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BB King

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Eric Clapton

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BB King & Eric Clapton

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BB King *Eric Clapton*

Design & Fabrication

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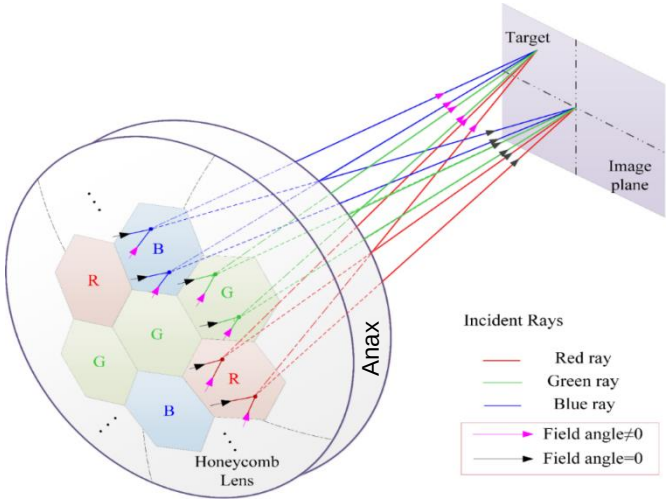

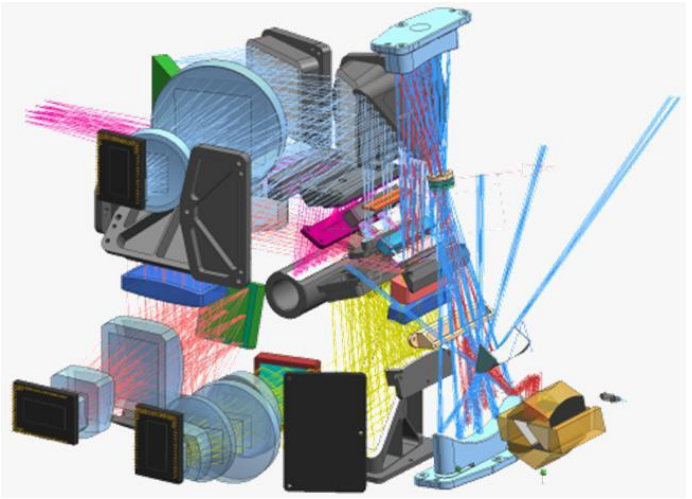

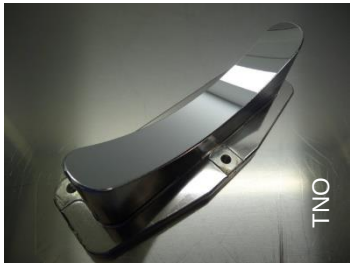

Oliver Faehnle

- *www.PanDao.ch, Switzerland*
- *OST University, Switzerland*

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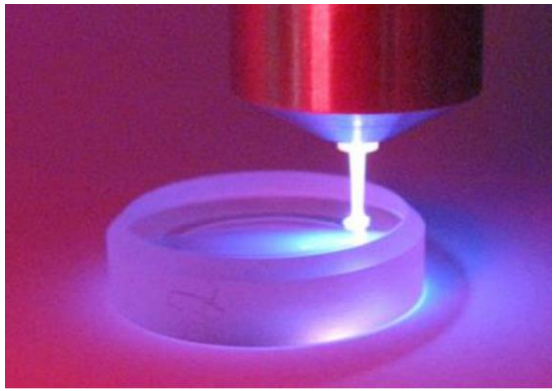
conquering the freeform TRILEMMA:

1. design

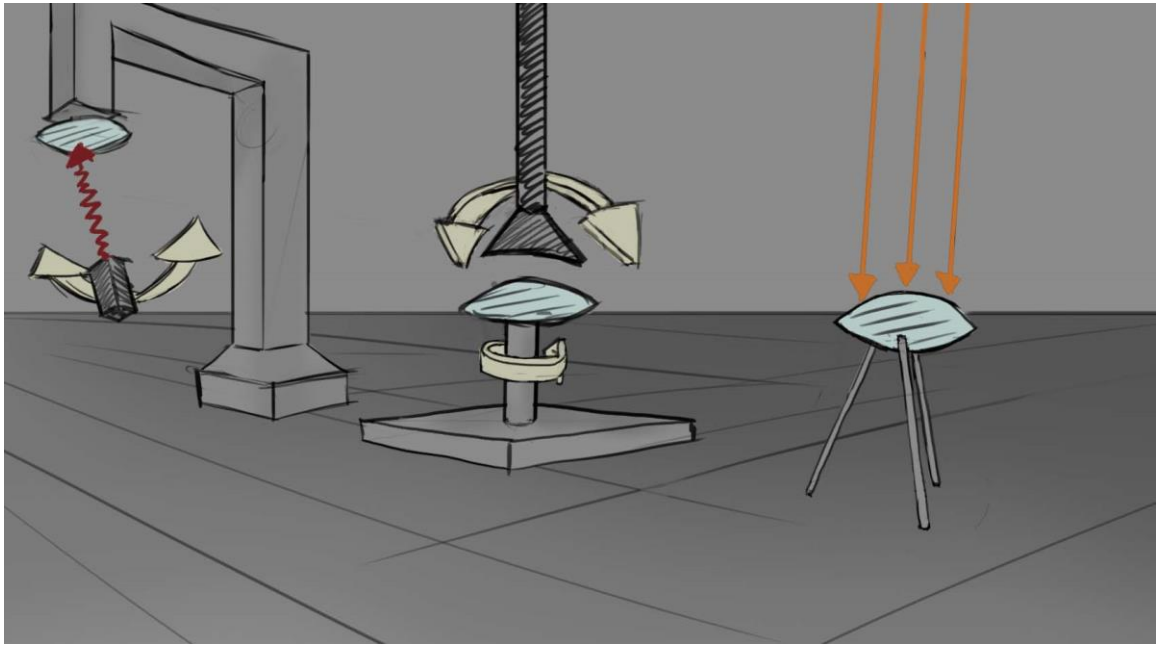
2. producibility analysis

3. optimum fabrication chains

fab process → →



fab chain



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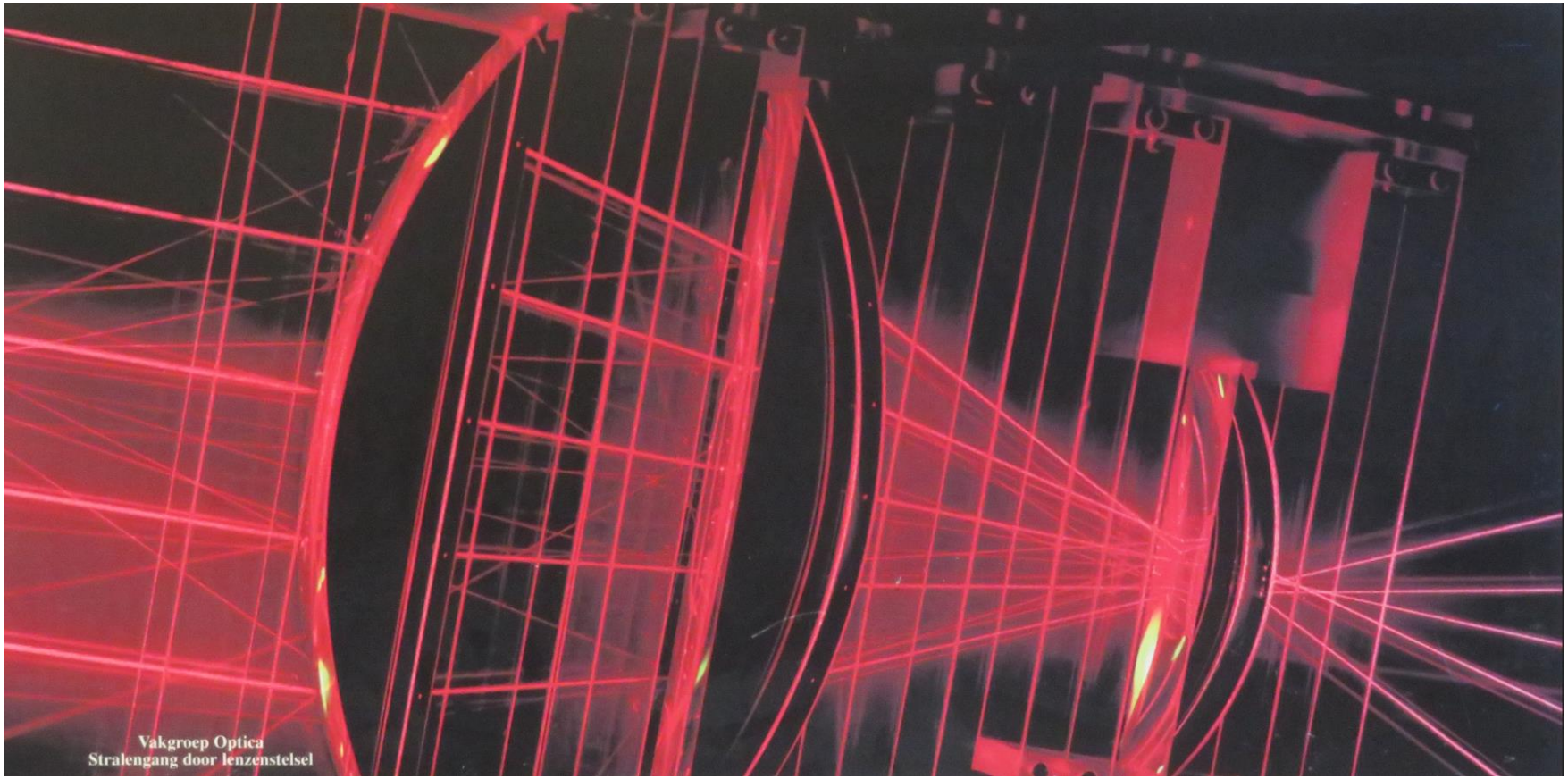

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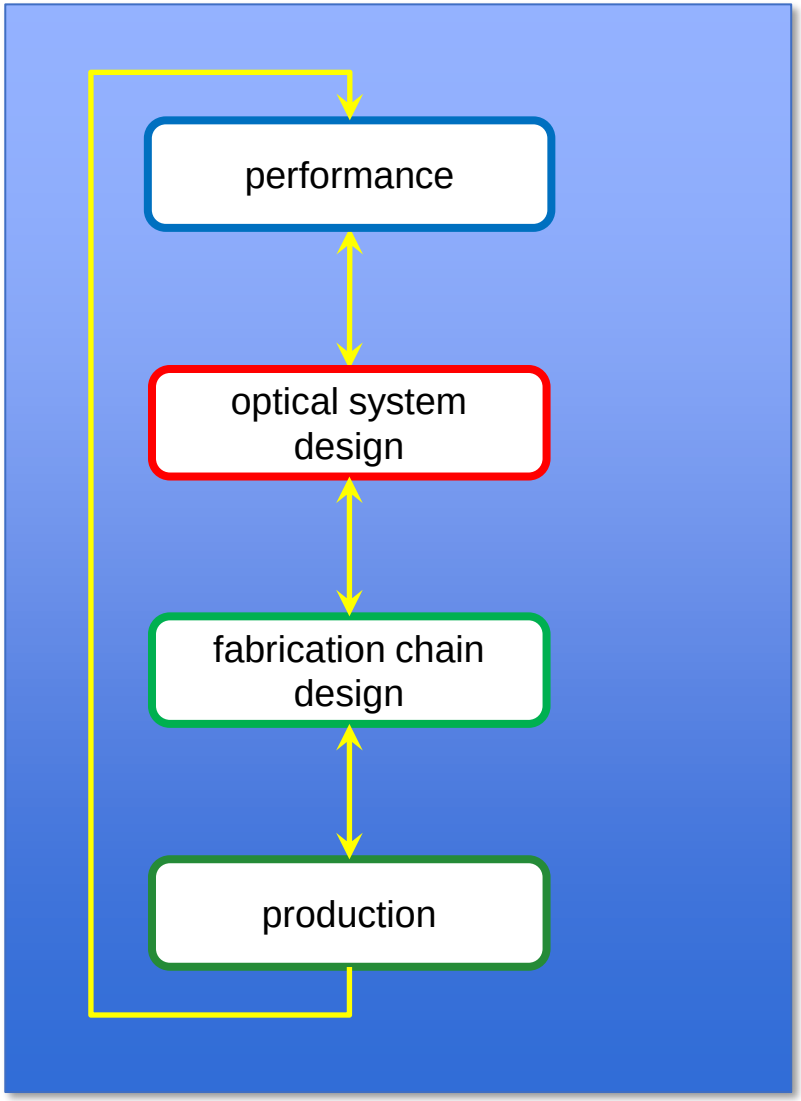

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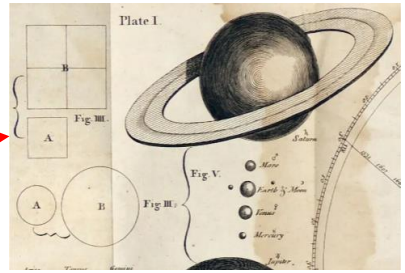
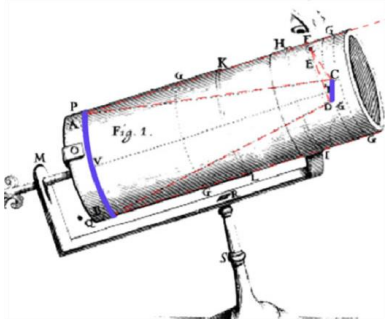
performance

optical system design

fabrication chain design

production





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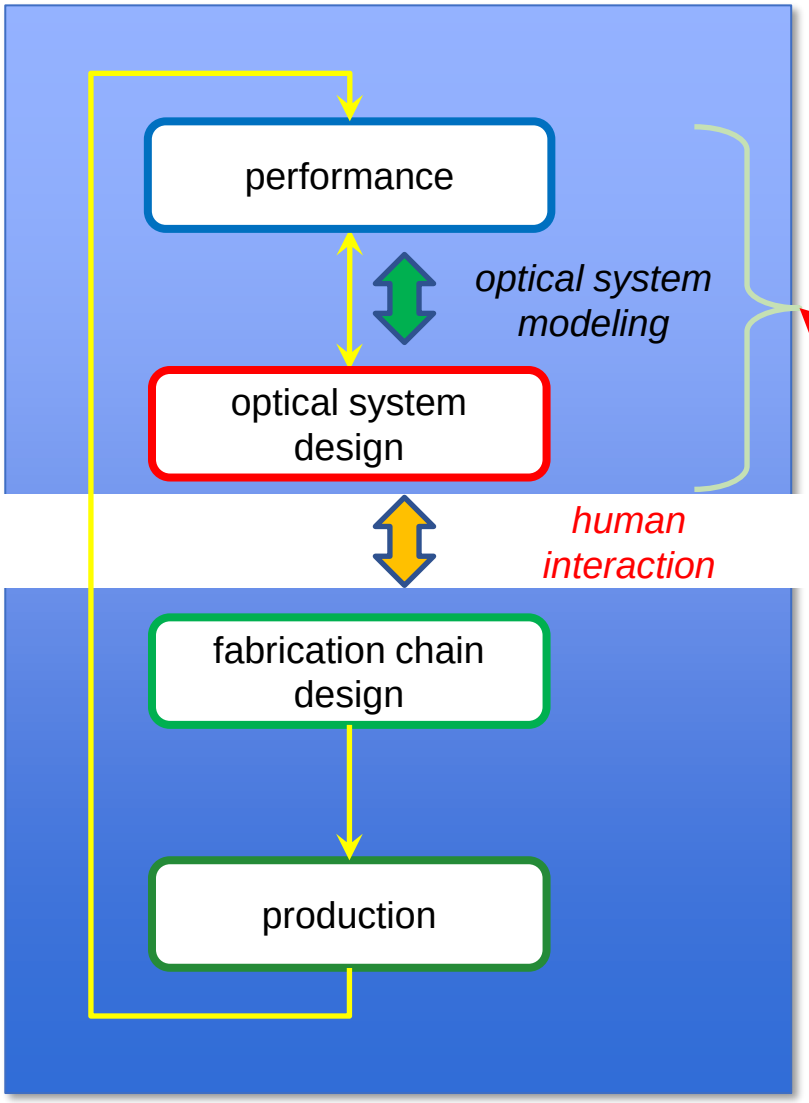
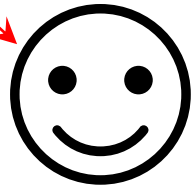


performance



➢ design for best performance…

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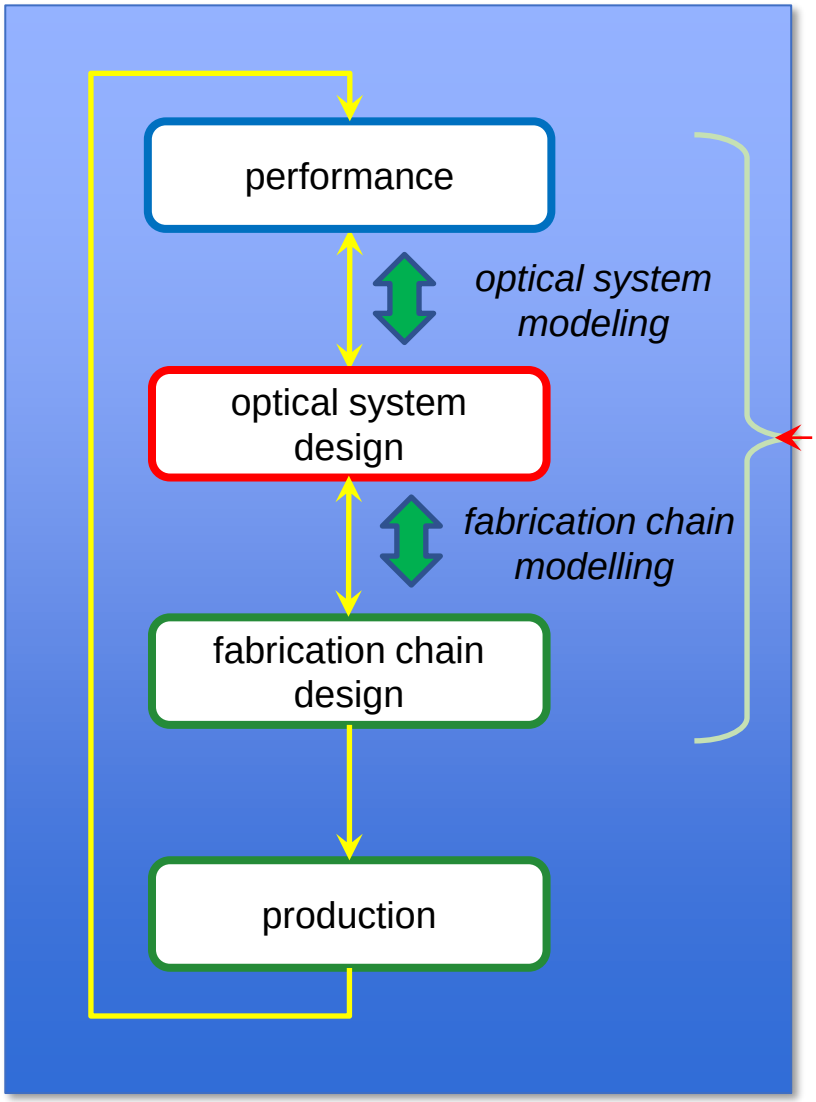

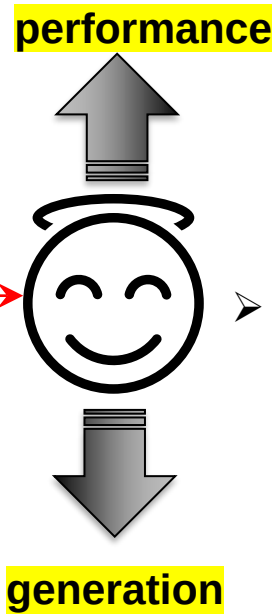

➢ design for best performance and best producibility

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- material → glasses, plastics, crystals, metals, germanium, silicium, CaF2. WC
- quality → IR to EUV
- dimension → 0.3 mm to 1.5 m
- geometry → plano, spherical, cylindrical, aspherical, off-axis aspherical, freeforms
- throughput → prototyping to mass production
- characteristics → ☺

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INPUT

- ISO10110
- throughput

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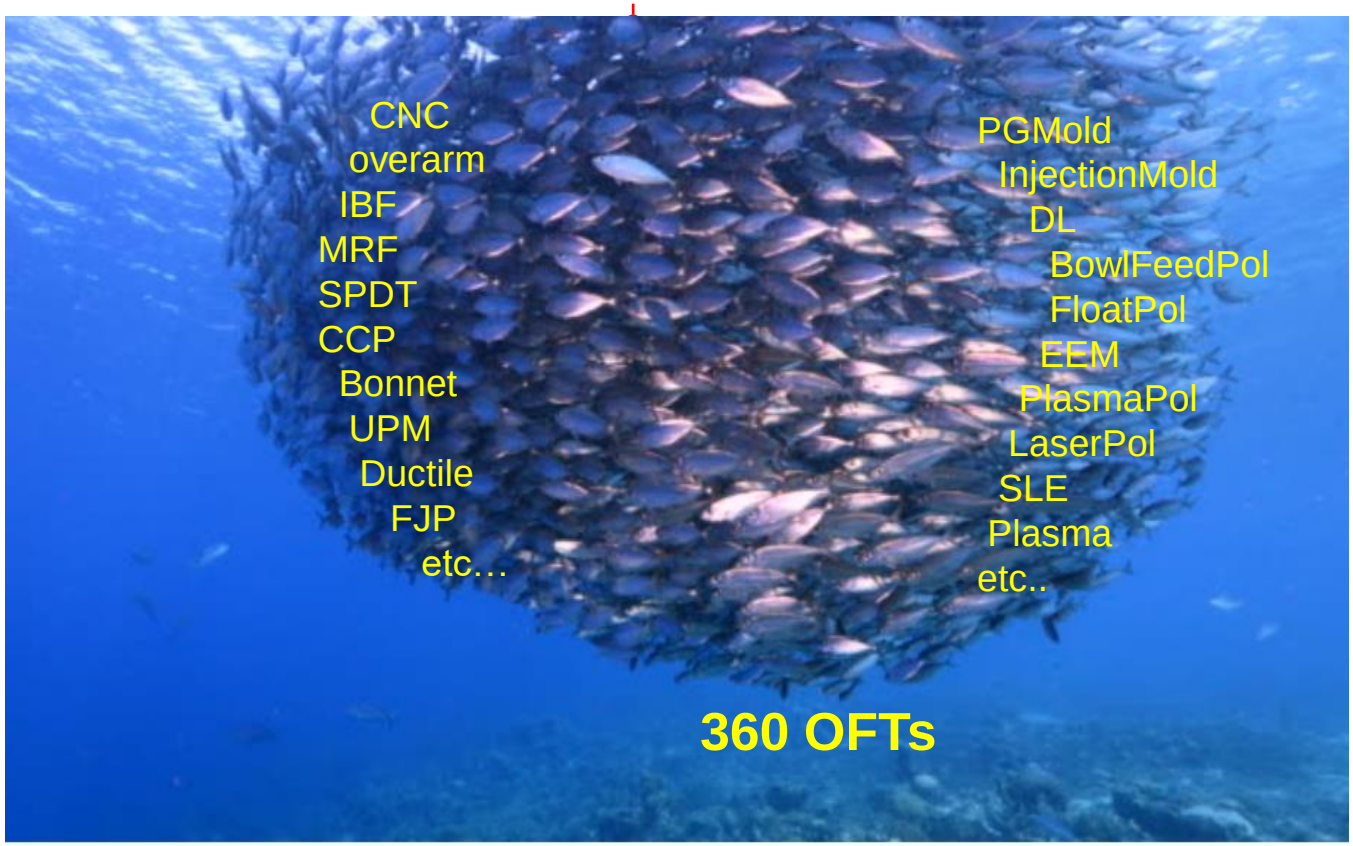
OUTPUT

- best fabrication chain



INPUT

- ISO10110
- throughput

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OUTPUT

- best fabrication chain
  - cheapest
  - fastest
- risk analysis
  - technological
  - financial
- fabrication cost

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INPUT

- ISO10110
- throughput

PANDAO
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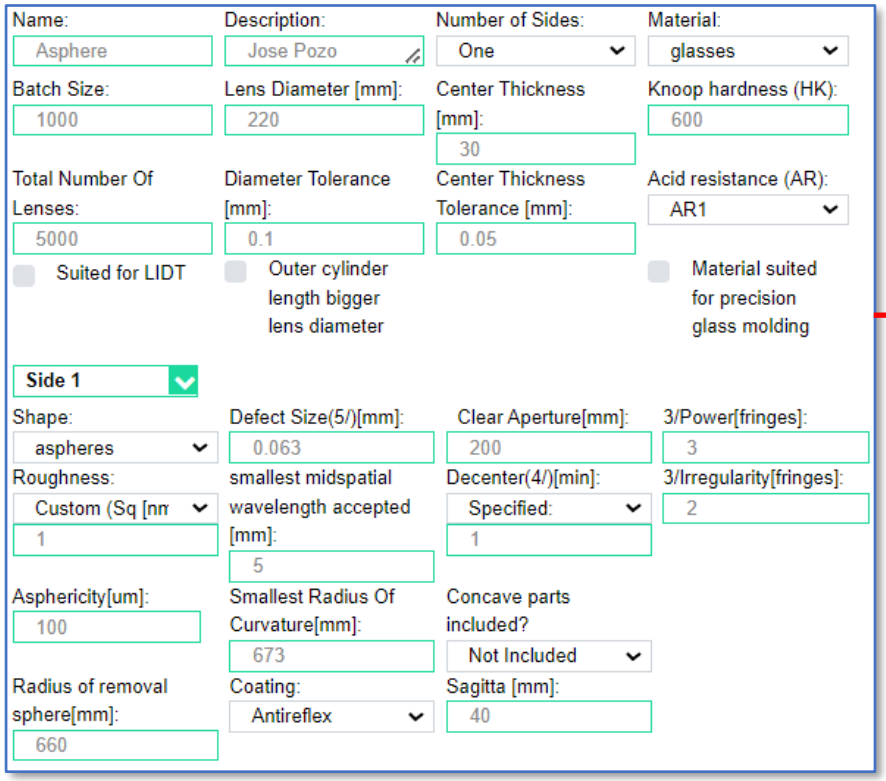
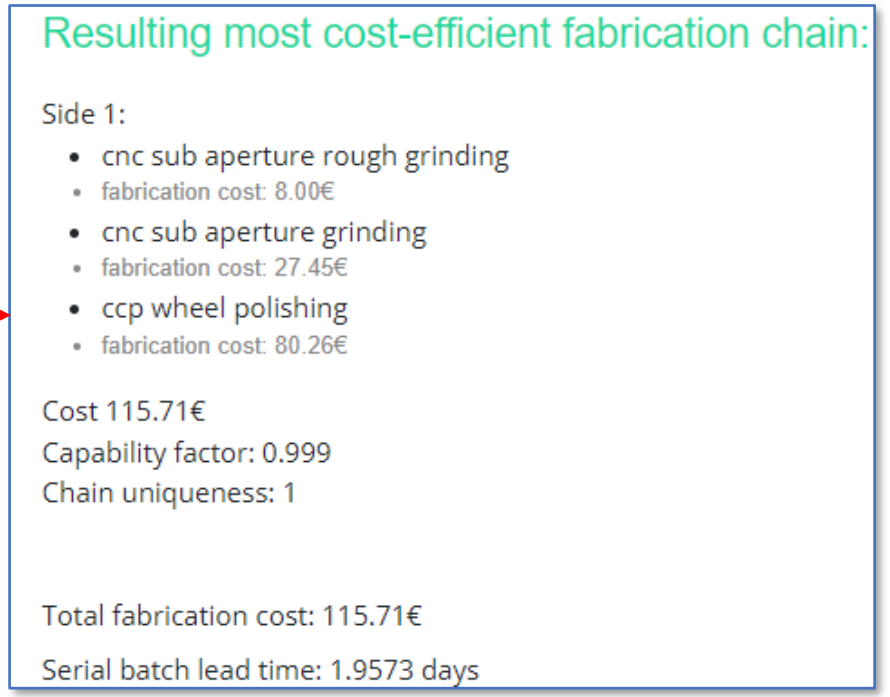
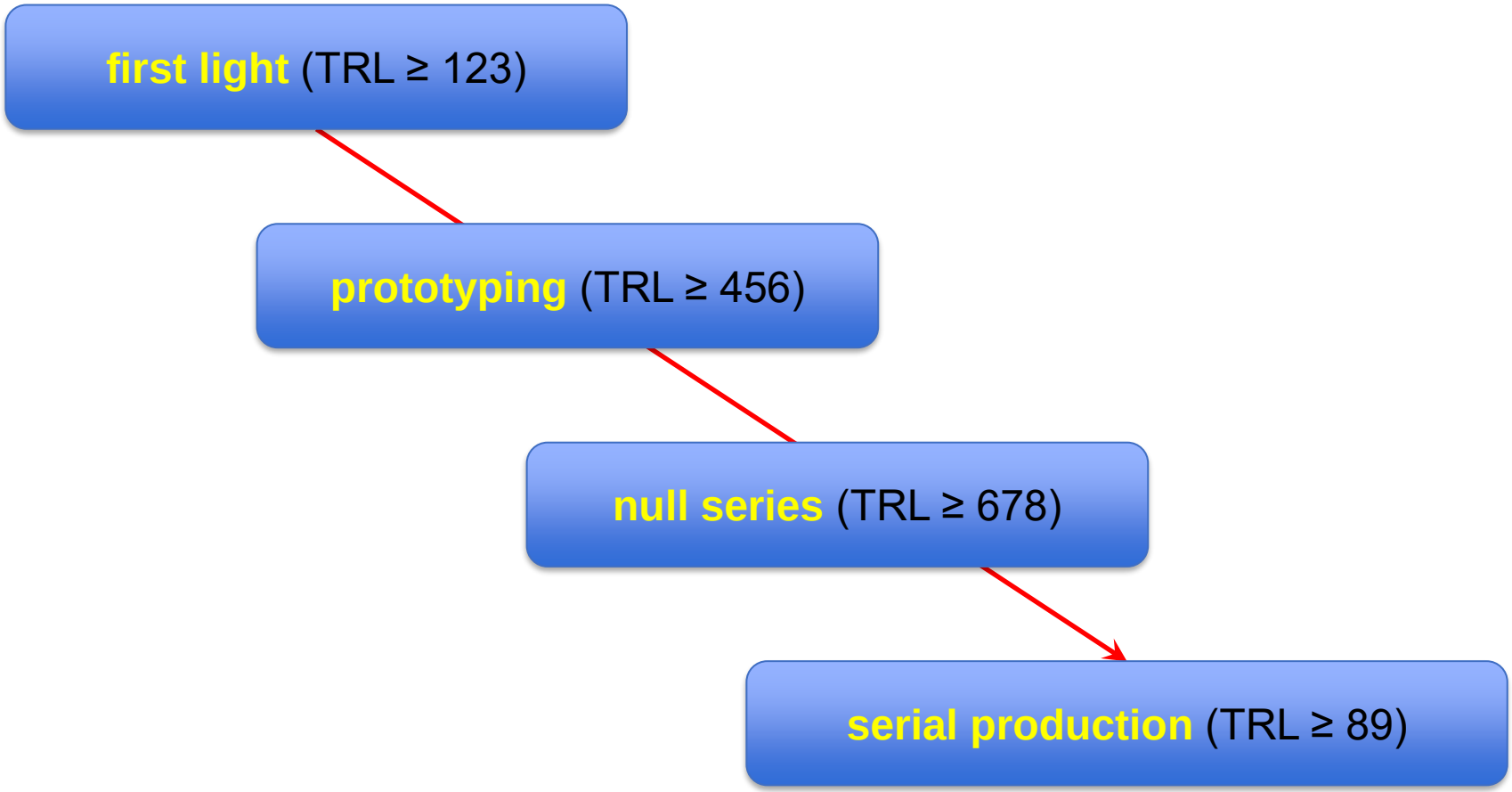
OUTPUT

- best fabrication chain

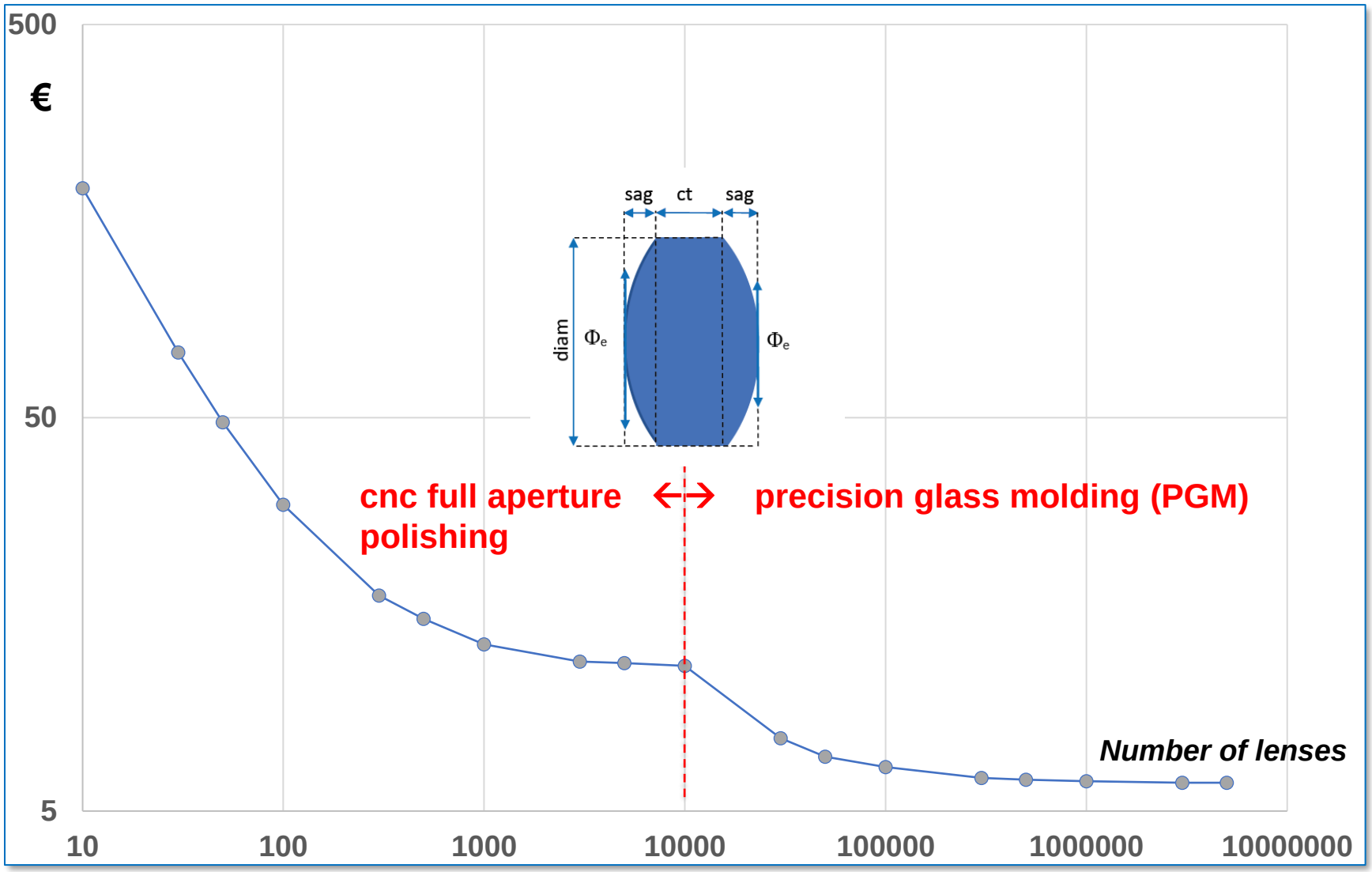




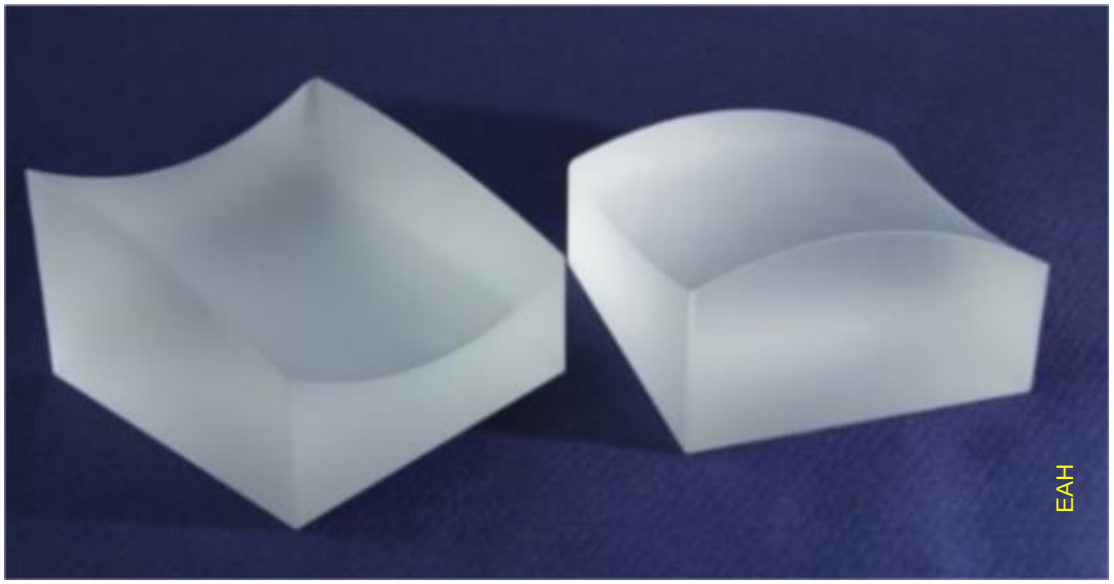
Product life cycle example



Product life cycle example

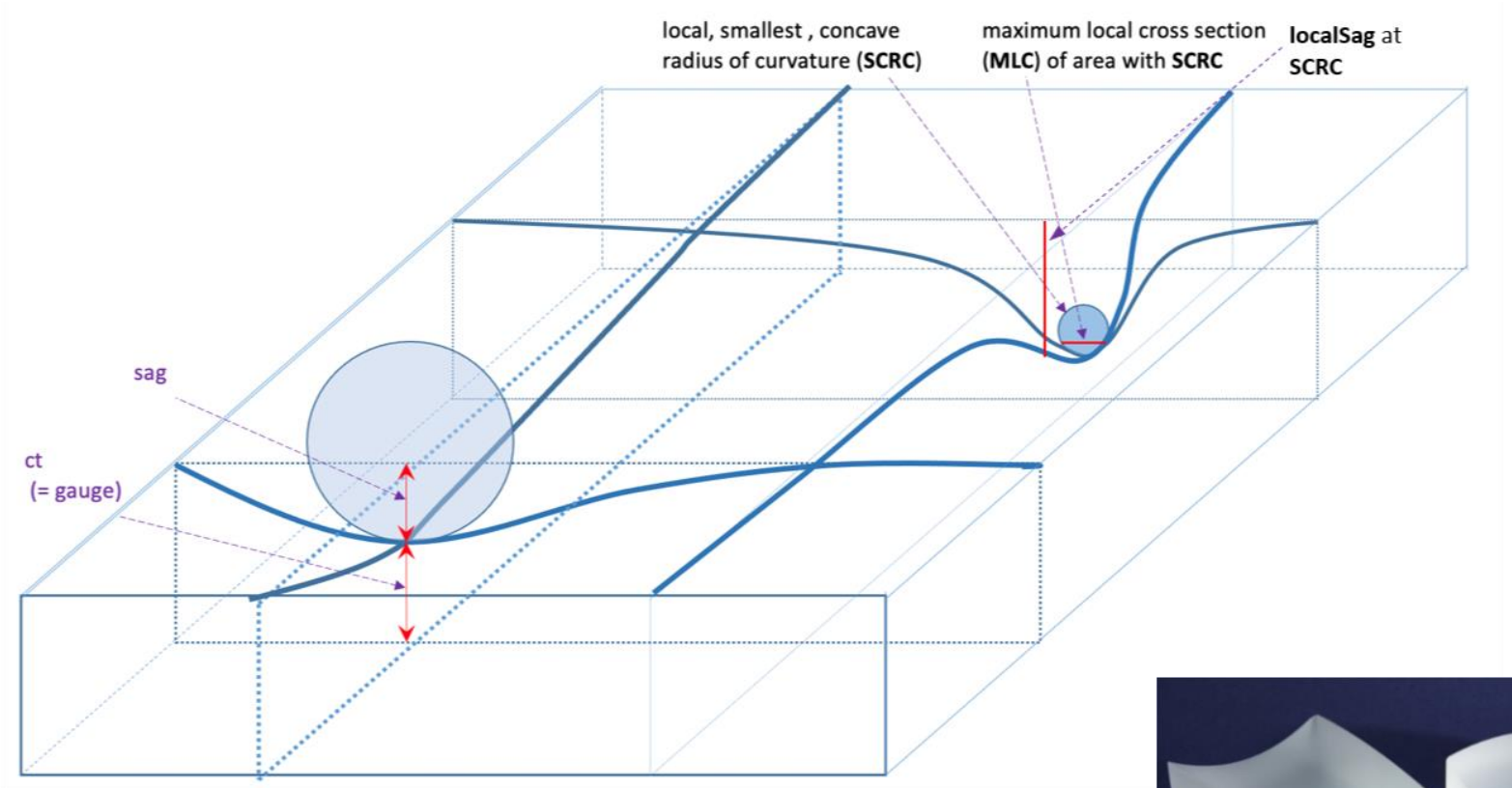


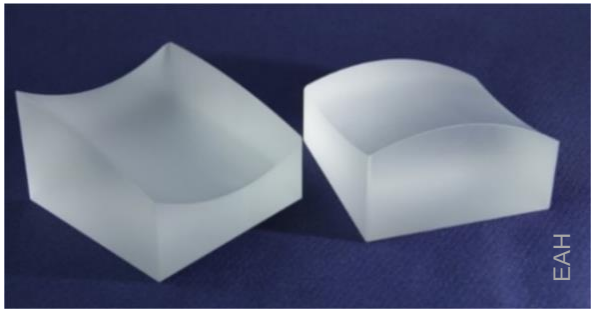
Freeform example



Freeform optics

- no symmetry: z(x,y)
- MSW, Slope, SLRC, MLC, LS, gauge, etc





Freeform example

TRL	material	3/	numbers	size	MSW	chain

Specify your Product:

Load/Store Products

Load from File | Clear all parameters | Load stereotype product: Please select: | Load typical tolerances: Please select:

General Information

Name: PanDao D4 freeform_sphCX	Description: type D freeform_sphericalCX	Number of Sides: Two	Material: Custom
Batch Size: 20	Lens Diameter [mm]: 132	Center Thickness [mm]: 60	Material type: glasses
Total Number Of Lenses: 500	Diameter Tolerance [mm]: 0.1	Center Thickness Tolerance [mm]: 0.1	Material cost per Volume [€/l]: 0
☐ Suited for LIDT	☐ Outer cylinder length bigger lens diameter	Non-circular circumference[mm]: Not Specified	Knoop hardness (HK): 600
			Acid resistance (SR): AR1
			Alpha (-30/70) [1/°C]: 7
			☑ Material suited for precision glass molding

Freeform example

TRL	material	3/	numbers	size	MSW	chain
789	glass	3	500	132	5	ccp bonnet

Resulting most cost-efficient fabrication chain:

Side 1:

- cnc sub aperture rough grinding
  - fabrication cost: 7.77€
  - fabrication time: 10.55min
- cnc sub aperture grinding
  - fabrication cost: 18.76€
  - fabrication time: 38.67min
- ccp bonnet
  - fabrication cost: 57.34€
  - fabrication time: 89.64min

Cost 83.87€
Time 138.86min
Capability factor: 0.998
Chain uniqueness: 2

Freeform example

TRL	material	3/	numbers	size	MSW	chain
789	glass	3	500	132	5	ccp bonnet
789	glass	3	500000	132	5	PGM

Resulting most cost-efficient fabrication chain:

Side 1:

- precision glass molding
  - fabrication cost: 22.81€
  - fabrication time: 17.58min

Cost 22.81€
Time 17.58min
Capability factor: 1.000
Chain uniqueness: 0

Freeform example

TRL	material	3/	numbers	size	MSW	chain
789	glass	3	500	132	5	ccp bonnet
789	glass	3	500000	132	5	PGM
789	glass	0.07	500	132	5	IBF

Resulting most cost-efficient fabrication chain:

Side 1:

- cnc sub aperture rough grinding
  - fabrication cost: 7.77€
  - fabrication time: 10.55min
- cnc sub aperture grinding
  - fabrication cost: 18.76€
  - fabrication time: 38.67min
- ccp bonnet
  - fabrication cost: 57.34€
  - fabrication time: 89.64min
- ccp ion beam figuring
  - fabrication cost: 69.64€
  - fabrication time: 59.04min

Cost 153.52€
Time 197.90min
Capability factor: 0.993
Chain uniqueness: 0

Freeform example

TRL	material	3/	numbers	size	MSW	chain
789	glass	3	500	132	5	ccp bonnet
789	glass	3	500000	132	5	PGM
789	glass	0.07	500	132	5	IBF
789	glass	3	500	132	0.1	IBF

Resulting most cost-efficient fabrication chain:

Side 1:

- cnc sub aperture rough grinding
  - fabrication cost: 7.77€
  - fabrication time: 10.55min
- cnc sub aperture grinding
  - fabrication cost: 18.76€
  - fabrication time: 38.67min
- ccp bonnet
  - fabrication cost: 57.34€
  - fabrication time: 89.64min
- ccp ion beam figuring
  - fabrication cost: 22.66€
  - fabrication time: 9.23min

Cost 106.53€
Time 148.09min
Capability factor: 0.337
Chain uniqueness: 0

Freeform example

TRL	material	3/	numbers	size	MSW	chain
789	glass	3	500	132	5	ccp bonnet
789	glass	3	500000	132	5	PGM
789	glass	0.07	500	132	5	IBF
789	glass	3	500	132	0.1	IBF
456	glass	3	500	132	0.1	FJP

Resulting most cost-efficient fabrication chain:

Side 1:

- cnc sub aperture rough grinding
  - fabrication cost: 7.77€
  - fabrication time: 10.55min
- cnc sub aperture grinding
  - fabrication cost: 18.76€
  - fabrication time: 38.67min
- ccp wheel polishing
  - fabrication cost: 52.52€
  - fabrication time: 80.73min
- ccp fluid jet polishing
  - fabrication cost: 16.68€
  - fabrication time: 17.01min

Cost 95.73€
Time 146.96min
Capability factor: 0.999
Chain uniqueness: 4

Freeform example

TRL	material	3/	numbers	size	MSW	chain
789	glass	3	500	132	5	ccp bonnet
789	glass	3	500000	132	5	PGM
789	glass	0.07	500	132	5	IBF
789	glass	3	500	132	0.1	IBF
456	glass	3	500	132	0.1	FJP
789	german	3	500	132	0.1	SPDT

Resulting most cost-efficient fabrication chain:

Side 1:

- cnc sub aperture rough grinding
  - fabrication cost: 16.32€
  - fabrication time: 27.42min
- cnc sub aperture grinding
  - fabrication cost: 49.98€
  - fabrication time: 100.55min
- diamond turning
  - fabrication cost: 67.46€
  - fabrication time: 90.29min

Cost 133.75€
Time 218.26min
Capability factor: 0.997
Chain uniqueness: 0

Freeform example

TRL	material	3/	numbers	size	MSW	chain
789	glass	3				ccp bonnet
789	glass	3				PGM
789	glass	0.0				IBF
789	glass	3				IBF
456	glass	3				FJP
789	german	3				SPDT
123	fused silica	3	500	3	0.1	full aperture laser polish

Resulting most cost-efficient fabrication chain

Side 1:

- cnc sub aperture rough grinding
  - fabrication cost: 1.73€
- cnc sub aperture grinding
  - fabrication cost: 1.49€
- ccp laser melting
  - fabrication cost: 0.72€

Cost 3.94€
Capability factor: 0.997
Chain uniqueness: 0

Total fabrication cost: 8.96€

Prototype batch lead time: 10.67 days

Freeform example

TRL	material	3/	numbers	size	MSW	chain
789	glass	3				ccp bonnet
789	glass	3				PGM
789	glass	0.0				IBF
789	glass	3				IBF
456	glass	3				FJP
789	german	3				SPDT
123	fused silica	3	500	3	0.1	full aperture laser polish
789	fused silica	3	500	3	0.1	PGM

Resulting most cost-efficient fabrication chain

Side 1:

- precision glass molding
- fabrication cost: 82.01€

Cost 82.01€
Capability factor: 1.000
Chain uniqueness: 1

Total fabrication cost: 86.70€

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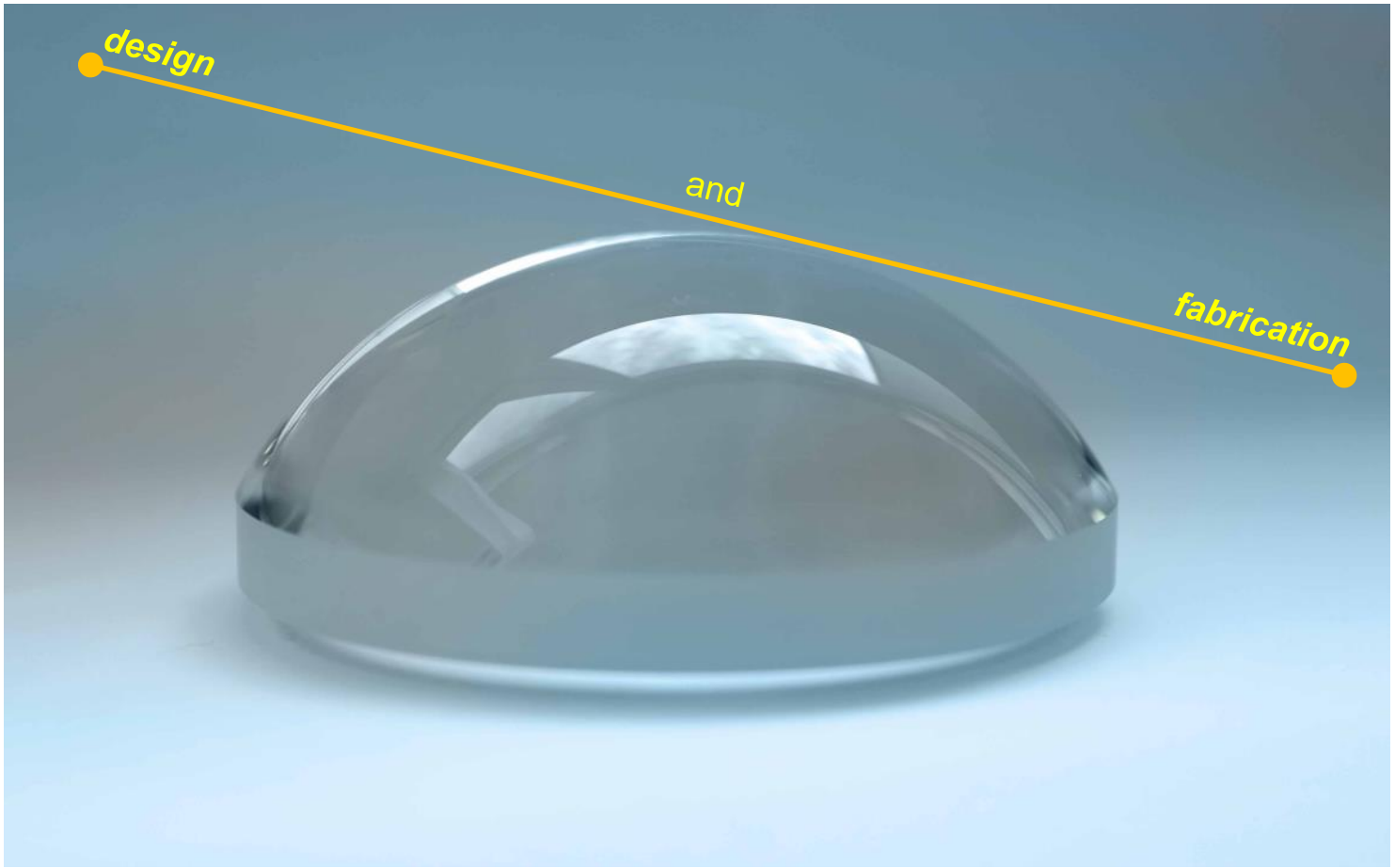
Optics Industry's Game Changer

- reads in lens data
- determines the optimal fabrication chain at minimum cost and risk$



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Optics Industry's Game Changer

- reads in lens data
- determines the optimal fabrication chain at minimum cost and risk$
- balancing design and fabrication

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…selected customers

HHV ADVANCED Technologies
A HHV GROUP COMPANY

Cooke

Carl Zeiss AG
Jena, Germany

ZEEKO Ltd

JOY TEAM
Optical Systems Design

INSTITUTO DE ASTROFISICA DE CANARIAS · IAC ·

INNOVIZ™
TECHNOLOGIES

bi-POL

ANAX Optics

**Leica Camera,
Wetzlar, Germany**

eo Edmund optics | worldwide

SAFRAN

HENSOLDT
Detect and Protect.

VUB

B-PHOT
BRUSSELS
PHOTONICS

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…selected applications

Optics Purchasing

- → cuts down vendors quotes by 30%
- → minimize risk of vendors failure
- → enables vendors audits

Optics Design

- → cuts down development time by factor of 2
- → cuts down number of meetings
- → cost impact analysis of design parameters

Optics Production

- → cuts down 20% fab chains cost
- → fab chain marketability analysis
- → capacity steering with one click

Training

- → annual UNIVERSITY lectures at Rochester, Arizona, Huddersfield and in Jena
- → in-company training of Optics Fab engineers

… based on the information provided by PanDao customers

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- *many thx*
- *dōmo arigatō*
- *grazie*
- *dank je wel*
- *dzenkuje*
- *vielen Dank*

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