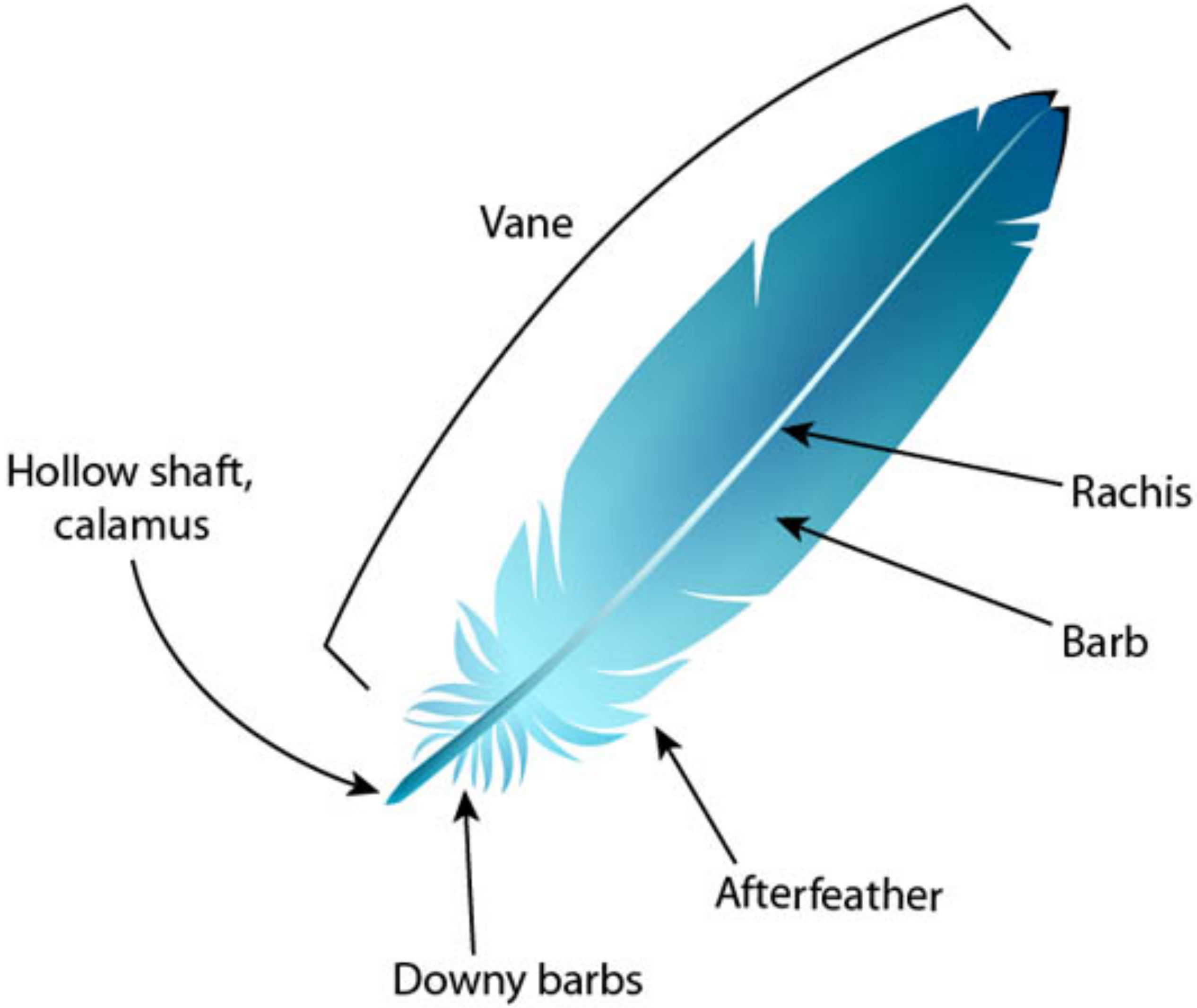
Lightweight Coronal Imager for Solar-C

Frédéric Auchère

Institut d'Astrophysique Spatiale

`frederic.auchere@ias.u-psud.fr`



Objectives

-Context imaging from high latitudes:

- Variety of morphologies and uniqueness of the opportunity calls for:

    - Full Sun imaging
    - Multiple wavelengths to cover a range of temperatures
    - 1 arcsecond class resolution
    - Compatible exposure times (~ 10s)

- All this in a compact, lightweight package due to the off-ecliptic mission profile

Towards compactness

-This  is a much lighter camera than this 

as less functionalities.

- A lot can still be achieved in a compact package: this 

MPixels camera.

How to make a compact, high performance, Soft X-Ray/EUV imager ?

- A telescope size (thus its mass) is proportional to its focal length
  - Rule of thumb: L ~ F/2

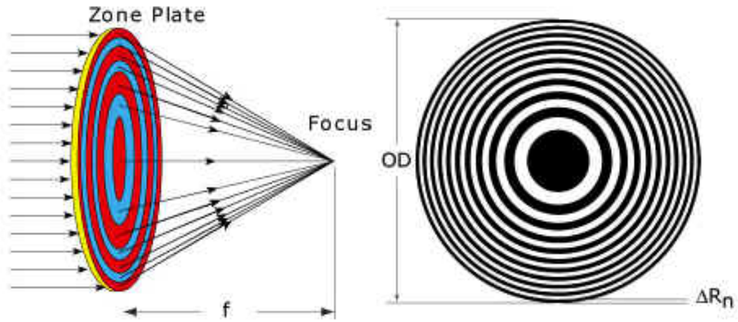
- Therefore, we need to reduce the focal length (& the detector plate scale) to make a shorter & lighter telescope

- This is difficult to achieve with traditional two-mirror imagers:
  - increased pots sizes, impossible fabrication & alignment tolerances

- A family of Fresnel Zone Plates (FZP) may offer a solution

Lightweight optics : Fresnel Zone Plates (FZP)

- Thin metallic plate made of alternating opaque and transparent rings



- Radii of the N rings defined by co-phasing of the rays at focus:

$$R_N^2 + f^2 = (f + N\lambda)^2 + R_N^2 \sim N\lambda f$$

- The spot size is approximated by $1.22\,\lambda f/2R$, i.e. the width of the last zone.

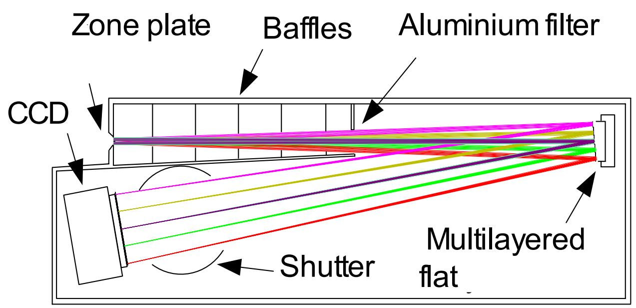
  - The resolution is driven only by the fabrication limit

-Several advantages:
  - Lightweight: thin metallic plate
  - Works at any wavelength
  - Images as sharp as the fabrication limit
  - Possible to use small plate scale detectors (compactness at hand !)

- Heritage:
  - Zone plates are common on X-Ray synchrotron beam lines
  - X-Ray images of the Sun taken with FZPs on sounding rockets (Elwert, 1968)

Possible concept

- Spectral selection using a multilayer coated flat (→ length ~F/2)



- Example: λ = 19.5 nm, FOV 0.8°, 2k x 2k, detector

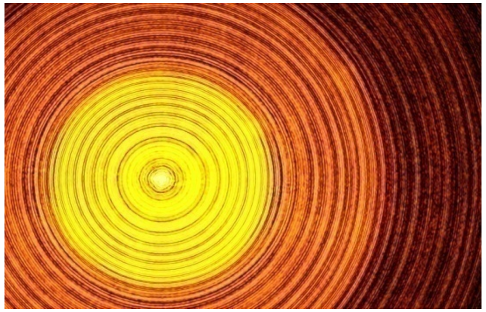
	10 microns pixels	5 microns pixels
f	1466 mm	733 mm
Fabrication Limit $\Delta R = 10\ \mu m$	$R = 1.43$ mm $N = 71$ zones f / D = 514	$R = 0.71$ mm N = 35 zones f / D = 733
Fabrication Limit $\Delta R = 1\ \mu m$	$R = 14.3$ mm $N = 7146$ zones f / D = 51	$R = 7.14$ mm N = 3573 zones f / D = 72

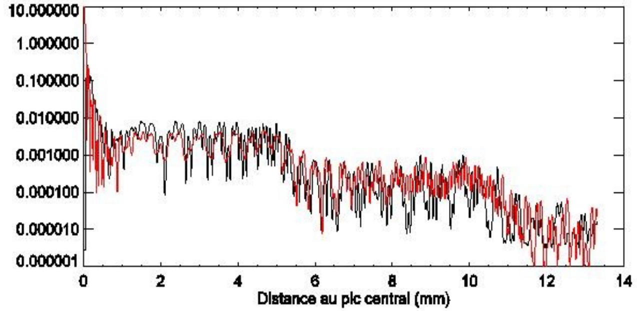
- Decrease pixel size → more compact → but less light (f/D) → need to decrease fabrication limit. Or use tricks (more on this later)

Limitations of classical FZPs

- Typically small diameter imposed by the fabrication limit

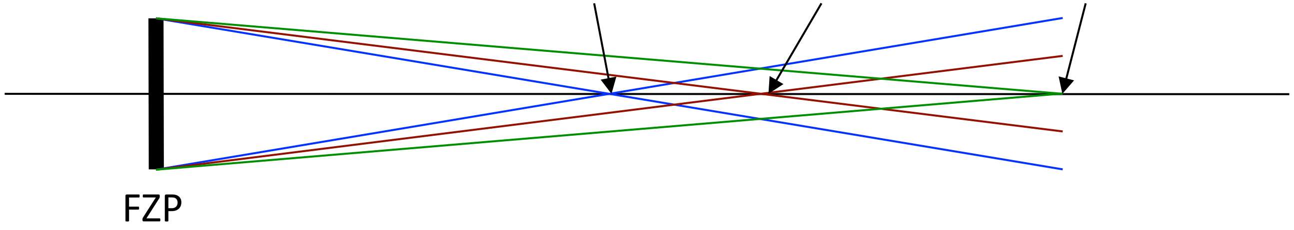
- Extended PSF wings: source point image (log scale) made at IAS, and radial cut:





- Very peaked PSF, but concentric plateaus at 10^{-4} of central peak, 10^{-5}, etc.

-Very chromatic devices: act as a diffraction grating along the optical axis



-PSF plateaus correspond to intersection of primary focal plane with higher order focusing cones

Modified Fresnel Zone Plates (MFZP)

- Several recent studies have shown that it is possible to overcome the limitations of classical FZPs

- **A modification of the zones radii law** suppresses the high diffraction orders:

  - Most of the energy is put back in the primary focus
  - PSF plateaus are suppressed along with the high order foci
  - Possible to increase the MFZP radius without changing fabrication limit: f/D ↘

-MFZP allow f/D ratios similar to those of two-mirror EUV telescopes:

  - STEREO EUVI f/D = 30 is easily achievable

- MFZPs have been fabricated and successfully tested at IAS

Conclusions

- Significant gains in mass can be achieved if focal length can be reduced

- Image quality is hard to maintain with a limited number of reflective optics

- Fresnel Zone Plates (FZPs) are intrinsically high resolution imaging devices

- The limitations of traditional FZPs can resolved with MFZPs

- An imager using a Modified Fresnel Zone Plate can be made very compact

    - A 2k x2k , 5 μm/pixel full-Sun imager can fit in a 30 x 10 x 10 cm box
    - Resolution & sensitivity are comparable to those of the equivalent classical imagers