Quantum Entanglement and the Flow of Time Animations

By Mark Egdall 6/15/ 09

Partially based on Brian Greene's *The Fabric of the Cosmos*

Quantum Entanglement and the Flow of Time Animations

Which Path?
Part II

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6. Animation on Which Path/ Delayed Choice Part II:

Explaining the Delayed Choice Experiment with Quantum Field Theory

Quantum Field Theory

Is Light – A Wave or a Particle?

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• What is it exactly that does the traveling?

- The wave function.

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The wave function for a *single* photon splits into two wave functions after the beam-splitter. (There is a finite probability that the photon is either on the left path or right path.)

With a detector in one of the paths:

- when a photon is detected, *both* wavefunctions collapse. (We now know where the photon is.)

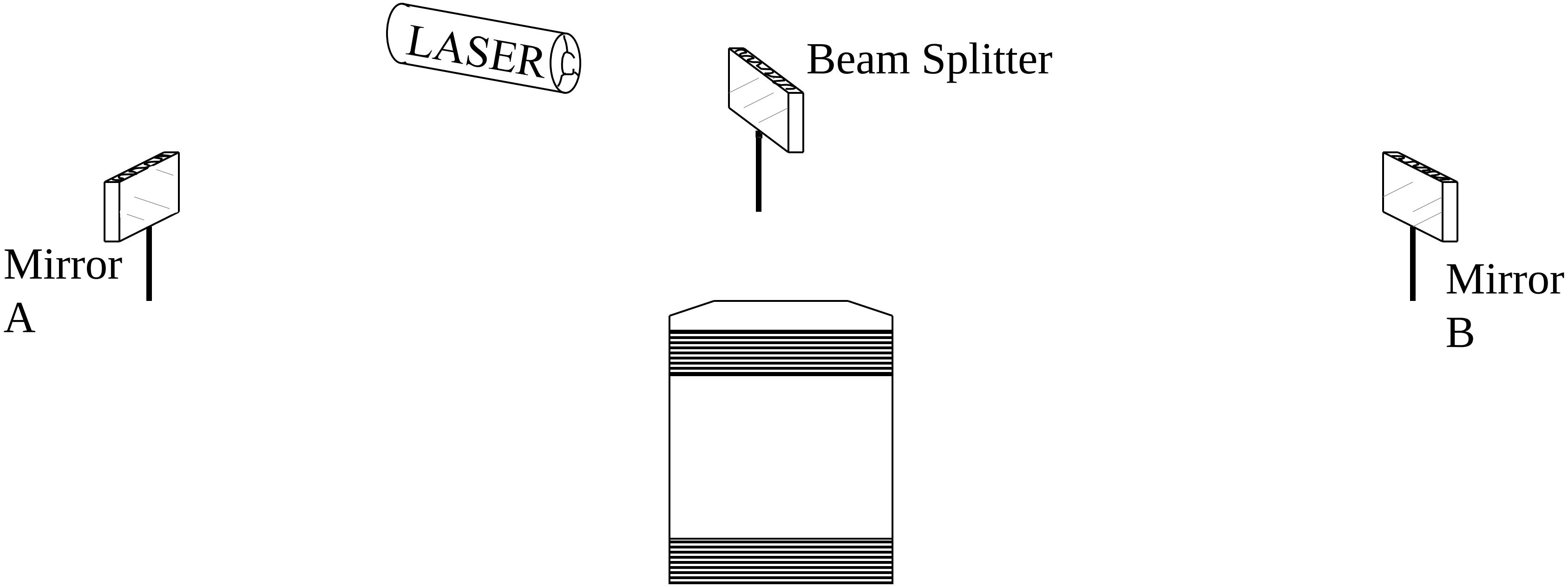
Note to the mathematically inclined: The wave function is a complex exponential function. One has to square it (take the complex conjugate) to derive the probability function.

Caveats:

-Wave functions in this animation not rigorously depicted.

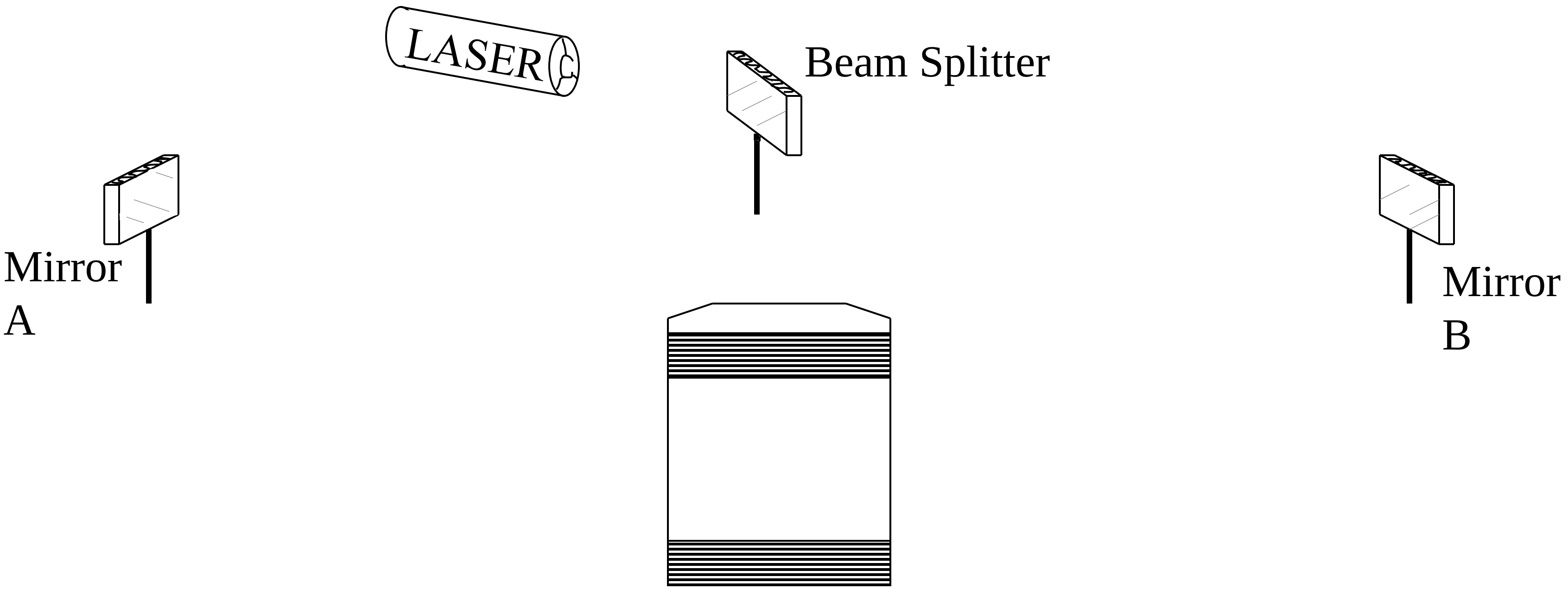
- Most likely outcomes depicted. (In quantum theory, a photon emitted by the laser can be detected *anywhere*, including the far side of the Moon. It is just a much, much less probable outcome.

With *no detector* in the path:



* p. 187, *The Fabric of the Cosmos*, B. Greene

With *no detector* in the path: **A single photon**



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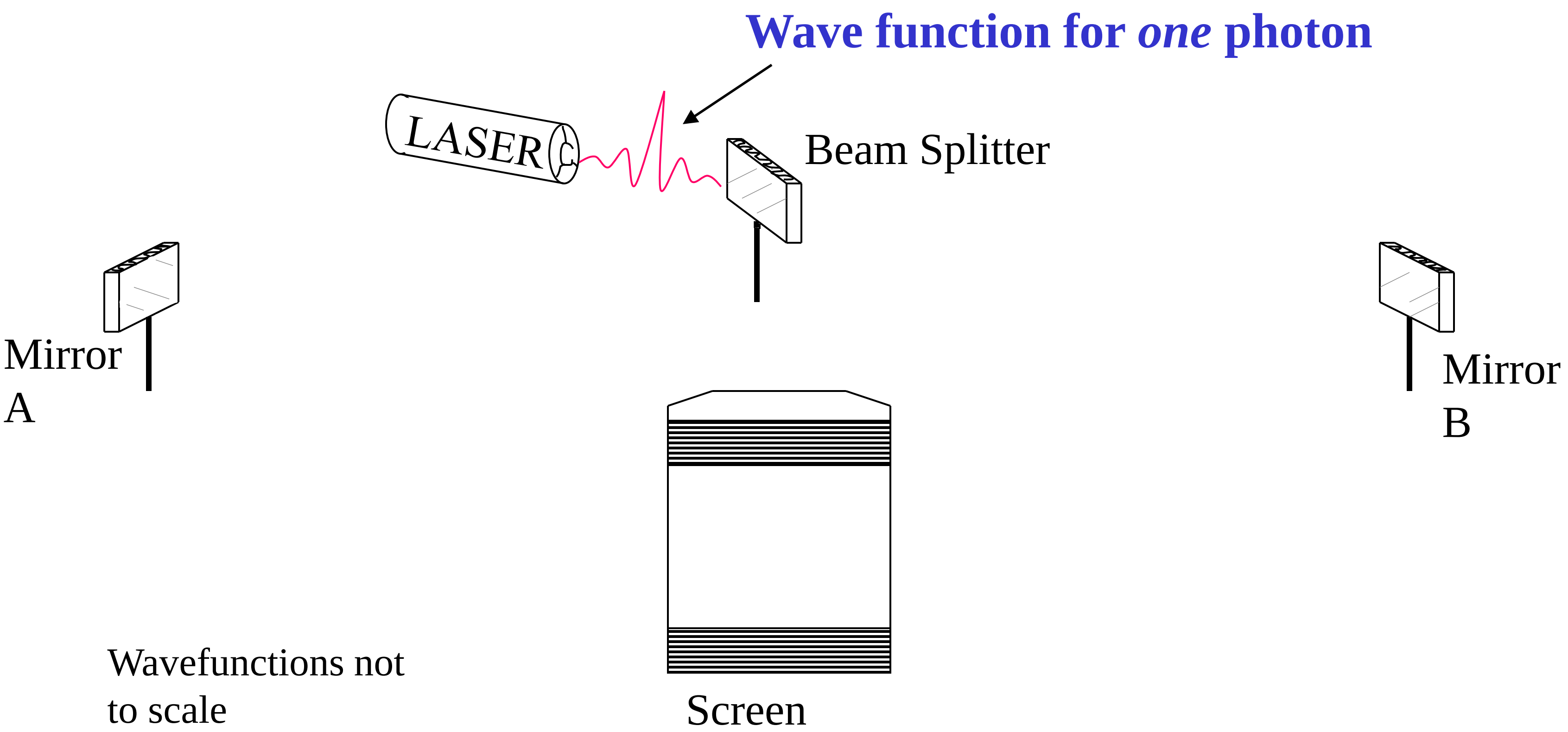

Wavefunctions not to scale

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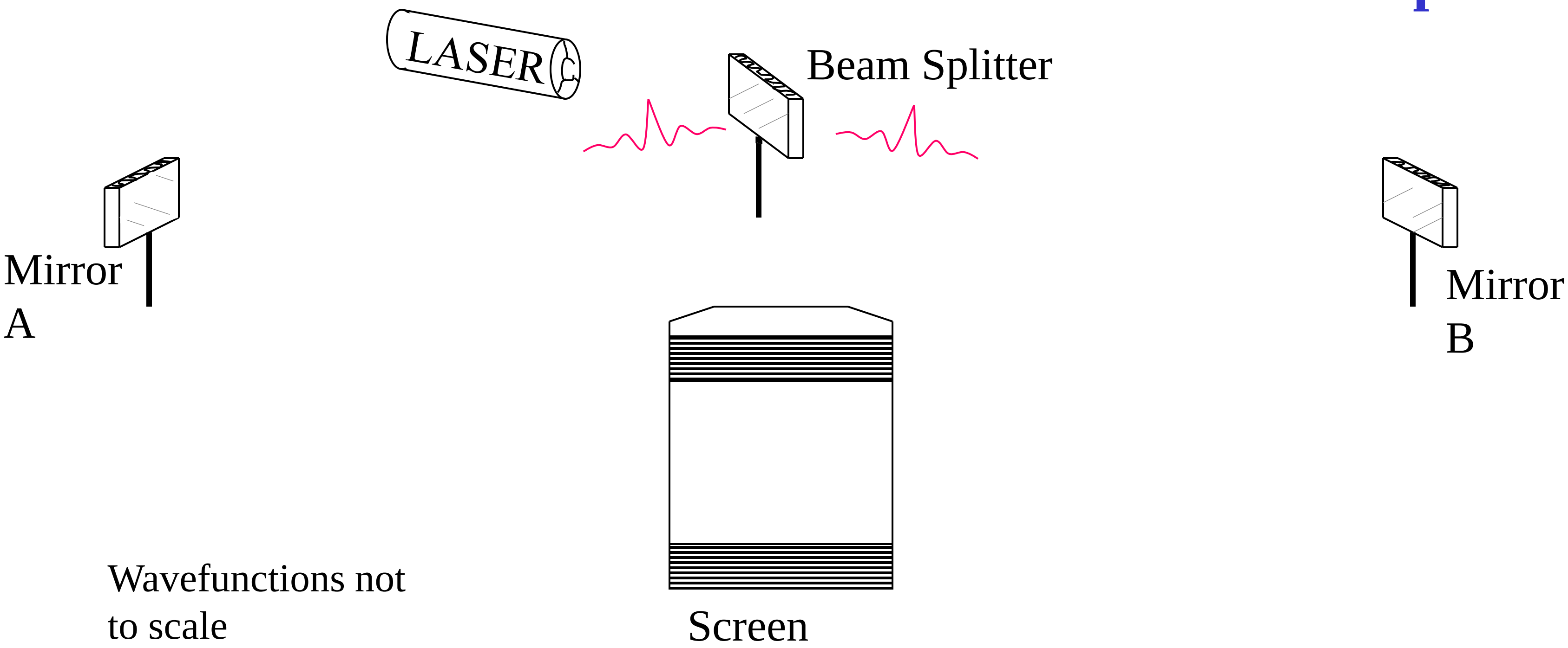
With *no detector* in the path: **A single photon**

Wave function splits into two wave functions after beam-splitter



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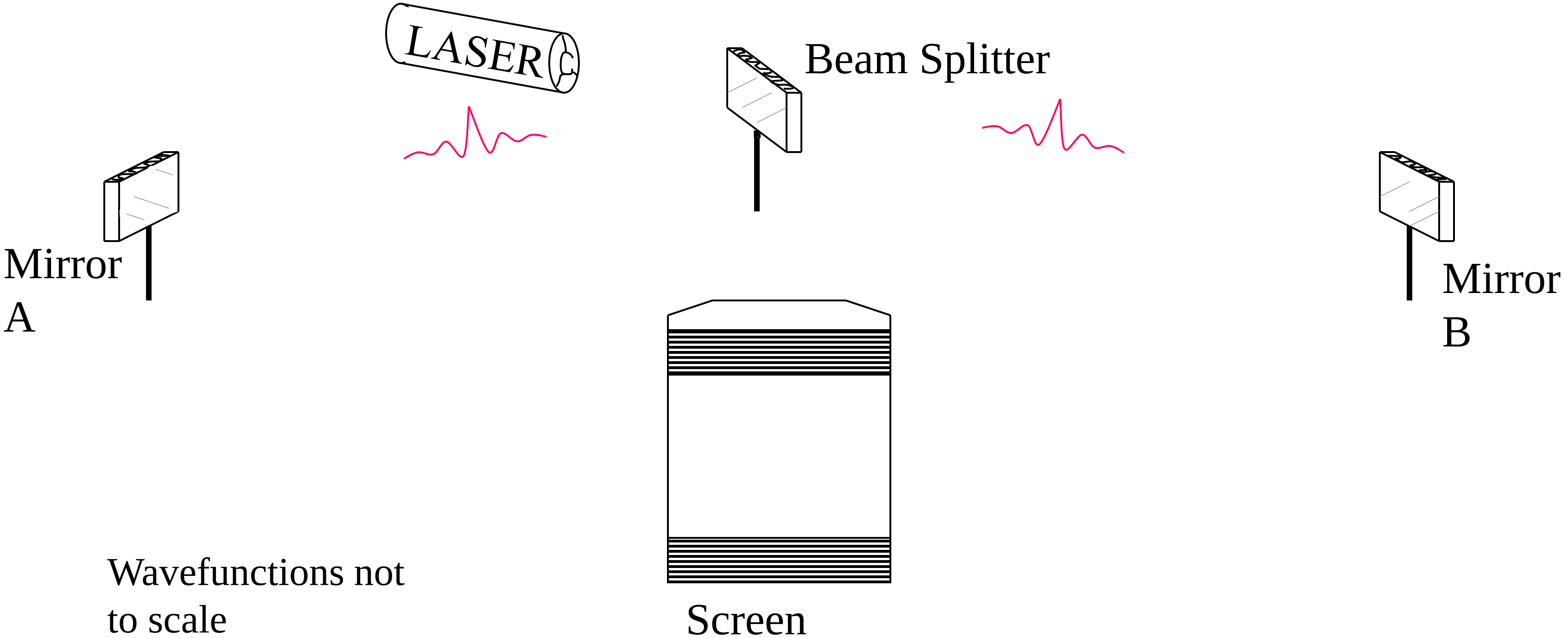

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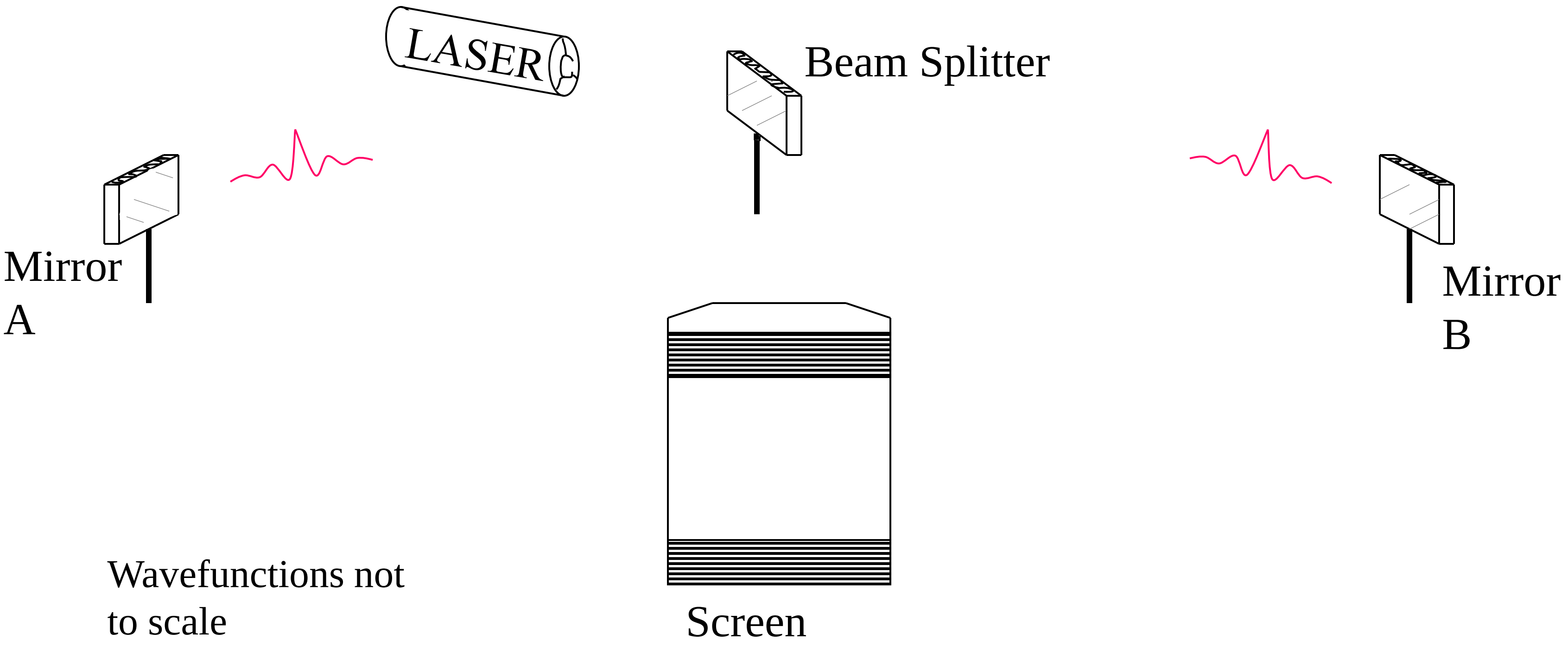

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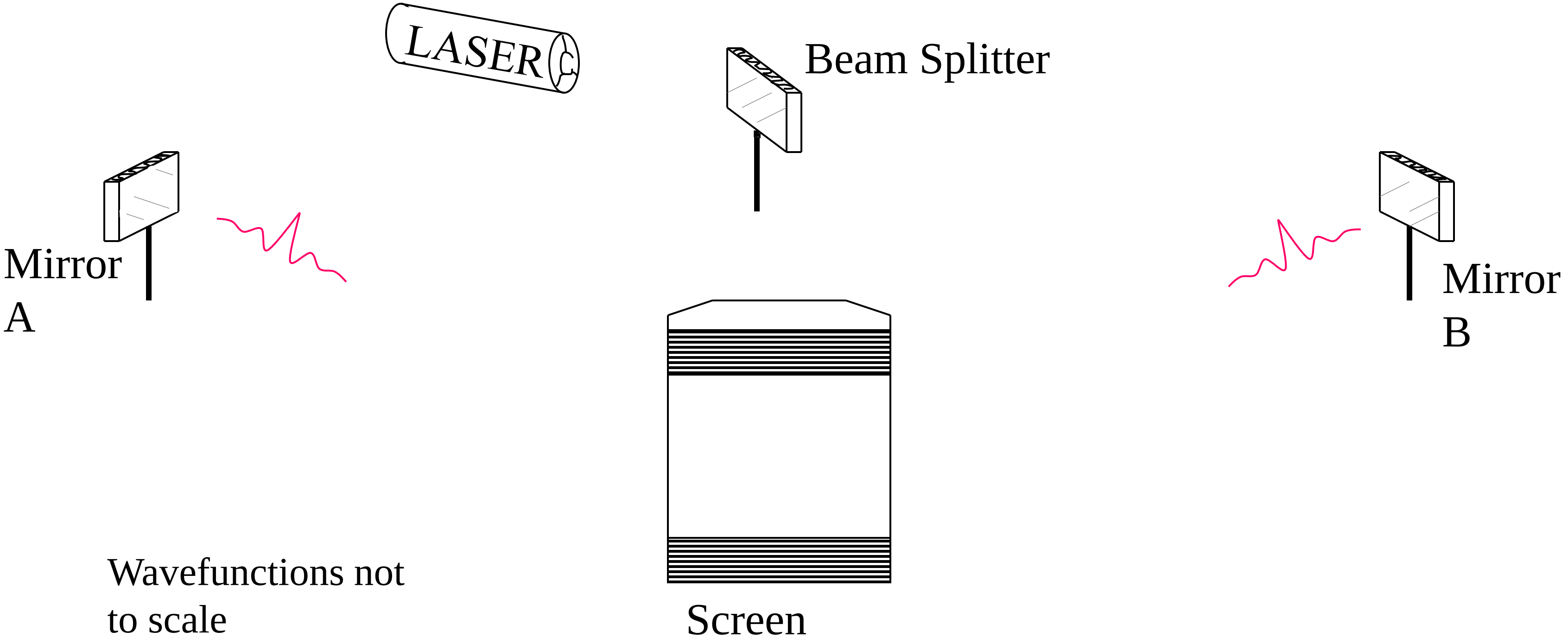
With *no detector* in the path: **A single photon**

Wave functions reflect off mirrors



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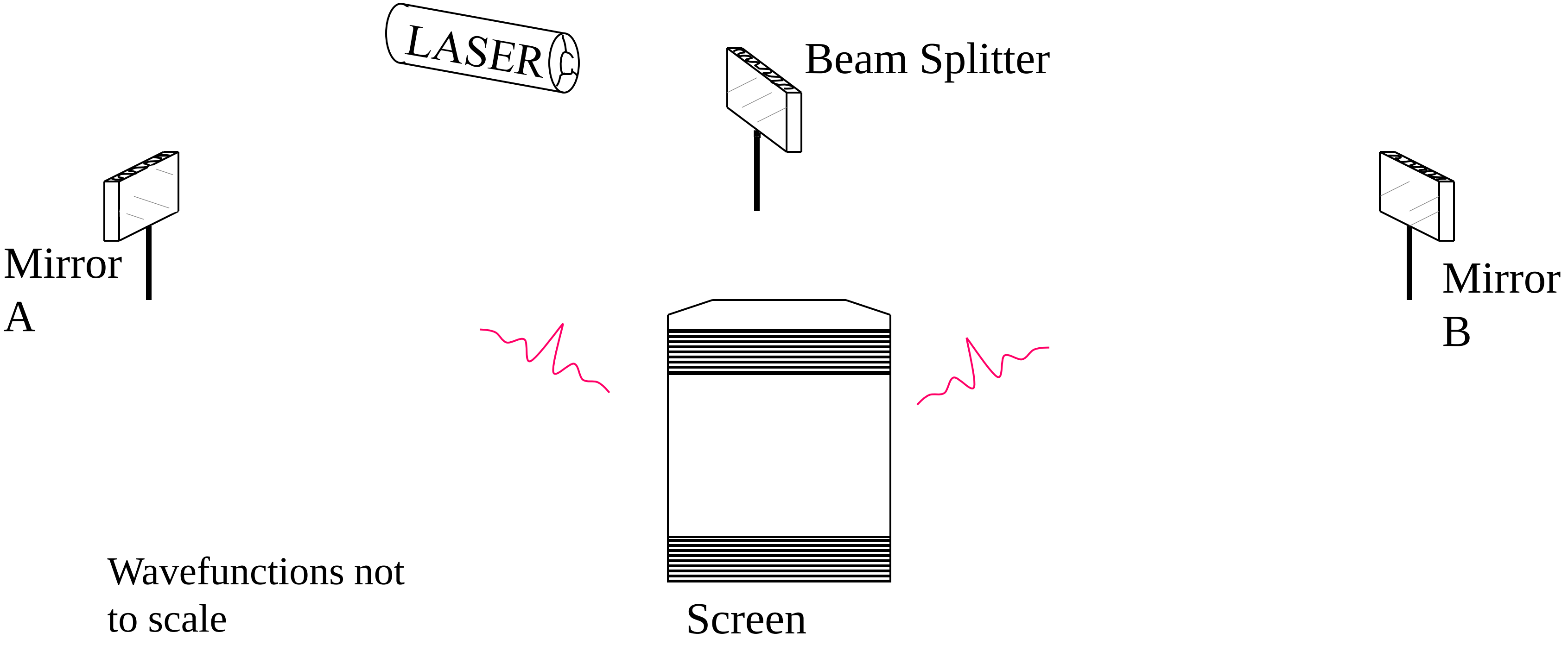

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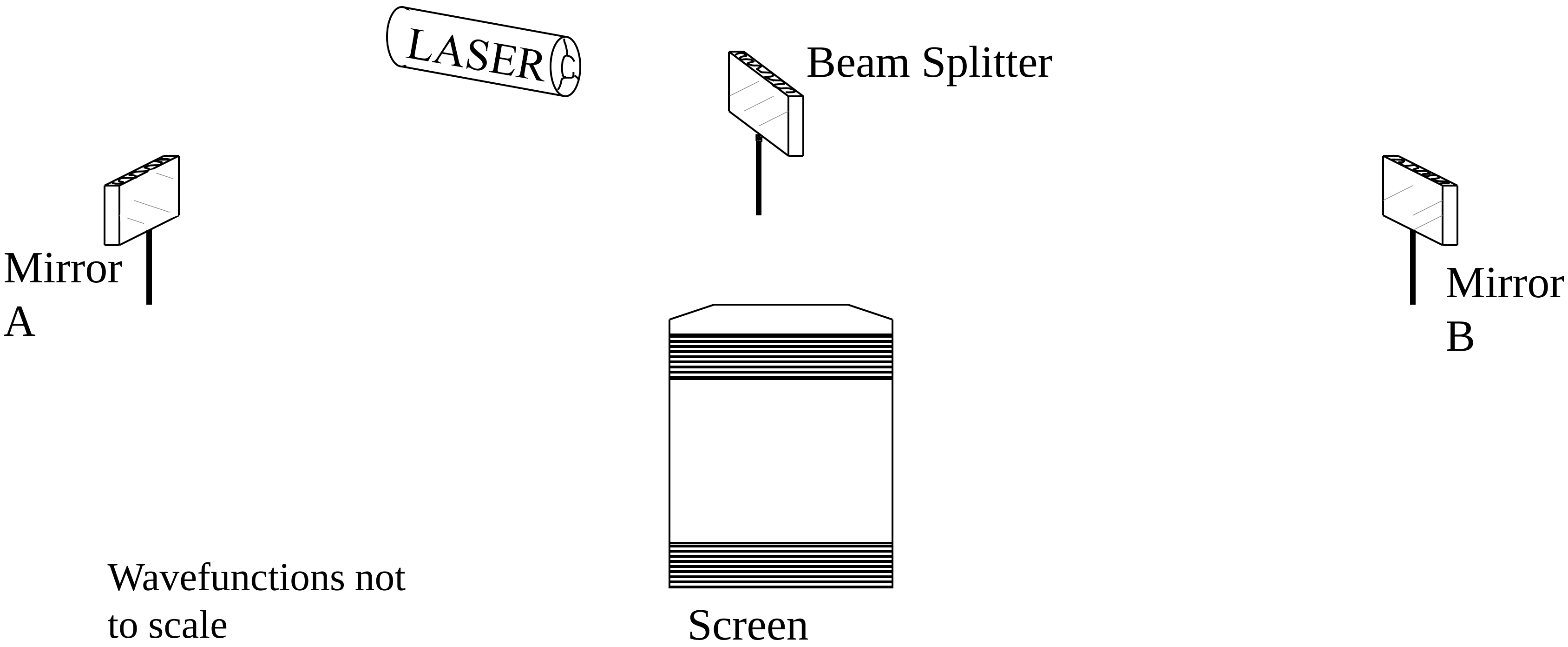

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Both wavefunctions reach the screen and interfere with each other

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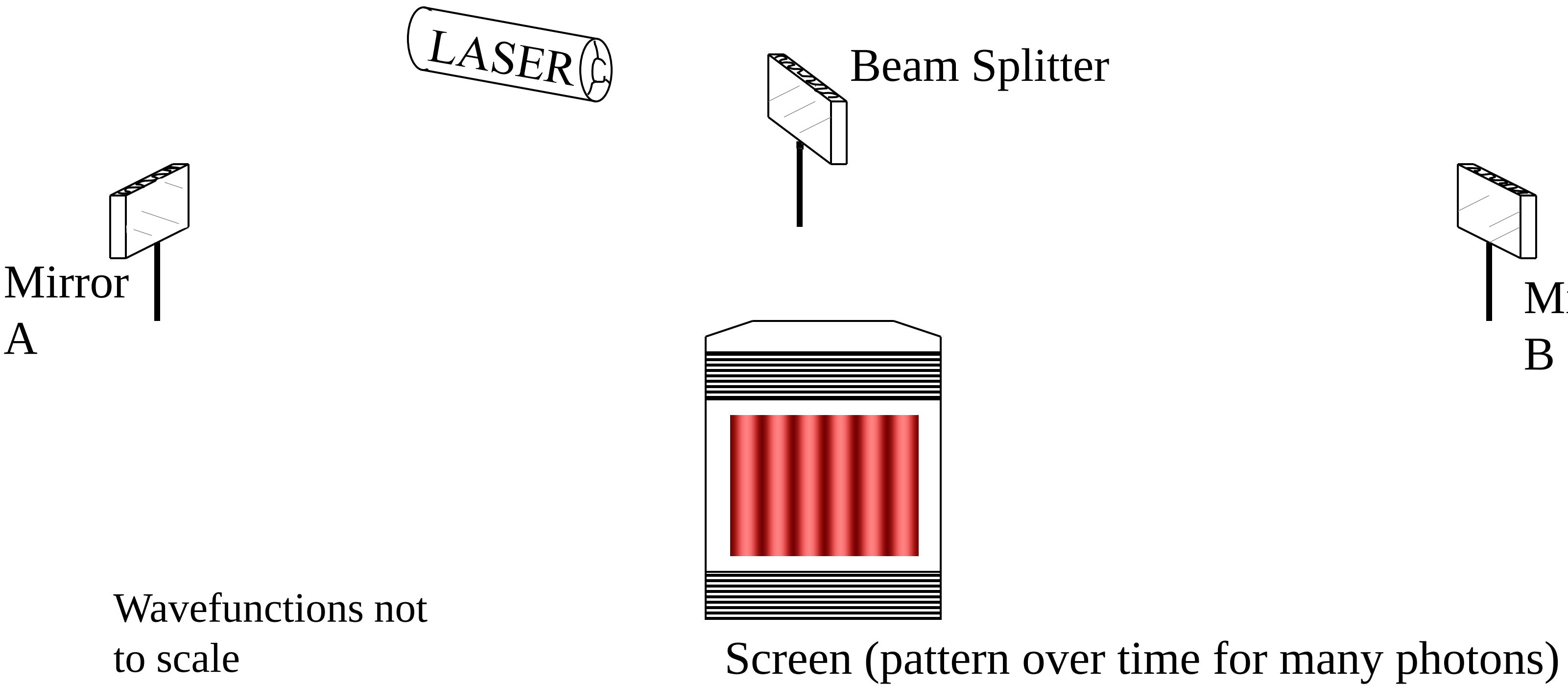

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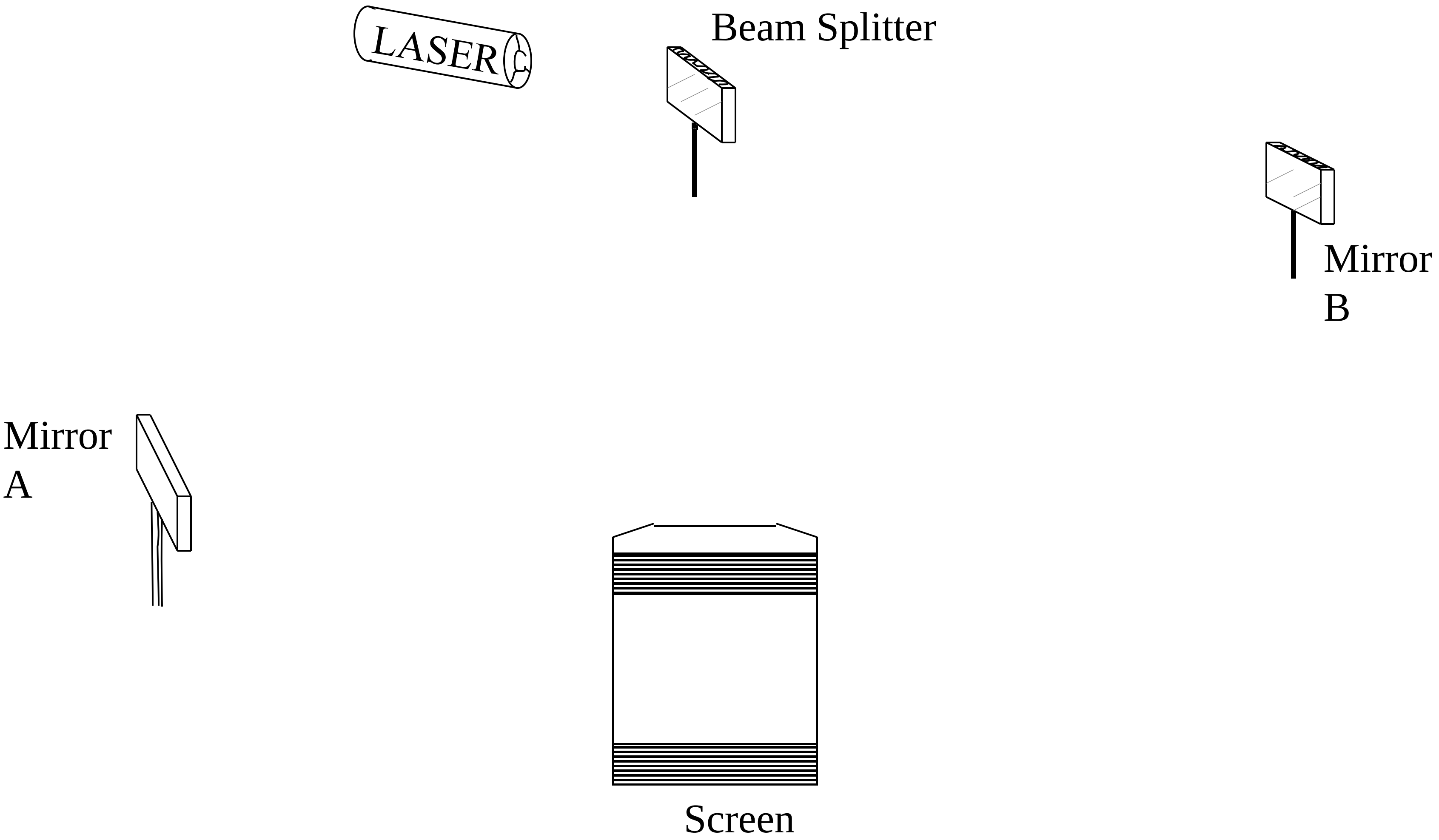
With *detector* in the path:

Delayed Choice



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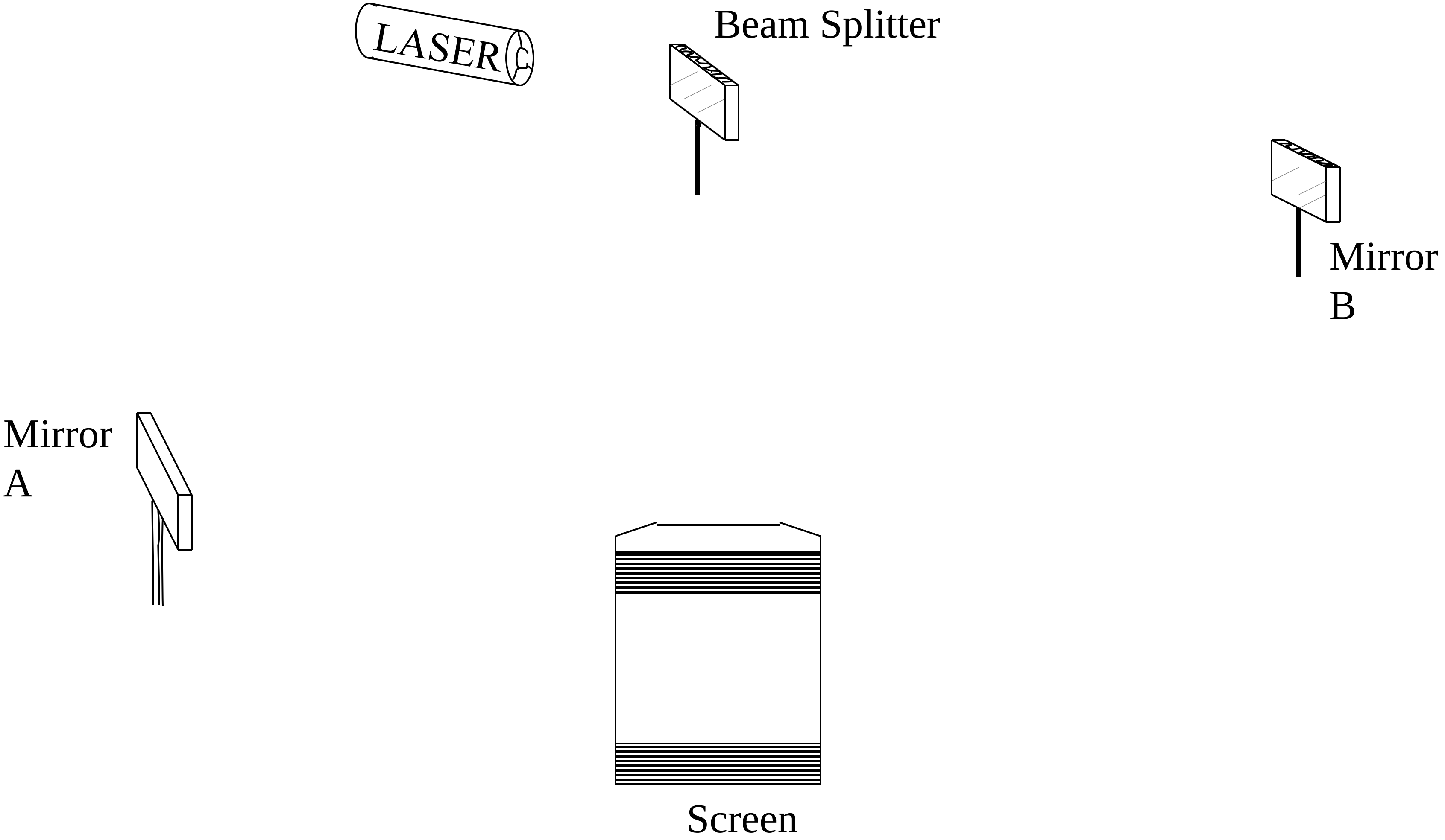

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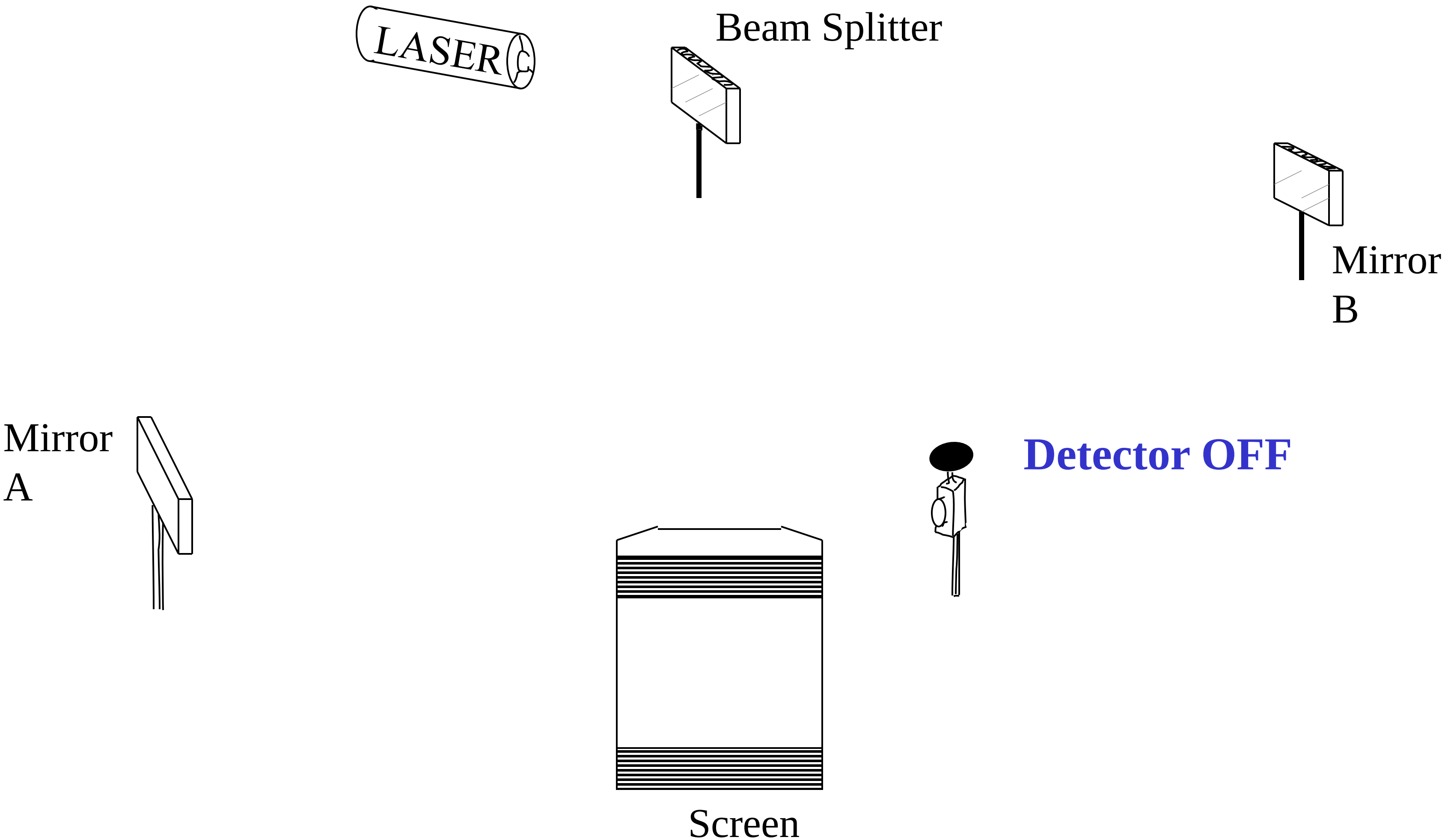

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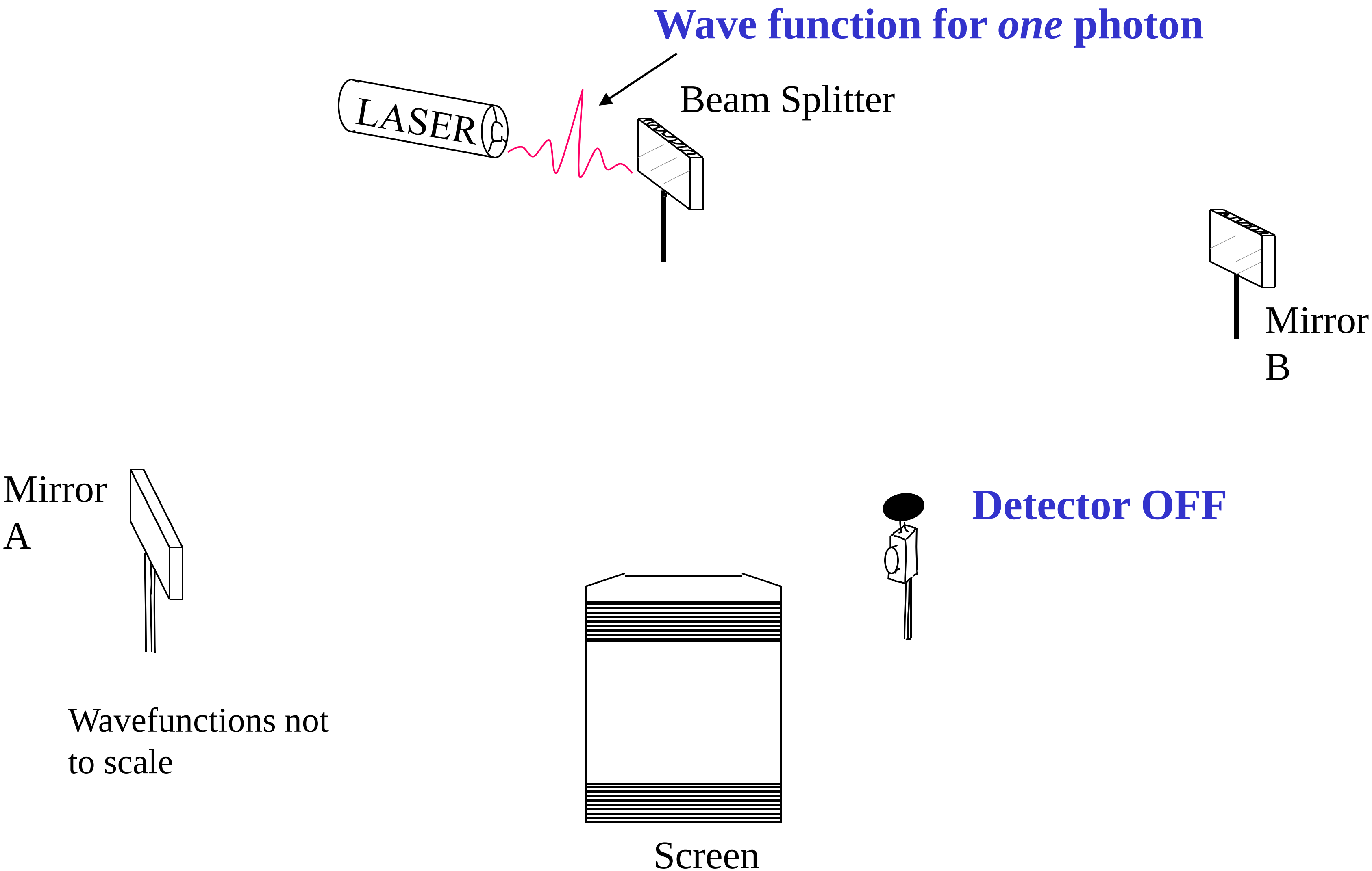

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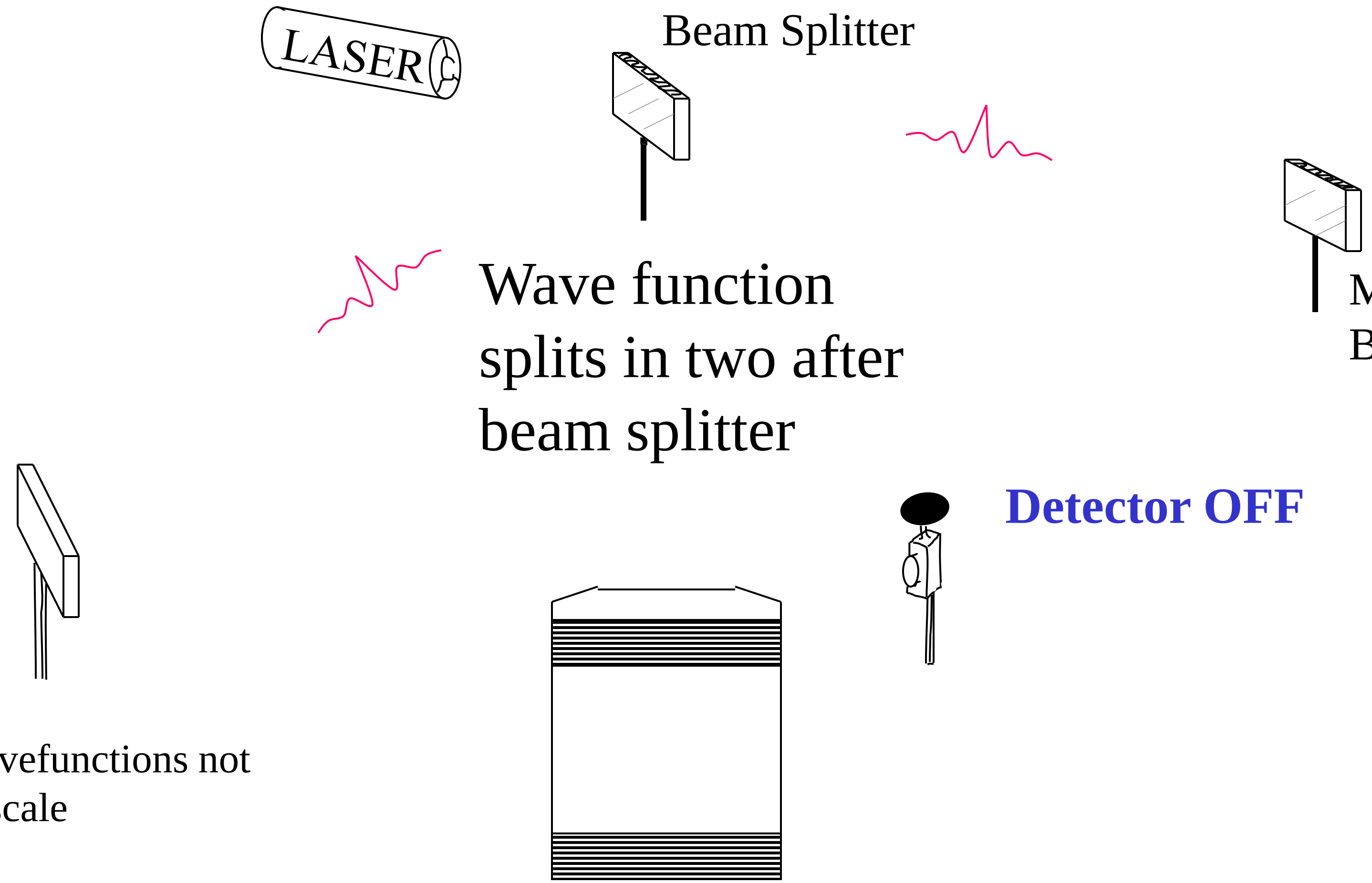

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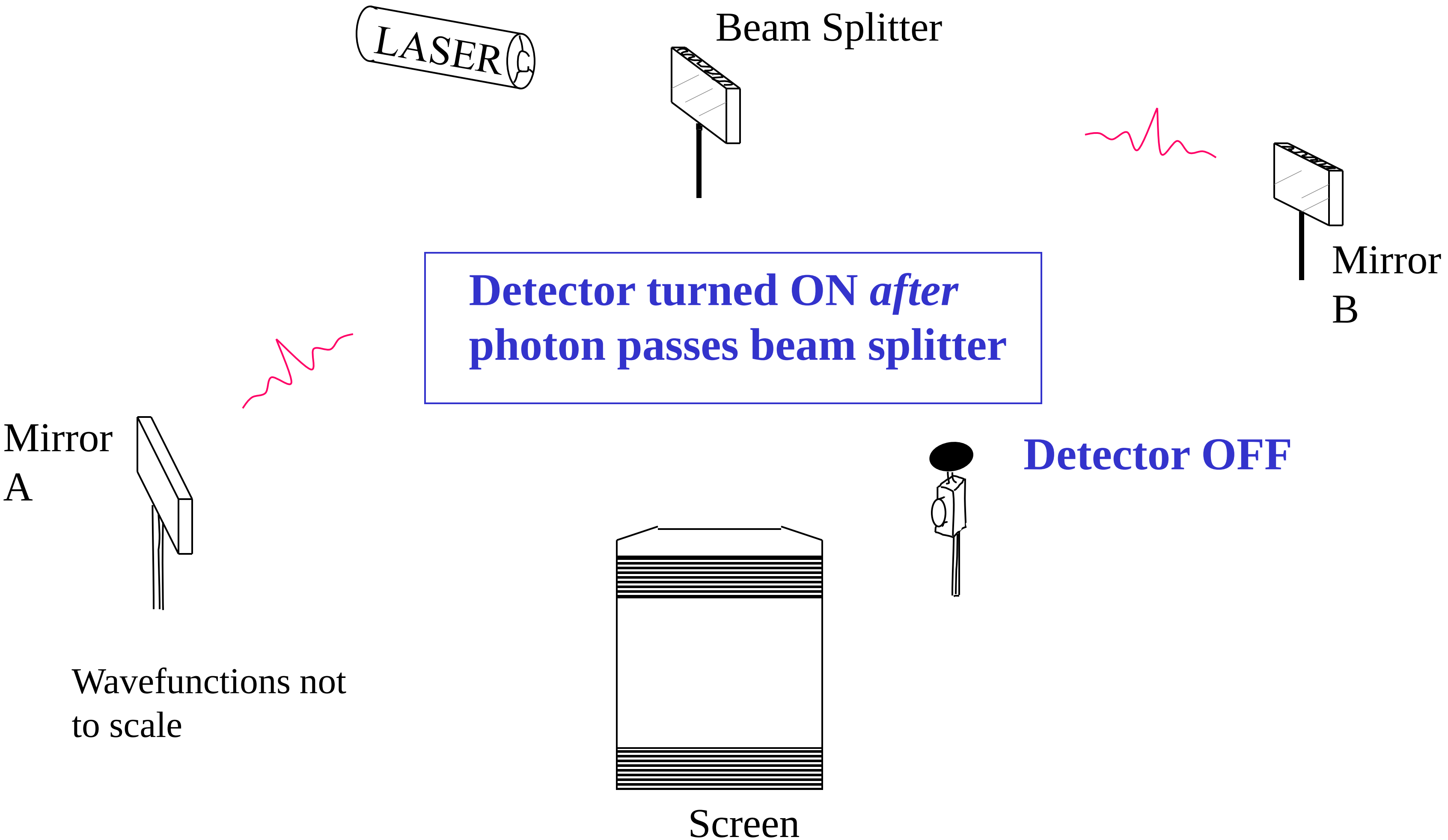

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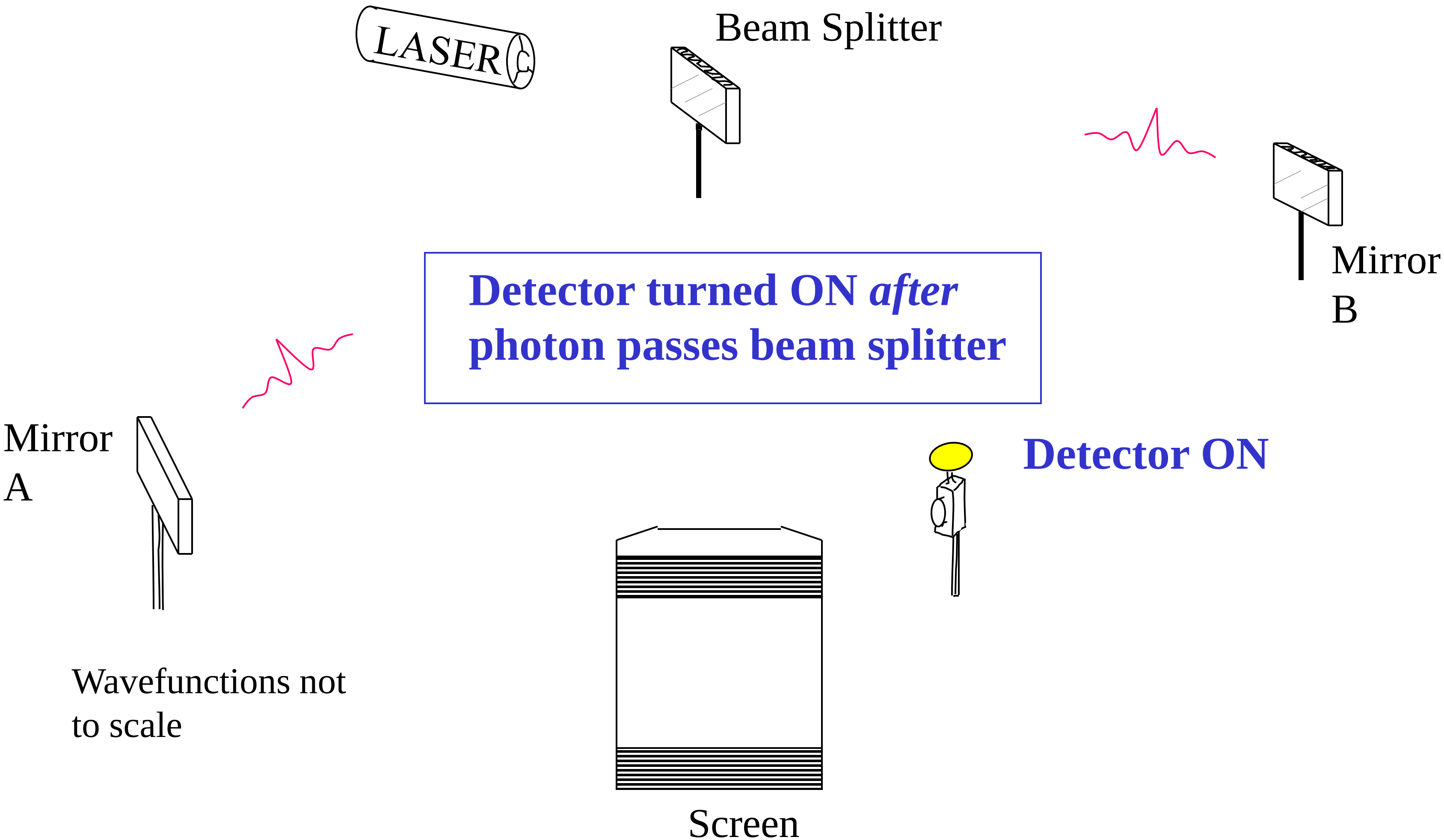

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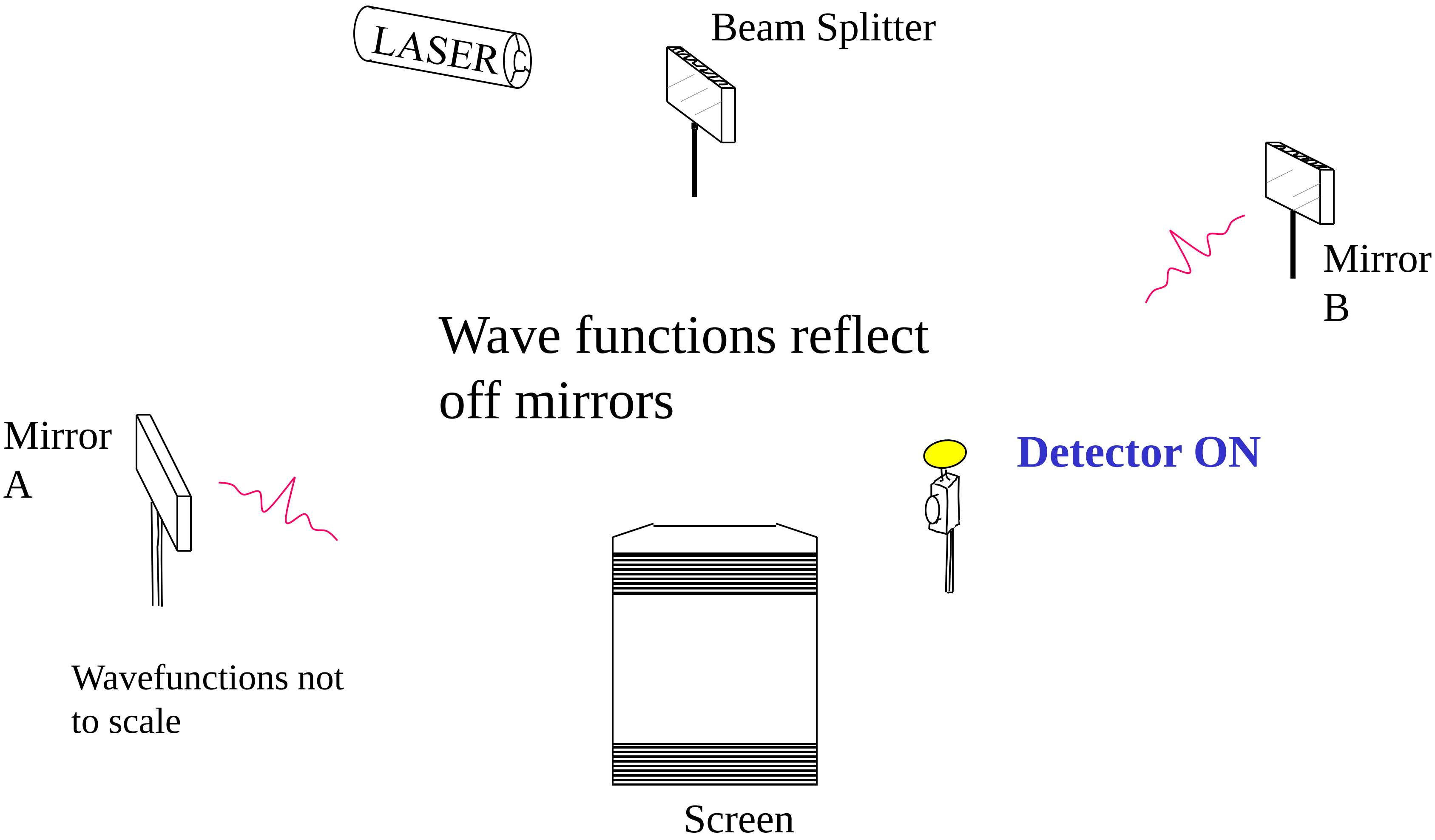

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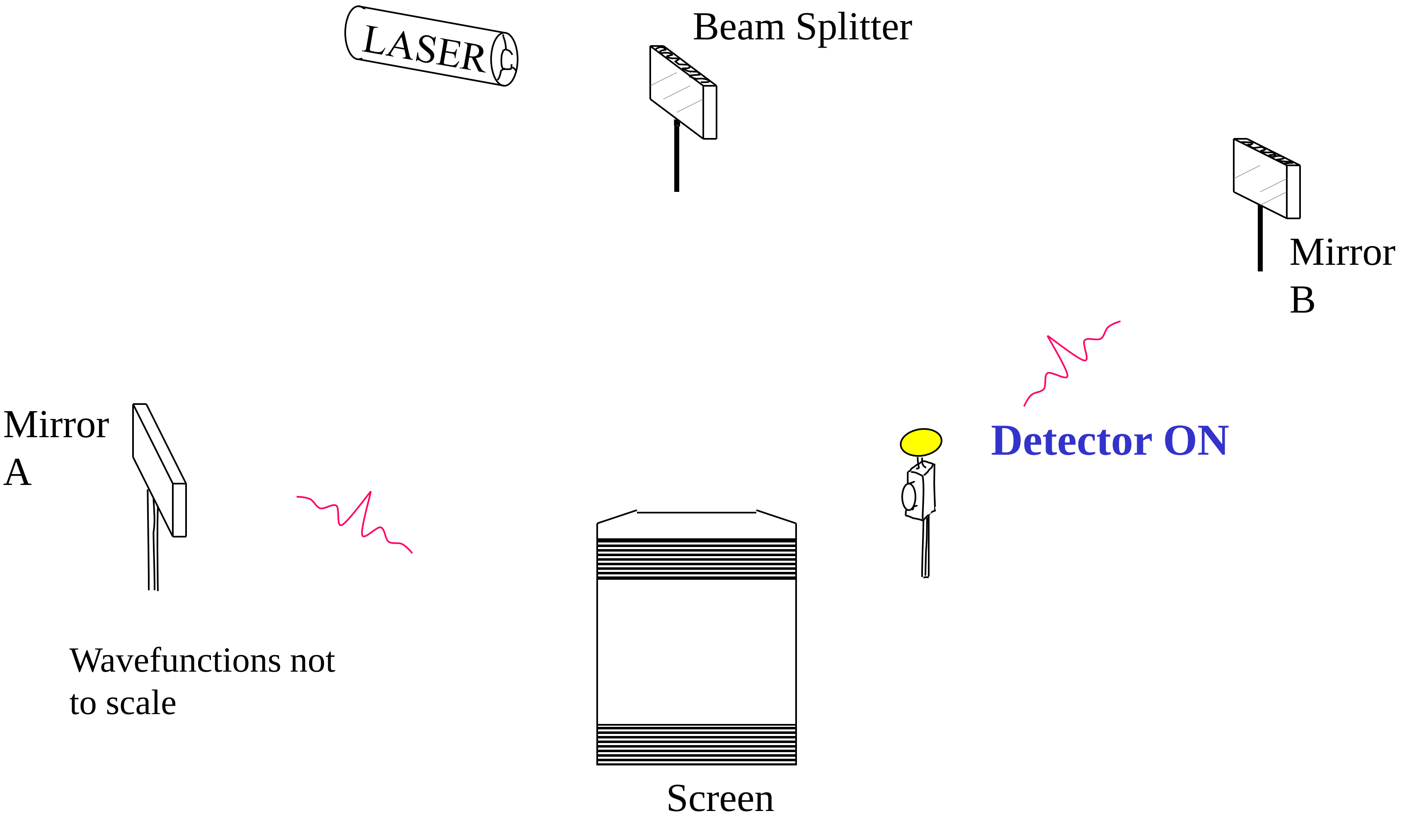

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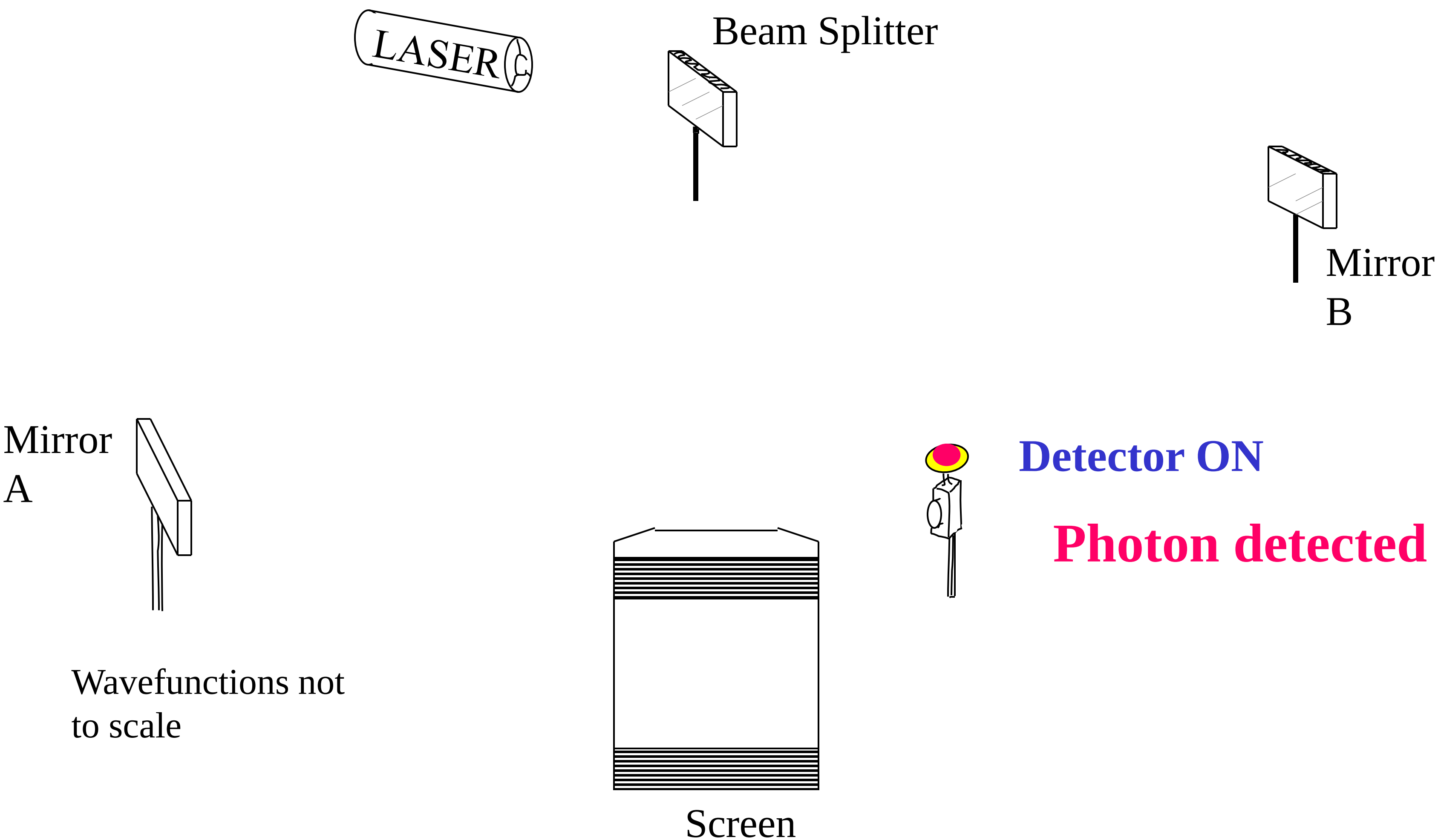

With *detector* in the path:

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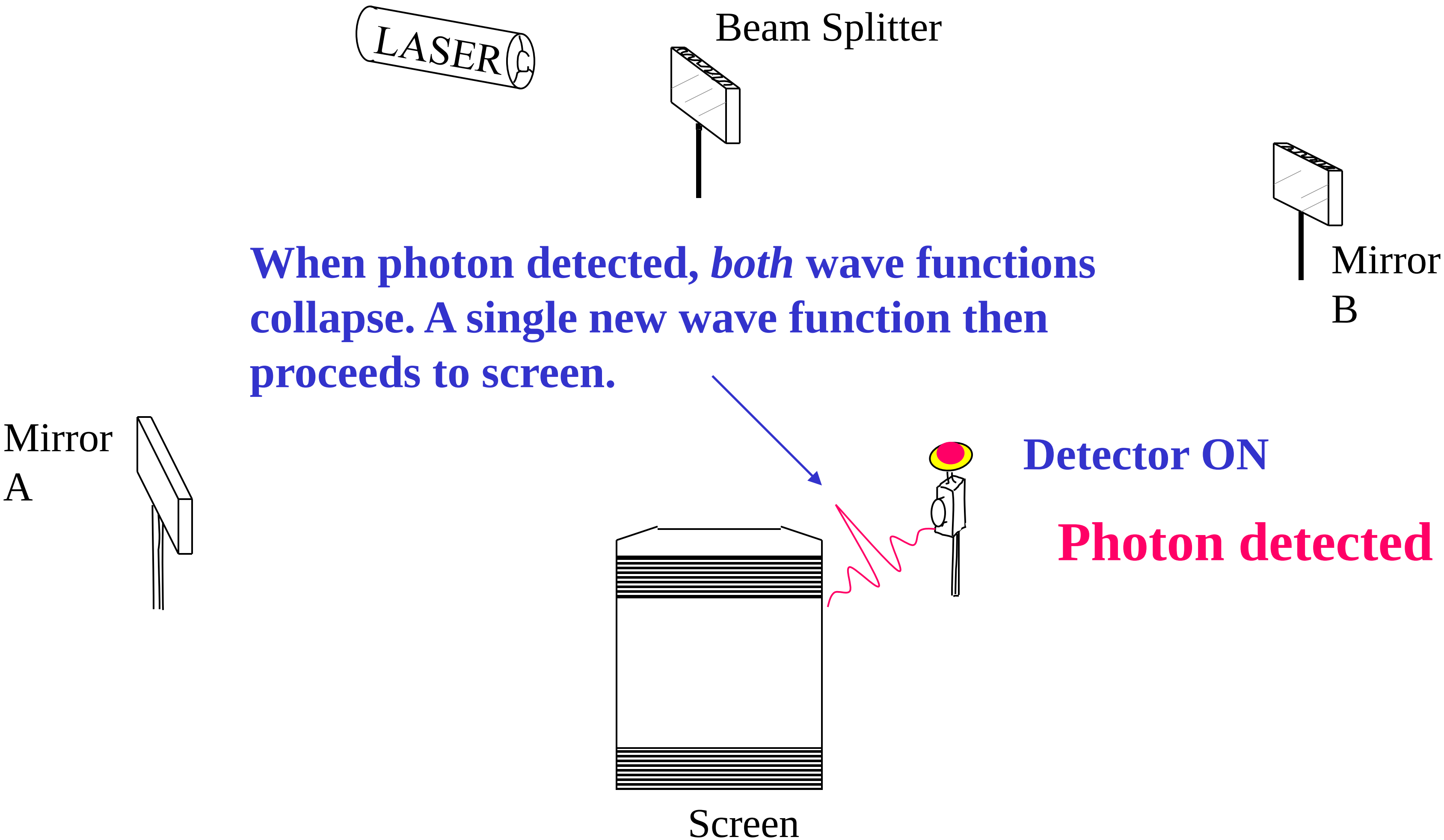
A single photon

When photon detected, *both* wave functions collapse. A single new wave function then proceeds to screen.



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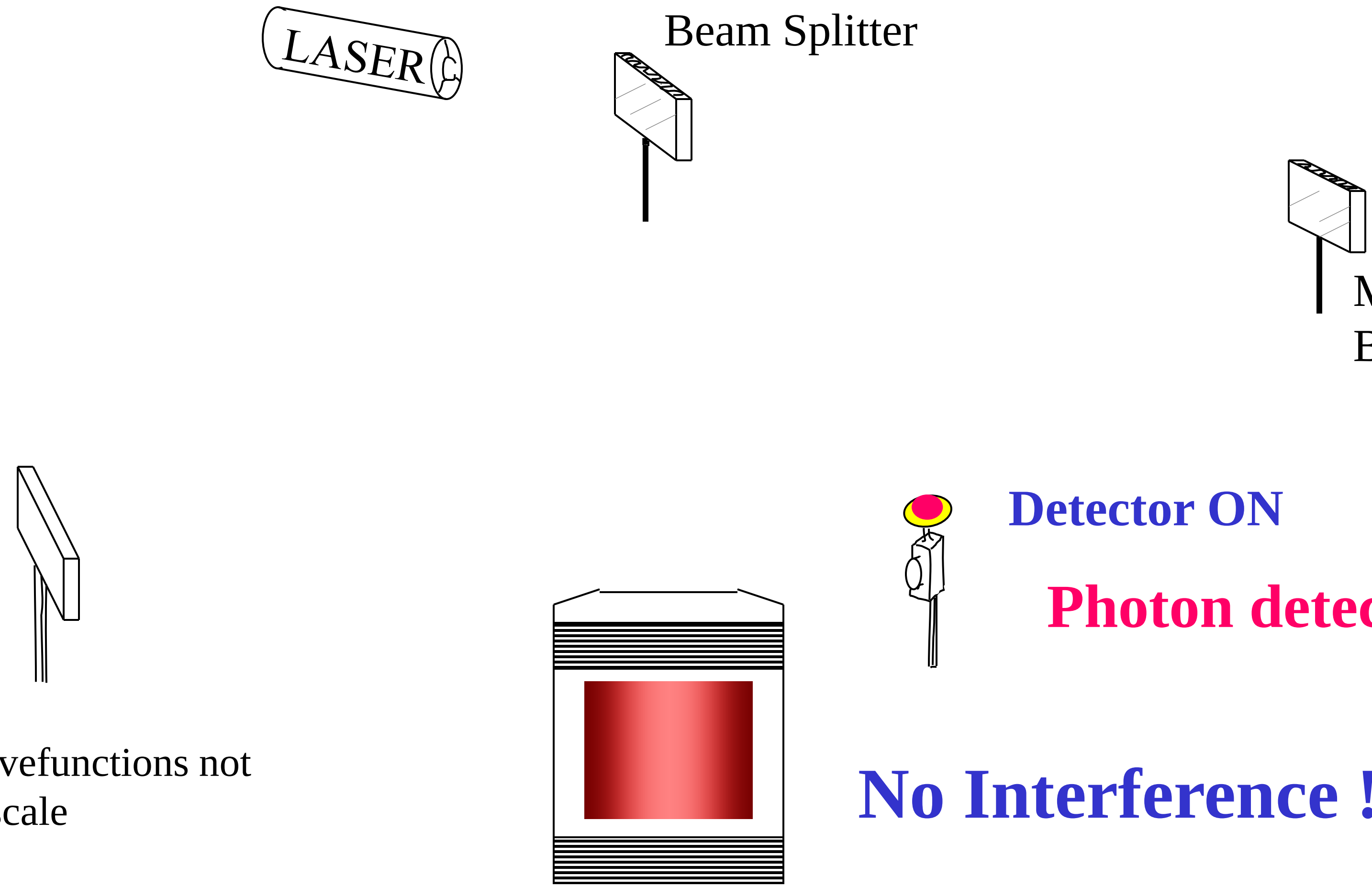

No Interference !

Wavefunctions not to scale

Screen (pattern over time for many photons)

What if the detector is *on*, but it does *not* detect the photon?

The wavefunction at the detector collapses.

- After all, the probability of there being a photon located at the detector is now zero.

- Only the wavefunction on the *left* side proceeds to the screen

Thus there is still *no interference* at screen

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Every experiment conducted to date has obeyed this simple yet profound law of nature.

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End of Animation