Conception d'optique freeform à TAS

SFO 3e journée de calcul optique

N.TETAZ

17/06/16

19/05/2016

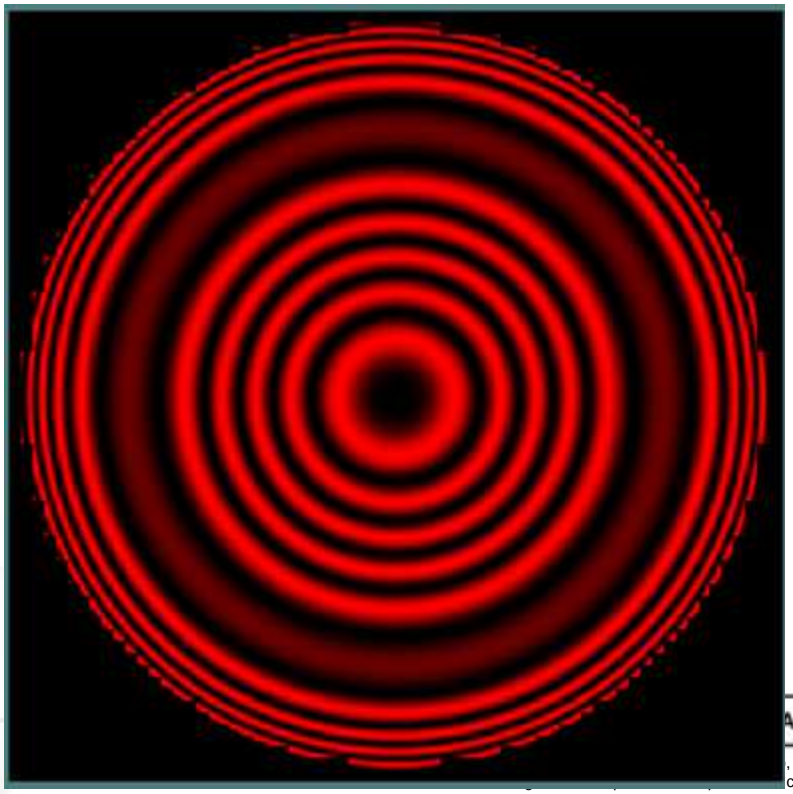
Ref.:

ThalesAlenia Space

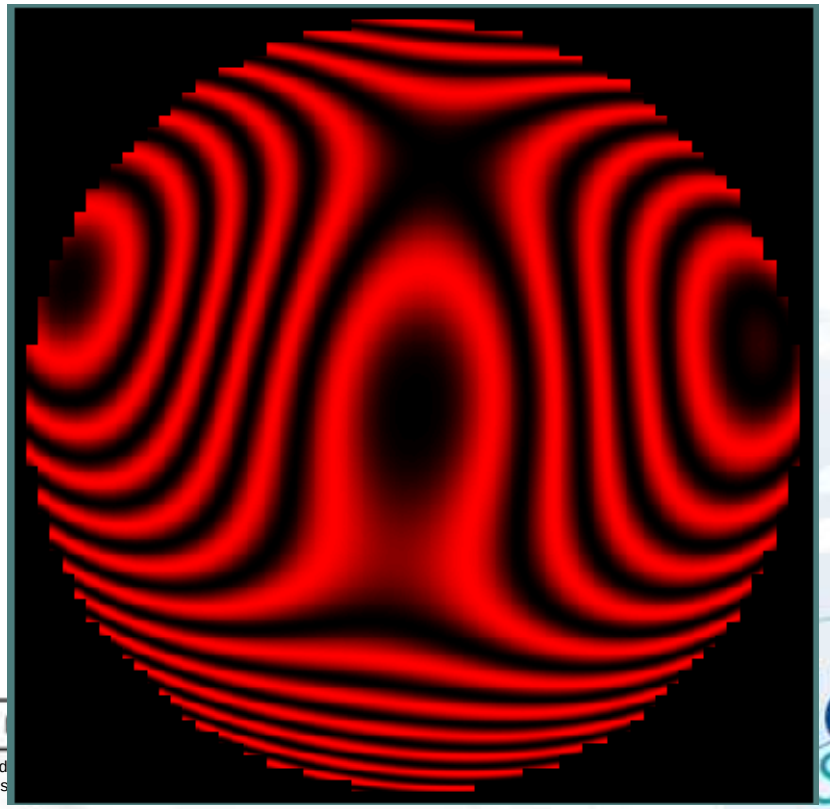
Freeform definition

- What is a freeform surface ?
  - In the past, “simple” toroidal surface are considered as freeform,
  - Today the label freeform is applied to rotationally non-symmetric polynomial aspheres.

Classical Asphere



Freeform

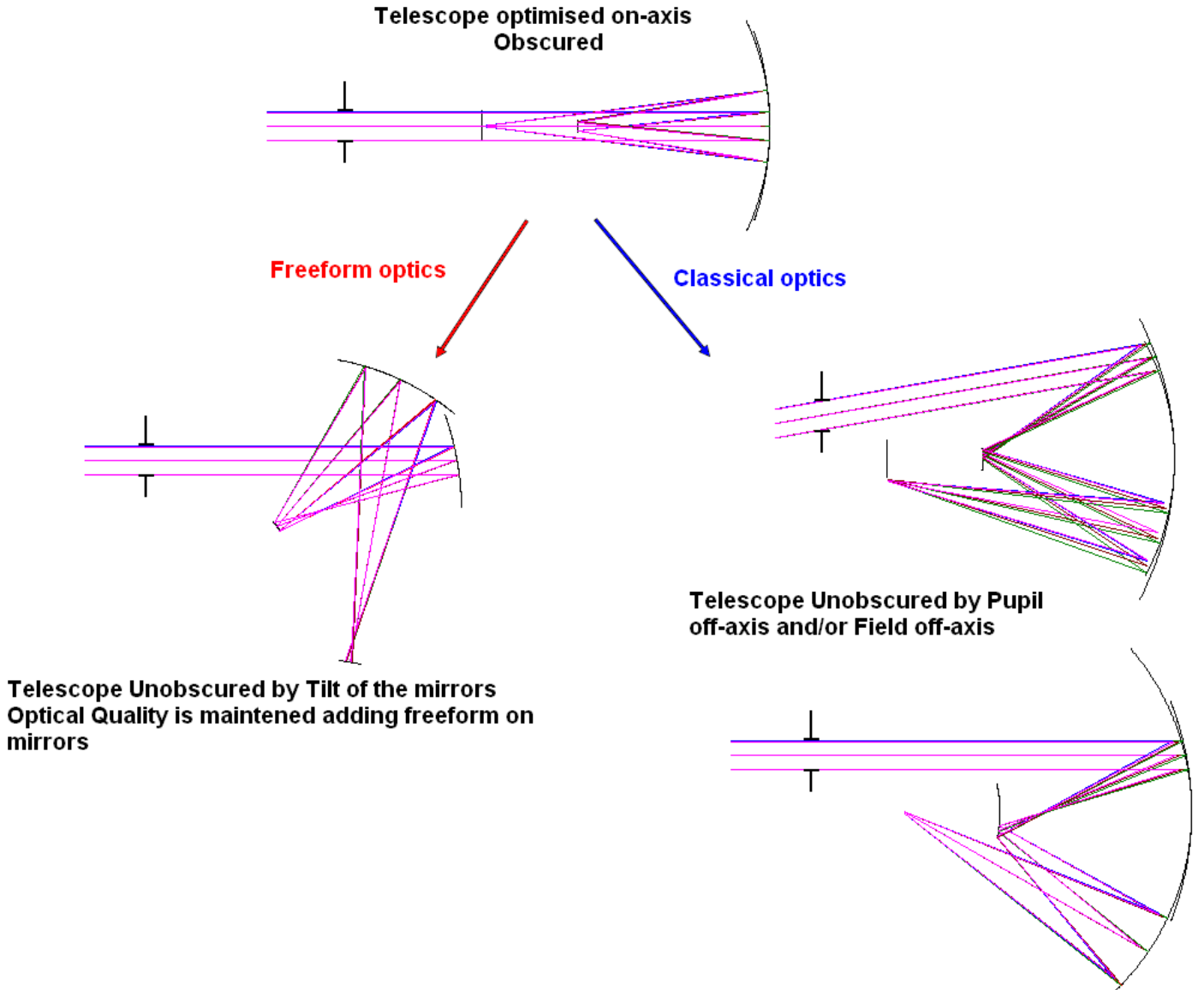


Freeform a new approach

- Freeform optics shall not be considered as a « super aspheric »
- The best way to design a freeform seems not to convert an aspheric to freeform.
- Freeform optics shall be considered as a new possible way to obtain unobscured, high quality reflective optics.
  - Indeed with classical optics, the only way to create an unobscured telescope corrected on-axis and over the field, is to work off-axis using a biased field of view and/or a pupil offset.
  - Freeform enables exploring another way: tilting (and/or decentering) mirrors. This is impossible without freeform surfaces. Tilting a classical aspheric mirror generates an unacceptable field asymmetric coma aberration

Freeform a new approach

- Freeform optics shall be seen as a new way to design an unobscured telescope corrected on axis and across the effective FFOV.



How designing freeform optics

- Thales Alenia Space has acquired experience in design of freeform surfaces represented by Zernike polynomials.

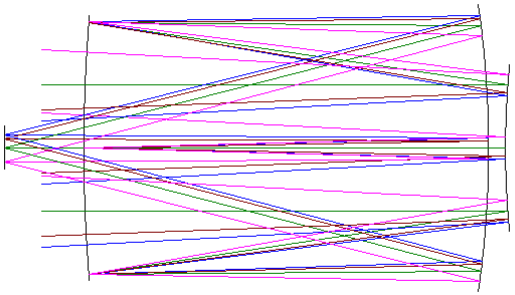
$$z = \frac{c\rho^2}{1+\sqrt{1-(1+k)c^2p^2}} + \sum_{j=1}^{n} C_j Z_j$$

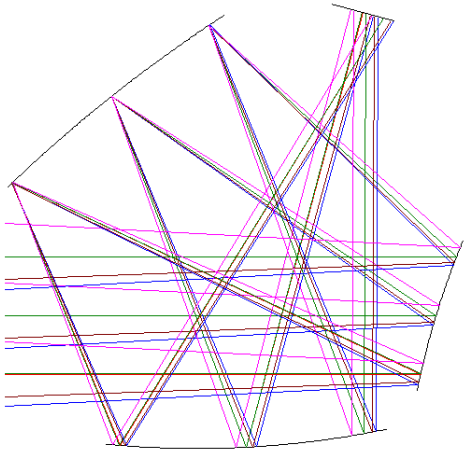
- The theory of aberrations for freefrom optical design is based on Nodal Aberration Theory (NAT), which is still an active subject of study.

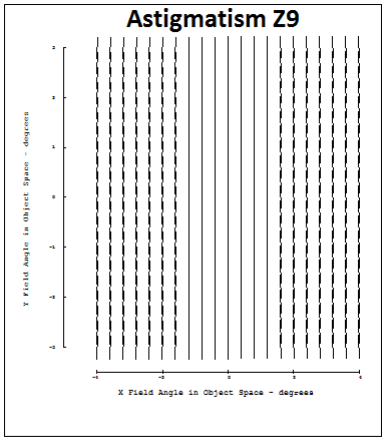
- Freeform optical designs made by TAS are based on an effective empirical method developed at the University of Rochester guided by new and unique insights into the intrinsic aberrations field structures for these designs forms.

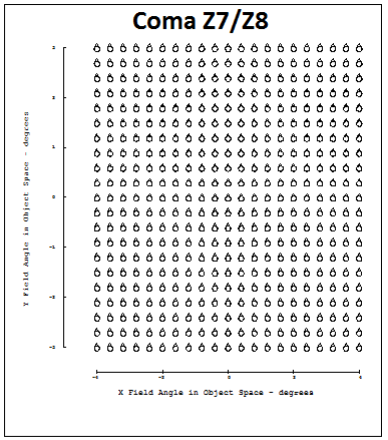
How designing freeform optics

- Used method (developped by University of Rochester) :
  - Optimisation of the on-axis design
  - Tilt of the mirrors => add coma and astigmatism
  - Reduction of coma and astigmatism added by the tilt, thanks to freeform mirror

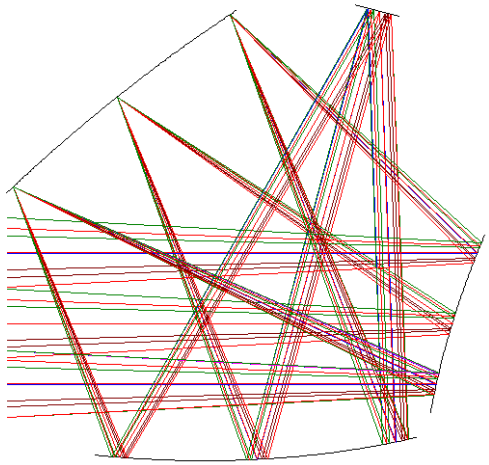


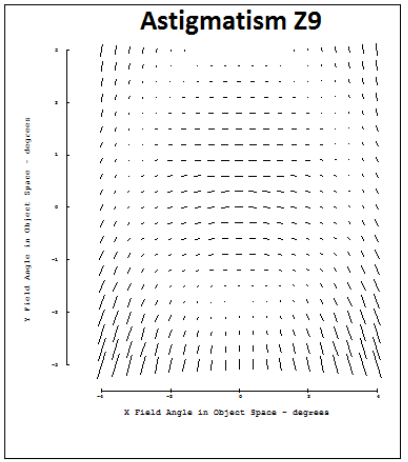


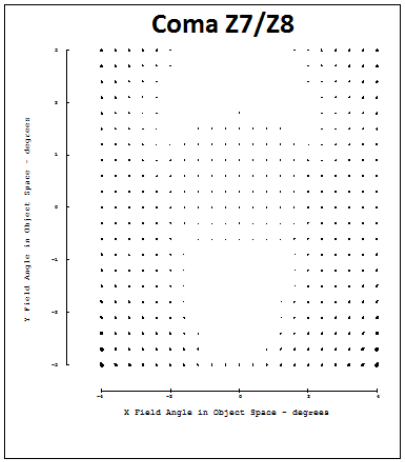




1000 λ







0.1 λ

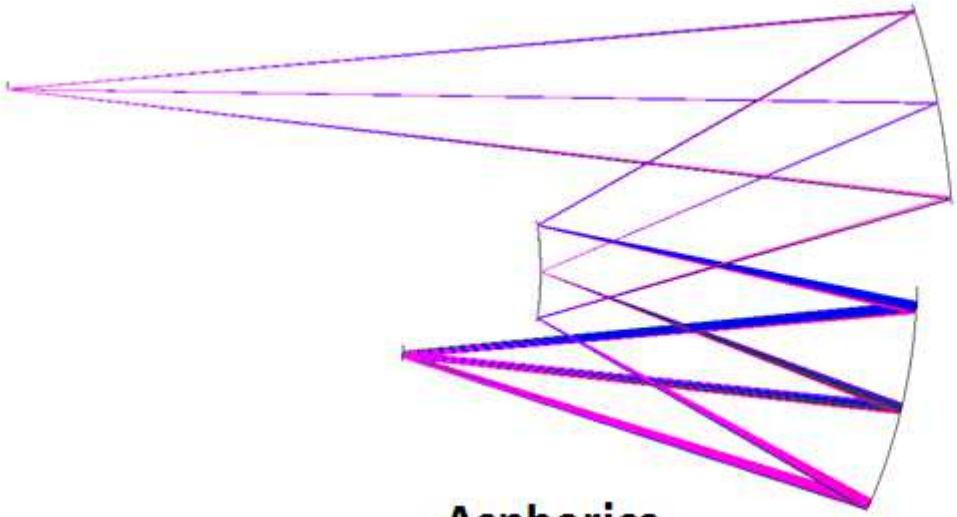
Interest of freeform optics for space mission

- Freeform optics could be used to :
  - Increase FoV and/or
  - Reduce instrument volume and/or
  - Reduce distorsion and/or
  - Increase image quality

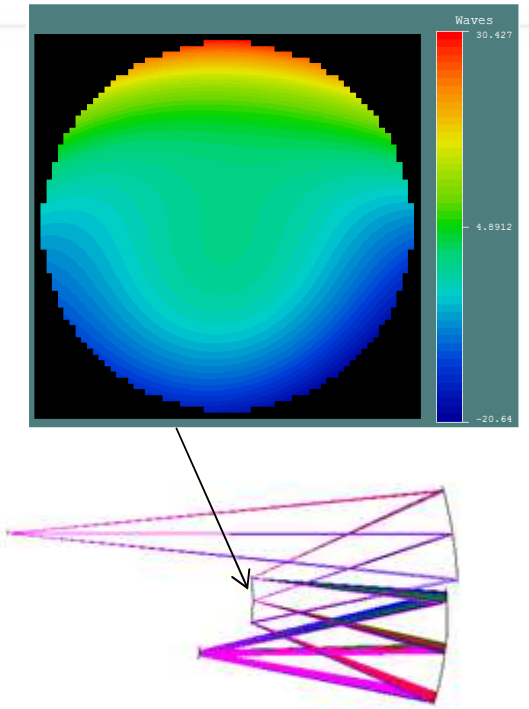
- TAS systematically investingates freeform solutions for new optical designs taking into account available control/manufacturing constraints

Gain on volume

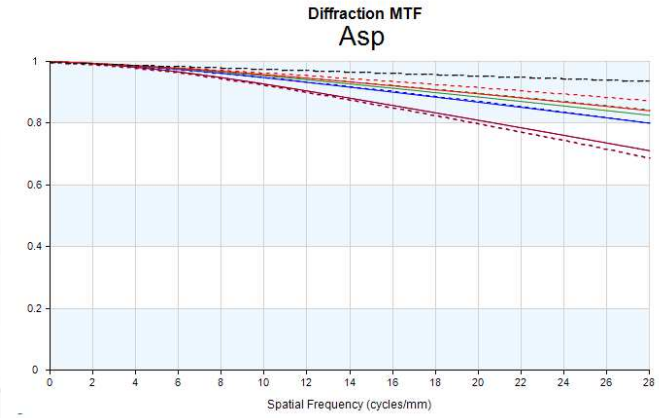
- Ex : Offner spectrometer (Magnification ½, NA=0.1)
- Strongly reduced volume with similar MTF

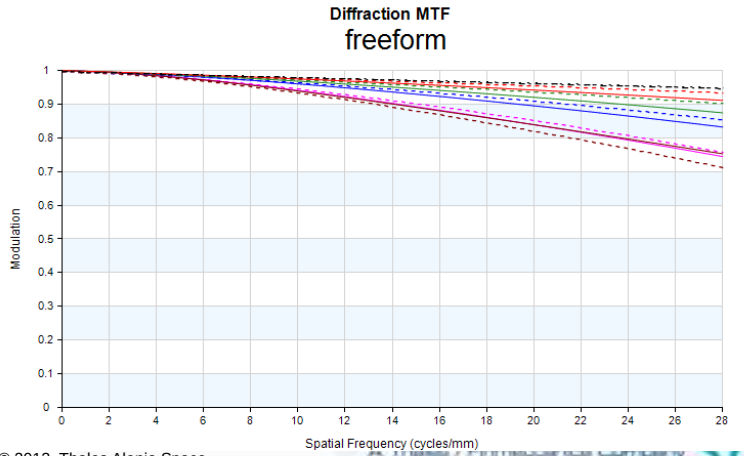


Aspherics



Freeform

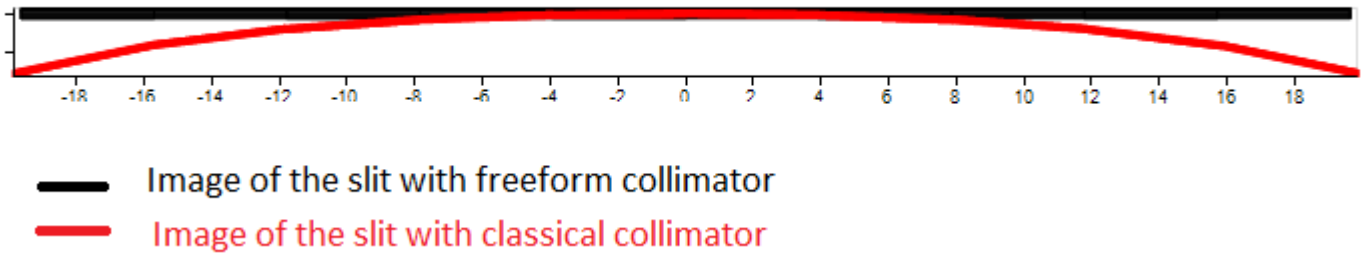




Gain on distortion

- Ex : Image of a slit through a collimator
- In spectrometer distortion of the slit (called « smile ») should be minimized
- Freeform solution has same number of mirrors, same volume and same mass, but « smile » is strongly reduced :
  - Classical aspheric design : distortion « smile » 200um
  - Freeform design : « smile » <1um

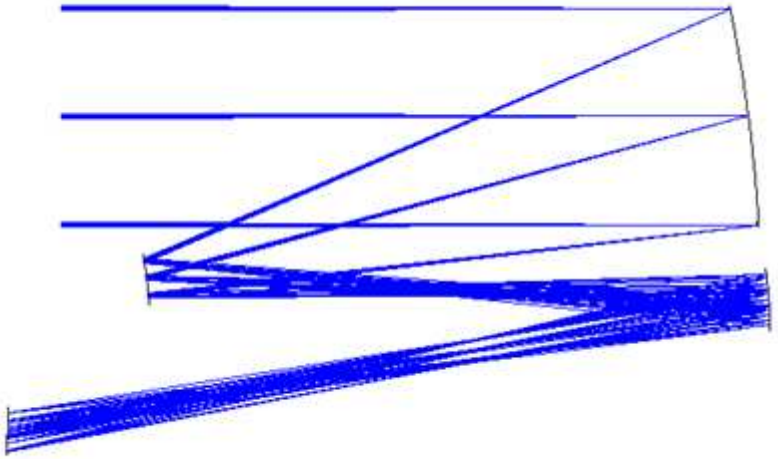
Patent Pending



Gain on FoV

- Ex: Large FoV Korsch telescope
- TAS is curently patenting an unobscured Korsch with FoV <6°
- Freeforms enabling to increase FoV, to unobsured Korsch design and to avoid machining central hole in primary mirror.

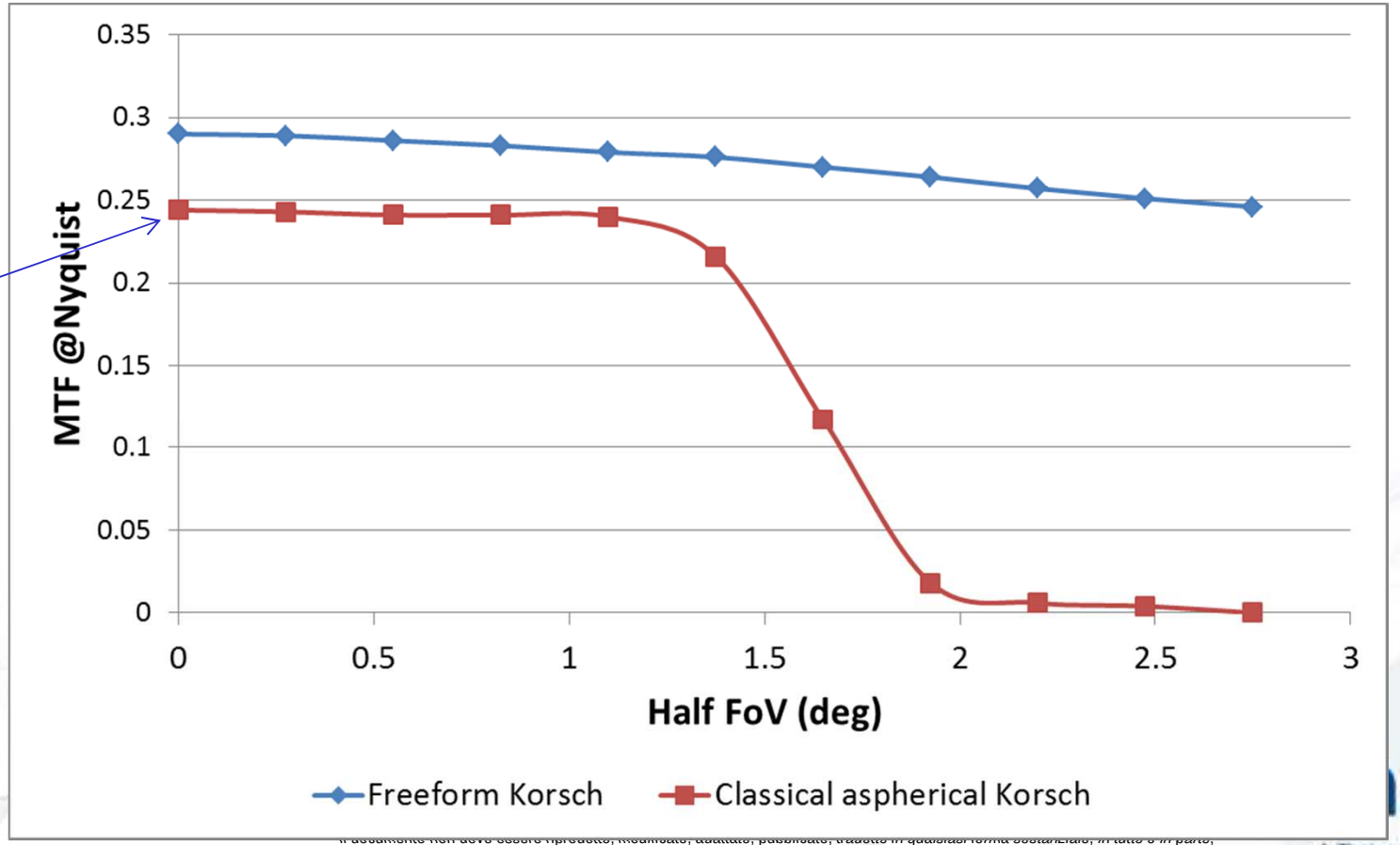
Patent Pending

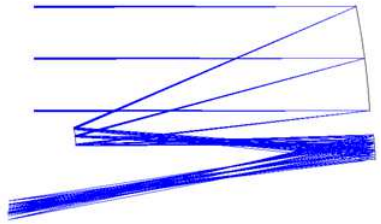


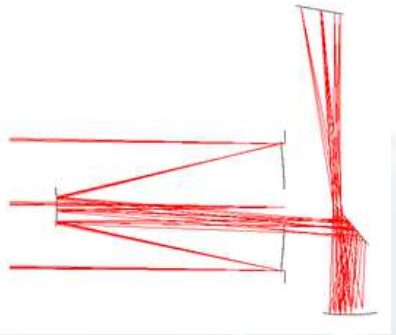
Gain on FoV

- Freeforms enable to double FoV (linear FoV : 3°->6°)
- Unobscured system has :
  - Better MTF and radiometry
  - Less straylight

20% obscuration

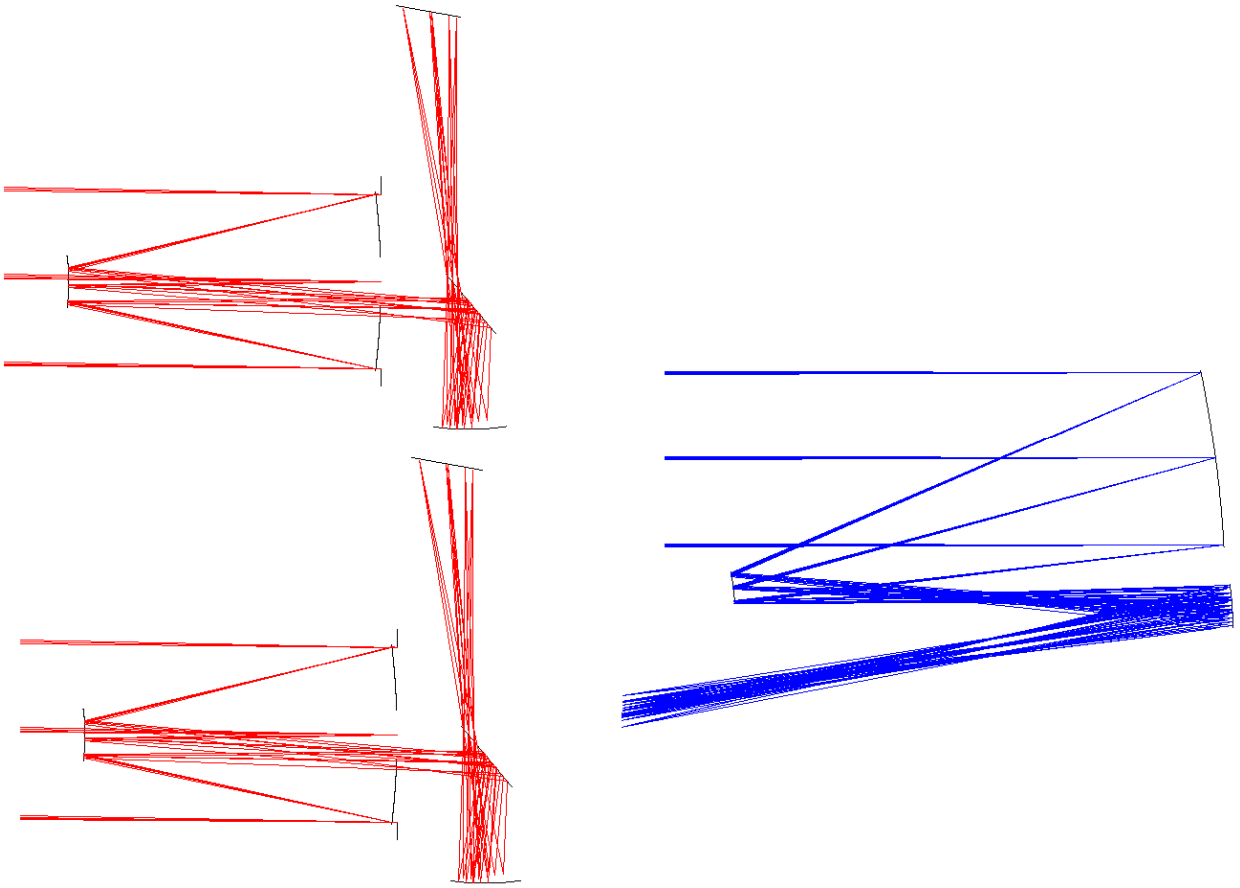






Gain on FoV

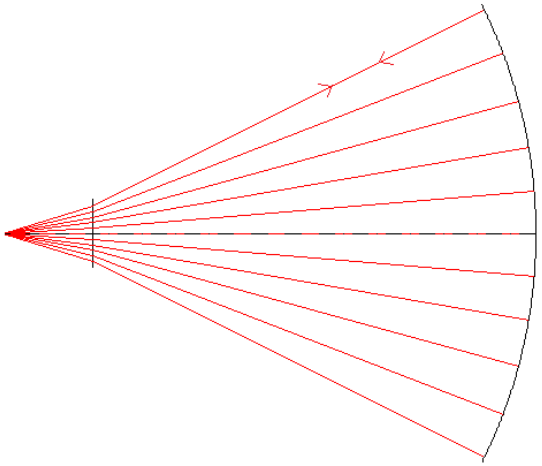
- Possible applications
  - For large FoV applications, use of one instrument instead of two
  - Unobscured Korsch could be used in stringent straylight requirements applications

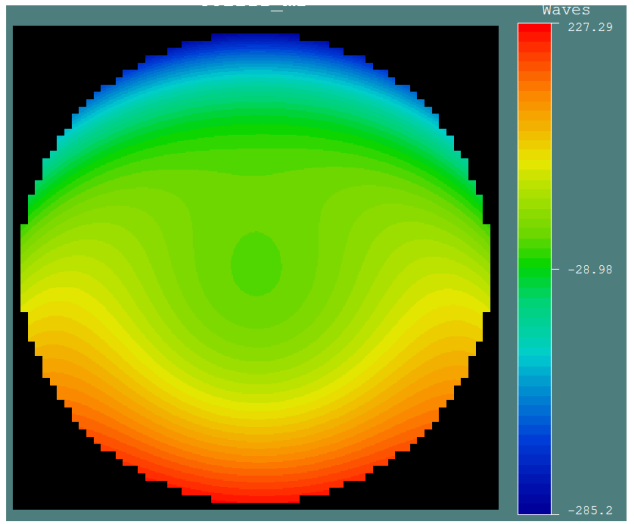


Tools developed in TAS

- During design phase it is difficult to estimate freeform mirror manufacturing difficulty
- TAS developed tools to estimate freeform difficulty and feasabilty
  - Delta-sag and slope between freeform and best sphere
  - Calculation of CGH needed to measure freeform

- However TAS needs from manufacturers
  - Criterias for estimating manufacturing difficulties
  - Amplitude of these criterias
  - Explanation of manufacturing and control process
    - Needs of transitional CGH ?...





Conclusion

- Freeform surfaces seems really promising
- TAS is now familiar with the design of these new surfaces and systematically try to integrate freeform surfaces in new designs
- TAS already found interesting designs based on freeform
- TAS expects during this workshop to interact with manufacturers and to discuss about their abilities and limitations on freeform manufacturing