PARAX 2.0
A Software Tool with a Powerful GUI for Initial Step Optical Design

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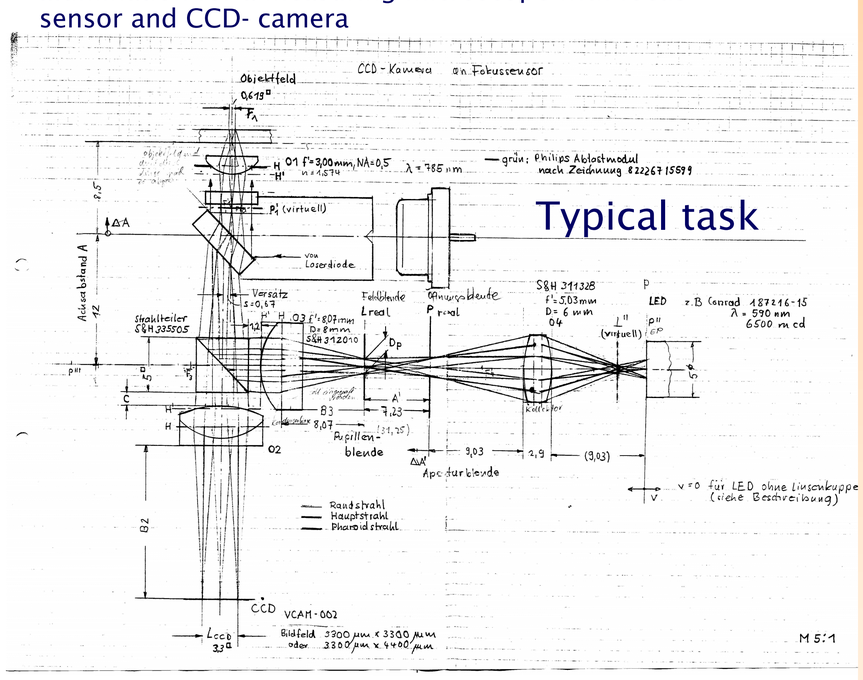
Motivation

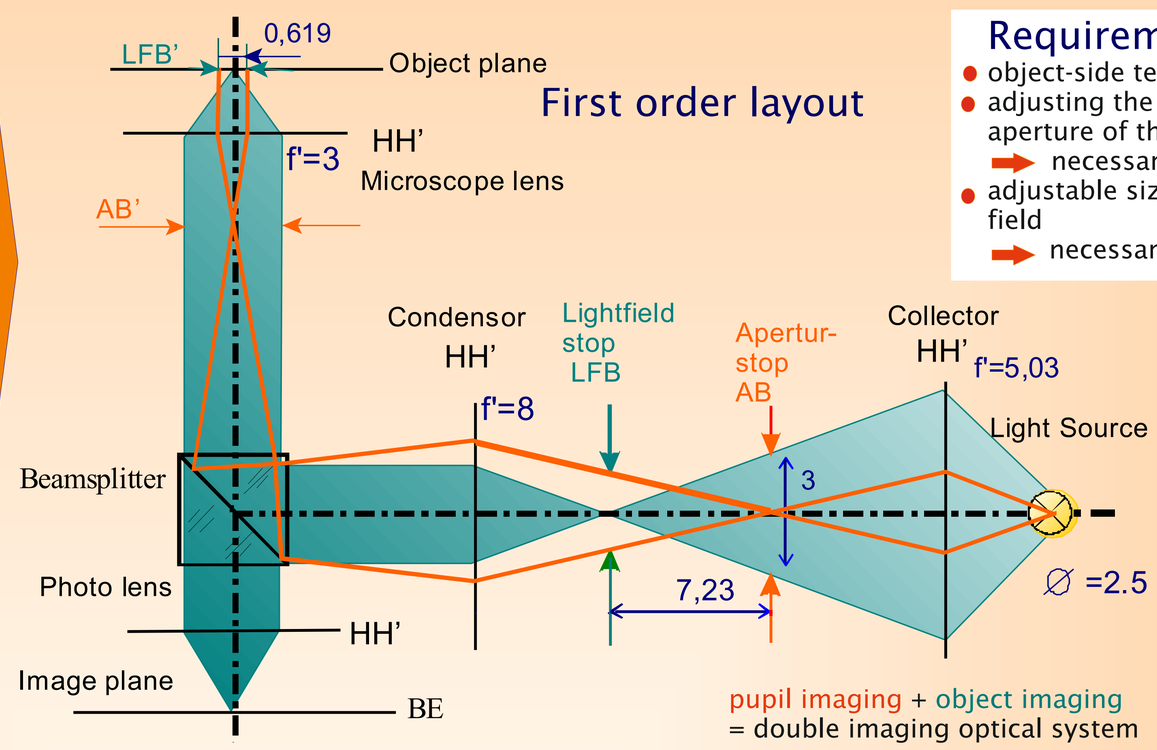
Illumination for a measuring microscope with focus sensor and CCD- camera



How can the optical layout be optimized?

Figure 1: Basic structure of the double imaging optical system example

Example
Adapting the illumination system to the imaging system



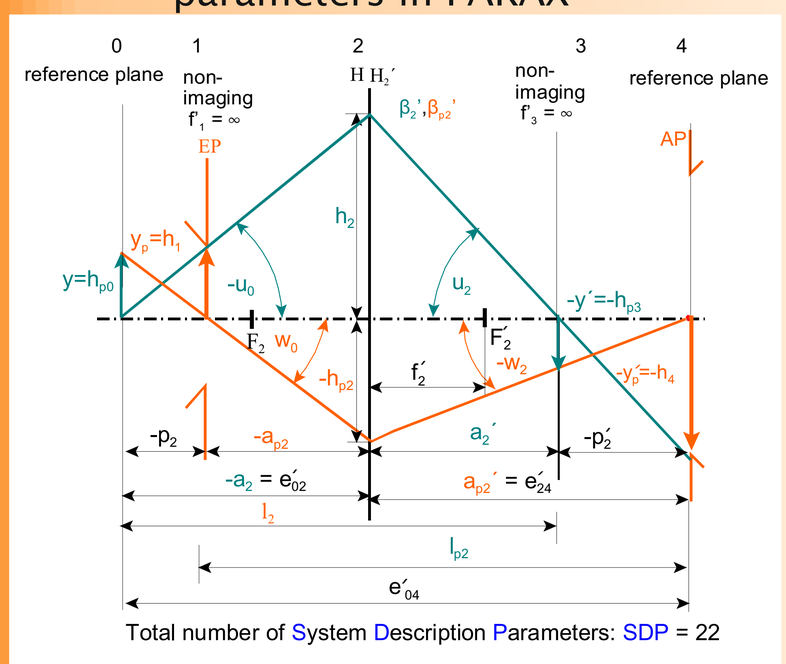
Requirements

- object-side telecentric beam path
- adjusting the aperture of the illumination to the aperture of the microscope
  - ➡ necessary variable aperture stop
- adjustable size of the illumination of the object field
  - ➡ necessary variable field stop

Figure 2: Basic principle of the optical system

pupil imaging + object imaging
= double imaging optical system

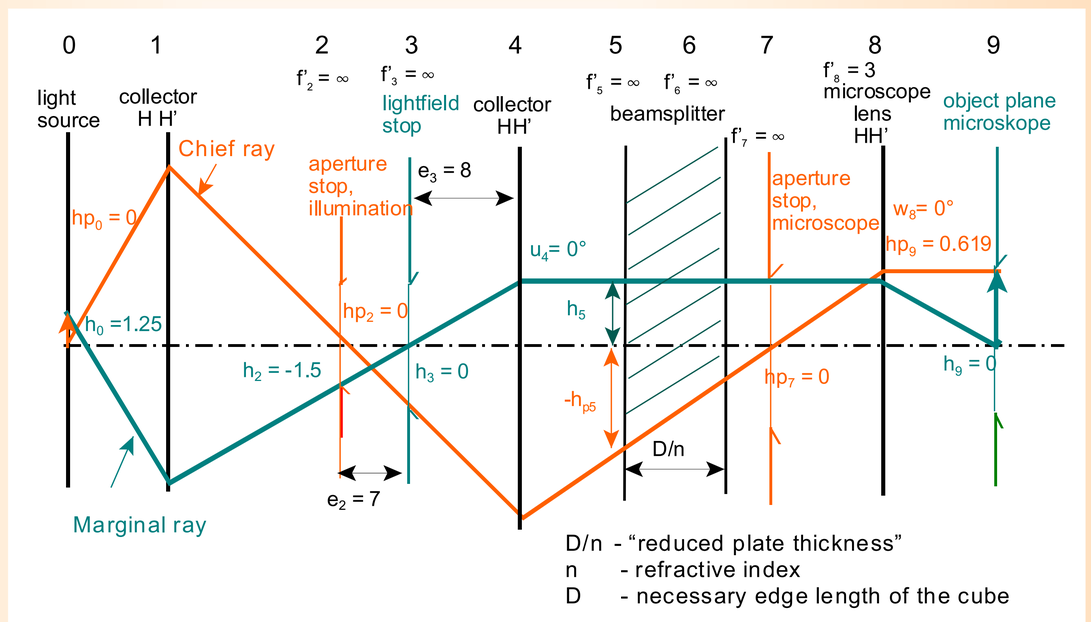
Possible system parameters in PARAX



Total number of System Description Parameters: SDP = 22

Figure 3: Possible local and global system parameters for a double imaging optical system with 5 planes

Derivation of local and global system parameters for the input tables in PARAX



Global parameters:

1. lateral magnification: $\beta'_{48} = -0.38$
2. pupil imaging magnification: $\beta'_{p14} = 1.34$

Degree of freedom for the example:

$k = 10 \Rightarrow FG = 21$

Figure 4: 19 local and 2 global system default values for initial step optical design with Parax

Degree of freedom and basic equations

Degrees of Freedom (FG):
= number of independent predefined system variables

$$FG(k) = 3 + 2(k-1)$$

$$k = 5 \Rightarrow FG = 11$$

k - Number of planes (system components)

Number of basic arithmetic combinations:

$$C_{SDP}^{(FG)} = \binom{SDP}{FG}$$

For a double imaging optical system with 5 planes:

$k = 5 \Rightarrow SDP = 22 \quad \Rightarrow FG = 11$

$$C_{SBG}^{(FG)} = \binom{SDP}{FG} = \binom{22}{11} = 705432$$

Linking the marginal ray and the chief ray via the Helmholtz-Lagrange-Invariant:

$$h'_{pi} \tan u'_i - h'_i \tan w'_i = h_{pi} \tan u_i - h_i \tan w_i$$

Helmholtz-Lagrange-Invariant for the pupil imaging:

$$\beta'_i \, \beta'_{pi} = \frac{p'_i}{p_i} \Rightarrow \frac{y'_i y'_{pi}}{p'_i} = \frac{y_i y_{pi}}{p_i}$$

Free radius of the optical element on plane „i“: $\rho_i = |h_{pi}| + |h_i|$

Free aperture of the optical element on plane „i“: $K_i = \frac{2\rho_i}{f'_i}$

➡ Free radius on plane 5= necessery half edge length of the beam splitter cube

Results with analysis tools

Local variables

	Plane 0	Plane 1	Plane 2	Plane 3	Plane 4	Plane 5	Plane 6	Plane 7	Plane 8	Plane 9
f' : Effective focal length		5.030000000	oo	oo	7.894736842	oo	oo	oo	3.000000000	
e' : Distance between one and the next plane	9.263531590	11.006310667	7.000000000	7.894736842	8.798575386	5.000000000	3.000000000	3.000000000	3.000000000	
h : Marginal ray height	1.262484570	-3.858495143	-1.500000000	0.000000000	1.691729323	1.691729323	1.691729323	1.691729323	1.691729323	0.000000000
u : Half maximal aperture angle	28.934288657	-12.094757077	-12.094757077	-12.094757077	0.000000000	0.000000000	0.000000000	0.000000000	29.419076152	
ß' : Lateral magnification		-2.579783433	1.000000000	1.000000000	oo	1.000000000	1.000000000	1.000000000	0.000000000	
l : Imaging length		24.986086736	0.000000000	0.000000000	oo	0.000000000	0.000000000	0.000000000	oo	
a : Object distance		-6.979776069	7.000000000	0.000000000	-7.894736842	oo	oo	oo	oo	0.000000000
a' : Image distance	2.283755521	18.006310667	7.000000000	0.000000000	oo	oo	oo	oo	3.000000000	
hp : Chief ray height	0.000000000	-2.561242971	0.000000000	1.628947368	3.466106055	1.650666667	0.619000000	0.000000000	-0.619000000	-0.619000000
w : Half maximal field angle	15.455412023	-13.099971593	-13.099971593	-13.099971593	11.658420337	11.658420337	11.658420337	11.658420337	0.000000000	
ßp' : Lateral pupil magnification		-1.188133333	1.000000000	1.000000000	-1.127819549	1.000000000	1.000000000	1.000000000	oo	
lp : Pupil imagi length		20.269842257	0.000000000	0.000000000	31.693312228	0.000000000	0.000000000	0.000000000	oo	
ap : Entrance pupil distance		-9.263531590	0.000000000	-7.000000000	-14.894736842	8.000000000	3.000000000	0.000000000	-3.000000000	oo
ap' : Exit pupil distance	0.000000000	11.006310667	0.000000000	-7.000000000	16.798575386	8.000000000	3.000000000	0.000000000	oo	
p' : Distance: pupil-object/image		2.283755521	7.000000000	7.000000000	7.000000000	oo	oo	oo	oo	-oo
ρ : Free radial distance	1.262484570	6.419738114	1.500000000	1.628947368	5.157835378	3.342395990	2.310729323	1.691729323	2.310729323	0.619000000
K : Relative aperture		2.552579767	0.000000000	0.000000000	1.306651629	0.000000000	0.000000000	0.000000000	1.540486216	

Figure 5: Input and results table (Input values in black)

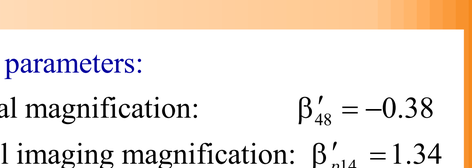
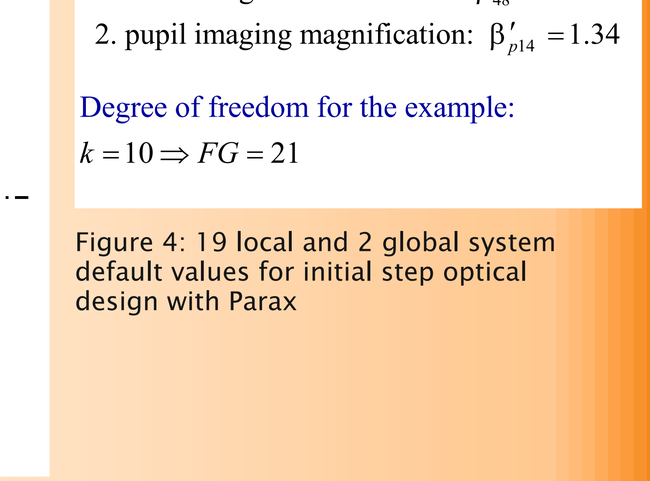


Figure 6: Delano diagram - a powerful visual design tool

Figure 7: Parameter variation and parameter iteration

Sizes for review

Figure 8: Ray tracing with both imaging paths:
1.for the on-axis point
2. for a field point



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Acknowledgements

The authors would like to thank the German Research Foundation (DFG) for founding this wok within to project VopSys "Verallgemeinerte optische Abbildungssysteme" FKZ: SI 573/9.Ho 2667/1-1.

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DGaO-Proceedings 2016 - http://www.dgao-proceedings.de - ISSN: 1614-8436 - urn:nbn:de:0287-2016-P063-3
eingegangen: 10.06.2016 veröffentlicht: 12.08.2016