Systematic Optimization of a Lightguide Coupling Setup

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Summary

Gratings for coupling light into or out of lightguides for near-to-eye display systems are optimized regarding the angular dependency of the field of view. Uniformity and relatively high efficiency over large FOV are obtained by a systematic design and optimization approach.

Introduction

Lightguide structures are widely applied in different applications, and, nowadays, they are drawing special interest in the field of near-to-eye display systems. Such systems are typically realized with lightguides together with gratings for coupling light into or out of the lightguides. For the application in display, the field of view (FOV) supported by the lightguide parts becomes an important issue for the system design. In this work, we analyze the behavior of typical gratings for lightguide coupling, especially taking the angular dependency into account. It will be shown that obtaining uniformity and relatively high efficiency over large FOV is a challenging task.

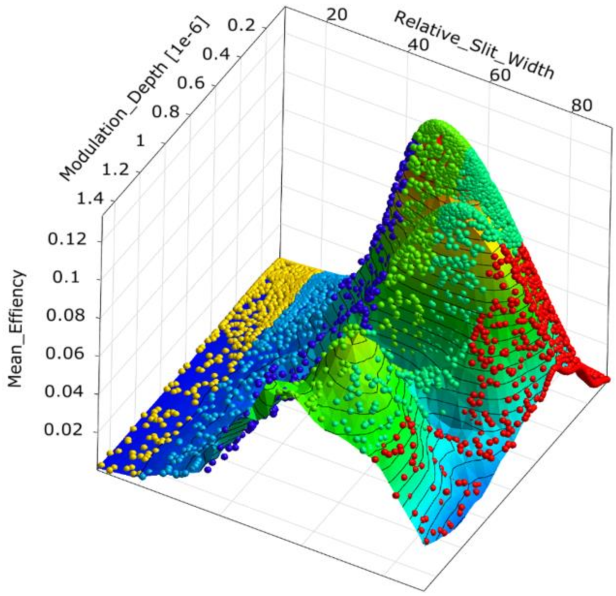

Fig. 1. Metamodel of Optimal Prognosis that shows the influence of the two input parameters modulation depth and relative slit width on the mean coupling efficiency of the binary grating.

To accelerate the virtual product development using optical simulation software, additional design optimization methods are applied. First, with a sensitivity analysis followed by a Pareto optimization, we optimize the coupling grating structure to minimize uniformity and maximize mean efficiency over the desired FOV.

Discussion

As a pre-optimization step, we thoroughly explored the coupling grating structures by means of sensitivity analysis. This includes the identification of relevant input parameters and the (meta)modelling of inputs vs. outputs to understand their dependencies and interactions. In Fig. 1 a metamodel for the mean efficiency of a binary grating to couple light into a lightguide is shown as an example. It can be seen, that the coupling efficiency can be maximized by the modulation depth and relative slit width at the same time. Several local optima can be identified. Dynardo's Metamodel of Optimal Prognosis has the ability to predict data points that haven't been used for modelling [1,2]. This gives insights in the optimization problem and is therefore the basis for the subsequent optimization.

The intelligent definition of objective functions for an efficient optimization is of high importance for multi-objective optimization tasks. If the objectives are in conflict, they should be defined in separate objective functions (Pareto optimization). As a result, not only one design, but a front of best designs is obtained to find the best trade-off between two or more merit functions, and the most appropriate design(s) can be selected by the decision maker. These best designs are usually plotted as Pareto front as shown in Fig. 2. Additionally, further understanding of the optical design can be obtained by clustering interesting parameters and coloring each of these resulting clusters. In Fig. 2 a cluster analysis of the fill factor of a slanted grating was considered to understand its influence on the performance (uniformity error as well as mean efficiency to couple light into a lightguide). It is obvious, that high fill factors lead to lower efficiencies, but also lower uniformity errors. Here, the trade-off between uniformity error and mean efficiency gets visible: the higher the efficiency the higher the uniformity error. The design of several grating structures was tuned using this design exploration and Pareto optimization approach.

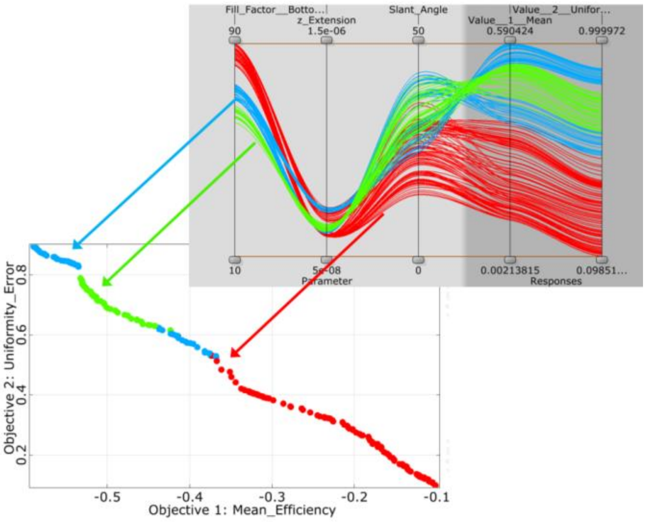

Fig. 2. Anthill plot with Pareto front designs (lower left plot) representing the trade-off between uniformity error and mean efficiency of a slanted grating. The colors correspond to the color of the cluster analysis illustrated in the parallel coordinates plot (upper right plot). Here, the fill factor was separated into 3 clusters.

Conclusions

The presented approach illustrates the power of design exploration and Pareto optimization for the determination of the best trade-off between contradicting objectives. With this approach, the optical designer can make the final decision about the best optical design with other decision makers together by analysing the trade-off between several criteria including output performance but also input constraints at the same time.

References

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