Uzbek Journal of Physics
Vol.21(№4) 2019 PP.245-249

FOCAL SPOT STRUCTURE OF FRESNEL LENS AND ITS HOMOGENIZATION

A. Sherniyozov and Sh. Payziyev

Institute of Ion-Plasma and Laser Technologies of AS RUz, Tashkent, 100125, Uzbekistan
anvarsher87@yahoo.com
(Received 27.02.2019)

Мақолада фотонлар траекториясини кузатиб боришнинг статистик Монте-Карло усулидан фойдаланиб, ясси Френел линзасининг фокал соҳадаги фотонлар тақсимоти ўрганилди. Дисперсия натижасида фокал соҳадаги фотонлар тақсимотининг жиддий ўзгариши кўрсатилди. Шунингдек, фокал соҳадаги фотонлар тақсимотини биржинисли қилиш яъни гомогенизациялаш имкониятини берувчи усул намойиш қилинди. Ушбу мақсадда тўғри тўрт бурчакли шаффоф призмадан фойдаланиш мумкин.

Используя статистический метод Монте-Карло для прослеживания фотонов, проведено численное исследование структуры фокального пятна плоской линзы Френеля. Показано, что из-за дисперсии в материале линзы структура фокального пятна значительно изменяется. Кроме того, продемонстрирована гомогенизация сильно сфокусированных фотонов. Прямоугольная призма может быть применена для достижения гомогенизации.

Using statistical Monte-Carlo photon-tracing method, we numerically studied focal spot structure of flat Fresnel lens. It has been shown that due to dispersion effect, focal spot structure changes considerably. In addition, we demonstrated homogenization of strongly focused photons. Rectangular prism can be applied to achieve the homogenization.

Introduction. Solar concentrators are one of extensively studied [1] fields in recent decades. As the search for optimal solar concentrators for particular application settings continues, Fresnel lens has one of preferences in solar pumped lasers. Compared to traditional concentrators such as parabolic mirror or convex lens, Fresnel lenses have practical advantages like small volume and cost effectiveness. Utilizing Fresnel lens to focus natural sunlight, the authors of the study [2] achieved 11%–14% slope efficiency of solar-pumped laser by Cr-codoped Nd:yttrium-aluminum garnet ceramic. Later, in 2009, using Fresnel lens, 80 W output laser power generated [3], demonstrating preference of Fresnel lens over mirror-type concentrators. This corresponds to 4.3% of conversion efficiency from solar power into laser. Furthermore, another study [4] showed that the Fresnel lens enables higher solar laser collection efficiency. These experimental studies indicate that Fresnel lens as a concentrator has the potential to improve solar pumped lasers. Fresnel lens concentrator is the part of the pumping scheme and the pumping process determines laser's key parameters, knowing the focal field structure is important. Therefore, in this paper, we intend to study focal field structure of Fresnel lens.

Fresnel lens. Most studies conducted on concentrated solar energy applications using Fresnel lenses for various purposes can be classified into two main groups: imaging Fresnel lenses [5] and non-imaging Fresnel lenses [6, 7]. Imaging Fresnel lens is used to create an image, whereas nonimaging Fresnel lens is used to collect solar energy. So, how to explain physical shape of Fresnel lens? If we cut out rectangular parallelepipeds (as it

is shown in Fig. 1, left) from convex lens's bulk and remaining surface pieces will be placed down on a flat surface, then we end up with theoretical Fresnel lens (Fig. 1, right).

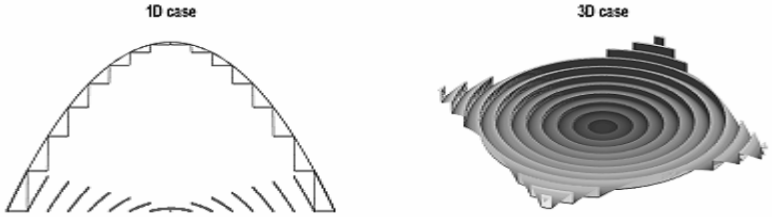


Figure 1. 1D case and 3D case of the real surface of Fresnel lens.

In ideal situation, Fresnel lens's sawtooth-shaped groove surface supposed to be spherical or parabaloidal. However, due to manufacturing complexities of spherically curved, micro-sized surfaces, the real Fresnel lens is essentially a chain of prisms on a flat (Fig. 2, left) or curved (Fig. 2, right) surface.

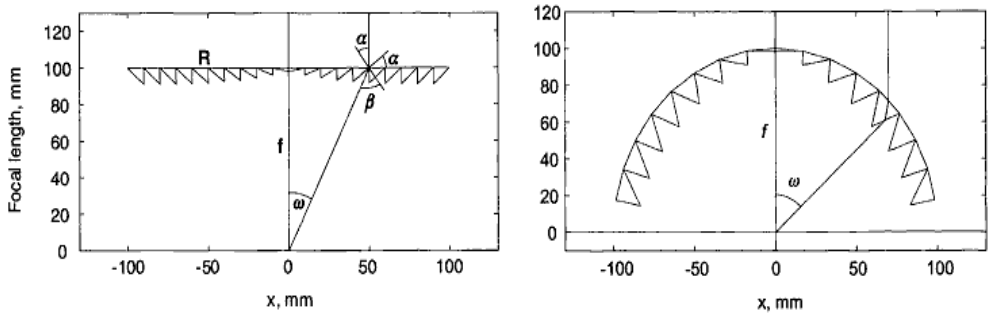


Figure 2. Flat and curved Fresnel lenses.

Depending on Fresnel lens types, focal spot structure will be different. Each type will have advantages and disadvantages in particular configuration settings. Therefore, before applying Fresnel lens in practice, it is necessary to know the focal spot structure.

Statistical photon-tracing method. As already mentioned, imaging Fresnel lens is used to create an image of a object where optical aberrations and wavefront distortions play fundamental role, and therefore it should be studied in the framework of wave optics theory [5]. In contrary, nonimaging Fresnel lens is aimed for optimally collecting solar energy. For this reasoning, study of nonimaging Fresnel lens can be done using principles of geometrical optics [6]. In this paper, to study the spot structure, we use a statistical photon-tracing method [8], which, to some extent, resembles ray-tracing method [9]. The latter is by nature completely deterministic, whereas the former method involves randomness. Similarity is that trajectory of a photon is determined from the sequence of intersection points by using geometrical optics. Difference is that the elementary processes such as reflection, refraction, absorption, and emission will be modelled by Monte-Carlo method. Detailed comparison of above mentioned two methods, advantages and disadvantages, practicality and applicability limits are not subject of this paper.

Focal spot structure of flat Fresnel lens. We consider the "grooves out" flat Fresnel lens for the study of focal field. Its focal length and number of prisms are given. Since each prism has different angles, it is required to find them individually (Fig. 3).