PATENT COOPERATION TREATY

From the
INTERNATIONAL SEARCHING AUTHORITY

To:	PCT
EUREK, JUSTIN Kilpatrick Townsend & Stockton LLP Mailstop: IP-Docketing-22 1100 Peachtree Street NE Suite 2800 Atlanta, Georgia 30309 (US)	WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY (PCT Rule 43*bis*.1)
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Applicant's or agent's file reference		FOR FURTHER ACTION
1115965		See paragraph 2 below
International application No. PCT/US2018/065041	International filing date *(day/month/year)* 11/12/2018	Priority date *(day/month/year)* 07/12/2018

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G02B 26/10 (2006.01) *G01S 17/93 (2006.01)* *G01S 7/481 (2006.01)*

Applicant
DIDI RESEARCH AMERICA, LLC

1. This opinion contains indications relating to the following items:

- ☒ Box No. I — Basis of the opinion
- ☐ Box No. II — Priority
- ☐ Box No. III — Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- ☐ Box No. IV — Lack of unity of invention
- ☒ Box No. V — Reasoned statement under Rule 43*bis*.1(a)(i) with regard to novelty, inventive step and industrial applicability; citations and explanations supporting such statement
- ☐ Box No. VI — Certain documents cited
- ☐ Box No. VII — Certain defects in the international application
- ☒ Box No. VIII — Certain observations on the international application

2. **FURTHER ACTION**

If a demand for international preliminary examination is made, this opinion will be considered to be a written opinion of the International Preliminary Examination Authority ("IPEA") except that this does not apply where the applicant chooses an Authority other than this one to be the IPEA and the chosen IPEA has notified the International Bureau under Rule 66.1*bis*(b) that written opinions of this International Searching Authority will not be so considered.

If this opinion is, as provided above, considered to be a written opinion of the IPEA, the applicant is invited to submit to the IPEA a written reply together, where appropriate, with amendments, before the expiration of 3 months from the date of mailing of Form PCT/ISA/220 or before the expiration of 22 months from the priority date, whichever expires later.

For further options, see Form PCT/ISA/220.

Name and mailing address of the ISA/SG	Date of completion of this opinion	Authorized officer
IPOS Intellectual Property Office of Singapore **Intellectual Property Office of Singapore** 51 Bras Basah Road #01-01 Manulife Centre Singapore 189554 Email: pct@ipos.gov.sg	22/03/2019 *(day/month/year)*	Huang Wen (Dr) IPOS Customer Service Tel. No.: (+65) 6339 8616

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY	International application No. PCT/US2018/065041

Box No. I Basis of this opinion

1. With regard to the **language**, this opinion has been established on the basis of:

   ☒ the international application in the language in which it was filed.

   ☐ a translation of the international application into _________ which is the language of a translation furnished for the purpose of international search (Rules 12.3(a) and 23.1 (b)).

2. ☐ This opinion has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43*bis*.1(b)).

3. ☐ With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, this opinion has been established on the basis of a sequence listing:

   a. ☐ forming part of the international application as filed:

      ☐ in the form of an Annex C/ST.25 text file.

      ☐ on paper or in the form of an image file.

   b. ☐ furnished together with the international application under PCT Rule 13*ter*.1(a) for the purposes of international search only in the form of an Annex C/ST.25 text tile.

   c. ☐ furnished subsequent to the international filing date for the purposes of international search only:

      ☐ in the form of an Annex C/ST.25 text file (Rule 13*ter*.1(a)).

      ☐ on paper or in the form of an image file (Rule 13*ter*.1(b) and Administrative Instructions, Section 713).

4. ☐ In addition, in the case that more than one version or copy of a sequence listing has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that in the application as filed or does not go beyond the application as filed, as appropriate, were furnished.

5. Additional comments:

Box No. V Reasoned statement under Rule 43*bis*.(1)(a)(i) with regard to novelty, inventive step and industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Claims	1-40	YES
	Claims	NONE	NO
Inventive step (IS)	Claims	NONE	YES
	Claims	1-40	NO
Industrial applicability (IA)	Claims	1-40	YES
	Claims	NONE	NO

2. Citations and explanations:

The following citations are referred to in this written opinion. Full bibliographic details are provided in the International Search Report:

D1 – US 2005/0036196 A1
D2 – US 2017/0153445 A1
D3 – US 2012/0228460 A1
D4 – CN 106353891 A
(the original non-English language document was used for the purpose of establishing the written opinion)
D5 – US 2012/0281266 A1
D6 – CN 1667449 A
(the original non-English language document was used for the purpose of establishing the written opinion)

1. Novelty

None of the available prior art documents individually discloses all the features of any of claims 1-40, and therefore said claims are novel and comply with PCT Article 33(2).

2. Inventive step

Claims 1-40 do not involve an inventive step and therefore do not comply with PCT Article 33(3).

Claims 1 and 20

Document **D1** discloses the following features of independent of claim 1 (strikethrough wordings refer to features that are not disclosed in **D1** and have been highlighted by the examiner):

A device for beam steering in a Light Detection and Ranging (LiDAR) system of an autonomous vehicle (fig. 19, micro-mirror device 1900 suitable for use in LiDAR systems), the device comprising:

- a mirror (fig. 19a, mirror 1902);
- a spring mechanically coupled with the mirror (fig. 19a, torsion spring 1904);
- a combdrive actuator configured to move the mirror, the spring, or both the mirror and the spring (fig. 19a, stator comb drive 1914b, comb drive rotor 1908b); and
- a limiter configured to limit a range of motion of the mirror, the spring, or both the mirror and the spring (para. [0072], "beams 1916 contact stoppers (not shown, but located for example on the handle layer) at the end of the mirror rotation, causing the bouncing effect", fig. 13d, stoppers 1312', 1312''), wherein:
  - ~~the mirror is part of the plurality of mirrors~~; and
  - ~~the plurality of mirrors are synchronized to move together in time based on the limiter limiting the range of motion of the mirror, so that angular rotation of the plurality of mirrors in time are the same~~.

D1 differs from claim 1 in that claim 1 defines a plurality of mirrors that are synchronized to move together in time based on the limiter limiting the range of motion of the mirror, so that angular rotation of the plurality of mirrors in

Box No. V Reasoned statement under Rule 43*bis*.(1)(a)(i) with regard to novelty, inventive step and industrial applicability; citations and explanations supporting such statement

time are the same. However, synchronized rotation of a mirror array for MEMS scanning devices is well-known in the art (see for example, **D2**: para. [0025], fig. 1; **D3**: para. [0140]-[0148], fig. 10; **D4**: para. [0017], fig. 1), and it would be obvious to the skilled person to consider such synchronized mirror array configuration with micro-mirror with a limiter of **D1** for improved scanning field. Therefore, an inventive step cannot be acknowledged for claim 1.

The method defined in claim 20 largely corresponds to the subject matter of claim 1, and additionally defines a mirror support, a shaft that mechanically couples the mirror support with the spring, and rotors and stators of a driver to move the shaft. The aforementioned reasoning for claim 1 applies *mutatis mutandis* to claim 20, and additionally, the mirror support, the rotors and stators of a driver are disclosed by **D1** ([0076], "SOI wafer", fig. 19a, stator comb drive 1914b, comb drive rotor 1908b) and the shaft directs to common constitutes of scanning mirror system that would be obvious to the skilled person. Therefore, an inventive step cannot be acknowledged for claim 1.

Claim 17

Document **D2** discloses the following features of independent of claim 17 (strikethrough wordings refer to features that are not disclosed in **D2** and have been highlighted by the examiner):

A method of using a mirror array (para. [0025], "synchronized oscillation of multiple rotating elements"), the method comprising:

- rotating a plurality of mirrors (para. [0028], "mirrors 22 and 24 are configured to rotate about hinges 28 at a resonant frequency of array 25"), wherein:
  - rotating comprises using a plurality of drivers operating at the same frequency (para. [0028], "mirrors 22 and 24 may be driven directly, for example by a suitable magnetic, electrostatic or piezoelectric drive operating at the resonant frequency"); and
  - rotating the plurality of mirrors is performed so that motion of the plurality of mirrors is synchronized (para. [0033], [0039] and [0040], controller to regulate synchronization of oscillations of mirrors);
- shining a laser beam at the plurality of mirrors (para. [0031], "mirrors 22 and 24 scan the transmitted and received beams of light together over a predefined angular range", fig. 1, transmitter 36);
- reflecting the laser beam using the plurality of mirrors, so that the mirrors act as a single mirror to reflect the laser beam (para. [0031], "mirrors 22 and 24 scan the transmitted and received beams of light together over a predefined angular range"); and
- ~~partially blocking movement of each mirror of the plurality of mirrors using a limiter at each mirror so that movement of each mirror is nonlinear, wherein the nonlinear movement facilitates synchronization of movement of the plurality of mirrors while driving the plurality of mirrors at the same frequency~~.

D2 differs from claim 17 in that claim 17 defines partially blocking movement of each mirror of the plurality of mirrors using a limiter at each mirror so that movement of each mirror is nonlinear wherein the nonlinear movement facilitates synchronization of movement of the plurality of mirrors while driving the plurality of mirrors at the same frequency. However, micro-mirror scanning devices with limiters to partially block movement of the micro-mirror for non-linear movement are well-known in the art (see for example, **D1**: para. [0072], "beams 1916 contact stoppers (not shown, but located for example on the handle layer, fig. 13d, stoppers 1312', 1312'') at the end of the mirror rotation, causing the bouncing effect", ; **D5**: para. [0038], fig. 1A, overhang section 17; **D6**: pg. 3, ln. 19, stop point in cavity 31, fig. 2), and it would be obvious to the skilled person to implement such micro-mirrors with limiters into synchronized mirror array of **D2** to facilitate synchronization with non-linear movement for an easier match in mirror oscillation. Therefore, an inventive step cannot be acknowledged for claim 17.

Claim 21

Document **D2** discloses the following features of independent of claim 21 (strikethrough wordings refer to features that are not disclosed in **D2** and have been highlighted by the examiner):

A device for beam steering in a Light Detection and Ranging (LiDAR) system of an autonomous vehicle (fig. 1, scanning device 20 suitable for beam steering in LiDAR), the device comprising:

- a first mirror (fig. 1, mirror 22), wherein the first mirror is part of an array of mirrors (fig. 1, mirrors 22, 24);
- a spring mechanically coupled with the first mirror (fig. 1, torsion hinge 28);
- a comb drive configured to move the first mirror, the spring, or both the first mirror and the spring (para.

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[0037] and [0039]-[0040], potential difference between combs to damp or boost oscillation of mirrors, figs. 1 and 3, adjustment circuit 46 with conductive combs 60, 62), the comb drive comprising:

- a rotor (fig. 3, conductive combs 62); and
- a stator (fig. 3, conductive combs 60);
- a sensor configured to monitor a rotation of the first mirror (para. [0038], fig. 3, sensor 64); and
- electronics (para. [0033], fig. 1, controller 44) configured to:
- provide a drive signal (para. [0033], controller 44 applies a corrective signal to mirrors to alleviate the discrepancy), wherein the drive signal determines how the rotor is ~~electromagnetically~~ attracted and/or repulsed by the stator (para. [0037], "controller 44 applies a corrective signal as an electrical potential difference between the combs 60 and 62");
- determine the first mirror is oscillating out of sync with a second mirror of the array of mirrors, based on data from the sensor, wherein the second mirror oscillates in a first steady state and the first mirror oscillates in a second steady state (para. [0028] and [0038], "controller 44 receives output signals from sensors 64, which indicate when there is discrepancy in synchronization of the oscillation between mirrors 22 and 24" implies that two mirrors oscillate out of sync at different steady states); and
- alter the drive signal so that a phase difference between the rotation of the first mirror and the drive signal changes, such that the first mirror oscillates in the first steady state (para. [0033] and [0040], controller apply a time-varying potential to the combs to synchronize the phase and frequency of oscillation of mirror 24 relative to mirror 22).

D2 differs from claim 21 in that claim 21 defines that the rotor is electromagnetically attracted and/or repulsed by the stator. **D1** discloses electrostatic comb drive actuators (para. [0037]). However, electromagnetic comb drive is a common type of actuators. It would be obvious to the skilled person to consider alternative design option of various types of actuators that only require minor modifications to drive the mirrors for optimized scanning performance. Therefore, an inventive step cannot be acknowledged for claim 21.

<u>Claim 28</u>

Document **D2** discloses the following features of independent of claim 28 (strikethrough wordings refer to features that are not disclosed in **D2** and have been highlighted by the examiner):

A method of using a ~~non-linear~~ system to synchronize motion of a plurality of mirrors (para. [0025], "synchronized oscillation of multiple rotating elements"), the method comprising:

- identifying a steady state of operation of a mirror-spring system (para. [0028], "mirrors 22 and 24 are configured to rotate about hinges 28 at a resonant frequency of array 25" implies identification of a steady state that mirrors synchronously rotate at the resonant frequency, fig. 1, scanning device 20), wherein the mirror-spring system comprises a first mirror that is part of a mirror array and a spring coupled with the first mirror (fig. 1, mirrors 22, 24, torsion hinge 28);
- identifying an initial phase, or set of initial phases, between a rotation of the first mirror and a first drive signal (para. [0033], identifying a discrepancy in the synchronization of oscillation of mirrors implies that mirrors rotate out of sync at an initial phase), wherein:
    - a first comb drive is used to rotate the mirror-spring system (para. [0037] and [0039]-[0040], potential difference between combs to damp or boost oscillation of mirrors, figs. 1 and 3, adjustment circuit 46 with conductive combs 60, 62);
    - the first comb drive comprises a rotor and a stator (fig. 3, conductive combs 62, 60);
    - the first drive signal determines how the rotor is ~~electromagnetically~~ attracted and/or repulsed by the stator (para. [0037], "controller 44 applies a corrective signal as an electrical potential difference between the combs 60 and 62"); and
    - ~~starting to rotate the mirror-spring system at the initial phase, or phases of the set of initial phases, will case the mirror-spring system to operate at the steady state of operation in relation to the first drive signal~~;
- ~~applying the first drive signal to the first comb drive at the initial phase, or one of the phases from the set of initial phases~~;
- operating the first comb drive so that the mirror-spring system is rotating at the steady state of operation (para. [0033] and [0039], controller applies a corrective signal to mirror 22 in order to alleviate discrepancy to achieve synchronization);
- applying a second drive signal to a second comb drive (para. [0037] and [0040], controller applies a corrective signal to combs for mirror 24); and

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- operating the second comb drive so that a second mirror of the mirror array is rotating at the steady state of operation in sync with the first mirror (para. [0033] and [0040], controller applies a corrective signal to mirror 24 in order to alleviate discrepancy to achieve synchronization).

D2 differs from claim 28 in that claim 28 defines a non-linear system, electromagnetically coupling between the rotor and stator, and the starting step of driving the comb drive at an initial phase or one of a set to rotate the mirror-spring system to operate at the steady state of operation in relation to the first drive signal. Non-linear systems of micro-mirror scanning devices with limiters are well-known in the art as discussed for claim 17, and electromagnetic comb drive is a common type of actuators directing to a mere design option that lie within normal practice of the skilled person as discussed for claim 21. Moreover, **D2** discloses that mirrors may be driven directly by various types of drives operating at the resonant frequency, which suggests that the controller can set drive signals at an initial phase for synchronized oscillation of mirrors instead of the initial phase with discrepancy in the synchronization of oscillation of mirrors followed by corrective drive signals. Such control configuration of setting drive signals at an initial phase with staring parameters for synchronized oscillation of mirrors is obvious to the skilled person when considering fewer steps to achieve synchronized oscillation of mirrors. Therefore, an inventive step cannot be acknowledged for claim 28.

Claim 38

Document **D2** discloses the following features of independent of claim 38 (strikethrough wordings refer to features that are not disclosed in **D2** and have been highlighted by the examiner):

A method of using a ~~non-linear~~ system to synchronize motion of a plurality of mirrors (para. [0025], "synchronized oscillation of multiple rotating elements"), the method comprising:

- using a first combdrive actuator to move a first mirror at an amplitude and a frequency (para. [0033], [0037] and [0039], controller applies a corrective signal to combs for mirror 22 in order to alleviate discrepancy to achieve synchronization);
- using a second combdrive actuator to move a second mirror at the amplitude and at the frequency of the first mirror so that the first mirror and the second mirror move in a synchronized motion para. [0033], [0037] and [0040], controller applies a corrective signal to combs for mirror 24 in order to alleviate discrepancy to achieve synchronization), wherein the motion is ~~non-linear~~ having a first steady state of operation and a second steady state of operation (para. [0028] and [0038], "controller 44 receives output signals from sensors 64, which indicate when there is discrepancy in synchronization of the oscillation between mirrors 22 and 24" implies that two mirrors oscillate out of sync at different steady states); and
- ~~configuring the first mirror and the second mirror to have starting parameters so that the first mirror and the second mirror will both operate at the first steady state of operation~~.

D2 differs from claim 38 in that claim 38 defines a non-linear system and configuring the first mirror and the second mirror to have starting parameters so that the first mirror and the second mirror will both operate at the first steady state of operation. Non-linear systems of micro-mirror scanning devices with limiters are well-known in the art as discussed for claim 17. Moreover, the control configuration of setting drive signals at an initial phase with staring parameters for synchronized oscillation of mirrors is obvious to the skilled person when considering fewer steps to achieve synchronized oscillation of mirrors as discussed for claim 28. Therefore, an inventive step cannot acknowledged for claim 38.

Claims 5, 12, 15, 22, 27, 34-35 and 37

The additional features defined in the following claims are disclosed in **D1** or **D2** (references in parentheses refer to **D1**-**D2**):

- claim 5: (**D1**: [0076], "SOI wafer" as mirror support, reflective surface is implicit for a mirror);
- claim 12: (**D1**: fig. 19, stator comb drive 1914b, comb drive rotor 1908b);
- claim 15: (**D1**: para. [0002], "MEMS");
- claims 22 and 34: (**D2**: para. [0001], "MEMS");
- claims 27 and 35: (**D2**: fig. 1, rectangular mirrors 22, 24);
- claim 37: (**D2**: para. [0038], fig. 3, sensor 64).

Therefore, claims 5, 12, 15, 22, 27, 34-35 and 37 are not inventive.

Box No. V Reasoned statement under Rule 43*bis*.(1)(a)(i) with regard to novelty, inventive step and industrial applicability; citations and explanations supporting such statement

Claims 2-4, 6-11, 13-14, 16, 18-19, 23-26, 29-33, 36 and 39-40

The additional features defined in claims 2-4, 6-11, 13-14, 16, 18-19, 23-26, 29-33, 36 and 39-40 relates to details of mirrors, various configurations of the limiter, driving frequencies, application in LiDAR and details of operation control. Said features are either known in the art or design options that are obvious to the skilled person working in the field of micro-mirror scanning systems. Therefore, an inventive step cannot acknowledged for claims 2-4, 6-11, 13-14, 16, 18-19, 23-26, 29-33, 36 and 39-40.

3. Industrial applicability

Claims 1-40 are industrially applicable and therefore comply with PCT Article 33(4).

Box No. VIII Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:

1. Clarity

Claims 1 and 28 do not comply with PCT Article 6.

The term "the plurality of mirrors" (pg. 22, ln. 10) defined in claim 1 lacks an antecedent basis. For the purpose of establishing this opinion, the term is construed as "a plurality of mirrors".

Claim 28 defines that "starting to rotate the mirror-spring system at the initial phase, or phases of the set of initial phases, will case the mirror-spring system to operate at the steady state of operation in relation to the first drive signal", which appears to a typological error on the term "case". For the purpose of establishing this opinion, the term is construed as "cause".