Digital Camera Obscuras

ISS-334, January 17, 2023

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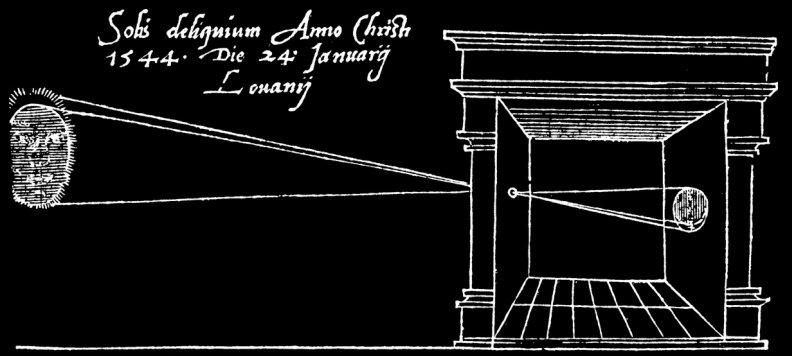
Camera Obscura

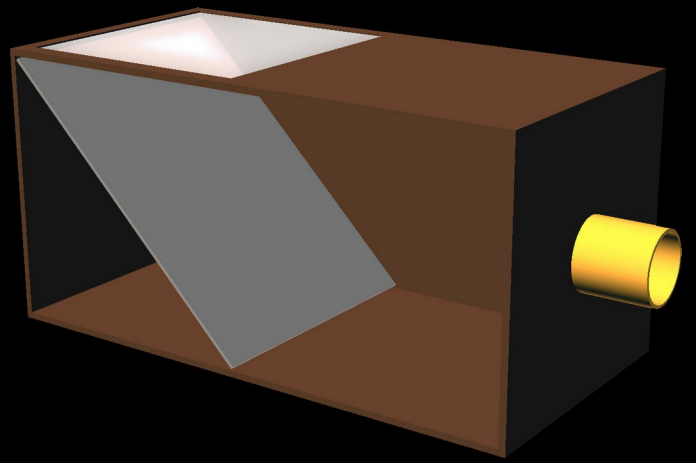
A darkened chamber into which an image of a bright outside scene is projected by a pinhole or lens



Gemma Frisius, "De Radio Astronomica et Geometrica," 1545

- Religious uses
- Observe the Sun
- Trace the image to make a permanent copy

Camera Obscura Advances



- Front Side Illumination (FSI)
  - Project on *opaque* screen
  - Viewer casts a shadow
- Back Side Illumination (BSI)
  - Project on *translucent* screen
  - Image orientation is still rotated 180°
- Use one or more mirrors to correct orientation

Digital Camera Obscura

- Camera *replaces* manual copying with film or sensor
- Digital camera obscura (DCO) uses a complete digital camera to re-image and capture the appearance of the obscura screen
  - A big screen behaves like a big sensor
  - Camera sensor size is irrelevant

Pinhole DCOs

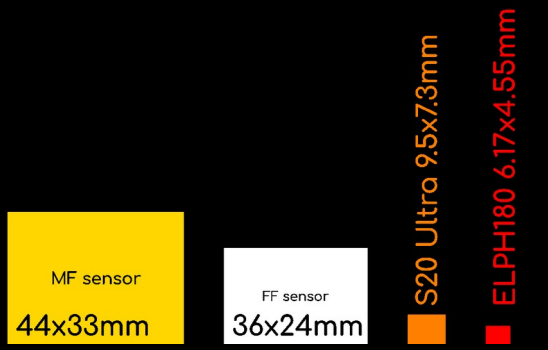
- Pinhole imaging
  - Infinite Depth of Field (DoF)
  - No geometric distortion
  - Zoom by moving pinhole
  - Dim image, shows dust
  - Ideal pinhole diameter in mm = $0.0366\sqrt{f}$
- Resolution in line pairs per mm is fixed with f, only way to increase resolution is larger image

Shallow DoF Lens DCOs

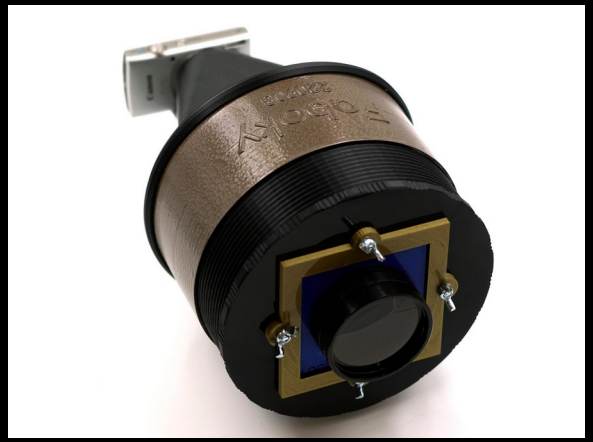
- DCO is often called DoF adapter or Bokeh adapter
- What makes DoF shallow?
  - Long focal length (f)
  - Big aperture, small N in f/N:
    $N \approx 1/(2 * \sin(\Theta))$, so is $N<0.5$ possible?
  - For same field of view (FoV), **equivalent DoF** divides both f & N by crop factor

Crop Factors

- Crop factor is ratio of image diagonals (circle diameters)
- Faboky's screen is 144x108mm, so full frame (FF) is a 4.16x crop
- CHEM's screen is 44x33mm, so FF is a 1.27x crop (covered by *many* FF lenses)



Faboky Equivalent f & f/number



32mm f/0.53

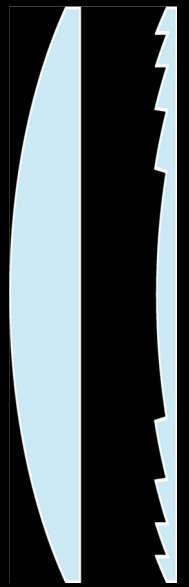
70mm f/0.4

23mm f/0.13

- Fastest commercial FF lens was f/0.7
- Cost <$25, weight <1/2 Nikon 58mm f/0.95 Noct

Shallow DoF Lens DCO Options

- Use as much of image circle as possible
- Conventional moderately-fast lenses
  - Faboky: 4x5 135mm f/2.2 ⇒ 32mm f/0.53
  - CHEM: FF 58mm f/1.2 ⇒ 46mm f/0.94
- Fresnel lenses
  - Thin, large, cheap, usually plano-convex
  - Can use 1-3 elements together
  - Poor image quality



BSI DCO Prototype Families

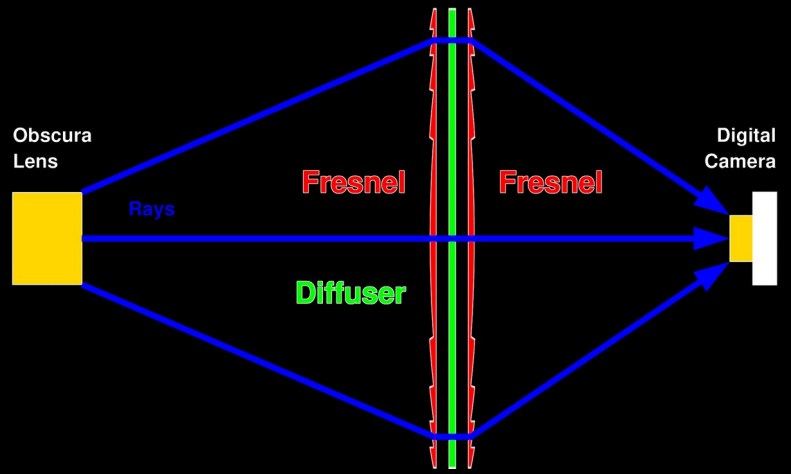
Faboky: Fresnel Apodized Bokeh Adapter from KY
4x5ob: 4x5 Obscura Back
CHEM: Canon Hack Emulating Medium format

BSI DCO Screen Options

- Ideal material characteristics?
  - No obvious texture nor color cast (some screens move to blur texture)
  - Thin to avoid ghosting, CA, & internal diffusion
  - High opacity: no hot spot, very dim image
  - High diffusion: even brightness, smears detail
- Materials include: ground/etched glass/plastic, tracing paper, Vellum, white film, & diffusers

BSI DCO Screen Options

- Low opacity, low diffusion gives bright and sharp image, *but so does clear glass or air...*
  - Might not form an image plane
  - Rays that pass without deflection can be lost
- Fresnel lens sandwich can even brightness



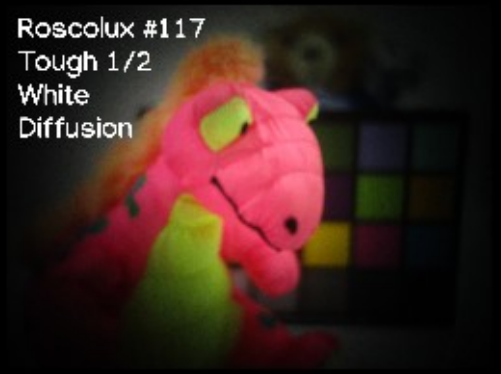

Native Lens
ELPH180


HP C3885A
High-Gloss
White Film
(front)


HP C3885A
High-Gloss
White Film
(back)

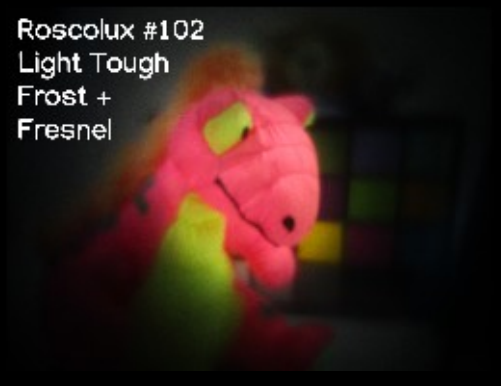

Recollections
Vellum
Paper


Roscolux #111
Tough
Rolux


Roscolux #117
Tough 1/2
White
Diffusion


Native Lens
ELPH180 +
Fresnel


Roscolux #102
Light Tough
Frost


Roscolux #102
Light Tough
Frost +
Fresnel

BSI DCO Construction

- Bigger is better… if it fits on the bed of your 3D printer
- Interchangeable modules allow different lengths and mounts
- Can support different types of cameras:
  - Canon PowerShot (ELPH180)
  - Cell phone (S20 Ultra)

FSI DCO Angle Issues

- Camera can’t be where obscura lens is
  - Tilt camera and digitally correct
  - Use camera with shift lens
  - Semi-silvered mirror to bend obscura light path
- Can’t see viewfinder from behind the camera
  - Selfie mirror
  - Repositionable live view display

FSI DCO Prototype Family

FSIO: Front Side Illuminated Obscura

- Focus by threaded screen plate within barrel
- Digitally correct for camera angle

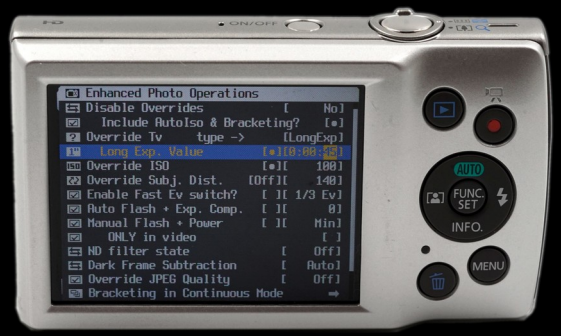
FSI DCO Screen Options

- Ideal material characteristics?
  - No obvious texture nor color cast
  - No specular reflections (gloss isn’t good)
  - High reflectance from surface
- Materials include: ordinary, photo printing, and art papers, white film, etc. – be sure to check characteristics of *both* sides

Digital Camera Options & Issues

- Ideal digital camera?
  - BSI fixed focus; FSI focus for screen in DoF
  - Long exposures/high ISOs for dim screens
  - Texture reference shot & texture removal
  - HDR for correcting uneven brightness
  - Perspective correction for FSI, mirroring
- CHDK (Canon hack development kit) makes PowerShots good programmable platforms

CHDK & `faboky.lua`



- CHDK itself provides raw capture, overrides for exposure parameters, manual focus, etc.
- `faboky.lua` does HDR captures for Faboky

Faboky BSI DCO with Cell Phone

- Cell phone is programmable, so live view could be corrected, etc.
- Low light performance is unusable for pinholes

Sample DCO Images

Pinhole

32mm f/0.53

23mm f/0.13

- Faboky BSI screen limits to ~ 4-6MP resolution
- FSIO FSI screen limits to ~ 20MP resolution

Conclusion

- 3D-printed DCOs viable to produce unique look
  - BSI DCOs much easier to use than FSI DCOs
  - FSI DCOs produce better IQ
  - Easy: leveraging lens coverage
  - Hard: screen & camera control/processing
- 89-page Instructable on Faboky construction:
  `https://www.instructables.com/3D-printed-Digital-Camera-Obscuras/`
- Others will be at linked from Aggregate.Org UNBRIDLED COMPUTING

Additional BSI DCO Images

- Taken with 4x5ob and 127mm *f*/4.7 Ektar
- Equivalent to 35mm *f*/1.3 on FF