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Apertures & Viewpoints

Hank Dietz

Computational Photography, Sept. 30, 2011

University of Kentucky
Electrical & Computer Engineering

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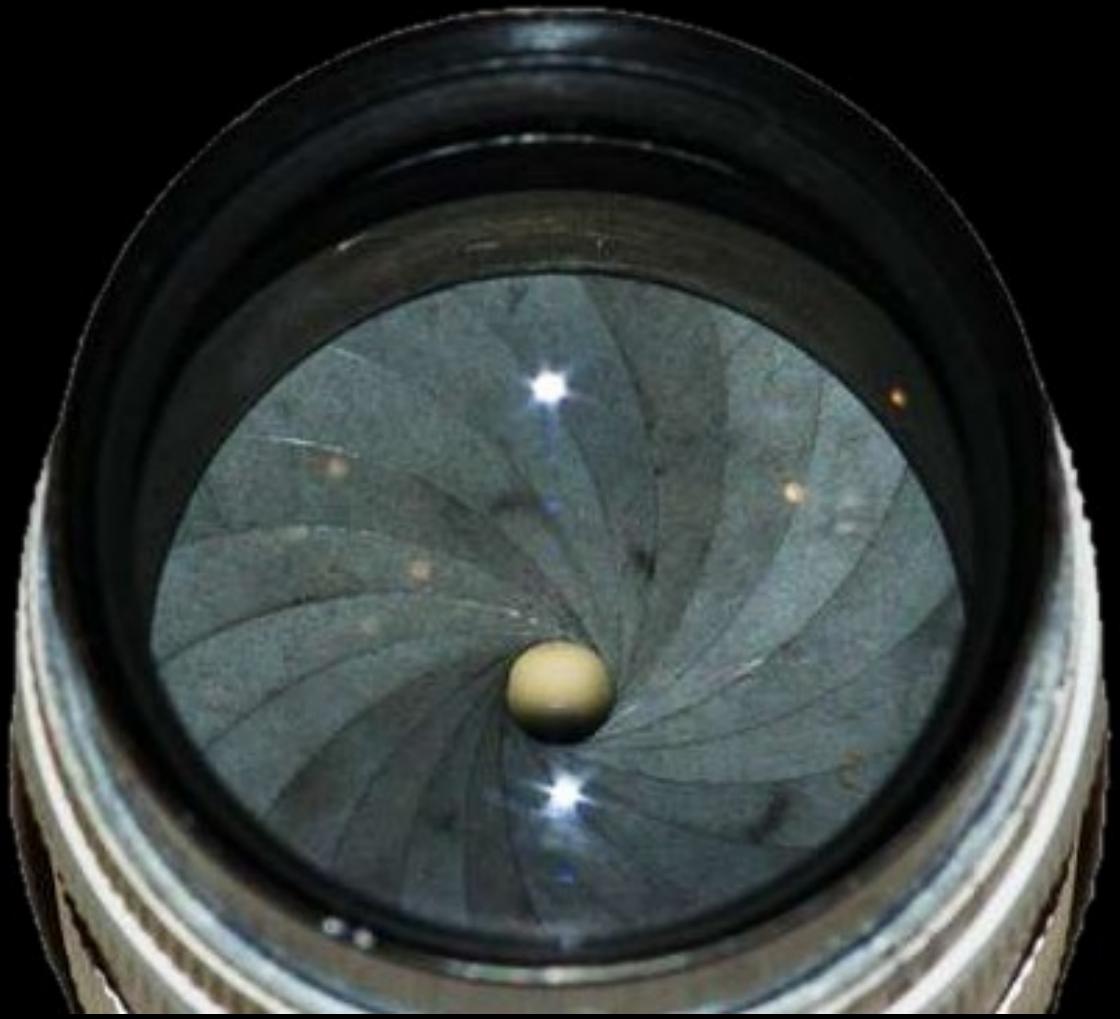
Aperture

- The aperture of a lens represents the area through which light is admitted by the lens
- Assuming a circular opening, the ***f/number*** of a lens is the *focal length / diameter*
- Light admitted is proportional to 1 / f^2

  0.7 *1 1.4 2 2.8 4 5.6 8 11 16 22 32 45*
- Effective *f* given transmission is *t/number*

Aperture



Aperture

- The aperture can be implemented by:
  - The lens barrel (when wide open)
  - Movable blades – an iris
  - Waterhouse stop – a hole in a plate
  - LC or other controllable opacity material
- The aperture can't be placed arbitrarily; incorrect placement causes vignetting
- Correct placement forms a “stop”

Stop Placement

- Usually more than one place it can go
  - In front of lens: easy to access
  - Inside lens: most common by far
  - Behind lens: a few camera bodies did this
- Aberrations may be affected by position
- To be a stop, aperture *effectively* must be no larger than any other stop...

Vignetting

- Darkened corners
- Three types:
  - Artificial vignetting due to lens length; common cause of cat's eye/swirl bokeh
  - Natural vignetting due to $\cos^4$ falloff; often worse on sensors with microlenses
  - Mechanical vignetting from external obstructions in the field of view
    – e.g., when aperture isn't a stop

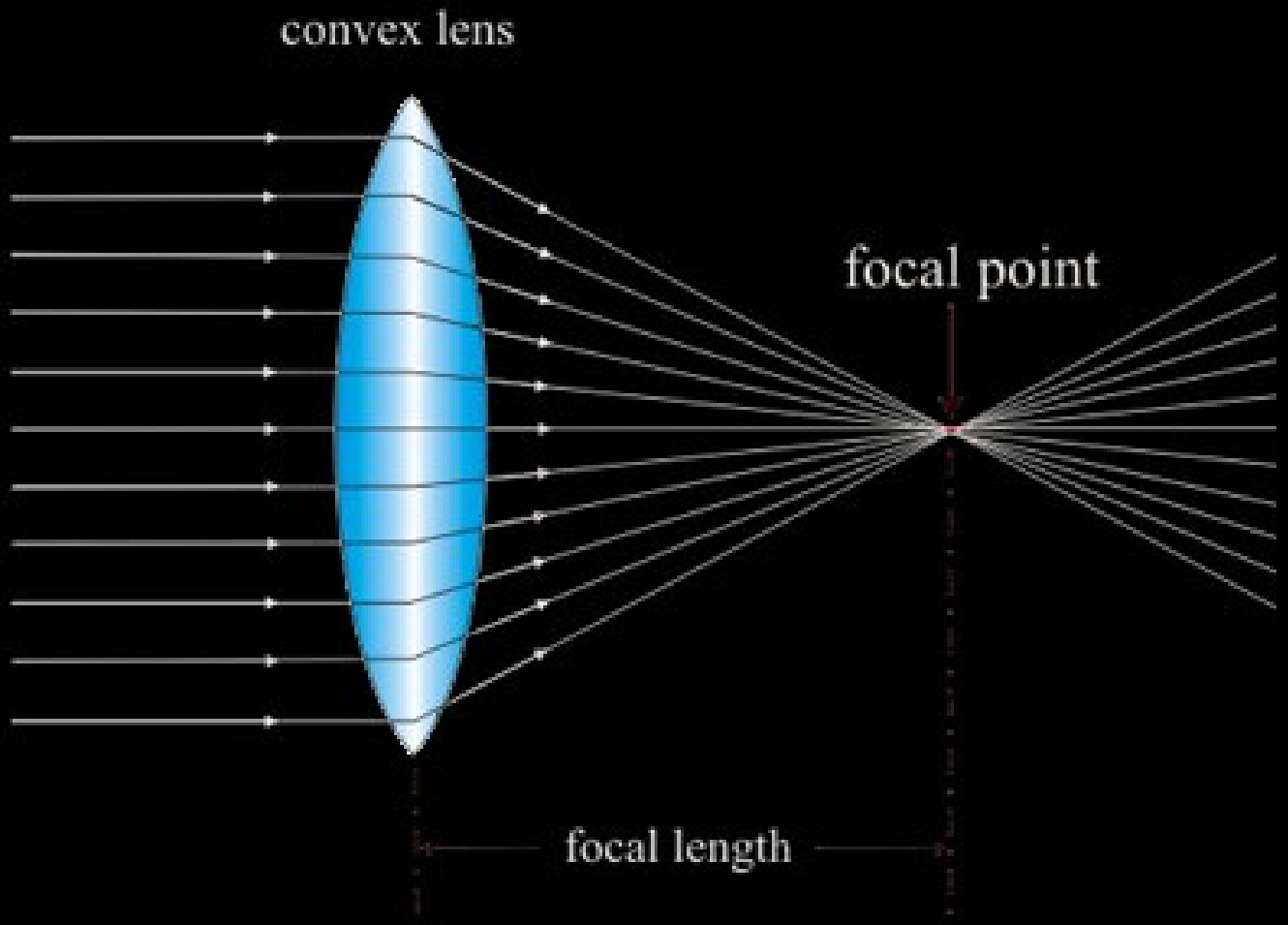
Depth-Of-Field (DOF)

- The range of depths in acceptable focus (i.e., with “small enough” PSF diameter)
- Larger *f/number* implies greater DOF; Depth-Of-Focus increases too
- Large *f/numbers* make diffraction significant, acting like pinholes and limiting resolution

Why Does The PSF Get Bigger When OOF?

- Recall that the PSF echoes (is clipped by) the shape of the aperture
- When a point is in focus, all rays from that point that pass through the lens end at the same spot on the film/sensor
- OOF, they land at different spots
- PSF grows in proportion to defocus because the point source rays separate different views

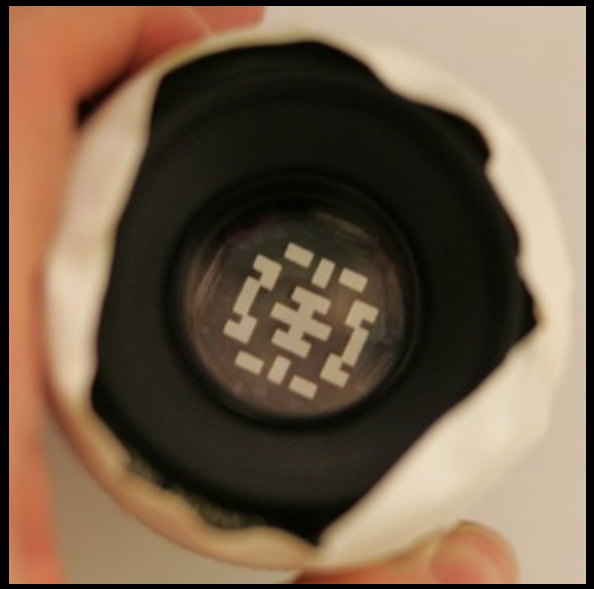
Let's Trace Some Rays...



Apertures Block Some Rays

- An aperture that acts as a stop simply blocks some rays – that's why its shape is imposed
- Using an easy-to-recognize aperture shape makes computational PSF recognition faster and more reliable
  - Coded aperture (originally in astronomy)
  - Aka, Structured or Shaped aperture

Some Coded Apertures (from MIT CSAIL)



Why Bother?

- Soft-focus effects!
- Cool bokeh effects!
- Recognizing PSFs in the captured image means knowing depth of the corresponding points in the scene!
- You know all those cool things you can do with Plenoptic (light field) cameras...
  you can do them with this too!

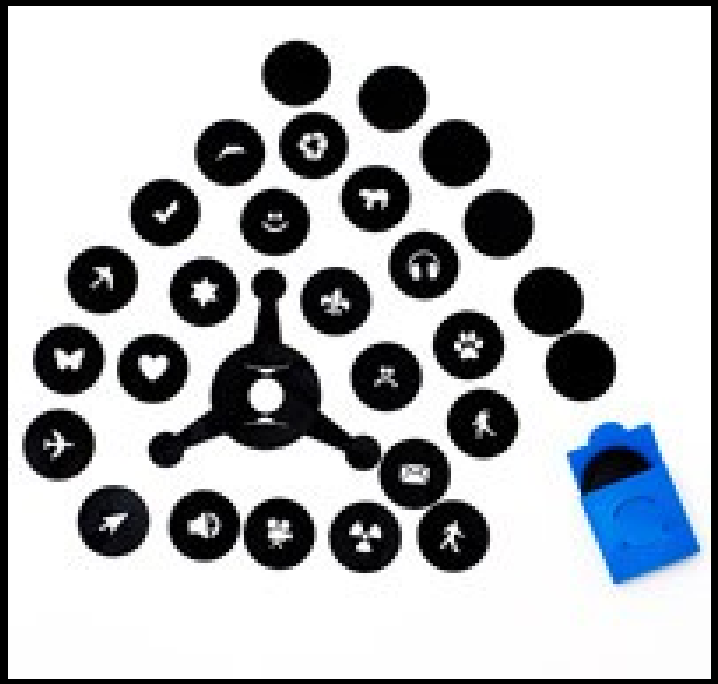
Soft Focus?

- Imagon & Fujinon “Sink Strainer” apertures

(images borrowed from internet)

Cool Bokeh Effects?

- E.g., from `bokehmasterskit.com`

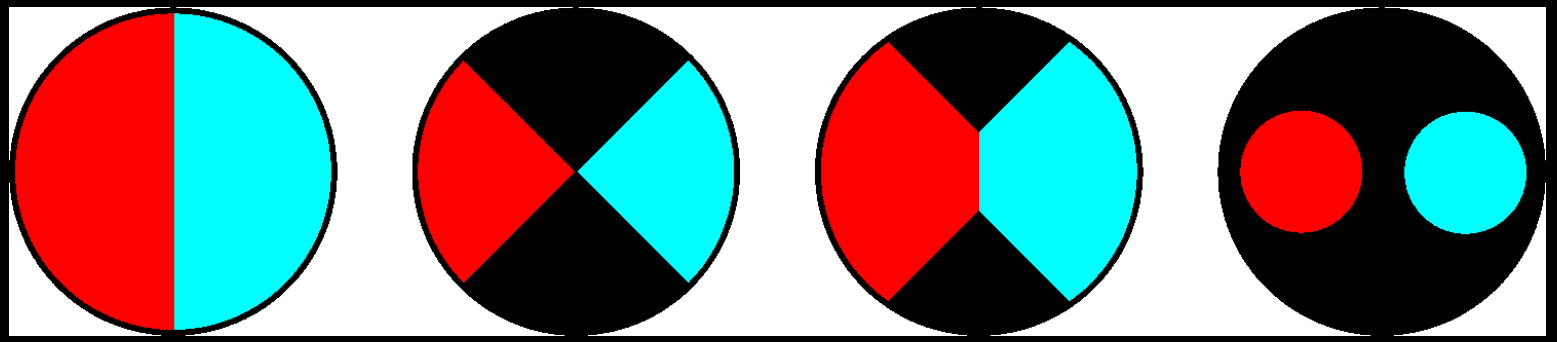


How To Computationally Recognize A Coded PSF

- Deconvolution (typically in frequency domain)
  – this is the standard approach
- Search for scene + PSF structure that create the image captured
  – my approach using Genetic Algorithm (GA), based on Allebach's Diffractive Optic (DO) direct binary search design method
- Use spectral (color) coding of the PSF
  – me, Baek et al., & Songer's 1973 patent!

Songer's 1973 Patent

- Use a color-coded aperture to directly capture a “3D” Anaglyph with a single shot, one lens
- Apparently used in Vivitar Qdos lens



My Single-Shot Anaglyphs

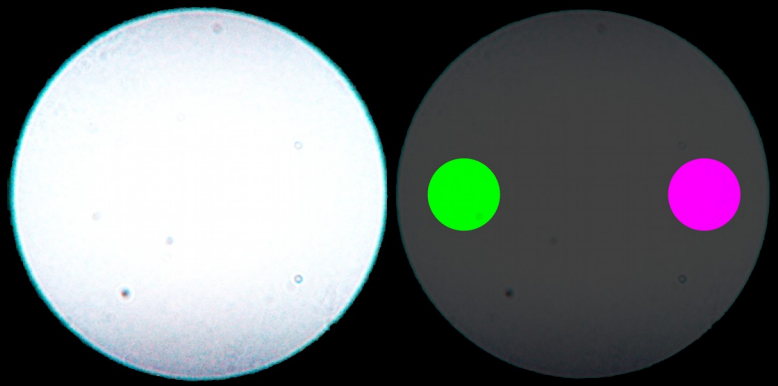
- Anaglyph encodes left/right views by color
- Impose an appropriately color-shaped PSF and the anaglyph is directly captured
- Transformation from anaglyph into full color stereo pair doesn't require stereo matching
- Technique can work with most cameras using a stop in front of the lens

Anaglyph Capture Issues

- Color choices (not about viewing!)
  - Balance average value for pixels
  - Color isolation (Bayer and JPEG issues)
  - Pixel count per spectral band
- PSF shaping & location of stop
  - Vignetting: artificial, natural, & mechanical
  - Depth ambiguity vs. aperture width
  - Depth of focus
  - Bokeh shape issues

My Color-Coded Apertures

- `aggregate.org/anaperture` designs them
- Programmable paper cutter makes them
- Use standard green/magenta gels



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My Anaglyph

instructables

- Published 11/22/2010, featured by editors
- 19,500+ readers; 6,900+ uses of design tool

Intro: Use Your Camera To Capture "3D" Anaglyphs

An anaglyph is a color image that creates the illusion of "3D" depth when viewed through color filters that separate the left and right views. The image shown here is an example viewable through green/magenta glasses.

Although various color combinations and processing variations have emerged over the years, the basic concept of an anaglyph is largely unchanged since the 1850s. Nearly all methods start by capture of a stereo pair of images which are then manipulated to create the anaglyph. In contrast, the method discussed here involves **modifying a digital still or video camera to directly capture a high-quality anaglyph in a single shot -- with no post-processing needed** .

Did I mention that the **reversible modification** to your camera can **cost less than $1** ?

Image Notes

1. A green/magenta anaglyph captured using this little trick. Pretty cool, eh?

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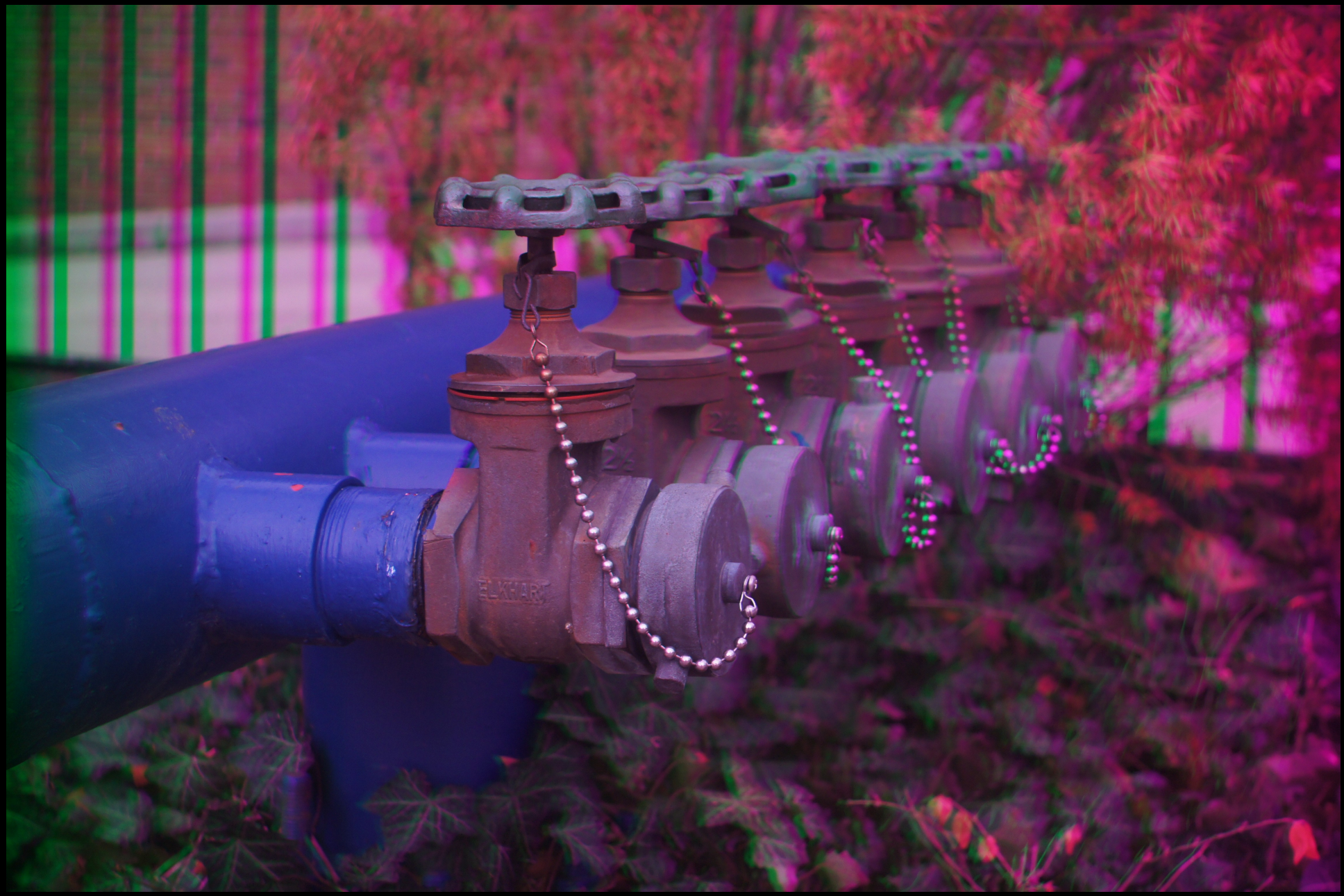
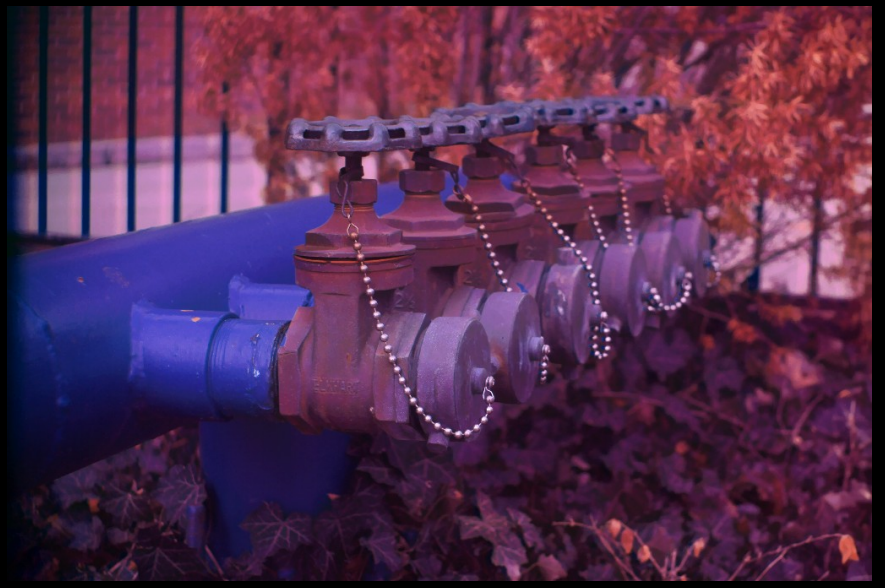
1878
1916
1865
UNITED WE STAND - DIVIDED WE FALL
MAIN BUILDING
Opened in 1882 and
known as the Main or
College Building, it



So Why Am I Dealing With Anaglyphs?

- Single-shot anaglyph capture is now in PD (1973 patent could have been an issue)
- Lots of anaglyph images out there
- I'm using anaglyphs as light fields:
  - Can refocus or do other PSF substitutions
  - Can get full-color stereo pairs (for all those “3D” TVs, etc.)



Recover Missing Colors?