Automatic Design of Backlight Systems

A. Garbul (1), D. Zhdanov (2), A. Voloboy (1), V. Sokolov (1), V. Mayorov (1), K. Tsuchiya (3), V. Galaktionov (1)
1 : The Keldysh Institute of Applied Mathematics RAS, Moscow, Russia
2 : NRU ITMO, St. Petersburg, Russia, 3 : Integra Inc., Tokyo, Japan.
E-mail: tsuchiya@integra.jp

Abstract: The approach for autodesign of optical characteristics of backlight units is considered. Suggested software solution allows to find optimal configuration of scattering structure providing necessary distribution of output light. The results of car speedometer design is presented.

Keywords: backlight system, autodesign, illumination distribution, LED, microstructure

1. Introduction

Main design target of backlight unit of any device (mainly it is used for liquid crystal displays [1]) contributes to dropping energy consumption and increasing output brightness. In addition, taking ergonomics requirements into account (such as uniformity of display brightness, both spatial and angular) we have a really sophisticated design problem.

Design features of backlighting units may differ from one vendor to another. However general unit schemes remain close to each other. High and uniform brightness is provided by optimal set of scattering microstructure parameters. Usually side-illuminated backlight microstructure is located on bottom reflector plane and desired light distribution is achieved by tuning shape of microelements, their orientation, size and properties.

In the paper the developed solution of backlight autodesign is considered. It is illustrated by an example of backlight system used for illumination of automotive speedometer of car dashboard. Its scheme is presented in Fig. 1. The system is illuminated by two LED. Light enters guiding plate, propagates there and exits it due to scattering on microelements (like dimples, diffuse dots or others). Leaving guiding plate light illuminates speedometer face with scale and digits drawn on it.

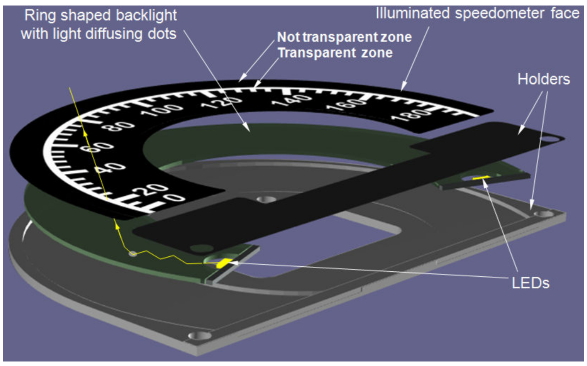

Fig. 1. Scheme of speedometer.

Light while traveling through device experiences deterministic total internal reflections and multiple scatterings on microstructure elements, thus making entire light distribution process stochastic. To compute such systems Monte-Carlo ray tracing methods are used. Main peculiarity of these computation methods is presence of white noise in resultant distribution [2]. To reduce noise amount longer computation time is needed. On modern high-end clusters acceptable levels of noise can be reached within hours. It makes estimation of influence of microstructure parameters (which can be thousands or even millions) on final luminance distribution next to impossible. Therefore the ordinary optimization methods are useless here. On the other hand, microstructure parameter influence is usually local, that is only small area of output display is affected by certain element. Also we can considerably reduce the number of designed parameters by uniting elements into groups with the same parameter value, like dimple size. This was used for proposed optimization method which is based on approach [3].

2. Principle

Software solution, embodying optimization method is composed of two phases: design pre-processing and optimization phase.

During pre-processing phase influence coefficients of parameter zones is estimated. To estimate the influence coefficient of single parameter cell various illumination conditions are calculated for the cell. Only several zones are considered here. All other coefficients are interpolated or extrapolated. Estimation of influence coefficients in separate phase is not that expensive in terms of resources and time, and much more effective then performing the same action during main optimization phase.

The main phase is composed of three different cyclic actions:

- For existing (initial at first cycle) microstructure the output display luminance and each parameter zone illumination are computed.
- The deviation from target output distribution is estimated in form of RMS and if the deviation is acceptable then the process stops. If not then new parameter values are calculated with following assumptions: using the influence coefficient and redetermination of influence coefficient conducted during computation action.
- Accordingly parameter values are changed and first action is performed again.

Several iterations are needed due to system nonlinearity and starting assumptions. In real systems each parameter zone influences distance areas of backlight.

Currently optimization algorithm is restricted to only one parameter distribution can be designed: it's either size or density or orientation of dimples.

3. Speedometer backlight design

Autodesign of the speedometer backlight was performed by elaborated software. The speedometer possesses complex contour of output display and requires high uniformity rate to provide the device visibility under different environment illumination conditions. In this optimization process the density of elements was designed. Initial microelement distribution is shown in Fig. 2. Lighting simulation with initial scene produces output luminance of speedometer presented in Fig. 4.

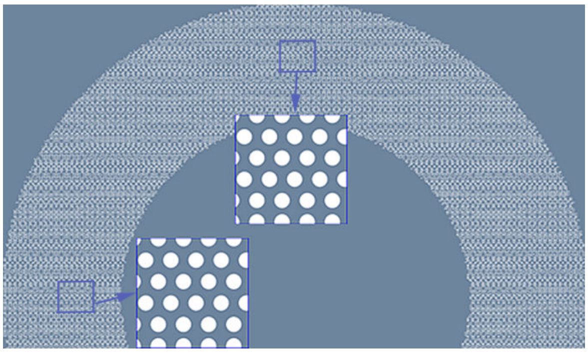

Fig. 2. Initial dimple distribution.

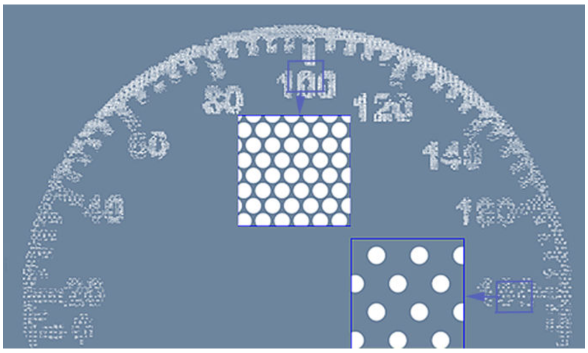

Fig. 3. Designed dimple distribution.

In the result of 12 design steps (total time – 8 hours for Intel Core 2 Quad, 2.4 GHz, 8 Gb RAM) the speedometer luminance distribution became uniform (Fig. 5). It should be noted that not only uniformity but also overall system efficiency is improved. The reason of efficiency improvement can be seen in Fig. 3: final dimple distribution corresponds to transparent zone of speedometer. It means that light is maximally focused on speedometer scale and digits illumination.

4. Conclusions

As demonstrated the algorithm is effective for backlight system design. While the results are present for the speedometer backlight the elaborated software

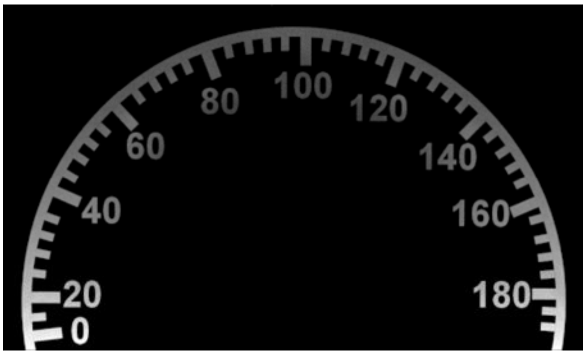

Fig. 4. Initial speedometer luminance.

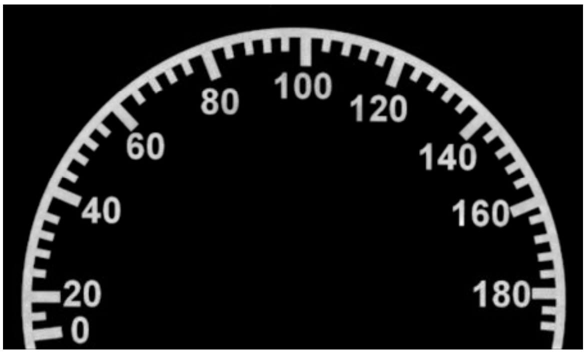

Fig. 5. Designed speedometer luminance

can be used for any backlight design, in particular for various kinds of LCD.

Numerous simulations were performed for different systems, and following conclusions were made:

- algorithm is effective for different backlight systems with various complexity;
- in most cases system can be optimized during 10-20 design steps. It requires several hours of computational time.

Autodesign program module is integrated with SPECTER optical simulation software [4].

5. References

1) Tagaya, A., M. Nagai, Y. Koike, K. Yokoyama, Thin Liquid-Crystal Display Backlight System with Highly Scattering Optical Transmission Polymers, Applied Optics, Vol. 40, Issue 34,. 2001, p. 6274-6280.

2) A. Garbul, D. Zhdanov, V. Mayorov, V. Sokolov. Non deterministic ray tracing in light scattering and lighting system modeling. In Proc. IX Int. Conf. "Applied optics-2010", 2010, p. 259-264 (in Russian).

3) T.L.R.Davenport and W.J.Cassarly. Optimizing Density Patterns to Achieve Desired Light Extraction For Displays, Proc. SPIE 6342, 63420T (2007);

doi:10.1117/12.692259.

4) SPECTER – Integra Inc.

http://www.integra.jp/en/specter/index.html