HAUNTED QUANTUM ENTANGLEMENT

DOUGLAS SNYDER

ANNUAL MEETING OF THE CALIFORNIA AND NEVADA SECTIONS OF THE APS

OCTOBER 29-30, 2010 AT CAL TECH

I AM GOING TO BE SPEAKING TODAY ABOUT HAUNTED QUANTUM ENTANGLEMENT. MY INTEREST IN THIS TOPIC GREW OUT OF READING ABOUT THE HAUNTED MEASUREMENT AND THE QUANTUM ERASER. I HAVE FIVE SLIDES THAT I INTEND TO USE TO ILLUSTRATE MY POINTS.

SLIDE 1 **IS A DEPICTION OF*:***

- **GREENBERGER AND YASIN'S HAUNTED MEASUREMENT**

  THERE IS A NEUTRON INTERFEROMETER WITH AN ISOLATED FLEXIBLE MIRROR APPARATUS ALONG ONE ARM.

  WHILE THE NEUTRON PASSES THROUGH THE FLEXIBLE MIRROR APPARATUS, THERE IS WW INFORMATION REGARDING THE PATH OF THE NEUTRON. THE WW INFORMATION IS PRODUCED BY THE CHANGE IN MOMENTUM AND POSITION OF THE FLEXIBLE MIRROR APPARATUS THAT RESULTS FROM ITS INTERACTION WITH THE NEUTRON.

AFTER THE NEUTRON EXITS FLEXIBLE MIRROR APPARATUS, ALL WW INFORMATION IS ELIMINATED AND INTERFERENCE IS RESTORED AS IF THE WW INFORMATION NEVER EXISTED. THE ORIGINAL MOMENTUM AND POSITION OF THE FLEXIBLE MIRROR APPARATUS ARE RESTORED.

SLIDE 2 **IS A DEPICTION OF*:***

- **SCULLY, ENGLERT, AND WALTHER'S QUANTUM ERASER**

AN ATOM ENTERS THE MICROMASER CAVITY SYSTEM, ON THE LEFT OF THE FIGURE, AND EMITS A PHOTON INTO ONE OF THE TWO CAVITIES. THE CAVITIES HAVE NO OTHER PHOTONS IN THEM, AND THEY ARE TUNED TO THE SAME FREQUENCY. THE CAVITIES ARE SEPARATED BY SHUTTERS. BETWEEN THE SHUTTERS IS A PHOTODETECTOR.

THE ATOM EXITS THE CAVITY SYSTEM, PASSES THROUGH THE DOUBLE SLIT, AND PASSES ON TO THE DETECTION SCREEN. SOMETIME AFTER EXITING THE CAVITY SYSTEM, THE SHUTTERS ON THE MM CAVITIES ARE OPENED AND THE PHOTODETECTOR IS EXPOSED. THERE IS A 50-50 CHANCE THE PHOTON WILL BE DETECTED AT THE PHOTODETECTOR.

WHETHER OR NOT THE PHOTON IS DETECTED AT THE PHOTODETECTOR, WW INFORMATION IS LOST. THE RESULT IS

FRINGES AND ANTI-FRINGES WHEN ATOM DETECTION DATA AND PHOTODETECTION DATA ARE CORRELATED.

- **THE AUTHORS OF THE ARTICLES ON THE HAUNTED MEASUREMENT AND THE QUANTUM ERASER ACKNOWLEDGED SIMILARITIES IN THEIR WORK.**

- **BOTH THE HAUNTED MEASUREMENT AND THE QUANTUM ERASER CREATE WHICH WAY INFORMATION THROUGH ENTANGLEMENT AND WW INFORMATION IS SUBSEQUENTLY ELIMINATED.**

- **THERE IS A DIFFERENCE BETWEEN THE HAUNTED MEASUREMENT AND THE QUANTUM ERASER:**

  IN THE HAUNTED MEASUREMENT, INTERFERENCE IS RESTORED AS IF THE WHICH WAY INFORMATION NEVER EXISTED.

  IN THE QUANTUM ERASER, THERE ARE FRINGES AND ANTI-FRINGES THAT SUM TO AN *OVERALL ONE WIDE HUMP INDICATIVE OF WHICH WAY INFORMATION*.

- **WHAT IS THE BASIS FOR THE DIFFERENCE IN THE DISTRIBUTION PATTERNS IN THE HM AND THE QE?**

  IN A HAUNTED MEASUREMENT, THE ENTANGLEMENT IS LOST BEFORE ANY MEASUREMENT INFORMATION IS RELEASED TO THE

ENVIRONMENT. THE FLEXIBLE MIRROR APPARATUS IS ISOLATED.

IN THE QUANTUM ERASER, THE ENTANGLEMENT IS MAINTAINED. I SUSPECT THE ENTANGLEMENT IS MAINTAINED IN PART DUE TO THE RELEASE OF INFORMATION THAT A WW MEASUREMENT HAS OCCURRED WITH THE PASSAGE OF THE ATOM THROUGH THE DOUBLE SLIT. THE MM CAVITIES THEMSELVES ARE ISOLATED.

WITH THE OPENING OF THE SHUTTERS BETWEEN THE MM CAVITIES, INFORMATION REGARDING IN WHICH *SPECIFIC* MM CAVITY THE PHOTON WAS EMITTED IS LOST. INFORMATION THAT A WW MEASUREMENT HAS OCCURRED IS PRESERVED DUE TO THE RELEASE OF THIS INFORMATION.

- **IN A SETUP LIKE THE QUANTUM ERASER, CAN ONE OBTAIN INTERFERENCE AS IF THE WHICH WAY INFORMATON NEVER EXISTED AND WHERE THE WW INFORMATION WAS CARRIED BY THE PHOTON?**

  TO ACCOMPLISH THIS TASK, THE QE SCENARIO NEEDS TO BE CHANGED SO THAT THE ENTANGLEMENT BETWEEN THE PHOTON AND THE ATOM IS LOST *BEFORE* THE ATOM REACHES THE DOUBLE SLIT SCREEN.

SLIDE 3

- **AT END OF THE QE PAPER, THE AUTHORS PRESENT A SCENARIO LIKE THE QE BUT IN WHICH THE ATOM CARRIES THE WW INFORMATION, NOT THE PHOTON. THERE IS A SINGLE WALL SEPARATING THE MM CAVITIES. THE MICROMASER CAVITIES ARE FILLED WITH CLASSICAL MICROWAVE RADIATION, AND THE PHOTON THAT THE ATOM EMITS IS LOST IN THIS RADIATION. IT IS NOT KNOWN INTO WHICH CAVITY THE PHOTON WAS EMITTED.**

  THE ATOM ITSELF CARRIES WW INFORMATION BECAUSE THE MICROMASER CAVITIES ARE TUNED TO DIFFERENT FREQUENCIES. AT ONE EXIT OF THE MM CAVITY SYSTEM, AN RF COIL IS PLACED SO THAT IF THE ATOM PASSED THROUGH THE CAVITY ASSOCIATED WITH THAT EXIT, THE ATOM IS PLACED IN THE SAME STATE IT WOULD BE IN IF IT HAD EXITED THE OTHER CAVITY. THE RESULT IS AN INTERFERENCE PATTERN LIKE GREENBERGER AND YASIN'S, AS IF THE WW INFORMATION HAD NEVER EXISTED.

SLIDE 4

- **TO ACCOMPLISH THE GOAL OF OBTAINING INTERFERENCE AS IF WW INFORMATION NEVER EXISTED AND WHERE THE PHOTON CARRIED THE WW INFORMATION, A SINGLE WALL SEPARATES THE MICROMASER CAVITIES. THERE ARE RESERVOIRS OF CLASSICAL MICROWAVE RADIATION ADJACENT TO EACH MM CAVITY. IF THE CLASSICAL MICROWAVE RADIATION IS NOT RELEASED INTO THE MM**

CAVITIES, THE RESULTING DISTRIBUTION OF THE ATOMS IS THE ONE WIDE HUMP CHARACTERISTIC OF WW INFORMATION.

- **[SHOW SLIDE 2 AND POINT OUT ONE WIDE HUMP.]**

SLIDE 5

CONTINUING ON WITH THE STEPS NEEDED TO ACCOMPLISH THE GOAL OF OBTAINING INTERFERENCE AS IF WW INFORMATION NEVER EXISTED AND WHERE THE PHOTON CARRIED THE WW INFORMATION, THE ENTANGLEMENT IS ELIMINATED BY LOSING THE PHOTON *BEFORE* THE ATOM REACHES THE DOUBLE SLIT. THE PHOTON IS LOST BY FILLING BOTH MM CAVITIES WITH CLASSICAL MICROWAVE RADIATION *AFTER* THE PHOTON IS EMITTED AND THE ATOM EXITS THE CAVITY SYSTEM.

ANY POSSIBILITY OF THE ATOM ITSELF CARRYING WW INFORMATION IS ELIMINATED BY PLACING AN RF COIL THAT EXTENDS A FIELD OVER BOTH PATHS FROM THE EXITS OF THE MICROMASER CAVITIES THAT PLACES THE ATOM IN THE STATE IT HAD BEFORE IT EMITTED THE PHOTON.

- **THIS IS HAUNTED QUANTUM ENTANGLEMENT WHERE INTERFERENCE IS OBTAINED AS IF THE WW INFORMATION NEVER EXISTED AND THE PHOTON CARRIED THE WW INFORMATION FOR THE ATOM THAT IS DISTANT FROM IT. THE WW INFORMATION CARRIED BY THE PHOTON IS ELIMINATED *AT A DISTANCE* FROM THE**

ATOM WITH THE LOSS OF THE ENTANGLEMENT BETWEEN THE ATOM AND THE PHOTON.

GREENBERGER AND YASIN DEMONSTRATED HAUNTED QUANTUM ENTANGLEMENT IN THEIR EXPERIMENT WHERE THEY OBTAINED INTERFERENCE AS IF THE WW INFORMATON PROVIDED BY THE FLEXIBLE MIRROR APPARATUS HAD NEVER EXISTED. WW INFORMATION IN THEIR HAUNTED MEASUREMENT, THOUGH, IS ELIMINATED BY A DIRECT INTERACTION BETWEEN THE FLEXIBLE MIRROR APPARATUS AND THE NEUTRON INSTEAD OF AT A DISTANCE BETWEEN THEM AS OCCURS IN THE HQE SCENARIO PRESENTED HERE.

PROVIDE REFERENCES –

HAUNTED MEASUREMENTS IN QUANTUM THEORY – DANIEL GREENBERGER AND ALAINE YASIN – FOUNDATIONS OF PHYSICS, VOL. 19, NO. 6, 1989, PS. 678-704.

QUANTUM OPTICAL TESTS OF COMPLEMENTARITY – MARLAN SCULLY, BERTHOLD-GEORG ENGLERT, HERBERT WALTHER – NATURE, VOL. 351, MAY 9, 1991, PS. 111-116.

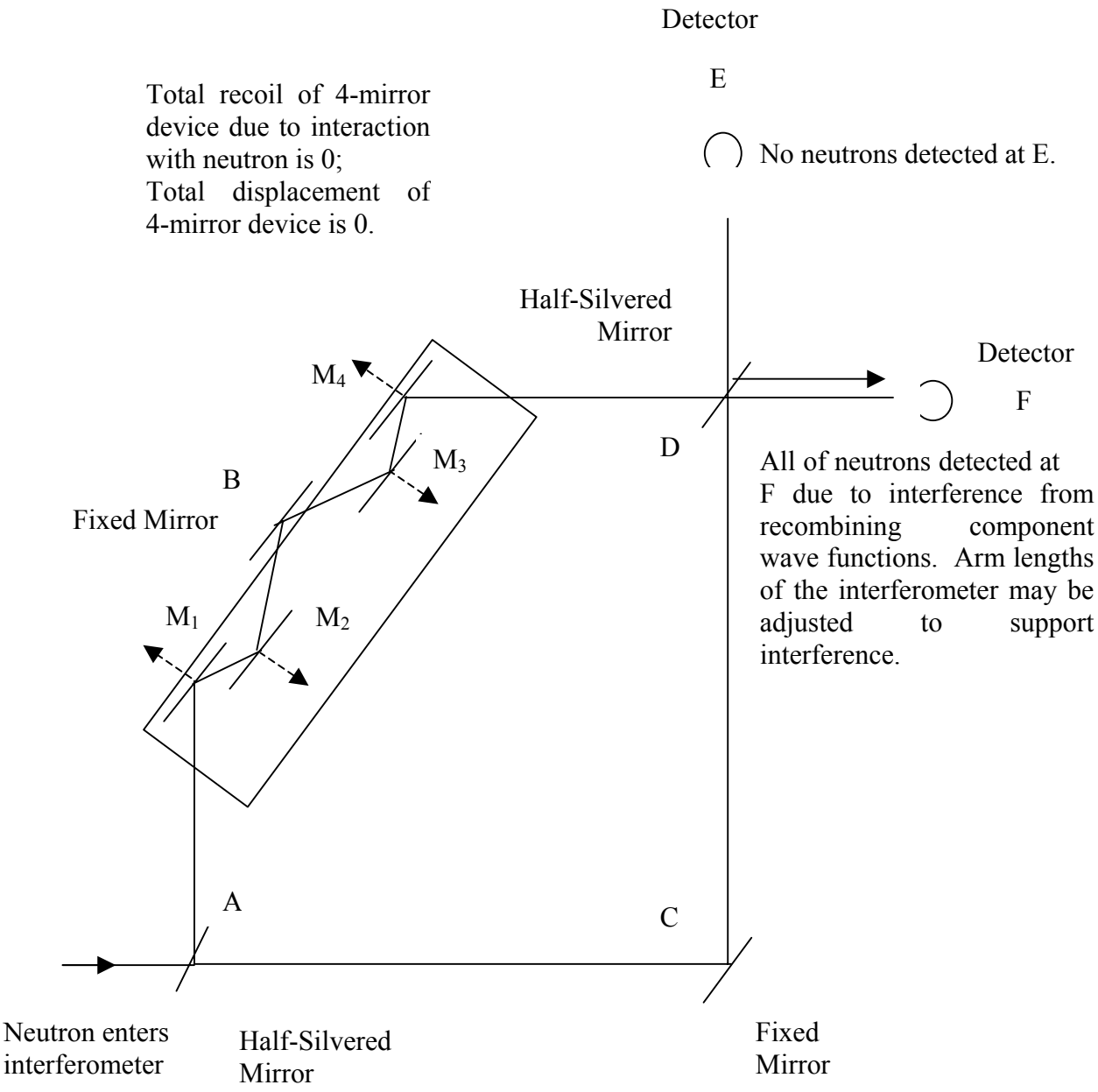

Figure 1: Interferometer with 4-Mirror Device Separated from the Environment: Component Wave Functions Are Recombined to Demonstrate Interference

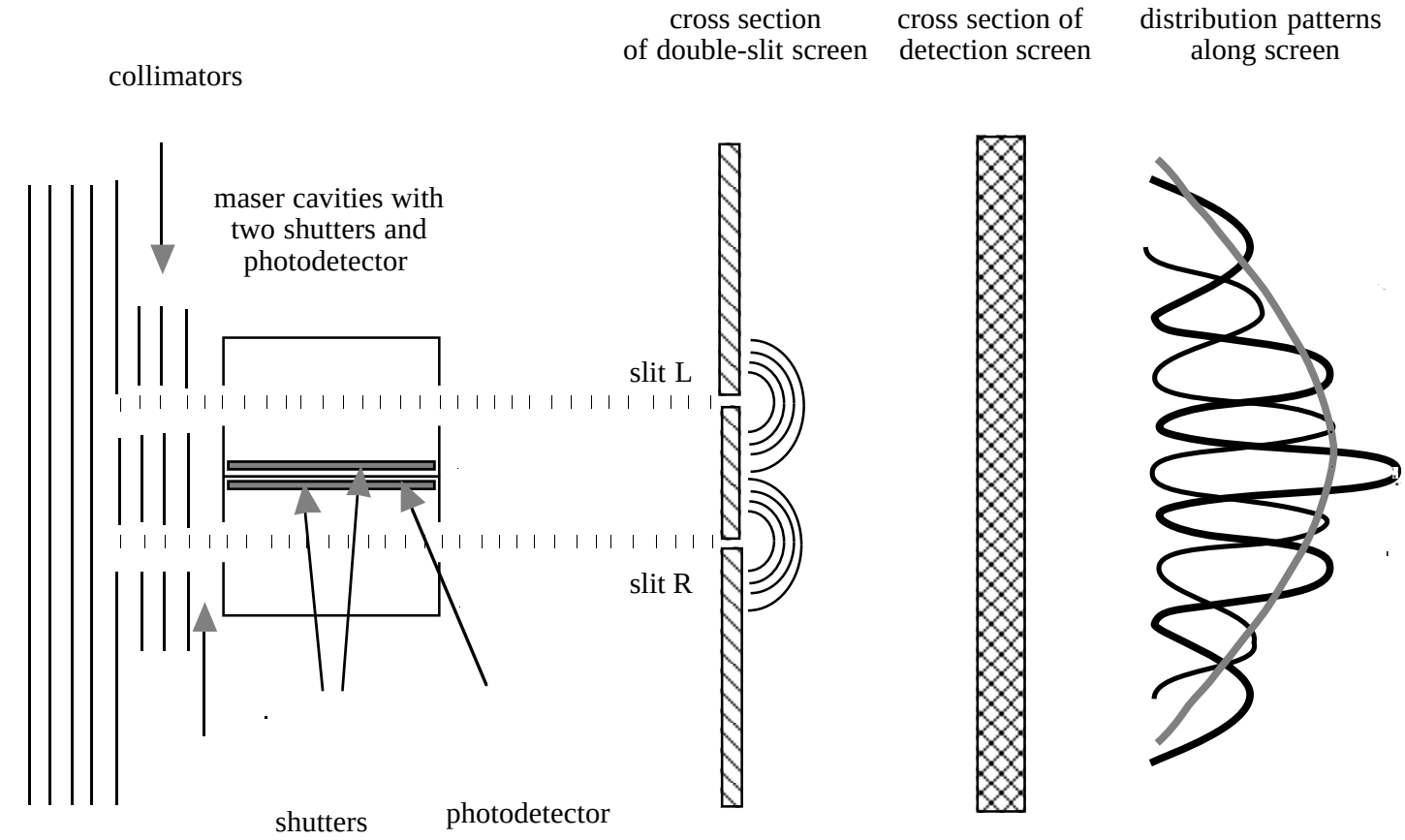
cross section
of double-slit screen
cross section of
detection screen
distribution patterns
along screen
collimators
maser cavities with
two shutters and
photodetector
slit L
slit R
shutters
photodetector
laser
plane atom
wave
Sub-interference pattern 1
Sub-interference pattern 2
Sample shape of distribution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

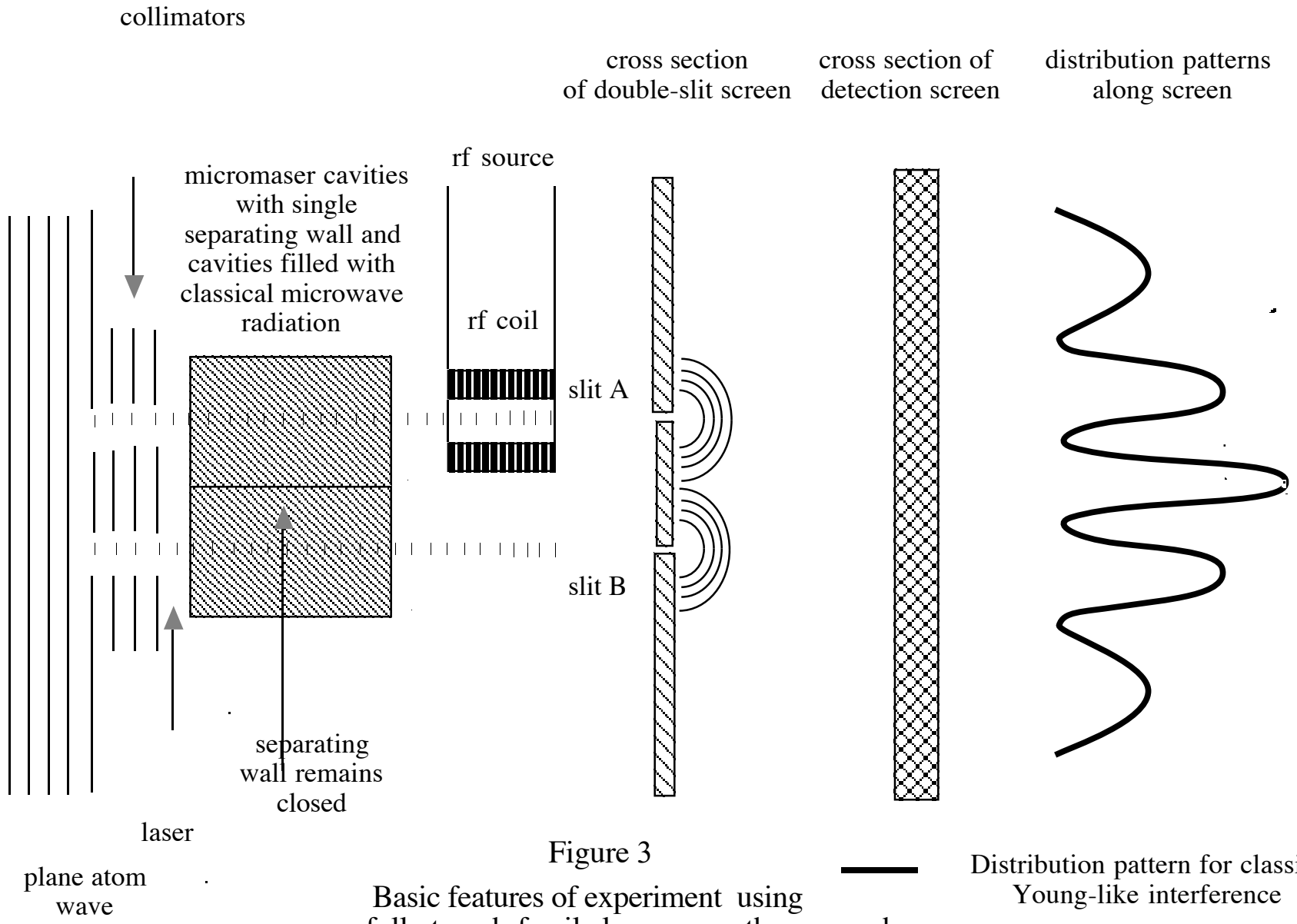

Figure 3

Basic features of experiment 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.

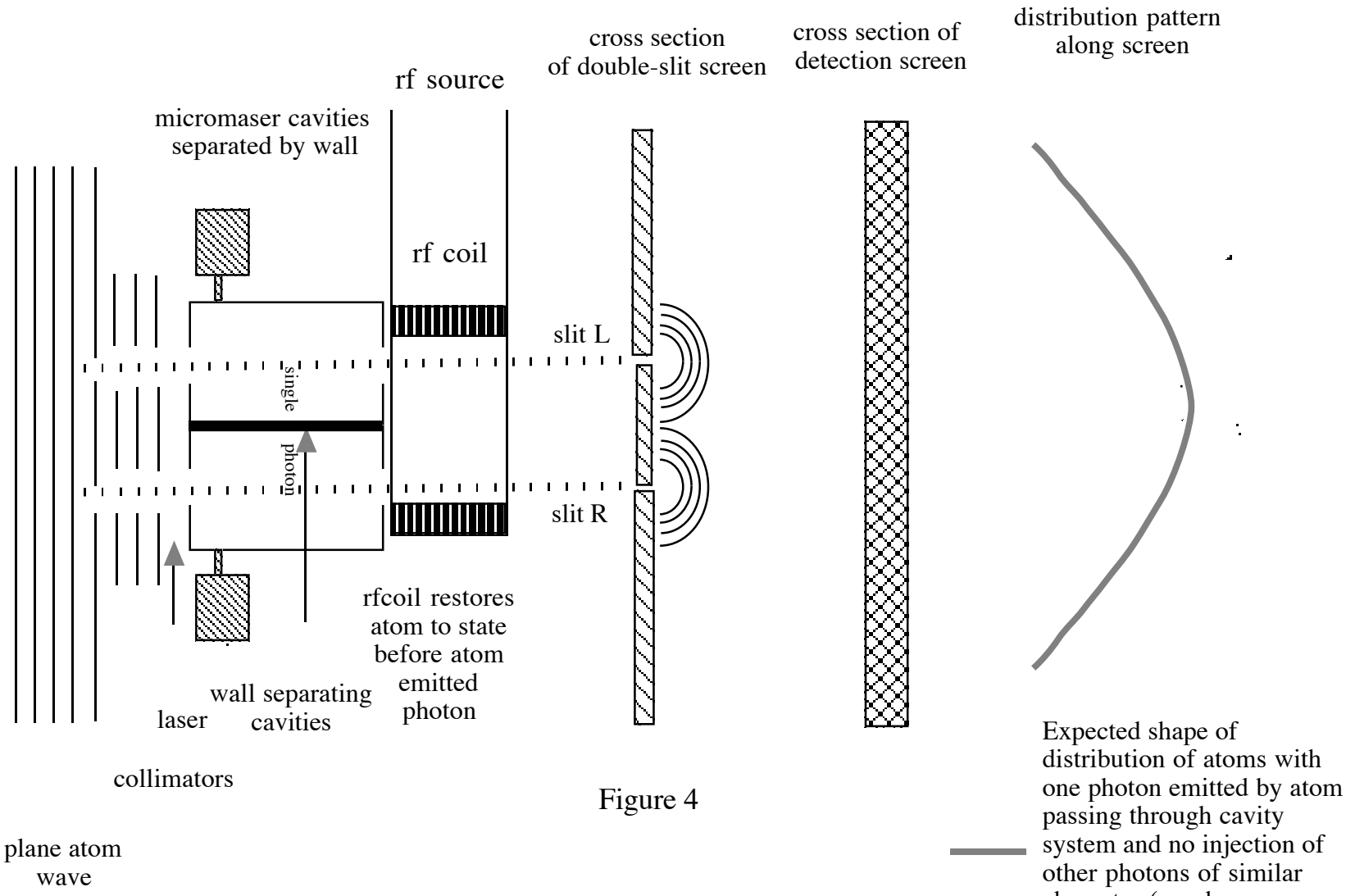
cross section
of double-slit screen
cross section of
detection screen
distribution pattern
along screen
rf source
micromaser cavities
separated by wall
rf coil
slit L
single
photon
slit R
rfcoil restores
atom to state
before atom
emitted
photon
wall separating
cavities
laser
collimators
plane atom
wave
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 4

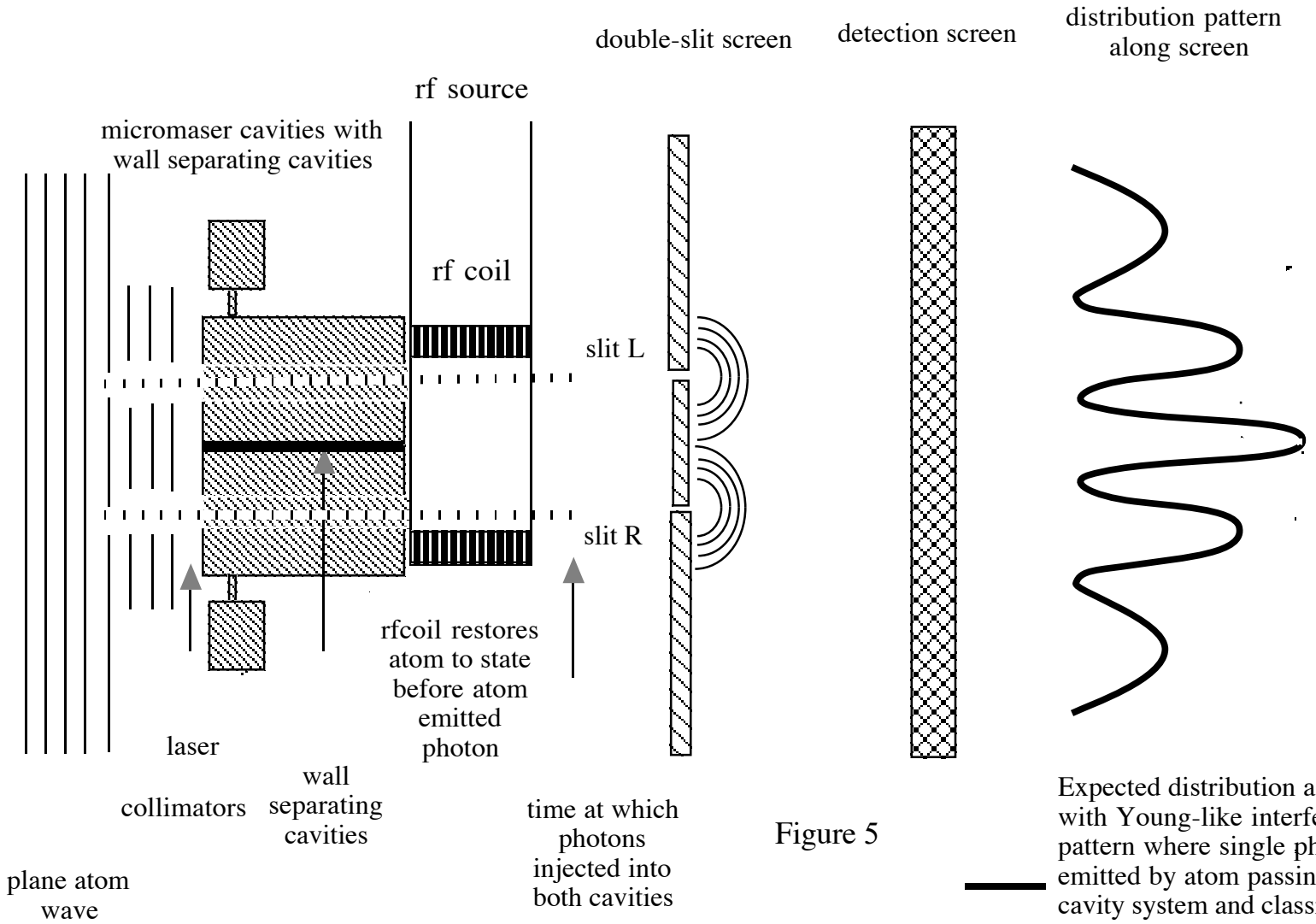

Figure 5

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.