Design Using Saddle Point Construction in Complex Lens Systems

Zhe Hou, Yueqian Zhang, Florian Bociort

1Delft University of Technology, Optics Research Group, Lorentzweg 1, 2628CJ, Delft, the Netherlands. 2Friedrich Schiller University Jena, Institute of Applied Physics, Albert-Einstein-Str. 15, D-07745 Jena, Germany

email: z.hou@tudelft.nl

Summary

We show how saddle point construction (SPC) can be used to find new high-quality solutions in practical lens design problems. Complex lens examples such as a lithographic lens and a microscope objective demonstrate the effectiveness and the systematic approach of using SPC.

Introduction

The presence of multiple local minima has always been an issue in lens design problems. Conventional lens design approaches only lead the designer to one solution each time, and, especially when the designer has only limited experience, often better solutions exist. We have recently developed a technique called Saddle-Point Construction (SPC) [1] that makes it possible to switch rapidly between different local minima. With SPC, the search for new local minima is reduced to one-dimensional searches starting from local minima of simpler systems. Combined with the insight of the designer, we expect that SPC will facilitate the design process and that satisfactory solutions will be reached faster.

Using Saddle Point Construction in Complex Lens Design

In previous papers, we have studied the general version of SPC with simple systems [2-3]. In this paper, our emphasis is on the practical aspects that are important when SPC is used on more complex systems. With multiple lens elements, the number of local minima is increased, and optimization can be easily trapped in a poor solution.

One of the examples is a lithographic system with 22 elements and a NA=0.85 for 193 nm [4]. We first use a default merit function to perform SPC (Step 1). Then, in Step 2 we include all requirements in the merit function to optimize further the new lens systems obtained with SPC. In the lithographic lens example, we show that four new solutions were found when one SPC operation was applied to the original system. With the new solutions obtained from SPC, further optimization with other constraints led to four different final solutions. As shown in Fig. 1, M1-M4 are the four new solutions in addition to the original solution M0. We can see that the main difference between the different solutions is localized around the position where SPC was performed. The new solutions are compared with the original one, in Table 1. As we can see, M1 and M3 are both better than the original patent in wavefront RMS, and M3 is superior in three different aspects compared to all other systems.
Another example will be a microscope objective with moderate complexity where the system performance is not satisfied. Traditional methods for improving the system and SPC are compared. In this design case, we show the possibility of using SPC combined with the designer’s experience to search for better solutions effectively.

Conclusion

The effectiveness of the saddle point construction applied in complex lens design is demonstrated. In a highly complex system such as a lithographic objective, despite the increased complexity of the design landscape, SPC is still able to obtain alternative high-quality solutions. When combined with designers’ experience, SPC can be a useful tool to switch to a better solution from a poor one.

References