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(71) Applicant *(for all designated States except US)*: **MIMOS BERHAD** [MY/MY]; Technology Park Malaysia, 57000 Kuala Lumpur (MY).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: **MOHD NORZALIMAN Mohd Zain** [MY/MY]; C/O Mimos Berhad, Technology Park Malaysia, 57000 Kuala Lumpur (MY). **SURYADI** [MY/MY]; C/O Mimos Berhad, Technology Park Malaysia, 57000 Kuala Lumpur (MY). **SUHAIRI Saharudin** [MY/MY]; C/O Mimos Berhad, Technology Park Malaysia, 57000 Kuala Lumpur (MY). **MOHD Fared Abdul Khir** [MY/MY]; C/O Mimos Berhad, Technology Park Malaysia, 57000 Kuala Lumpur (MY). **ZALHAN MD YUSOF** [MY/MY]; C/O Mimos Berhad, Technology Park Malaysia, 57000 Kuala Lumpur (MY). **WAHIDDIN Mohamed Ridza** [MY/MY]; C/O Mimos Berhad, Technology Park Malaysia, 57000 Kuala Lumpur (MY).

(74) Agent: **MIRANDAH, Patrick**; Patrick Mirandah CO. (Malaysia) SDN BHD, Suite 3b-19-3 Plaza Sentral, Jalan Stesen Sentral 5, 50470 Kuala Lumpur (MY).

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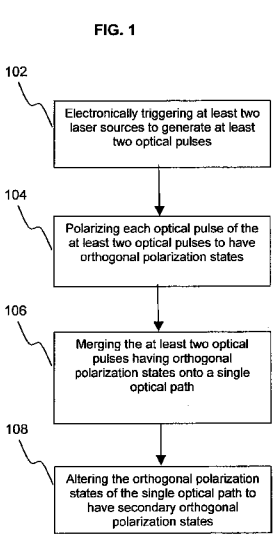
— *with international search report (Art. 21(3))*

(54) **Title**: METHOD AND APPARATUS FOR OPTICAL POLARIZATION PHOTON GENERATOR

FIG. 1



(57) **Abstract**: A method and apparatus for optically generating polarized photons with at least four polarization states is disclosed. The method and apparatus comprises at least two laser sources that are electronically triggered at random to generate at least two optical pulses (102), an arrangement of passive optical components that polarize each optical pulse of the at least two optical pulses to have orthogonal polarization states (104) and merge the at least two optical pulses having orthogonal polarization states onto a single optical path (106) and an active optical component that alters the orthogonal polarization states of the single optical path to have secondary orthogonal polarization states (108).

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METHOD AND APPARATUS FOR OPTICAL POLARIZATION PHOTON GENERATOR

FIELD OF INVENTION

The present invention relates generally to a method and apparatus for optical polarization photon generator that is capable of generating at least four polarization states.

BACKGROUND ART

Quantum Cryptography or commonly known as Quantum Key Distribution (QKD) is a solution to create and distribute secret keys for use during encryption. Therefore, a QKD system involves two parties, conventionally known as "Alice" and "Bob", where "Alice" represents an encoder and "Bob" represents a decoder. In practice of a QKD system, encoded photons propagate from "Alice" and the same is received and detected by "Bob" through a quantum channel that resides over optical fibers or free space medium. In free space medium, quantum channel is a dedicated transmission channel for polarized single photon pulse between "Alice" and "Bob". Therefore, either "Alice" or "Bob" is required to generate the polarized single photon source before "Alice" proceeds with the encoding process in the QKD system.

In summary, QKD system requires single photon optical source to encode light element into various states of polarization. The number of polarization states depends on the Quantum protocol. The preparation of photon into various states of polarization is a delicate process. For instance, free space four deterministic protocol would require at least four polarization or quantum states. Conventional methods to prepare the four polarization states is by using four different laser sources with each require a set of passive polarizer. This apparatus is bulky and financially inefficient.

SUMMARY OF INVENTION

In one embodiment of the present invention is a method for optically generating polarized photons, the method comprises electronically triggering at least two laser sources to generate at least two optical pulses, polarizing each optical pulse of the at least two optical pulses to have orthogonal polarization states, merging the at least two optical pulses having orthogonal polarization states onto a single optical path and altering the orthogonal polarization states of the single optical path to have secondary orthogonal polarization states.

In a further embodiment of the present invention is the method for optically generating polarized photons, the method further comprises altering the orthogonal polarization states of the single optical path to have secondary orthogonal polarization states to generate horizontal polarization states or anti-diagonal polarization states from the vertical polarization states or diagonal polarization states and vertical polarization states or diagonal polarization states from the horizontal polarization states or anti-diagonal polarization states.

In another embodiment of the present invention is an apparatus for optically generating polarized photons, the apparatus comprises at least two laser sources, an arrangement of passive optical components and an active optical component. The at least two laser sources further comprises a first laser source and a second laser source having identical wavelength and a high degree of coherence and chromaticity. The arrangement of passive optical components further comprises at least two half wave plates, at least two polarizers, and at least one beam combiner.

The present invention consists of features and a combination of parts hereinafter fully described and illustrated in the accompanying drawings, it is being understood that various

changes in the details may be made without departing from the scope of the invention or sacrificing any of the advantages of the present invention.

BRIEF DESCRIPTION OF THE ACCOMPANYING DRAWINGS

To further clarify various aspects of some embodiments of the present invention, a more particular description of the invention will be rendered by references to specific embodiments thereof, which are illustrated, in the appended drawings. It is appreciated that these drawings depict only typical embodiments of the invention and are therefore not to be considered limiting of its scope. The invention will be described and explained with additional specificity and detail through the accompanying drawings in which:

FIG. 1 illustrates a flowchart of a method for optically generating polarized photons.

FIG. 2 illustrates an arrangement of apparatus for optically generating polarized photons.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention relates to a method and apparatus for optical polarization photon generator having at least four polarization states. Hereinafter, this specification will describe the present invention according to the preferred embodiments of the present invention. However, it is to be understood that limiting the description to the preferred embodiments of the invention is merely to facilitate discussion of the present invention and it is envisioned that those skilled in the art may devise various modifications and equivalents without departing from the scope of the appended claims.

The various embodiments of the present invention describe a method and an apparatus for an optical polarization photon generator that is capable of generating four polarization or quantum states. Reference is collectively being made to FIGS. 1 & 2. FIG. 1 illustrates a flowchart of a method for optically generating polarized photons. FIG. 2 illustrates an arrangement of apparatus for optically generating polarized photons.

The method according to the present invention for optically generating polarized photons comprises the steps of electronically triggering at least two laser sources to generate at least two optical pulses (102), polarizing each optical pulse of the at least two optical pulses to have orthogonal polarization states (104), merging the at least two optical pulses having orthogonal polarization states onto a single optical path (106) and altering the orthogonal polarization states of the single optical path to have secondary orthogonal polarization states (108).

The apparatus according to the present invention for optically generating polarized photons comprises at least two laser sources, an arrangement of passive optical components and an active optical component.

The at least two laser sources further comprises a first laser source (202) and a second laser source (214) having identical wavelength and a high degree of coherence and chromaticity. The first laser source (202) and the second laser source (214) are electronically triggered at random to generate a first optical pulse and a second optical pulse.

The arrangement of passive optical components further comprises at least two half wave plates (206, 218), at least two polarizers (208, 220) and at least one beam combiner (226). The first optical pulse is passed through half wave plate (206) and polarizer (208) to generate vertical polarization states or diagonal polarization states. The second optical pulse is passed through half wave plate (218) and polarizer (220) to generate horizontal polarization states or anti-diagonal polarization states.

The first optical pulse and the second optical pulse having orthogonal polarization states are passed through the at least one beam combiner (226) to merge the first optical pulse and the second optical pulse having orthogonal polarization states onto a single optical path. The beam combiner (226) may be a polarized beam combiner.

The orthogonal polarization states of the single optical path is passed through the at least one electronically triggered active optical component (236) to generate horizontal polarization states or anti-diagonal polarization states from the vertical polarization states or diagonal polarization states and vertical polarization states or diagonal polarization states from the horizontal polarization states or anti-diagonal polarization states. The at least one active optical component (236) may comprise a pockel cell.

The method and apparatus of the present invention reduces the system complexity and cost through the elimination of redundant laser sources and passive polarizers used in

conventional optical polarization photon generators capable of generating four polarization states.

According to one of the embodiments of the present invention, the method of generating four polarization states begins with the first laser source (202) or the second laser source (214) randomly producing monochromatic first optical pulse (204) and second optical pulse (216) respectively. The first optical pulse (204) generated by the first laser source (202) will pass through the arrangement of passive optical components, comprising the half wave plate (206) and polarizer (208), while the second optical pulse (216) generated by the second laser source (214) will pass through half wave plate (218) and polarizer (220).

The half wave plates (206, 218) are passive and therefore are manually rotated to generate the desired polarization state. The polarizers (208, 220) purify the polarization states generated and allow only a single polarization state to pass through it. In one embodiment of the polarizer configuration, the first optical pulse (204) from the first laser source (202) will generate optical pulse with vertical polarization state (210), while the second optical pulse (216) from the second laser source (214) will generate optical pulse with horizontal polarization state (222).

Alternatively, the first optical pulse (204) from the first laser source (202) may generate optical pulse with diagonal (+45°) polarization state, while the second optical pulse (216) from the second laser source (214) may generate optical pulse with anti-diagonal (-45°) polarization state.

The vertical polarized optical pulse (210) will travel on optical path (212) while the horizontal polarized optical pulse (222) will travel on optical path (224). When passed through another passive optical component, that is the beam combiner (226), the vertical polarized optical

pulse (210) and the horizontal polarized optical pulse (222) are merged onto a single optical path (230). Therefore, the resultant output pulse (228) from the beam combiner (226) travels on optical path (230). This resultant output pulse (228) comprises optical pulse with vertical polarization state (234) and optical pulse with horizontal polarization state (232), or alternatively optical pulse with +45° polarization state and optical pulse with -45° polarization state. The resultant output pulse (228) is then passed through an active optical component (236).

The active optical component (236) alters the polarization state of any optical pulses that passes through the device when it is switched on or electronically triggered. This active optical component (236) is essentially a voltage controlled half wave plate, wherein its characteristics change when an applied voltage is varied.

When no voltage is applied to the active optical component (236), the resultant output pulse (228) travelling on optical path (230) will retain its polarization states while passing through the active optical component (236). In this case, the output optical pulse (238) will be identical to the resultant output pulse (228) that may possibly comprise of optical pulse with vertical polarization state (234) and optical pulse with horizontal polarization state (232), or alternatively optical pulse with +45° polarization state and optical pulse with -45° polarization state.

When a certain voltage is applied to the active optical component (236), the characteristic of the active optical component (236) take off a half wave plate, and is capable of altering the polarization state of the resultant output pulse (228) travelling on optical path (230) that passes through the active optical component (236). Optical pulses with vertical polarization states or horizontal polarization states will be altered to have diagonal polarization states or anti-diagonal polarization states, and vice-versa.

In one embodiment of the present invention, optical pulse with vertical polarization state (234) will be altered to optical pulse with +45° polarization state (242) with reference to a Poincare Sphere, while optical pulse with horizontal polarization state (232) will be altered to optical pulse with -45° polarization state (244) with reference to a Poincare Sphere.

The number of polarization states may possibly be increased from four to a higher number by using an arrangement of active optical component (236). The electronic triggering of the at least two laser sources and the active optical component is controlled by electronic signals from the same electronic system.

The electronic signals which trigger the first laser source (202) or the second laser source (214) to generate optical pulses are random and synchronized with the electronic signals that trigger a voltage to the active optical component (236).

The embodiments of the present invention is part of the system implementation in QKD protocol with four polarization states at an equatorial planar with reference to a Poincare Sphere that adopt 'weak pulse laser' in the absence of a truly single photon laser source.

CLAIMS

1. A method for optically generating polarized photons, wherein the method (100) comprises

electronically triggering at least two laser sources to generate at least two optical pulses (102);

polarizing each optical pulse of the at least two optical pulses to have orthogonal polarization states (104);

merging the at least two optical pulses having orthogonal polarization states onto a single optical path (106); and

altering the orthogonal polarization states of the single optical path to have secondary orthogonal polarization states (108).

2. The method according to claim 1, wherein electronically triggering the at least two laser sources to generate the at least two optical pulses further comprises electronically triggering at random a first laser source and a second laser source to generate a first optical pulse and a second optical pulse.

3. The method according to claim 2, wherein polarizing each optical pulse of the at least two optical pulses to have orthogonal polarization states further comprises

passing the first optical pulse through passive optical component to generate vertical polarization states or diagonal polarization states; and

passing the second optical pulse through passive optical component to generate horizontal polarization states or anti-diagonal polarization states.

4. The method according to claim 3, wherein merging the at least two optical pulses having orthogonal polarization states onto a single optical path further comprises passing the at least two optical pulses having orthogonal polarization states through

passive optical component to merge the at least two optical pulses having orthogonal polarization states onto a single optical path.

5. The method according to claim 4, wherein altering the orthogonal polarization states of the single optical path to have secondary orthogonal polarization states further comprises passing the orthogonal polarization states of the single optical path through an electronically triggered active optical component to generate

horizontal polarization states or anti-diagonal polarization states from the vertical polarization states or diagonal polarization states; and

vertical polarization states or diagonal polarization states from the horizontal polarization states or anti-diagonal polarization states.

6. The method according to claim 1, wherein the polarized photons comprises at least four polarization states.

7. An apparatus for optically generating polarized photons, the apparatus comprises

at least two laser sources;

an arrangement of passive optical components; and

an active optical component (236);

characterized in that

the at least two laser sources further comprises a first laser source (202) and a second laser source (214) having identical wavelength and a high degree of coherence and chromaticity; and

the arrangement of passive optical components further comprises

at least two half wave plates (206, 218);

at least two polarizers (208, 220); and

at least one beam combiner (226).

8. The apparatus according to claim 7, wherein the first laser source and the second laser source are electronically triggering at random to generate a first optical pulse and a second optical pulse.

9. The apparatus according to claim 8, wherein

the first optical pulse is passed through half wave plate (206) and polarizer (208) to generate vertical polarization states or diagonal polarization states; and

the second optical pulse is passed through half wave plate (218) and polarizer (220) to generate horizontal polarization states or anti-diagonal polarization states.

10. The apparatus according to claim 9, wherein

the first optical pulse and the second optical pulse having orthogonal polarization states are passed through the at least one beam combiner (226) to merge the first optical pulse and the second optical pulse having orthogonal polarization states onto a single optical path.

11. The apparatus according to claim 10, wherein the orthogonal polarization states of the single optical path is passed through the at least one active optical component (236) electronically triggered to generate

horizontal polarization states or anti-diagonal polarization states from the vertical polarization states or diagonal polarization states; and

vertical polarization states or diagonal polarization states from the horizontal polarization states or anti-diagonal polarization states.

12. The apparatus according to claim 7, wherein the polarized photons comprises at least four polarization states.

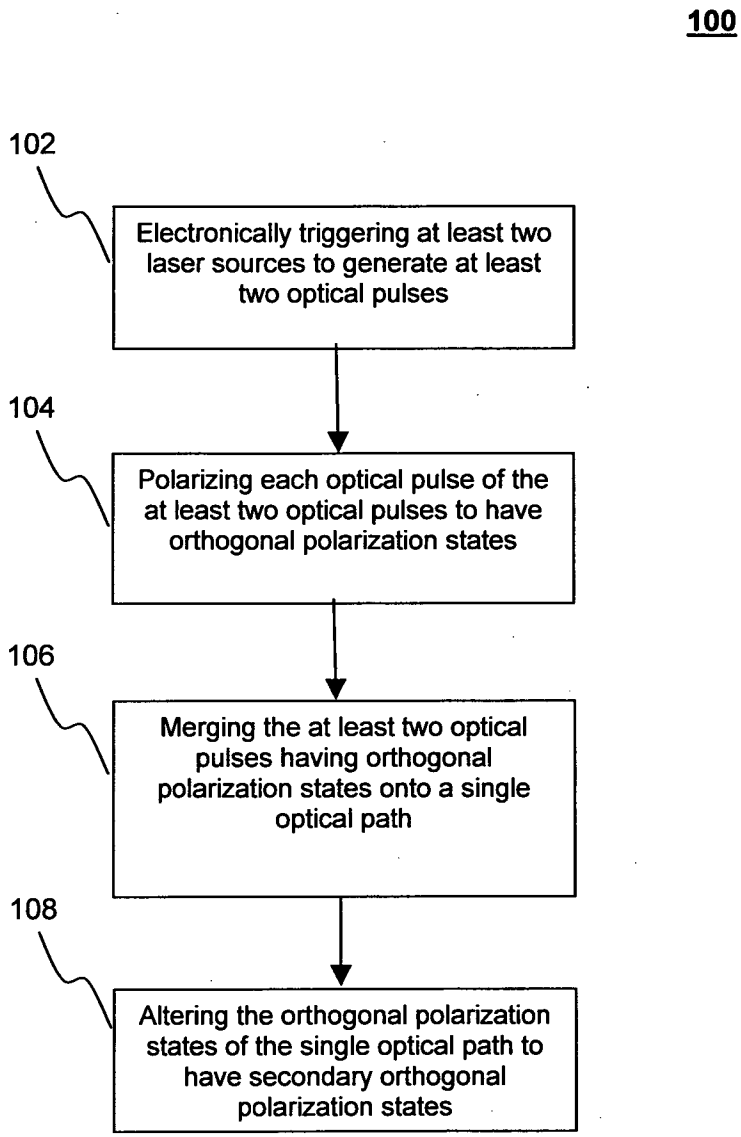
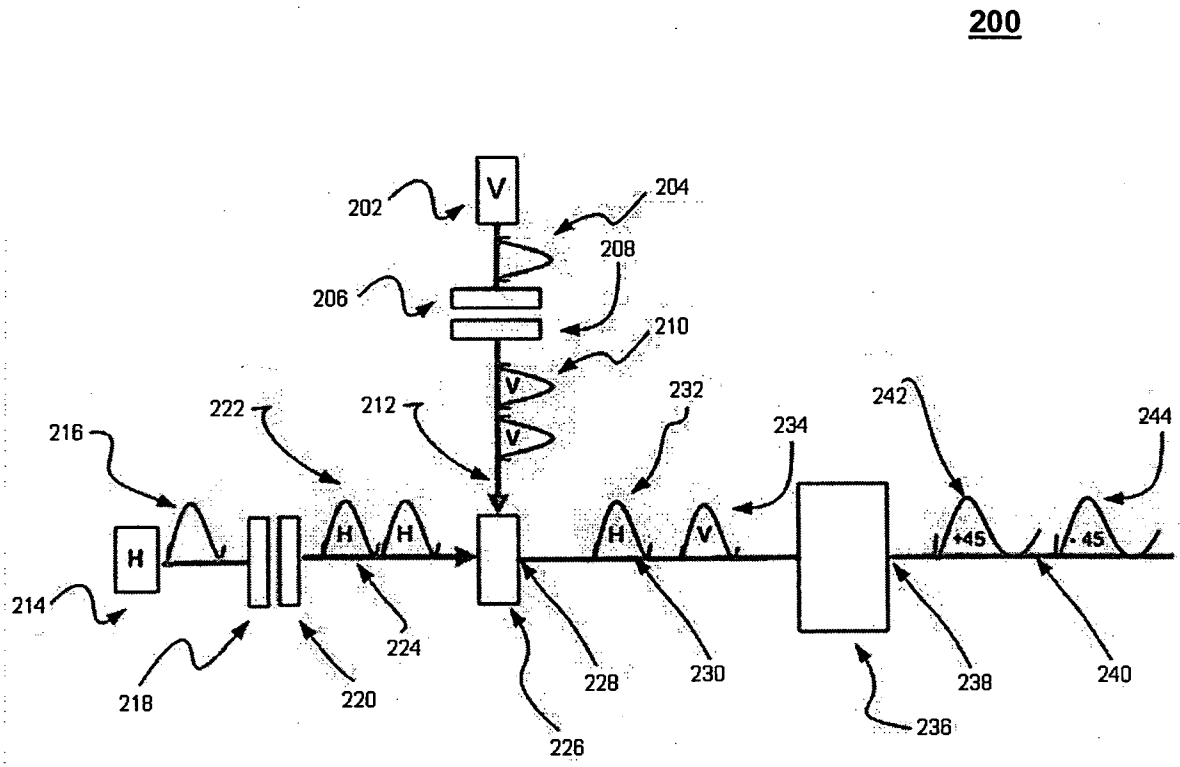

100
102
Electronically triggering at least two laser sources to generate at least two optical pulses
104
Polarizing each optical pulse of the at least two optical pulses to have orthogonal polarization states
106
Merging the at least two optical pulses having orthogonal polarization states onto a single optical path
108
Altering the orthogonal polarization states of the single optical path to have secondary orthogonal polarization states

FIG. 1


200
V
202
204
208
206
210
V
V
212
222
232
234
242
244
216
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H
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+45
-45
214
218
220
224
226
228
230
236
238
240

FIG. 2

INTERNATIONAL SEARCH REPORT

International application No.
PCT/MY2010/000194

A. CLASSIFICATION OF SUBJECT MATTER

H04B 10/12(2006.01)i, H01S 3/00(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H04B 10/12; G02F 1/335; H04L 9/12; H04B 10/06; H04L 9/00; G02B 6/00; H01S 3/08

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & Keywords: polarize, beam combiner, orthogonal, laser

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	US 2008-0050126 A1 (SHAPIRO et al.) 28 February 2008 See abstract, Fig.3, paragraph [62]-[66], claims 15-16	1-6 7-12
Y	US 6522796 B1 (ZIARI; MEHRDAD et al.) 18 February 2003 See abstract, Figs. 2-3, column 8 line 3-23, 40-59	1-6
A	US 7536012 B1 (MEYERS RONALD E. et al.) 19 May 2009 See abstract, Fig.1	1,7
A	US 2005-0135627 A1 (ANTON ZAVRIYEV et al.) 23 June 2005 See abstract, Fig.1	1,7

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:

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Date of the actual completion of the international search	Date of mailing of the international search report
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Korean Intellectual Property Office
Government Complex-Daejeon, 189 Cheongsa-ro,
Seo-gu, Daejeon 302-701, Republic of Korea

Facsimile No. 82-42-472-7140

Authorized officer

LEE, Jin Ick

Telephone No. 82-42-481-5770

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/MY2010/000194

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2008-0050126 A1	28.02.2008	WO 2008-027640 A2	06.03.2008
		WO 2008-027640 A3	19.06.2008
		WO 2008-027640 B1	31.07.2008
US 6522796 B1	18.02.2003	None	
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US 2005-0135627 A1	23.06.2005	US 7606371 B2	20.10.2009