Generation of optical systems for lithography via saddle points

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Why?

Finding new local minima in the multidimensional merit function space of an optical system is a difficult task especially for lithographic objectives that have many variables. Only methods, such as the present one, that use for this purpose a small number of local optimizations can be helpful. We use the fact that the local minima in the merit function space are connected via paths containing a certain type of saddle points.

What?

A new method to generate saddle points systematically:

1) start from a local minimum with N surfaces
2) at given positions in the system insert two new surfaces (with parameters computed with our method) -> saddle point with N+2 surfaces
3) perturb it on both sides of the "saddle"
4) locally optimize the resulting two points -> two local minima with N+2 surfaces

Where?

DUVL

From the system in **Fig. 1** six saddle points (SP) are created. They are linked to one relaxed solution (Hub) and six strained solutions (LM_i) (**Fig.2.**). The significant deviations from the hub are shown in blue. The hatches indicate the inserted lens. Similar results are obtained for the first bulge, too.

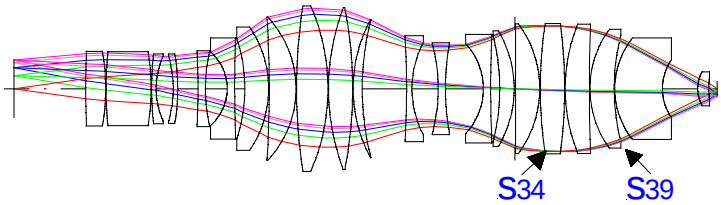

Fig.1. Starting local minimum with N = 43. The numerical aperture is 0.56 and the magnification is -0.25 at 248.3 nm.

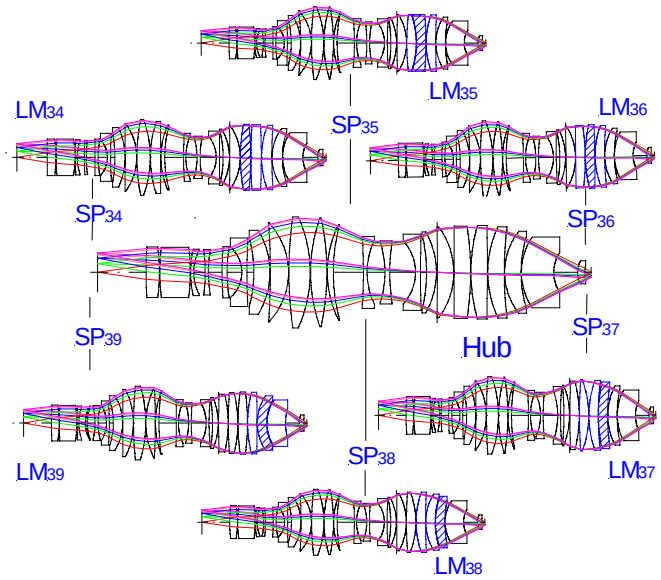

Fig.2. Part around the hub of the network of local minima for a monochromatic lithographic objective with N+2 = 45 surfaces. The indices show the surface in the original system where an extra lens has been inserted.

EUVL

A saddle point is constructed at the second surface of the system shown in **Fig.3.** and two new solutions are generated (**Fig.4.**). The tendency for a relaxed solution is maintained (LM1).

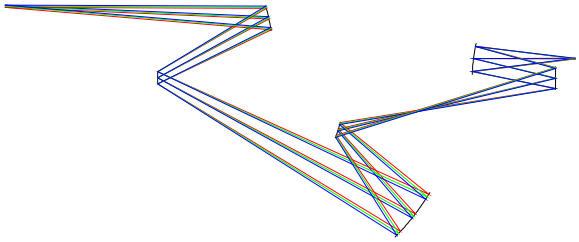

Fig.3. Starting local minimum (N = 6). At a numerical aperture of 0.16, the object heights are in-between 114 and 118 mm and the magnification is 0.25.

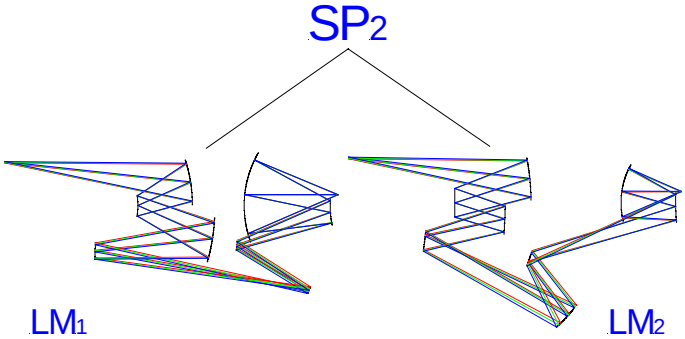

Fig.4. Solutions resulting from a constructed SP at the second surface (N+2 = 8) are reoptimized for a numerical aperture of 0.4. LM_2 is poor, but for LM_1 the strehl ratio is larger that 0.996 and the distortion is below 1 nm.

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