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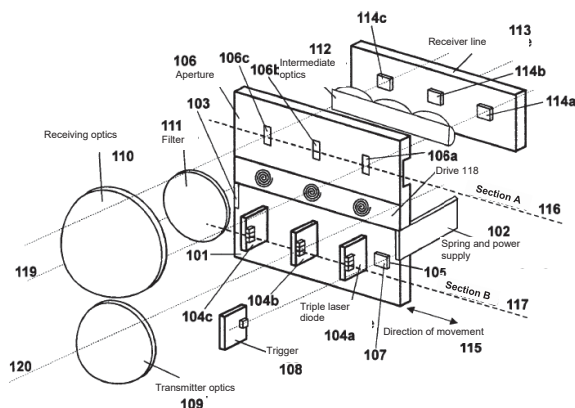
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(56) Publications considered for the assessment of
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DE 197 17 399 C2
DE 41 27 168 C2
DE 196 26 298 A1
DE 38 25 081 A1
US 52 25 882 A

(54) Title: **System for generating a range image with electromagnetic pulses**

(57) Main claim: System for generating a range image, that uses the transit time determination of electromagnetic pulses for distance measurement, with one or more pulse sources, a transmission optics and a receiver optics, an aperture having one or more aperture openings and one or more receivers, wherein the one or more pulse sources are moved in a plane or on a cylinder jacket and the one or more aperture openings of the aperture are designed in this way that the image of the surfaces illuminated by the pulse sources fills precisely these aperture openings and wherein this aperture is moved in this way, in all movement positions, the illustration of the areas illuminated by the pulse sources fits into these aperture openings and the radiation power available behind the aperture openings is guided to the one or more receivers.



Description

Example of an embodiment

Prior art

[0001] To generate a distance image with electromagnetic pulses, e. g. the following documents are known:

US 5 225 882 A

This document describes an arrangement in which a receiver element and a transmitter element are each mapped onto a rotary mirror via one optic. Thus, only a limited angular range can be detected with a relatively volume-intensive device.

DE 196 26 298 A1

This document shows a pivoting of the laser beams by moving a laser diode laterally behind an optic.

DE 38 25 081 A1

This document shows the possibility of deflecting a light beam for scanning purpose by moving a fiber optic cable.

DE 41 27 168 C2

This document shows a signal processing, which, at different signal quality, applies a signal processing method adapted to this signal quality with the inclusion of an estimator.

[0002] All of these systems have the following disadvantages:

- If the arrangement is coaxial or the arrangements have a single mapping system used for the transmitting and receiving devices, close distances are very difficult to evaluate and not at all when operated in backscattering media such as fog and rain.
- Systems with mirrors upstream of the optics have the disadvantage that very large masses must be moved and thus the scanning frequency becomes very low.

Task

[0003] The object of this present invention is to represent a system for generating a distance image with electromagnetic pulses, which has the following advantageous properties:

- Compact construction with high resistance to environmental influences
- Small moving masses
- Good signal-to-noise ratio already at the receiver
- High operational safety even during long-term operation
- Manageable production and testing effort in series production

[0004] This invention will be described in the following with reference to **Figs. 1** to **9**. The system operates according to the pulse runtime method and is designed in such a way that only very small masses have to be moved for one scan.

[0005] One example of an embodiment is a system with semiconductor lasers as transmitters and semiconductor photodiodes as receivers; these elements work in the range of approx. 500 nm to approx. 2000 nm. However, the system is also suitable for mm waves.

[0006] According to **Fig. 1**, one frame **101** has, e. g. three transmitter units e. g. each with a triple laser diode **104a**, **104b** and **104c**. These triple laser diodes are mapped to the scene to be scanned via the transmission optics **109**. The backscattered light pulses are rendered via the receiving optics **110** by the filter **111** on the aperture matrix located on the frame **101** with the aperture openings **106a**, **106b** and **106c**. If the entire frame **101**, held by the springs **102** and **103**, is e. g. oscillating or force-controlled back and forth in the direction of movement **115** through an electromagnetic drive **118**, the light pulses of the triple laser diodes are also moved back and forth on the scene via the transmission optics **109** and thus scan the scene in parallel. By allocating the aperture openings **106a**, **106b** and **106c** on the same frame **101**, the pulses reflected by objects are projected directly onto said aperture openings via the receiving optics. Thus, foreign light that is not generated by the pulsed lasers does not reach the intermediate optics **112**, but only the light of the areas illuminated by the lasers. The intermediate optics **112** are designed such that, regardless of the position of the motion of the frame **101**, the light pulses that pass the aperture openings **106a** - **106c** are respectively mapped to the associated receivers **114a**, **114b** and **114c** of the receiver line **113**. The frame **101** is held via the springs **102** and **103** and these springs also serve themselves or via bonded conductor tracks to supply power to the lasers and to connect the control unit to the coils of the electromagnetic drive **118**. The drive is designed in such a way that permanent magnets with alternating pole sequences are arranged in front of and behind the coil arrangement and the coils are controlled according to known linear motor arrangements. In the figures, the permanent magnets required for the drive are omitted for a better illustration of the system.

[0007] The selection of the lasers within the scan movement and the trigger function for precise time allocation is effected via a further laser diode **108** that beams onto the photodiode **107**.

[0008] For better understanding, the optical design of the receiver part is shown in **Fig. 1a** in section A 116 of the drawing in **Fig. 1**. The scene from which a range image is to be generated is displayed on the aperture **106** via the receiver optics **110** and the filter **111**.

[0009] In each position of the aperture **106**, the intermediate optics **112** maps the energy passing through the apertures to the receivers **114a**, **114b**, and **114c** of the receiver line **113**.

[0010] In the transmitter unit according to section B 117 of **Fig. 1**, the g. triple laser diodes **104a**, **104b**, and **104c** which are on the carrier **101** according to **Fig. 1b** are mapped on the scene via the transmission optics **109**. The arrangement according to the invention achieves that only the transmitter elements with control, in the example the laser diodes and the apertures, must be moved on the carrier. Experience has shown that these elements have a very small mass and are very small in size. In addition, the transmitter elements can be selected and triggered very easily as shown. All other components with a larger mass such as receiver **110** and transmission optics **109** are permanently arranged. The intermediate optics **112** and the receiver line **113** are also permanently arranged.

[0011] By using 3 units each of triple laser diodes **104a** to **104c** and also 3 apertures **106a** to **106c**, a range with a width of **122** is scanned according to **Figure 1b** in the direction of movement **115**, while the carrier only has to carry out an amplitude from the distance **121**. If this distance **121** is sufficient for the system, only one triple laser diode is required such as **104b** and only one aperture opening, e. g. **106b**. Here, one part of the interim optics is omitted and only one receiver, e. g. **114b** is required. The e. g. triple laser diodes **104a** to **104c** are selected as an example, such that a remote image of e. 3 x 100 pixels can be recorded. Individual diodes can be used here, but also diode lines with e. g. 16 to 32 laser diodes

[0012] To separate the backscattered signals, when operating in media that backscatter in their volume, such as fog and rain, this arrangement allows attaching also the optical axis of the receiver part **119** dislocated from the optical axis of the transmitter part **120**.

[0013] A further embodiment is shown in **Fig. 2**. As in **Fig. 1**, the carrier **101** contains the triple laser diodes **104a** to **104c** and the aperture arrangement **106**. The receiver optics **110**, the filter **111** and the transmitter optics **109** are again fixed. The retaining springs **203a**, **203b**, **203c** and **203d** are designed such that both a movement in the direction of x **204** and a movement in the direction of y **205** are possible. The standing intermediate optics **207** and the receiver **202** are designed in such a way that the surfaces depicted on the aperture matrix are illuminated completely on the surface of the lasers **104a** to **104c** in the scene to be measured within the freedom of movement in all directions **204** and **205**.

receiver **202**. The drive **118** is designed such that all surfaces to be measured can be approached controlled by means of corresponding control. **Fig. 3** shows the section of the receiver optics through their optical axis **119**. The receiving optics **110** maps the areas illuminated by the lasers **104a** to **104c** onto the aperture matrix **106** via the filter **111**. The intermediate optics **201** are designed such that all aperture surfaces in all layers of the aperture matrix **106** are mapped on the one receiver **202**. This ensures that only one single system reception channel must be used for serially controlled lasers. As opposed to others, this arrangement results in a significant advantage in relation to the component costs.

[0014] A further embodiment is shown in **Fig. 4**. As shown in **Fig. 1**, the carrier **101** is held and supplied by the springs **102**. The drive **118** corresponds to **Fig. 1**. The lasers **104a** to **104c** accordingly correspond to **Fig. 1** and **Fig. 2**. The aperture openings **106a** to **106c** correspond to **Fig. 1** and **Fig. 2**. The intermediate optics **201** and the receiver **202** correspond to **Fig. 2**. The transmitter optics **120** and the receiver optics **110** with filter **111** along with

the other optics are not drawn for a better overview. On the transmitter side, the triple laser diodes **402a** to **402b** are still located on the carrier **101**, and at a distance from the triple laser diodes **403a** to **403b**, both are mapped via separate optics **501** and **502** according to the section **410** according to **Fig. 5**, e. g. via a deflection double prism **503**, so that the optical axes **504** and **505** are deflected accordingly. The aperture openings **404a** to **404c** and **405a** to **405c** are arranged on the carrier **101** according to these images of the lasers, wherein the surfaces of the apertures **404a** to **404c** are imaged on the receiver **408** by the intermediate optics **406**. The surfaces of the apertures **405a** to **405b** are mapped on the receiver **409** via the intermediate optics **407**. **Fig. 5** shows the section **411** through this plane, wherein the surfaces illuminated by the lasers are imaged by the double prism onto the receiving optics **506** and **507** from the optical axes **509** and **510** onto the aperture matrix. The intermediate optics **406** and **407** map the surfaces of the aperture matrix onto the receivers **408** and **409**.

[0015] With this arrangement, three different angular ranges can be scanned in parallel with a moving carrier **101**.

[0016] A further embodiment of the invention is shown in **Fig. 6**. The transmitter carrier **601** is held by the springs **602** which serve both e. g. the control and supply. The transmitter carrier contains the transmitter drive **603** and e. g. groups of three of the multiple lasers, e. g. the triple laser groups **604**, **605** and **606**. Each multiple laser group is associated with a transmission optic that respectively covers a different area and can also have a different focal length. The multiple laser group **604** is the transmitter optics **609** and the transmitter optics **608** is assigned to the multiple laser group **605**. The transmitter optics **607** are allocated to the multiple laser group **606**.

[0017] The aperture carrier **611** is completely separated from the transmitter carrier **601** and has its own supply and holder via its springs **612** and it has its own drive **613**. The receiving optics **617** maps the surface illuminated by the laser group **606** onto the aperture group **616**. The penetrating beams are mapped in each position from the intermediate optics **622** to the receiver **625**. The receiver optics **619** maps the surfaces illuminated by the laser group **604** onto the aperture group **614**. The penetrating beams are rendered by the intermediate optics **620** onto the receiver **623**. The receiving optics **618** maps the surfaces illuminated by the laser group **605** onto the aperture group **615**. The penetrating beams are mapped onto the receiver **624** via the intermediate optics **621**. The receiving optics **618** maps the surfaces illuminated by the laser group **605** onto the aperture group **615**. The penetrating beams are mapped onto the receiver **624** via the intermediate optics **621**.

[0018] In the continuation of the invention, a larger angular range can be covered with one single laser or one multiple laser. According to **Fig. 7**, a movement in the plane is not scanned by the elements, but behind the optics at a constant focal distance. The carrier **701** is fastened to the retentions **702a** and **703a** via the springs **702** and **703**. These springs are used for retention and for supplying current for e. g. the triple laser **705** and the drive **708**. At the same time, an aperture **706** with its opening **707** is fastened to the carrier **701**. Through the drive, the triple laser **705** executes a movement about a circular path section with the center point in the transmission optics **709** with the radius formed from the distance between the transmitter optics **709** and the triple laser **705**. The aperture **706** with its opening **707** executes a movement in the circular path section with the center point in the receiving optics **711** with the radius formed from the distance between the receiving optics and the opening **707** of the aperture **706**.

[0019] The springs **702** and **703** are designed such that the pivot point is at **704** within the optics **709** and **711**. For a better overview, the components of the interim optics, the lens **712** and the filter **713** in **Fig. 7** are drawn slightly away from the aperture **706**, although both parts are located directly behind the aperture opening **707** and are firmly connected to the aperture **706**.

[0020] The second part of the intermediate optics **714** is firmly arranged, as is the receiver diode **715**. If the carrier **701** is moved about the angle **708a** via the drive **708**, the triple laser **705** scans the angular range **719** to **720** via the transmission optics **709** according to **Fig. 7a**. The position **718** is the

resting position drawn in **Fig. 7**. Since the aperture **706** is attached to the same carrier **701**, as shown in **Fig. 7a**, the same angular range as on the transmitter is scanned via the receiving lens **711** through the aperture opening **707**. According to **Fig. 7a**, the aperture opening moves in the angular range **716** to **717**.

[0021] Part of the interim optics, namely the lens **712** and the filter **713**, are permanently connected to the aperture **706**. The lens **712** forms from the divergent light beam that passes through the aperture opening, a nearly parallel light beam that passes through the filter **713** and is then guided to the receiving diode **715** via the fixed intermediate optics **714** in each angular position of the carrier **701**. Thus, only one laser diode and one receiving diode are required for the entire scan range if no further resolution is required in elevation.

[0022] Of course, the arrangement shown in **Fig. 7** and **Fig. 7a** can also contain several single or multiple laser diodes at a fixed angular position on the carrier **701**, and the aperture **706** can contain the associated aperture openings in the same angular position and it is shown in

Fig. 1 for movement in one plane. Thus, the angle scanned with the system will remain large while the carrier must only be e. g. deflected by 1/3 of the angular range if 3 lasers and 3 aperture openings are used. A plurality of planes one above the other, as shown in **Fig. 4** are also possible for an arrangement in one plane with the system according to **Fig. 7**. The separation of the drive and the carrier for the laser transmitter and receiving apertures with associated intermediate optics is also feasible in the arrangement according to **Fig. 7** analogous to the planar arrangement in **Fig. 6** in accordance with the invention.

[0023] The electronic system control and evaluation of the signals in the systems according to **Fig. 1**, **Fig. 2**, **Fig. 4** and **Fig. 7** is carried out according to **Fig. 8**. The carrier **101** with the aperture matrix **106** of the transmission matrix lies behind the receiver optics **110** and the transmitter optics **109**, e. g. **104a** to **104c** driven by the linear motor **118**. The processor **802** takes over the control of the scanning sequence and the time control. The position is determined by the motor controller **803** via the linear motor **118**, then the transmission controller **801** takes over the triggering of the lasers **104a** to **104c** in succession and in the correct chronological sequence.

[0024] The full width at half maximum of the light pulses is approx. 10-20 ns. The light pulses are reflected by the scene to be surveyed and arrive at the receiver at maximum distances of approx. 150 m after 1 μ s and are evaluated in their time difference and amplitude in the signal evaluation **805** according to one of the methods described in DE 197 17 399 C2 and DE 41 27 168 C2. Since a corresponding light pulse can be sent every 2 μ s for temporal separation, it is not necessary that the motor controller **901** stops between the pivot positions, rather the process can proceed continuously.

The individual points evaluated according to runtime, which corresponds to the distance and amplitude, are forwarded by the signal evaluation **805** to the processor signal evaluation **806**, analyzed there according to plausible data in connection with the resulting distance image and the individual data is forwarded to the processor for tracking and track finding **807**. This processor searches for objects that are contiguous based on the speeds, position and distances and evaluates them in the movement path of the vehicle carrying the sensor according to the invention.

[0025] For a length or transverse control, the data for the vehicle is then available via the interface **808** on the bus **810**.

[0026] The entire system is connected via the on-board power supply **809**, e. g. with 12 V or 24 V. The power supply and interface **808** supply all internal components with the necessary voltage.

[0027] In systems according to **Fig. 6** or **Fig. 7** according to the system of **Fig. 6**, in which the laser matrix and the aperture matrix are each provided with a separate drive **603** and **613**, the signal is acquired and evaluated according to **Fig. 9**. Due to the fact that the diameter of the transmission optics **607** can be much smaller than the receiver optics **617**, their focal length can also be significantly smaller. Thus, with the same deflection in the plane according to **Fig. 6** or at an angle according to **Fig. 7**, only a smaller deflection range of the laser matrix relative to the aperture matrix **614**, **615**, **616** is necessary. This is achieved via the processor for time and scan control **902** and the motor control **901**. The two motors **603** and **613** are controlled in their incremental width and total deflection in the ratio of the focal length of the receiver optics **617** to the focal length of the transmitter optics **607**.

[0028] By means of the motors and their control to an adjustment in the direction of movement at the end of the manufacturing process of the sensor can be omitted, since said sensor can perform a self-adjustment via the signal evaluation. If very large angles should be scanned at a very high speed, the transit time between transmitter and receiver can be compensated even at long distances by different positions between the aperture matrix and the transmission matrix. The remaining components in **Fig. 9** which have the same designation as in **Fig. 8** have the same function as described in **Fig. 8**. The system in the variants described according to the invention is primarily intended for use in the infrared range. However, it can also be used even at very short wavelengths analogously for electromagnetic impulses of other wavelengths. There, the laser diodes are e. g. small emitters or oscillating circuits including e. as Gunn diodes. As receivers, the photodiodes are e. g. planar antennas or e. g. by the input circuit of mixers or receiver stages.

Claims

1. System for generating a range image, that uses the transit time determination of electromagnetic pulses for distance measurement, with one or more pulse sources, a transmission optics and a receiver optics, an aperture having one or more aperture openings and one or more receivers, wherein the one or more pulse sources are moved in a plane or on a cylinder jacket and the one or more aperture openings of the aperture are designed in this way that the image of the surfaces illuminated by the pulse sources fills precisely these aperture openings and wherein this aperture is moved in this way, in all movement positions, the illustration of the areas illuminated by the pulse sources fits into these aperture openings and the radiation power available behind the

aperture openings is guided to the one or more receivers.

2. System according to Claim 1, wherein the pulse sources are designed as laser diodes or multiple laser diodes and one or more receivers are designed as photodiodes.

3. System according to Claim 1, wherein the one or more pulse sources are configured as mm wave transmitters and the one or more receivers are configured as mm wave receivers.

4. System according to any one of the preceding Claims, wherein intermediate optics are attached behind the one or the aperture openings, which are designed in such a way that the radiation output of each aperture opening is respectively mapped to a receiver independently of the position of the aperture openings and pulse sources.

5. System according to any one of Claims 1 to 3, wherein intermediate optics are attached behind the one or the aperture openings, which are designed in such a way that the radiation output of a plurality of aperture openings is respectively mapped to a receiver independent of the position of the aperture openings and pulse sources.

6. System according to any of the preceding Claims, wherein pulse sources and apertures are mounted on a carrier and thus moved parallel in the plane or on a cylinder jacket.

7. System according to any one of Claims 1 to 5, wherein the pulse sources are mounted on a carrier and the aperture on a further carrier, and in which both carriers are independently moved by one drive each time such that the depiction of the surfaces illuminated by the pulse sources fits spatially into the respective aperture openings at each movement position.

8. System according to Claim 7, wherein the drives are moved in such a way that the mapping of the area illuminated by the pulse source fits spatially and temporally precisely into the respective aperture openings at each movement position.

9. System according to Claim 7 or 8, wherein the position is assigned by the carrier of the pulse sources and carrier of the aperture via the evaluation of the signals during operation.

10. System according to Claim 7 or 8, wherein the position is assigned by the carrier of the pulse sources and carrier of the aperture via the evaluation of the signals during operation and during each individual movement process.

11. System according to any one of the preceding Claims, wherein a collective lens is fastened behind each aperture opening, which forms the divergent light beam into an almost parallel light beam.

12. System according to Claim 11, wherein a filter is fastened behind each aperture opening in addition to the collecting lens, which is irradiated by parallel beams and is thus more selective.

There are 7 pages of drawings

Attached drawings

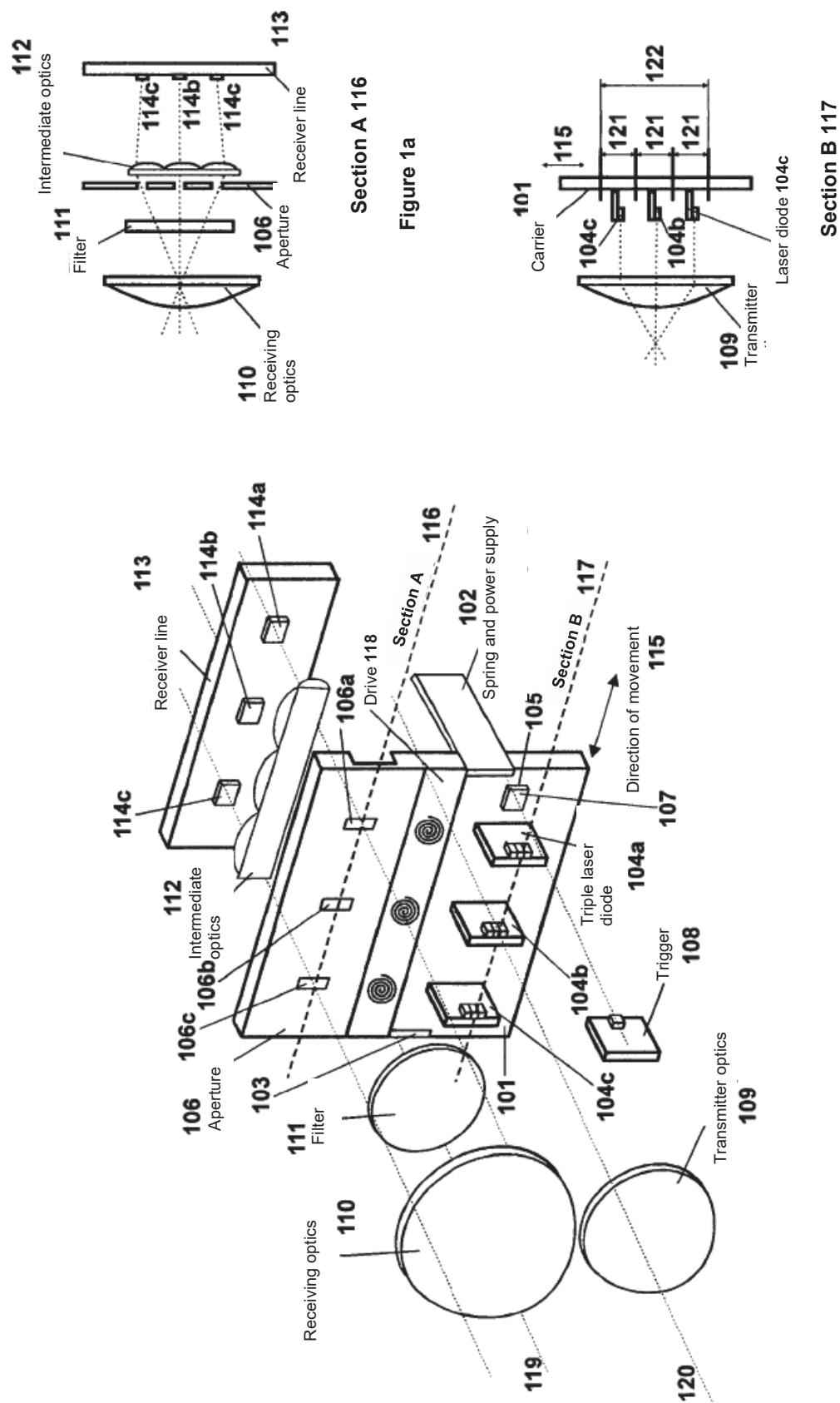
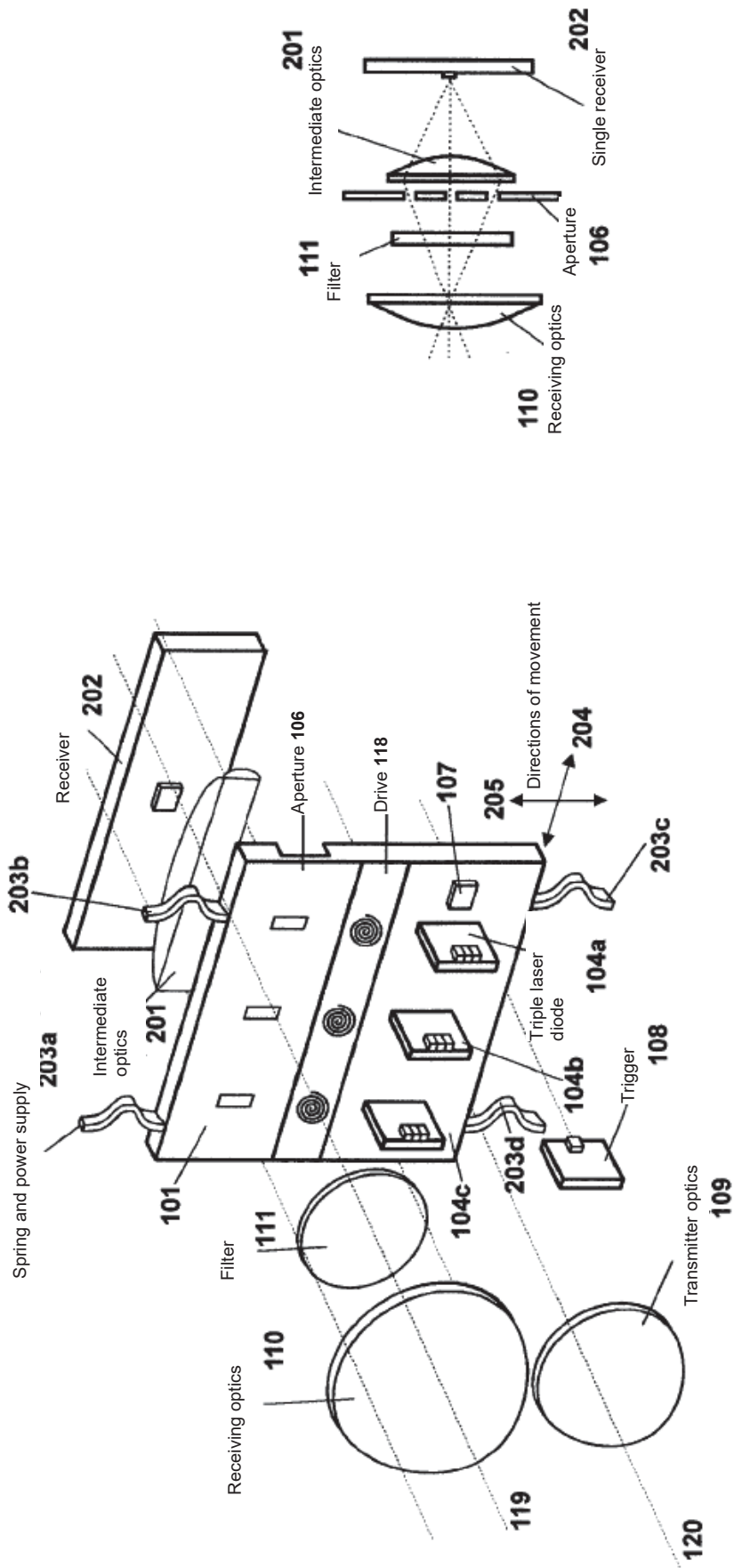


Figure 1

Figure 1b



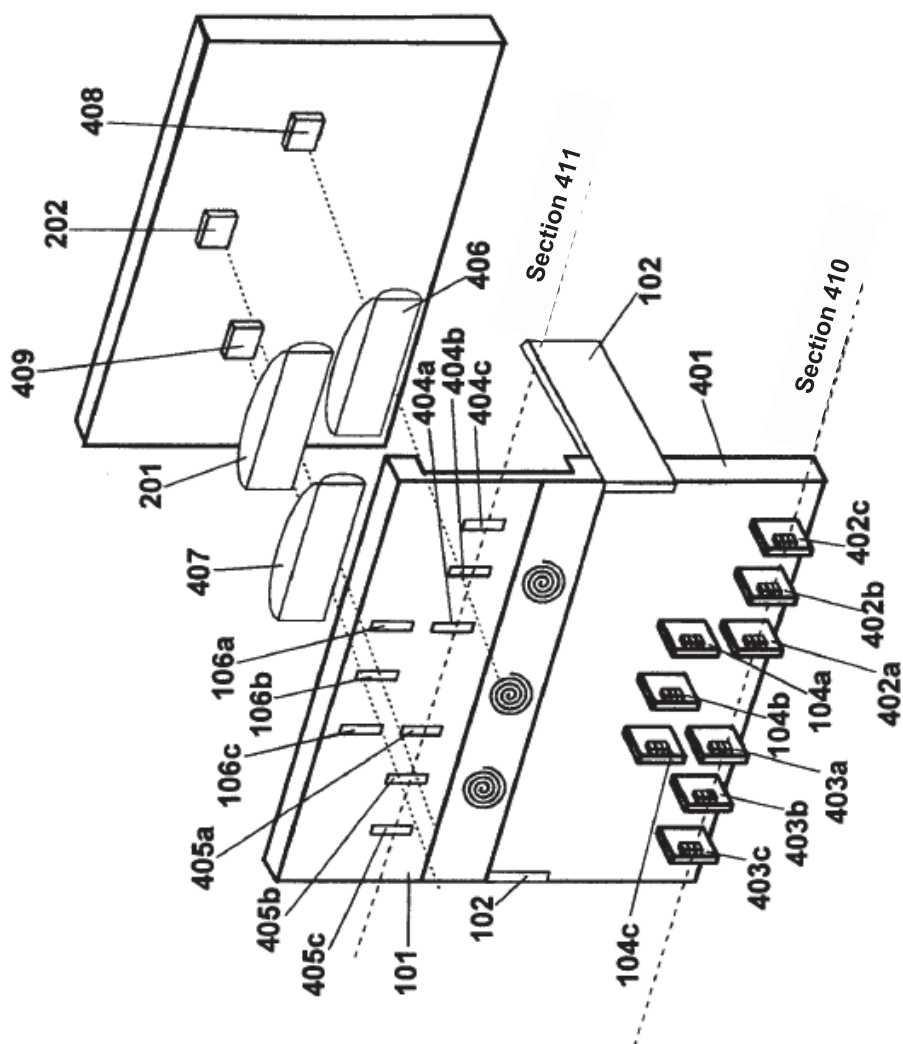


Figure 4

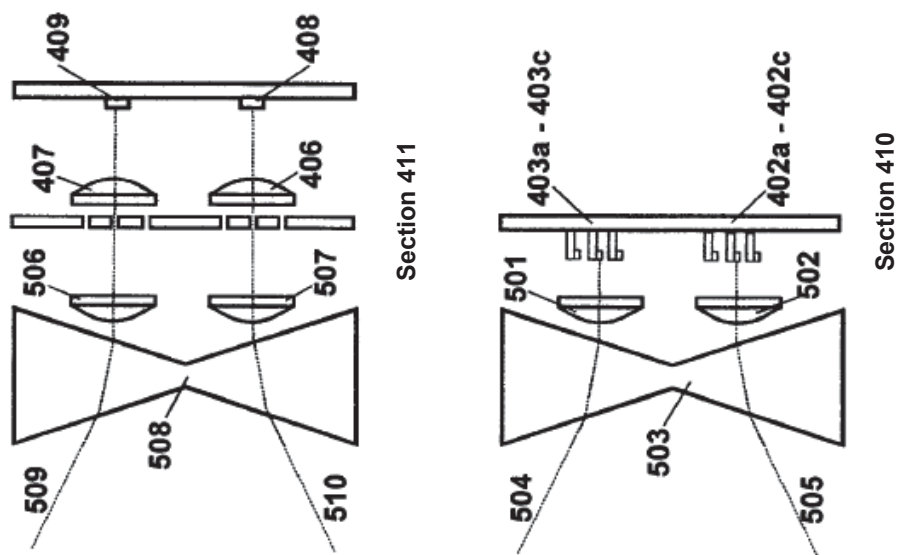


Figure 5

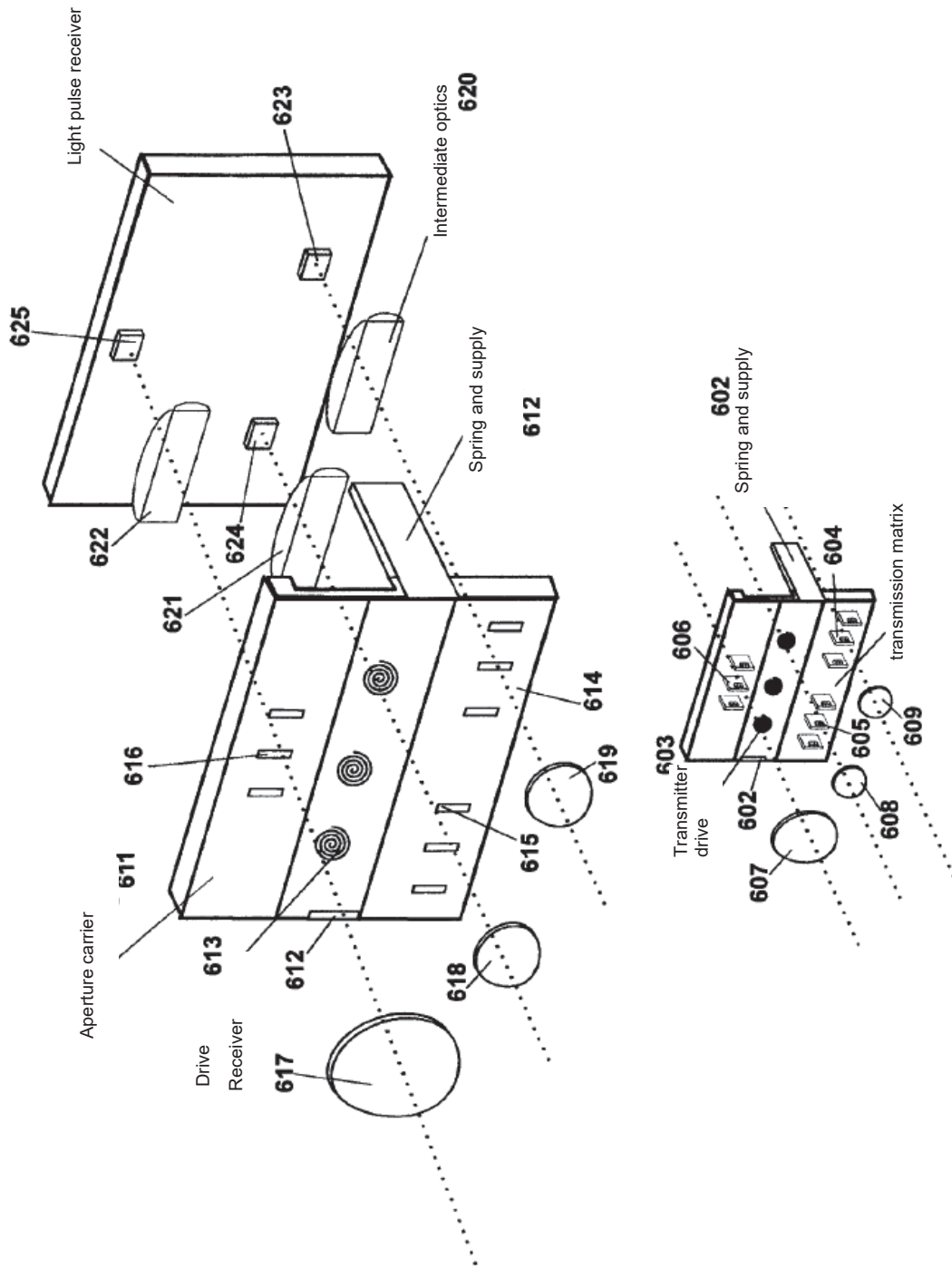


Figure 6

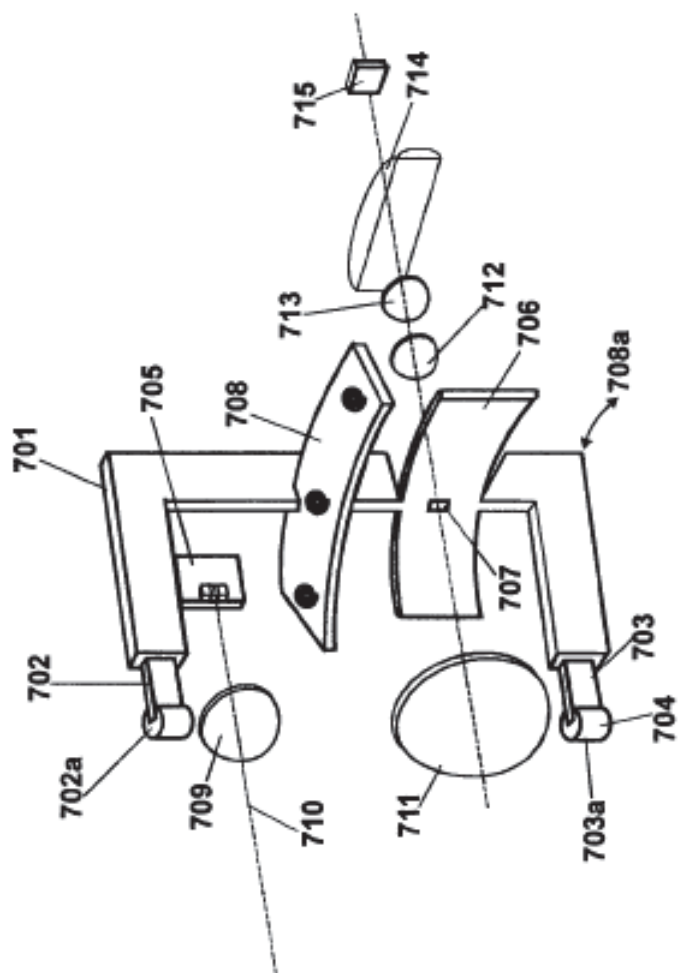


Figure 7

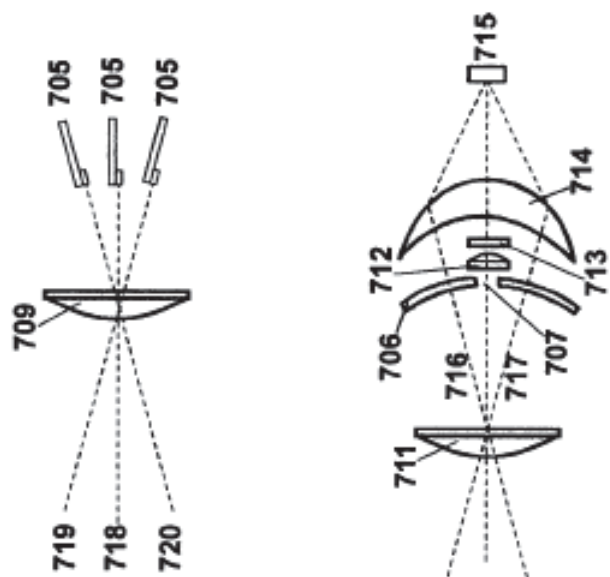


Figure 7a

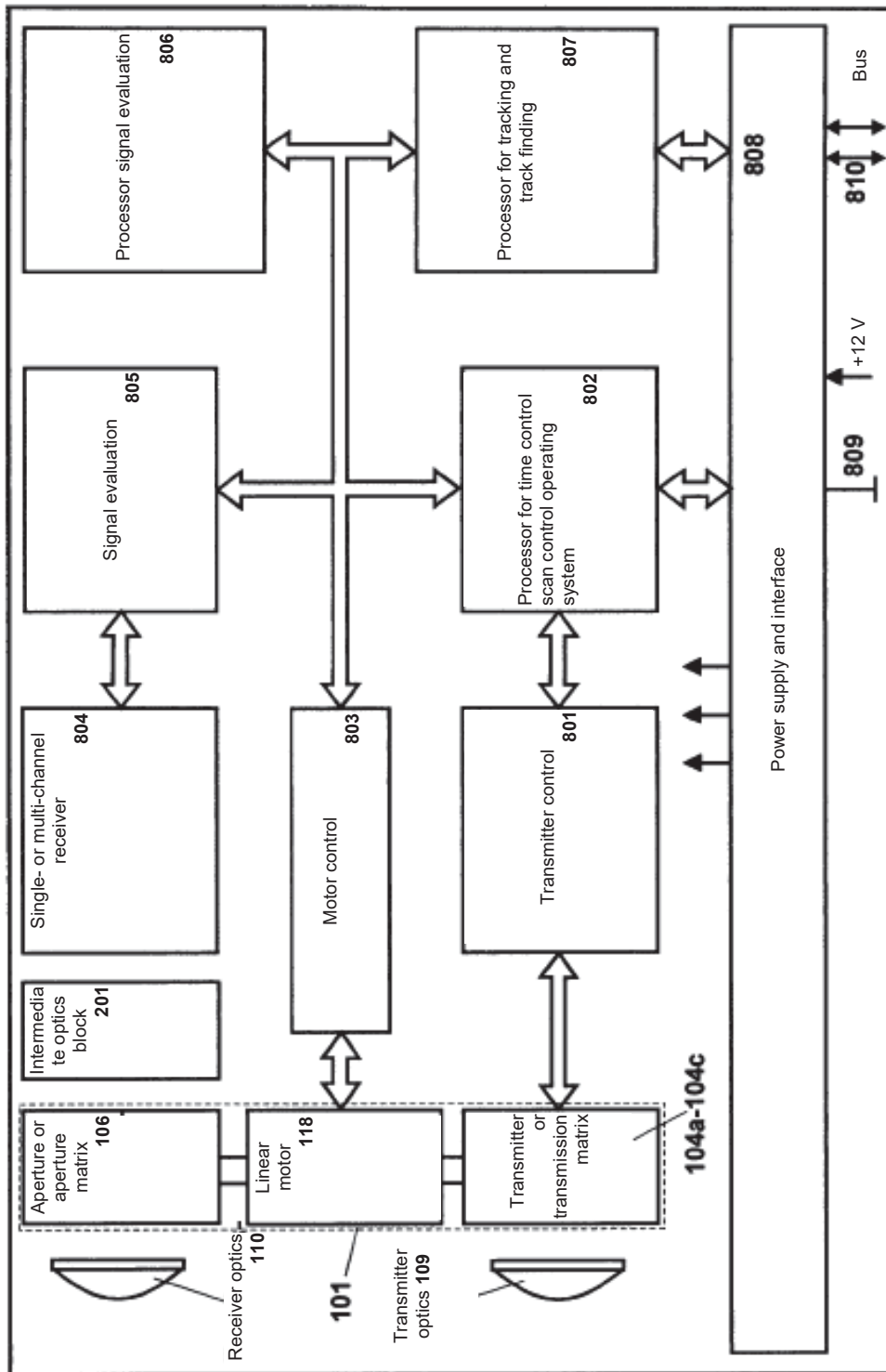


Figure 8

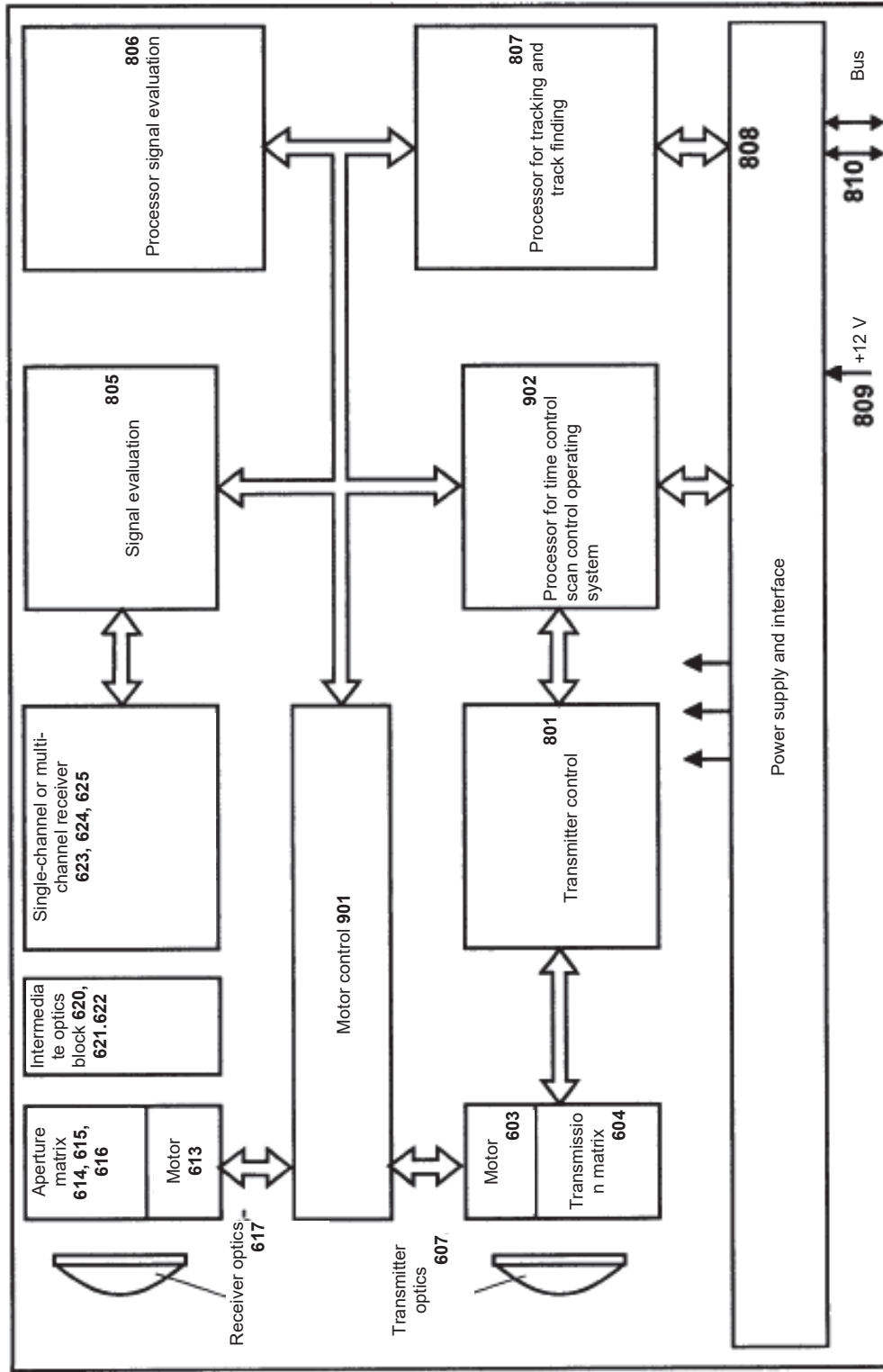


Figure 9