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(54) **LENS APPARATUS AND RELATED ASSEMBLIES AND VEHICLES FOR LASER IMAGING SYSTEMS**

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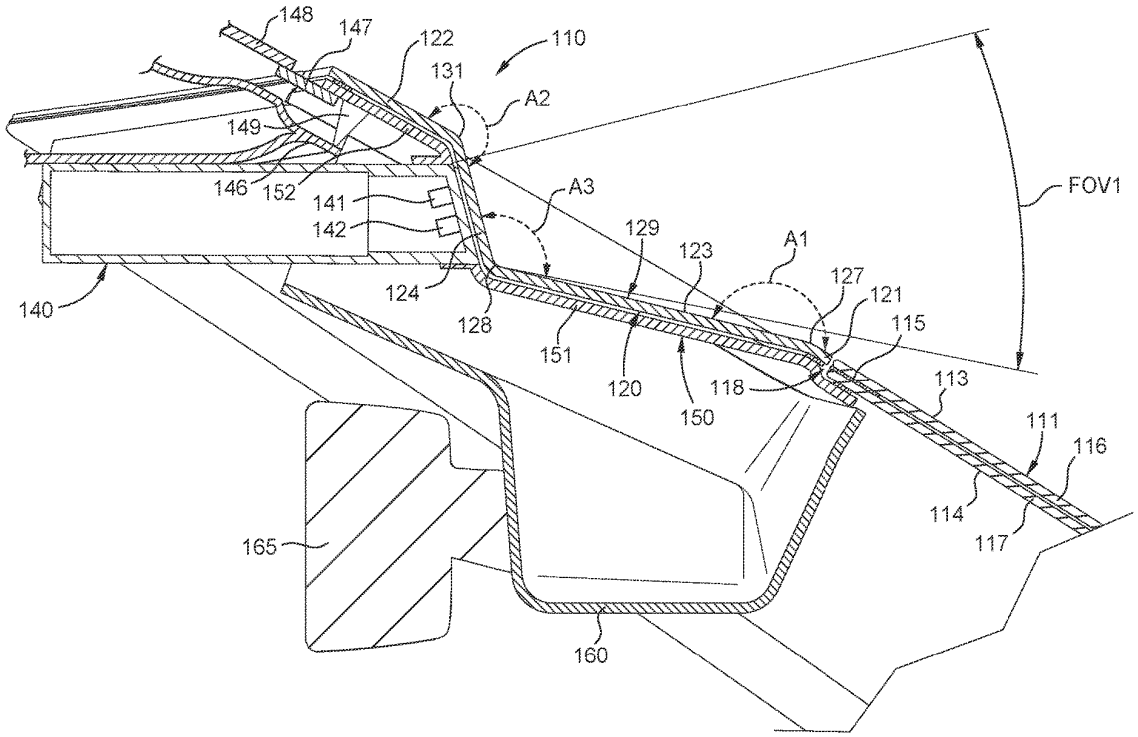
(57) **ABSTRACT**

The present disclosure relates to lenses, and related assemblies and vehicles, for laser imaging systems. In one or more embodiments, a lens assembly includes a view panel including an outer perimeter and an opening formed in the outer perimeter, and a lens positioned at least partially in the opening. The lens assembly includes a support structure attaching the lens to a second outer surface of the view panel.



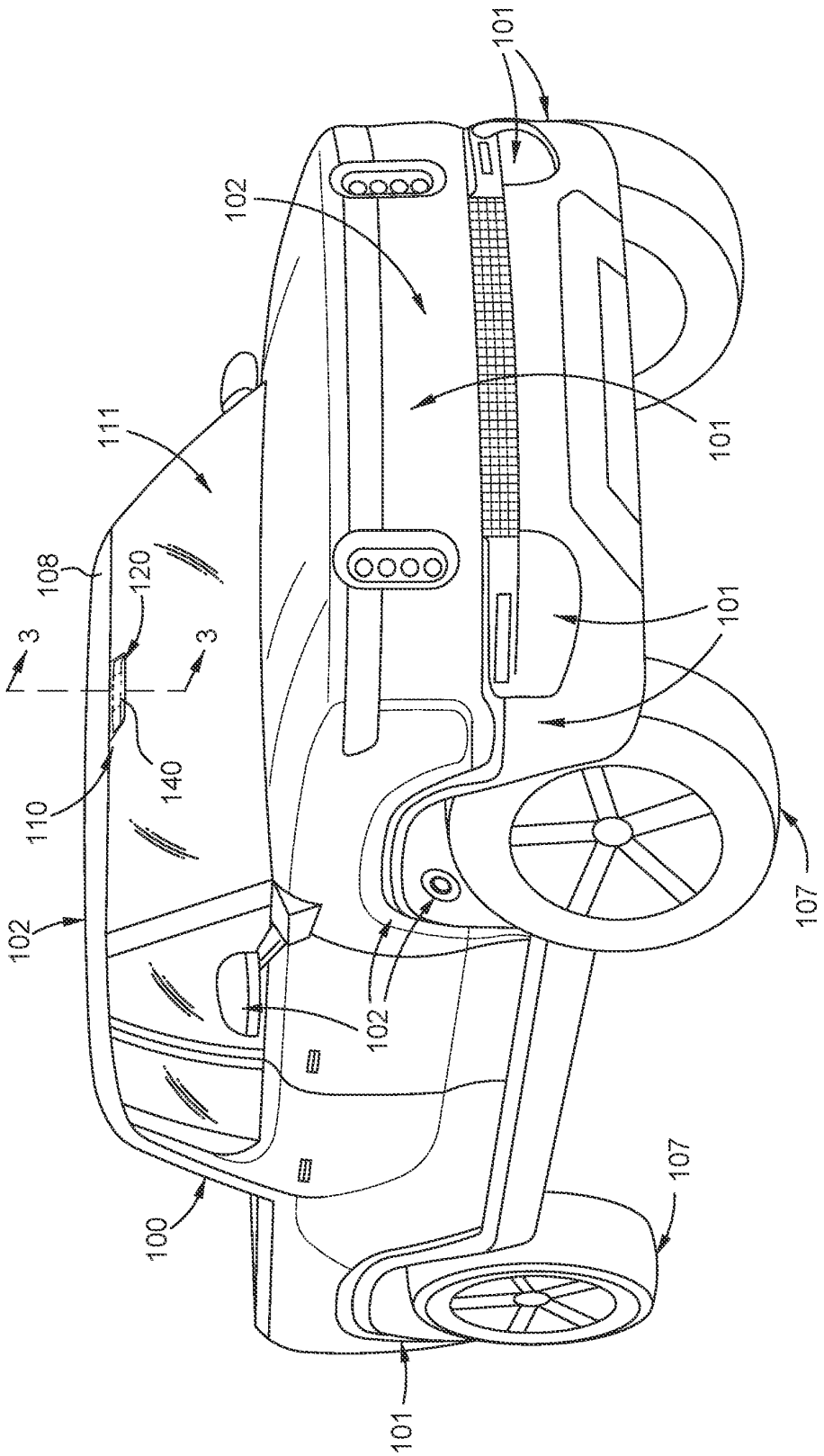


FIG. 1

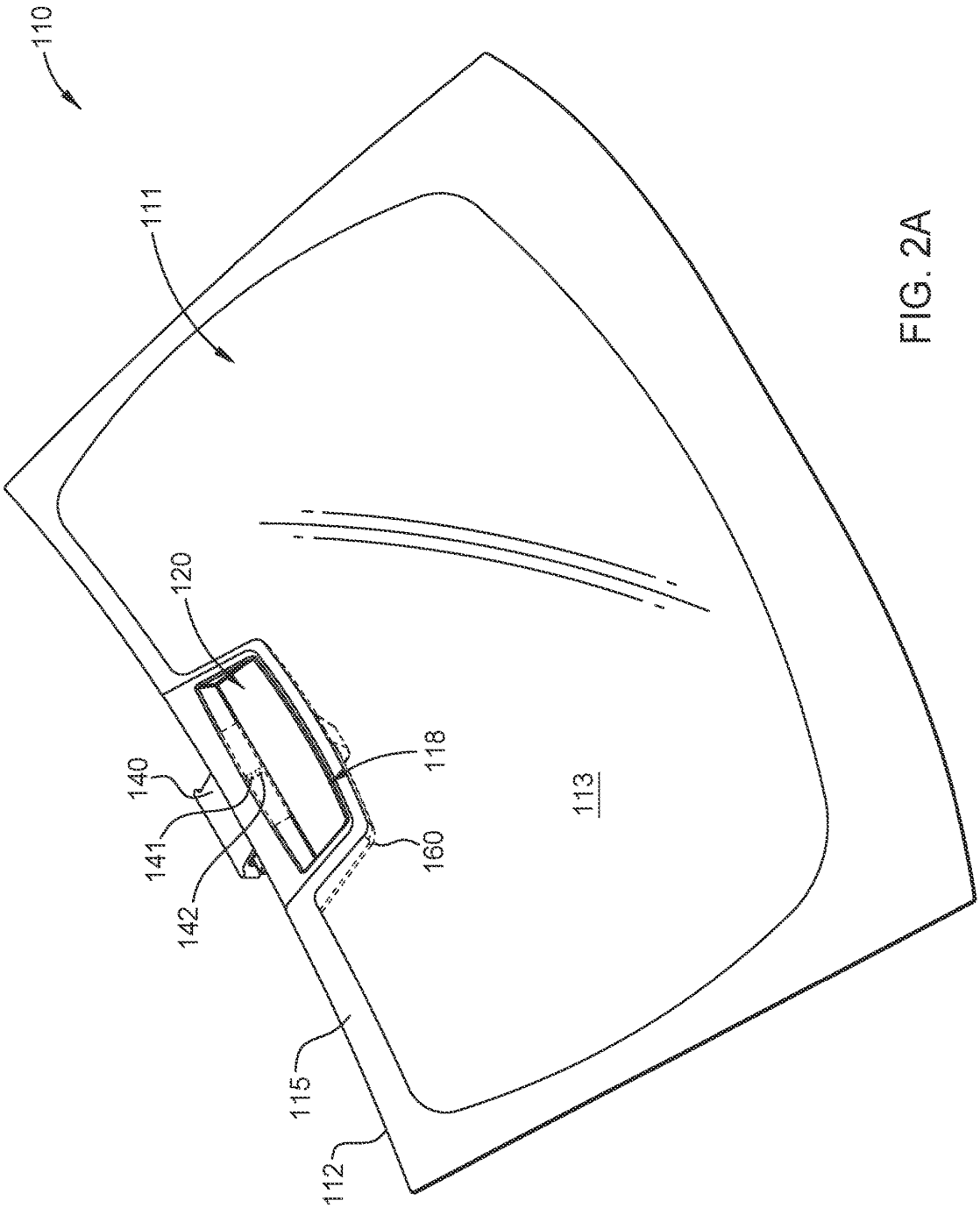


FIG. 2A

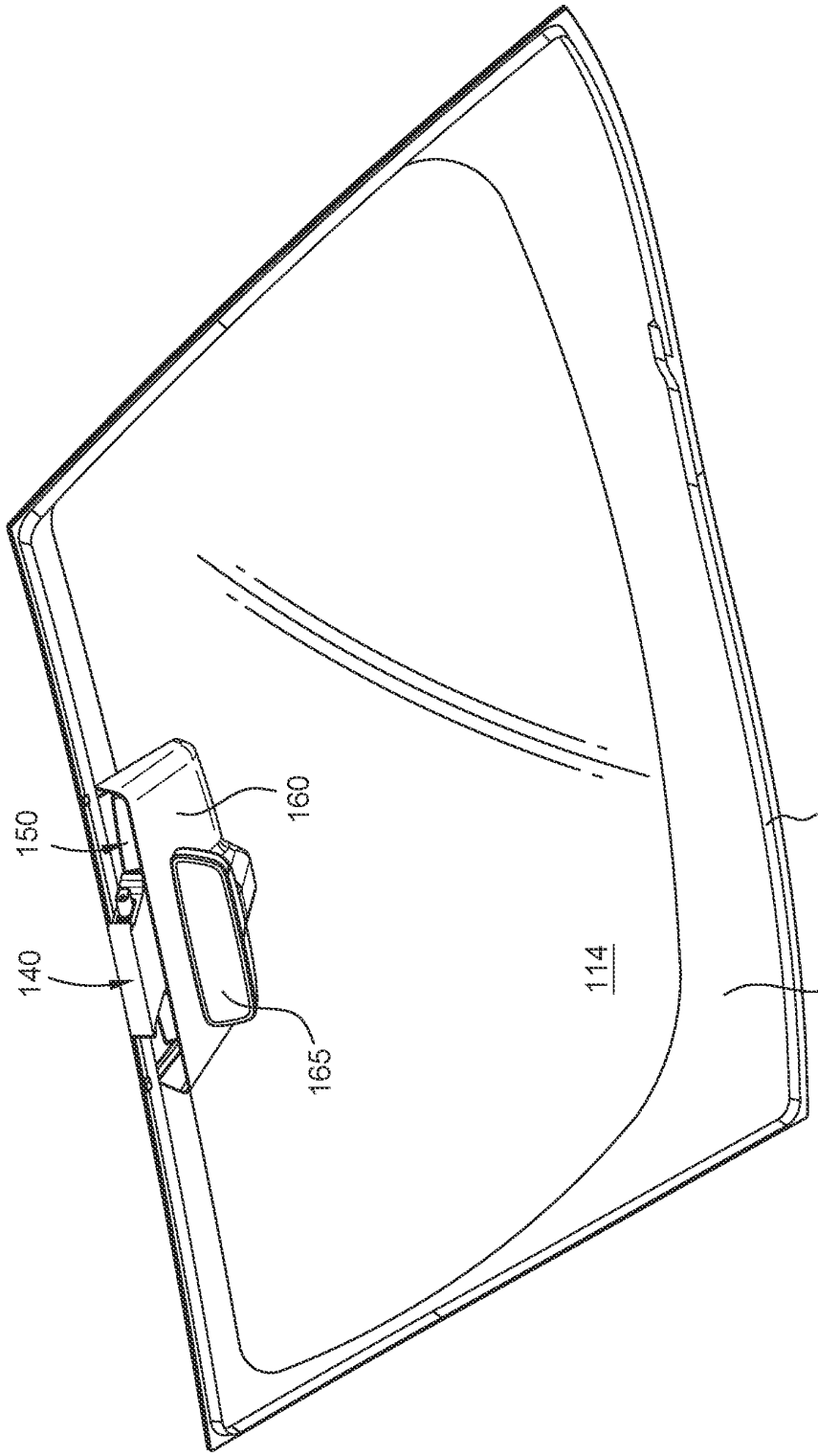


FIG. 2B

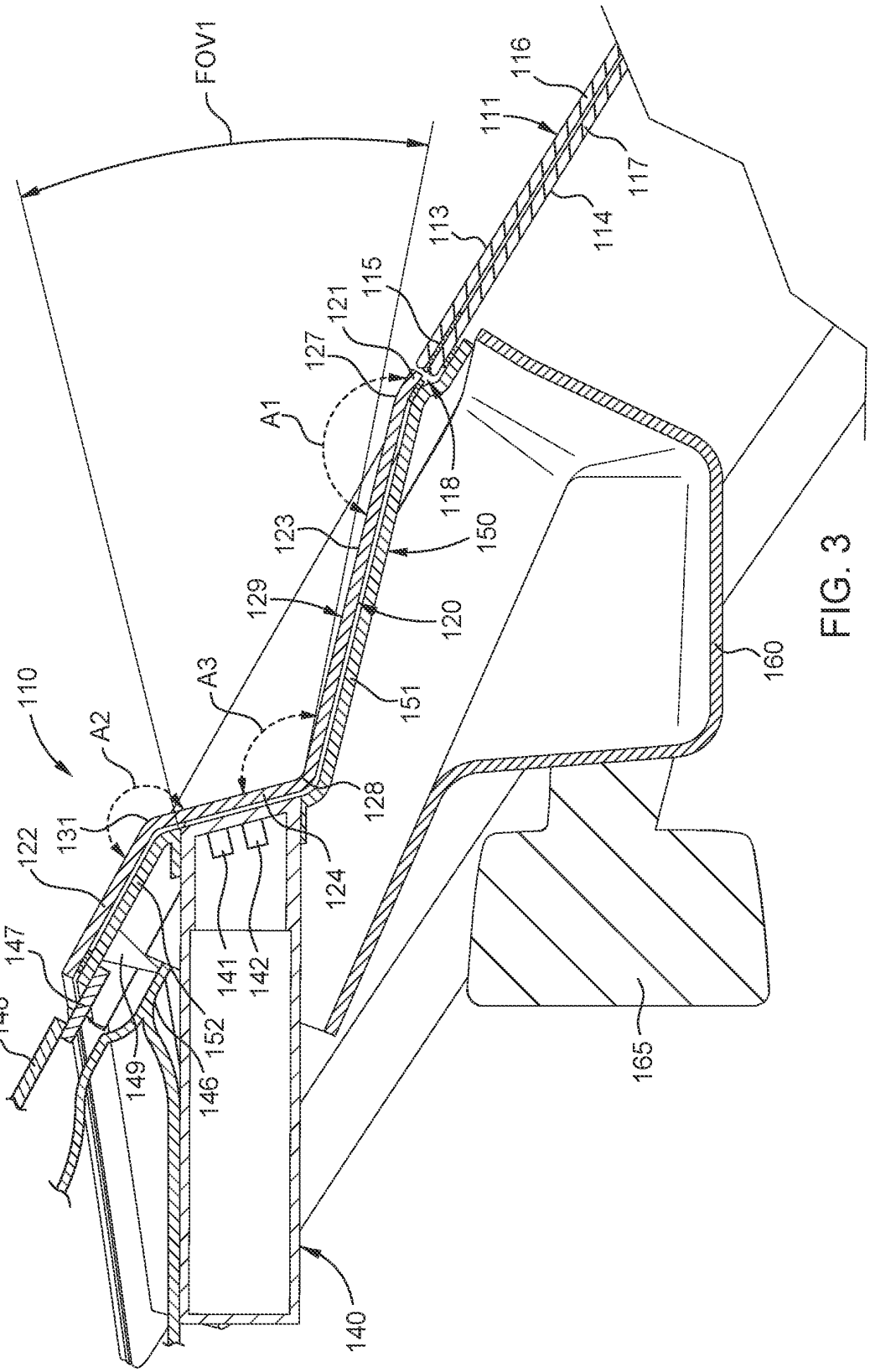
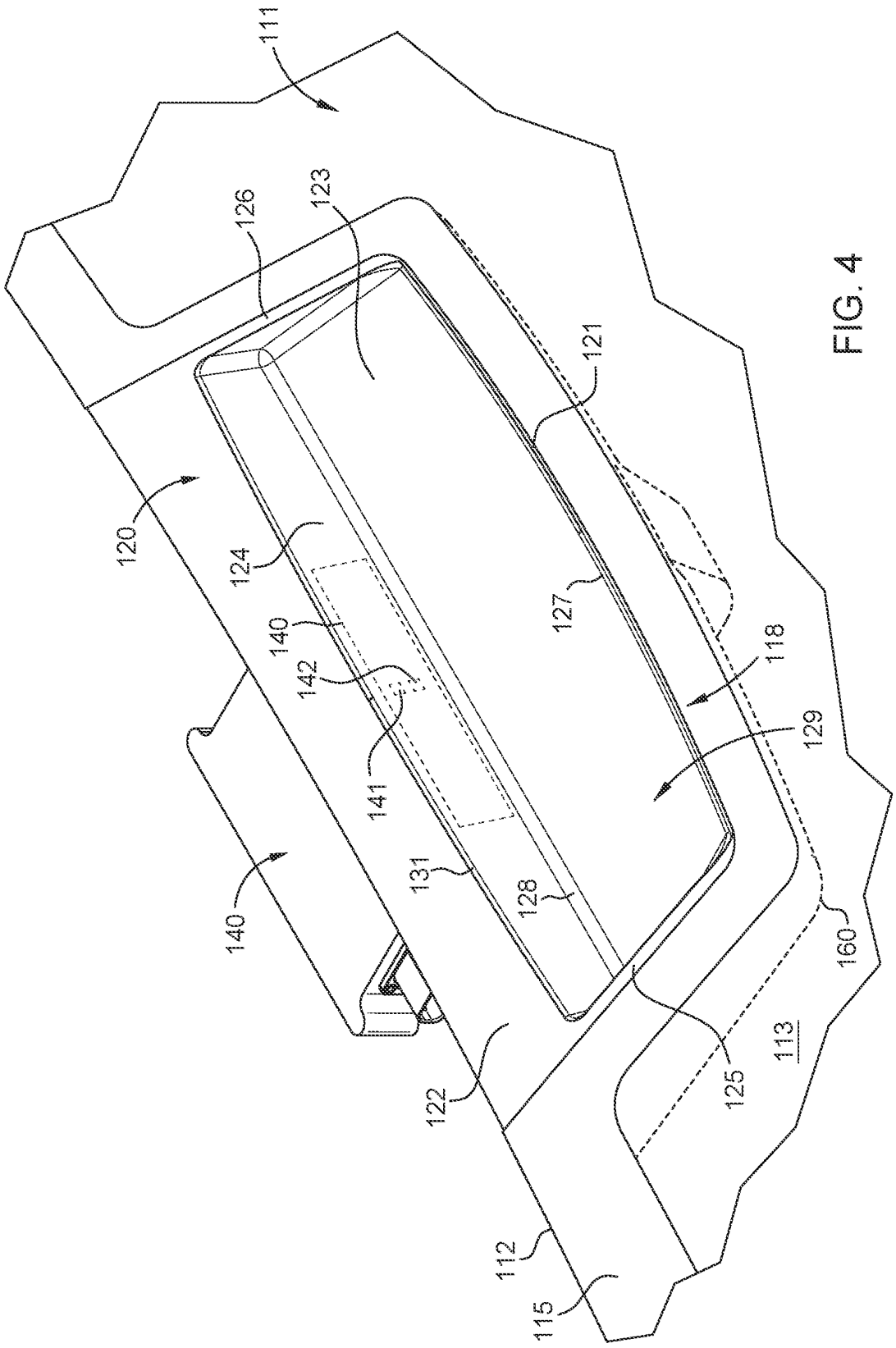

FOV1
116
111
117
114
113
115
121
127
A1
118
123
150
129
120
151
A3
110
A2
128
131
122
124
147
141
142
148
152
149
146
140
165
160

FIG. 3


111
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115

FIG. 4

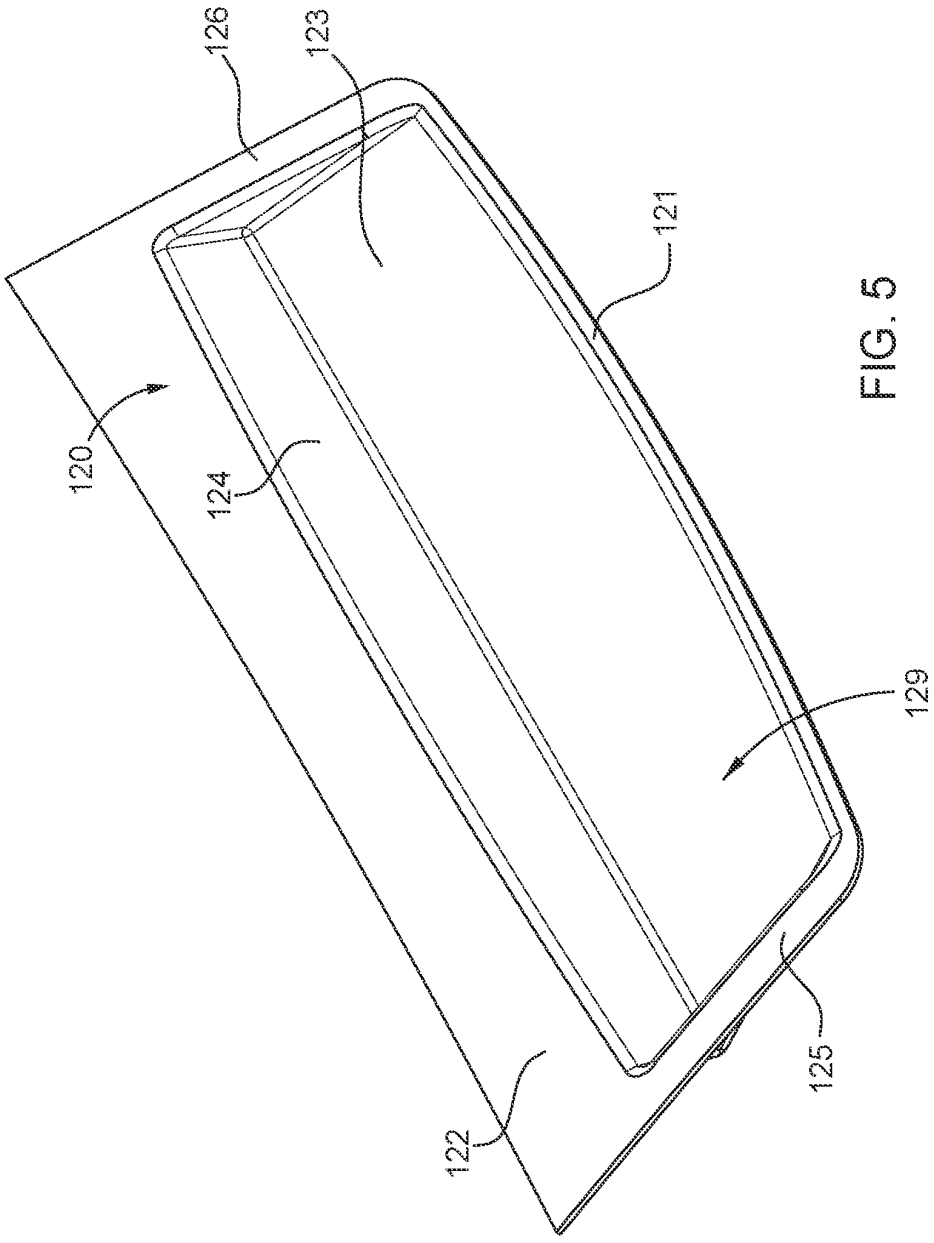


FIG. 5

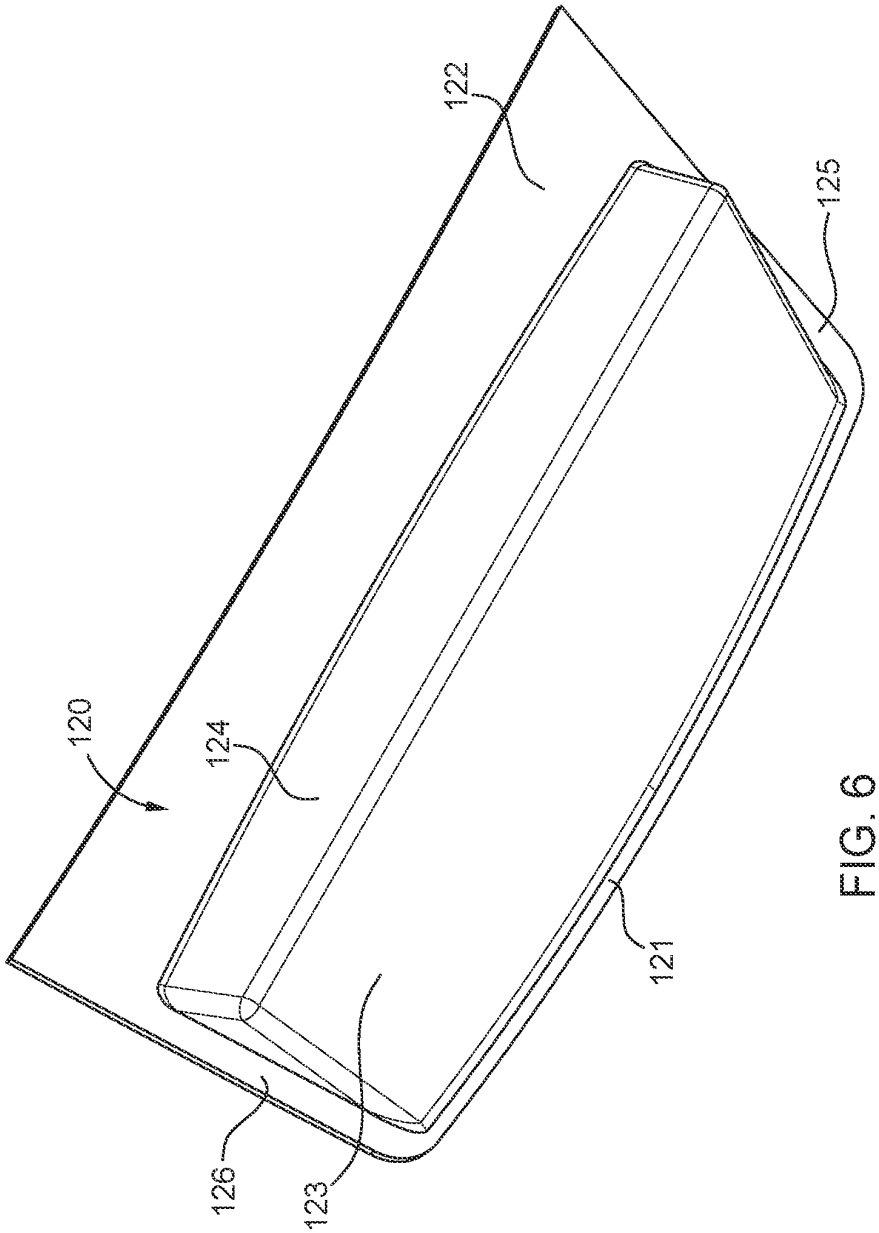
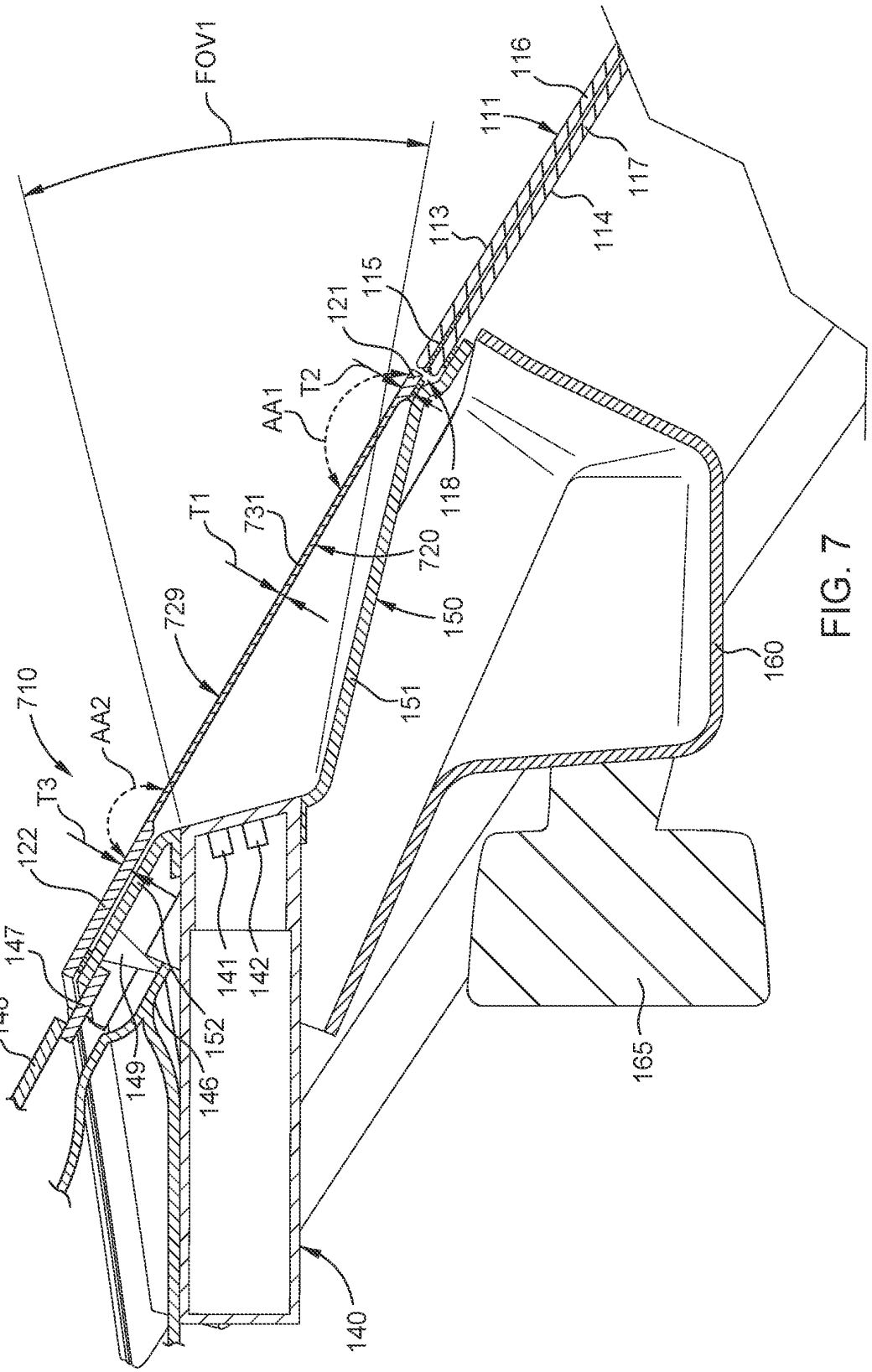


FIG. 6


FOV1
116
111
117
114
113
115
121
T2
AA1
118
T1
731
720
729
150
151
160
710
AA2
T3
122
147
148
141
142
152
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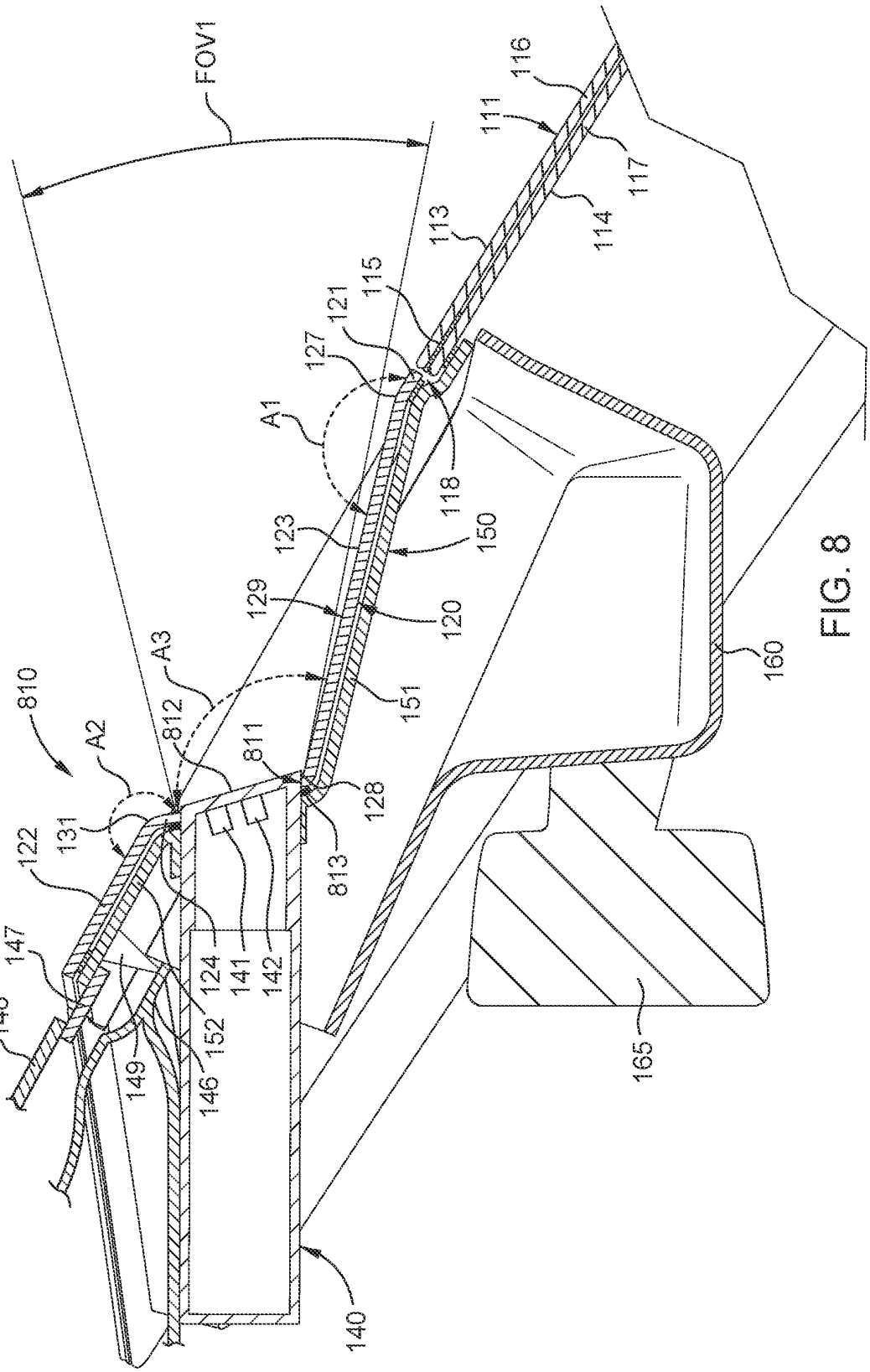
146
140
165

FIG. 7


FOV1
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A1
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812
811
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A2
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813
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147
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141
142
148
152
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146
140
165
160

FIG. 8

LENS APPARATUS AND RELATED ASSEMBLIES AND VEHICLES FOR LASER IMAGING SYSTEMS

INTRODUCTION

[0001] Various vehicle systems involve the use of light-based devices. However, mounting light-based devices can be difficult. For example, mounting a light-based device on an outer side of a vehicle can make vehicle assembly difficult and time-consuming, and can undermine aesthetic appeal of the vehicle. As another example, one or more vehicle components can interfere with light transmission paths, which may hinder operation and calibration of the light device.

SUMMARY

[0002] The present disclosure relates to lenses, and related assemblies and vehicles, for laser imaging systems.

[0003] In one or more embodiments, a lens assembly includes a view panel including an outer perimeter, an opening formed in the outer perimeter, a first outer surface, and a second outer surface. The lens assembly includes a lens positioned at least partially in the opening. The lens assembly includes a support structure attaching the lens to the second outer surface of the view panel.

[0004] In one or more embodiments, a vehicle includes a vehicle body and a view panel mounted to the vehicle body. The view panel includes an outer perimeter and an opening formed in the outer perimeter. The vehicle includes a lens positioned at least partially in the opening.

[0005] In one or more embodiments, an infrared lens includes a first section, a second section spaced from the first section, and a plurality of angled sections extending between the first section and the second section. The plurality of angled sections at least partially define a recessed face. The plurality of angled sections include a first angled section oriented at a first angle relative to the first section, and a second angled section oriented at a second angle relative to the second section. The second angle is larger than the first angle.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] So that the manner in which the above recited features of the present disclosure can be understood in detail, a more particular description of the disclosure, briefly summarized above, may be had by reference to embodiments, some of which are illustrated in the appended drawings. It is to be noted, however, that the appended drawings illustrate only exemplary embodiments and are therefore not to be considered limiting in scope, and may admit to other equally effective embodiments.

[0007] FIG. **1** is a schematic perspective view of a vehicle, according to one or more embodiments.

[0008] FIG. **2**A is a schematic partial perspective front view of the lens assembly shown in FIG. **1**, according to one or more embodiments.

[0009] FIG. **2**B is a schematic partial perspective back view of the lens assembly shown in FIG. **1**, according to one or more embodiments.

[0010] FIG. **3** is a schematic cross-sectional side view of the lens assembly along Section **3-3** shown in FIG. **1**, according to one or more embodiments.

[0011] FIG. **4** is a schematic enlarged perspective view of the lens assembly shown in FIG. **2**A, according to one or more embodiments.

[0012] FIG. **5** is a schematic perspective front view of the lens shown in FIGS. **1-4**, according to one or more embodiments.

[0013] FIG. **6** is a schematic perspective back view of the lens shown in FIG. **5**, according to one or more embodiments.

[0014] FIG. **7** is a schematic cross-sectional side view of a lens assembly, according to one or more embodiments.

[0015] FIG. **8** is a schematic cross-sectional side view of a lens assembly, according to one or more embodiments.

[0016] To facilitate understanding, identical reference numerals have been used, where possible, to designate identical elements that are common to the figures. It is contemplated that elements and features of one embodiment may be beneficially incorporated in other embodiments without further recitation.

DETAILED DESCRIPTION

[0017] The present disclosure relates to lenses, and related assemblies and vehicles, for a laser imaging system. In one or more embodiments, a lens assembly includes a view panel (such as a windshield or another structure, such as a window) including an opening formed in an outer perimeter thereof, and a lens positioned at least partially in the opening. The lens includes a recessed face that is recessed relative to a front face of the view panel. The lens assembly also includes a support structure that attaches the lens to a back face of the view panel. The lens includes one or more angled sections that at least partially define the recessed face. A laser module including a laser source is configured to emit light through at least one of the one or more angled sections of the lens, which has improved transmission characteristics with respect to light generated by the laser source as compared to the view panel. Transmitting the light through the lens enables more reliable light detection and ranging (LiDAR) operations and simplifies calibration of the laser source. Positioning the lens in the perimeter opening maintains an aesthetic appeal while simplifying both vehicle assembly and wiring.

[0018] The lens assembly is mounted to a vehicle. In one or more embodiments, the vehicle is an automotive vehicle, such as an electric vehicle (e.g., an electric truck, a sport-utility vehicle (SUV), or a service van) or an internal combustion vehicle.

[0019] The disclosure contemplates that terms used herein such as "attaches," "attaching," "attach," "attached," "couples," "coupling," "couple," and "coupled" may include but are not limited to bonding, embedding, welding, fusing, melting together, interference fitting, and/or fastening such as by using bolts, threaded connections, pins, and/or screws. The disclosure contemplates that terms such as "attaches," "attaching," "attach," "attached," "couples," "coupling," "couple," and "coupled" may include but are not limited to integrally forming. The disclosure contemplates that terms such as "attaches," "attaching," "attach," "attached," "couples," "coupling," "couple," and "coupled" may include but are not limited to direct attaching or coupling and/or indirect attaching or coupling, such as indirect attaching or coupling through components such as links, blocks, and/or frames.

[0020] FIG. **1** is a schematic perspective view of a vehicle **100**, according to one or more embodiments. The vehicle **100** may include multiple sensors **101** and/or multiple cameras **102**. The vehicle **100** includes one or more wheel modules **107**. In the implementation shown in FIG. **1**, the vehicle **100** is a truck. The present disclosure contemplates that the subject matter described herein can be used in any other type of vehicle having any numbers of wheels, such as vans and/or SUVs.

[0021] A lens assembly **110** is mounted to the vehicle **100**. The lens assembly **110** includes a view panel **111**, a lens **120**, and a laser source **141** and a sensor **142** positioned behind the lens **120**. In one or more embodiments, the view panel **111** mounted to a vehicle body **108** of the vehicle **100**.

[0022] FIG. **2**A is a schematic partial perspective front view of the lens assembly **110** shown in FIG. **1**, according to one or more embodiments. As shown, the view panel **111** includes an outer perimeter **112** and an opening **118** formed in the outer perimeter **112**. In the implementation shown in FIG. **2**A, the view panel **111** includes a windshield that includes a piece of laminated glass. The present disclosure contemplates that other materials (such as polycarbonate and/or tempered glass) can be used for the view panel **111**.

[0023] FIG. **2**B is a schematic partial perspective back view of the lens assembly **110** shown in FIG. **1**, according to one or more embodiments.

[0024] FIG. **3** is a schematic cross-sectional side view of the lens assembly **110** along Section **3-3** shown in FIG. **1**, according to one or more embodiments.

[0025] The laser source **141** and the sensor **142** are part of a laser module **140**. The lens **120** is positioned at least partially in the opening **118**. In one or more embodiments, the lens **120** is an infrared lens. The lens **120** includes a recessed face **129** that is recessed relative to a first outer surface **113** of the view panel **111**. The lens assembly **110** includes a support structure **150** attaching the lens **120** to a second outer surface **114** of the view panel **111**. In one or more embodiments, the second outer surface **114** faces an interior of the vehicle **100** and the first outer surface **113** faces an exterior of the vehicle **100** when the lens assembly **110** is mounted to the vehicle **100**.

[0026] The lens **120** includes a first section **121** and a second section **122** spaced from the first section **121** across the recessed face **129**. The lens **120** includes one or more angled sections **123**, **124** extending between the first section **121** and the second section **122**. The one or more angled sections **123**, **124** at least partially define the recessed face **129**. In one or more embodiments, the one or more angled sections **123**, **124** includes a plurality of angled sections. The one or more angled sections **123**, **124** (two are shown in FIG. **3**) include a first angled section **123** oriented at a first angle A**1** relative to the first section **121**, and a second angled section **124** oriented at a second angle A**2** relative to the second section **122**. The second angle A**2** is greater than the first angle A**1**. The first angle A**1** and the second angle A**2** are obtuse. The second angled section **124** is oriented at a third angle A**3** relative to the first angled section **123**. The third angle A**3** is less than the first angle A**1**, and the third angle A**3** is less than the second angle A**2**. In one or more embodiments, the first angle A**1** is 225 degrees or less. In one or more embodiments, the second angle A**2** is within a range of 215 degrees to 250 degrees. In one or more embodiments, the third angle A**3** is 90 degrees or greater. The present disclosure contemplates that one or more arcuate sections can be used in place of the one or more angled sections **123**, **124**. The present disclosure contemplates other values for the first angle A**1**, the second angle A**2**, and the third angle A**3**.

[0027] A first edge **127** transitions the first section **121** to the first angled section **123**, a second edge **128** transitions the first angled section **123** to the second angled section **124**, and a third edge **131** transitions the second angled section **124** to the second section **122**. The edges **127**, **128**, **131** can be sharp edges, tapered edges, and/or arcuate edges.

[0028] The support structure **150** includes a first bracket section **151** attached to the first section **121** of the lens **120** and the second outer surface **114** of the view panel **111**, and a second bracket section **152** attached to the second section **122** of the lens **120**. The first bracket section **151** and the second bracket section **152** can be integrally formed together or can include two pieces coupled together. The lens assembly **110** includes a laser module **140** received at least partially in the support structure **150**. The laser module **140** includes the laser source **141** oriented to emit light through at least one of the one or more angled sections **123**, **124**, and the sensor **142** oriented to sense reflected light through at least one of the one or more angled sections **123**, **124**. In one or more embodiments, the laser source **141** is oriented to emit light through the second angled section **124**, and the sensor **142** is oriented to sense reflected light through the second angled section **124**. In one or more embodiments, the light is infrared radiation (IR) having a wavelength in the IR range. In one or more embodiments, the light is collimated into laser beams. In one or more embodiments, the sensor **142** is part of a camera configured to capture images and sense reflected light in the images. The laser module **140** is configured to emit light and receive reflected light along a field of view FOV1. The present disclosure contemplates that the components of the lens assembly **110** can be attached to each other using bonding, such as bonding using adhesive between interfacing surfaces of components.

[0029] At least part of the lens **120** (such as at least the second angled section **124**) has a higher transmissivity for IR light than the view panel **111**. In various embodiments, at least part of the lens **120** (such as at least the second angled section **124**) includes quartz and/or borosilicate glass.

[0030] In some embodiments, at least part of the lens **120** (such as at least the second angled section **124**) has a higher quartz and/or borosilicate glass content than the view panel **111**. In one or more embodiments, one or more of the first angled section **123** or the second angled section **124** is formed of a composition that includes a silicon dioxide (SiO_2) atomic percentage of at least 75%. In one or more embodiments, the SiO_2 atomic percentage is at least 99%, such as 99.99% (4 N) or higher, for example 99.999% (5 N) or higher. In one or more embodiments, one or more of the first angled section **123** or the second angled section **124** is formed of a composition that includes a borosilicate atomic percentage of at least 75%. In one or more embodiments, the borosilicate atomic percentage is at least 99%, such as 99.99% (4 N) or higher, for example 99.999% (5 N) or higher.

[0031] A cover panel **160** is attached to the second outer surface **114** and at least partially covers the support structure **150** and the lens **120** on backsides thereof. A rearview device **165** is attached to the cover panel **160**. The rearview device **165** can include, for example, a mirror and/or a display. A pad **149** (such as an elastomer or foam pad) is disposed

along the second outer surface **114** of the view panel **111** and a backside of the second bracket section **152**. The second bracket section **152** is attached to a metal panel **148** of the vehicle body **108** using an attachment panel **147**. The lens assembly **110** can abut against a second metal panel **146** of vehicle body **108** using the pad **149**.

[0032] In one or more embodiments, and as described above, the view panel **111** includes a piece of laminated glass that includes a ceramic layer **115** positioned between two glass layers **116**, **117**. As shown in FIG. **2**A, the ceramic layer **115** is arranged along the outer perimeter **112** and inwardly of the opening **118**. In one or more embodiments the ceramic layer **115** includes polyvinyl butyral (PVB). A first glass layer **116** includes the first outer surface **113** and a second glass layer **117** includes the second outer surface **114**. The lens **120** is shown as positioned at least partially in the opening **118** of the view panel **111**. The view panel **111** is shown as a windshield. However, the present disclosure contemplates that the lens **120** and the laser module **140** can be used in relation to other view panel structures (such a rear window or a side window of the vehicle **100**). As an example, the view panel **111** (shown as a windshield) can be replaced with a window having the opening **118**, and the lens **120** can be positioned at least partially in the opening **118** formed in the window. In one or more embodiments, the window includes tempered glass.

[0033] FIG. **4** is a schematic enlarged perspective view of the lens assembly **110** shown in FIG. **2**A, according to one or more embodiments. The vehicle body **108** is not shown in FIG. **4**.

[0034] The lens **120** includes a first side section **125** and a second side section **126** spaced from the first side section **125** across the recessed face **129**. The first section **121**, the second section **122**, the first side section **125**, and the second side section **126** surround the recessed face **129**.

[0035] FIG. **5** is a schematic perspective front view of the lens **120** shown in FIGS. **1**-**4**, according to one or more embodiments. The view in FIG. **5** is from above the lens **120**.

[0036] FIG. **6** is a schematic perspective back view of the lens **120** shown in FIG. **5**, according to one or more embodiments. The view in FIG. **6** is from below the lens **120**. As shown in FIG. **6**, the first angled section **123** and the second angled section **124** protrude relative to the first section **121**, the second section **122**, the first side section **125**, and the second side section **126**.

[0037] FIG. **7** is a schematic cross-sectional side view of a lens assembly **710**, according to one or more embodiments. The lens assembly **710** is similar to the lens assembly **110** shown in FIG. **3** and includes one or more aspects, features, components, operations, and/or properties thereof.

[0038] The lens assembly includes a lens **720**. The lens **720** is similar to the lens **120** and includes one or more aspects, features, components, operations, and/or properties thereof. The lens includes a middle section **731** extending between the first section **121** and the second section **122**. The lens **720** includes a face **729**. In one or more embodiments, the face **729** is coplanar with the first outer surface **113** of the view panel **111**. The middle section **731** is oriented at a first angle AA**1** relative to the first section **121** and a second angle AA**2** relative to the second section **122**. In one or more embodiments, the first angle AA**1** and the second angle AA**2** are within a range of 175 degrees to 185 degrees, such as about 180 degrees. In one or more embodiments, the middle section **731** is oriented at the same angle as the view panel **111**.

[0039] The middle section **731** has a first thickness T**1** that is less than a second thickness T**2** of the first section **121** and a third thickness T**3** of the second section **122**. In one or more embodiments, the first thickness T**1** of the middle section **731** is half or less (such as one-third or less) of the respective second thickness T**2** and third thickness T**3**. The thickness T**1** facilitates reduced refractivity of the middle section **731**. The second thickness T**2** and the third thickness T**3** can be equal to or different from each other. In one or more embodiments, the first thickness T**1** is less than 2.0 mm, such as within a range of 0.5 mm to 1.5 mm. In one or more embodiments, the second thickness T**2** is 2.0 mm or higher, such as within a range of **2**.0 mm to 3.5 mm. In one or more embodiments, the third thickness T**3** is 2.0 mm or higher, such as within a range of 2.0 mm to 3.5 mm. Other values are contemplated for the thicknesses T**1**, T**2**, T**3**.

[0040] In one or more embodiments, the face **729** and the first outer surface **113** are arcuate and have the same radius of curvature.

[0041] FIG. **8** is a schematic cross-sectional side view of a lens assembly **810**, according to one or more embodiments. The lens assembly **810** is similar to the lens assembly **110** shown in FIG. **3** and includes one or more aspects, features, components, operations, and/or properties thereof.

[0042] In the lens assembly **810** shown in FIG. **8**, an opening **811** (e.g., a through-hole) is formed in the second angled section **124** of the lens **120**, and the laser module **140** is positioned at least partially in the opening **811**. In one or more embodiments, the laser module **140** extends through the opening **811** such that a front face **812** of the laser module **140** extends past the opening **811**. The front face **812** can be part, for example, of a lens (such as a LiDAR lens) of the laser module **140**. One or more seals **813** (such as watertight seal(s)) are positioned between the lens **120** and the first and second bracket sections **151**, **152** of the support structure **150**.

[0043] In various embodiments, benefits of the present disclosure include easily and quickly mounting the lens assembly **110** to the vehicle body **108** for laser imaging operations; enhancing aesthetic appeal of vehicles; reliable light transmission paths; reliable and accurate operation and calibration of laser imaging devices; and ease of calibration of laser imaging devices. Benefits also include ease of coupling electrical power and/or data connections to the laser imaging devices. For example, electrical wiring need not be passed through to an exterior of the vehicle to connect to the laser module **140** during or after the mounting of the lens assembly **110** to the vehicle body **108**.

[0044] It is contemplated that one or more aspects disclosed herein may be combined. As an example, one or more aspects, features, components, operations and/or properties of the vehicle **100**, the lens assembly **110**, the lens **120**, the view panel **111**, the lens assembly **710**, the lens **720**, the lens assembly **810**, and/or the opening **811** may be combined. Moreover, it is contemplated that one or more aspects disclosed herein may include some or all of the aforementioned benefits.

[0045] While the foregoing is directed to embodiments of the present disclosure, other and further embodiments of the

disclosure may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.

What is claimed is:

1. A lens assembly comprising:

a view panel comprising an outer perimeter, an opening formed in the outer perimeter, a first outer surface, and a second outer surface;

a lens positioned at least partially in the opening; and

a support structure attaching the lens to the second outer surface of the view panel.

2. The lens assembly of claim **1**, wherein the lens comprises:

a first section;

a second section; and

one or more angled sections extending between the first section and the second section, the one or more angled sections at least partially defining a recessed face that is recessed relative to the first outer surface of the view panel, wherein the second section is spaced from the first section across the recessed face.

3. The lens assembly of claim **2**, wherein the one or more angled sections comprise:

a first angled section oriented at a first angle relative to the first section; and

a second angled section oriented at a second angle relative to the second section, wherein the second angle is larger than the first angle.

4. The lens assembly of claim **3**, wherein the first angle and the second angle are obtuse.

5. The lens assembly of claim **4**, wherein:

the second angled section is oriented at a third angle relative to the first angled section, the third angle is less than the first angle, and the third angle is less than the second angle; and

the first angle is 225 degrees or less, and the second angle is within a range of 215 degrees to 250 degrees.

6. The lens assembly of claim **2**, further comprising:

a laser module received at least partially in the support structure, wherein the laser module includes a laser source oriented to emit light through at least one of the one or more angled sections.

7. The lens assembly of claim **6**, wherein the at least one of the one or more angled sections comprises an opening, and the laser module is positioned at least partially in the opening.

8. The lens assembly of claim **1**, wherein the lens comprises:

a first section;

a second section; and

a middle section extending between the first section and the second section, the middle section having a first thickness that is less than a second thickness of the first section and a third thickness of the second section.

9. A vehicle, comprising:

a vehicle body;

a view panel mounted to the vehicle body, the view panel comprising an outer perimeter and an opening formed in the outer perimeter; and

a lens positioned at least partially in the opening.

10. The vehicle of claim **9**, wherein the view panel further comprises a ceramic layer positioned between two glass layers, wherein the ceramic layer is arranged along the outer perimeter and inwardly of the opening.

11. The vehicle of claim **9**, wherein the lens comprises:

a first section;

a second section; and

one or more angled sections extending between the first section and the second section, the one or more angled sections at least partially defining a recessed face that is recessed relative to a first outer surface of the view panel, wherein the second section is spaced from the first section across the recessed face.

12. The vehicle of claim **11**, wherein the one or more angled sections comprise:

a first angled section oriented at a first angle relative to the first section; and

a second angled section oriented at a second angle relative to the second section, wherein the second angle is larger than the first angle.

13. The vehicle of claim **12**, wherein the first angle and the second angle are obtuse.

14. The vehicle of claim **11**, further comprising a support structure attaching the lens to a second outer surface of the view panel, wherein the support structure is attached to the first section of the lens, the second section of the lens, and the second outer surface of the view panel.

15. The vehicle of claim **14**, further comprising:

a laser module received at least partially in the support structure, wherein the laser module includes a laser source oriented to emit light through at least one of the one or more angled sections.

16. The vehicle of claim **15**, wherein the at least one of the one or more angled sections comprises an opening, and the laser module is positioned at least partially in the opening.

17. The vehicle of claim **9**, wherein the lens comprises:

a first section;

a second section; and

a middle section extending between the first section and the second section, the middle section having a first thickness that is less than a second thickness of the first section and a third thickness of the second section.

18. An infrared lens, comprising:

a first section;

a second section spaced from the first section; and

a plurality of angled sections extending between the first section and the second section, the plurality of angled sections at least partially defining a recessed face, and the plurality of angled sections comprising:

a first angled section oriented at a first angle relative to the first section, and

a second angled section oriented at a second angle relative to the second section,

wherein the second angle is larger than the first angle.

19. The infrared lens of claim **18**, wherein the first angle and the second angle are obtuse, and one or more of the first angled section or the second angled section is formed of a composition that includes a silicon dioxide (SiO_2) atomic percentage of at least 75%.

20. The infrared lens of claim **19**, wherein the second angled section is oriented at a third angle relative to the first angled section, the third angle is less than the first angle, and the third angle is less than the second angle.

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