

# Digital Infrared Photography

**Solveiga (Vega) Buchbinder**

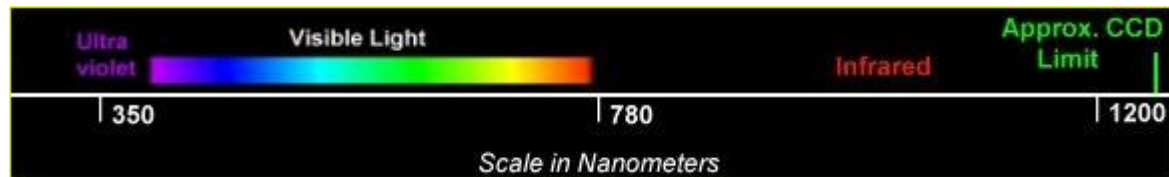
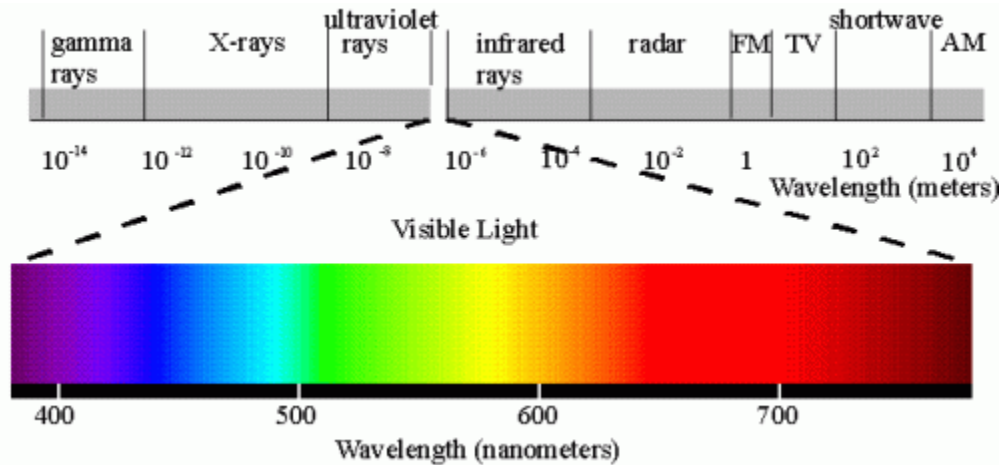


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# Digital Infrared Photography

- **What is infrared photography?**
- What equipment do I need?
- How do I photograph?
- What do I photograph?
- When can I photograph?
- How do I process my image files?
- Where can I find additional information?

# The electromagnetic spectrum



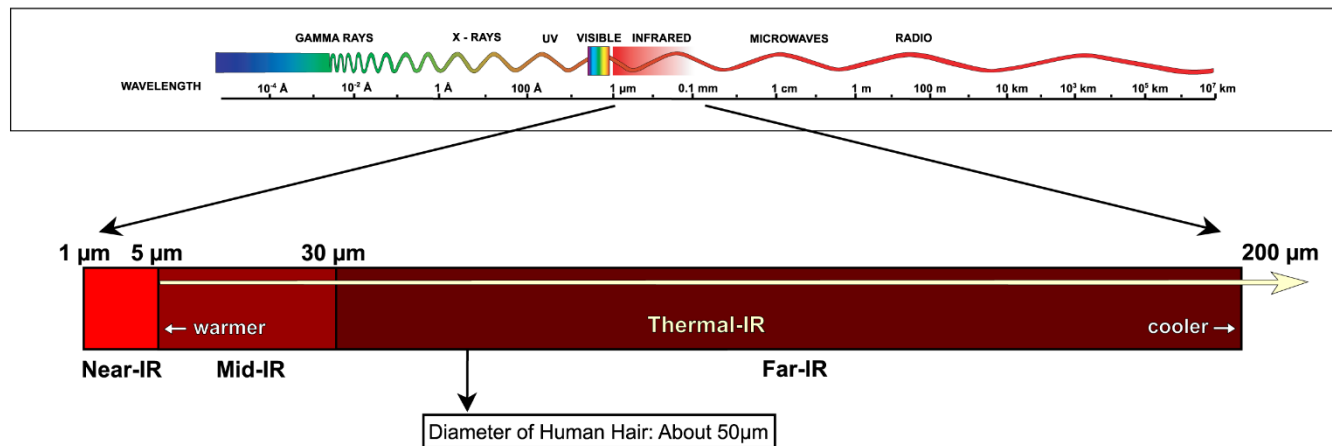
1 nm (nanometer) is 1/billionth of a meter  $10^{-9}$  m

1  $\mu$ m (micron) is 1/millionth of a meter  $10^{-6}$  m

1000 nm = 1  $\mu$ m

# The electromagnetic spectrum

Near, middle, and far infrared



<http://gallery.spitzer.caltech.edu/Imagegallery>

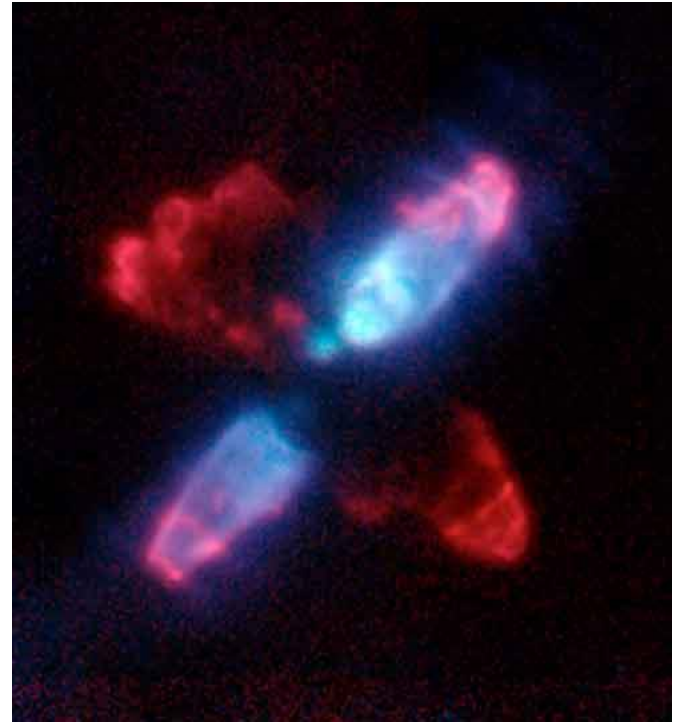
- IR photography uses near infrared
- Many astronomy images are made with mid infrared light
- Heat is far infrared



# The Egg Nebula



In visible light



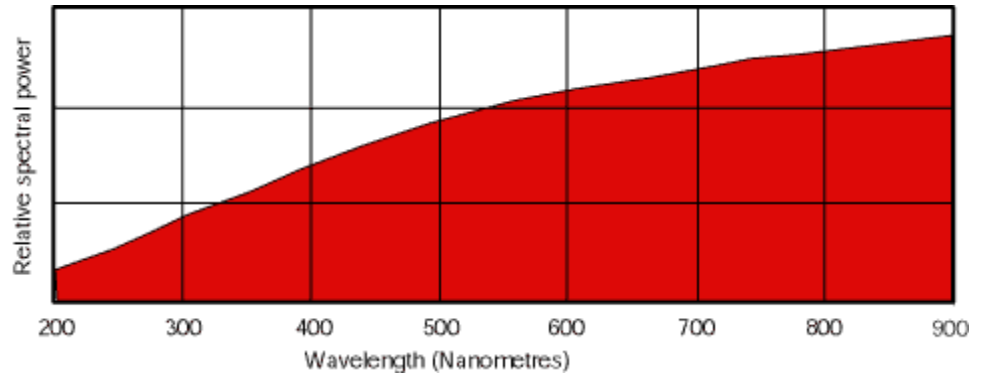
In near infrared

# Sources of IR radiation

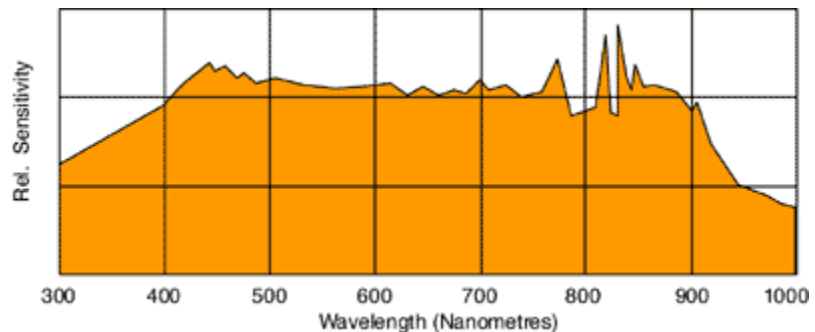
- Sunlight

Direct sunlight is:

47 % infrared  
46 % visible  
6 % ultra-violet



**The spectral output for tungsten lamps**



**The spectral output of the Nikon SB140 flash**

- Tungsten lamps
- Electronic flash

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# IR photography history

## Film



Kodak HIE film; B+W 093 filter

## Digital



Converted Nikon D70S camera;  
R72 filter

# IR photography history

## Film

- Need to bracket widely and can not see results until the film was developed
- Images are black and white, so there is no need to be concerned about the white balance

## Digital

- Can see results immediately and adjust exposure and focus in real time
- May get “false colors” or red, depending on the white balance setting

# Equipment

- Cameras and Sensors
- Filters
  - ❖ IR cutoff filter (and the anti-aliasing filter)
  - ❖ IR passing filters
- Lenses



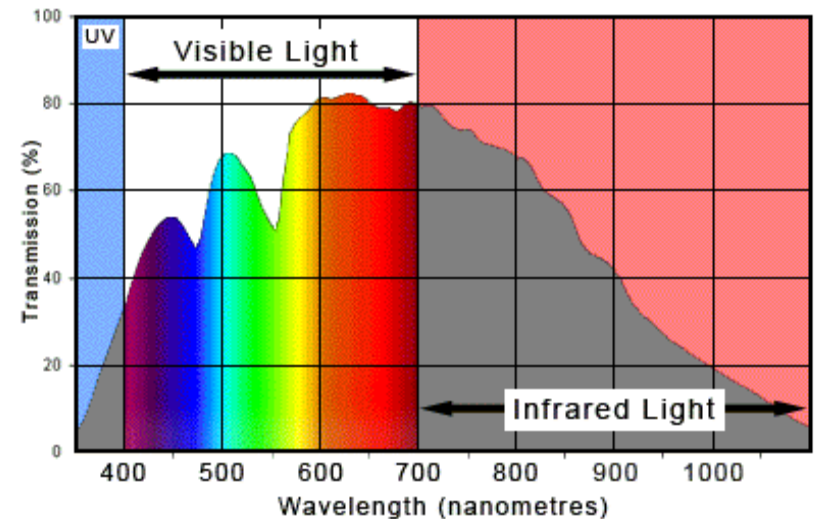
Canterbury Shaker Village, NH

# Spectral sensitivity

**The common silicon detectors are sensitive to ~ 1,100 nm**

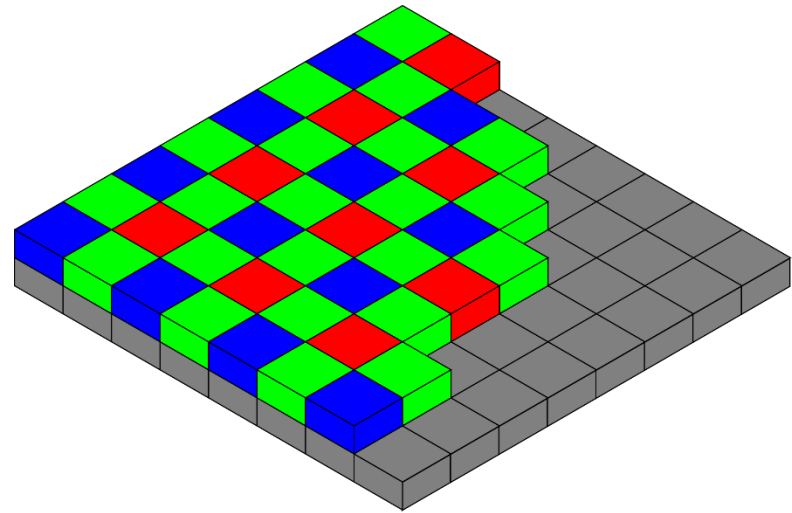
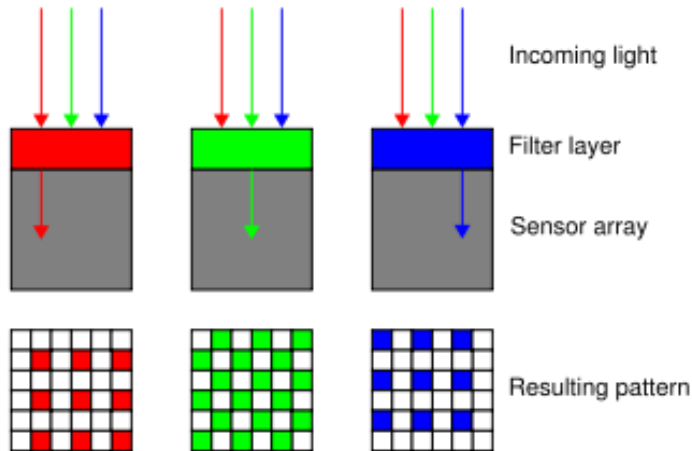
**This is what makes digital cameras perfect for IR photography**

- This is a spectral sensitivity graph for a standard photographic CCD sensor
- The visible spectrum uses only 60% of the CCD's sensitivity
- Ultraviolet and infrared light use the other 40%





# The Bayer filter mosaic



Typical photosensors detect light intensity.

A mosaic of tiny color filters is placed over the pixel sensors.

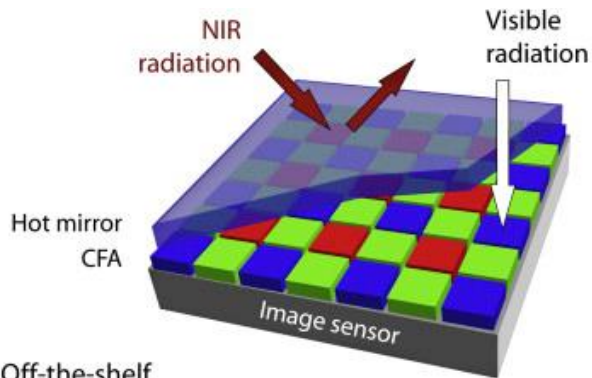
Notice there are twice as many green filters.

The Bayer arrangement of color filters on the pixel array of an image sensor.

A 2 x 2 pattern is used to determine color.

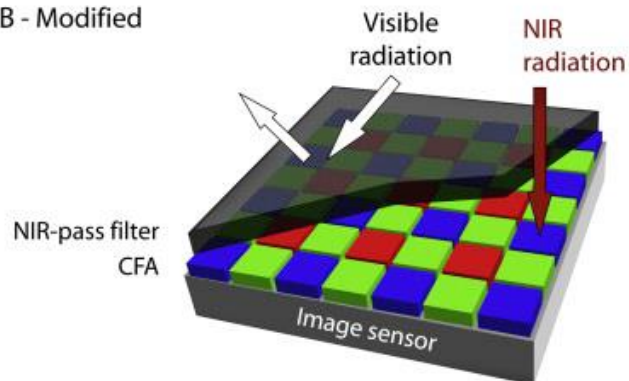


# IR cutoff filter



A - Off-the-shelf

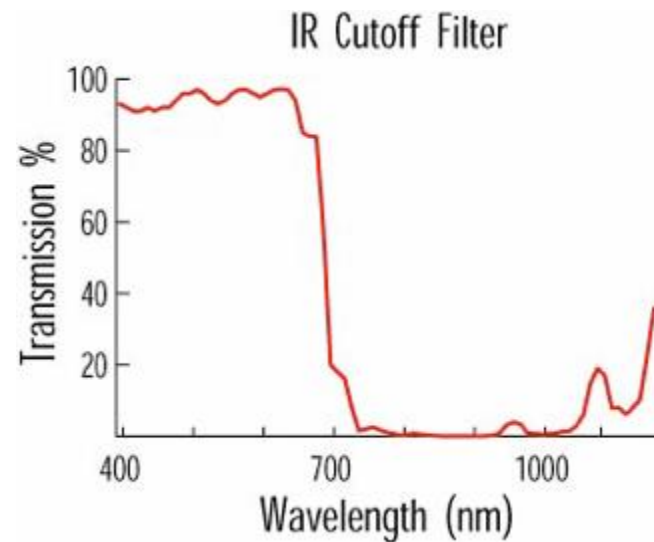
B - Modified



When a camera is converted, the top NIR blocking filter is removed and a visible light blocking filter is placed on the sensor.

# IR cutoff filter

- With most lenses, infrared radiation will focus differently than visible light
- An IR blocking filter is placed **on the sensor** in order to create a sharp image
- This type of filter is sometimes called a “hot mirror”
- **This filter is removed in converted digital cameras**



The spectral sensitivity curve of the typical IR blocking filter

# Anti-aliasing filter

## Digital SLRs have an anti-aliasing (AA) filter to prevent Moiré patterns

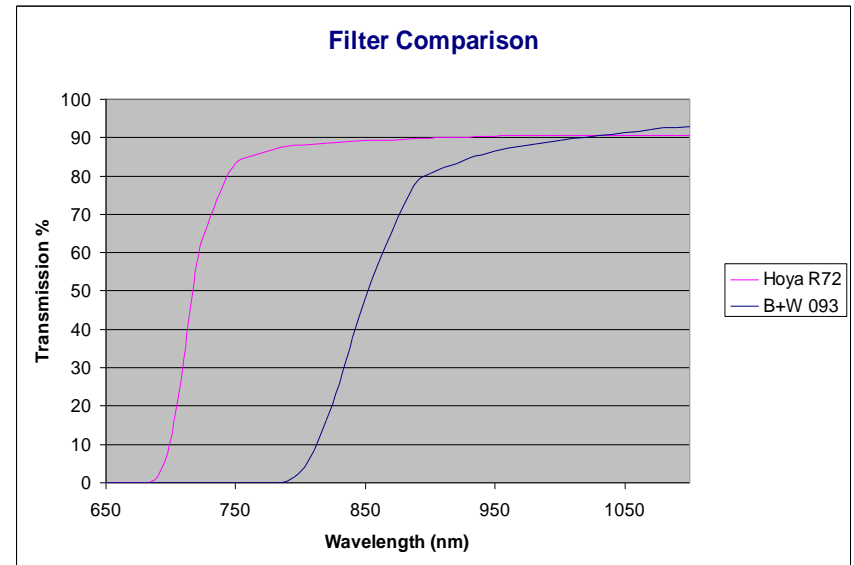
- Also called a “blur filter” or a “low pass” filter
- Usually sandwiched with the IR cutoff filter
- Vary in strength
- Work by making the image a bit fuzzy
  - ❖ A black pixel next to a white pixel will result in two gray pixels
  - ❖ A blue pixel next to a red pixel will result in blurred purple pixels
- **Is removed with the IR cutoff filter in converted cameras**
  - ❖ Images may be sharper

# IR passing filters

Two commonly used IR passing filters:

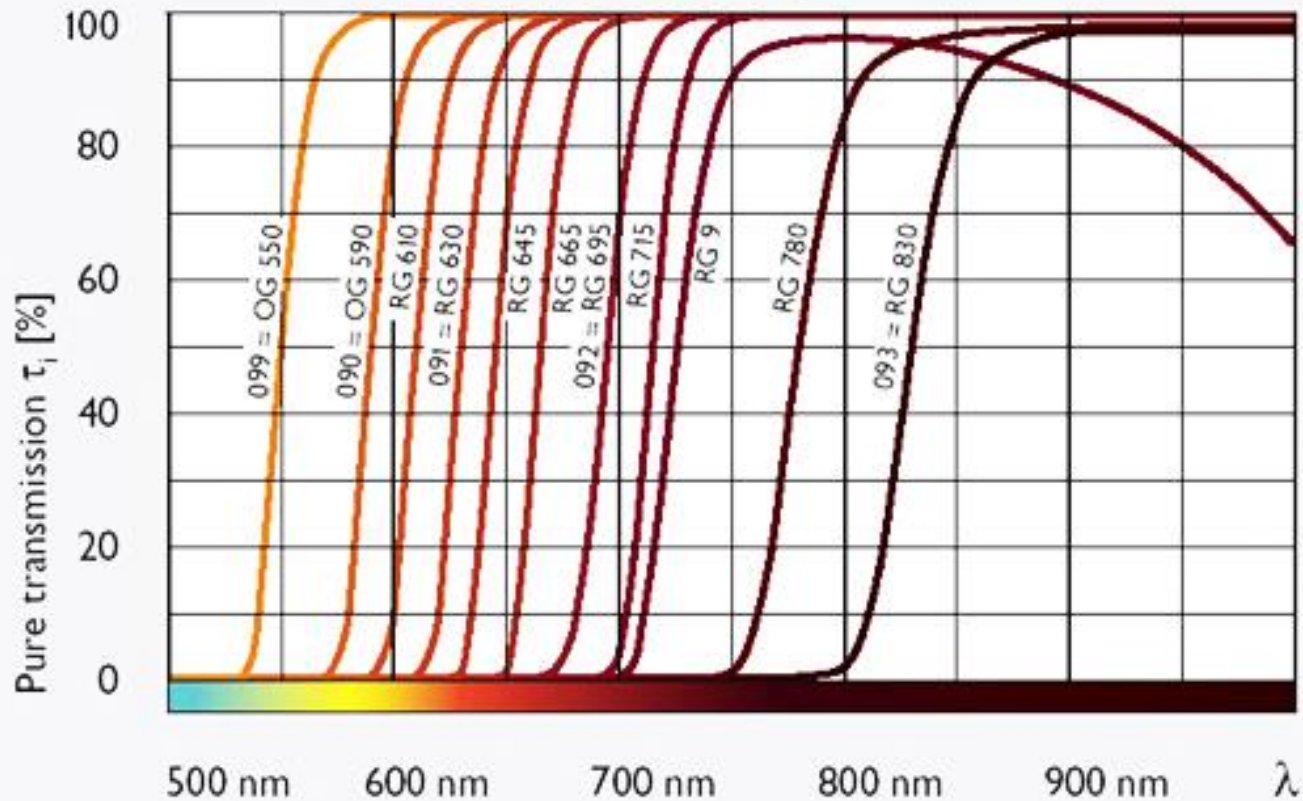
- **The Hoya R72 (B+W 092; Wratten 89B)**
  - ❖ Is dark purple, almost black, in color
  - ❖ Passes some visible red light
  - ❖ 50% cut-off at 720 nm
- **The B+W 093 (Wratten 87C)**
  - ❖ Totally opaque
  - ❖ Cuts out all visible light
  - ❖ Get stronger IR effect
  - ❖ 50% cut-off at 850 nm

**For non-converted cameras, use the R72 since the blocking filter in the camera may cut off too much of IR; as a result the 093 filter may be too strong**



# IR passing filters

## Infrared Filters 092, 093, 099, IR Special Filters P. 29



# IR passing filters



Images from [www.Lifepixel.com](http://www.Lifepixel.com)

- Enhanced filter
- Standard filter
- Deep Infrared filter

# IR passing filters

Filter Type	Range	Effect
Enhanced Color	665 to 1300 nm	<ul style="list-style-type: none"><li>•Includes more visible light, which results in a greater range of color</li><li>•Image has a lower contrast</li><li>•Harder to get a crisp B&amp;W image</li></ul>
Standard Infrared	720 to 1300 nm	<ul style="list-style-type: none"><li>•Includes some color information</li><li>•Normal B&amp;W image with good contrast</li></ul>
Deep Infrared	830 to 1300 nm	<ul style="list-style-type: none"><li>•Blocks all color information</li><li>•Produces high contrast B&amp;W images</li></ul>

# Cameras

## Unconverted camera

- Can your camera detect IR radiation?
- To test this, point a TV remote directly at your camera and take a picture of it while pressing any button on the remote
- Older cameras work better for IR photography
- Newer cameras have stronger IR blocking capabilities

## Converted camera

- The IR blocking filter on the sensor has been removed
- The anti-aliasing filter (sandwiched with the IR blocking filter) is also removed
- The blocking filter has been replaced with one passing mostly or only infrared (you choose), OR with glass
- Adjust the camera focusing mechanism
- Create a custom white balance
- Camera can now be used only for IR photography



# Cameras

## Unconverted camera

- Need to use IR filters and a tripod
- Hoya R72 for false colors; B+W 093 for IR only (monochrome)
- Use the camera's meter reading as a starting point, and adjust accordingly
- Long exposure times from tens of seconds to ~ 1 minute, hence the need for a tripod
- Foliage is blurred from wind
- Cover the viewfinder during exposure

## Converted camera

- There are many different flavors of converted DSLRs: the filter used as the replacement can be any version of an IR filter
- IR passing filter (blocks visual light) is on the sensor, not the lens. You can compose and focus naturally
- DSLRs use different sensors, and not the image sensor, for AF, AE, and AWB
- These sensors still see visible light in converted cameras
- Adjustments will be needed

# Lens hot spots

- Lenses are designed for visible light, not IR light
- Some lenses have “hot spots”
- They are brighter areas in the center of the frame
- Are internal reflections within the optical pathway
- Coatings on lenses create hot spots and flare more easily in IR
- More prominent on bright sunny days
- Again, older equipment better for IR
- Use the lens hood
- Can sometimes burn them in with Photoshop



Rock Meadow Conservation Area, Belmont  
(Nikon 17-55mm f2.8 G lens)

# Lens hot spots



Nikon 17-55mm f2.8 G lens

1/125 **f/14** -.7ev



Nikon 17-55mm f2.8 G lens

1/250 **f/11** 0ev

Smaller apertures (larger f/ number) can introduce hot spots

# Lens hot spots

**LifePixel recommends these lenses should be avoided.**

## CANON LENSES

16-35mm 2.8  
16-35mm 2.8 II  
20-35mm 2.8  
  
28-70mm 2.8  
24-70mm 2.8 II

## NIKON LENSES

24-70mm 2.8  
35mm 1.8  
24-85mm AF-S 3.5-4.5G  
ED VR

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# How to photograph

## Converted cameras

- Compose your picture while looking through the viewfinder
  - Take a meter reading
  - Bracket your exposures by .3 or .7 ev and verify using the histogram
  - You can also use a 093 filter, (in addition to the conversion), to block out the visible light that the R72 allows to pass, but you will not get the false colors
- 
- Shooting in visible light is no longer possible
  - Normal viewing is possible, using visible light

# How to photograph

Unconverted cameras

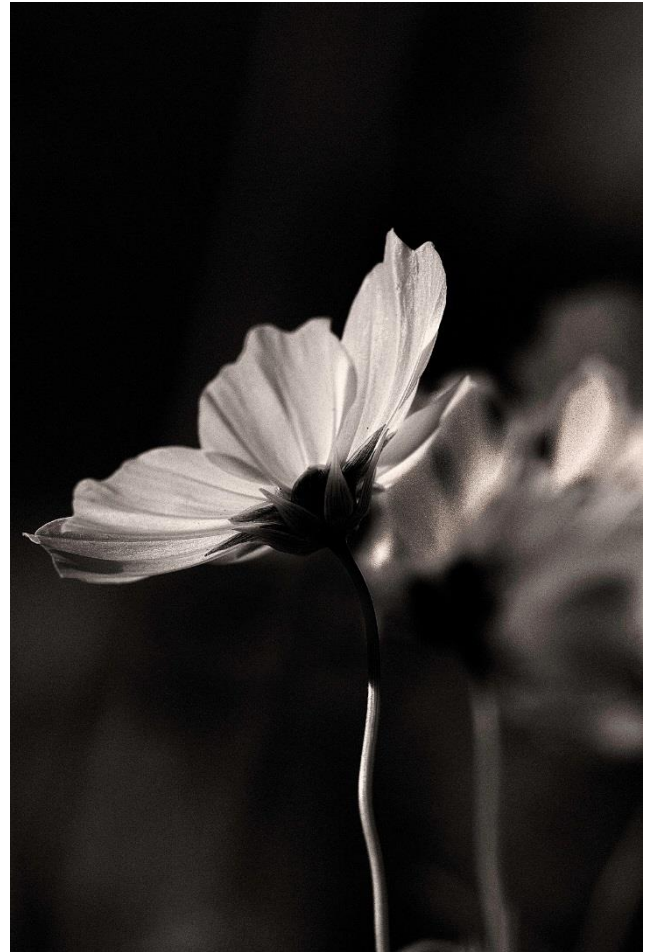
**IR passing filters are dark red to opaque**

- Place the camera on a tripod
- With the filter off, compose and focus
- Take a picture and adjust settings accordingly
- Place the filter on the lens
  - Ex. Hoya R72 for false colors; B+W 093 for IR only (monochrome)
- Use the camera's meter reading as a starting point, and adjust accordingly
- Take many shots, bracketing widely until correct exposure attained
- Exposures will be long because the filters are dark. Cover the viewfinder during exposure

# Issues

- Custom white balance
- Focus
- Exposure

These issues differ between unconverted cameras and converted cameras; and also between non-DSLRs and DSLRs





# Custom white balance

**If you don't white balance - you will get a red image**

- Check your camera to see if you can create a custom white balance preset
- Since foliage reflects IR light, making it the brightest, whitest part of your photo, you'll need to “calibrate” your camera to let it know that visible light green is equal to infrared white
- Create a preset custom white balance:

**Shoot grass full frame in full sunlight (around -1 EV to -2 EV)  
and use that image to set the white balance**

# Custom white balance preset

- There are some issues with setting a custom white balance preset for the following Nikon (converted) cameras:

Nikon D40, D40x, D80, D200

- Visit the Life Pixel and Photo.net web sites for additional information about these cameras

# Focus



# Focus

## For converted DSLRs

- Even though the sensor has been converted to pass only IR, **the autofocus system still uses visible light!**
- Focus cannot be completely adjusted because:
  - 1) Different IR wavelengths
  - 2) Different lens focal lengths (for zoom lenses)
  - 3) The ratio of infrared light to visible lightall influence where the focus point is

# Focus

## IR does not focus on the same plane as visible light

- Back focusing is an issue
- Back focus is when the camera actually focuses on something behind the intended subject
- Older lenses have a **red dot** to indicate where to focus IR
- This location may be different for the wide angle and telephoto ends of a zoom lens



# Focus

## Newer lenses often do not have the red dot, so what do we do?

- Focus on the important part of the scene that is closest to the camera
- Use a greater depth of field to counteract focus issues
  - ❖ Use f/8 or smaller aperture to minimize focus issues
  - ❖ Don't stop down too far! Diffraction is twice as bad with IR waves as it is with visible light!
- Focus bracket, especially in diffuse light, and for close subjects
- If your camera has Live View, use that to focus.



Autofocus



Manually focused closer

# Exposure

- The meter sees visible light, not IR
- DSLRs do not use the image sensor for light metering
- Bracket, bracket, bracket ...
- Anywhere from +1.0 EV to -1.0 EV from the camera's meter reading give good results
- After a while you can “feel” when to go over or under 0 ev

# Exposure

If you see cyan areas in the image, the **green** and **blue** channels are fully saturated

Cut back on the exposure

Nikon Capture NX2 can recover some of the data



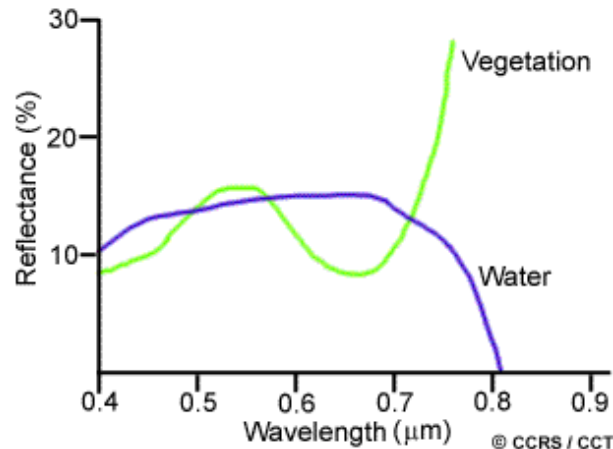
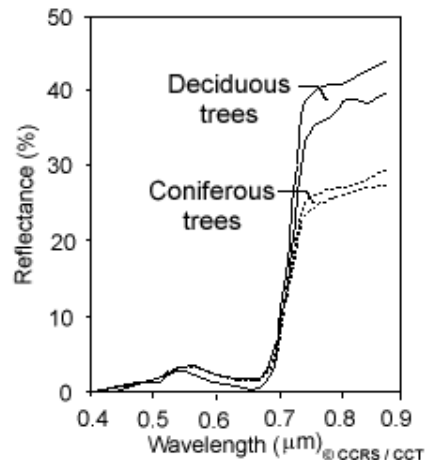
Myopia Hunt Club Road, South Hamilton, MA



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# The usual suspects – in bright sunlight



- **Foliage** in sunlight appears white
  - ❖ Willow trees give the best white tone
  - ❖ Deciduous trees are white also
  - ❖ Conifers give the darkest tone
- **Clouds** are clearly defined
- **Blue sky** appears black
- **Water** can appear black
- Buildings, roads, and other man-made structures often appear black unless they are in direct sunlight

# Sunny day



Rockport, MA



Essex, MA



# Foliage



Public Garden, Boston, MA

# Foliage

- The **air spaces** in leaves (not the chlorophyll) reflect IR
- In spring the air spaces are expanding as the leaves mature
- Full size occurs in summer

Boston Public Garden, Boston, MA



Spring

Newport, RI



Summer



# Sky and water



# Reflections



Pontiac Mills, Warwick, RI

# Clouds



Boston



# A cloudy damp afternoon



Belmont Country Club, Belmont, MA

# In the rain



Boston Public Garden, Boston, MA

# In fog



Prospect Hill Park, Waltham, MA

# In fog



Color camera



Infrared camera



# In snow

Cape Ann Golf Course, Essex, MA



Black and white from color image



Black and white from infrared image

# Interiors



Andrea's Flat



# Incandescent lights



Rockport, MA

# The ordinary



Rockport, MA



# The ordinary



Sailing on the Charles River, Boston, MA

# The ordinary



Tracks along the Charles River, Boston, MA

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# During the course of the day

- The **amount** of IR radiation from the sun is highest at noon (solar noon, not daylight saving's time)
- The **proportion** of IR radiation to light is highest just after dawn and just before sunset

# During the course of the day

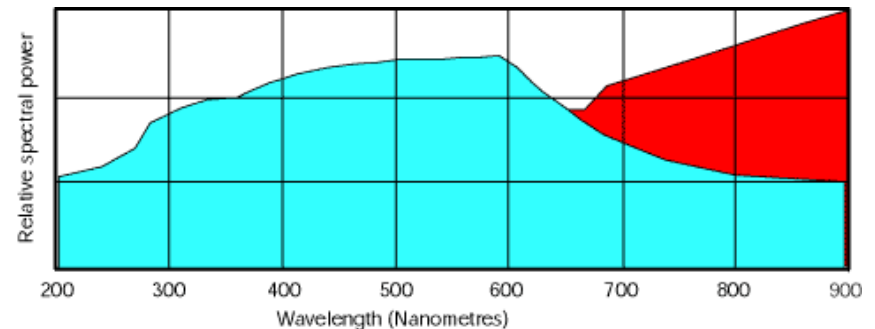
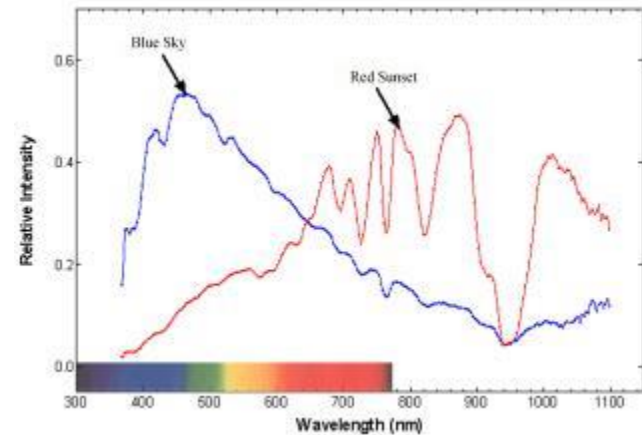
Comparison spectrum of blue sky to red sunset

*The Chemical Educator*

<http://chemeducator.org/sbibs/samples/spapers/34samplejg.htm>

Daylight is a very rich but unpredictable source of infrared radiation which changes its spectral qualities with changes in the time of day and atmospheric conditions

The blue curve shows the spectral distribution at noon, the red curve demonstrates the shift to red and infrared towards dusk



*Medical and Scientific Photography*

[http://msp.rmit.edu.au/Article\\_03/02a.html](http://msp.rmit.edu.au/Article_03/02a.html)

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# Post-Processing

- False colors
  - Raw converter software
  - Channel swap
- Converting to black and white



# False Colors



Essex, MA



Plum Island, MA



# False colors

- IR has no color
- Your image may display false colors
- These colors are the product of the camera's hardware and firmware
- Need portion of the visible red spectrum ( $\sim 720\text{nm}$ ) for false color
- If you use an opaque filter or have your camera modified to IR only wavelengths (beyond  $\sim 750\text{ nm}$ ) you may not get the false colors

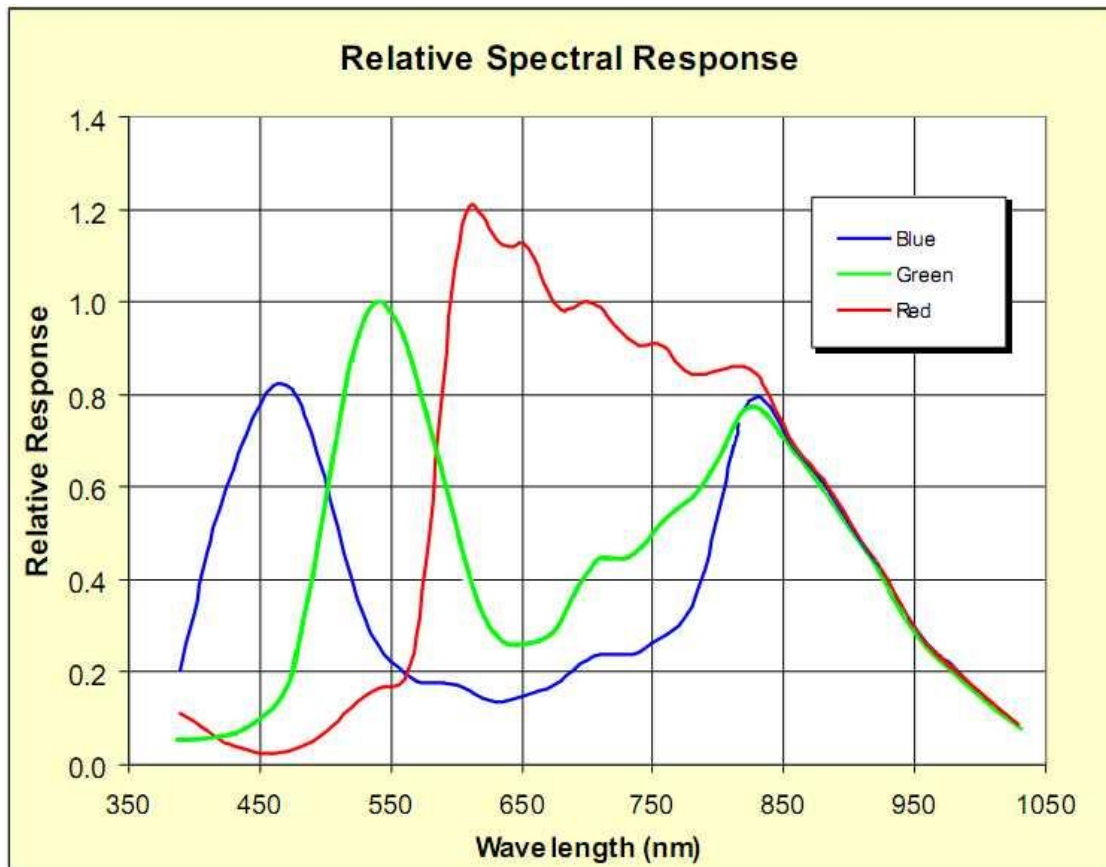


Rockport, MA



Essex, MA

# False colors



- Before ~ 850 nm you are more likely to see false colors
- After ~ 850 nm the RGB channels have about the same sensitivity, so you are more likely to see B+W images
- Your specific sensor may vary

Red line → red channel    Green line → green channel    Blue line → blue channel

# False colors

A



B



C



A  $\rightarrow$  1/60 f/10 -0.7 eV

B  $\rightarrow$  1/80 f/10 -1.0 eV

C  $\rightarrow$  1/100 f/10 -1.3 eV

# Raw converter software

**To preserve the false color, you need a raw converter to do a linear conversion**

- **White balance application**

The raw converter software must be able to apply the custom white balance

- Demosaicing

CCD/CMOS sensors only record one color for each pixel and the real color for a given pixel has to be interpolated from the surrounding pixels

Demosaicing is the process of converting Bayer raw images, which have one color per pixel, to standard images, which have three colors per pixel. In the process of demosaicing, missing detail for each channel is inferred from detail in other channels.



# Raw converter software

**The Nikon and Canon raw converters  
*will* preserve the false colors**

- Nikon: Nikon Capture and ViewNX
- Canon: Digital Photo Professional (DPP)

## **Other raw converters**

- Adobe Camera Raw
- BreezeBrowser
- Capture One DSLR
- DCRaw
- GIMP
- Microsoft RAW Image Thumbnailer and Viewer

and many more



City Square Park, Charlestown, MA

# Raw converter software

In RAW mode the camera is *not* doing *any* non-linear processing. All non-linear processing is done in the RAW converter.

The image will appear very dark because it has a gamma value of 1.0 from the camera and has not been adjusted to a gamma of 2.2 normally used for displaying images on a PC screen.

Camera profiles and tone curves need to be applied later (non-linear conversion).

# Raw converter software

Nikon Capture



Original raw file in camera (i.e., the linear file)



Raw file opened in Nikon Capture, auto contrast applied, saved as tif, sent to CS3 ...



... file opened in CS3

**Nikon D70S converted by Life Pixel. R72 filter applied. Custom white balance on a bright sunny day**

# Raw converter software

Adobe Camera Raw



Nikon D70S converted by Life Pixel. R72 filter applied. Custom white balance on a bright sunny day



# Raw converter software

Adobe Camera Raw (and Photoshop CS3)



Original raw file in the camera



Original raw file opened in **Adobe Camera Raw** and auto exposure applied ...



Original file with levels applied in **Nikon Capture**

... then opened in **PS CS3** and levels applied

**Nikon D70S converted by Life Pixel. R72 filter applied. Custom white balance on a bright sunny day**

# Channel swap

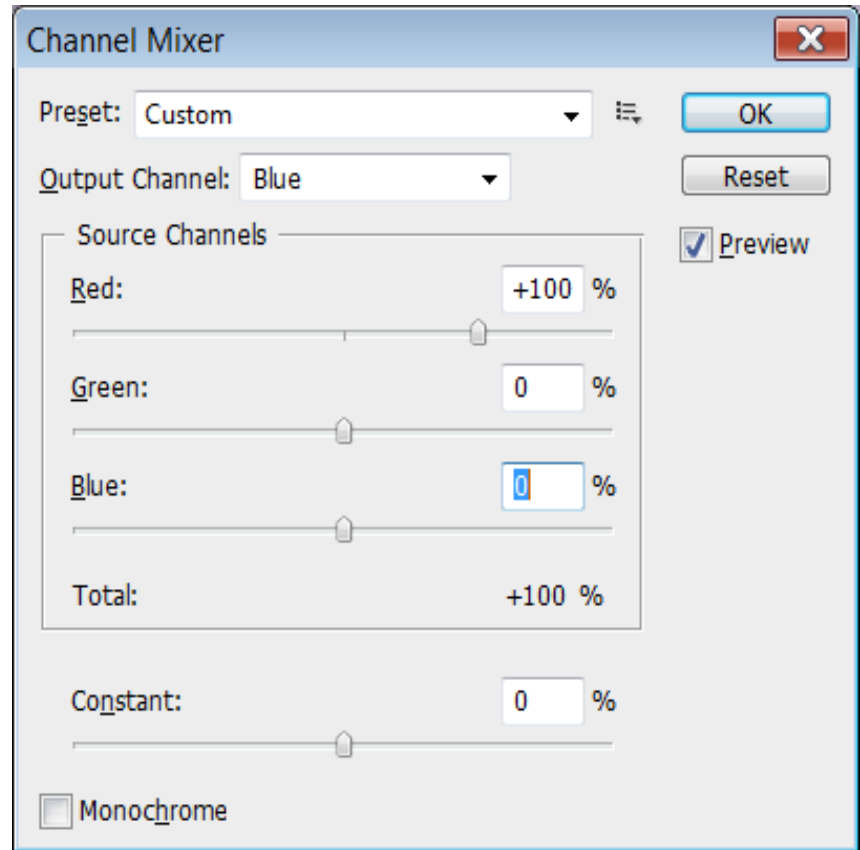
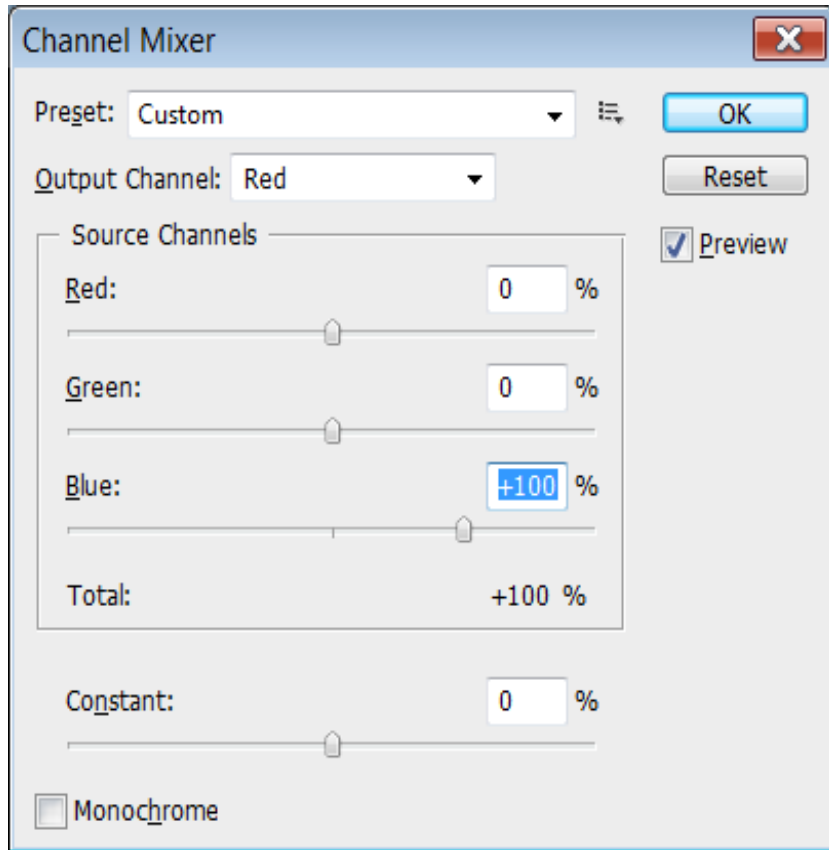
You can swap channels to make the sky look like the more natural blue color



Original images

After channel swap

# Channel swap



Set **Red** → **Blue**

and

Set **Blue** → **Red**



# Converting to black and white

	<b>Destructive</b>	<b>Non-Destructive</b>
<b>Luminosity</b>	<ul style="list-style-type: none"><li>• Grayscale</li><li>• Desaturate</li><li>• Lab Lightness</li><li>• Gorman-Holbert</li></ul>	<ul style="list-style-type: none"><li>• Gradient Map</li><li>• Calculations</li></ul>
<b>Color Altering</b>	<ul style="list-style-type: none"><li>• Channel separation</li></ul>	<ul style="list-style-type: none"><li>• Hue/Saturation</li><li>• Channel Mixer</li><li>• B+W Adjustment Layer</li></ul>

**Destructive** methods convert the image by destroying the color information. Once destroyed, the color information cannot be recovered

**Non-destructive** methods convert the image by adding new layers to the existing image

**Luminosity** based methods assign a shade of gray based only on the color's brightness or luminosity

**Color Altering** methods alter the colors in the photograph before converting it to grayscale

# Converting to black and white

These are some of the most obvious ways to convert an image from color to black and white:

- Image → Mode → Grayscale
- Image → Adjustments → Desaturate
- Image → Adjustments → Hue/Saturation → Saturation -100
- Layer → New Adjustment Layer → Hue/Saturation → Saturation -100

All of these commands produce, in varying ways, a monochrome image based on Photoshop's assumed ratio between the Red, Green and Blue channels

Photoshop will take **30% of the Red channel**, **59% of the Green channel** and **11% of the Blue channel** and combine them to create a monochrome image

There are other techniques that give you more control

# Converting to black and white

## Gradient Map

Boston Public Garden, Boston, MA



Original false colors



After Gradient Map

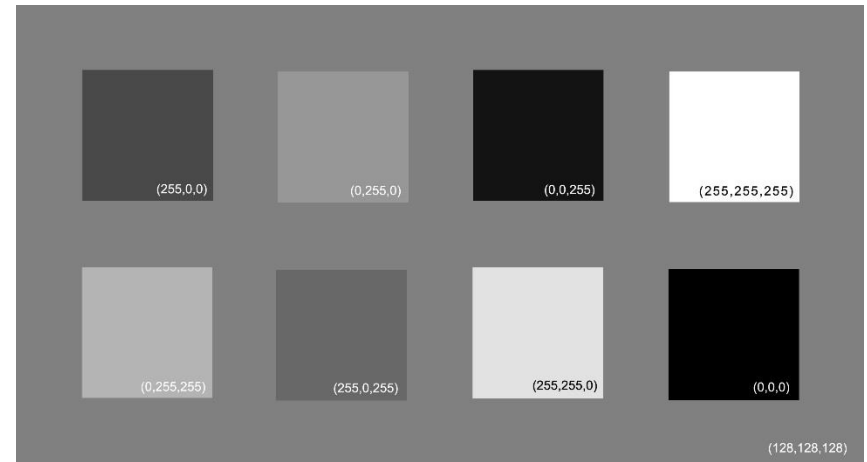
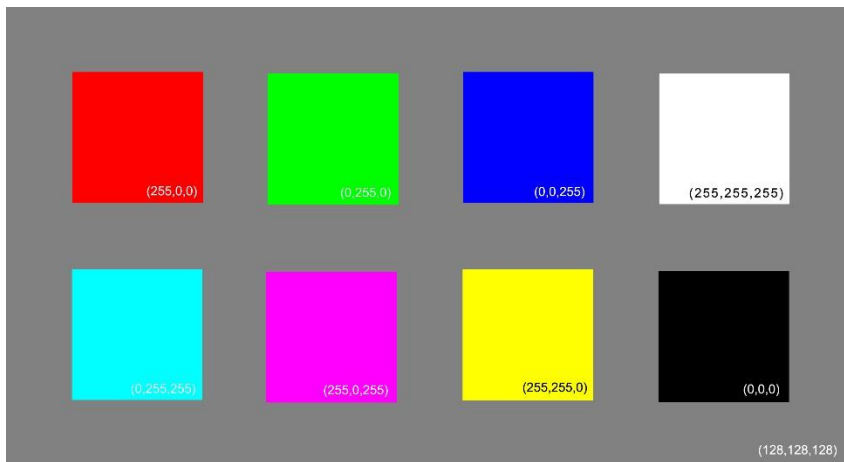


# Converting to black and white

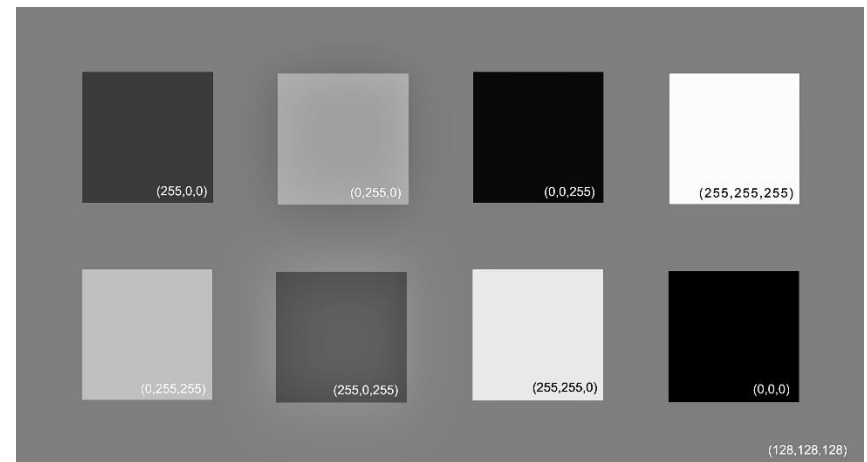
Nik Silver Efex Pro

Adobe PS plug-in tool to create  
black and white images

Can emulate the traditional B+W  
films, toners, and filters



Neutral



High Structure

# Converting to black and white

Nik Silver Efex Pro



Same file – different effects

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# Camera conversions

- **Life Pixel:** <http://www.lifepixel.com/>
- **LDP LLC:** <http://www.maxmax.com/>
- **Precision Camera:** <http://www.precisioncamera.com/infrared-conversion-services.html>
- **Spencer's Camera and Photo:** <http://www.spencerscamera.com/>



Canterbury Shaker Village, NH

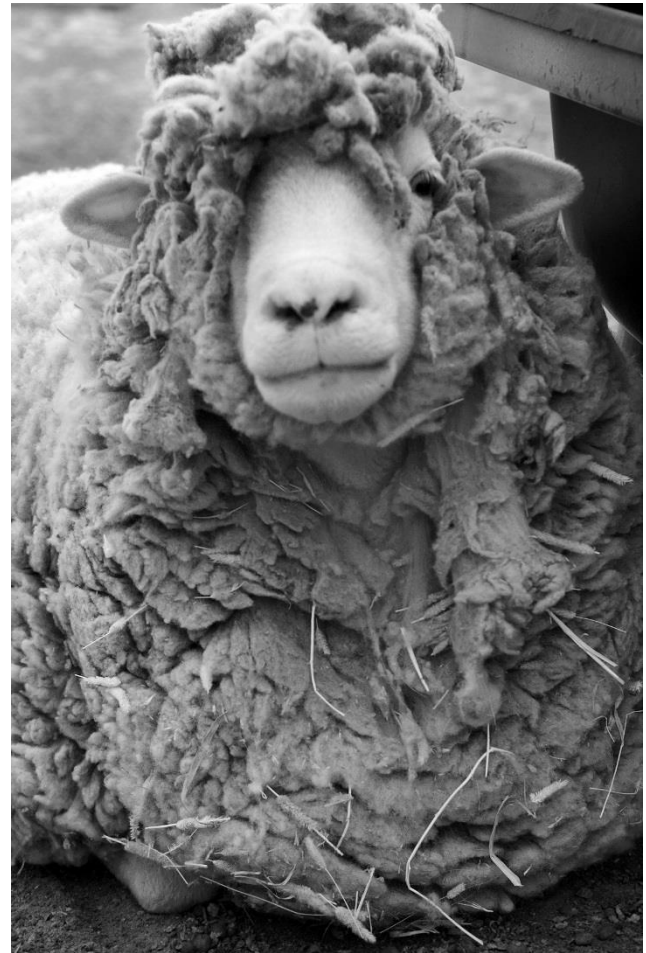


North Avenue, Wakefield, MA

# More information about digital IR

- *“Infrared Photography with a Digital Camera”*  
<http://www.wrotniak.net/photo/infrared/index.html>
- *“Introduction to Digital Infrared Photography”*  
<http://diglloyd.com/articles/Infrared/infrared-main.html>
- Apogee Photo Magazine, *“Digital Infrared Photography Made Easy”*  
<http://www.apogeephoto.com/may2003/odell52003.shtml>
- *“Digital Photography for What It’s Worth”*  
<http://dpfwiw.com/index.htm>
- *“A Gentle Introduction to Digital Infrared Photography”*  
<http://www.infraredphoto.eu/Site/Welcome.html>

# Thanks!



Parlee Farm, Tyngsboro, MA



# Questions?

How does near infrared relate to the 4<sup>th</sup> law of thermodynamics?

THE FOURTH LAW OF  
THERMODYNAMICS



the temperature in  
your office building  
will always be  
unbearably hot or  
unbearably cold -  
never somewhere in  
between