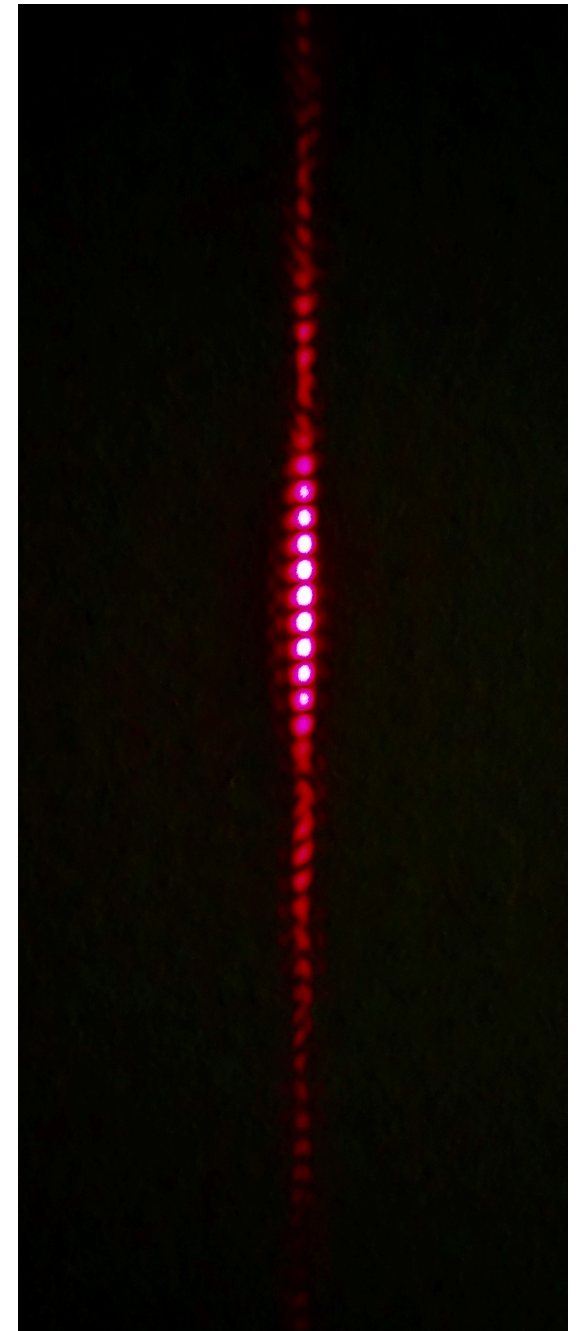
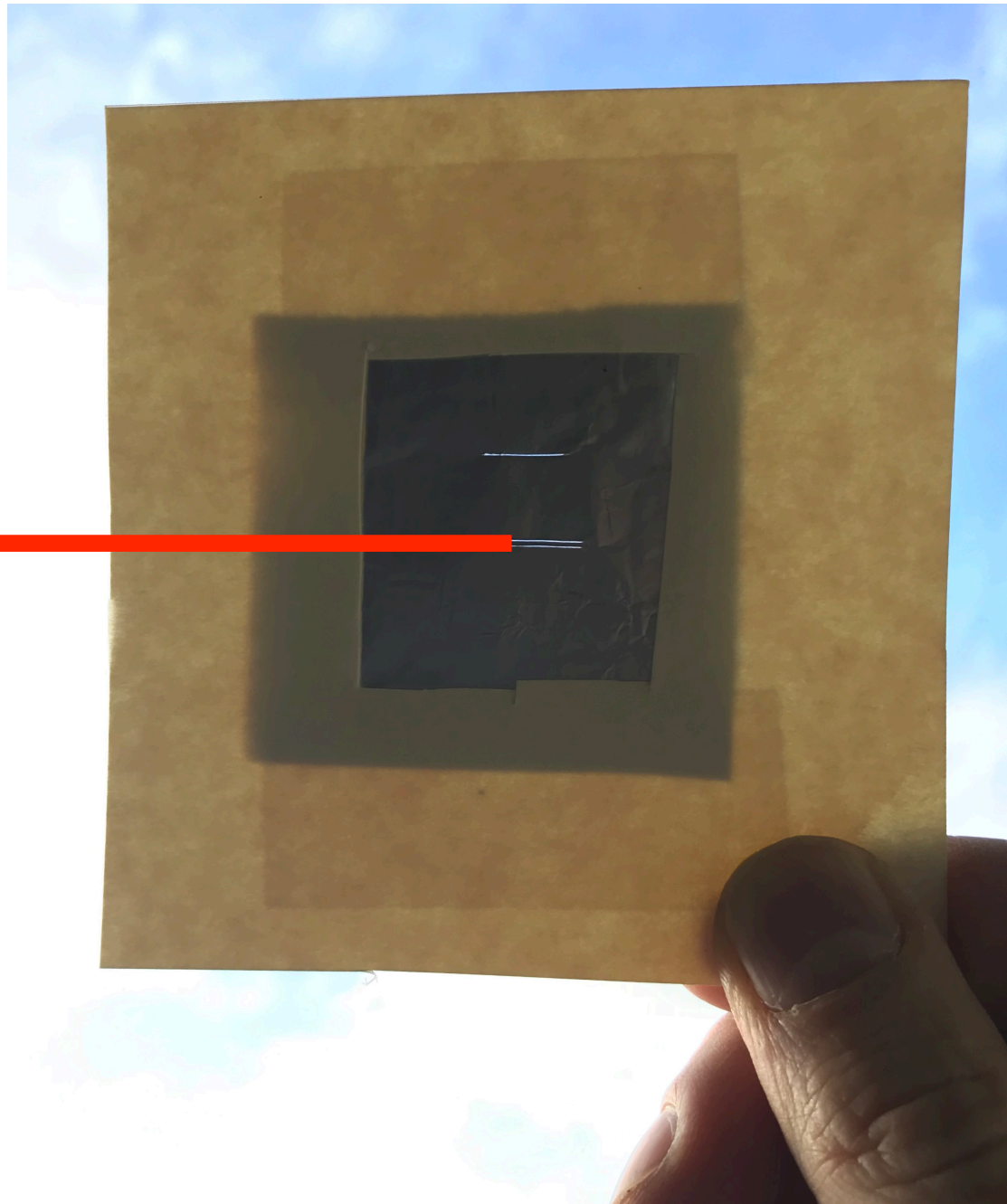
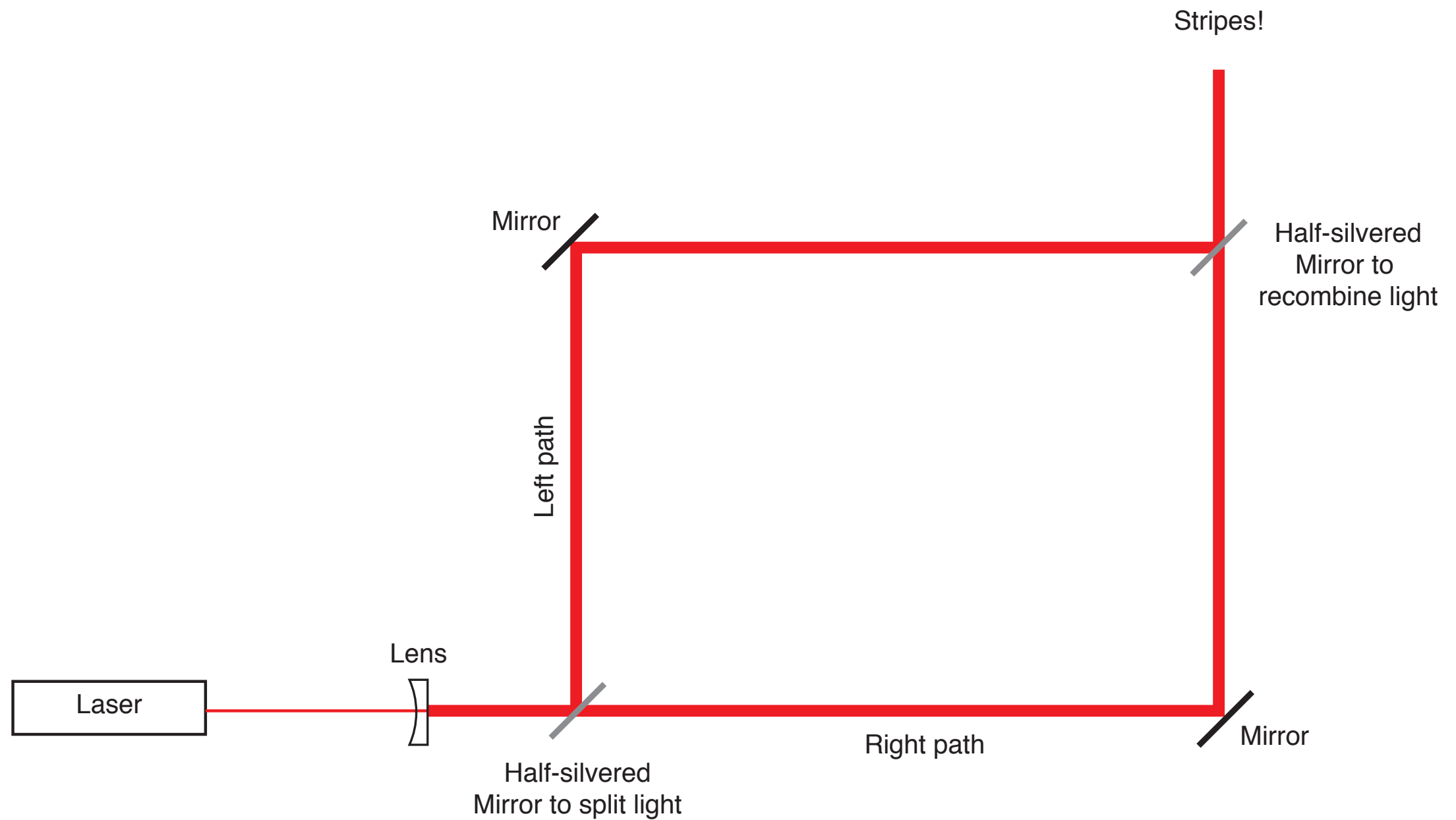


Particles

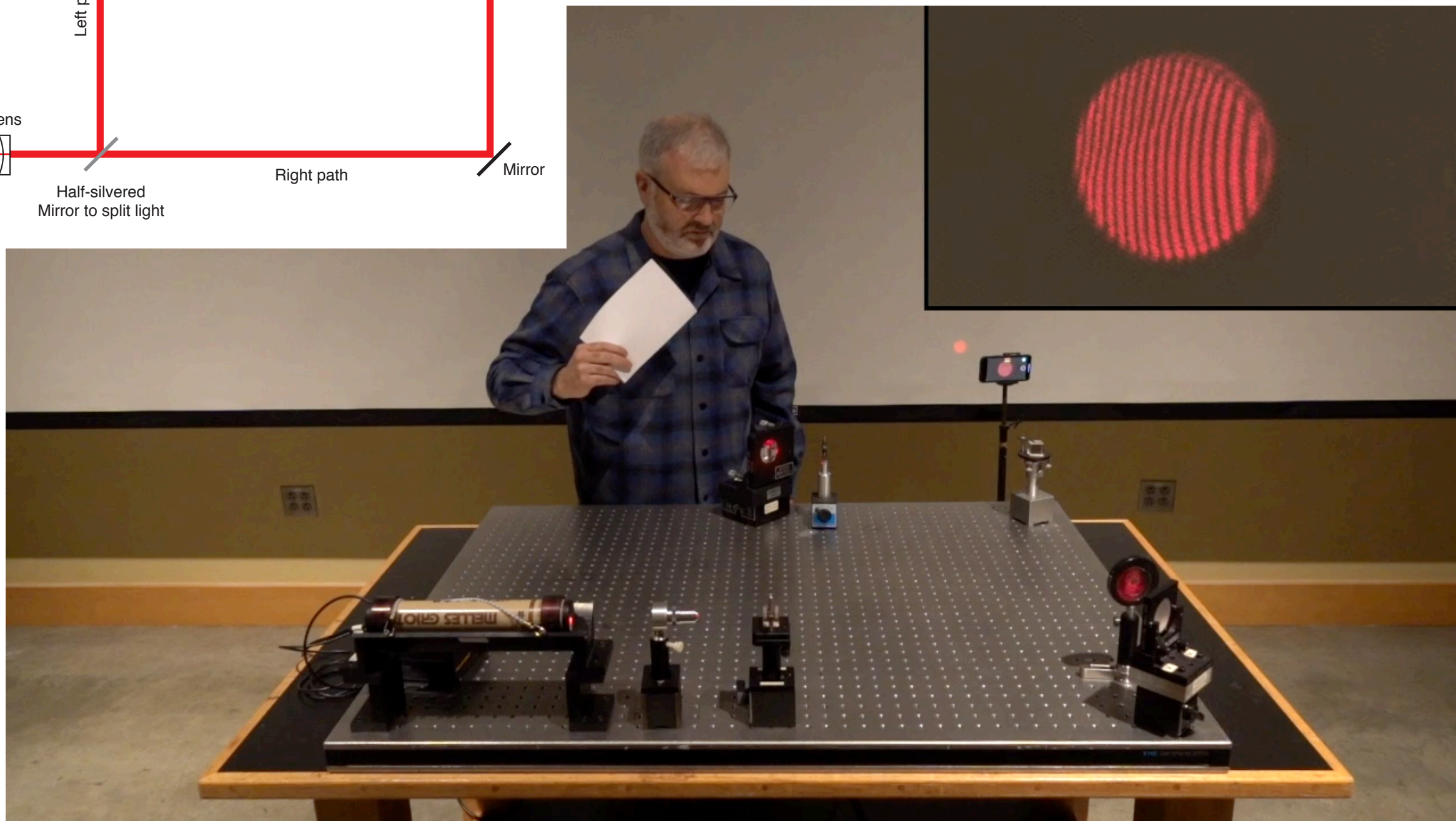
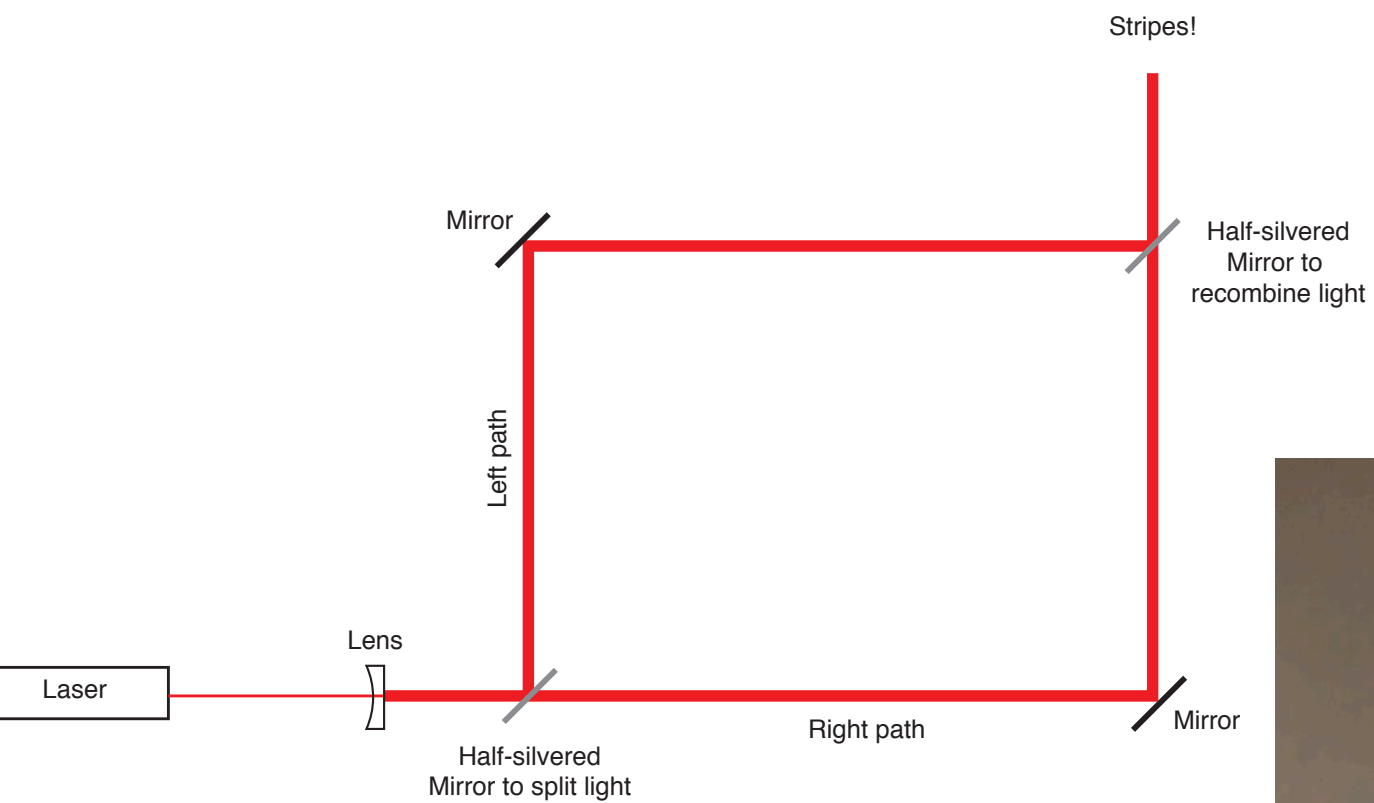
Double slit

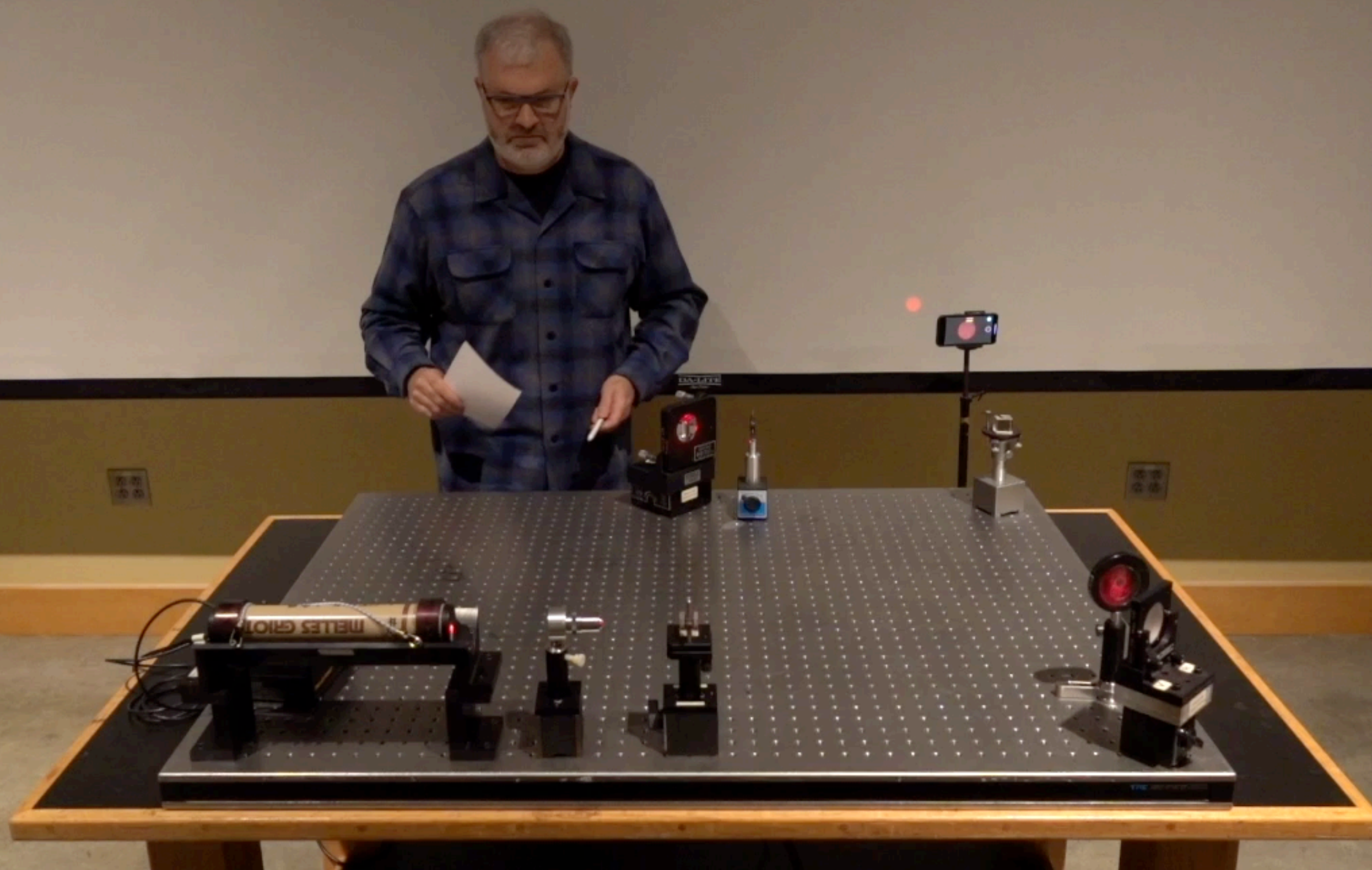


Bigger

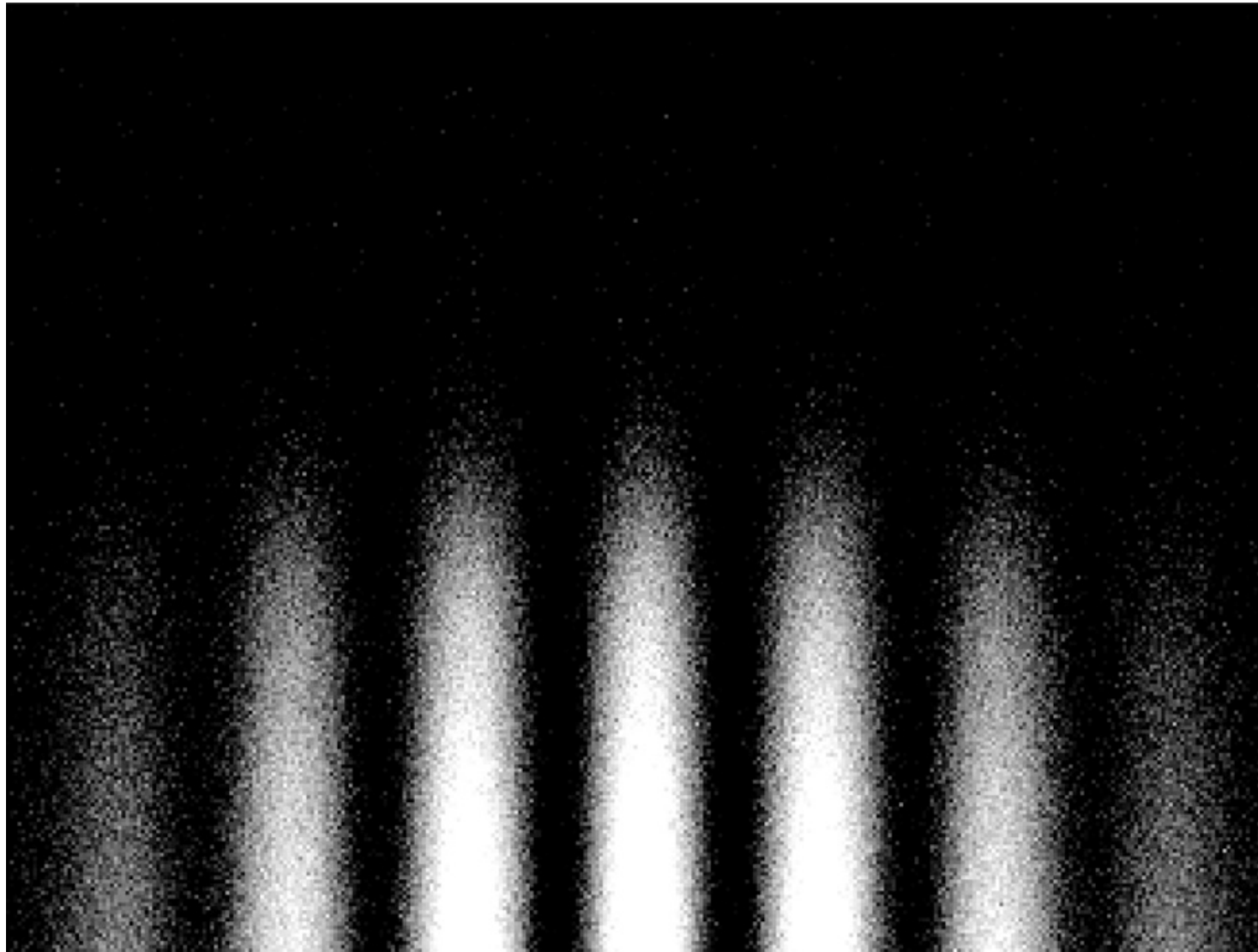


Bigger

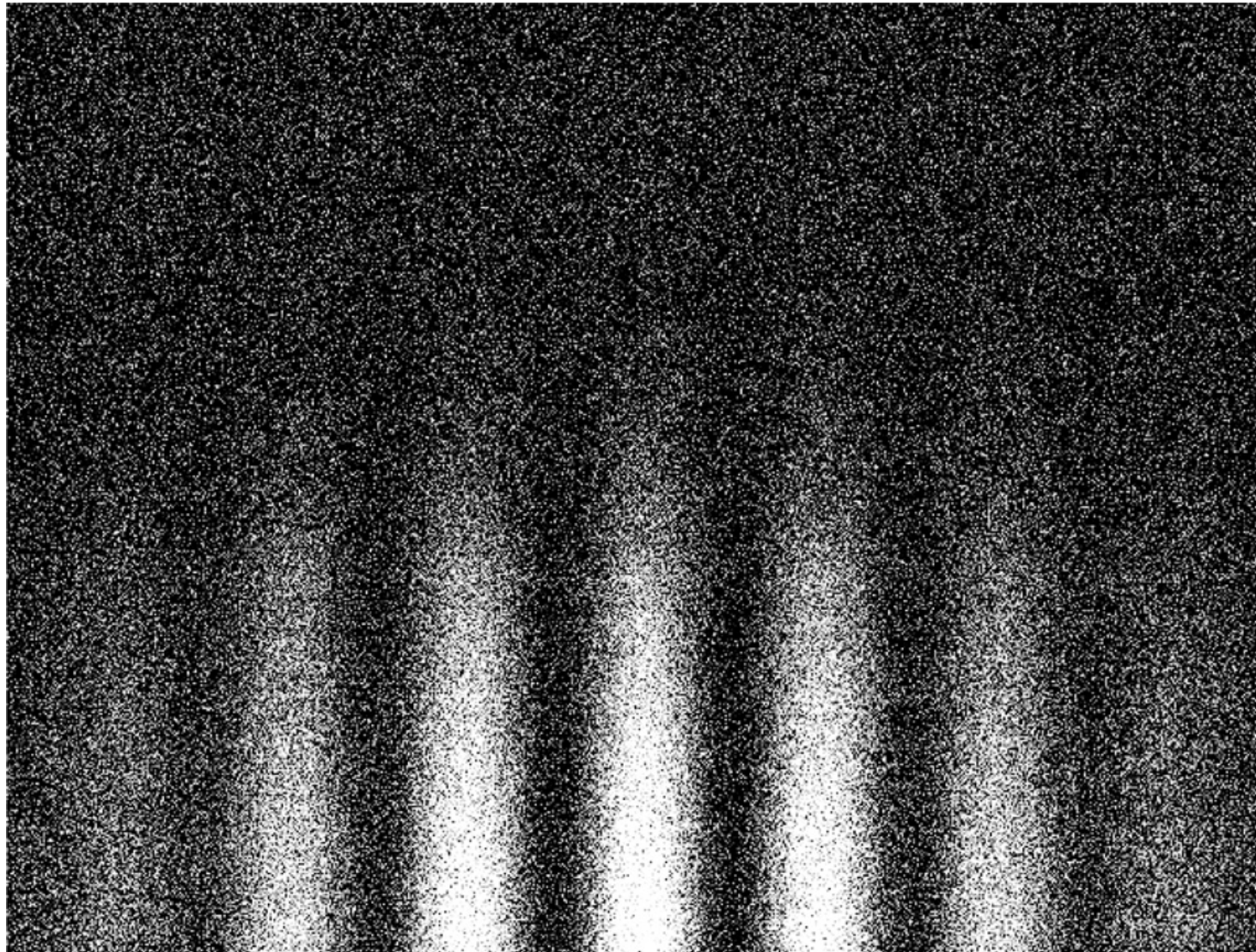




Bright laser



Dimmer

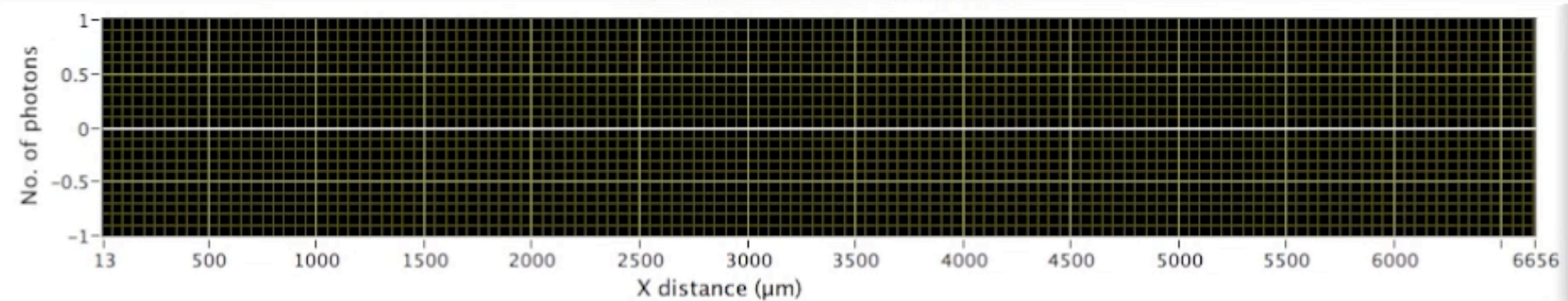


Young's double slit with a coherent source photon by photon

Vertical
Cross
Section

No. of photons= 0

Vertical cross section

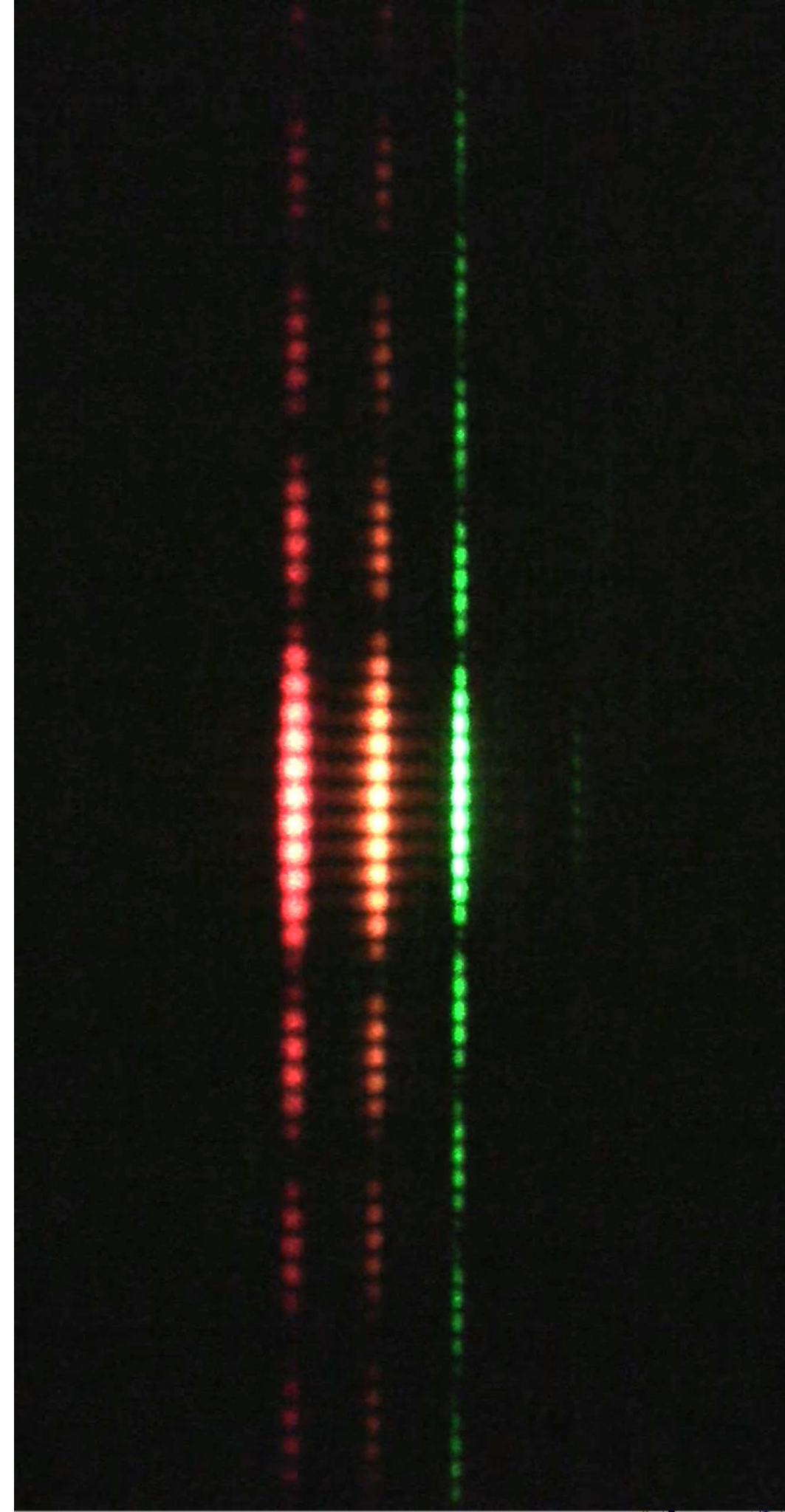


Photons

- Hit the screen like little paintballs

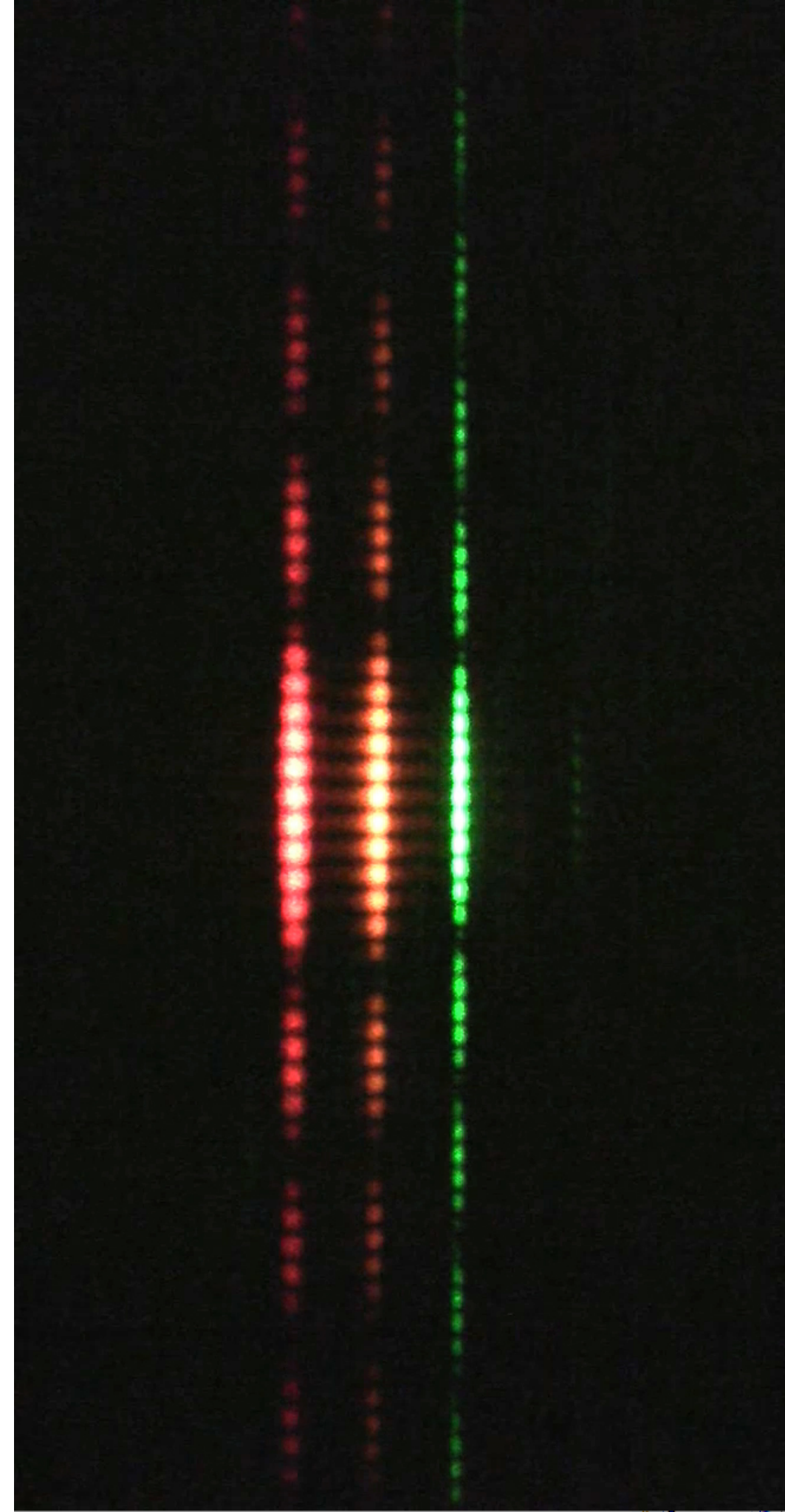
How hard do they hit?

- With fancy detectors, can measure how much each pixel heats up when hit—how hard it was hit.



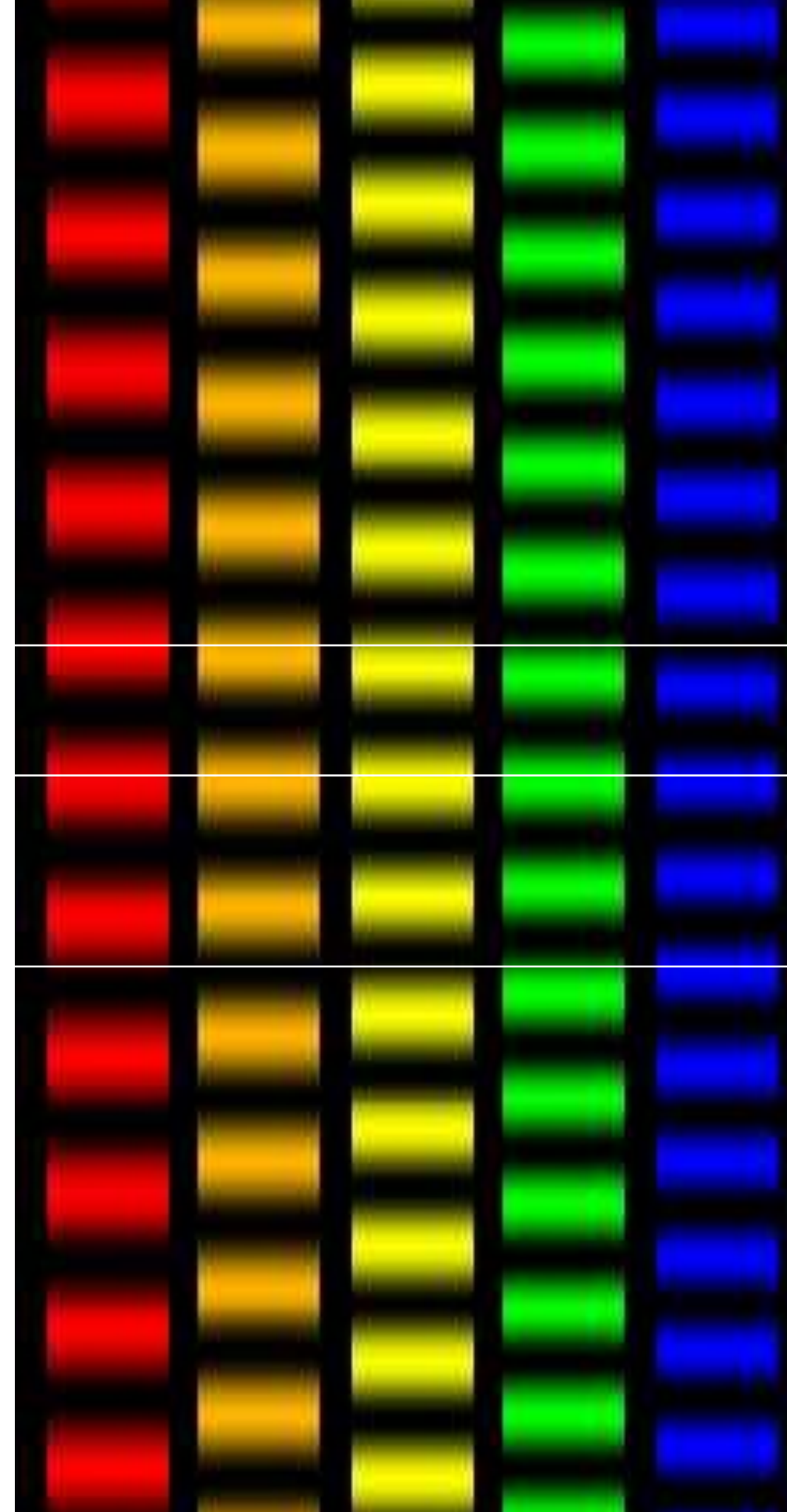
How hard do they hit?

- Every red photon hits with the same strength (energy)
- Every green photon hits with the same strength as other green photons; and harder than red photons



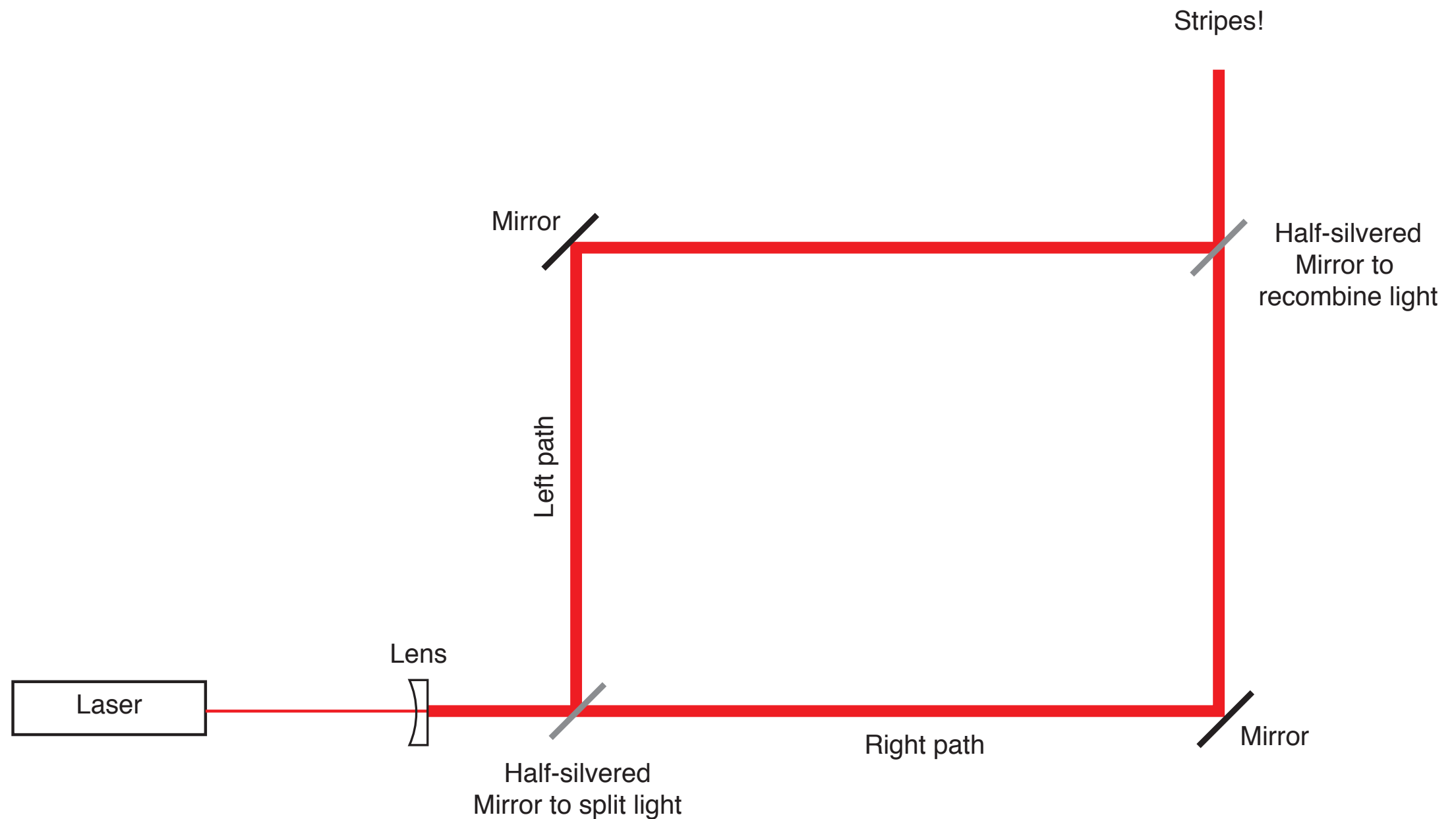
Color

- Color is related to the length of the wave (blue short, red long), *and*
- Color is related to how hard each photon hits (blue hard, red soft)

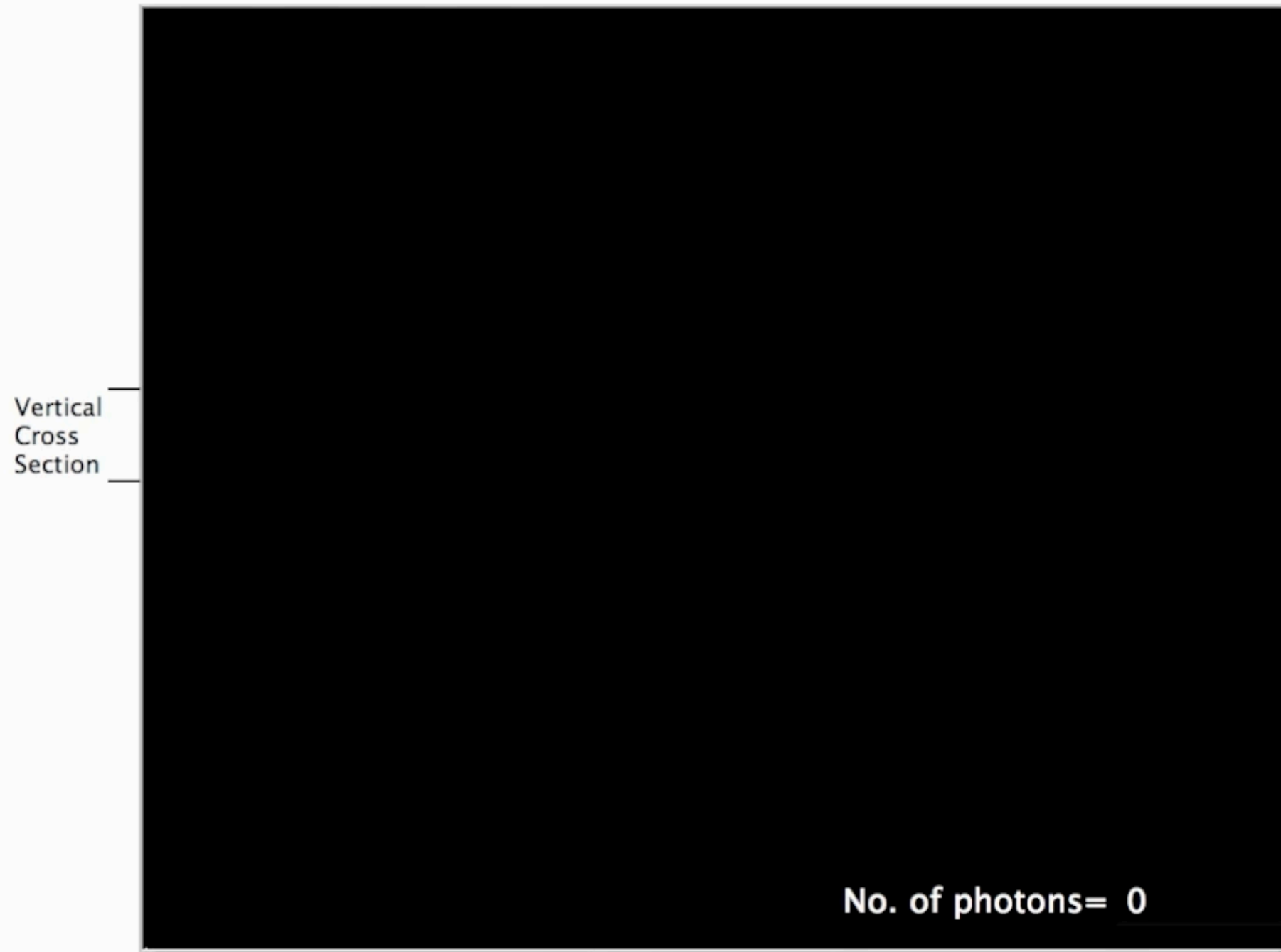


One photon at a time

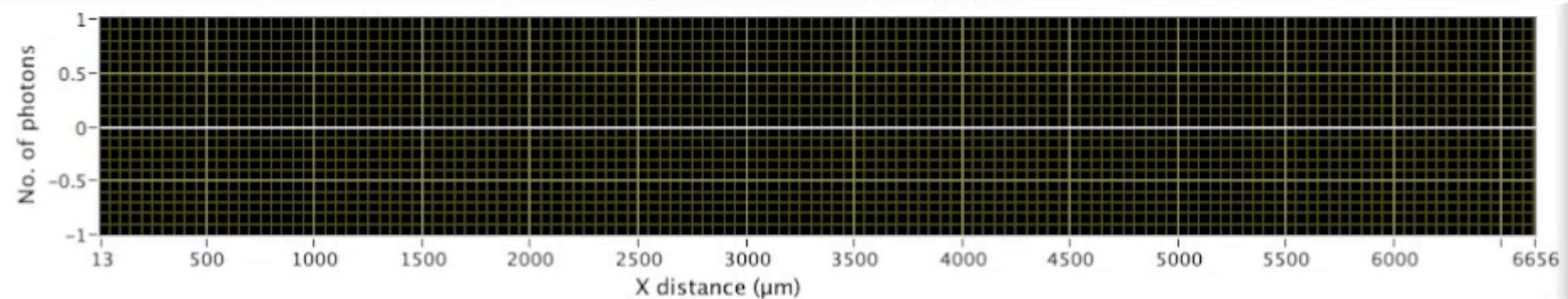
Which path did the photon take?



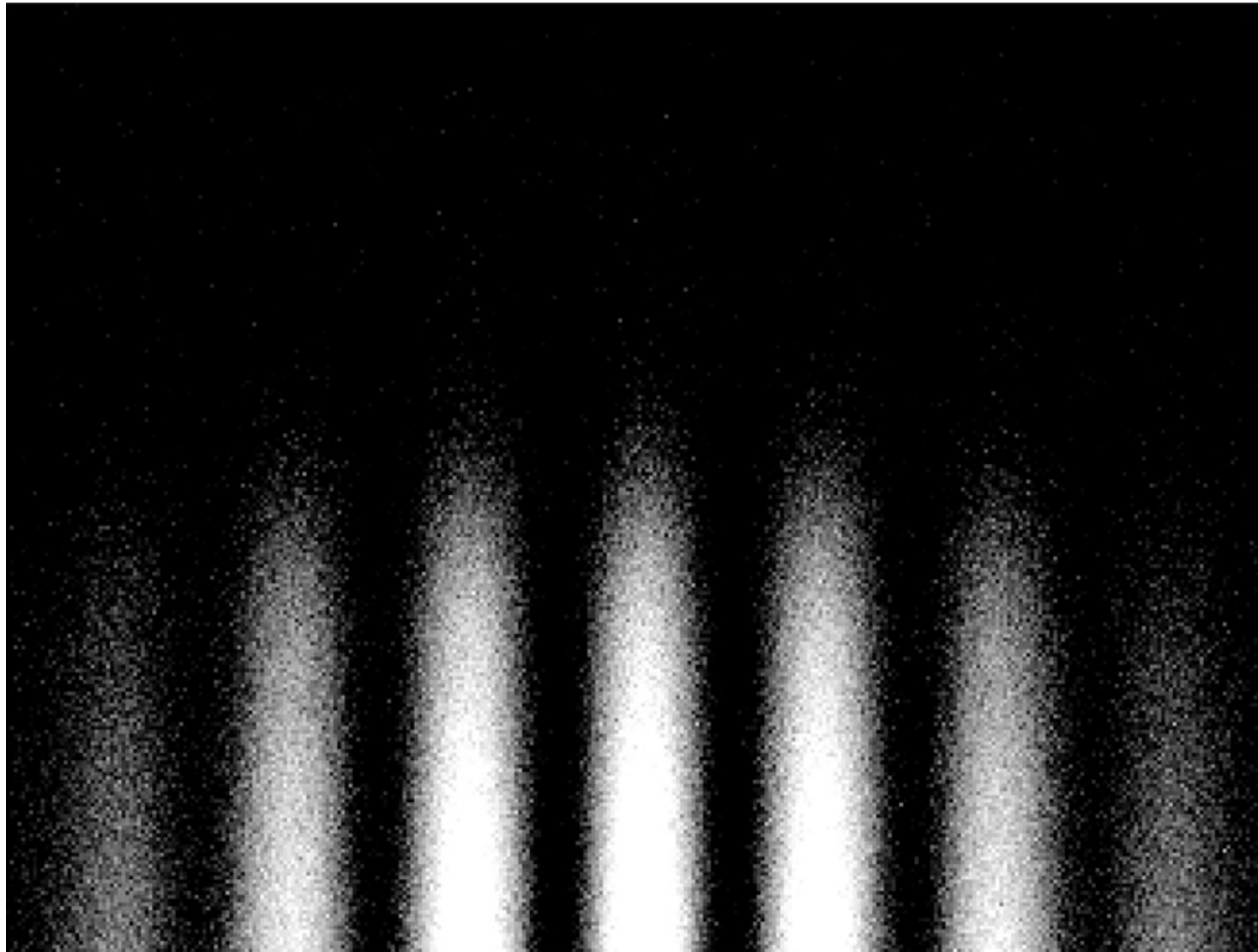
Young's double slit with a coherent source photon by photon



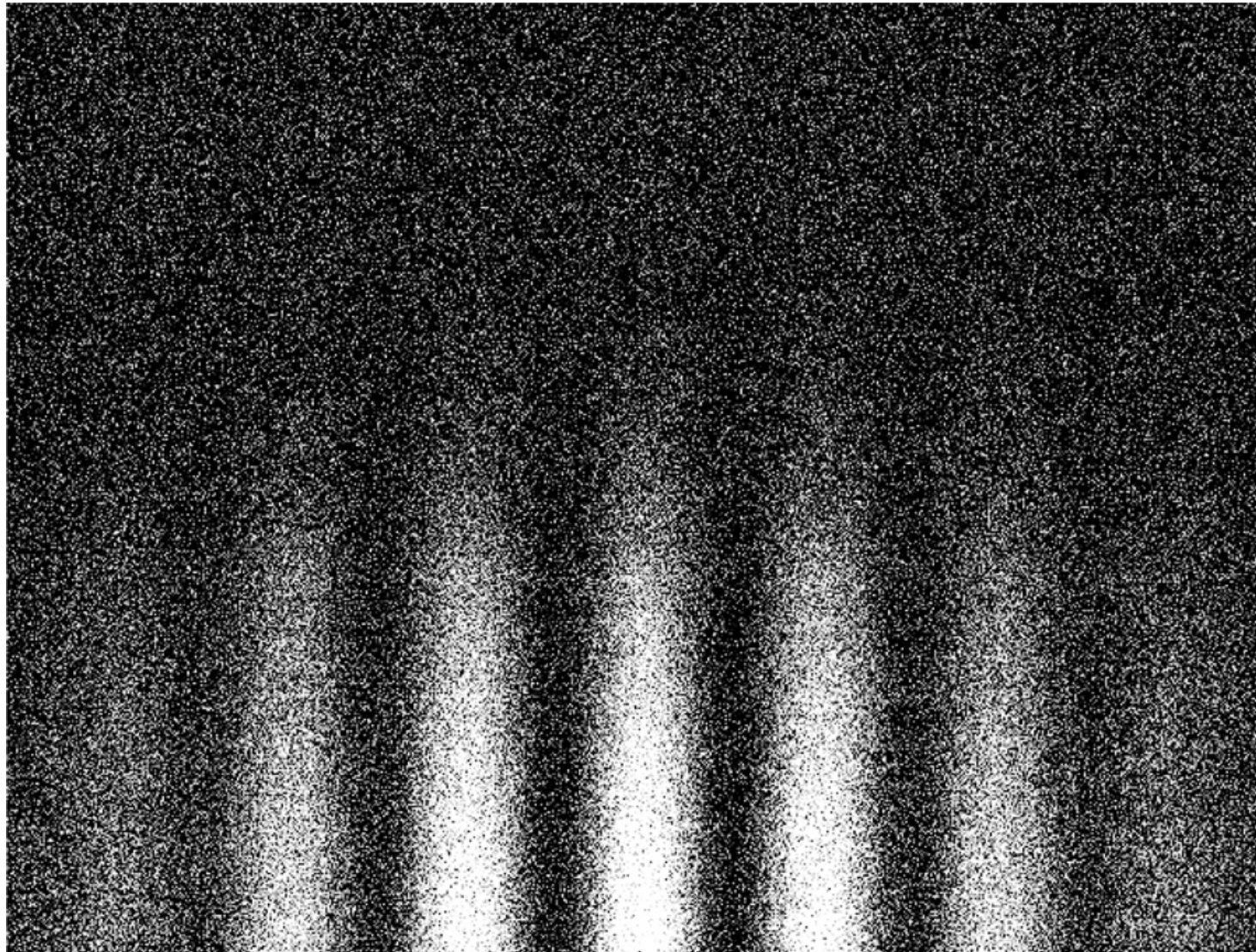
Vertical cross section



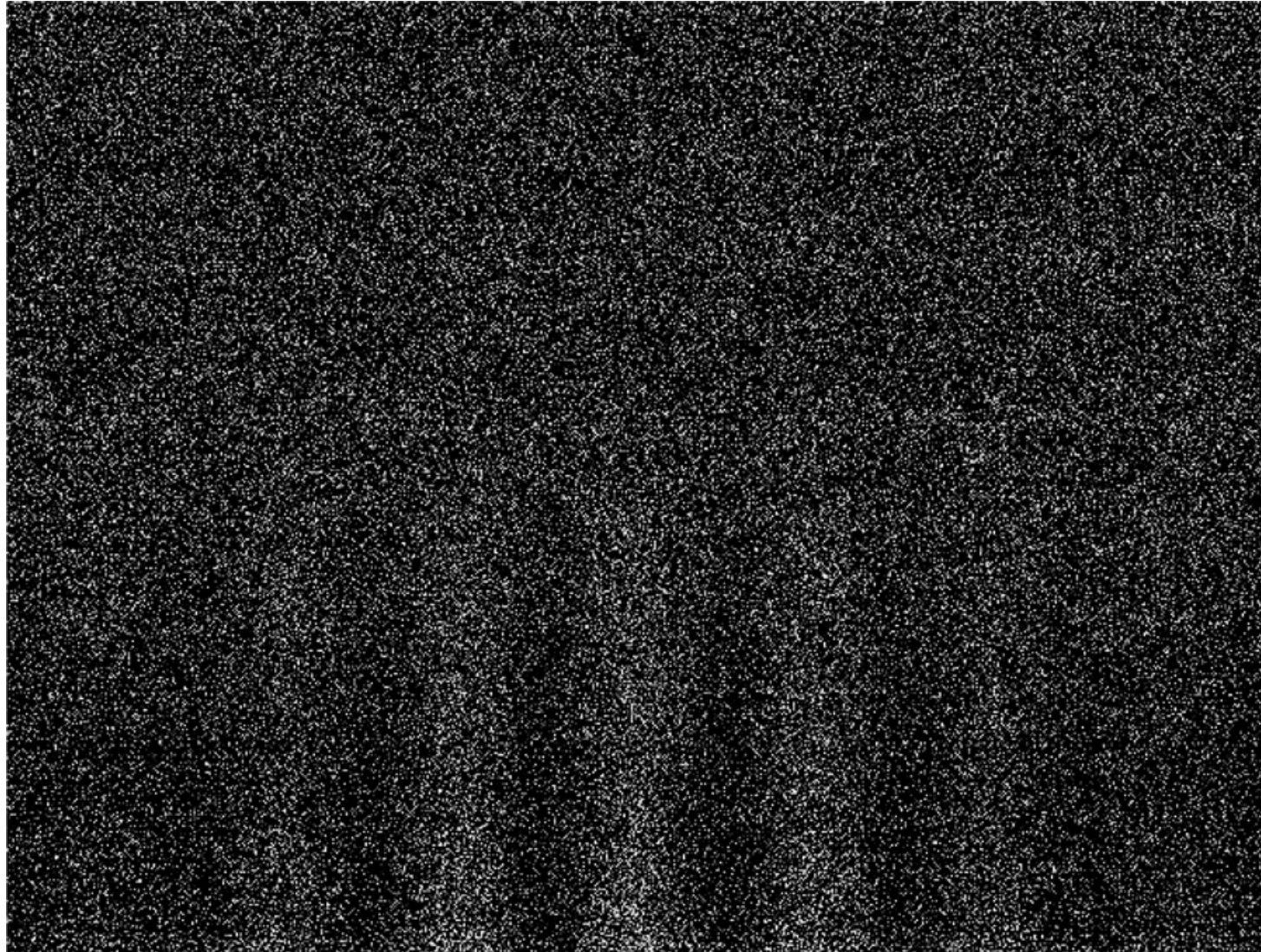
Bright laser



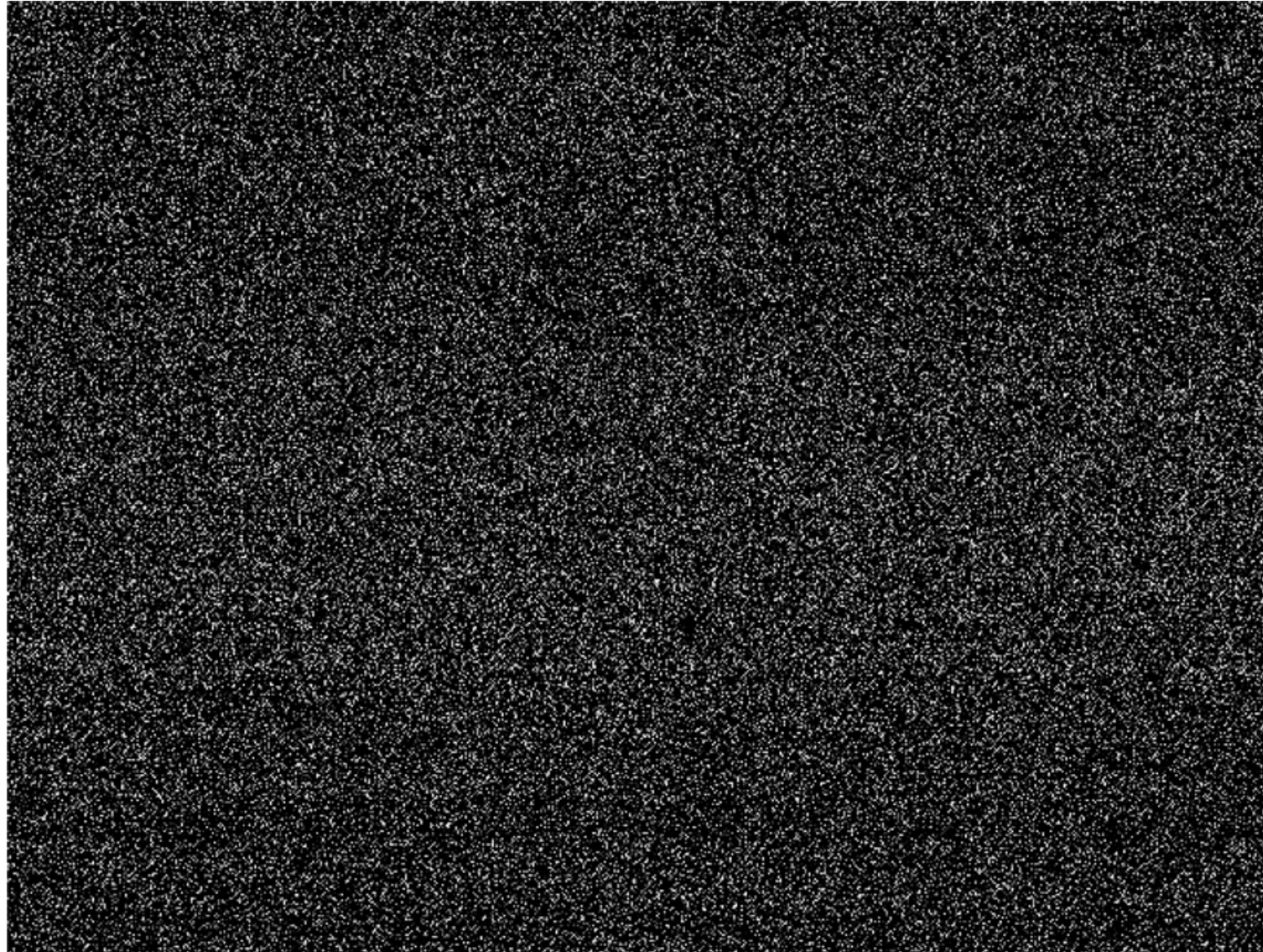
Dimmer



Even dimmer

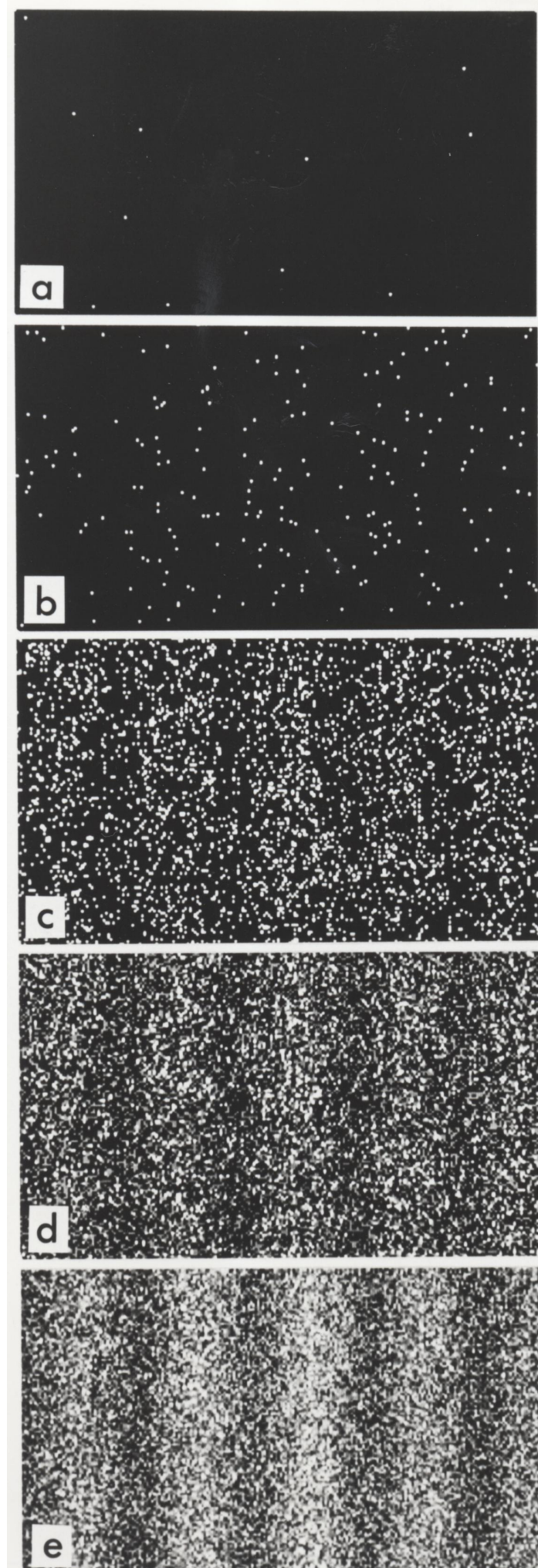


Block one path

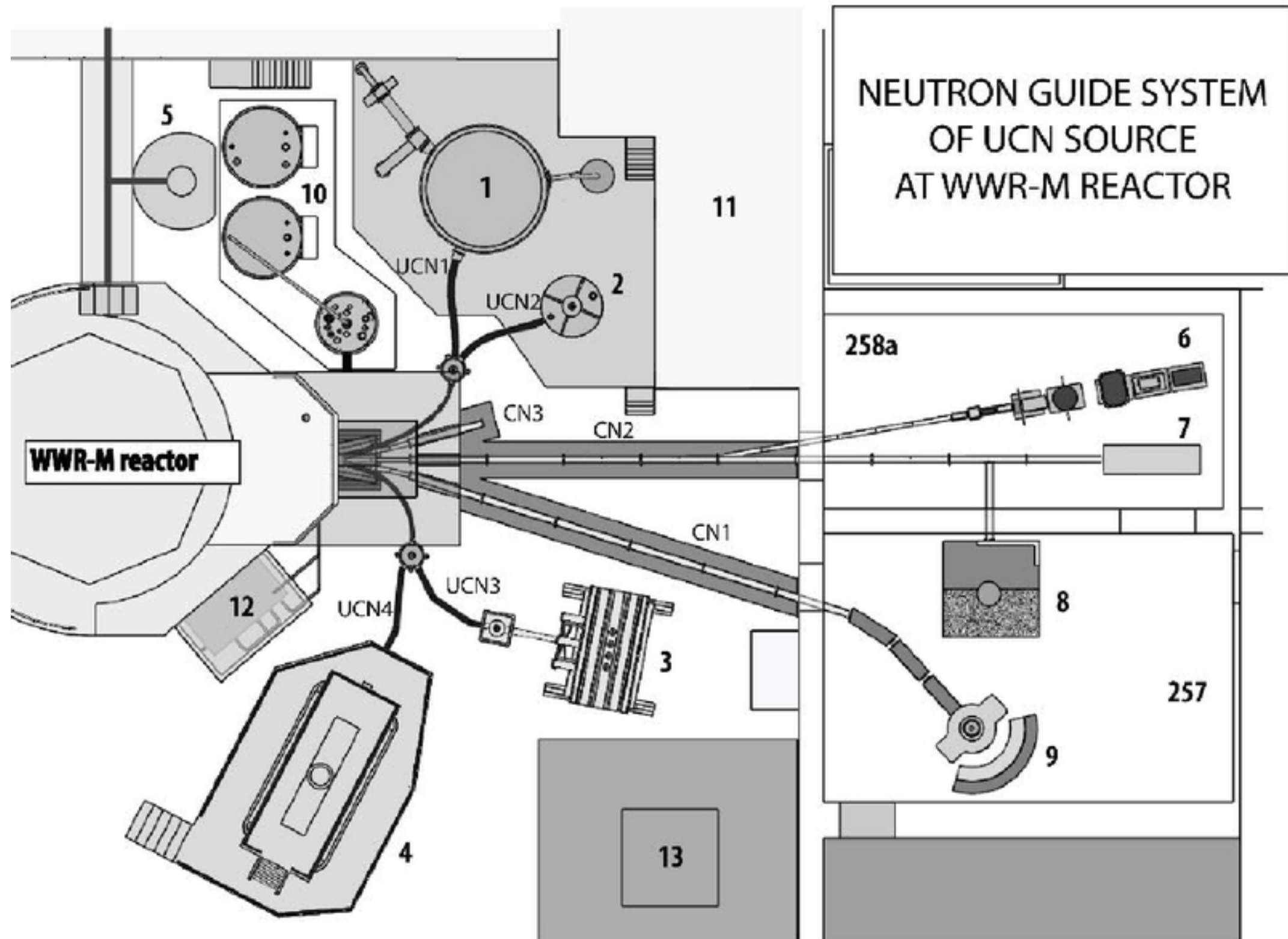


Particles **move** like waves and **hit** like particles

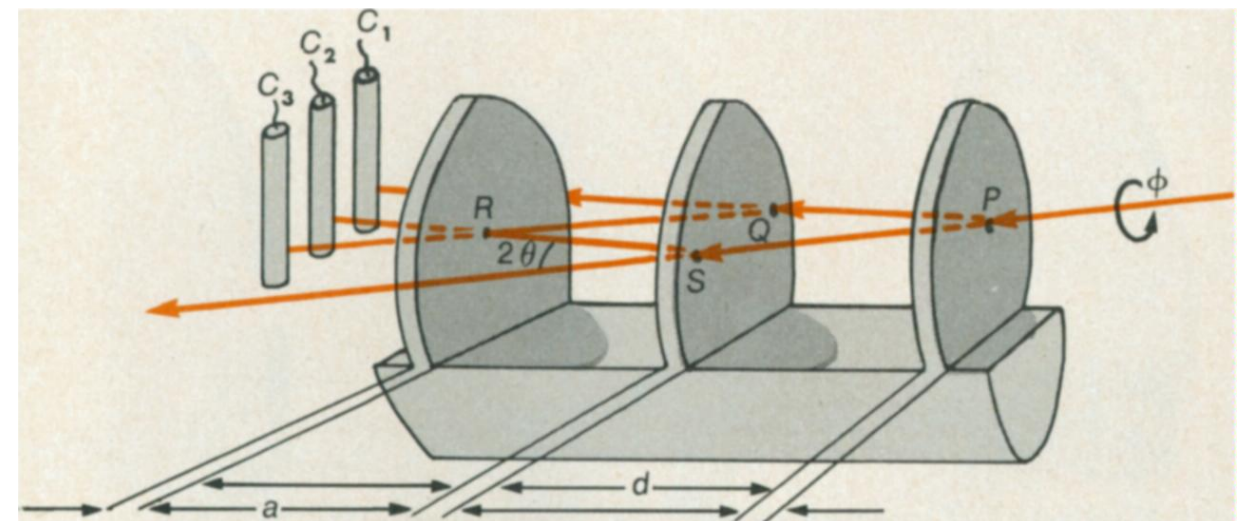
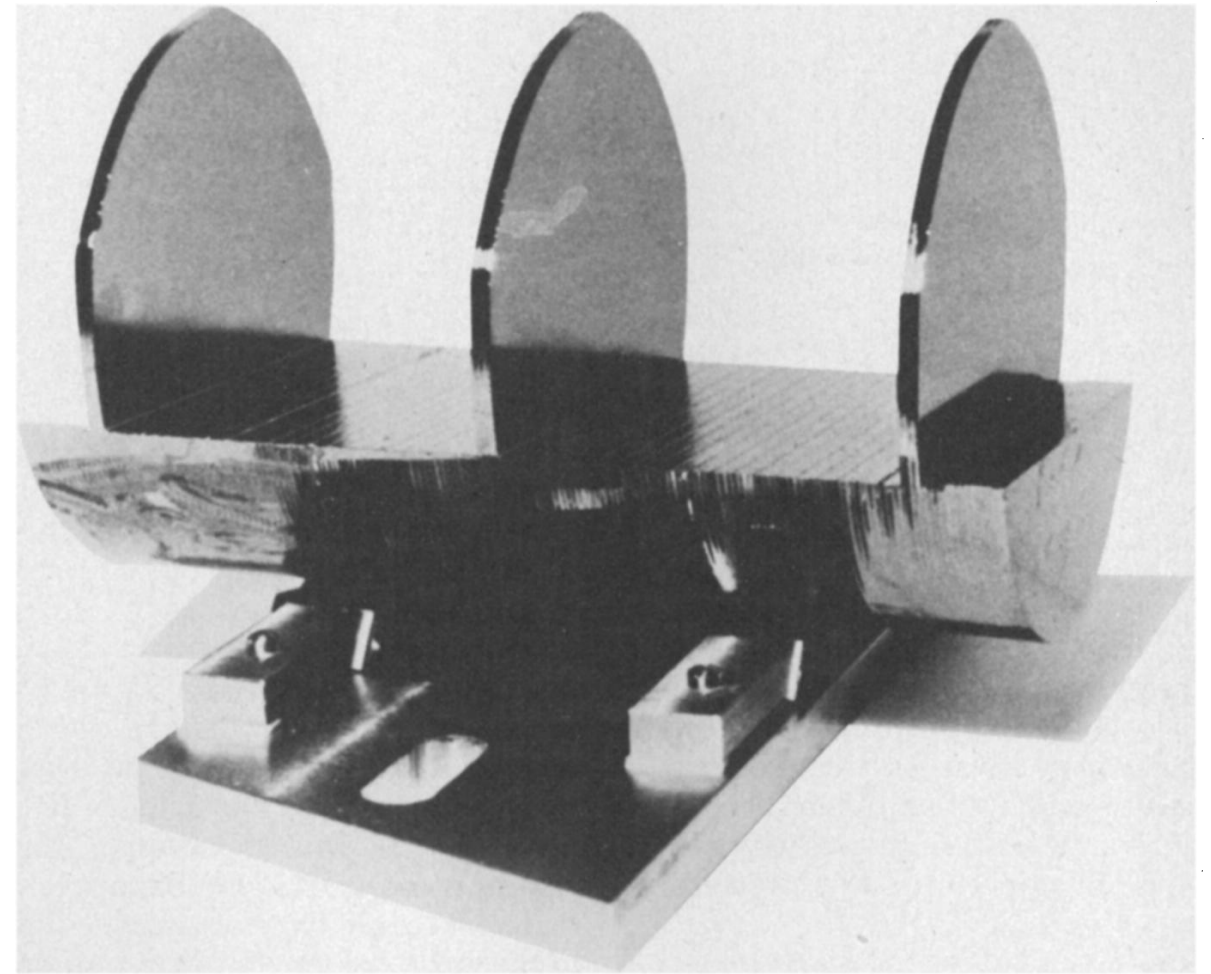
Electrons



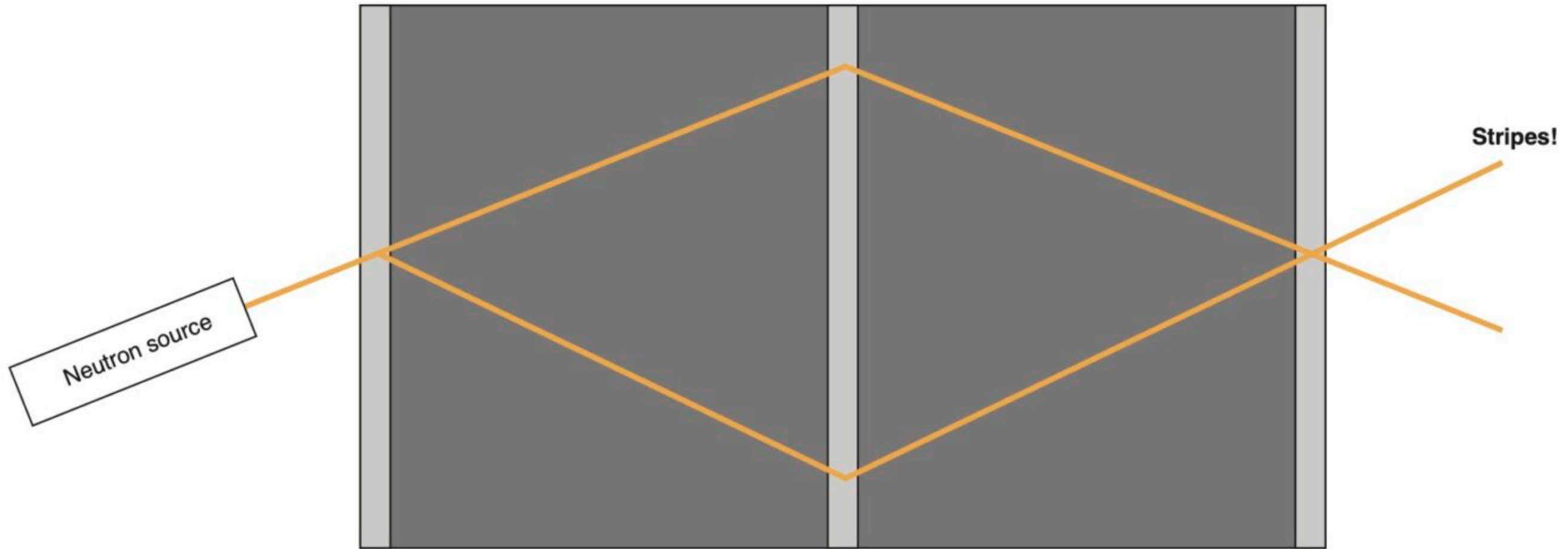
Neutron 'laser pointer'



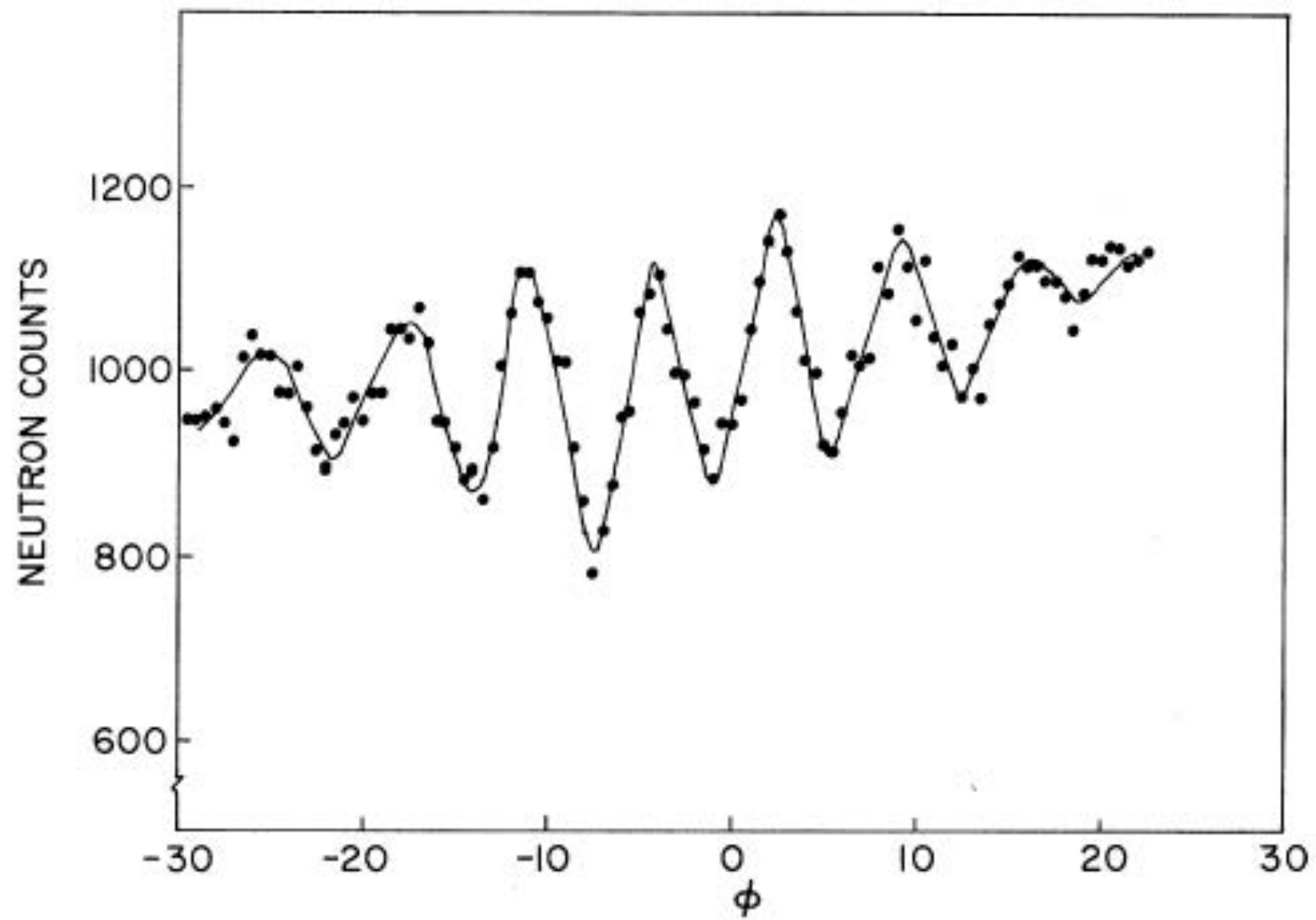
Neutrons



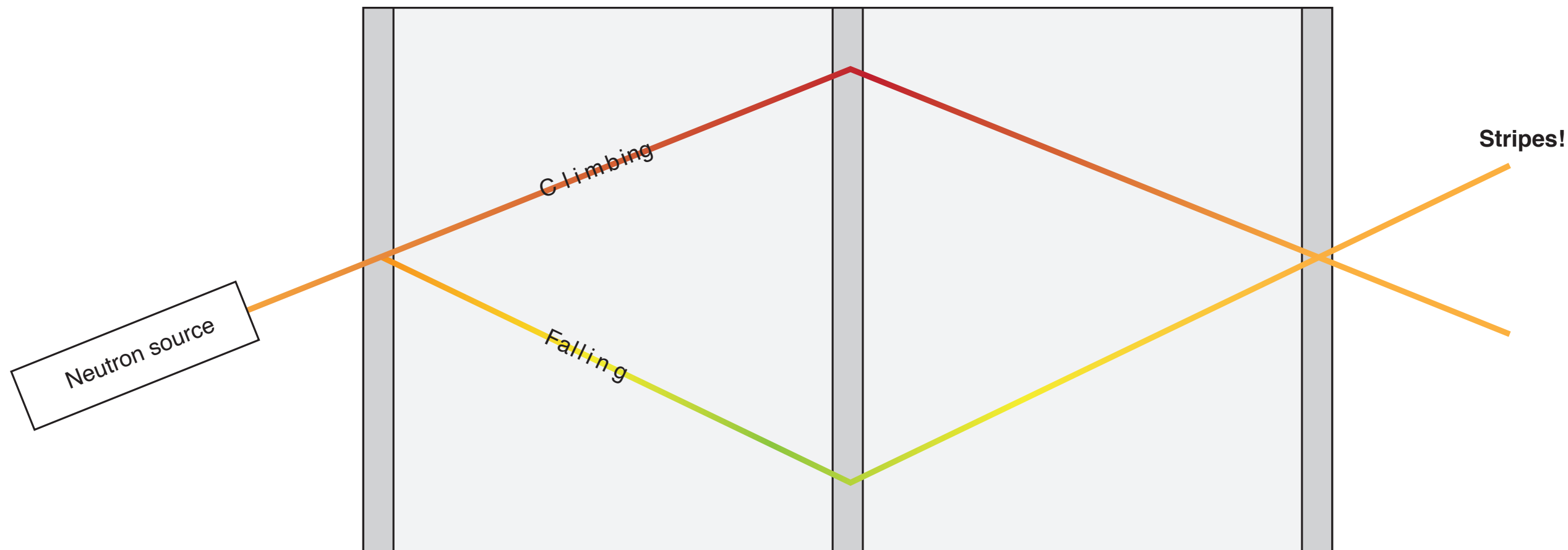
Neutron Interferometer



Neutrons



Vertical Neutron Interferometer

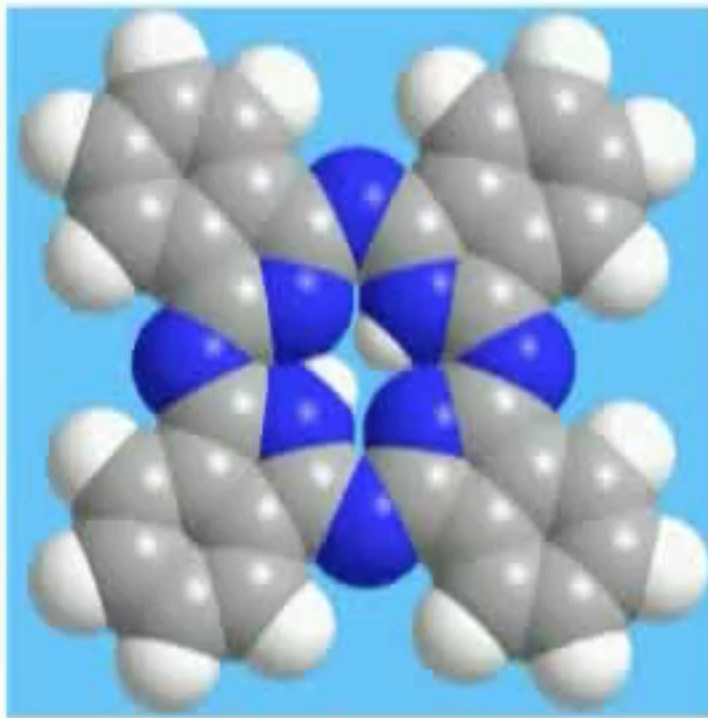


Can be used to measure strength of gravity

$C_{32}H_{18}N_8$ (~3000 particles)

The quantum molecular movie

The wave-particle duality of phthalocyanine



Thomas Juffmann
Adriana Milic
Michael Müllneritsch
Peter Asenbaum
Alexander Tsukernik
Jens Tüxen
Marcel Mayor
Ori Cheshnovsky and
Markus Arndt



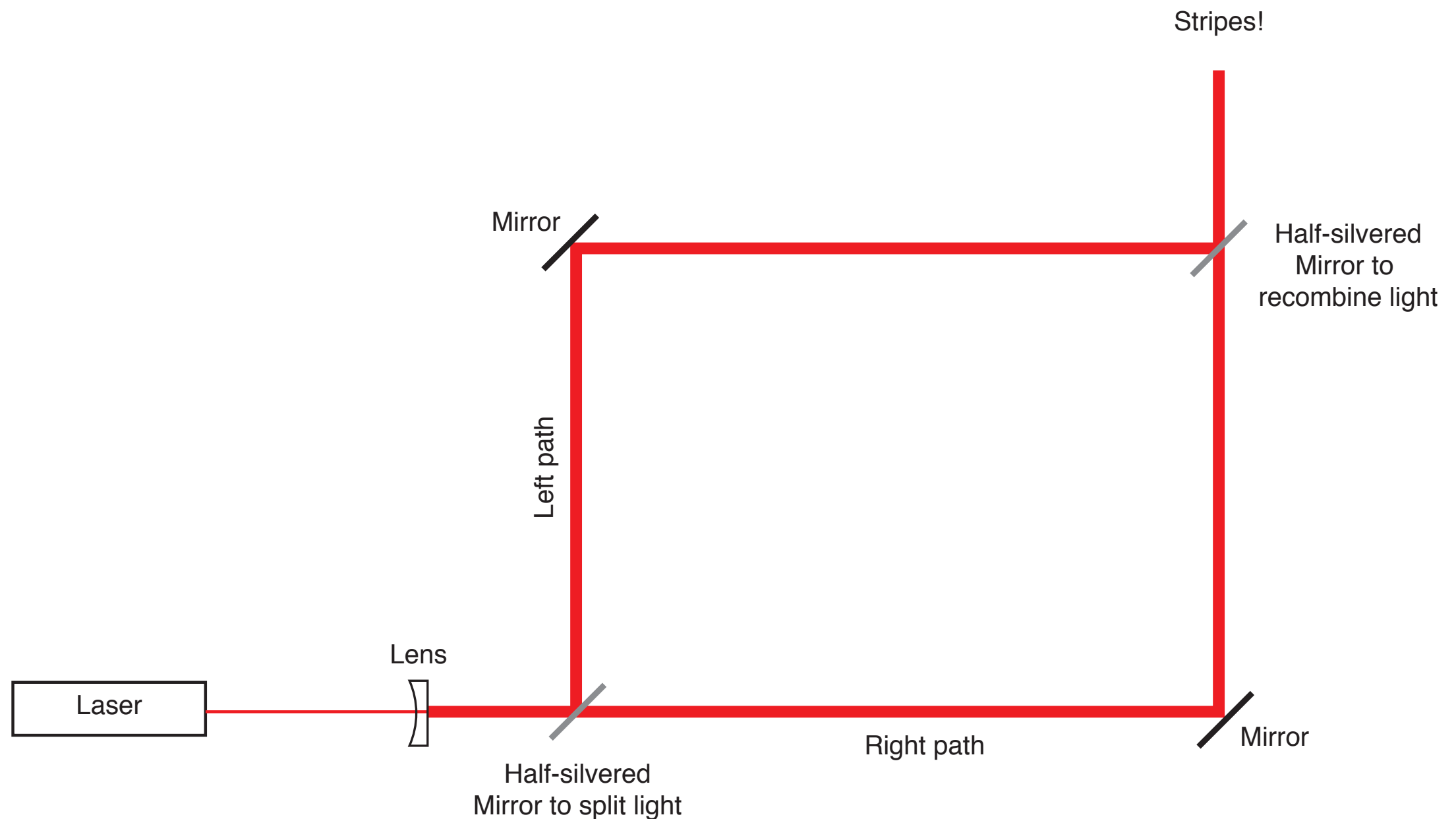
All particles **move** like waves and **hit** like particles

- From photons, to electrons, to neutrons, to molecules, they **all** move like waves and hit like particles
- Color is related to both wavelength and energy

Fundamental feature of how our universe works

But which path did the particle really take?

- Problem with the mental model



Particles **move** like waves and **hit** like particles
