

### Lesson 3: The Superposition Principle

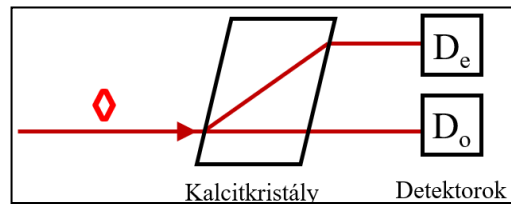
**Task 1.** Why probabilistic descriptions are used in the following situations? Compare them!

a) The top card of a mixed deck of French-suited playing card is red with  $1/2$  probability.

b) A dropped coin has  $1/2$  chance of showing the head side.

c) A  $45^\circ$  polarised photon has  $1/2$  chance of passing through a polariser with horizontal permitted direction.

**Task 2.** A single photon with  $45^\circ$  polarisation are emitted onto a birefringent calcite crystal. We put two detectors for the two possible paths. Experiments shows that the ordinary and extraordinary beam is polarised horizontally and vertically, respectively. The measurement is repeated many times.



a) Which statement is true? A single photon...

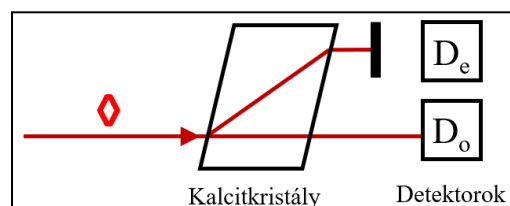
- ...will be found by one of the detectors at a time.
- ...will be found by the two detectors simultaneously.
- ...will be found only by the detector noted by \_\_\_\_\_.

b) Complete the open sentence relating to question a).

- A detector  $D_o$  has a \_\_\_% chance of finding a photon.
- A detector  $D_e$  has a \_\_\_% chance of finding a photon.

c) Cover the  $D_e$  detector. What is the expectation for the  $D_o$  detector?

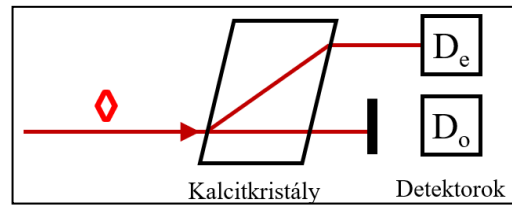
- It signals for each incident photons.
- It signals with 50% probability.
- A signal followed by a non-signal.
- It never signals.



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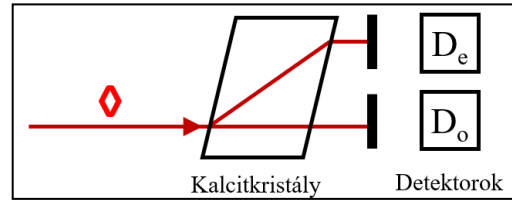
**d)** Cover the  $D_o$  detector. What is the expectation for the  $D_e$  detector?

- It signals for each incident photons.
- It signals with 50% probability.
- A signal followed by a non-signal.
- It never signals.



**e)** If we cover both detectors, what is the expectation?

- For each incoming photon, both detectors give a signal simultaneously.
- Each detector has a 50% chance of detecting a photon.
- One photon is detected by one detector and the other photon by the other detector.
- None of them signal.



**Task 3. a)** Can we say that photons follow a different path from the ordinary or extraordinary?

Yes    No

Justify!

**b)** Can we say that photons follow the two possible paths simultaneously?    Yes    No

Justify!

**c)** Can we say that half of the photons follow the ordinary, and the other half follow the extraordinary path?    Yes    No

Justify!

**d)** Is it possible to assign a trajectory to the single photons?    Yes    No

Justify!

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e) The trajectory of a photon cannot be tracked with the naked eye. In order to see something with the naked eye, light must be reflected from it to your eye, which is impossible in single photon cases. We can only infer the behaviour of the photons from the signals from the detectors. Can we say that the photon has chosen a path before the detector has given us any information about it?      Yes      No

**Task 4.** Let us re-interpret the polarisation example shown in the picture. What happens between the polariser and the detector?

