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(54) **LASER PROJECTOR**

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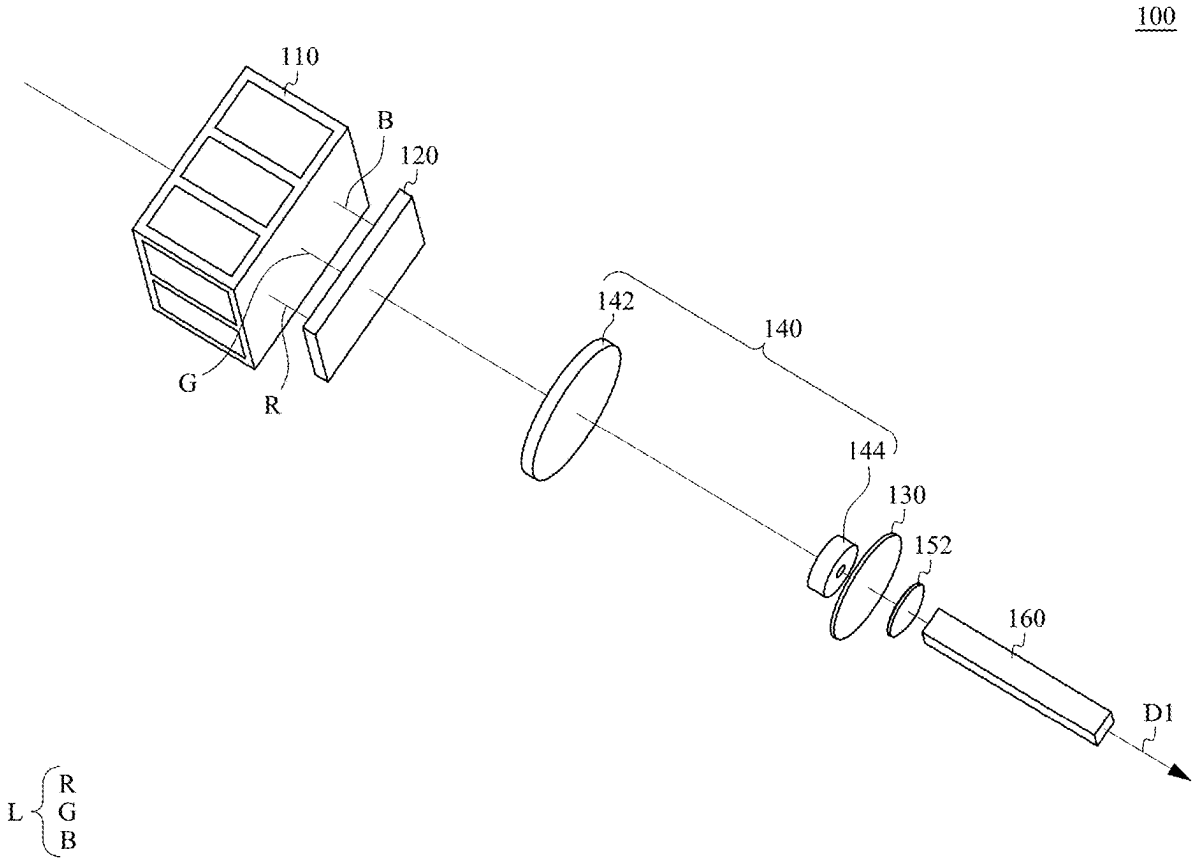
(57) **ABSTRACT**

A laser projector includes a laser light source configured to emit a laser light, a homogenizer configured to receive the laser light, a first diffusion element located between the laser light and the homogenizer, and a second diffusion element located between the laser light source and the homogenizer. The first diffusion element and the second diffusion element are different type.



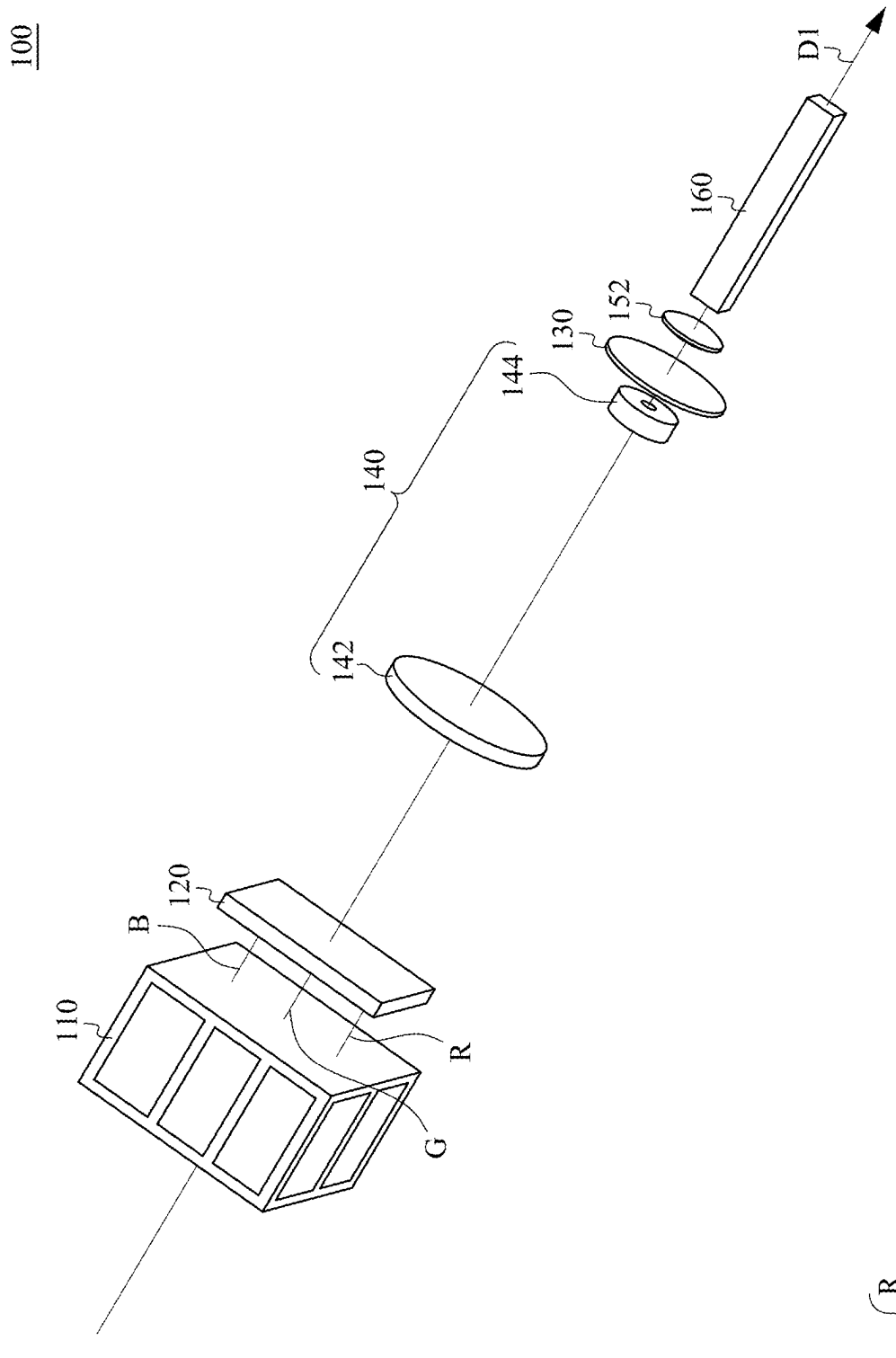


Fig. 1

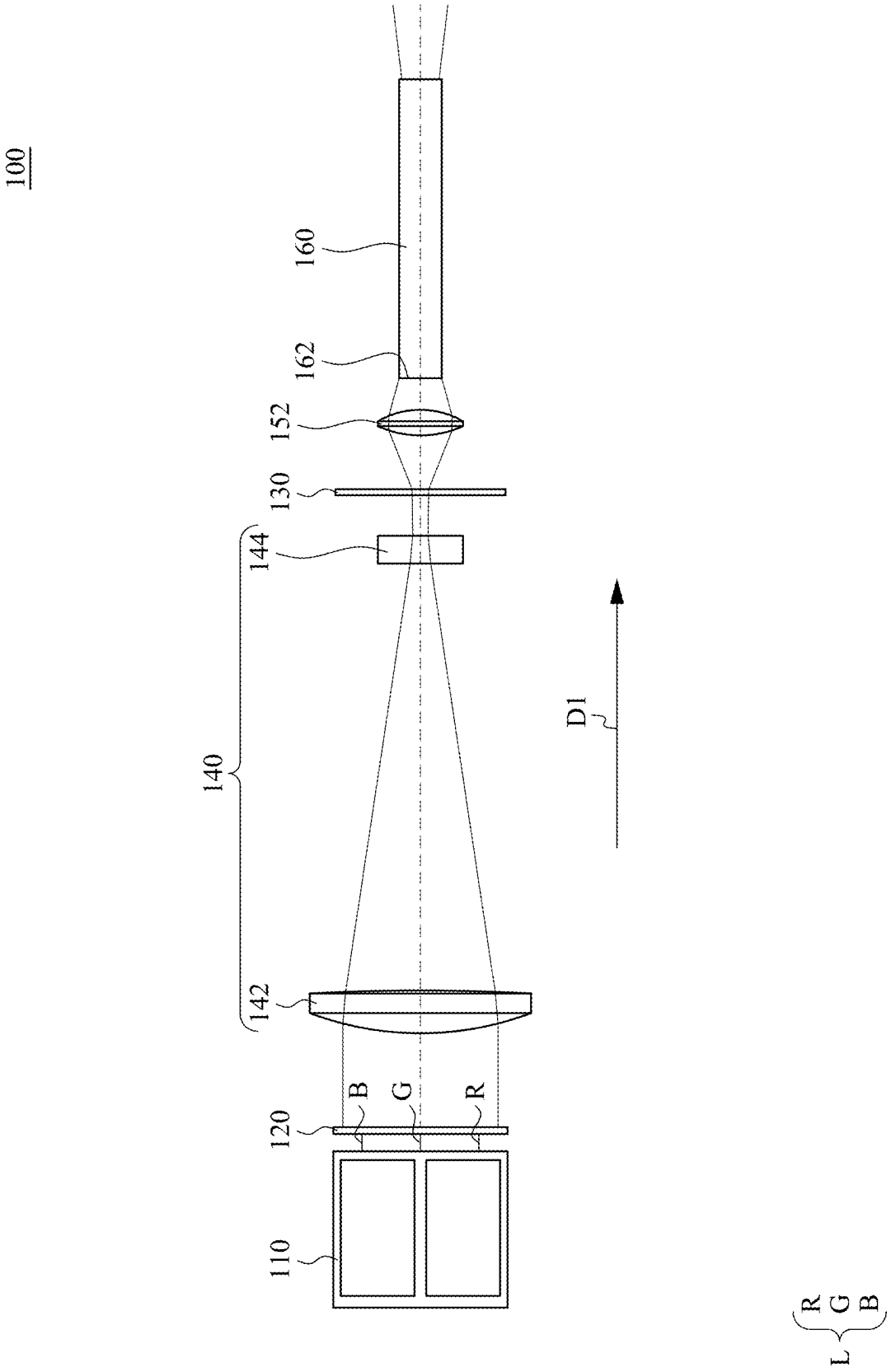


Fig. 2

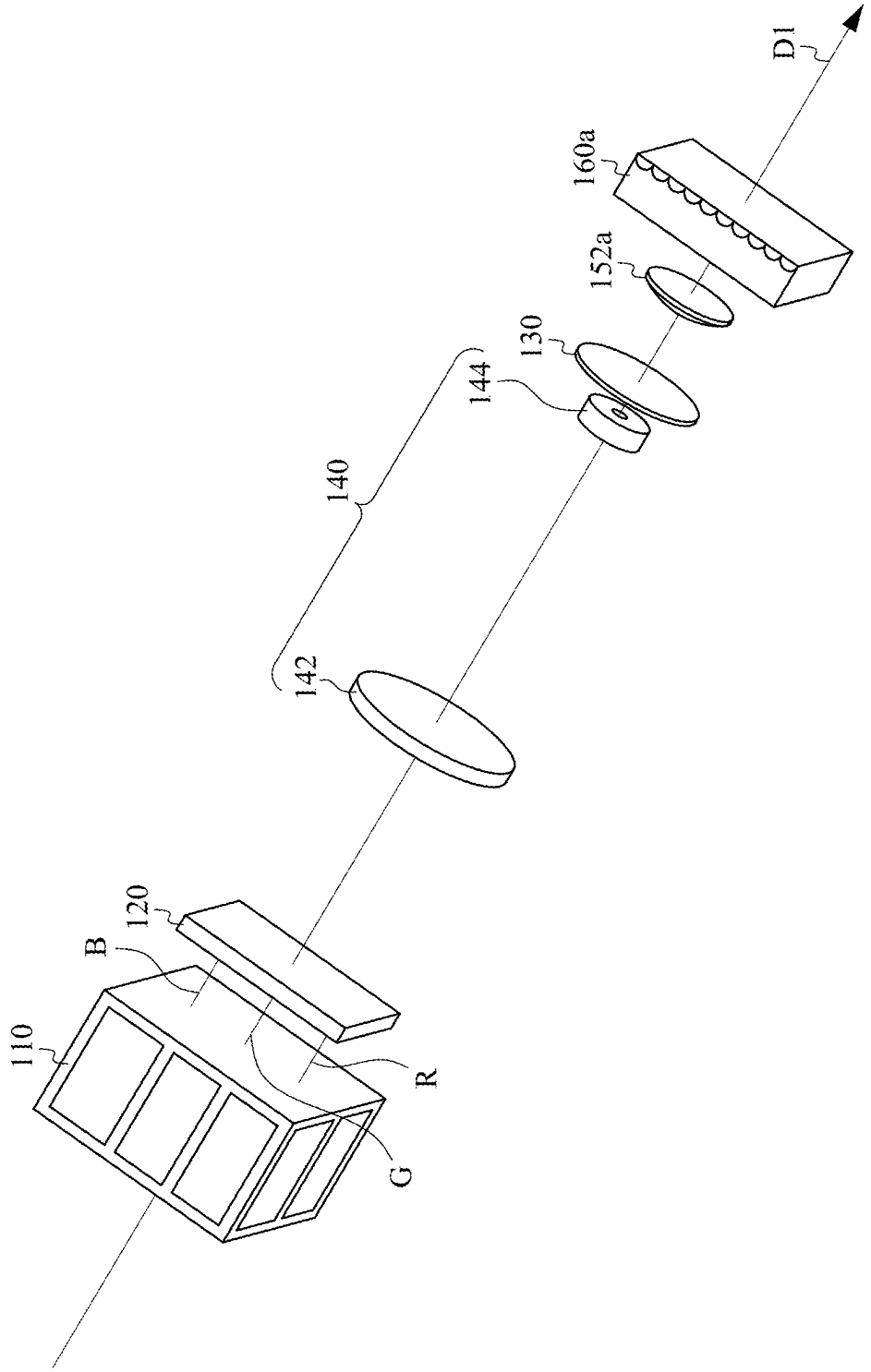


Fig. 3

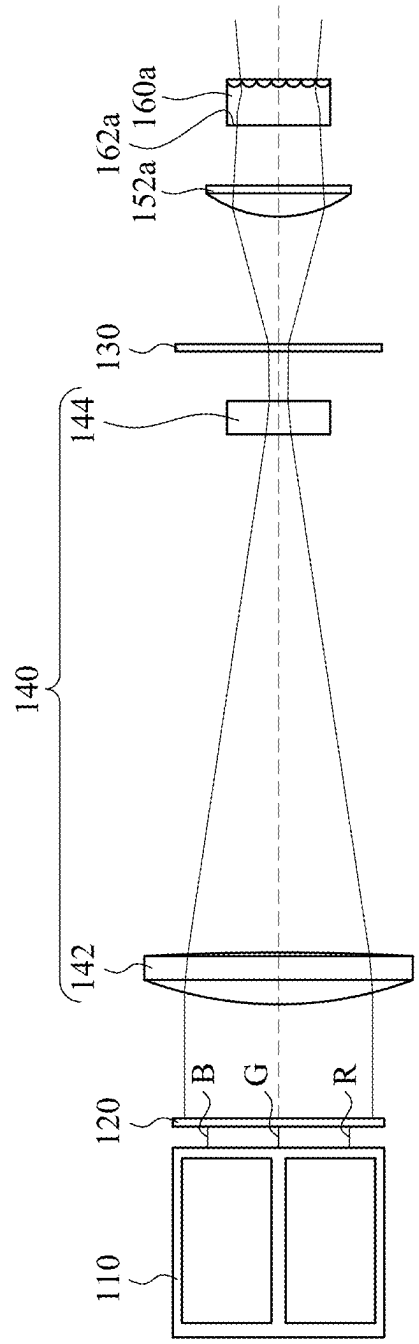


Fig. 4

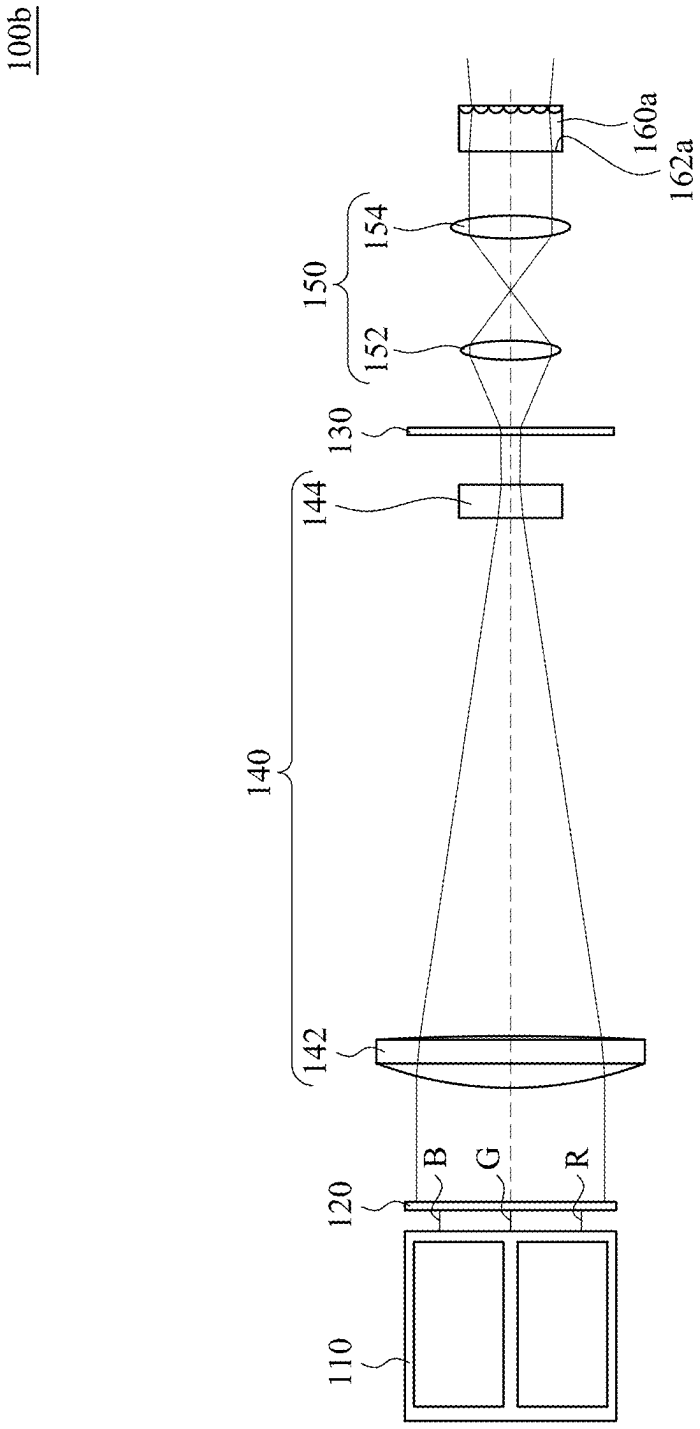


Fig. 5

LASER PROJECTOR

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims priority to China Application Serial Number 202410191035.1, filed Feb. 21, 2024, which is herein incorporated by reference in its entirety.

BACKGROUND

Field of Invention

[0002] The present invention relates to a laser projector.

Description of Related Art

[0003] Projectors which use pure lasers as light source have speckles on the display screen due to high coherence of the laser light. The ways to eliminate speckles involve the use of incoherent light, diffusion element, optical fiber, or shaking the screen. However, those methods above increase the Étendue of the projection system and cause a trade-off between the contrast and efficiency of the projection system. Without losing contrast or efficiency, the effect of speckle elimination is limited. Therefore, it is difficult to eliminate speckles while simultaneously maintaining high contrast and efficiency.

[0004] Accordingly, it is still a development direction for the industry to provide a laser projector that can solve the problems above.

SUMMARY

[0005] One aspect of the present disclosure is a laser projector.

[0006] In one embodiment, the laser projector includes a laser light source configured to emit a laser light, a homogenizer configured to receive the laser light, a first diffusion element located between the laser light and the homogenizer, and a second diffusion element located between the laser light source and the homogenizer. The first diffusion element and the second diffusion element are different type.

[0007] In one embodiment, the first diffusion element is a static diffusion system configured to shape the laser light.

[0008] In one embodiment, the second diffusion element is a dynamic diffusion element configured to eliminate speckles.

[0009] In one embodiment, the laser projector further includes a condenser lens located between the first diffusion element and the second diffusion element and configured to converge the laser light.

[0010] In one embodiment, the laser projector further includes a shrinking element located between the condenser lens and the second diffusion element. The shrinking element is configured to make the converging laser light become a parallel light and reduce a cross-sectional area of the laser light.

[0011] In one embodiment, the laser projector further includes a first light transmitting element located between the second diffusion element and the homogenizer. The first light transmitting element is configured to maintain an Étendue of the laser light and make the laser light adapted to the homogenizer.

[0012] In one embodiment, the homogenizer is a light tunnel.

[0013] In one embodiment, the homogenizer is a lens array.

[0014] In one embodiment, the laser projector further includes a second transmitting element located between the first transmitting element and the homogenizer. The second transmitting element is configured to maintain the Étendue of the laser light and allocate the laser light to the lens array.

[0015] Another aspect of the present disclosure is a laser projector.

[0016] In one embodiment, the laser projector includes a laser light source configured to emit a laser light, a homogenizer configured to receive the laser light, a light shrinking lens group, and a diffusion element located between the light shrinking lens group and the homogenizer. The light shrinking lens group includes a shrinking element configured to make the laser light become a parallel light, a condenser lens configured to converge the laser light. The condenser lens is located between the laser light source and the shrinking element.

[0017] In one embodiment, the diffusion element includes a dynamic diffusion element configured to eliminate speckles.

[0018] In one embodiment, the laser projector includes a static diffusion system located between the laser light source and the light shrinking lens group.

[0019] In one embodiment, the laser projector further includes a light transmitting lens group located between the diffusion element and the homogenizer. The light transmitting lens group is configured to maintain an Étendue of the laser light.

[0020] In one embodiment, the light transmitting lens group includes a first light transmitting element configured to make the laser light converge and a second light transmitting element located between the first light transmitting element and the homogenizer. The second light transmitting element is configured to allocate the laser light to the homogenizer.

[0021] In one embodiment, the homogenizer is a lens array.

[0022] In one embodiment, the homogenizer is a light tunnel.

[0023] In the aforementioned embodiment, the laser projector of the present disclosure can eliminate speckles and adapt the laser lights to the homogenizer through the first diffusion element and the second diffusion element. The speckle elimination effect provided by the second diffusion element can be unlimited by using the shrinking lens group. The laser lights are adapted to the homogenizer through the light transmitting lens group. Therefore, the laser projector disclosed in the present disclosure can simultaneously have high efficiency, high contrast and good speckle noise reduction effect.

BRIEF DESCRIPTION OF THE DRAWINGS

[0024] The invention can be more fully understood by reading the following detailed description of the embodiment, with reference made to the accompanying drawings as follows:

[0025] FIG. **1** is a schematic of a laser projector according to one embodiment of the present disclosure.

[0026] FIG. **2** is a schematic of a light path of the laser projector in FIG. **1**.

[0027] FIG. **3** is a schematic of a laser projector according to another embodiment of the present disclosure.

[0028] FIG. **4** is a schematic of a light path of the laser projector in FIG. **3**.

[0029] FIG. **5** is a schematic of a laser projector according to another embodiment of the present disclosure.

DETAILED DESCRIPTION

[0030] Reference will now be made in detail to the present embodiments of the invention, examples of which are illustrated in the accompanying drawings. Wherever possible, the same reference numbers are used in the drawings and the description to refer to the same or like parts.

[0031] FIG. **1** is a schematic of a laser projector **100** according to one embodiment of the present disclosure. FIG. **2** is a schematic of a light path of the laser projector **100** in FIG. **1**. The laser projector **100** includes a laser light source **110**, a first diffusion element **120**, and a second diffusion element **130**, and a shrinking lens group **140**, a first light transmitting element **152**, and a homogenizer **160** sequentially arranged along an optical axis direction D**1**. The laser light source **110** is configured to emit multiple laser lights L such as a red light R, a blue light B, and a green light G. The first diffusion element **120** is located between the laser light source **110** and the homogenizer **160**. The second diffusion element **130** is located between the homogenizer **160** and the first diffusion element **120**. The homogenizer **160** has a light incident surface **162** configured to receive the laser lights L passing the first diffusion element **120** and the second diffusion element **130**.

[0032] Since the laser lights L are high collimated beams, the red light R, the blue light B and the green light G emitted by the laser light source **110** are somewhat separated among each other and cannot fill the light incident surface **162** of the homogenizer **160**. The high coherence of laser lights L causes speckles to appear on the projection screen.

[0033] Étendue is defined as the integral of a cross-sectional area of the laser lights L and the beam solid angle: Étendue=$\pi S\ NA^2$, where S is the beam cross-sectional area and πNA^2 is the beam solid angle. In an ideal optical system that does not consider energy losses (such as scattering, absorption, etc.), the Étendue should be conserved.

[0034] The first diffusion element **120** is a static diffusion system that is configured to shape the laser lights L to fit the profile of the light incident surface **162** of the homogenizer **160**. After the laser lights L passes through the second diffusion element **130**, the red light R, the blue light B, and the green light G are diffused and adapted to the light incident surface **162** of the homogenizer **160**. In other words, the cross-sectional area of the diffused laser lights L can match the light incident surface **162**.

[0035] The second diffusion element **130** is a dynamic diffusion element configured to eliminate speckles. The dynamic diffusion element includes a diffuser and an actuator. The actuator can move or shake the diffuser in a direction perpendicular to the optical axis direction. The dynamic diffusion element may include coating or rough surface that used to disrupt the phase of the laser lights L.

[0036] The first diffusion element **120** and the second diffusion element **130** are used to eliminate speckles, but increase the Étendue of the laser projector **100**. Under this situation, a larger aperture is required in such optical system of which the Étendue is increased to maintain the efficiency of the laser projector **100**. As a result, the contrast of the laser projector **100** will be reduced.

[0037] For example, when the second diffusion element **130** is placed in an optical system, the laser lights L increase their scattering angle (the solid angle increases) after passing through the second diffusion element **130**. The light receiving element behind the second diffusion element **130** placed in the optical system (along the optical axis direction D**1** in FIG. **1**) cannot completely receive the laser lights L, which decreases the efficiency. Therefore, it is difficult to eliminate speckles yet have high efficiency and high contrast at the same time.

[0038] Generally speaking, if the cross-sectional area of the laser lights L entering the second diffusion element **130** is greater, the homogenizer **160** is more unlikely to fully receive and transmit the laser lights L that pass through the second diffusion element **130** to the rear imaging element (such as digital micro-reflective chip, DMD). Therefore, the scattering angle provided by the second diffusion element **130** is limited, and the speckle reduction effect is not satisfactory. Alternatively, without limiting the scattering angle of the second diffusion element **130**, an imaging element with a large aperture is required to completely receive the diffused laser lights L. As a result, the contrast of the laser projector **100** will be reduced.

[0039] The shrinking lens group **140** includes a condenser lens **142** and a shrinking element **144**. The condenser lens **142** is located between the first diffusion element **120** and the second diffusion element **130** and is configured to converge the laser lights L. The shrinking element **144** is located between the condenser lens **142** and the second diffusion element **130** and is configured to make the laser lights L become a parallel light and reduce a cross-sectional area of the laser lights L. In such arrangement, the scattering angle of the shrunk parallel light passing through the second diffusion element **130** is smaller than the scattering angle of a converged oblique light (for example, being a focus spot on the second diffusion element **130**) after incident on the second diffusion element **130**.

[0040] The configuration of the aforementioned first diffusion element **120** (static diffusion system), the shrinking lens group **140**, and the second diffusion element **130** (dynamic diffusion element) is beneficial to provide better speckle reduction effect. Specifically, the cross-sectional area of the laser lights L entering the second diffusion element **130** can be small through the first diffusion element **120** and the shrinking lens group **140**, and therefore the second diffusion element **130** with large scattering angle can be used to provide better speckle elimination effect. In other words, the scattering angle of the second diffusion element **130** is not limited, and there is no need to use a large aperture, which will not reduce the contrast of the laser projector.

[0041] The laser projector **100** includes a first light transmitting element **152** located between the second diffusion element **130** and the homogenizer **160**. The first light transmitting element **152** is configured to maintain the Étendue of the laser lights L. For example, the homogenizer **160** of the present disclosure is a light tunnel. The first diffusion element **120** is configured to shape the laser lights L to fit the rectangular shaped entry of the light tunnel. The scattering angle of the laser lights L increases after the laser lights L pass through the second diffusion element **130**, and the first light transmitting element **152** can fully receive the laser lights L passing through the second diffusion element **130**. Then the first light transmitting element **152** may make

the laser lights L converge and adapt the laser lights L to the homogenizer **160**. The first light transmitting element **152** can adjust the scattering angle and the cross-section area of the laser lights L such that the homogenizer **160** can fully receive the laser light L. Therefore, the laser projector **100** of the present disclosure has high efficiency, high contrast and good speckle elimination and noise reduction effect.

[0042] FIG. **3** is a schematic of a laser projector **100***a* according to another embodiment of the present disclosure. FIG. **4** is a schematic of a light path of the laser projector **100***a* in FIG. **3**. The laser projector **100***a* is similar to the laser projector **100** in FIG. **1**, and the difference is that the homogenizer **160***a* of the laser projector **100***a* is a lens array. The first light transmitting element **152***a* of the laser projector **100***a* is configured to maintain the Étendue of the laser lights L. The solid angle of the laser lights L after passing through the second diffusion element **130** increases, and the first light transmitting element **152***a* can completely receive the laser lights L passing through the second diffusion element **130**. The first light transmitting element **152***a* may make the laser lights L converge and adapt the laser lights L to the homogenizer **160***a*. The laser projector **100***a* and the laser projector **100** have the same advantages, which will not be described again.

[0043] FIG. **5** is a schematic of a laser projector **100***b* according to another embodiment of the present disclosure. The laser projector **100***b* is similar to the laser projector **100***a*, and the difference is that the laser projector **100***b* further includes a second light transmitting element **154**. The second light transmitting element **154** is located between the first light transmitting element **152***a* and the homogenizer **160***a*. The second light transmitting element **154** is configured to maintain the etendue of the laser lights L. The first light transmitting element **152** and the second light transmitting element **154** are configured as a light transmitting lens group **150**. In other embodiments, the light transmitting lens group **150** may have more than two elements.

[0044] In the present embodiment, the laser lights L are converged through the first light transmitting element **152***a*. The second light transmitting element **154** adjusts the laser lights L to be close to parallel lights, such that the laser lights L can enter the homogenizer **160***a* with a suitable cross-sectional area and solid angle for the light incident surface **162***a* of the homogenizer **160***a*. The second light transmitting element **154***d* is configured to allocate the parallel laser lights L to the lens array. The laser projector **100***b* and the laser projector **100***a* have the same advantages, which will not be described again.

[0045] In summary, the laser projector of the present disclosure can eliminate speckles and adapt the laser lights to the homogenizer through the first diffusion element and the second diffusion element. The speckle elimination effect provided by the second diffusion element can be unlimited by using the shrinking lens group. The laser lights are adapted to the homogenizer through the light transmitting lens group. Therefore, the laser projector disclosed in the present disclosure can simultaneously have high efficiency, high contrast and good speckle noise reduction effect.

[0046] Although the present invention has been described in considerable detail with reference to certain embodiments thereof, other embodiments are possible. Therefore, the spirit and scope of the appended claims should not be limited to the description of the embodiments contained herein.

[0047] It will be apparent to those skilled in the art that various modifications and variations can be made to the structure of the present invention without departing from the scope or spirit of the invention. In view of the foregoing, it is intended that the present invention cover modifications and variations of this invention provided they fall within the scope of the following claims.

What is claimed is:

1. A laser projector, comprising:
- a laser light source configured to emit a laser light;
- a homogenizer configured to receive the laser light;
- a first diffusion element located between the laser light and the homogenizer; and
- a second diffusion element located between the laser light source and the homogenizer, wherein the first diffusion element and the second diffusion element are different types.

2. The laser projector of claim **1**, wherein the first diffusion element is a static diffusion system configured to shape the laser light.

3. The laser projector of claim **1**, wherein the second diffusion element is a dynamic diffusion element configured to eliminate speckles.

4. The laser projector of claim **1**, further comprising:
- a condenser lens located between the first diffusion element and the second diffusion element and configured to converge the laser light.

5. The laser projector of claim **4**, further comprising:
- a shrinking element located between the condenser lens and the second diffusion element, wherein the shrinking element is configured to make the converging laser light become a parallel light and reduce a cross-sectional area of the laser light.

6. The laser projector of claim **1**, further comprising:
- a first light transmitting element located between the second diffusion element and the homogenizer, wherein the first light transmitting element is configured to maintain an etendue of the laser light and make the laser light adapted to the homogenizer.

7. The laser projector of claim **6**, wherein the homogenizer is a light tunnel.

8. The laser projector of claim **6**, wherein the homogenizer is a lens array.

9. The laser projector of claim **8**, further comprising:
- a second transmitting element located between the first transmitting element and the homogenizer, wherein the second transmitting element is configured to maintain the etendue of the laser light and allocate the laser light to the lens array.

10. A laser projector comprising:
- a laser light source configured to emit a laser light;
- a homogenizer configured to receive the laser light;
- a light shrinking lens group, comprising:
  - a shrinking element configured to make the laser light become a parallel light; and
  - a condenser lens configured to converge the laser light, wherein the condenser lens is located between the laser light source and the shrinking element; and
- a diffusion element located between the light shrinking lens group and the homogenizer.

11. The laser projector of claim **10**, wherein the diffusion element comprises a dynamic diffusion element configured to eliminate speckles.

12. The laser projector of claim **10**, further comprising a static diffusion system located between the laser light source and the light shrinking lens group.

13. The laser projector of claim **10**, further comprising:

a light transmitting lens group located between the diffusion element and the homogenizer, wherein the light transmitting lens group is configured to maintain an etendue of the laser light.

14. The laser projector of claim **13**, wherein the light transmitting lens group comprises:

a first light transmitting element configured to make the laser light converge; and

a second light transmitting element located between the first light transmitting element and the homogenizer, wherein the second light transmitting element is configured to allocate the laser light to the homogenizer.

15. The laser projector of claim **14**, wherein the homogenizer is a lens array.

16. The laser projector of claim **10**, wherein the homogenizer is a light tunnel.

* * * * *