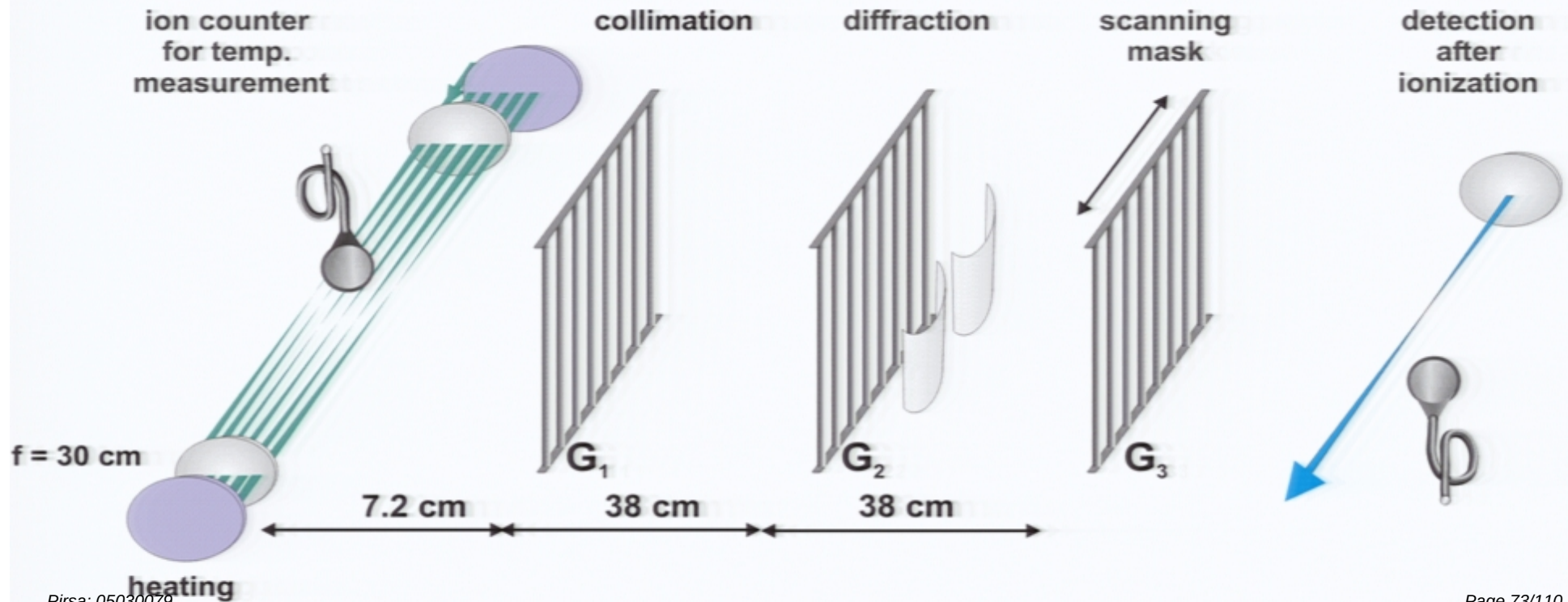
Collisional or Thermal Decoherence

Transition to Classical Dynamics



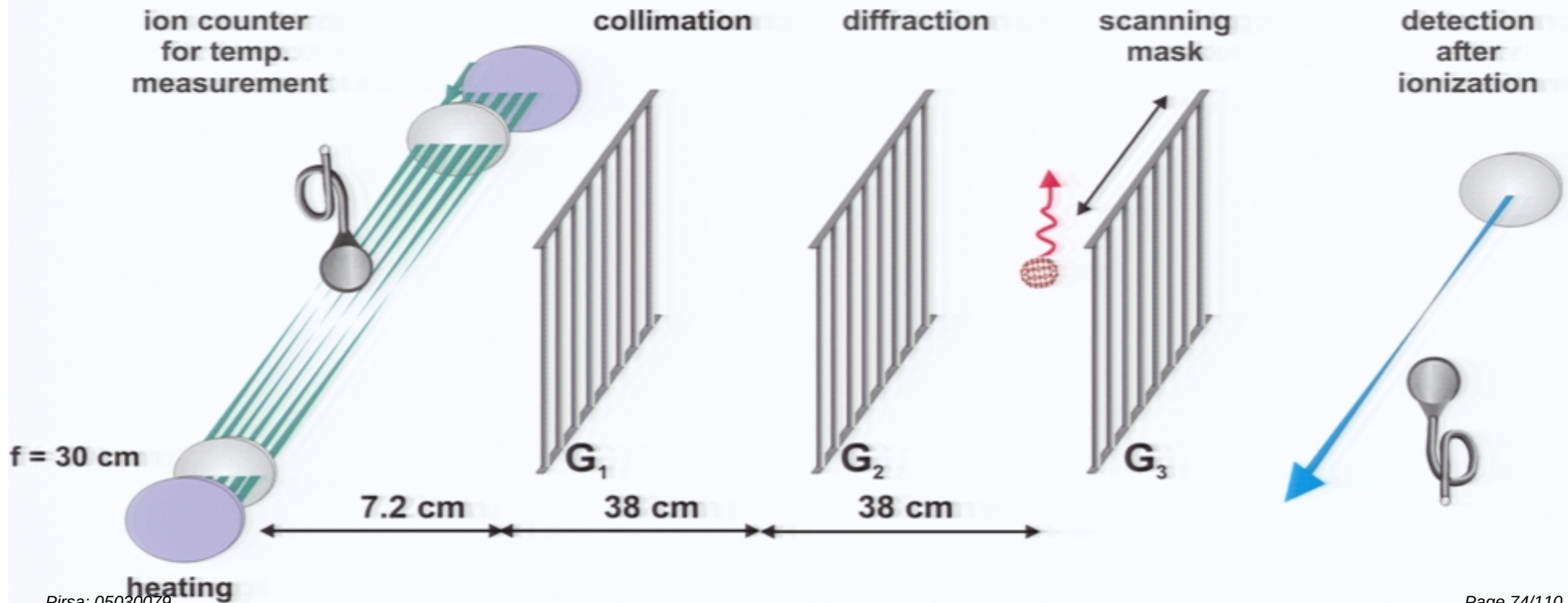
Decoherence by Emission of Thermal Radiation

Where are the Boundaries of the Quantum World?



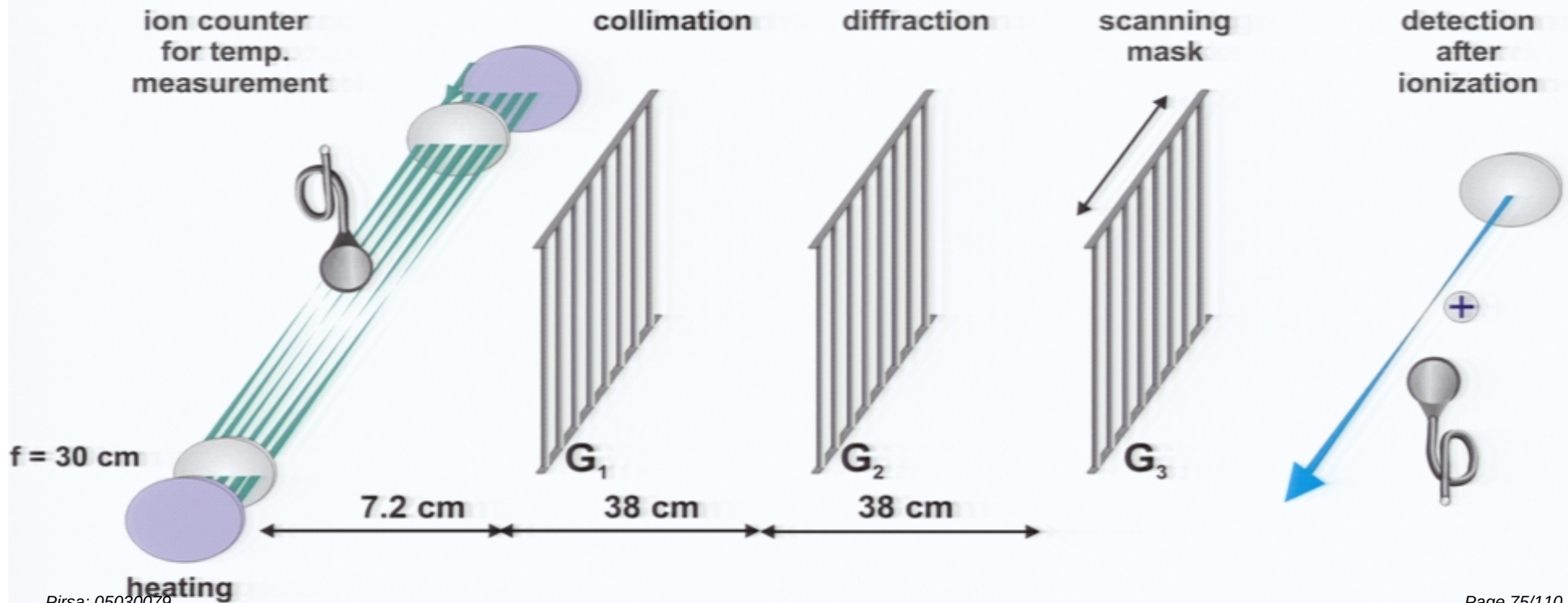
Decoherence by Emission of Thermal Radiation

Where are the Boundaries of the Quantum World?



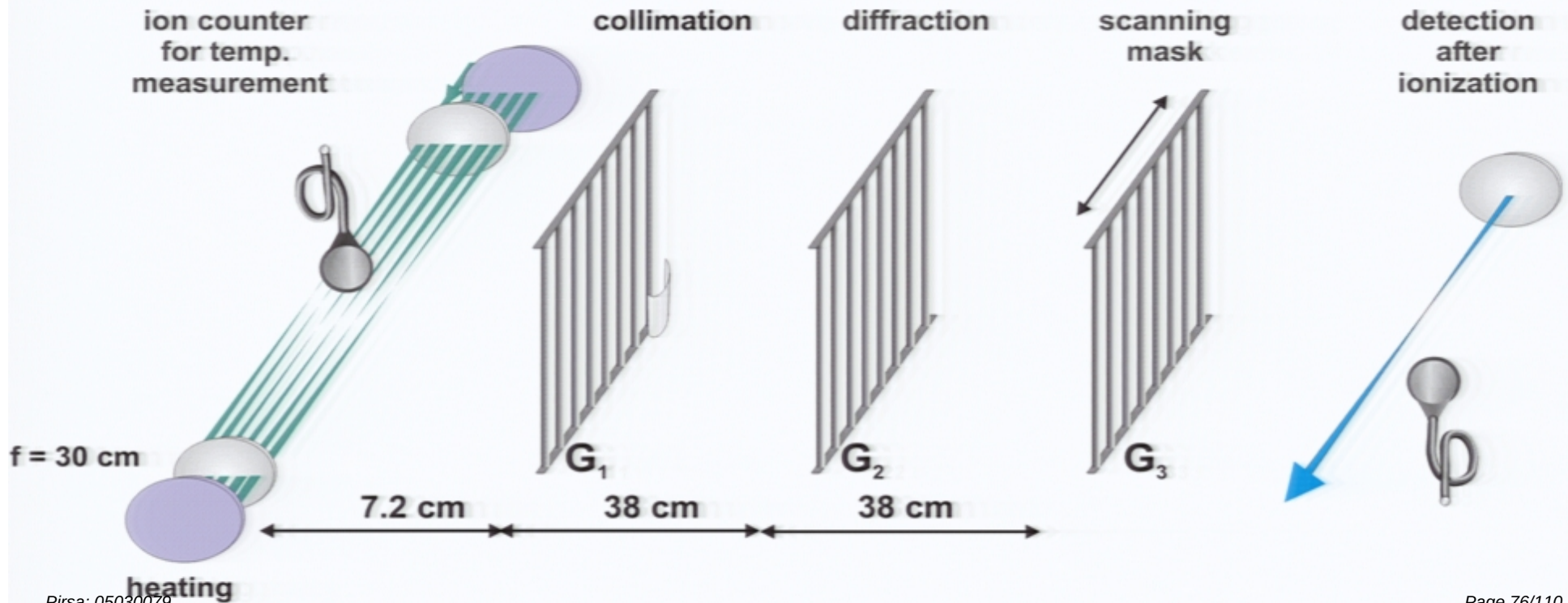
Decoherence by Emission of Thermal Radiation

Where are the Boundaries of the Quantum World?



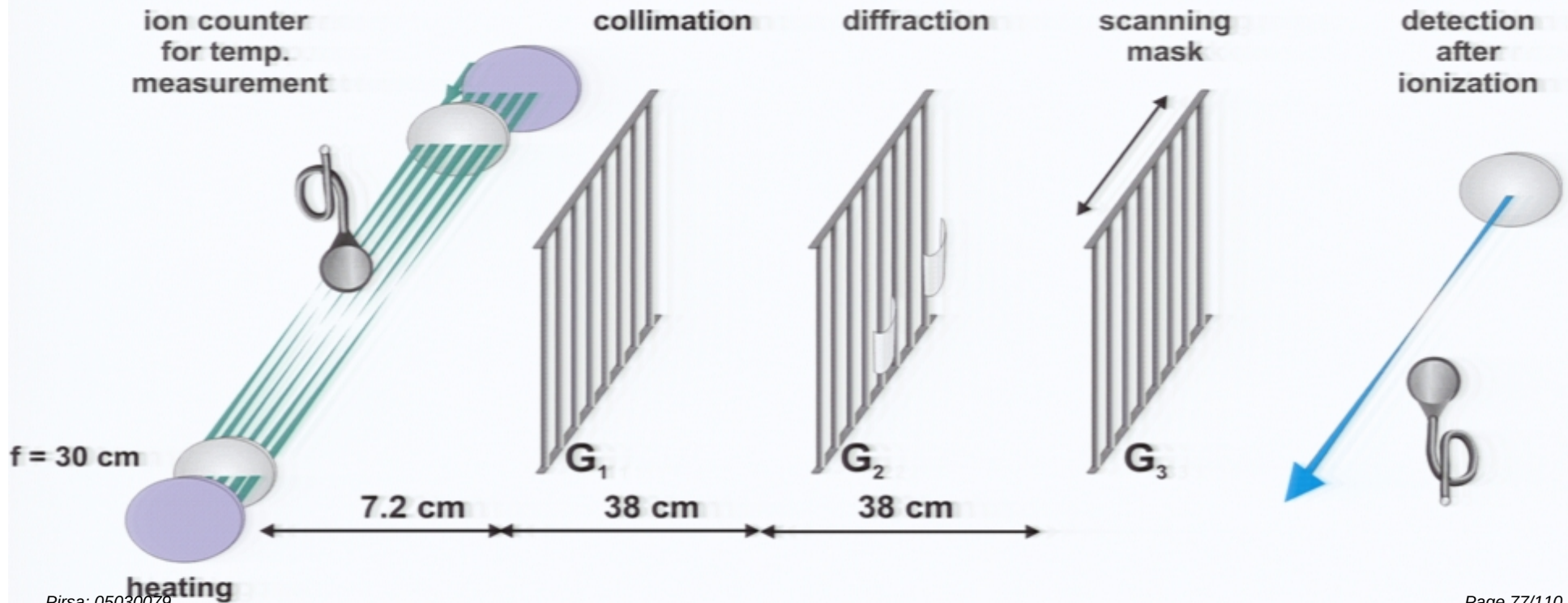
Decoherence by Emission of Thermal Radiation

Where are the Boundaries of the Quantum World?



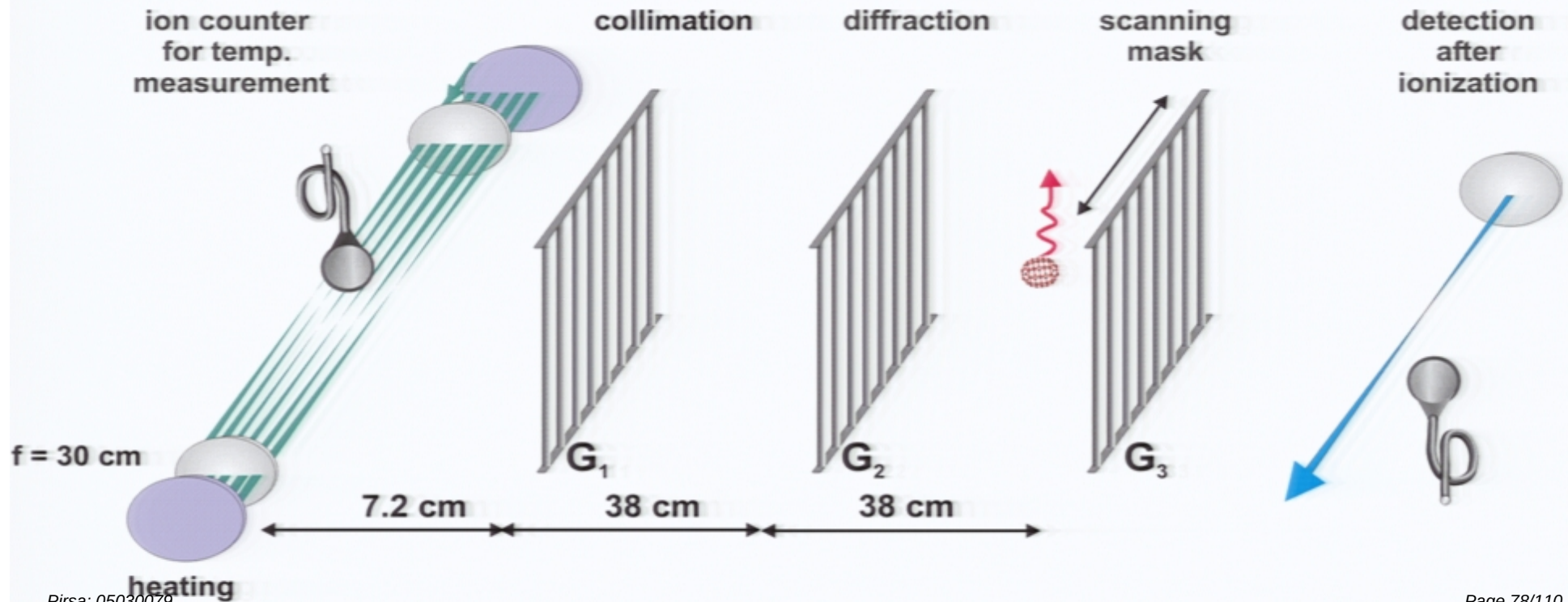
Decoherence by Emission of Thermal Radiation

Where are the Boundaries of the Quantum World?



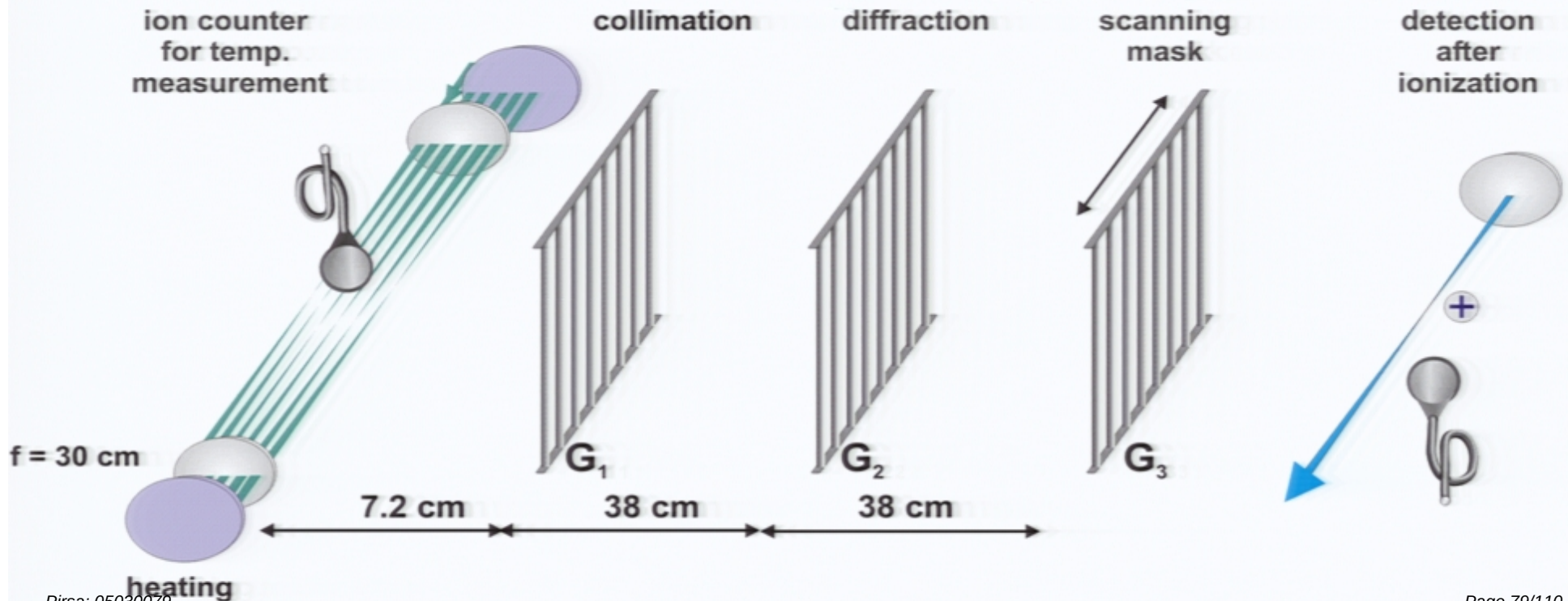
Decoherence by Emission of Thermal Radiation

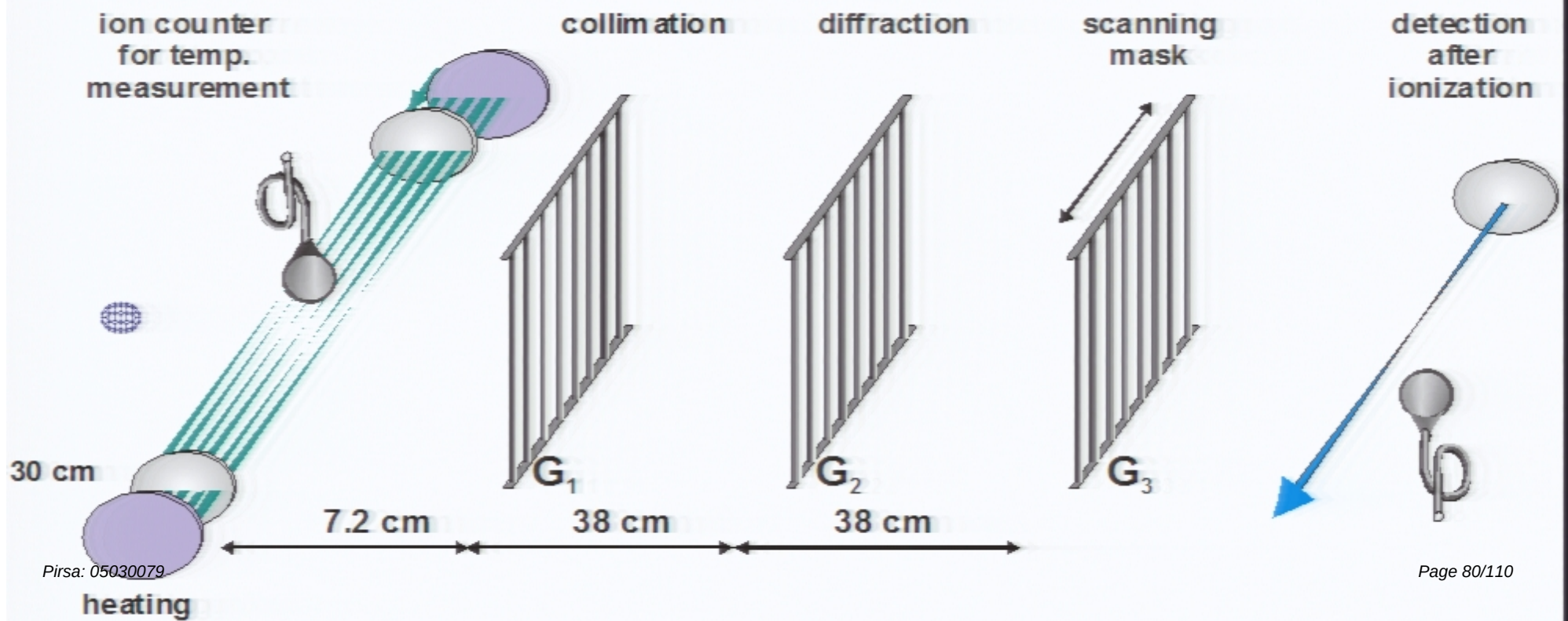
Where are the Boundaries of the Quantum World?

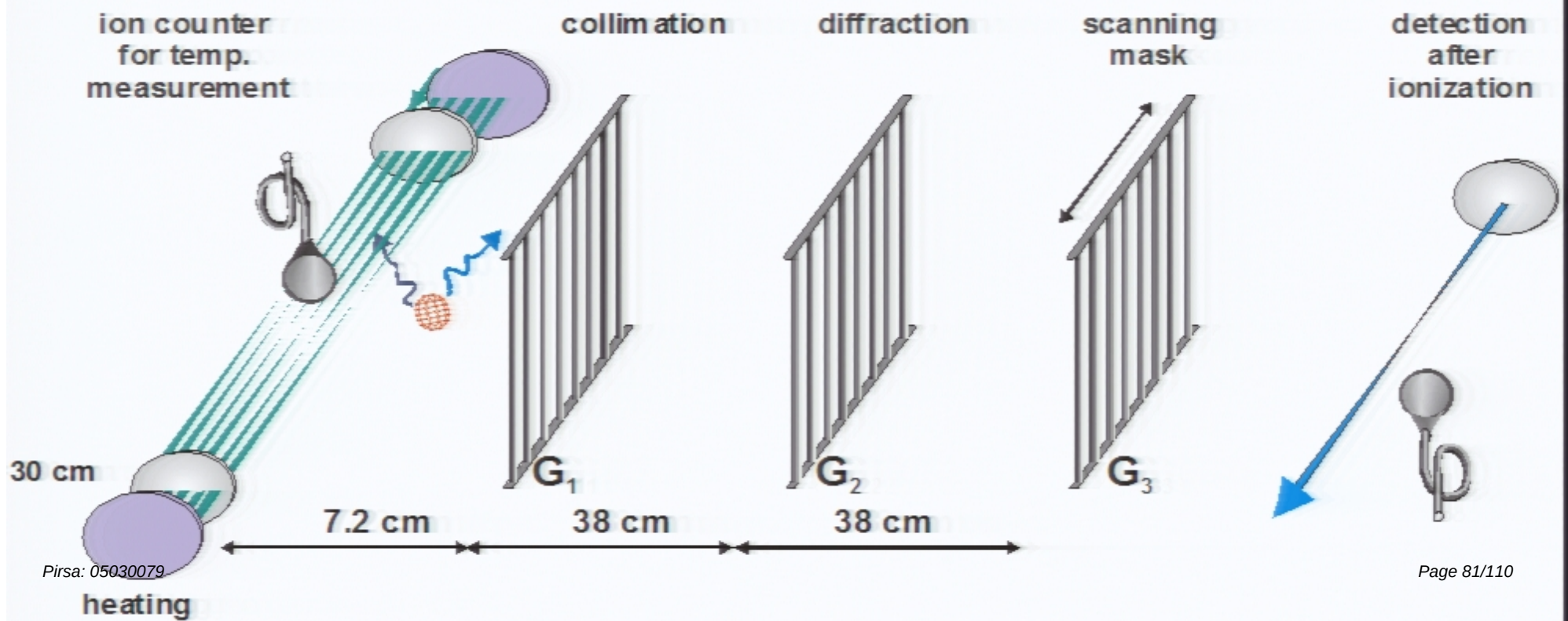


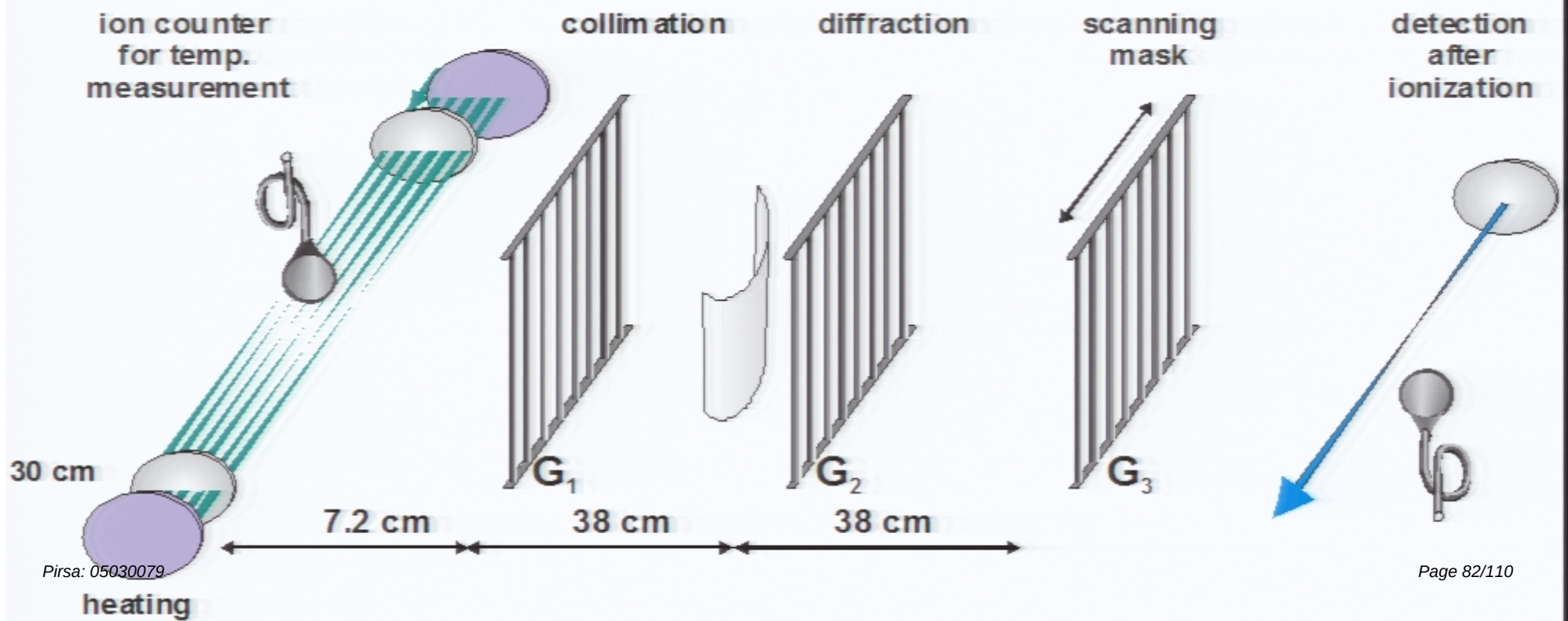
Decoherence by Emission of Thermal Radiation

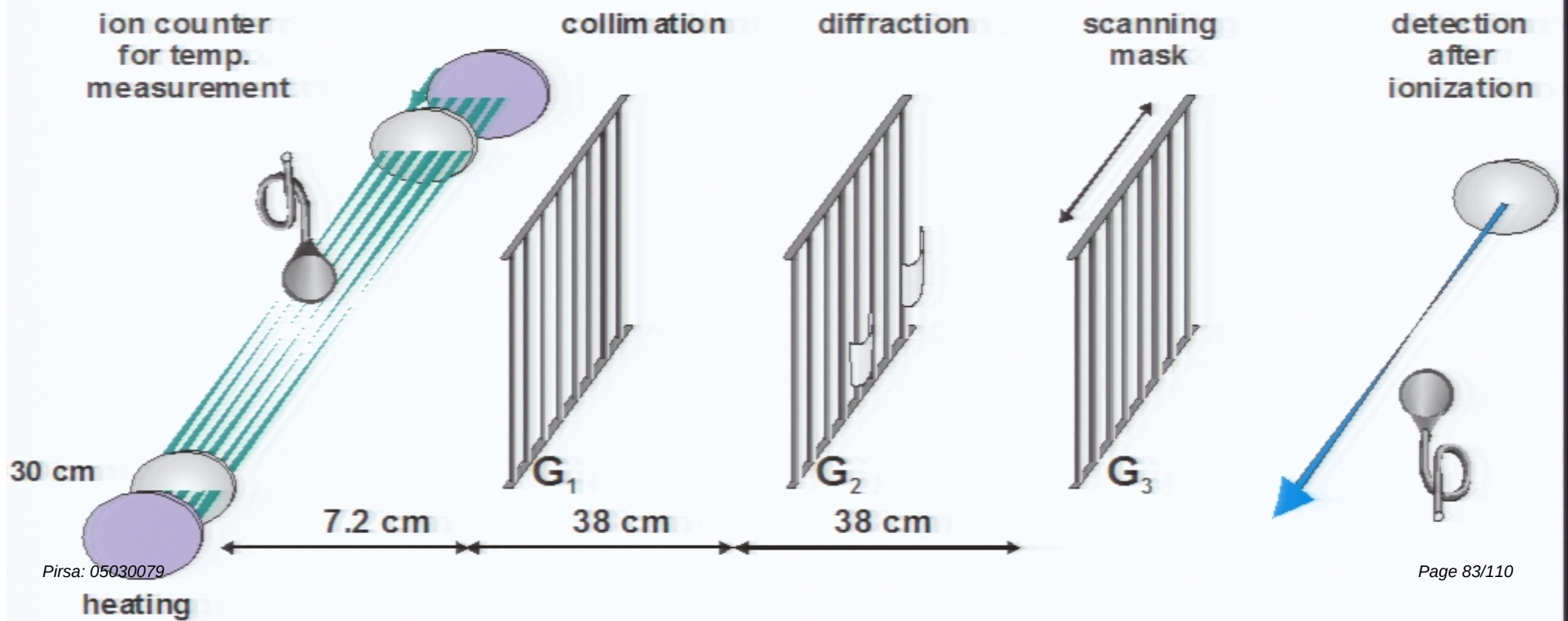
Where are the Boundaries of the Quantum World?

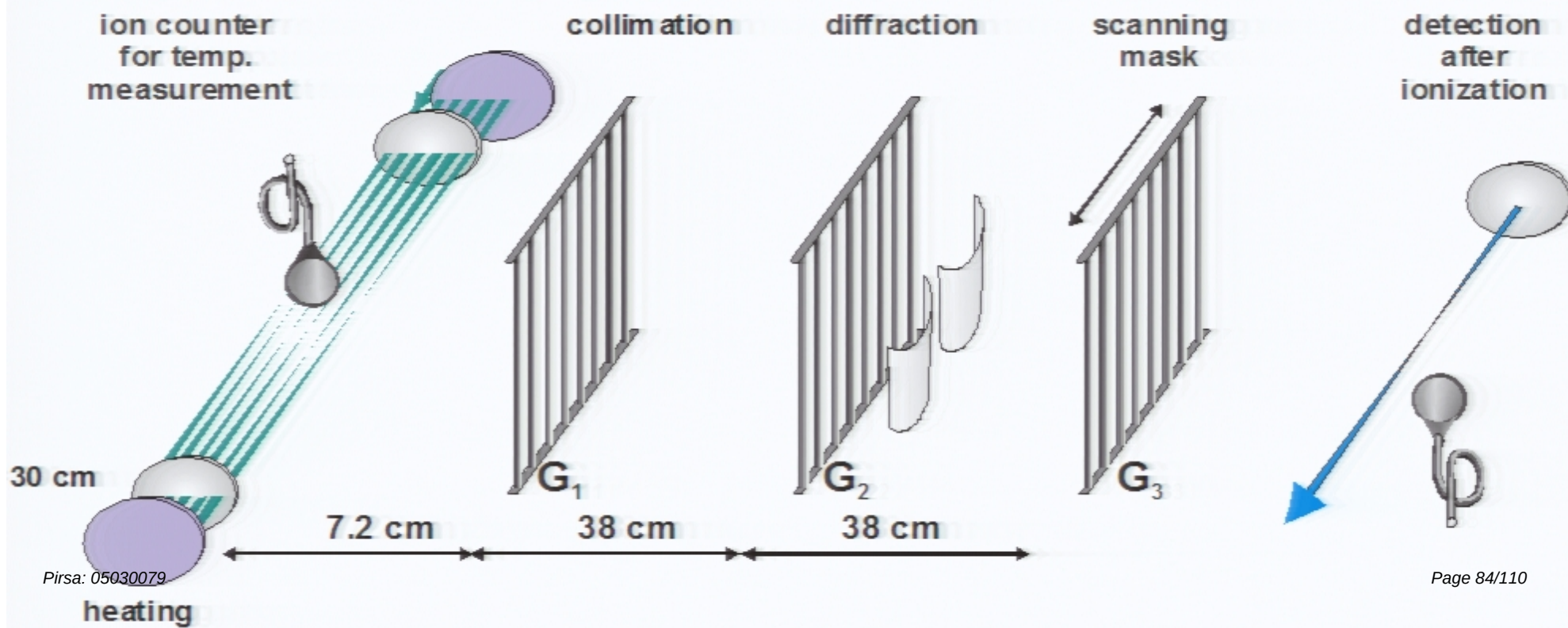


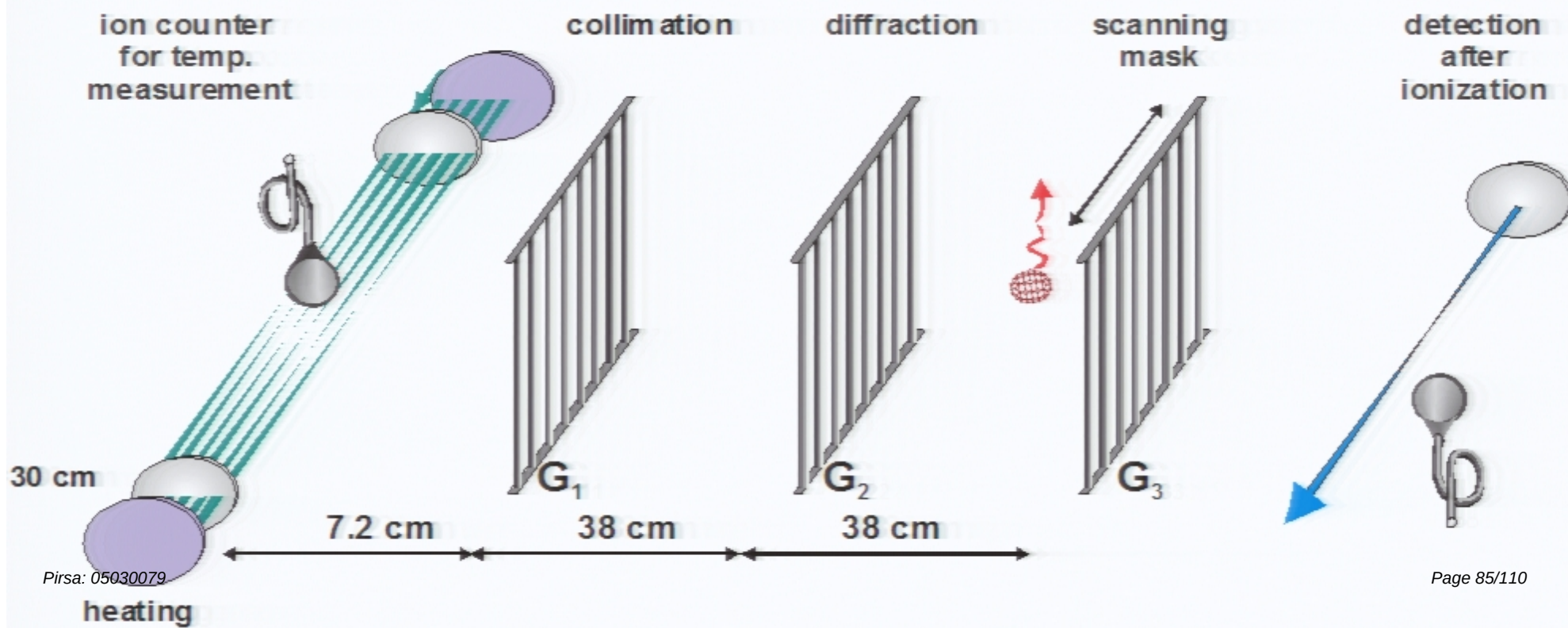






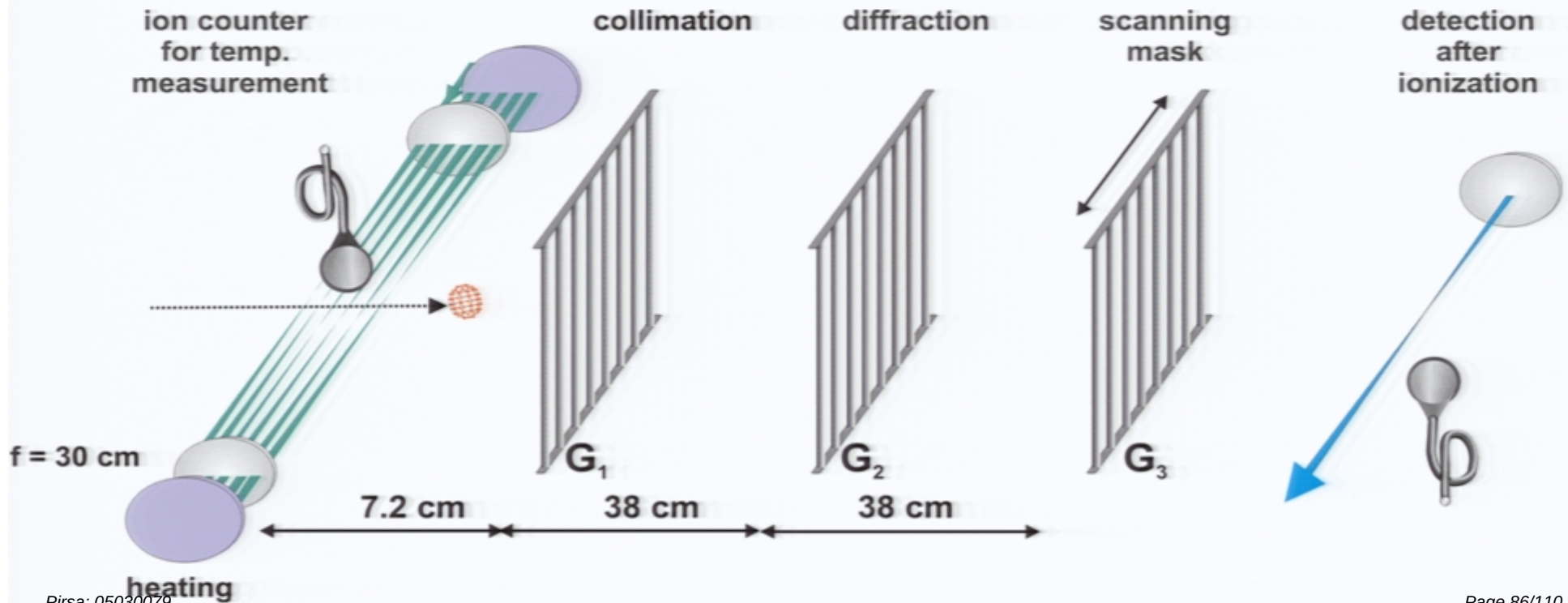




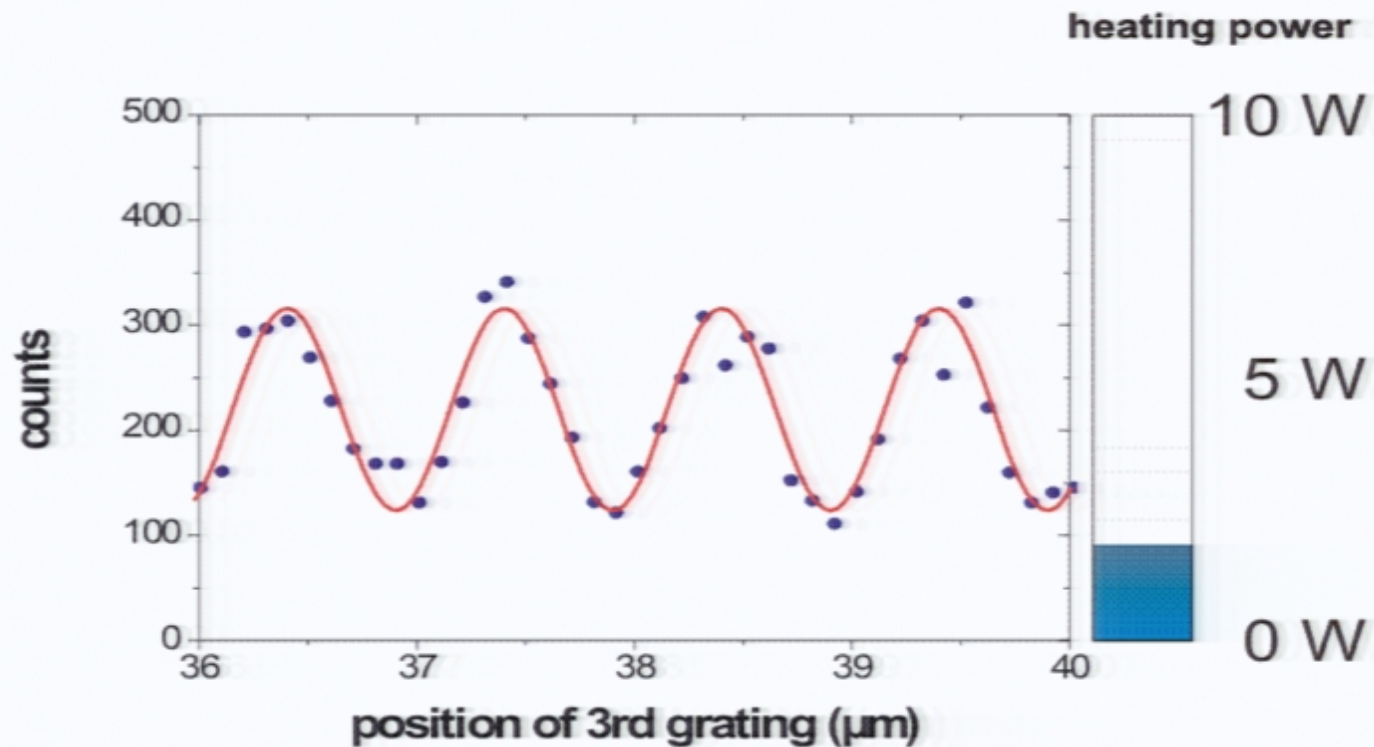


Decoherence by Emission of Thermal Radiation

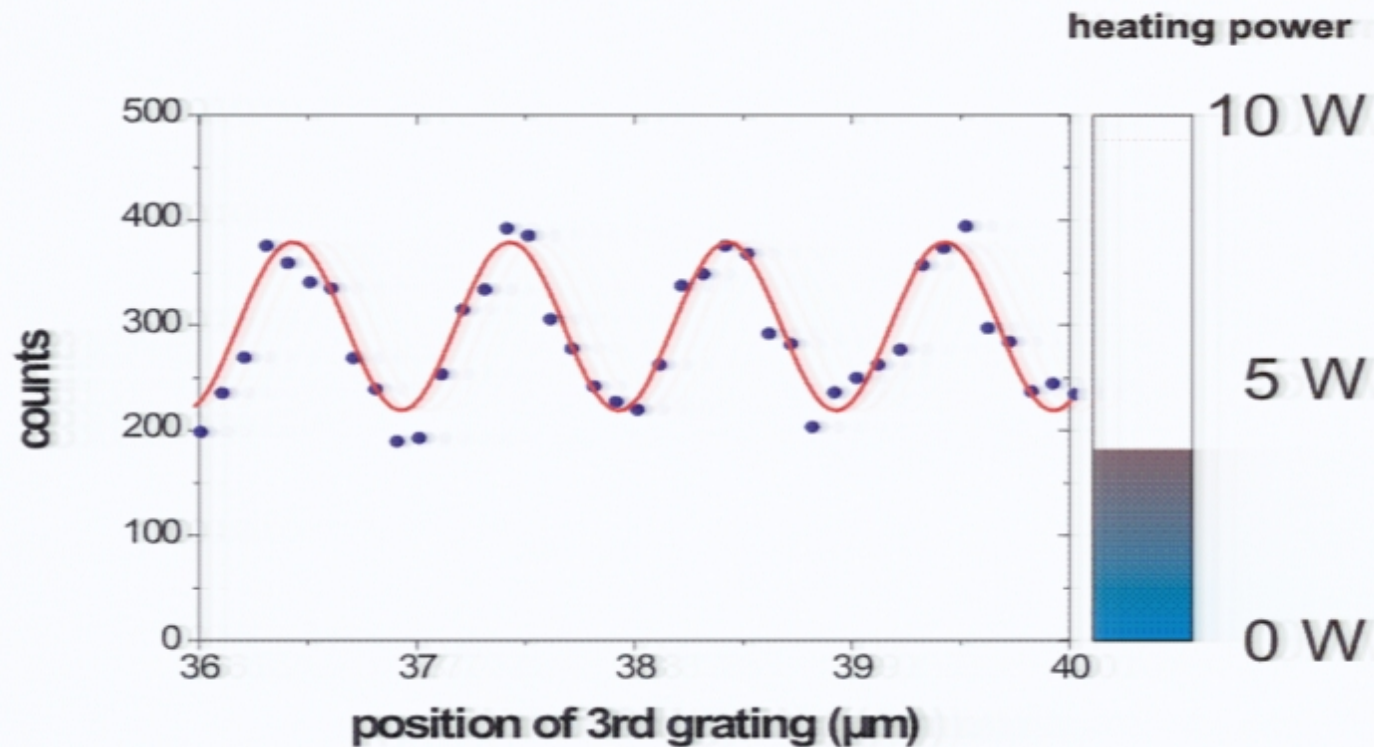
Where are the Boundaries of the Quantum World?



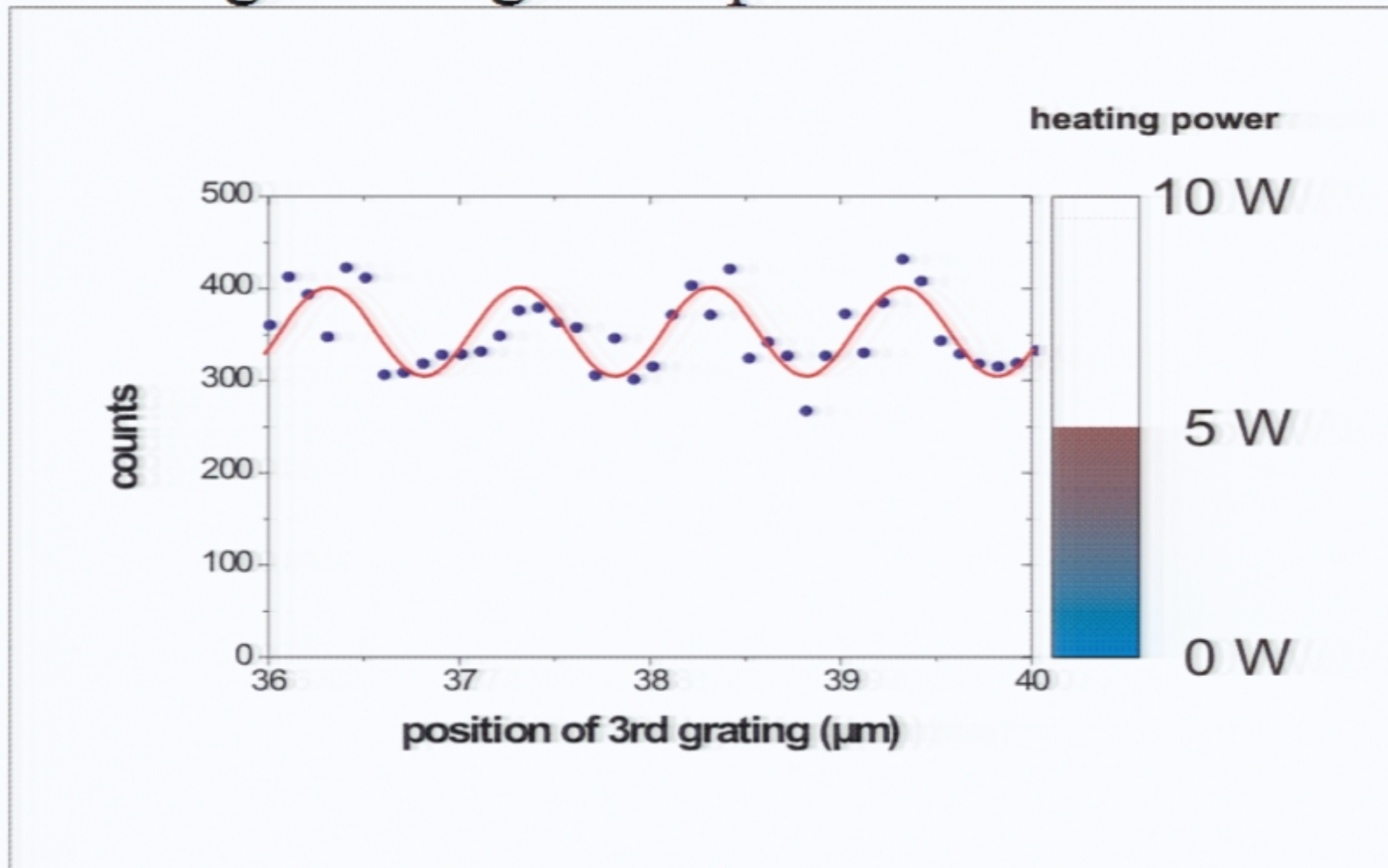
Interference patterns for Increasing heating laser power



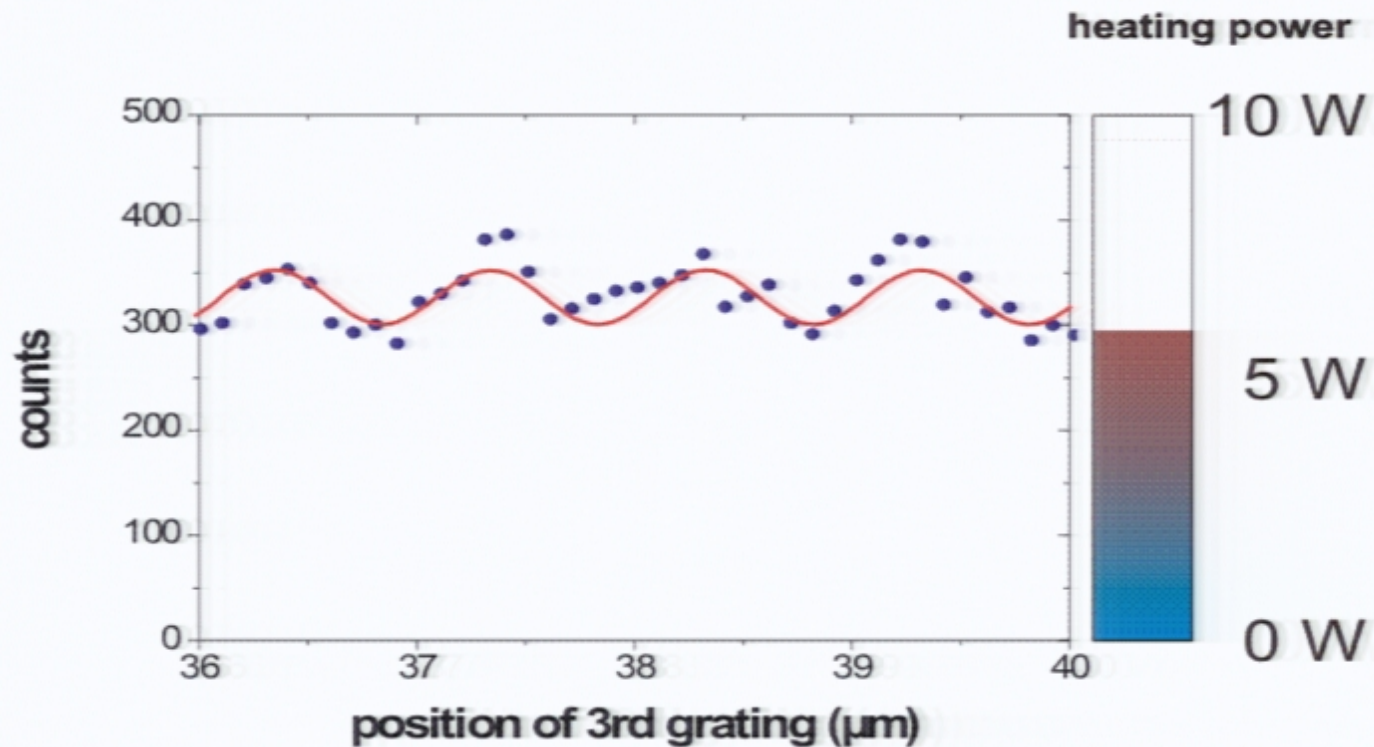
Interference patterns for Increasing heating laser power



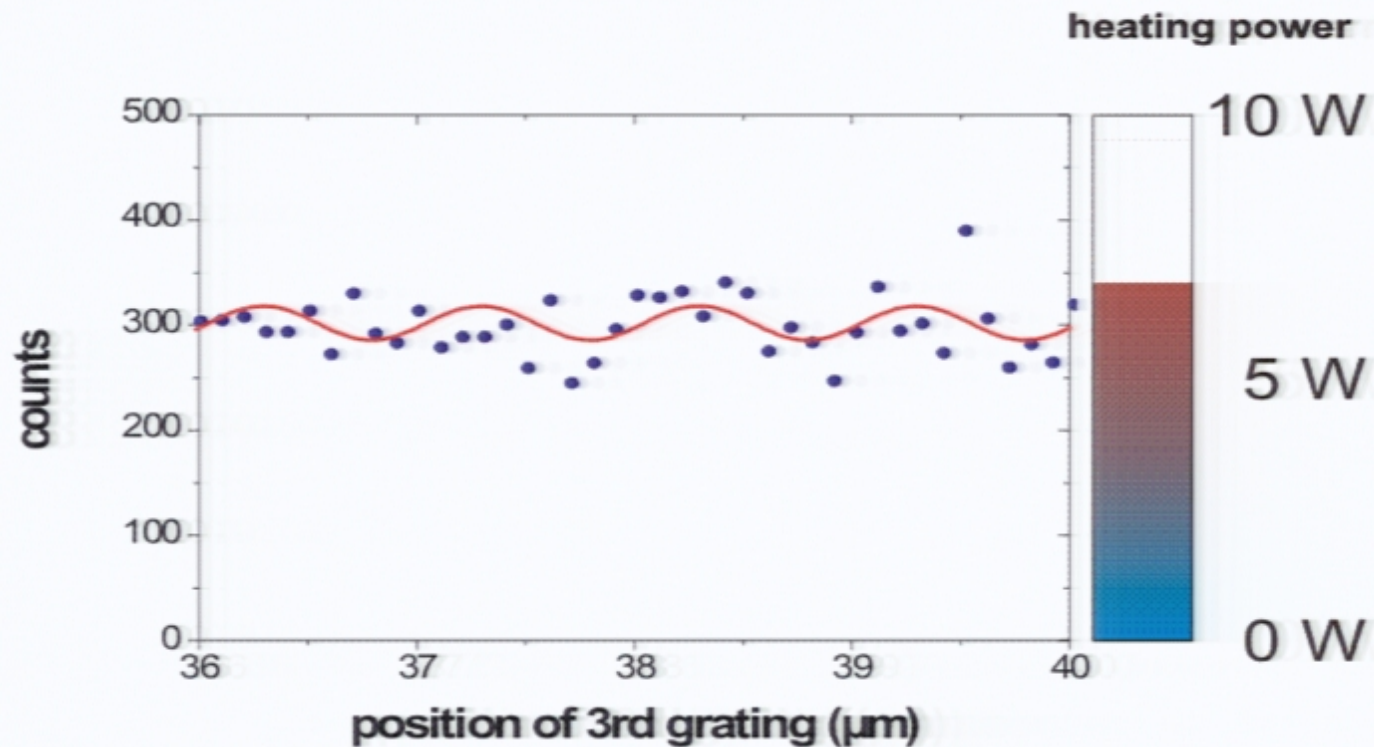
Interference patterns for Increasing heating laser power



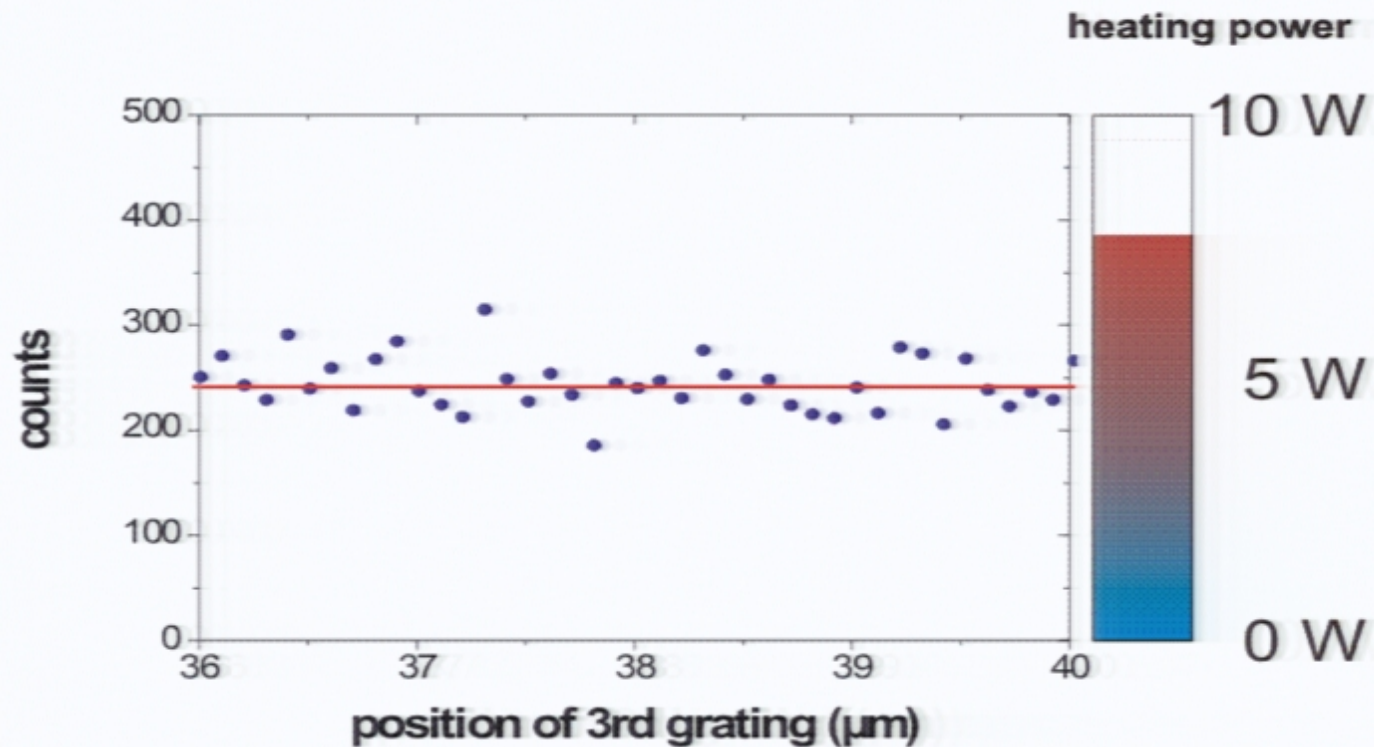
Interference patterns for Increasing heating laser power



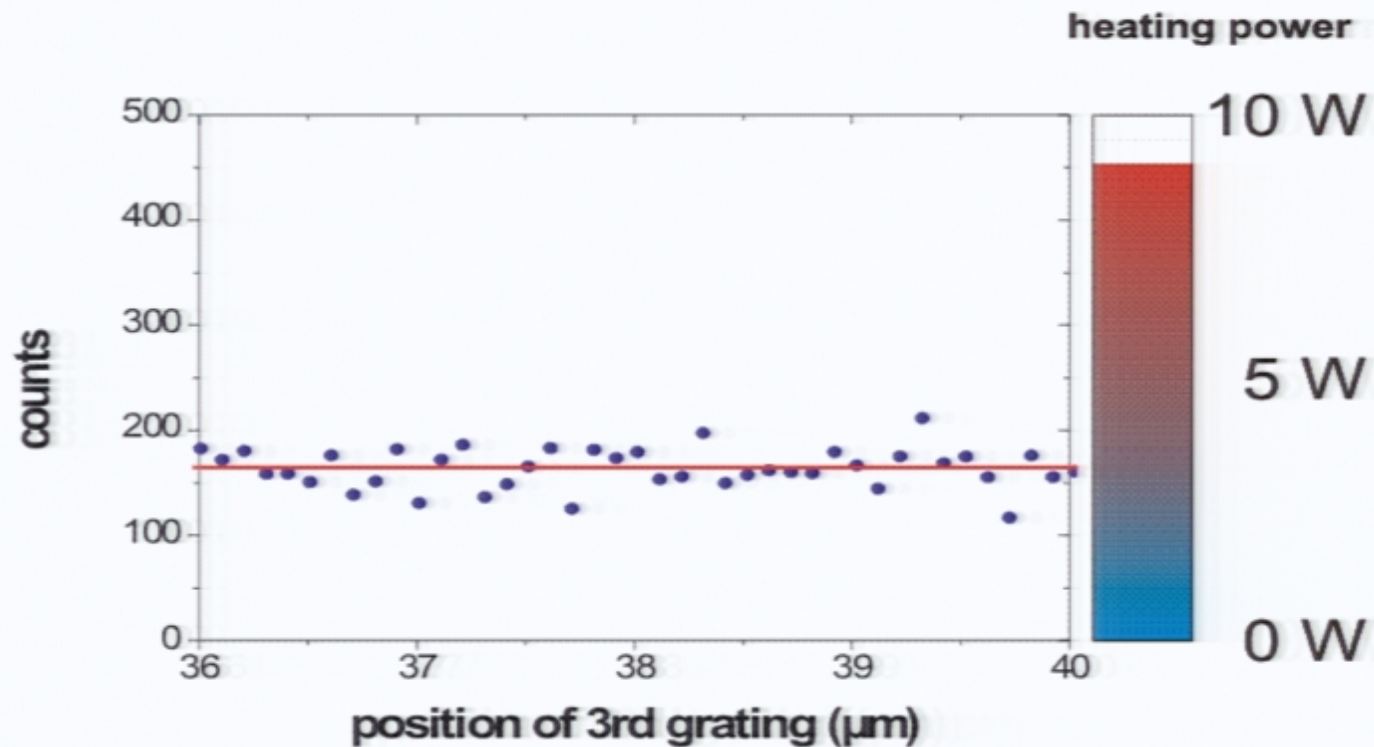
Interference patterns for Increasing heating laser power



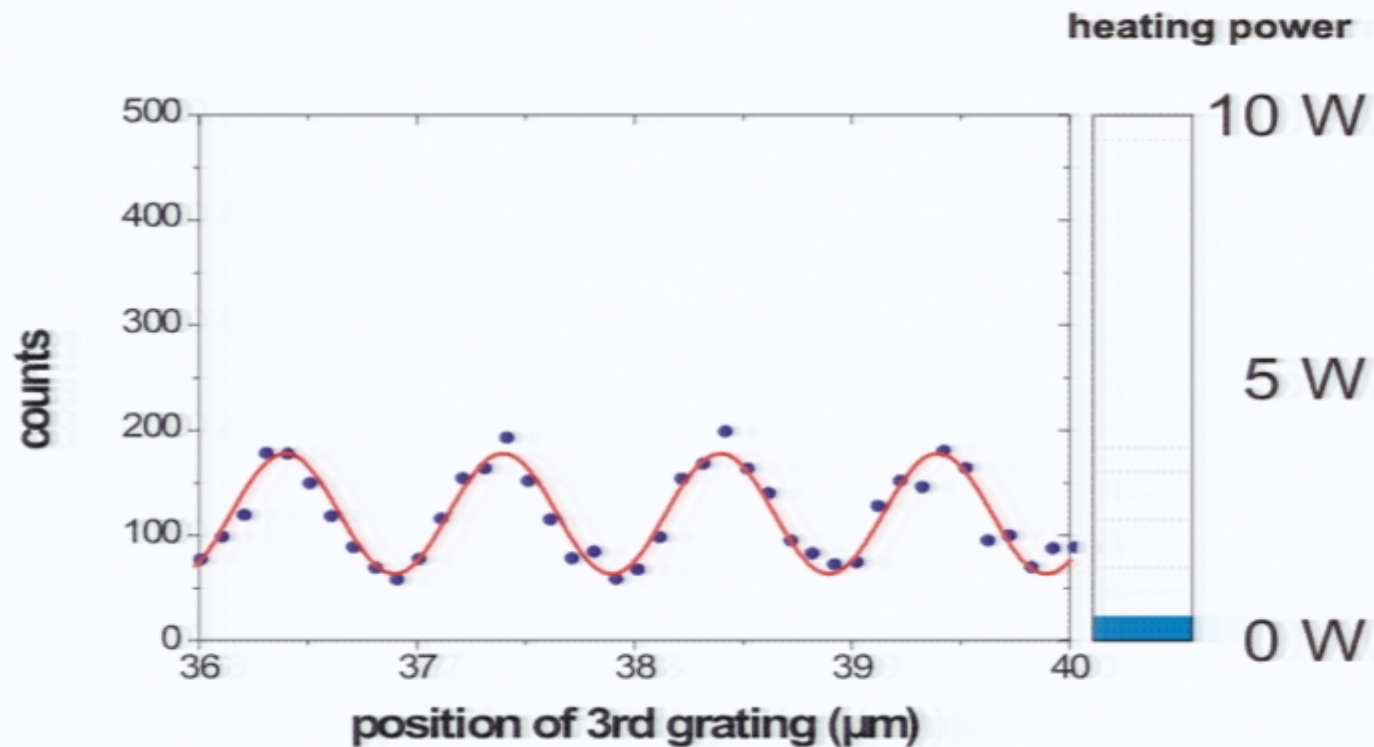
Interference patterns for Increasing heating laser power



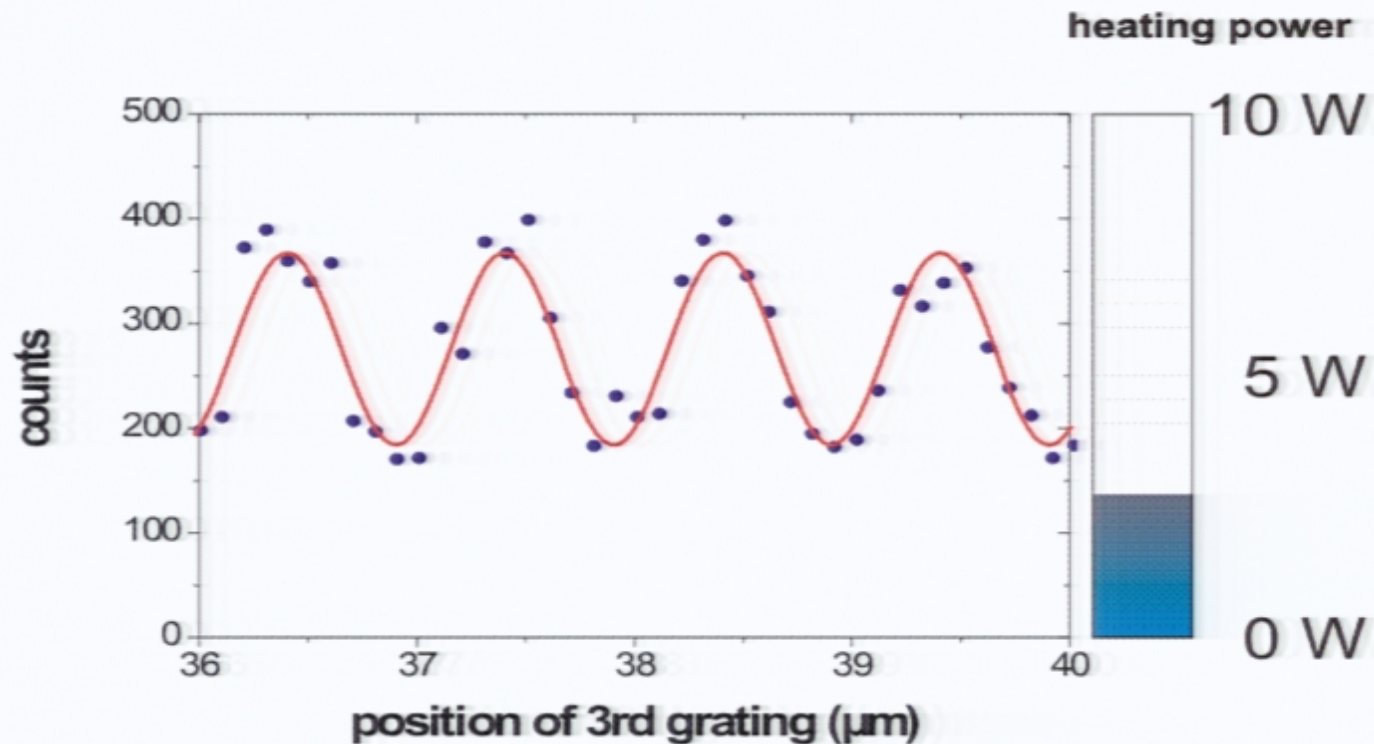
Interference patterns for Increasing heating laser power



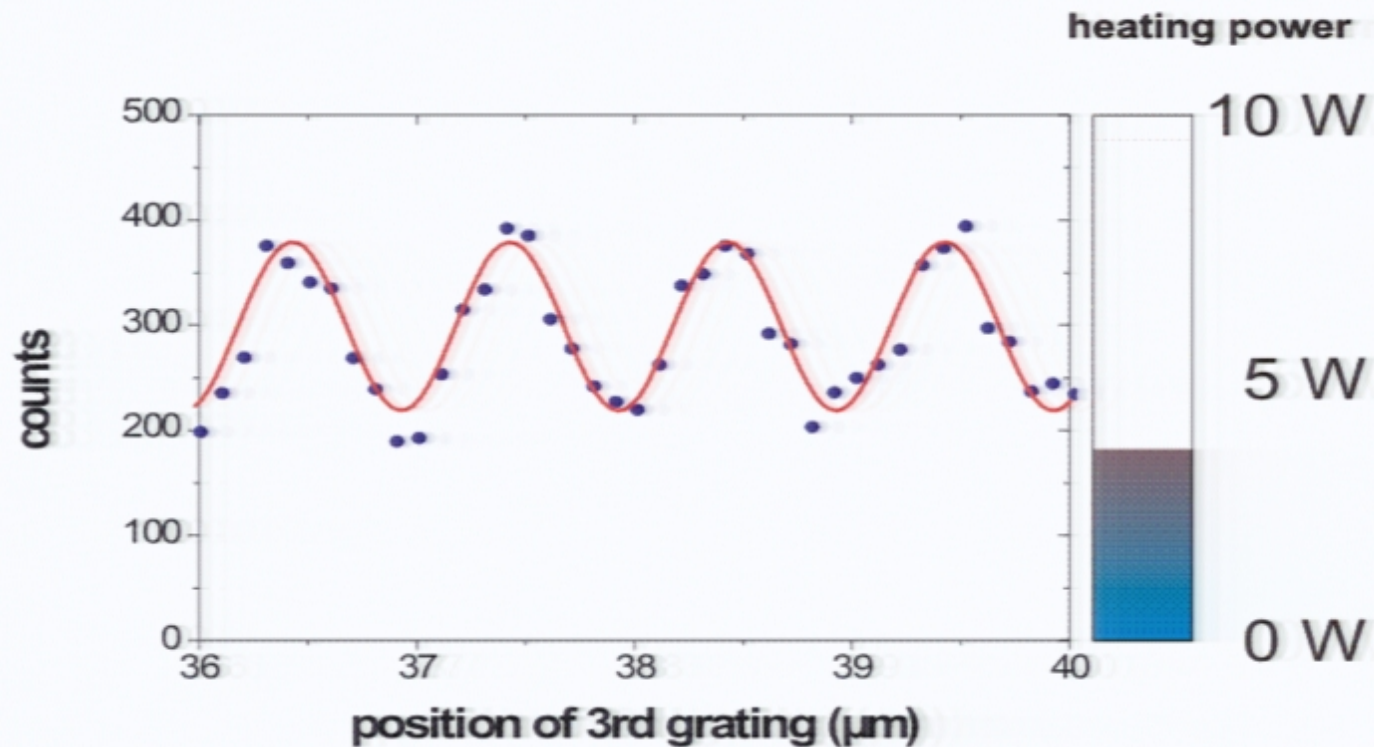
Interference patterns for Increasing heating laser power



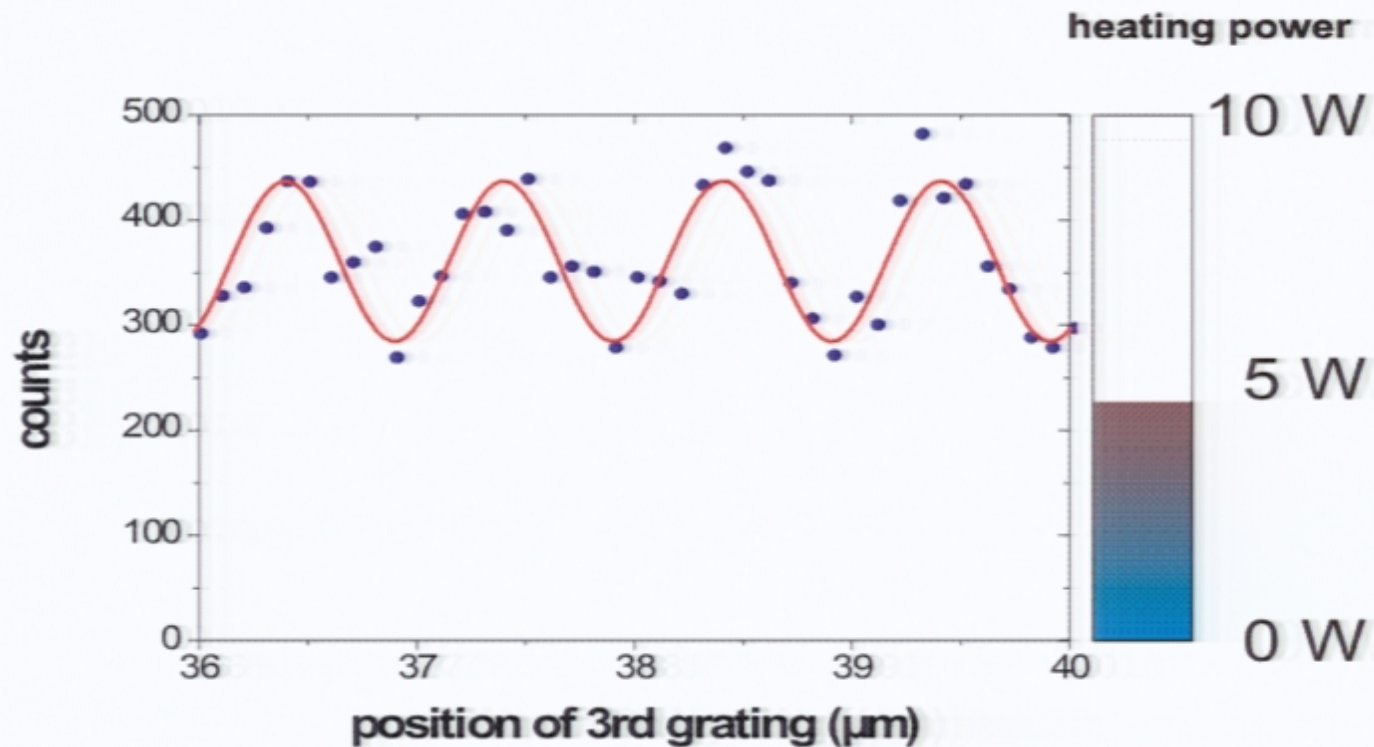
Interference patterns for Increasing heating laser power



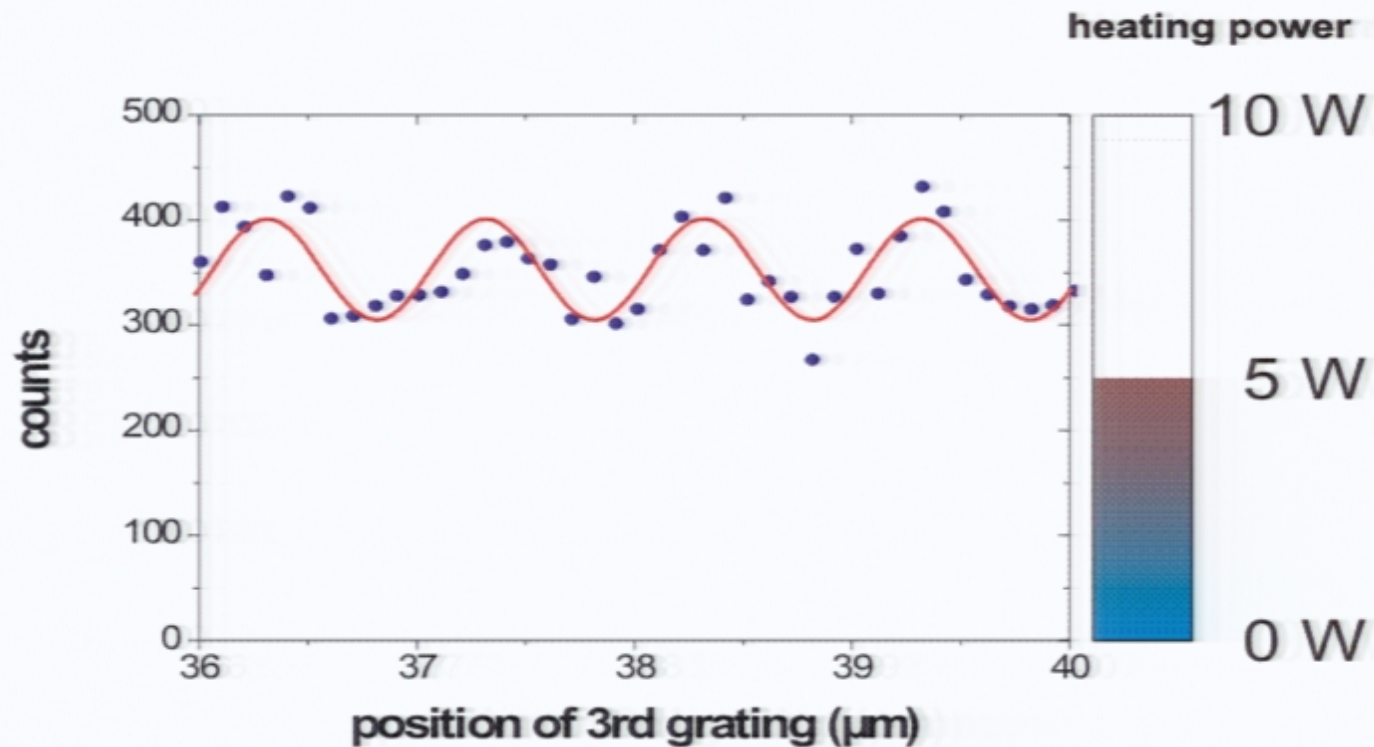
Interference patterns for Increasing heating laser power



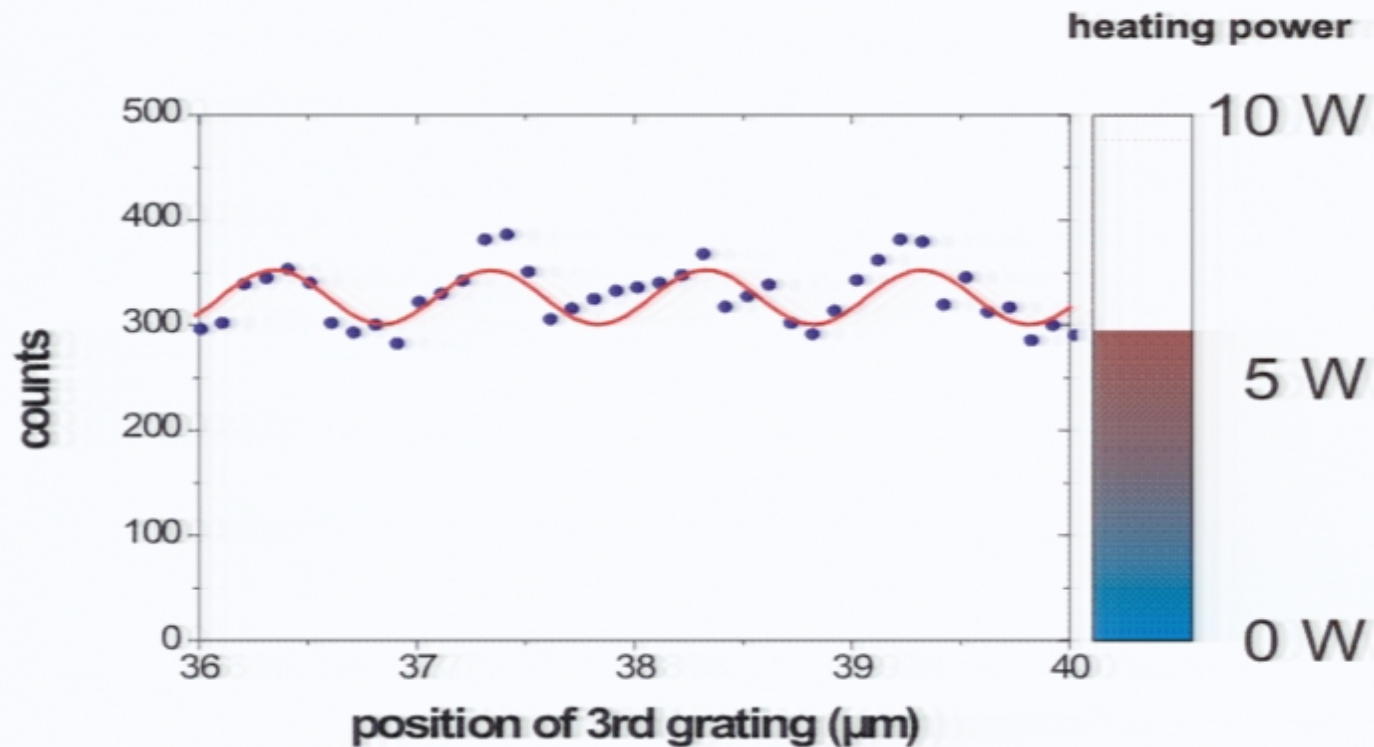
Interference patterns for Increasing heating laser power



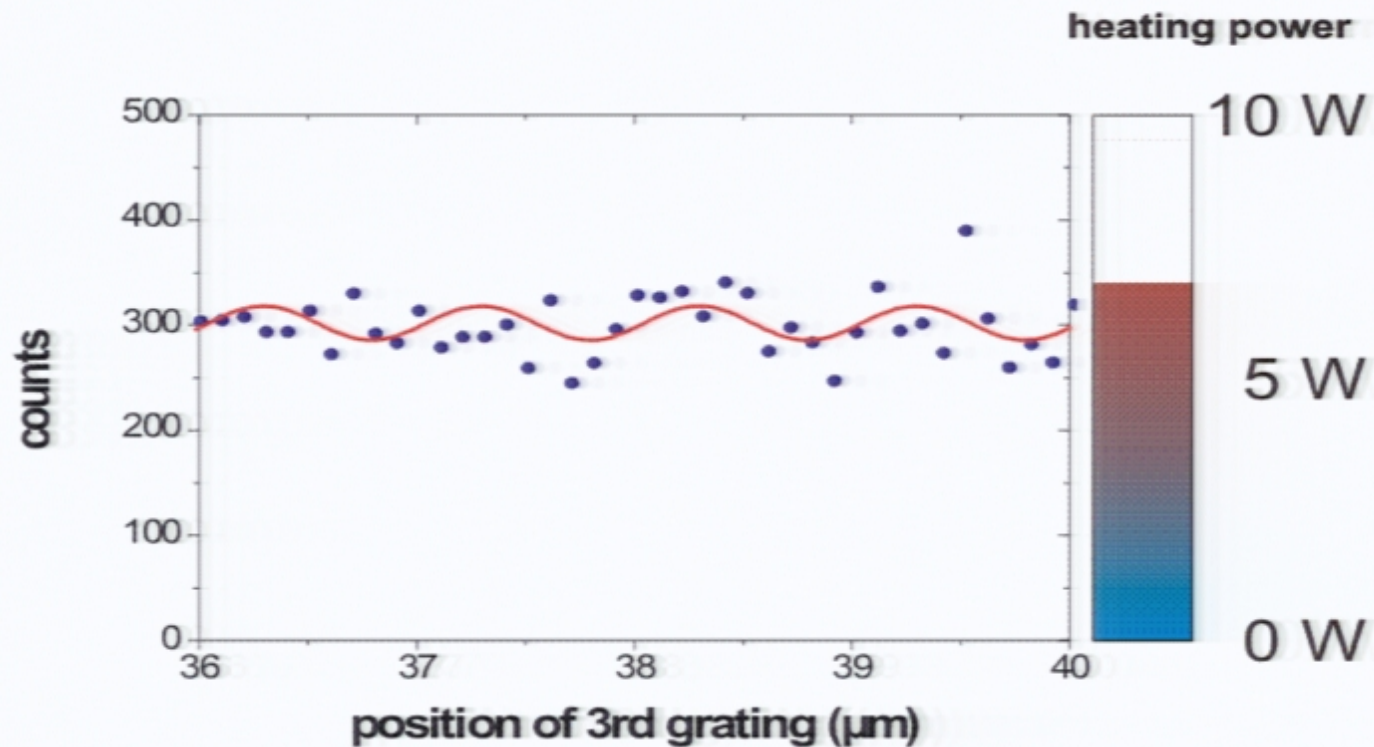
Interference patterns for Increasing heating laser power



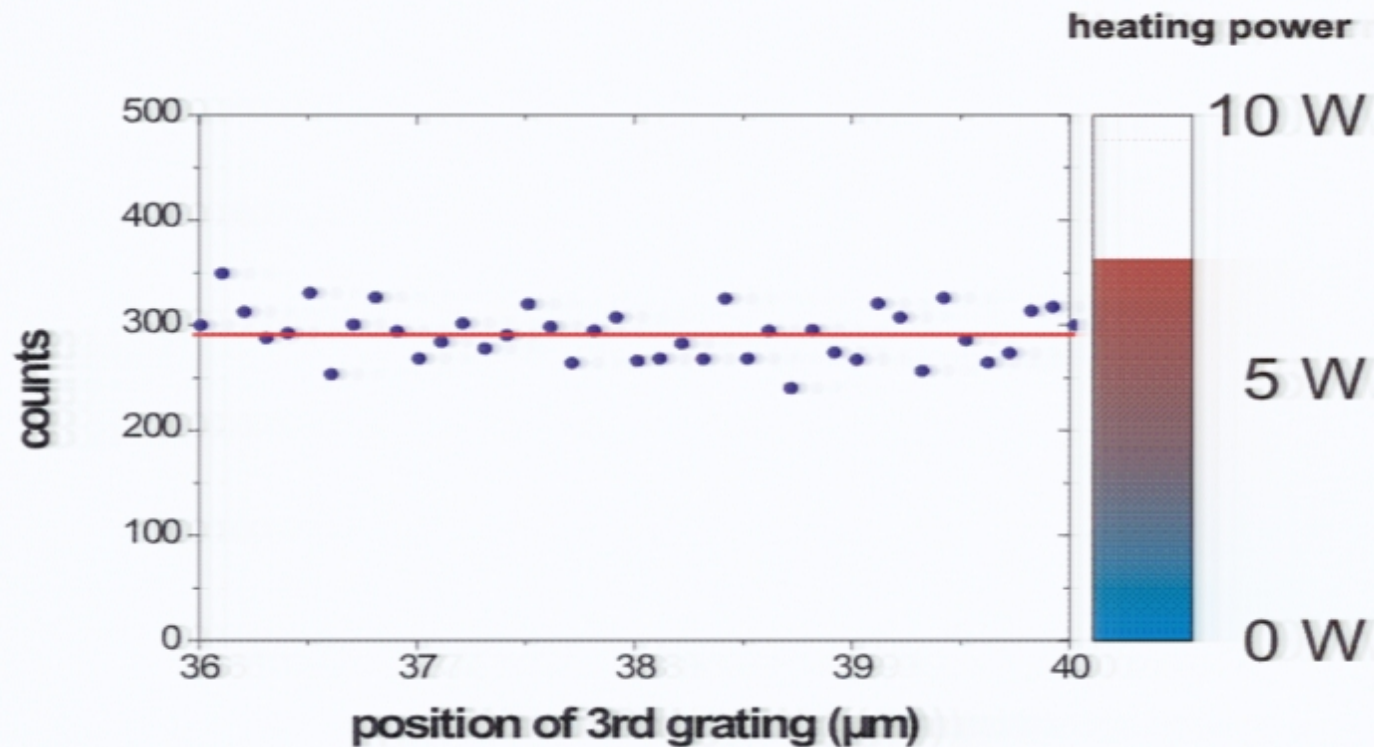
Interference patterns for Increasing heating laser power



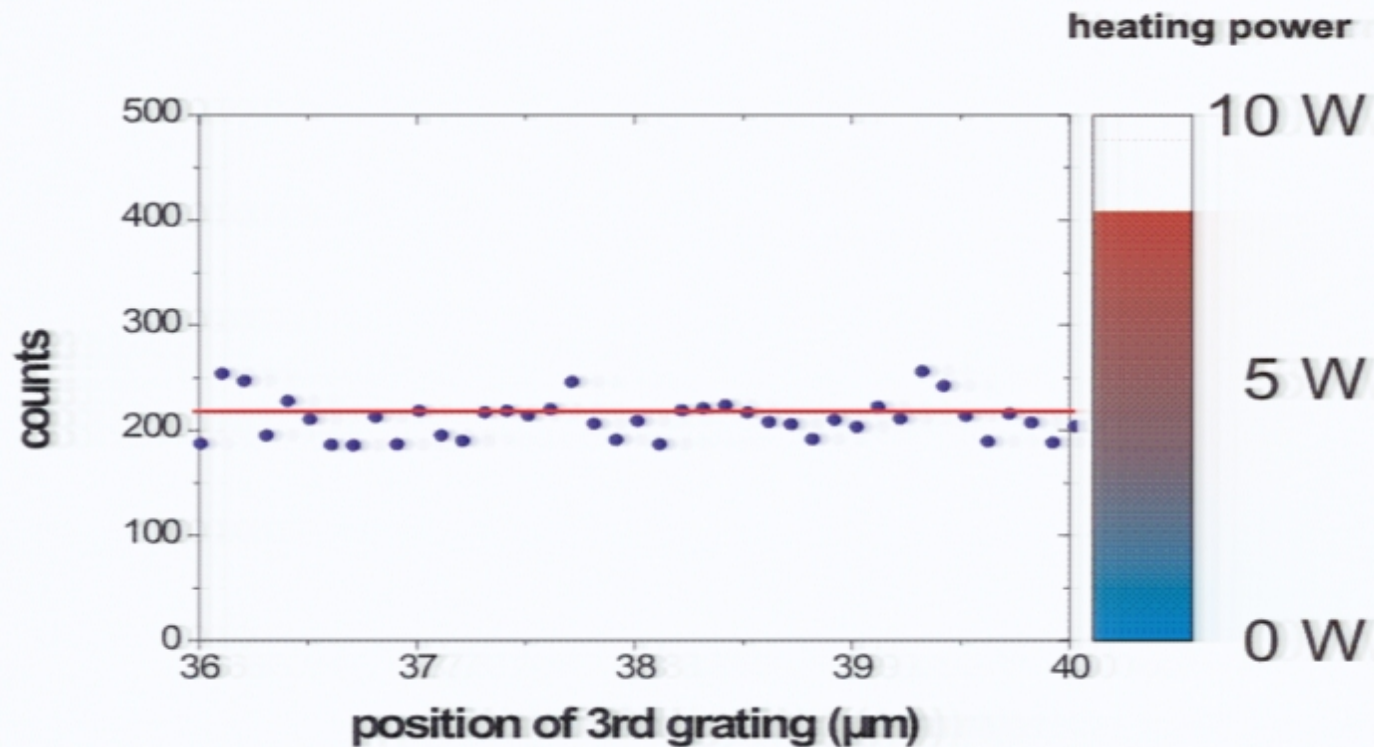
Interference patterns for Increasing heating laser power



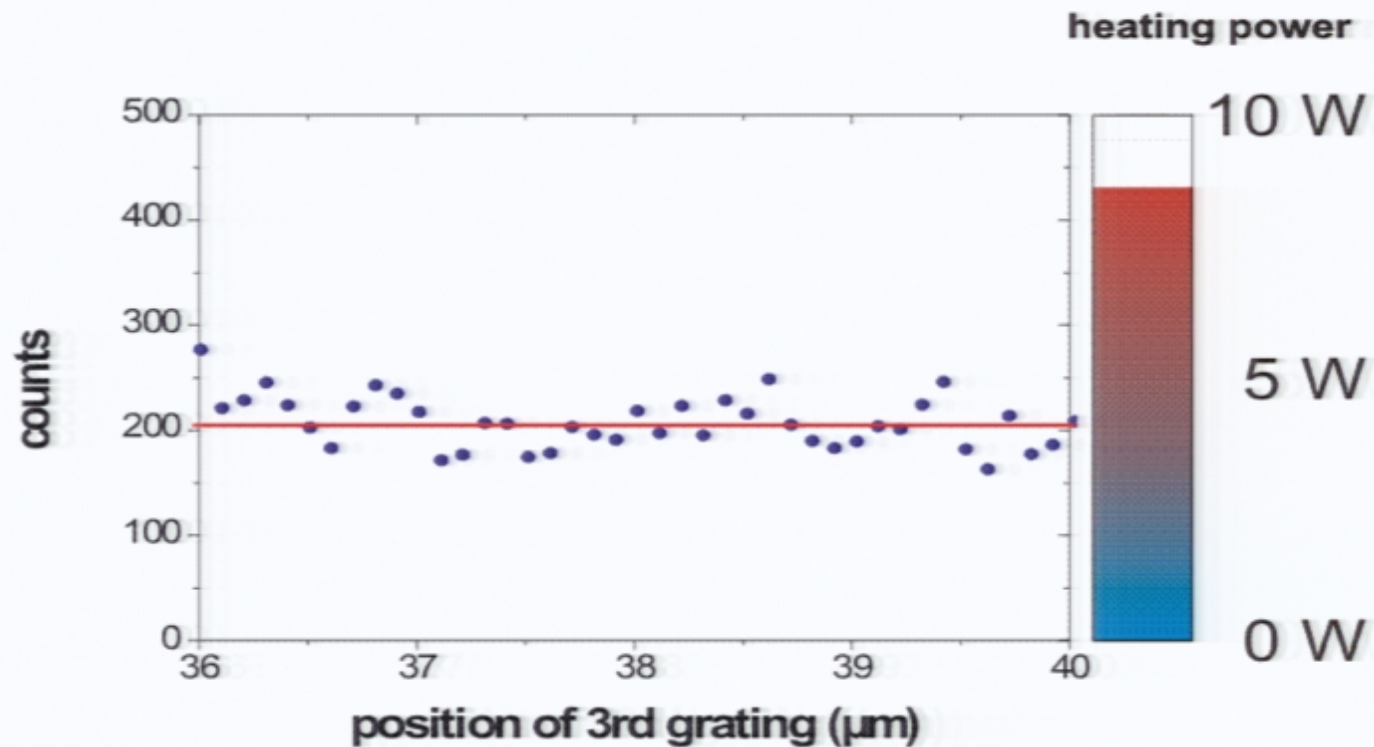
Interference patterns for Increasing heating laser power



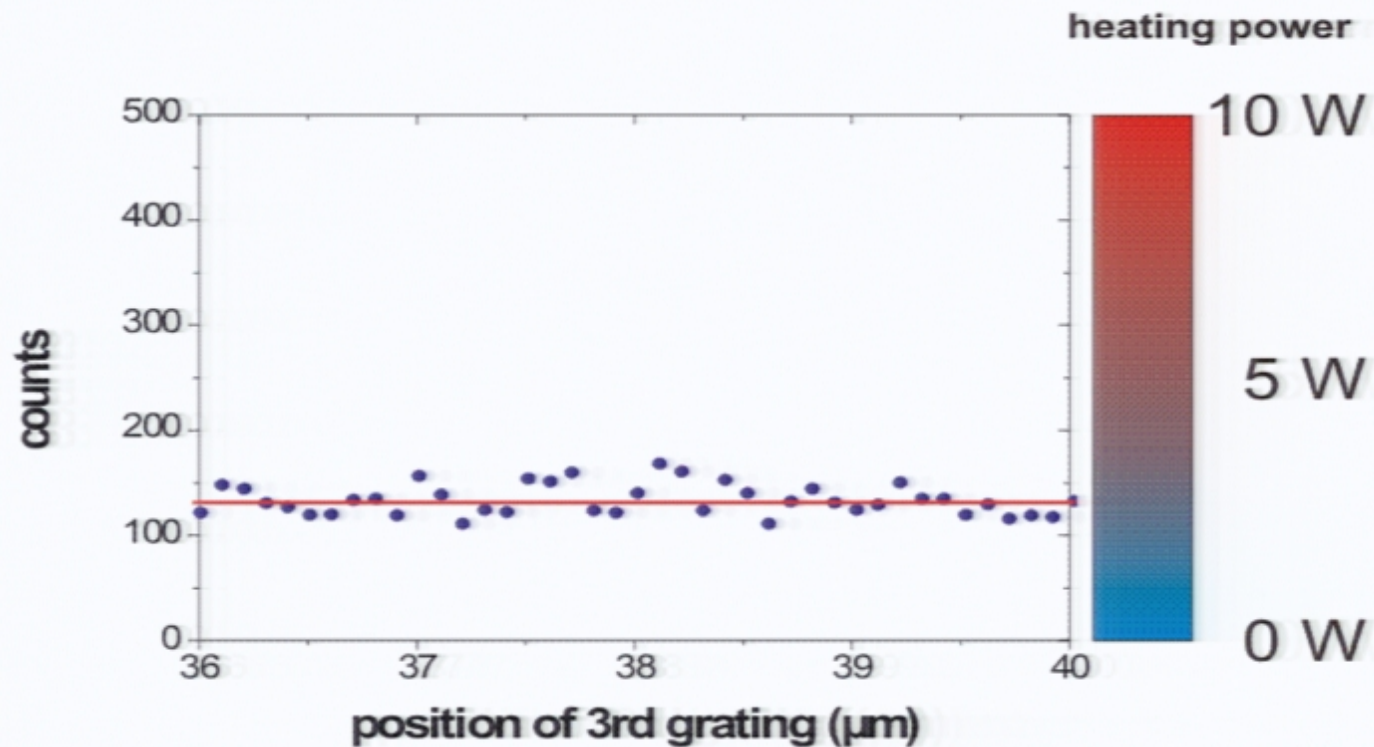
Interference patterns for Increasing heating laser power



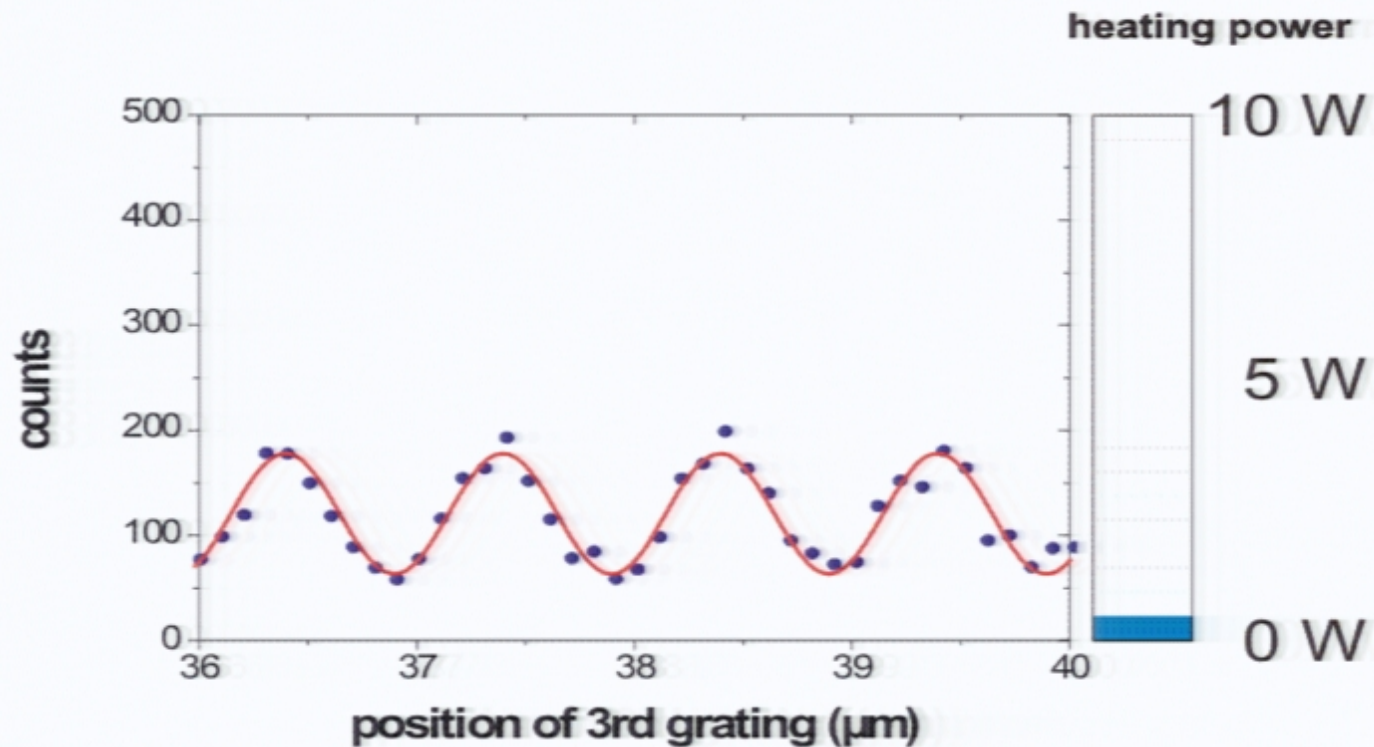
Interference patterns for Increasing heating laser power



Interference patterns for Increasing heating laser power

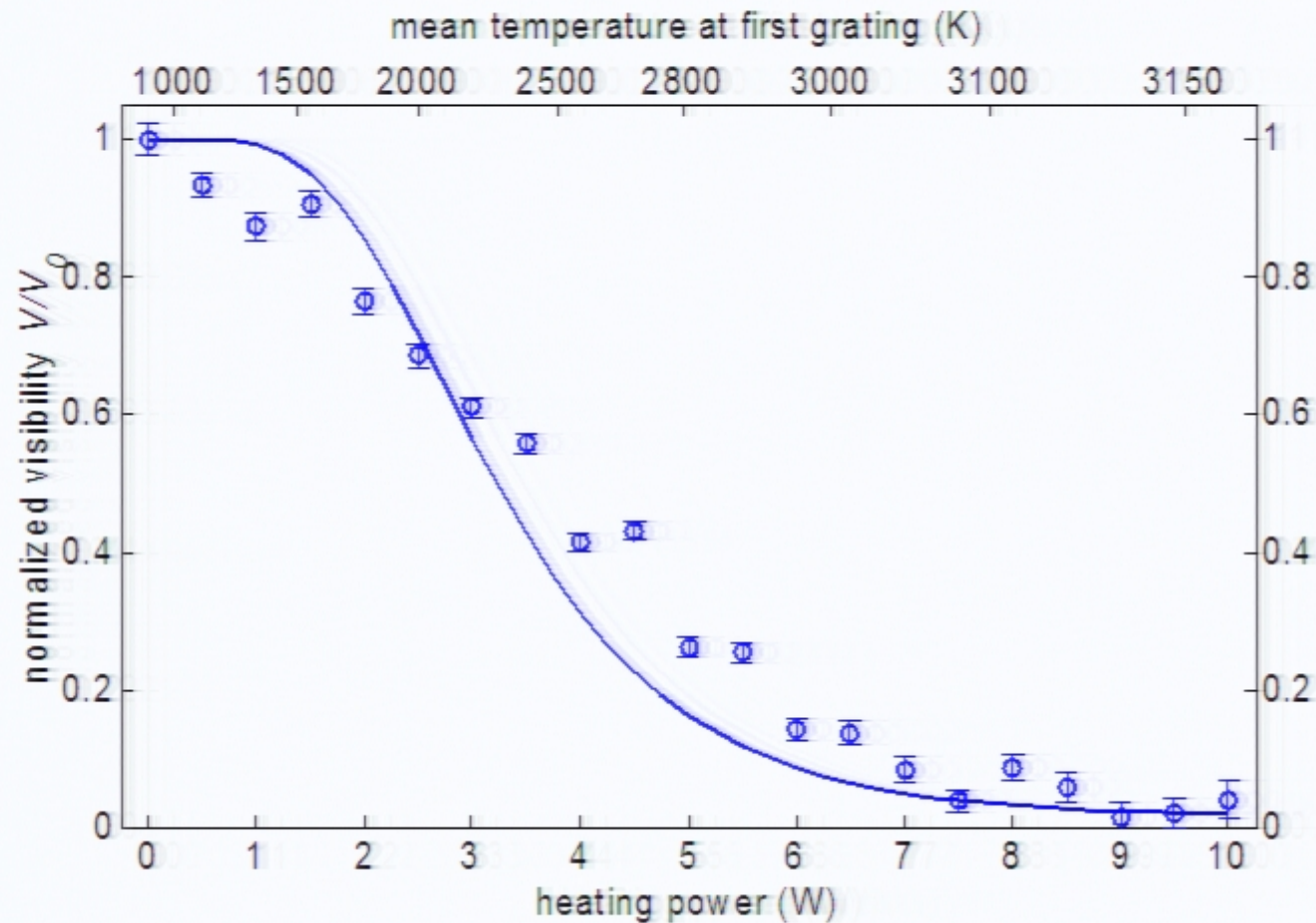


Interference patterns for Increasing heating laser power



Thermal Decoherence of C_{70}

Comparison between Experiment & Theory



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

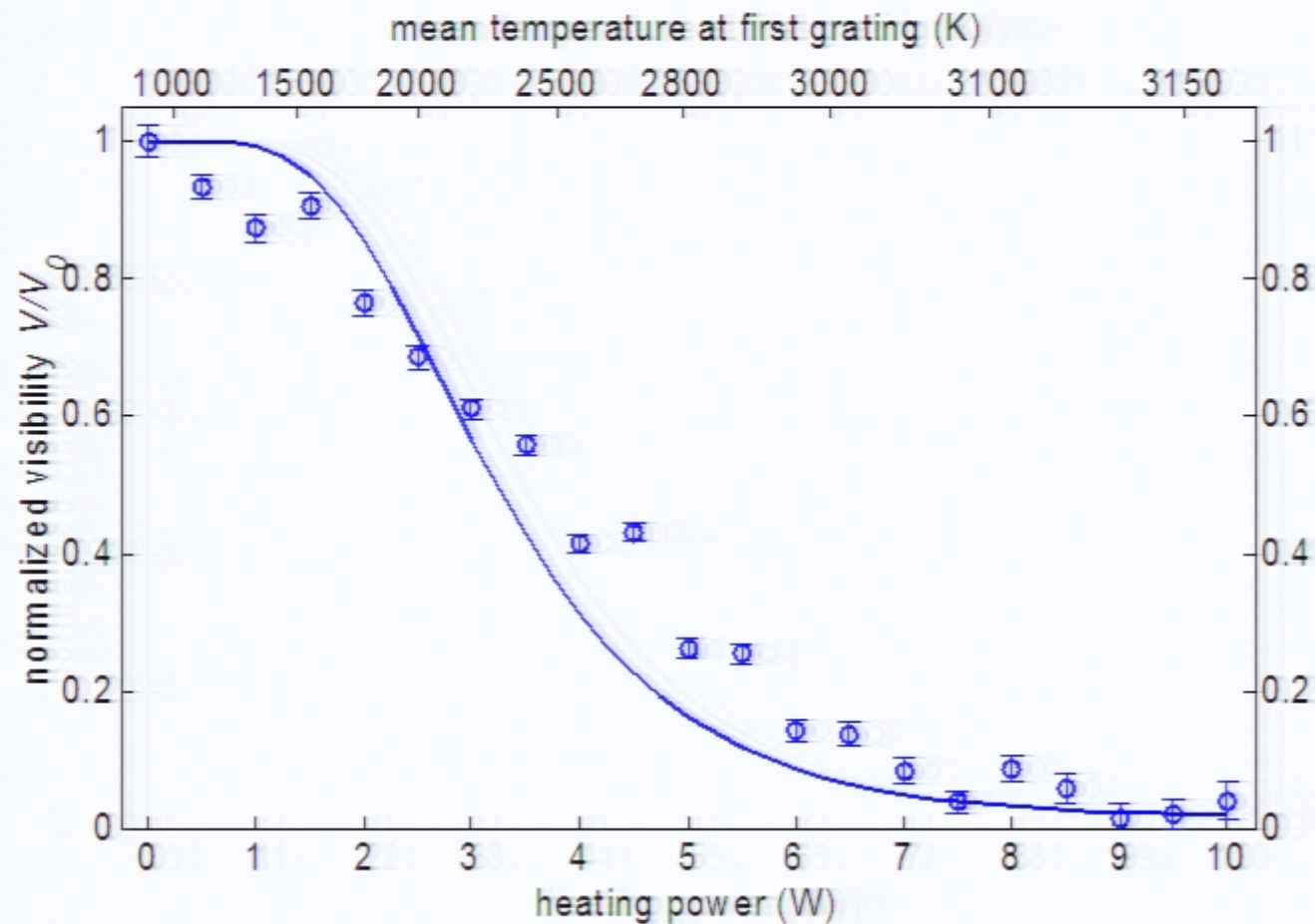
$$\Delta x \cdot \Delta p \sim h$$



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

Thermal Decoherence of C_{70}

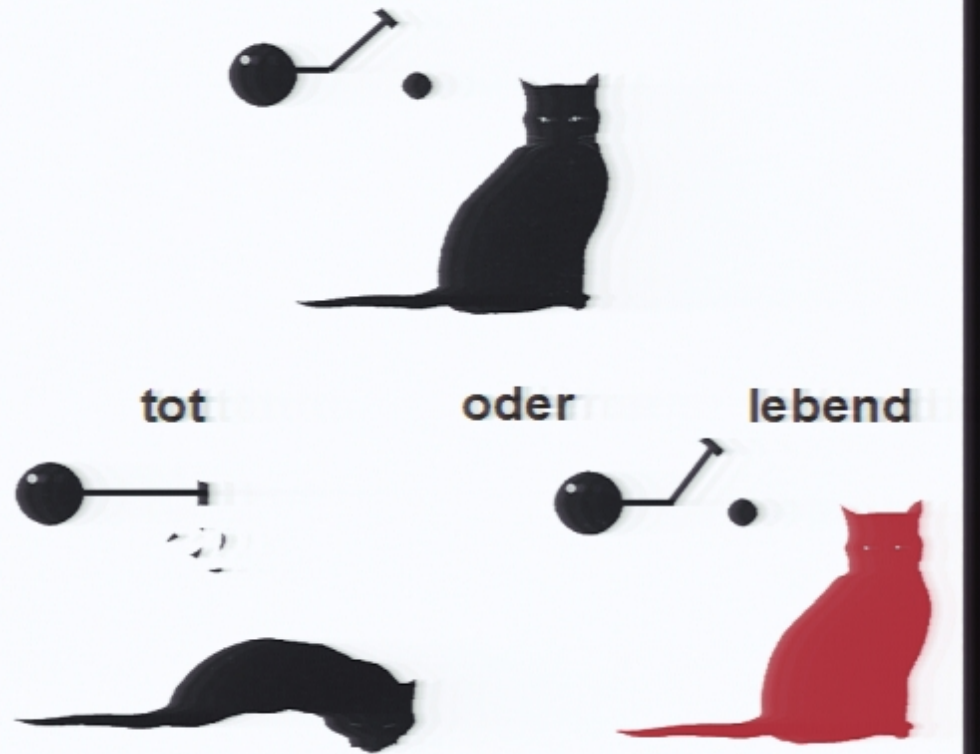
Comparison between Experiment & Theory



Schrödinger's Cat

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

Pirsa. 05030079



quantenmechanische Superposition

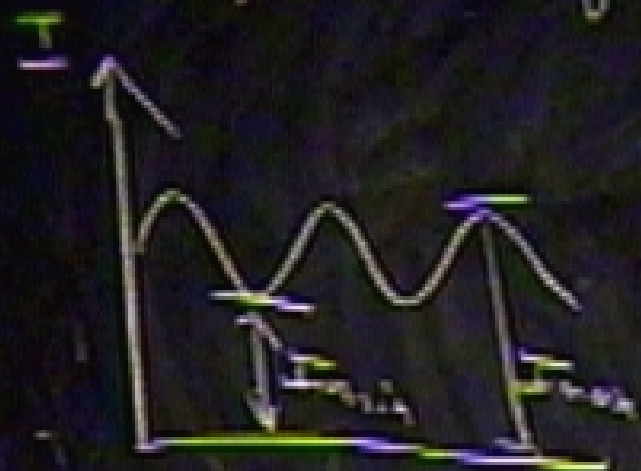


$$\Delta x \cdot \Delta p \geq \frac{\hbar}{2}$$

$$\Delta x \cdot \Delta p \sim \hbar$$

$$10^7 \text{ amu}$$

$$T \approx 300 \text{ K}$$



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