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(12) **United States Patent**
Beeson et al.

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(45) **Date of Patent:** Nov. 1, 2005

(54) **ILLUMINATION SYSTEMS UTILIZING LIGHT EMITTING DIODES AND LIGHT RECYCLING TO ENHANCE OUTPUT RADIANCE**

(58) **Field of Search** 313/110, 112-113, 313/498-512; 362/247, 310, 240, 544-545, 555, 800, 347, 31, 217, 26

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Scott M. Zimmerman, Baskin Ridge, NJ (US)

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(*) **Notice:** Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 64 days.

* cited by examiner

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(21) **Appl. No.:** 10/814,043

(22) **Filed:** Mar. 30, 2004

(65) **Prior Publication Data**

US 2004/0232812 A1 Nov. 25, 2004

Related U.S. Application Data

(63) Continuation-in-part of application No. 10/445,136, filed on May 23, 2003, now Pat. No. 6,869,206.

(51) **Int. Cl.**⁷ F21V 7/00; H01L 33/00

(52) **U.S. Cl.** 313/113; 313/498; 362/247; 362/545

(57) **ABSTRACT**

An illumination system has a light source that is at least partially enclosed within a light-recycling envelope. The light source is a light-emitting diode that emits light, and a fraction of that light will exit the light-recycling envelope through an aperture. The light-recycling envelope recycles part of the light emitted by the light source back to the light source in order to enhance the output radiance of the light exiting the illumination system.

38 Claims, 16 Drawing Sheets

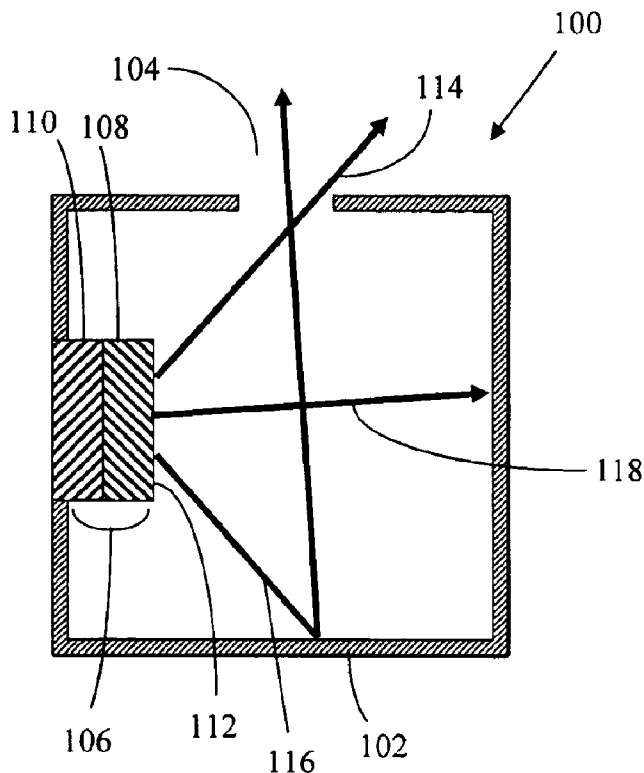


FIG. 1A
(Prior Art)

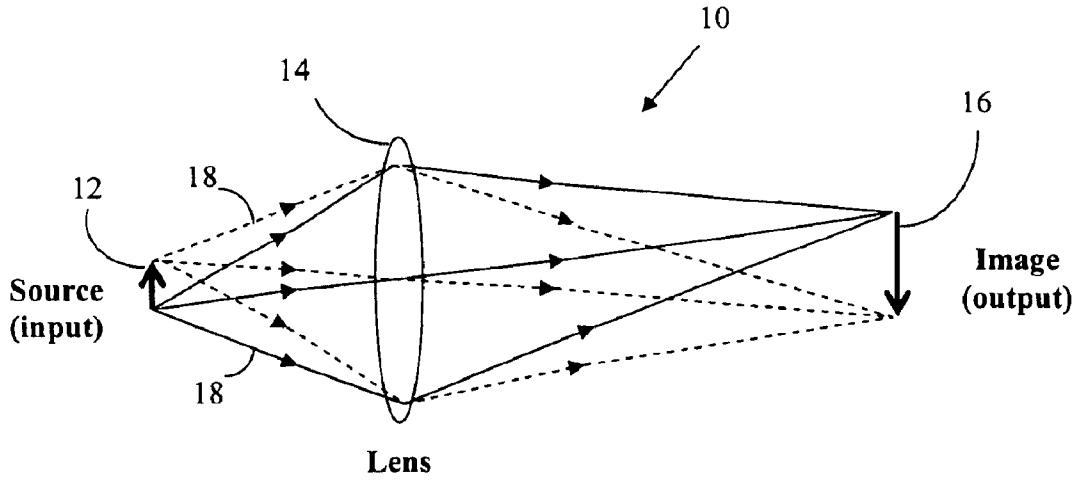


FIG. 1B
(Prior Art)

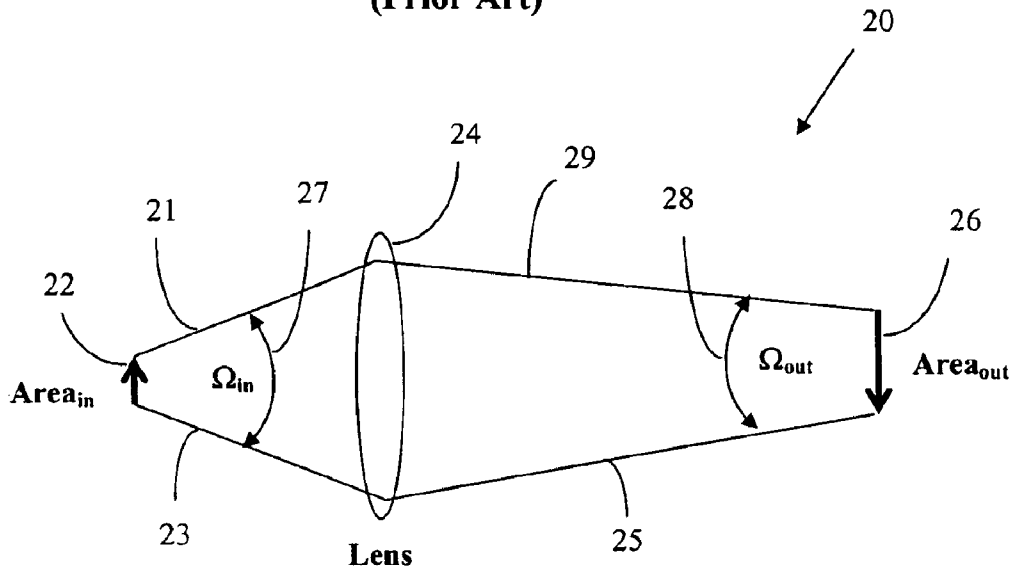


FIG. 2A
(Prior Art)

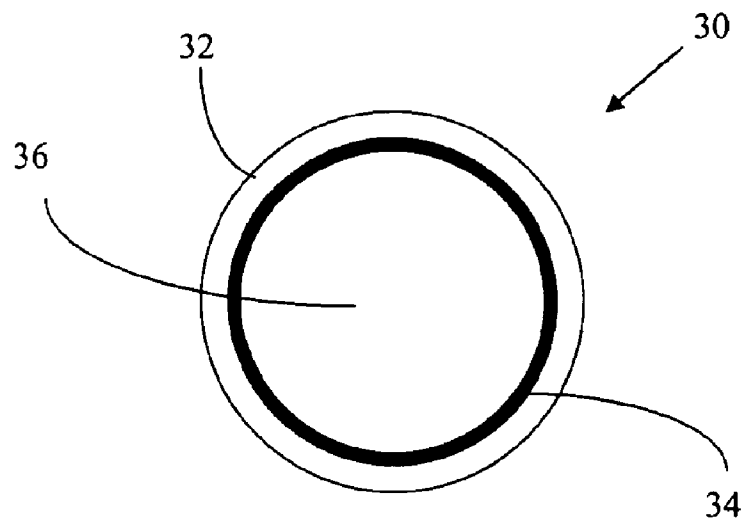


FIG. 2B
(Prior Art)

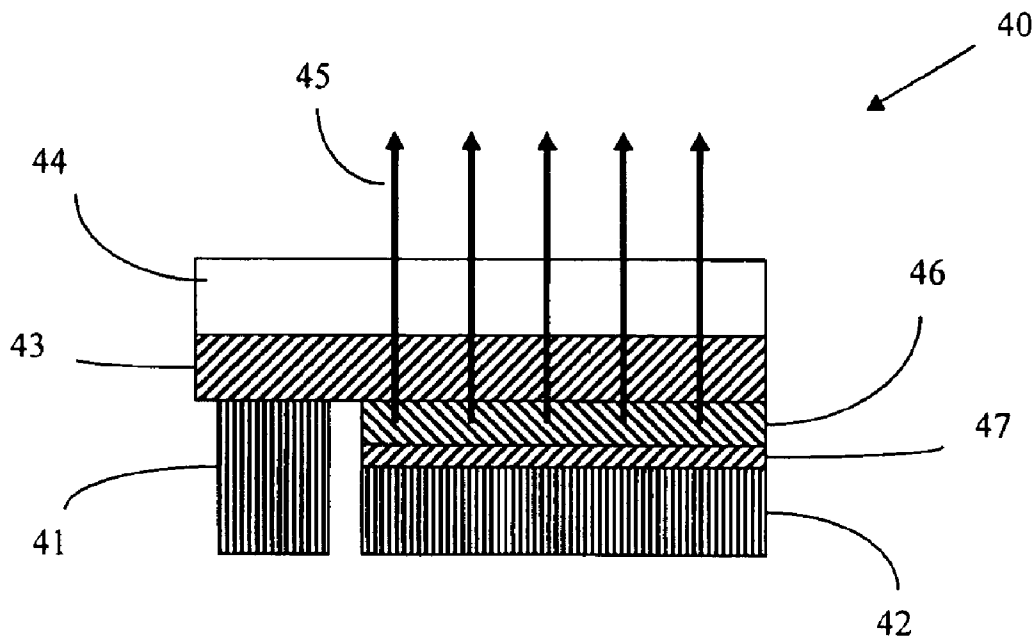


FIG. 3A

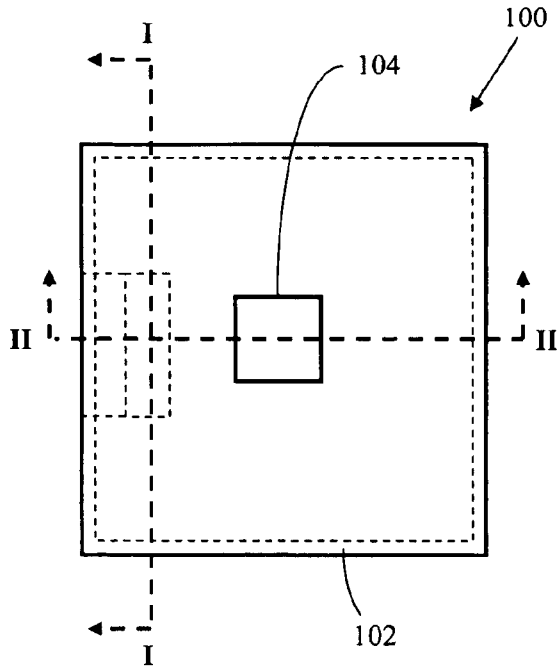


FIG. 3B

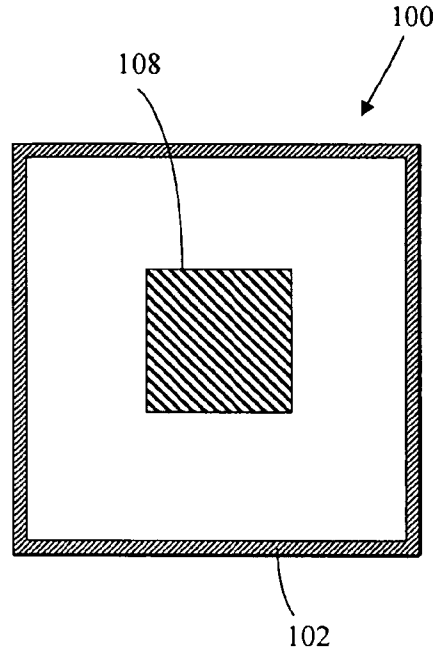


FIG. 3C

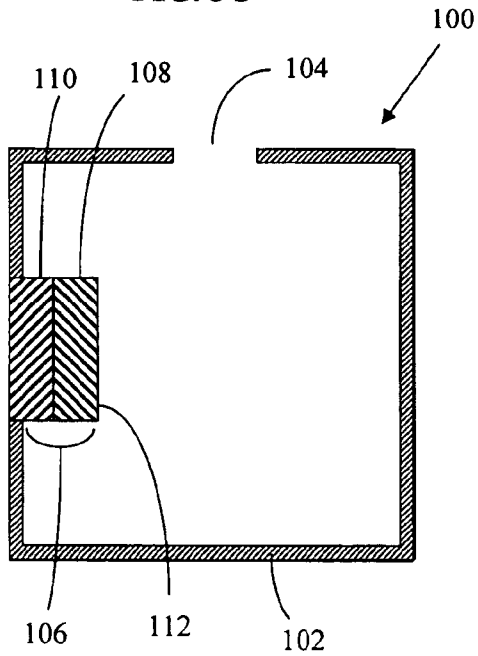


FIG. 3D

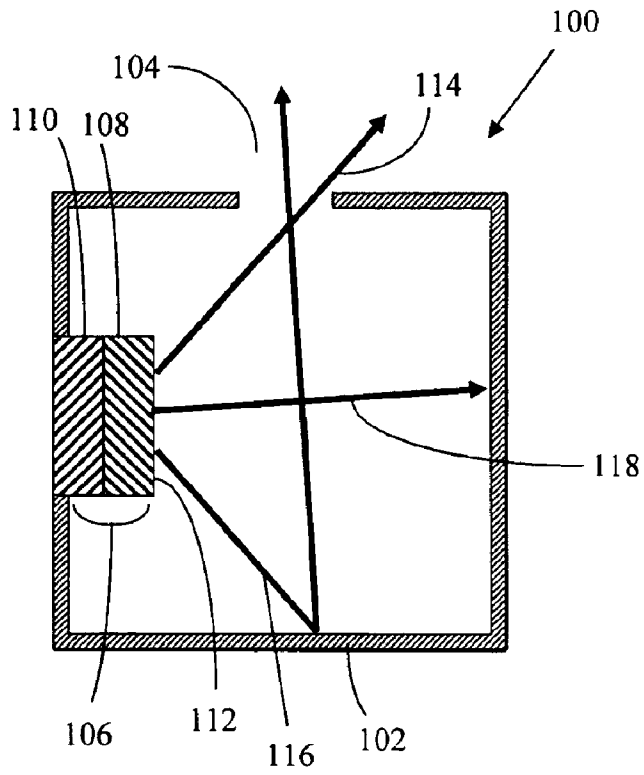
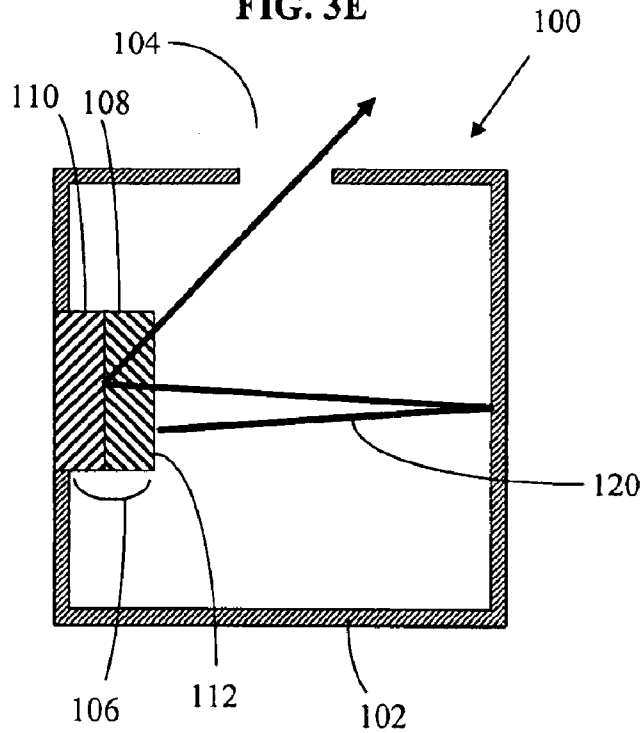


FIG. 3E



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