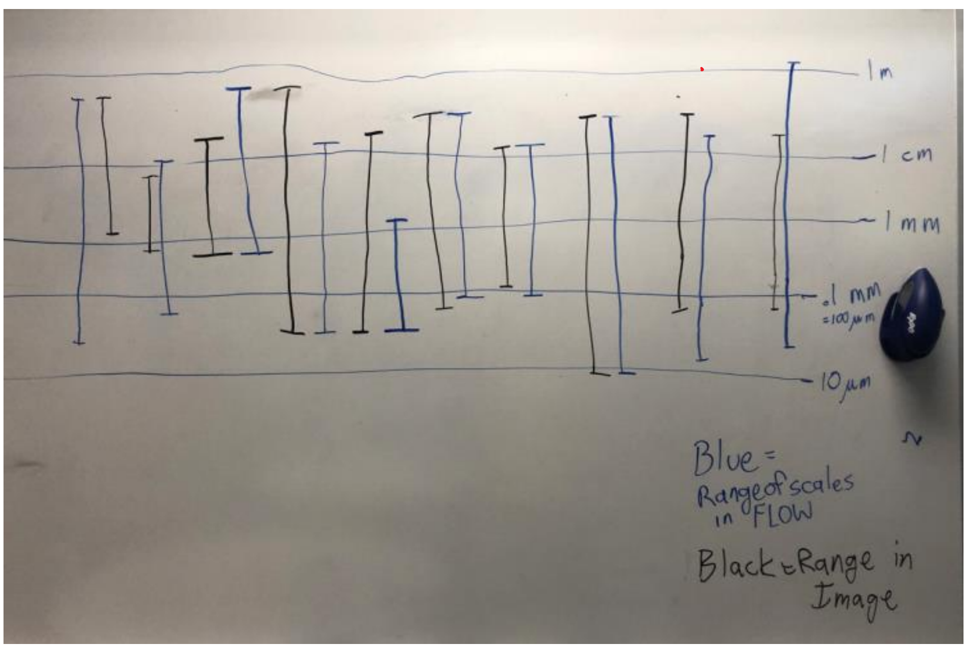
16.Resolution2 - Time
Monday, October 17, 2022 5:36 PM

Today:
Finish spatial resolution
Temporal resolution
Dynamic Range
Learning objectives: you will be able to analyze the spatial and temporal resolution of your images. You will be able to manipulate dynamic range of color channels in an editor.

Admin: Resources for reports
Guidebook on Flowvis.org website
Zotero library
Zotero is an open-source citation management database system, like Endnote and Mendeley. Has web, phone and computer app versions, but app for your computer is best. Interfaces with both your browser and word processor. We have a group library: Fluid Physics for Flow Vis. Has references (including PDFS) for many common Flow Vis topics: vortexes, splashes, clouds, ferrofluid, etc.
Zotero is the best-ever browser bookmark system. Stores snapshot of web pages, plus pdfs and any other document. Many ways to organize; folders, tags, related docs. Can even be used to organize your Google Drive nondestructively.

Class results: Flow scales vs Image resolved scales



Smallest scale in turbulence
Kolmogorov Scale
& dissipation scale

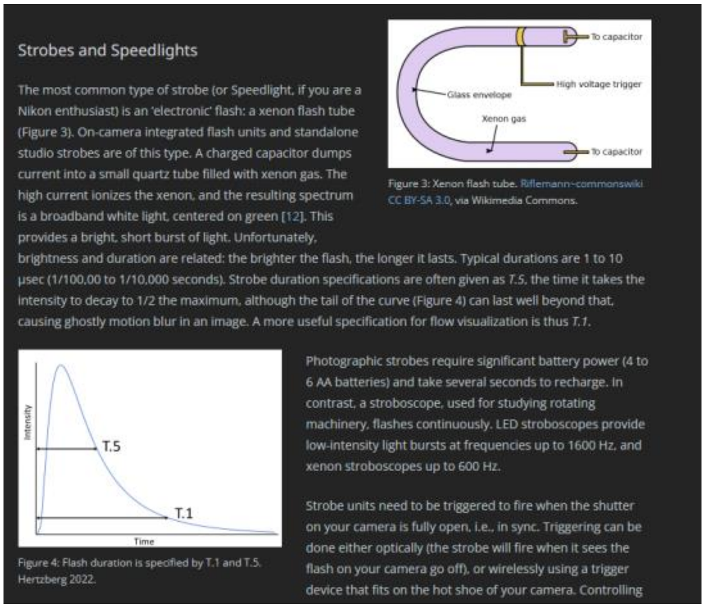
Time resolution

Other considerations of shutter speed:
Short enough to 'freeze' flow= TIME RESOLVED
VS long enough to get desired particle tracks
or long enough to be TIME AVERAGED.
Calculate motion blur. How many pixels long? If unacceptable, increase time resolution= shorter exposure time

Increase shutter speed

DSLR max = 1/4000 sec, = 250 μsec
Max on cell phone is 1/23000= 0.043msec, 43 μsec? At best.
High speed camera 30,000 fps ~ 3 x 10^{-5} sec = 30 μsec

Freeze the flow with short light source (won't work for light emitting fluids, i.e. flames)
Strobe, camera flash ~ 10-5 or -6 sec = 1-10 μsec
Best at low power
Good resource for high speed photography: http://www.hiviz.com/index.html



Strobes and Speedlights

The most common type of strobe (or Speedlight, if you are a Nikon enthusiast) is an 'electronic' flash: a xenon flash tube (Figure 3). On-camera integrated flash units and standalone studio strobes are of this type. A charged capacitor dumps current into a small quartz tube filled with xenon gas. The high current ionizes the xenon, and the resulting spectrum is a broadband white light, centered on green [12]. This provides a bright, short burst of light. Unfortunately, brightness and duration are related: the brighter the flash, the longer it lasts. Typical durations are 1 to 10 μsec (1/100,00 to 1/10,000 seconds). Strobe duration specifications are often given as *T.5*, the time it takes the intensity to decay to 1/2 the maximum, although the tail of the curve (Figure 4) can last well beyond that, causing ghostly motion blur in an image. A more useful specification for flow visualization is thus *T.1*.

Figure 3: Xenon flash tube. Riflemann~commonswiki CC BY-SA 3.0, via Wikimedia Commons.

Photographic strobes require significant battery power (4 to 6 AA batteries) and take several seconds to recharge. In contrast, a stroboscope, used for studying rotating machinery, flashes continuously. LED stroboscopes provide low-intensity light bursts at frequencies up to 1600 Hz, and xenon stroboscopes up to 600 Hz.

Strobe units need to be triggered to fire when the shutter on your camera is fully open, i.e., in sync. Triggering can be done either optically (the strobe will fire when it sees the flash on your camera go off), or wirelessly using a trigger device that fits on the hot shoe of your camera. Controlling

Figure 4: Flash duration is specified by T.1 and T.5. Hertzberg 2022.

Pulsed laser 3×10^{-9} sec = 3 nsec or less typically.
$600 will get you a 10-ns, 532-nm (green) pulse at up to 2000 mJ. Used for micromachining.
Special lasers go to femptoseconds (10^{-15}, a millionth of a billionth of a second), often low power and infrared.
Picosecond lasers (10^{-12}; seconds), red or blue, for tattoo removal, < $200 but only 7 mJ.

Not much info out there on LED flash units. Yes, requires only low power and has good repetition rate, but intensity and pulse rate depend on circuit details. No professional photography units are on the market so far.

Time averaged images. Other end of the scale from time-resolved.

If long shutter is needed, might be too much light, even at low ISO and small aperture.
Try a
NDF = Neutral Density Filter. Neutral = all wavelengths equally. Gray.
NDF 1 = 1 /10 light transmission, 3 stops
NDF 2 = 1/100 etc. Log scale. 7 stops
http://en.wikipedia.org/wiki/File:Strickland_Falls_Shadows_Lifted.jpg
30 seconds. NDF 8x = 1/100,000,000 = 27 stops

Need a tripod for macros, or shutters > 1/30 sec
Full size start at $25. Highly recommended.

Estimate motion blur *in pixels* to guide choice of shutter speed.
Alternately, use length of motion blur streak and shutter speed to estimate flow speed

Motion Blur Example:
Field of view = 10 cm
Fluid moving at 0.5 m/s
18 Mpx sensor

Groups/Breakout rooms: will 1/1000 sec shutter speed 'freeze' this flow? How many pixels will motion blur be? Calculate on group whiteboard please. Save for discussion; available from annotate tools.

Flow = .5 m/s

$.5 \text{ m/s} \times \frac{1}{1000} \text{sec} = .0005 \text{ m}$

$.05 \text{ cm}$ = streak length
= distance object moved

6k
3k

object: $\frac{10 \text{ cm}}{6000 \text{ px}} = 1.67e^{-7} \text{ cm/px}$

$\frac{.05 \text{ cm}}{1.67 e^{-7} \text{ px}} = 30 \text{ px}$

$\frac{30 \text{ px}}{6000 \text{ px}} = \frac{1}{200}$ of image

18 MPx ⇒ 5184 × 3456 px

5000px
10cm FOV
? 0.5 m/s for $\frac{1}{1000}$ sec = ? pixels

In flow, particle will move
0.5 m/s × $\frac{1}{1000}$ sec = .5/1000=0.0005 m = .05 cm
How many pixels will cover?

Given: 18 Mpx = W × H
FOV = 10 cm
shutter = $\frac{1}{1000}$ sec = t
B = Blur = 25 px

Assume aspect ratio standard for aps-c sensors
3
2

Image width W in px?
$H = \frac{2}{3} W$
$18 \text{ Mpx} = W \times H = (W)(\frac{2}{3} W)$
$W = \sqrt{(\frac{3}{2})(18 \times 10^6)}$

W= (18e6*3/2)^.5=5,196

Google says image width of 18 Mpx image is 5184. OK, sure, because 18 Mpx is an approximation.

Now we have
10 cm FOV
5184 px
Blur = 25 px

How long is Blur IRL?

$\frac{B_{IRL}}{25 \text{ px}} = \frac{10 \text{ cm}}{5184 \text{ px}}$

In flow, particle will move

$0.5\, m/s \times \frac{1}{1000}\, sec =$ .5/1000=0.0005 m = .05 cm

How many pixels will cover?

$\frac{5000\, px}{10\, cm} = \frac{?\, px}{.05\, cm}$

.05*5000/10=25.0 px = smear length.

$\xrightarrow{\;?\;}$ 0.5 m/s for $\frac{1}{1000}$ sec = ? pixels

How long is Blur

$\frac{B_{IRL}}{25\, px} = \frac{10\, cm}{5184\, px}$

$B_{IRL} = (10\, cm)\left(\frac{25\, px}{5184\, px}\right) =$ 10*25/5184=0.0482

Feature moved 0.0482 cm in $t = \frac{1}{1000}$ sec

$Velocity = \frac{distance}{time} = \frac{0.0481\, cm}{1/1000\ sec} = 48.1\, \frac{cm}{s}$

$\boxed{V = 0.48\, m/s}$

Do this analysis for each image; put in your report. Motion blur is surprisingly common and annoying.