I have worked on an idea for a number of years that involves a delayed choice experiment with haunted quantum entanglement. I extended the idea of Greenberger and YaSin's haunted measurement to entanglement and obtained interesting results.

Recently, I presented a poster on this experiment at the 2012 APS March Meeting entitled "Delayed Choice Method with Haunted Quantum Entanglement for Choosing at a Distance an Overall Distribution Exhibiting Either Which-Way Information or Interference" (http://meetings.aps.org/link/BAPS.2012.MAR.K1.303). One implementation of this method could be done with some changes to the quantum eraser experiment (Kim, Yu, Kulik, Shih, and Scully, Phys. Rev. Lett., 84, 1-5, 2000) which was purely optical. There are only a few labs in the world who could do such an experiment.

Here is the abstract from my poster at the 2012 Spring APS meeting:

"Particles 1 and 2 are entangled at one of two possible locations (providing which-way info). The entangled particles physically separate from each other where one particle [P1] preserves the ww information that accompanied entanglement and the other particle's motion [P2] supports interference in P2's overall distribution.
due to the device setup. With this step, P1 now supplies which-way info to P2 due to their entanglement.

Next, there is a delayed choice at a distance.

Choice A: P1 and the ww info it carries are essentially lost by releasing many other particles of similar character to P1 into the container with P1 before P2 is detected and before ww info for P1 becomes available to the environment or an irreversible ww measurement is made on P1. (The entanglement is then lost and so is the ww info supplied by P1 to P2.)

Choice B: P1 that carries ww info is not lost. (The entanglement is not lost and neither is the ww info P1 has supplied to P2.)

Repeat runs of method with choice A 100 times consecutively to develop an overall interference distribution pattern for P2 [not fringes and anti-fringes obtained in a quantum eraser], or instead repeat runs of method with choice B 100 times consecutively to develop an overall ww distribution pattern for P2."

I have attached the poster. I have also attached some drawings that indicate the changes that would be made to Kim's quantum eraser experiment. The Kim experiment is page 3 of the drawings (Fig. 5). My changes are on pages 6 and 7 (Figs. 8 and 9).

I also included drawings about how similar changes could be made to the micromaser thought experiment of Scully and his colleagues (Nature, vol. 351, p. 111, 1991). Professor Scully's micromaser experiments are on pages 1 and 2 (Figs. 3 and 4). In the figure on page 2, the micromaser cavities are filled with photons.
similar to the photon that is emitted by the atom passing through the cavity system. My changes are on pages 4 and 5 (Figs. 6 and 7).

I very recently found that a type of ultrafast switch might work with a single entangled photon (Hall-Altepeter-Kumar switch) might make the experiment feasible to perform. The switch routes an entangled photon along one of two possible routes. I attached 2 references to this work. I confirmed with one of the developers of the switch that the switch could be used in the experimental setup.

Two such switches in the paths of the idler photon (one along each path) could be thrown on or off before the signal photon reaches the detector screen. If the switches were off, the idler photon would be detected by one of the detectors located at the exit of the container through which the idler photon passes (which way distribution pattern). If the switches were turned on at the same time, the two possible paths of the idler photons would be diverted so that the idler photon would be lost in other similar photons before it was detected and before the signal photon reaches its detection screen (interference distribution pattern).

I had another idea about how to "lose" the idler photon if the idler photon traveled along either possible path in the interferometer and a HAP (Hall, Altepeter, Kumar) switch located along each of the two possible paths is in the closed position. I found an optical microcavity, and I thought that perhaps it could be filled with many photons similar to idler photon. I was not sure about this, so I asked an expert in the field who worked with Professor Vahala at Cal Tech. The professor responded that an optical microcavity could be used for the purpose I intended, including that the photons would not leak into
the environment around the cavity. So now there are the pieces to "lose" the idler photon in many other similar photons so that this process can be realized in an experiment. It appears that the experiment I proposed in theory can now be realized experimentally.

References


DELAYED CHOICE METHOD WITH HAUNTED QUANTUM ENTANGLEMENT FOR CHOOSING AT A DISTANCE AN OVERALL DISTRIBUTION EXHIBITING EITHER WHICH-WAY INFORMATION OR INTERFERENCE

DOUGLAS SNYDER – APS MARCH MTG 2012 - K1.00303

ENTANGLEMENT BETWEEN PARTICLES 1 AND 2 WHERE ENTANGLEMENT OCCURS AT ONE OF TWO POSSIBLE LOCATIONS (PROVIDING WHICH WAY INFORMATION).


With this step, Particle 1 now supplies which-way information to Particle 2 due to the entanglement.

DELAYED CHOICE AT A DISTANCE

CHOICE A
ESSENTIALLY LOSE P1 AND THE WW INFORMATION IT CARRIES BY RELEASING MANY OTHER PARTICLES OF SIMILAR CHARACTER TO P1 INTO CONTAINER WITH P1 BEFORE P2 IS DETECTED AND BEFORE WW INFO BECOMES AVAILABLE TO THE ENVIRONMENT OR AN IRREVERSIBLE WW MEASUREMENT IS MADE ON P1. (THE ENTANGLEMENT IS THEN LOST AND SO IS THE WW INFORMATION SUPPLIED BY P1 TO P2.)

Repeat runs of device with choice A 100 times consecutively to develop overall interference distribution pattern for P2.

CHOICE B
DO NOT LOSE P1 THAT CARRIES WW INFORMATION. (THE ENTANGLEMENT IS NOT LOST AND NEITHER IS THE WW INFORMATION P1 HAS SUPPLIED TO P2.)

Repeat runs of device with choice B 100 times consecutively to develop overall ww distribution pattern for P2.
cross section of detection screen

distribution pattern along screen

maser cavities with two shutters and photodetector

PRIOR ART

collimators

Figure 3

Sub-interference pattern 1
Sub-interference pattern 2
Sample shape of distribution where micromaser shutters are closed and atoms have passed through the two-slit screen. This distribution is the sum of sub-interference patterns 1 and 2 where there is quantum erasure.
Basic features of experiment 2 using a carefully tuned rf coil along one path proposed by Scully and colleagues where passage by coil changes state of atom on path to slit A to the same state the atom would have were it on path to slit B.
½ photons that reach Y are detected at D3
½ of all photons reflected from BS_Y and BS_Z reach D1
½ of all photons reflected from BS_Y and BS_Z reach D2
½ photons that reach Z are detected at D4

Schematic of Quantum Eraser Experiment by Kim and Colleagues

Figure 5

Sub-interference pattern for signal photons paired to idler photons detected at D1.
Sub-interference pattern for signal photons paired to idler photons detected at D2.
Sum of sub-distribution patterns. Distribution of signal photons paired to idler photons detected at D1 or D2. Does not include distribution of signal photons paired to idler photons detected at D3 or D4.

Signal photon

Two possible photon sources A and B

N

M

BS_Y

BS_Z

D4

D3

D2

D1
cross section of detection screen
distribution pattern along screen

Figure 6

Expected shape of distribution of atoms with one photon emitted by atom passing through cavity system and no injection of other photons of similar character (one-hump characteristic of which-way information).
Expected distribution associated with Young-like interference pattern where single photon emitted by atom passing through cavity system and classical microwave radiation injected into each cavity before atom reaches 2-slit arrangement.
½ idler photons are detected at D3

Signal photon paths overlap very soon after traversing the lens and signal photon provides no ww information itself.

From creation of photon until detection:

\[ \Psi_{\text{total}} = \frac{1}{\sqrt{2}}(\psi_{S\ A} \psi_{I\ A} + \psi_{S\ B} \psi_{I\ B}) \]

\[ <\psi_{I\ A}^* \psi_{I\ B}> = 0 \]

\[ <\psi_{I\ B}^* \psi_{I\ A}> = 0 \]

I – Idler
S – Signal

Figure 8
Schematic of Two Photon Haunted Quantum Entanglement Where Classical Light Not Injected Into Evacuated Box
Path length from photon sources to detector D3 > path length from photon sources to position where classical light injected; $t_{IL} < t_{S_x}$

Detection axis for D3

Region of overlapping signal photon paths

Signal photon $\psi_{S_B}$

Signal photon paths overlap very soon after traversing lens and provide no information itself as regards signal photon distribution at detection axis for D3.

Before time $t_{IL}$:

$\Psi_{total} = \frac{1}{\sqrt{2}}(\psi_{S_A} \psi_{I_A} + \psi_{S_B} \psi_{I_B})$

$<\psi_{I_A^*} \psi_{I_B}> = 0$

$<\psi_{I_B^*} \psi_{I_A}> = 0$

$I$ – idler

$S$ - Signal

After time $t_{IL}$:

$\Psi_{total\_signal} = [1/\sqrt{2} \ [\psi_{S_A} + \psi_{S_B}]]$

Idler photon effectively lost.

Time $t_{IL}$ when classical light injected into shielding box
Path length from photon sources to detector D3 > path length from photon sources to positions corresponding to the time the 2 HAP switches can be closed; $t_{IL} < t_{S,x}$

Detection axis for D3

Region of overlapping signal photon paths

Signal photon $\psi_{S_B}$

Signal photon paths overlap very soon after traversing the lens and provides no ww information itself.

From creation of photon until detection:

$$\Psi_{total} = 1/\sqrt{2}(\psi_{S_A} \psi_{I_A} + \psi_{S_B} \psi_{I_B})$$

$$<\psi_{I_A^*} \psi_{I_B}> = 0$$

$$<\psi_{I_B^*} \psi_{I_A}> = 0$$

I – Idler
S - Signal

Switches in open position
All idler photons to D1 or D2

Two possible photons sources A and B

OMC’s – Optical Microcavities

OMC’s filled with photons similar to idler

No idler photons lost in OMC radiation

HAP Switch

HAP Switch - Hall
Altepeter Kumar
Switch

$\frac{1}{2}$ idler photons are detected at D1

$\frac{1}{2}$ idler photons are detected at D2

Figure 1
Schematic of Two Entangled Photons Where Switch in Open Position
Path length from photon sources to detector D3 > path length from photon sources to positions corresponding to the time the 2 HAP switches can be closed; $t_C < t_{S_x}$

Region of overlapping signal photon paths

Signal photon $\psi_{S_B}$

Signal photon paths overlap very soon after traversing the lens and provides no information itself.

From creation of photon until time $t_{IL}$:

$$\Psi_{total} = \frac{1}{\sqrt{2}}(\psi_{S_A} \psi_{I_A} + \psi_{S_B} \psi_{I_B})$$

$$<\psi_{I_A}* \psi_{I_B}> = 0$$

$$<\psi_{I_B}* \psi_{I_A}> = 0$$

After time $t_{IL}$:

$$\Psi_{total\_signal} = [\frac{1}{\sqrt{2}} [\psi_{S_A} + \psi_{S_B}]]$$

Idler photon effectively lost.

Schematic of Two Entangled Photons Where Switch in Closed Position (Haunted Quantum Entanglement)

Switches in closed position at $t_C$ All idler photons lost in OMC's

Time $t_C$ when the 2 switches closed

D1 0 idler photons are detected at D1

OMC's filled with photons similar to idler

All idler photons lost in OMC radiation

Figure 2