Notes on How to Realize in the Lab the Delayed Choice Method with Haunted Quantum Entanglement for Choosing at a Distance an Overall Distribution Exhibiting Either Which-Way Information or Interference

DOUGLAS M. SNYDER
LOS ANGELES, CALIFORNIA

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 implemenation 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 routs 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 cold 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

Optical Microcavities, Nature, Kerry J. Vahala, vol, 424. 14 August 2003, ps. 839-846.

Ultrafast Switching of Photonic Entanglement, Matthew A. Hall, Joseph B. Altepeter, and Prem Kumar, Phys. Rev. Lett. 106, 053901 (2011) [4 pages]; also arXiv:1008.4879v2 [quant-ph]

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).

ENTANGLED PARTICLES PHYSICALLY SEPARATE FROM EACH OTHER WHERE ONE PARTICLE [P1] PRESERVES WW INFORMATION THAT ACCOMPANIED ENTANGLEMENT AND THE OTHER PARTICLE'S MOTION [P2] SUPPORTS INTERFERENCE IN P2'S OVERALL DISTRIBUTION DUE TO DEVICE SETUP.

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.

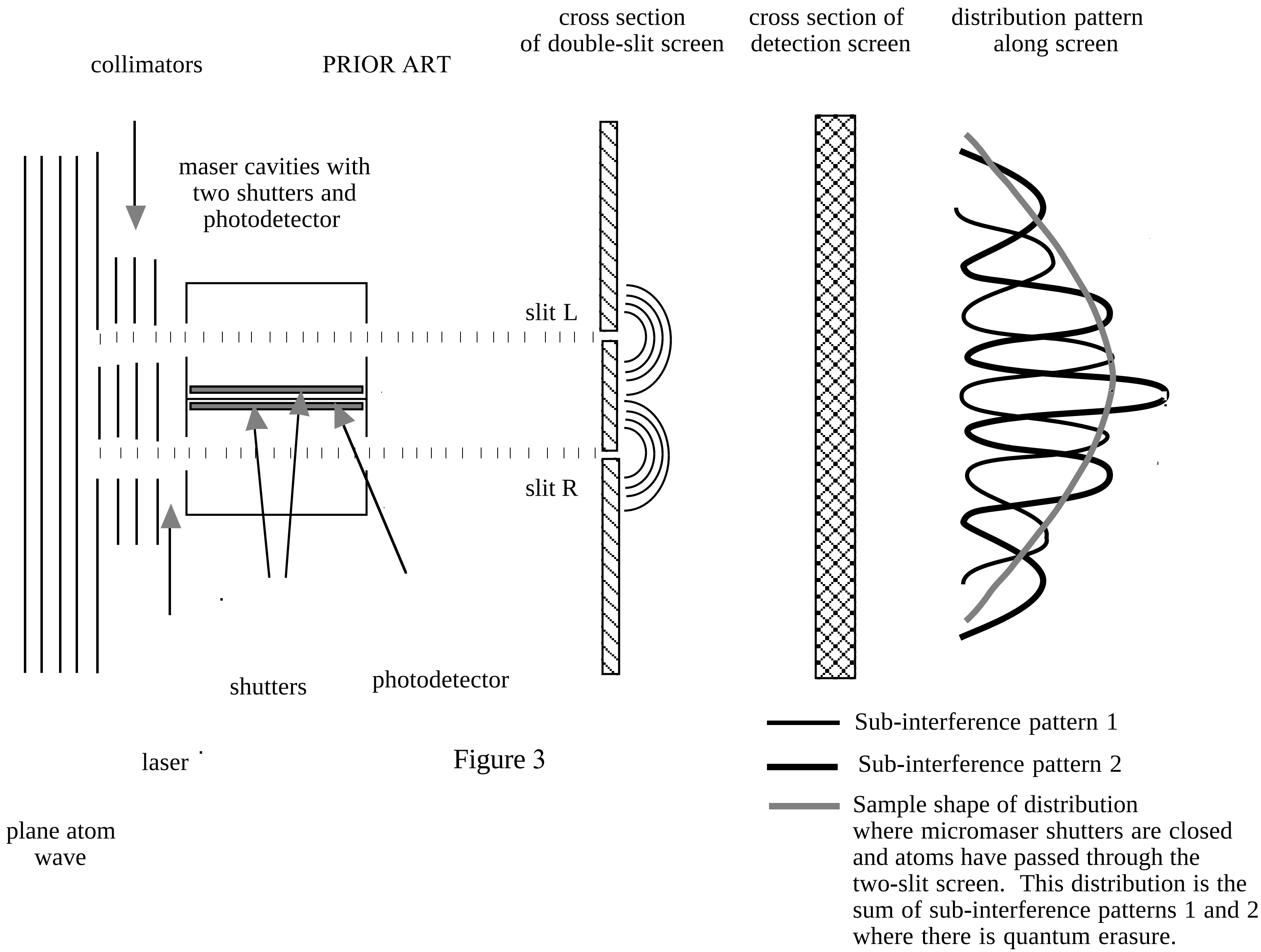

collimators
PRIOR ART
cross section
of double-slit screen
cross section of
detection screen
distribution pattern
along screen
maser cavities with
two shutters and
photodetector
slit L
slit R
shutters
photodetector
laser
plane atom
wave
Sub-interference pattern 1
Sub-interference pattern 2
Sample shape 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.

Figure 3

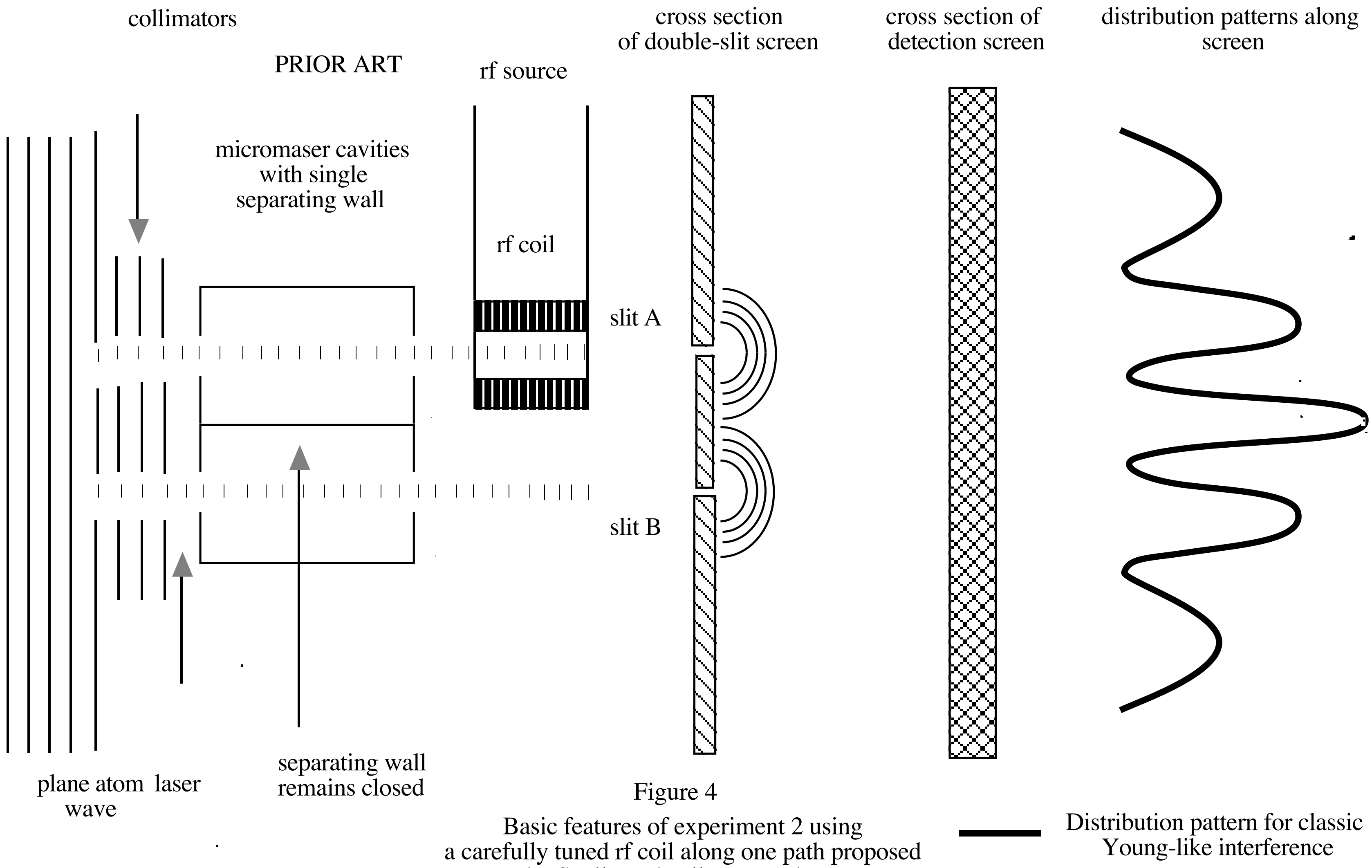
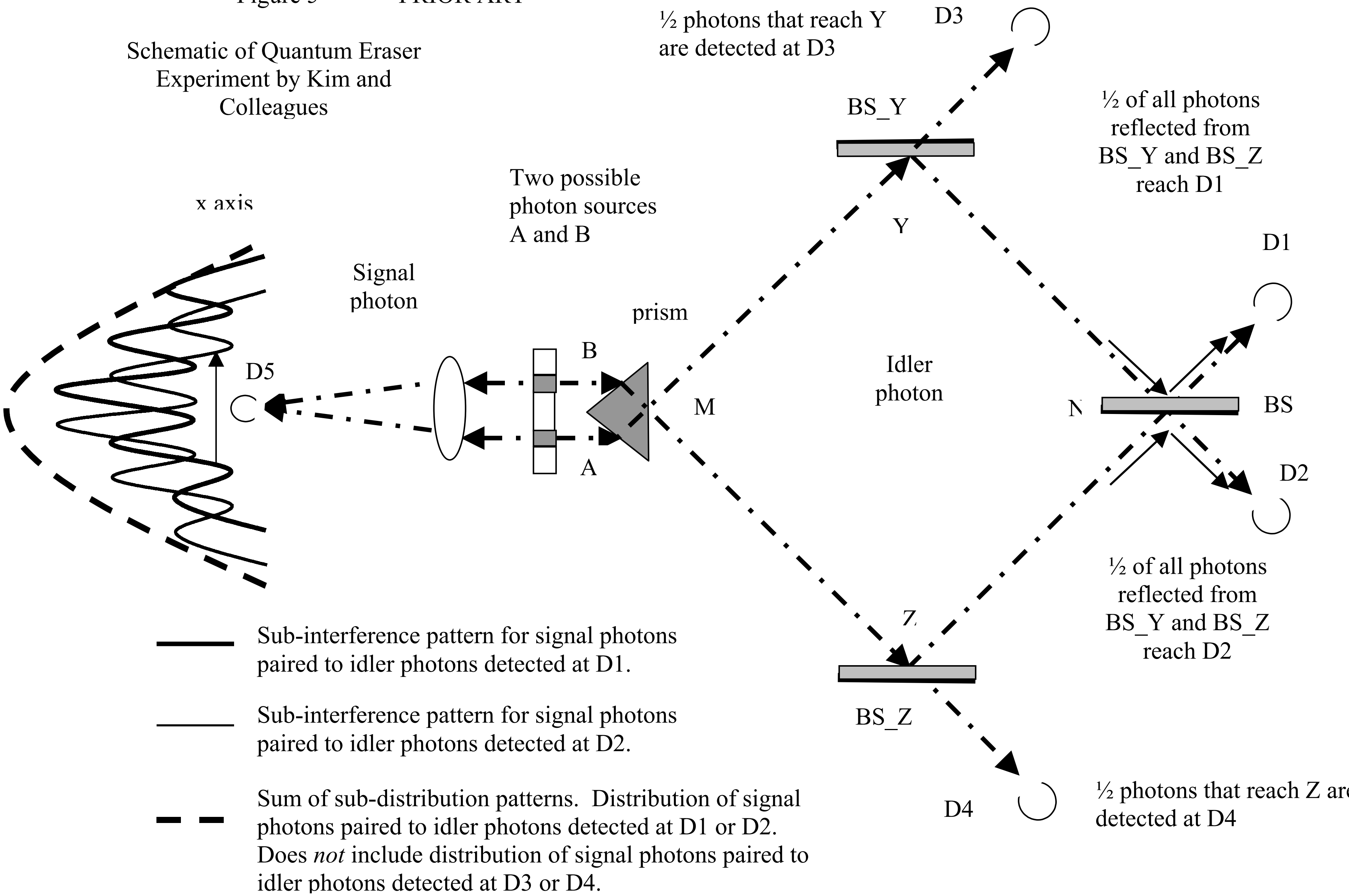


Figure 4

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.

Figure 5 PRIOR ART

Schematic of Quantum Eraser Experiment by Kim and Colleagues



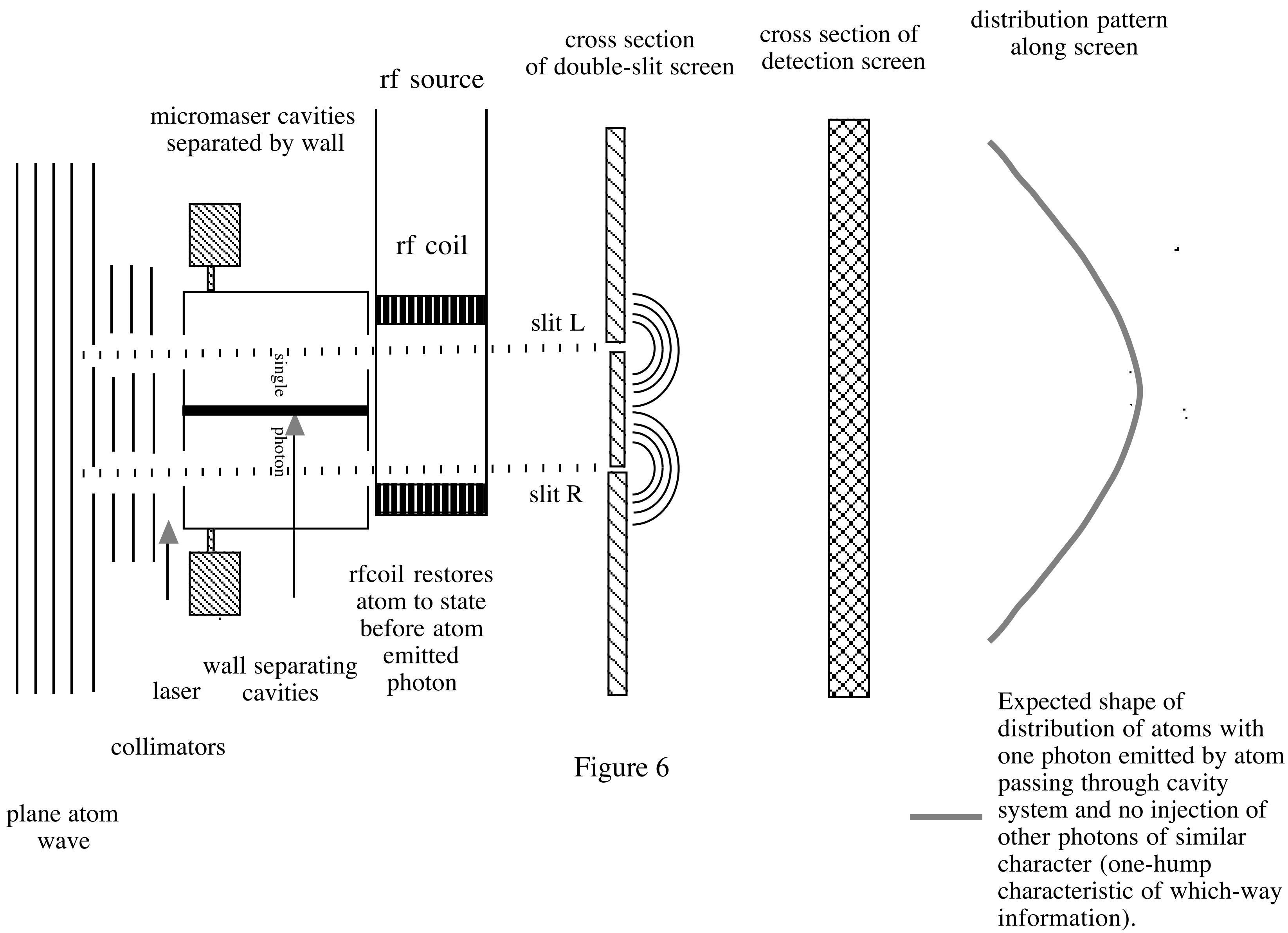

distribution pattern
along screen
cross section
of double-slit screen
cross section of
detection screen
rf source
micromaser cavities
separated by wall
rf coil
slit L
single
photon
slit R
rfcoil restores
atom to state
before atom
emitted
photon
wall separating
cavities
laser
collimators
plane atom
wave
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).

Figure 6

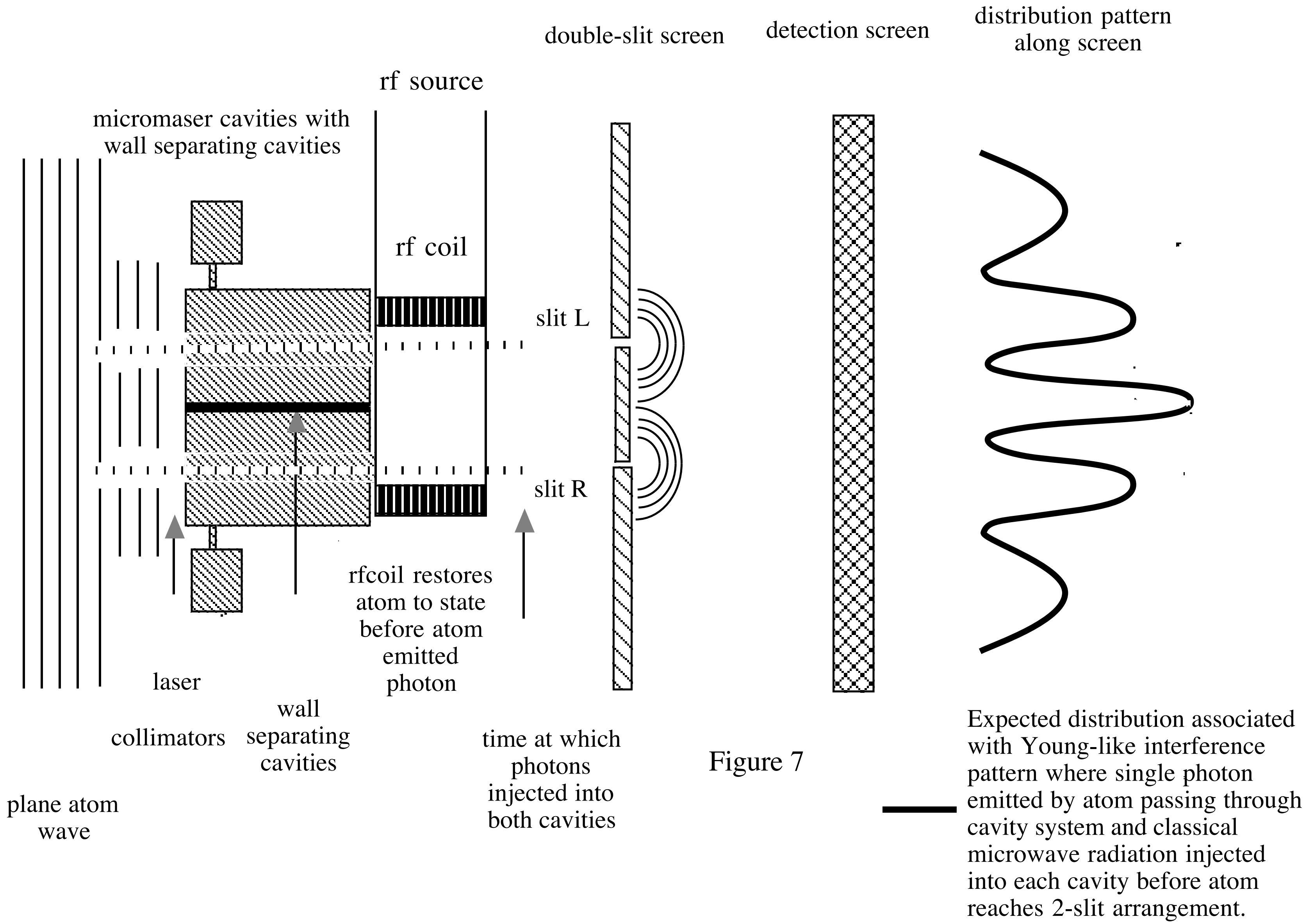

double-slit screen
detection screen
distribution pattern
along screen
rf source
micromaser cavities with
wall separating cavities
rf coil
slit L
slit R
rfcoil restores
atom to state
before atom
emitted
photon
laser
wall
separating
cavities
collimators
time at which
photons
injected into
both cavities
plane atom
wave
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.

Figure 7

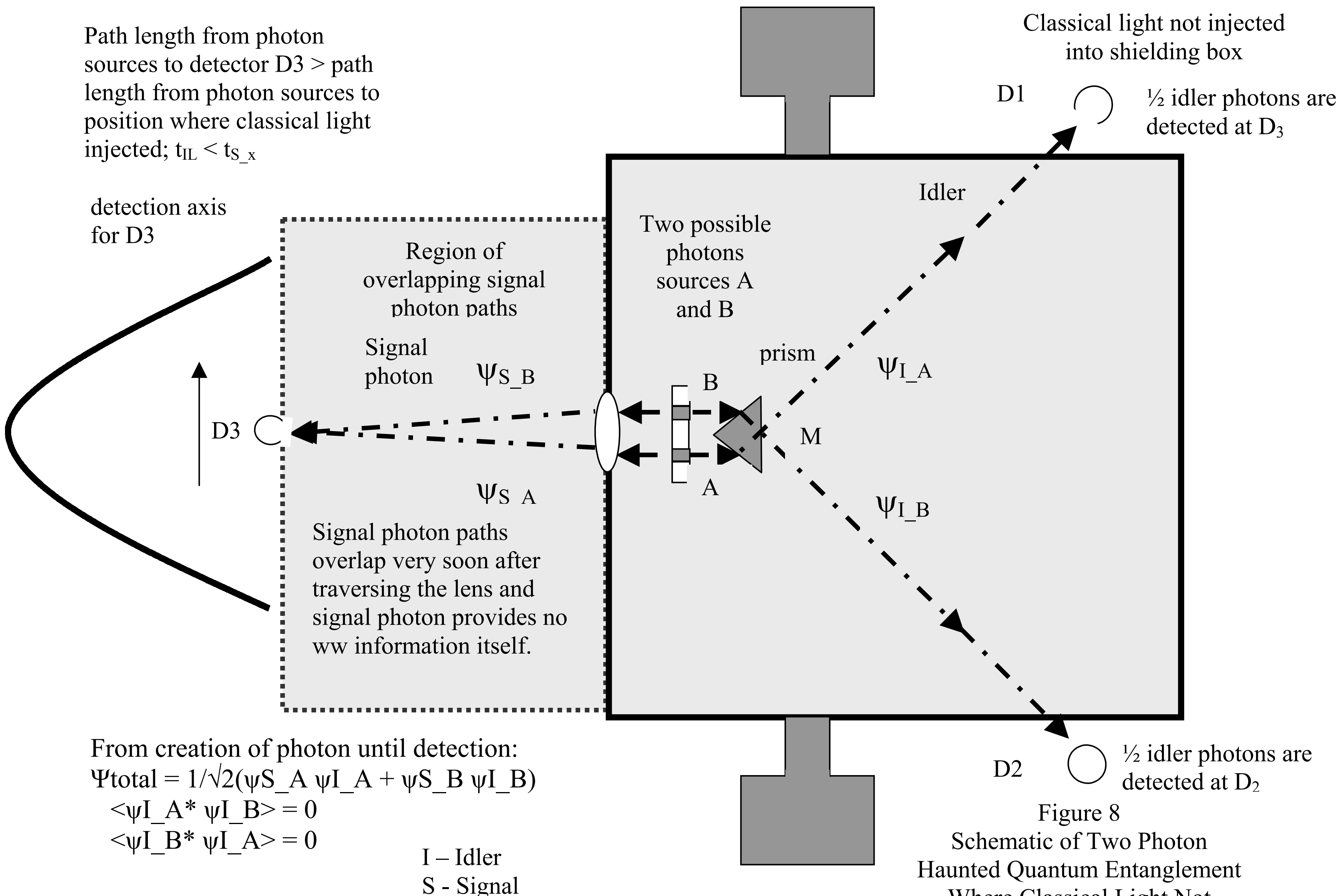


Figure 8
Schematic of Two Photon
Haunted Quantum Entanglement
Where Classical Light Not
Injected Into Evacuated Box

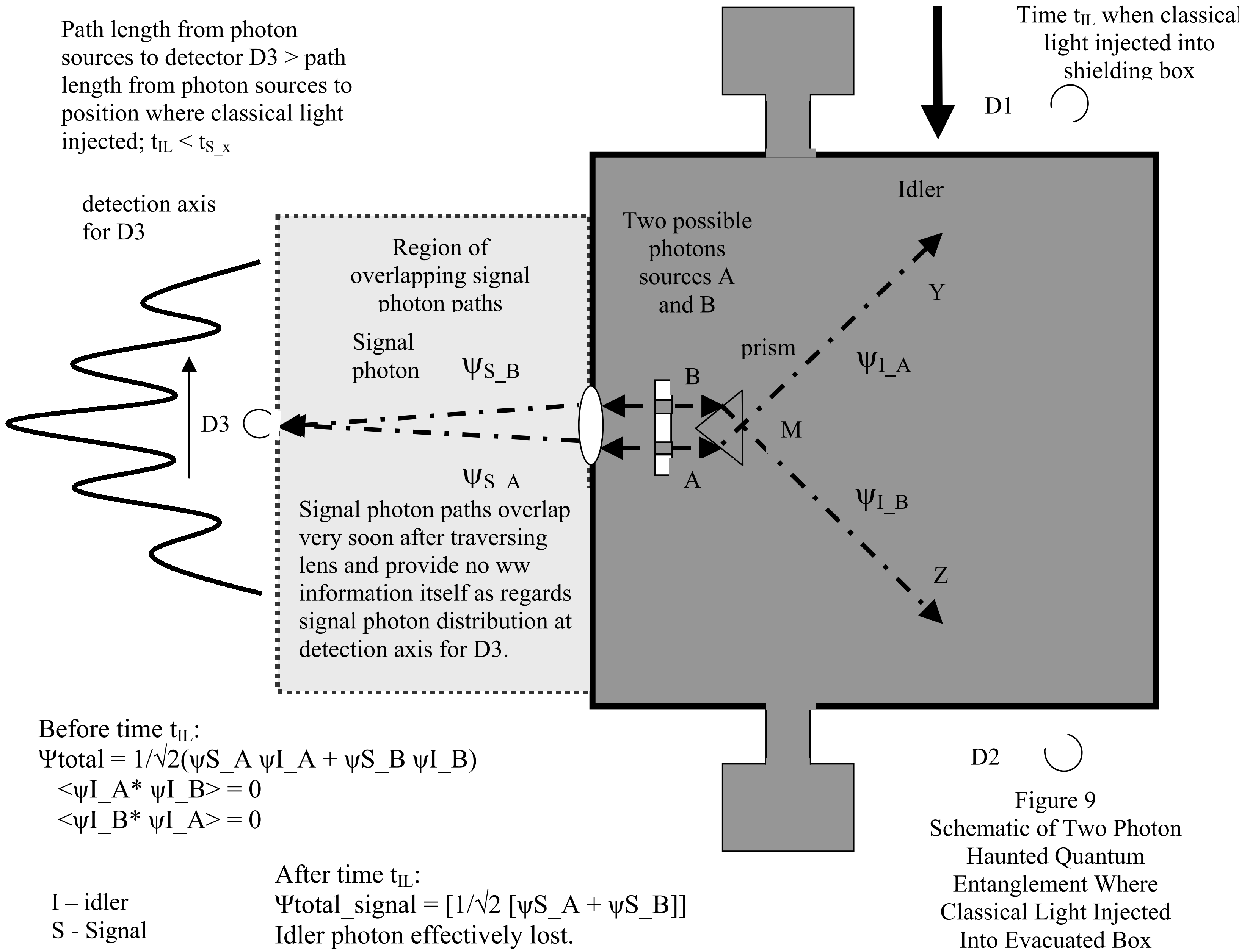
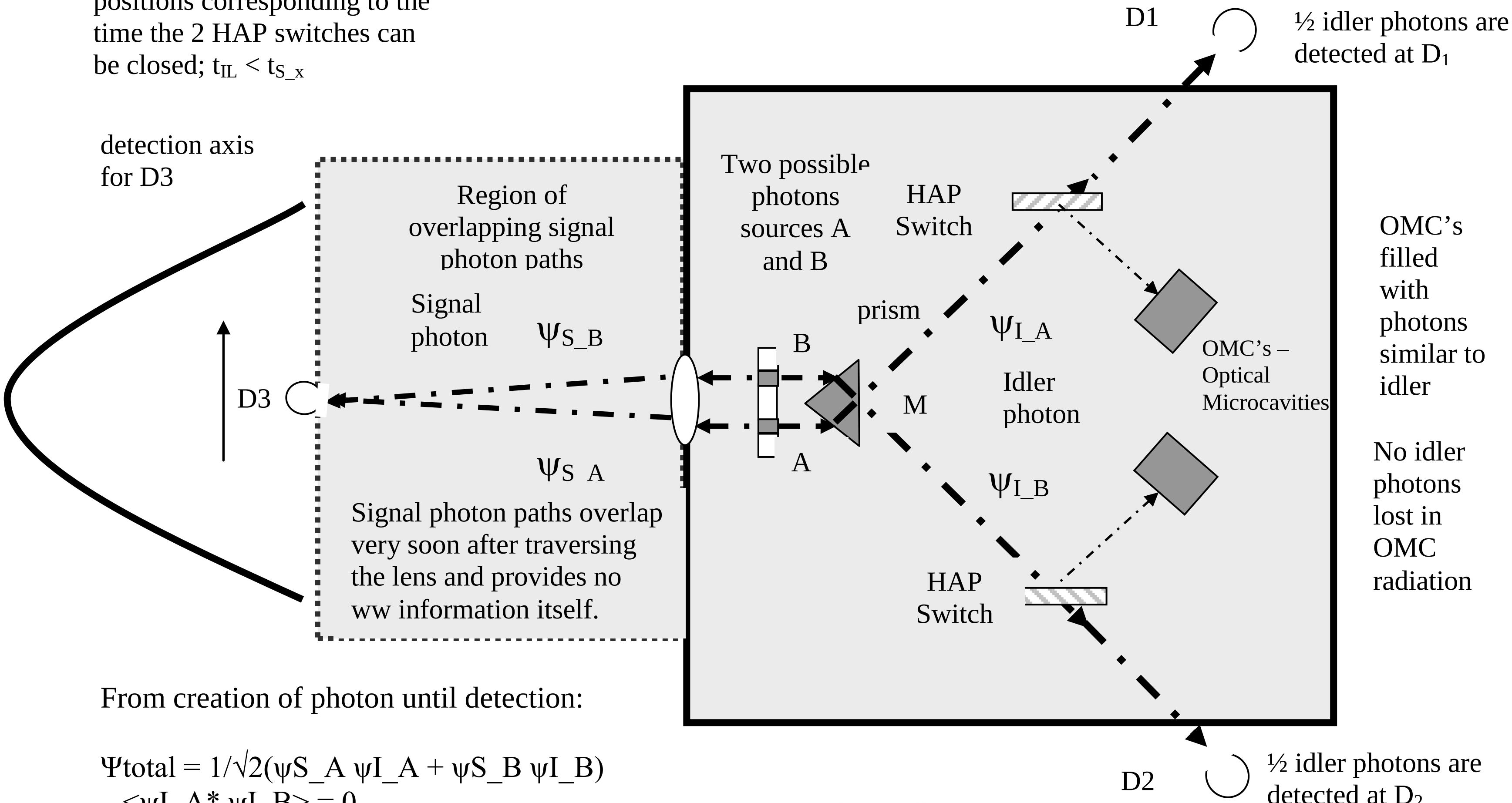


Figure 9
Schematic of Two Photon Haunted Quantum Entanglement Where Classical Light Injected Into Evacuated Box

Switches in open position
All idler photons to D1 or D2

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; $t_{IL} < t_{S\_x}$



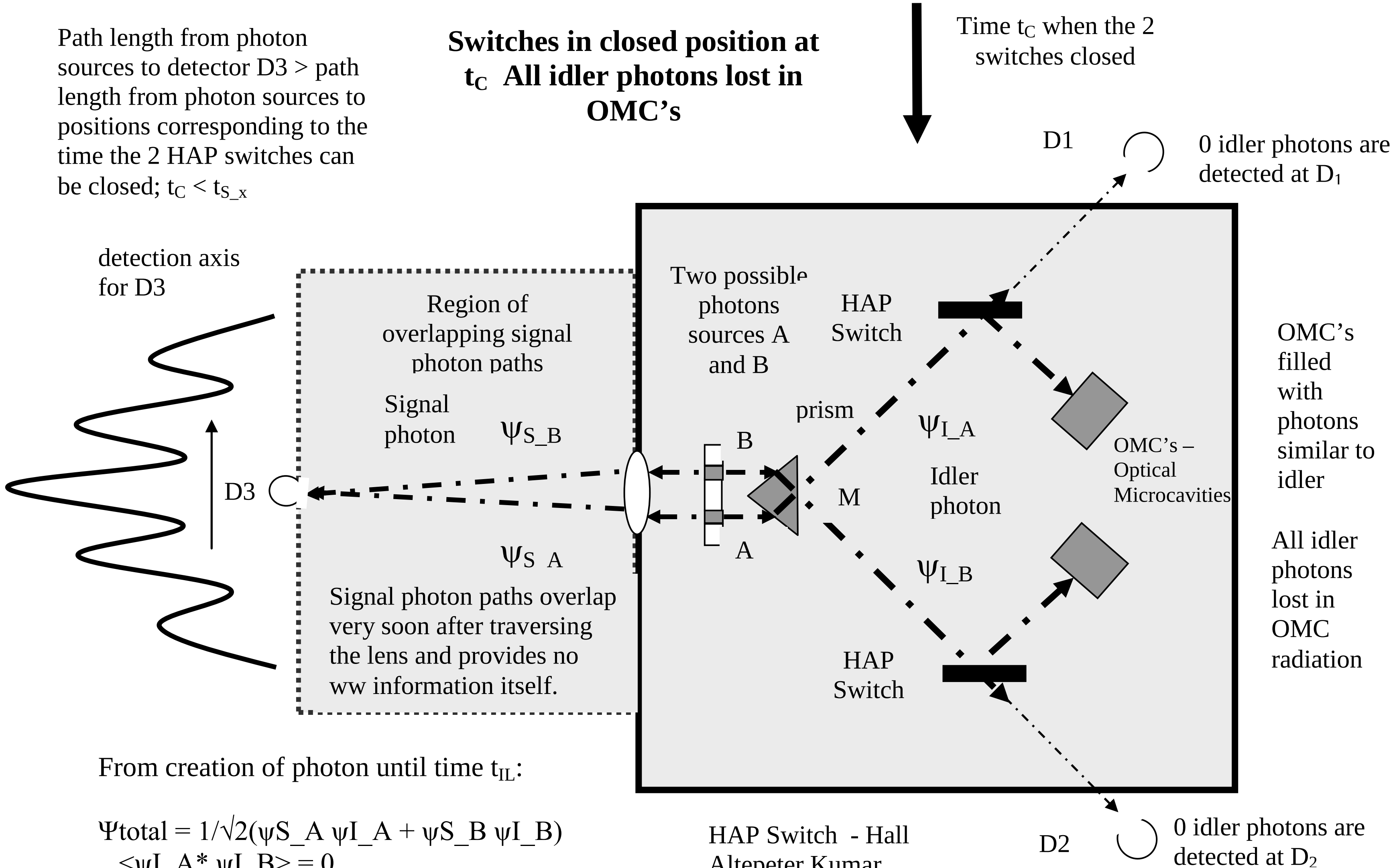
From creation of photon until detection:

$$\Psi total = 1/\sqrt{2}(\psi S\_A\ \psi I\_A + \psi S\_B\ \psi I\_B)$$
$$\langle \psi I\_A^*\ \psi I\_B \rangle = 0$$
$$\langle \psi I\_B^*\ \psi I\_A \rangle = 0$$

I – Idler
S - Signal

HAP Switch - Hall Altepeter Kumar Switch

Figure 1
Schematic of Two Entangled Photons Where Switch in Open Position



From creation of photon until time t_{IL}:

$\Psi total = 1/\sqrt{2}(\psi S\_A\ \psi I\_A + \psi S\_B\ \psi I\_B)$
$\langle \psi I\_A^*\ \psi I\_B \rangle = 0$
$\langle \psi I\_B^*\ \psi I\_A \rangle = 0$

After time t_{IL}:
$\Psi total\_signal = [1/\sqrt{2}\ [\psi S\_A + \psi S\_B]]$
Idler photon effectively lost.

HAP Switch - Hall Altepeter Kumar Switch

I – Idler
S - Signal

Figure 2
Schematic of Two Entangled Photons Where Switch in Closed Position (Haunted Quantum Entanglement)