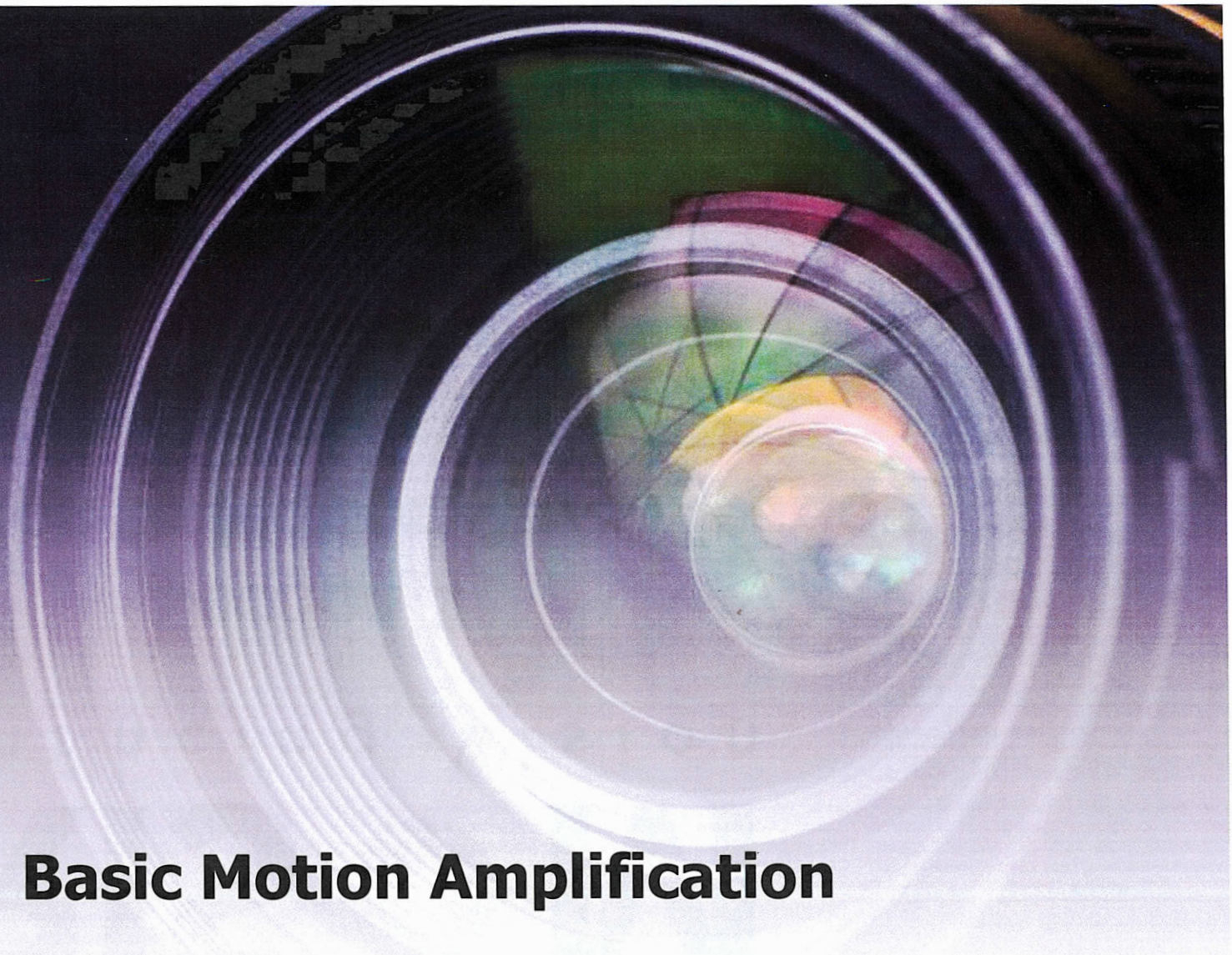
RDI TECHNOLOGIES



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VIMS

Basic Motion Amplification

Version 3.2

IRIS M

Enhancing Vision

Section 1
Introduction to Motion Amplification®

Objectives:

1. Introduce Motion Amplification Technology
2. How Motion Amplification compares with other predictive maintenance technologies
3. Review Motion Amplification Vibration Amplitude Units

Technology Overview

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- Motion Amplification (MA)
- Relatively new technology
- Easily visualize minute amounts of movement.
- High-speed machine grade camera, along with RDI patented processing algorithms.
- Creates data that can be analyzed using RDI's proprietary software.
- Converts each pixel in video image into a sensor that measures vibration and motion.

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Benefits of MA

- **Improved Safety** – Non-Contact
- **Reduced Unplanned Downtime** – Easy to see what "bad actors" are doing.
- **Complements RCA Activities** – Root Cause often visually apparent.
- **Diverse Applications** – Rotating machines, structures, process lines, piping, etc.

Benefits of MA

- **Quick and Easy –** Little set up, capture takes a few seconds, good troubleshooting tool.

- **Actionable Information –** Results easy to see enhancing communications.

- **Less Training –** MA technology takes only a few days to become proficient.

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Traditional Technologies

Vibration Analysis - Predictive maintenance and troubleshooting tool.

Typical process:

- Set up in analysis software.
- Transfer to portable vibration analyzer.
- Place accelerometer at measurement points, one by one.
- Transfer measurements to analysis software.
- Analysis of vibration spectra and waveforms - attempt to identify cause and severity of problem.
- Report generation of findings – communicate to maintenance/planning personnel.

Challenges:

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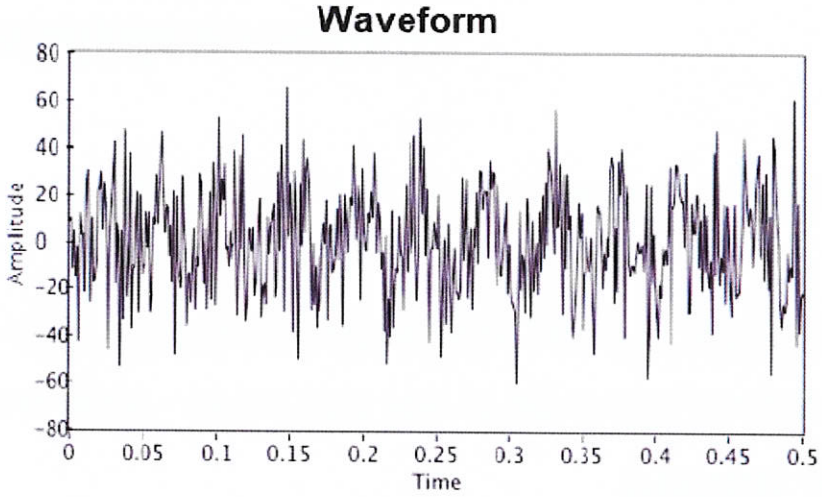
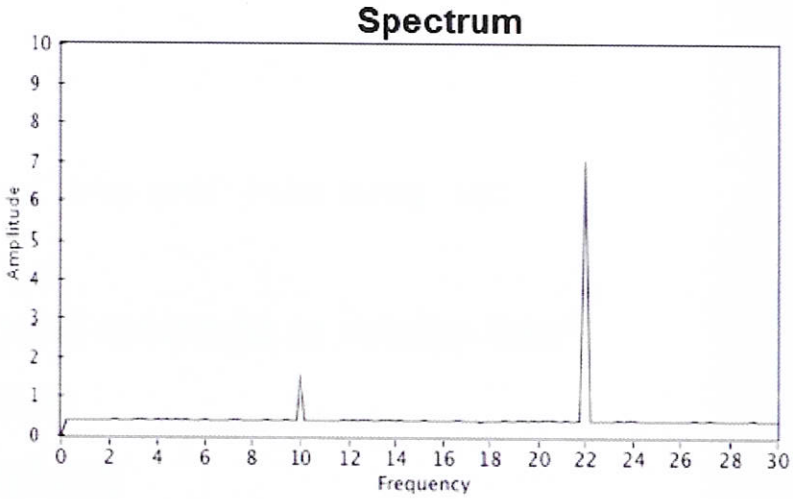
- Measurements typically made only at bearing housings.
- Measurement locations need to be accessible and clean.
- Data needs to be analyzed by an experienced vibration analyst.
- Many times inconclusive – more troubleshooting required (phase analysis or ODS).
- Data collection typically NON-Simultaneous - phase information requires a separate process.





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Phase Analysis

Phase Analysis - Often first line of advanced troubleshooting.

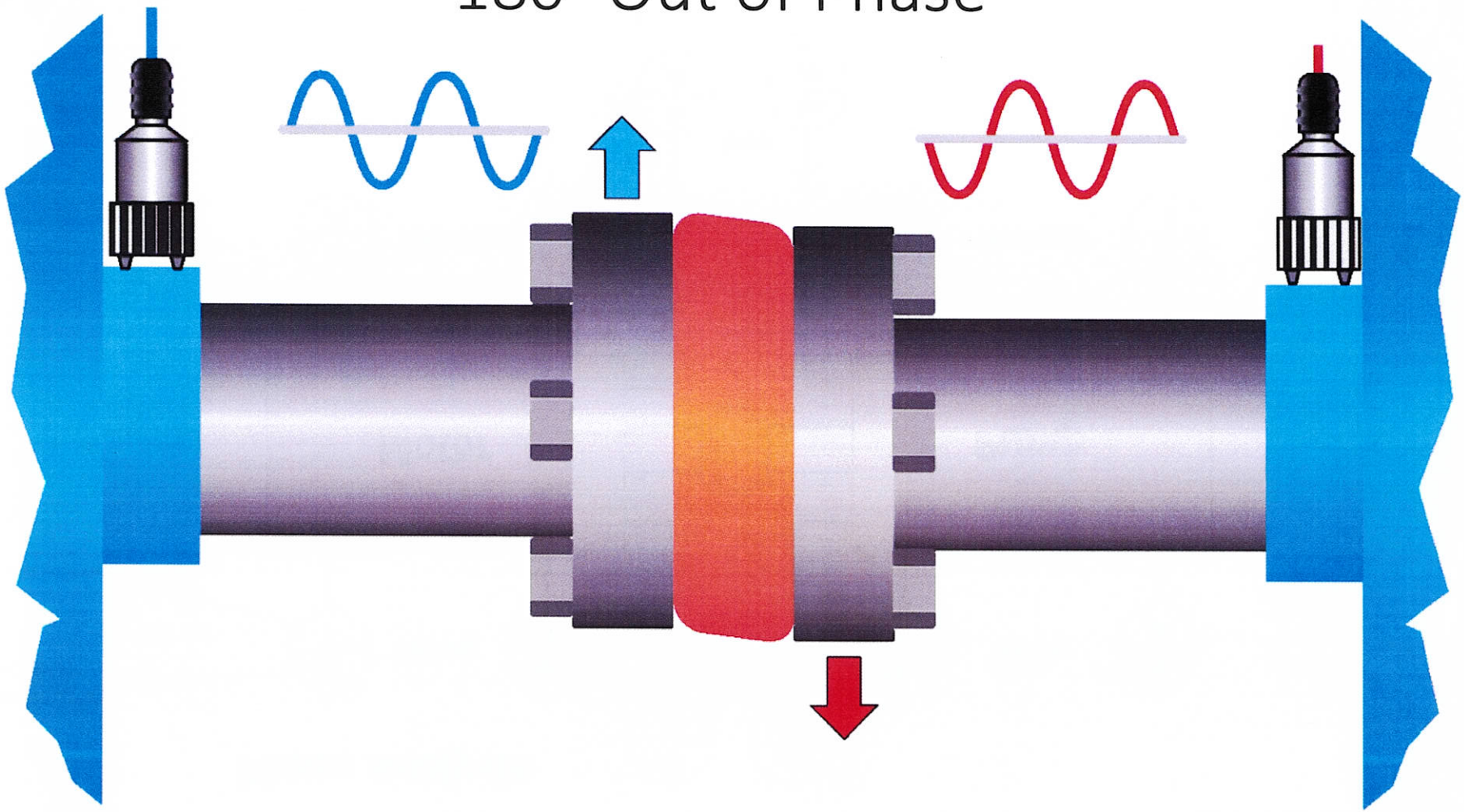
Provides relative timing of when one part of machine is moving compared to another part.

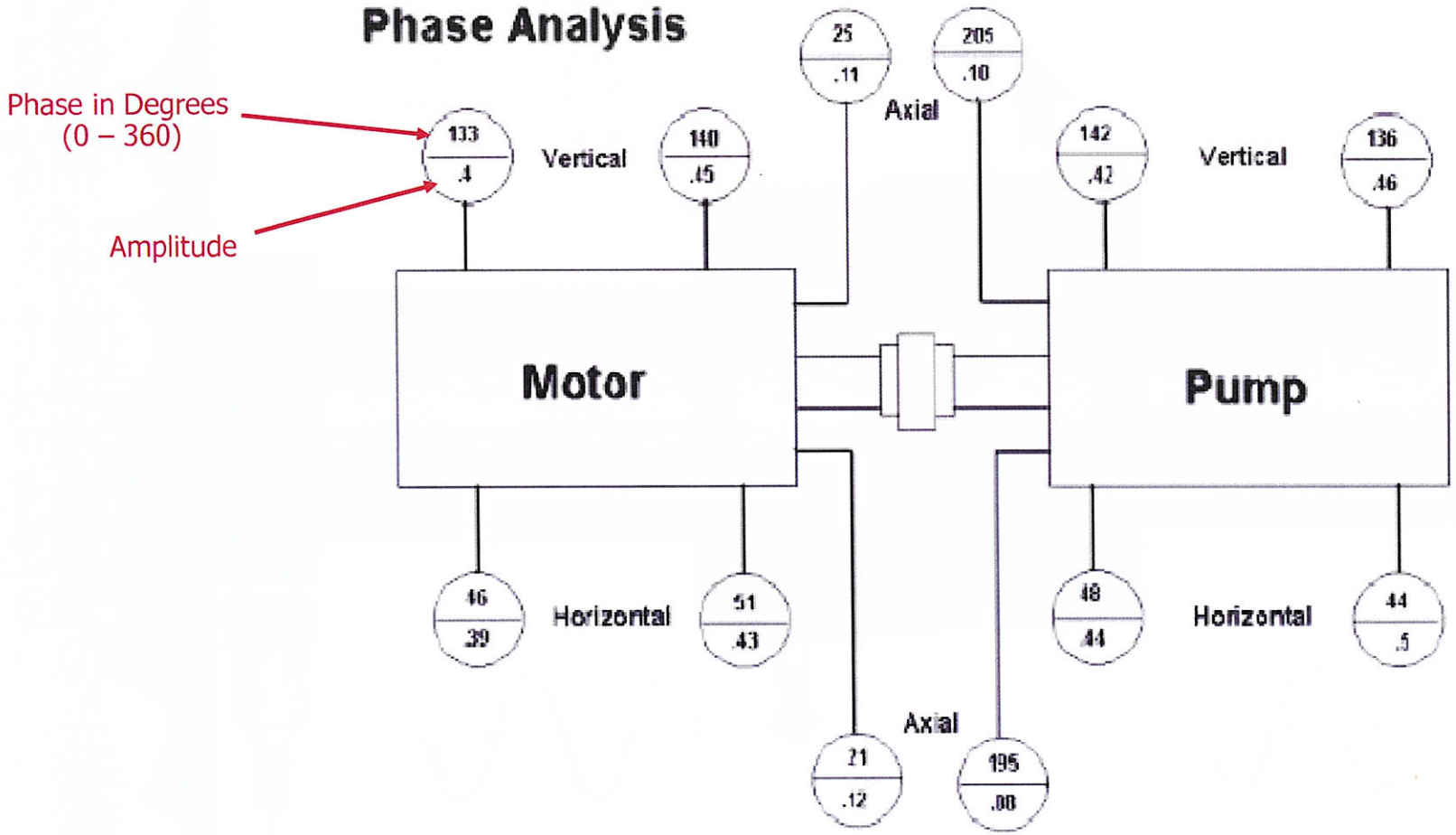
Can help identify conditions such as looseness, misalignment, soft foot, bent shaft, etc.

Phase analysis procedure:

- Stop machine to apply reflective tape to shaft.
- Set up photo tach - or if using two-channel analyzer, a reference vibration sensor.
- Acquire amplitude and phase measurements at each location.
- Manually record results to a bubble diagram.
- Analyze bubble diagram to interpret result.

180° Out of Phase





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Results need to be interpreted by an experienced vibration analyst.

ODS (Operational Deflection Shape)

ODS - Advanced method of phase analysis.

Provides an animation representing machinery motion.

ODS Procedure:

- Make diagram/sketch of machine.
- Create model of machine in ODS software.
- Acquire amplitude and phase measurements.
- Transfer data to ODS software.
- Number measurement points in model exactly as measurements were taken on machine.
- Assign measurement point data to numbered points in model.
- Perform animation function in ODS software – Create video for reporting

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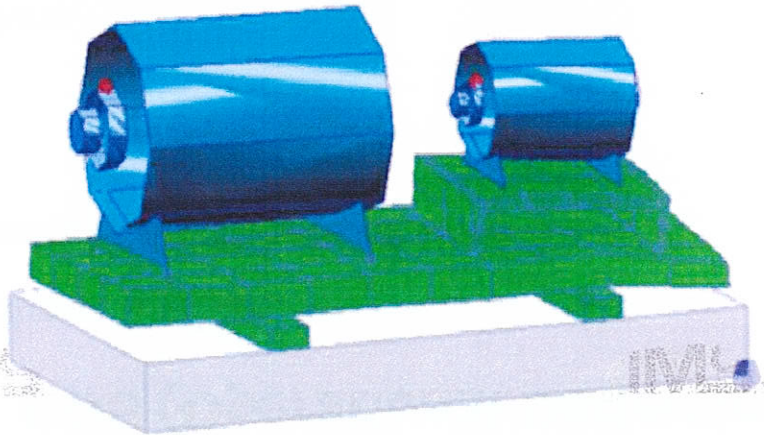
ODS

Properly executed ODS can help to solve even complex vibration related problems.

ODS Cost/Challenges:

- ODS software required
- Time spent modeling machine and acquiring data.
- Risk of getting questionable data and making errors assigning measurements.
- Important locations may still be missed
- ODS animation includes movement from "interpolated" points, which aren't actually measured.

ODS Animated Model



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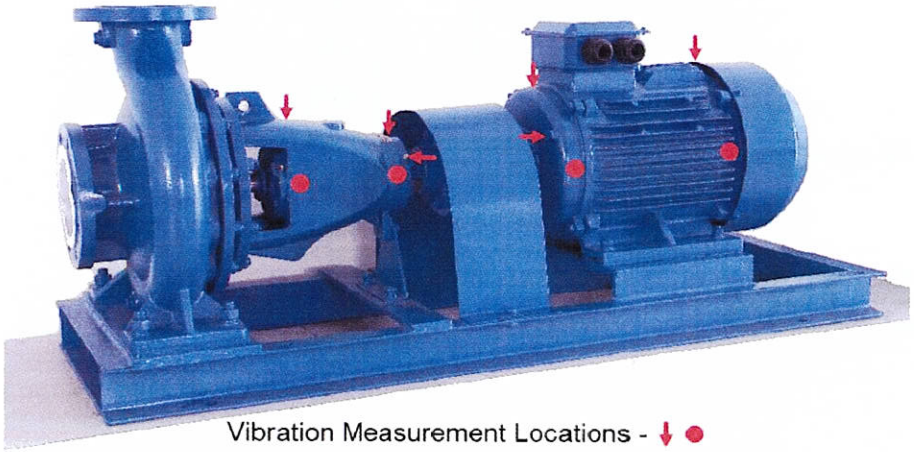
MA (Motion Amplification) - Combines many benefits of vibration analysis, phase analysis, and ODS.

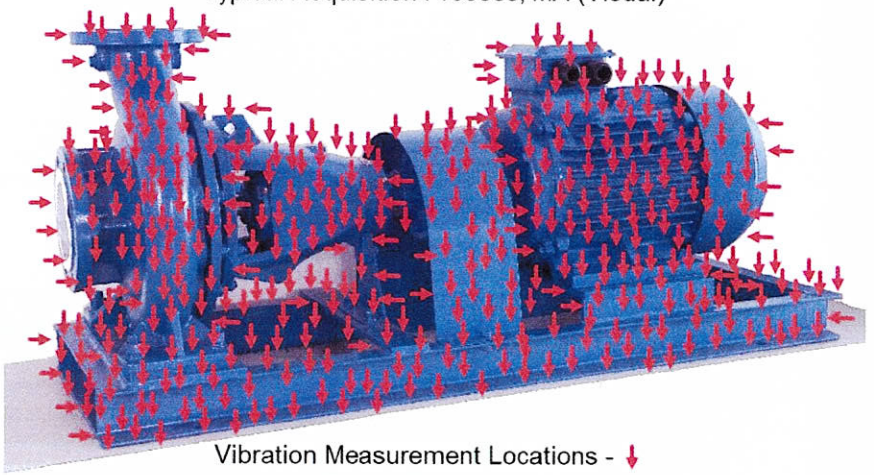
- Data is substantially more than with traditional vibration analysis.
- Data in entire image is acquired simultaneously - Provides phase information without using a separate process.
- Each pixel in image can be used as a vibration measurement.
- Instead of 10 to 12 measurements, MA provides vibration information from millions of locations.

Typical Acquisition Process, Traditional



Vibration Measurement Locations - ↓ ●

Typical Acquisition Process, MA (Visual)



Vibration Measurement Locations - ↓

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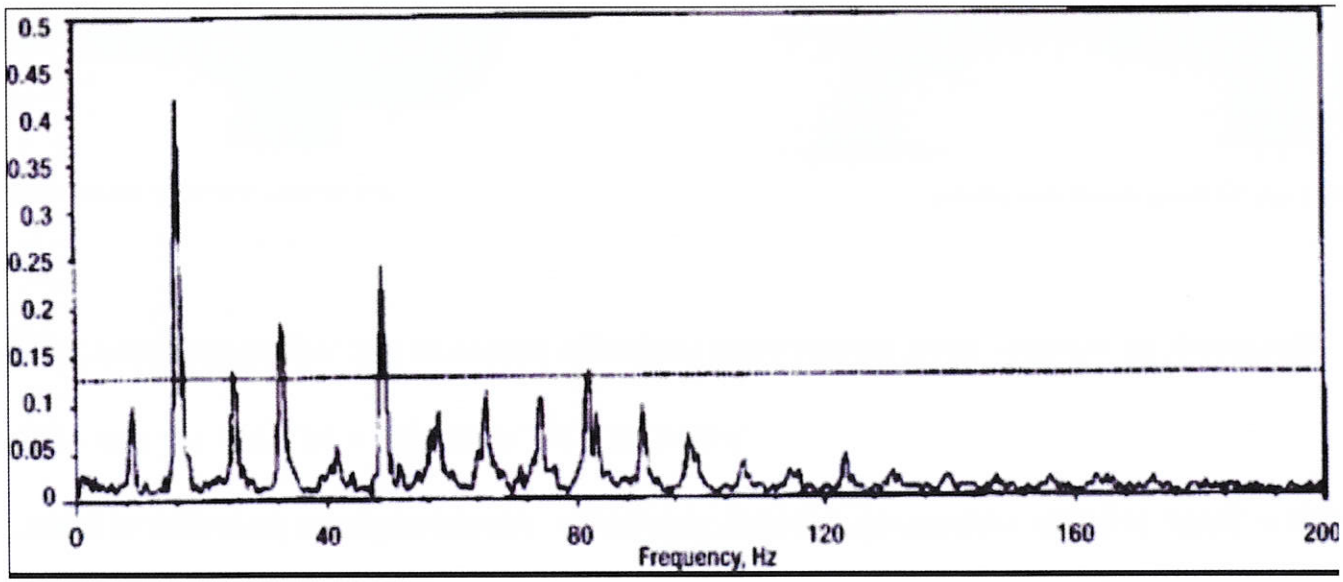
Traditional vibration analysis data/report

FFT Spectrum



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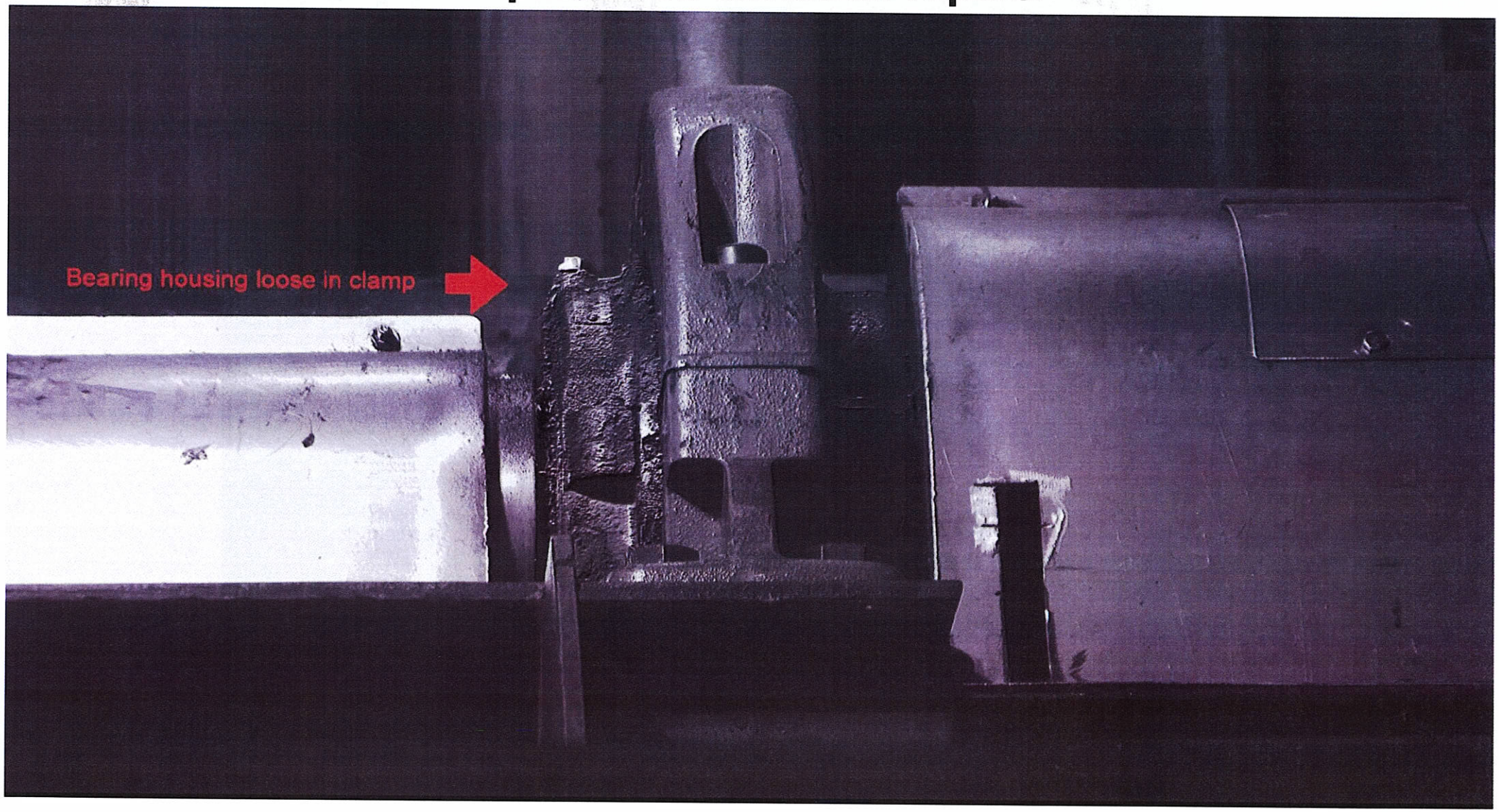
Motion Amplification customer report:



Misalignment

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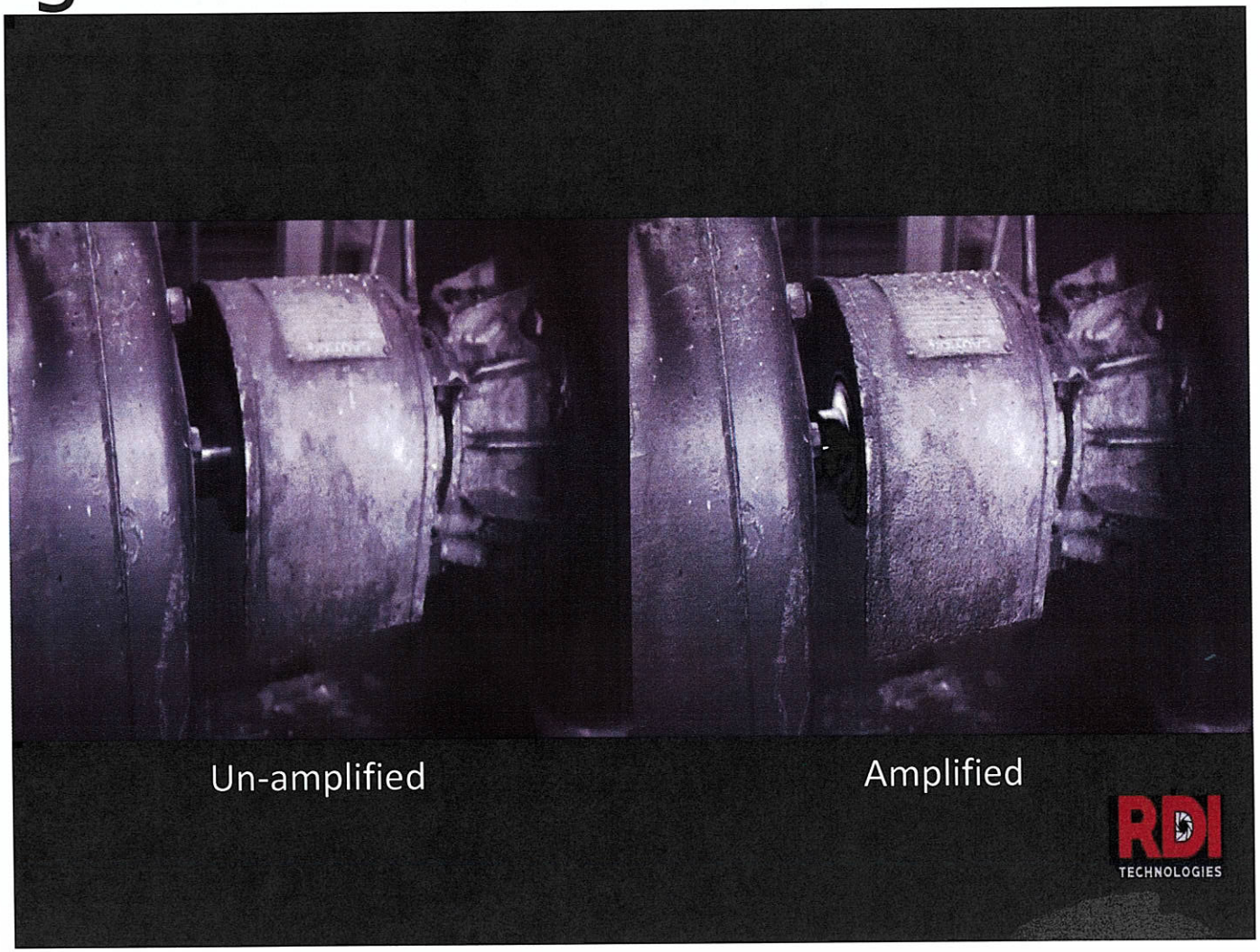

MA Vibration Amplitude Units

- Recording can be used to measure vibration frequency and amplitude of almost anything in image.
- Software can generate vibration waveform, spectrum data and orbit data.
- ***Vibration amplitude units are Mils (or microns) of displacement.***

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Vibration Amplitude Units

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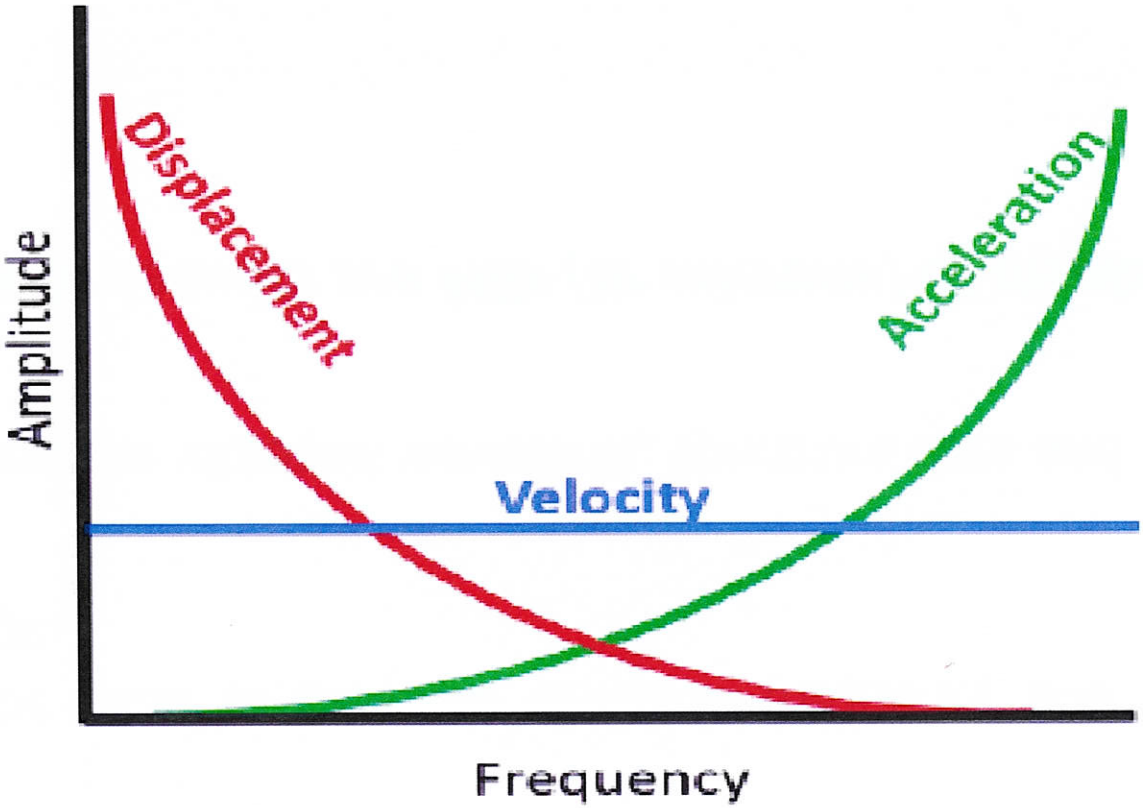

RDI TECHNOLOGIES

Motion Amplification:
Displacement in Mils

Traditional Vibration Analysis:
Acceleration in G's

Vibration Amplitude Units

MA measures actual displacement - remains very useful on very slowly rotating equipment.

Most forces that cause machinery to move with measurable displacement are:

- **Imbalance**
- **Misalignment**
- **Looseness**
- **Bent shaft**

Therefore, these are the most common forcing functions identified through MA vibration analysis.

RDI TECHNOLOGIES

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Vibration Amplitude Units

Higher frequency forcing functions:

- **Anti-Friction Bearing Defects**
- **Gear Mesh Vibration**
- **Lubrication Defects**

Better detected and analyzed using traditional vibration analysis techniques.

Section 1
Review

1. How is Motion Amplification safer than traditional route-based vibration analysis?
2. What are the native amplitude units measured with Motion Amplification?
3. In what ways does Motion Amplification differ from ODS?
4. What are the most common machinery forcing functions identified through Motion Amplification?

RDI TECHNOLOGIES

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IRIS M

Enhancing Vision

Section 2

Camera, Lighting, and Lenses

Objectives:

1. Gain understanding of basic photography techniques
2. Learn how to use equipment in Iris M and Iris MX kits
3. Understand common terminology associated with MA data acquisition

The Iris M Camera

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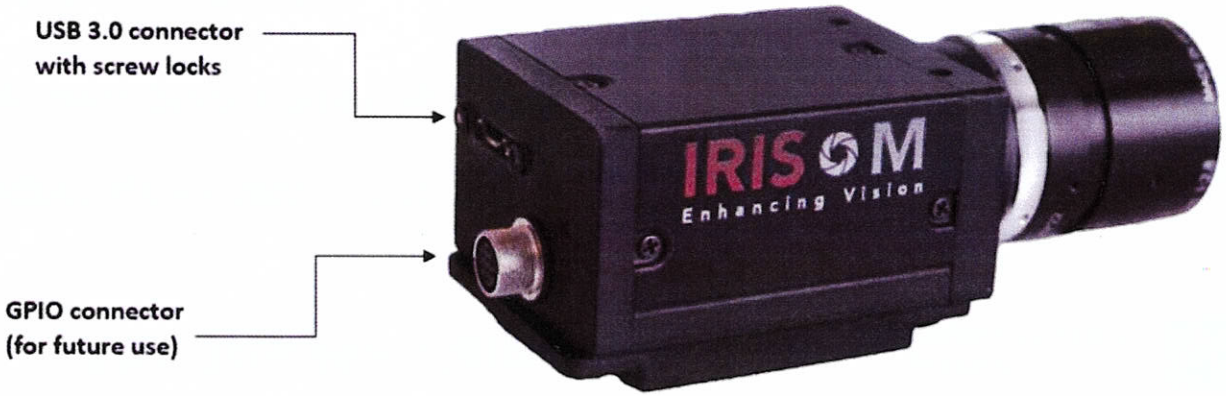
The Iris M - Industrial grade streaming video camera

- High quality grayscale.
- 12 bit CMOS sensor - pixel array 1920 x 1200, resolution over 2.3 MP.
- 1300 FPS at reduced resolution.
- USB 3.0 cable - power to camera and data streaming to acquisition unit.
- Cable connected to camera ***at all times*** by screw lock connector.



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The Iris MX Camera

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The Iris MX - Camera designed for higher speed data collection.

- Advanced 12 bit CMOS sensor - pixel array 2560 x 2048, resolution over 5.3 MP.
- High speed camera - 29,000 FPS at reduced resolution.
- Memory on board
- Power supplied by 10-26 VDC external power supply or Li-ion battery.

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Lenses

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12.5 mm (Focal Length)

25 mm (Focal Length)

50 mm (Focal Length)

100 mm (Focal Length)

- Kit includes several lenses with different focal lengths.
- Color coded for quick identification.
- C-Mount Lenses.
- All lenses are interchangeable between Iris M and Iris MX cameras except for 6mm lens.

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Focal Length

- ***Focal length determines field of view and magnification.***
- Lenses have a fixed focal length – <u>No Zoom</u>
- Only way to change focal length is to change lenses.
- Changing lens to double focal length = Magnification doubles, field of view decreases by one half.
- Changing lens to half focal length = Magnification decreases by one half, field of view doubles.

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Focal Length

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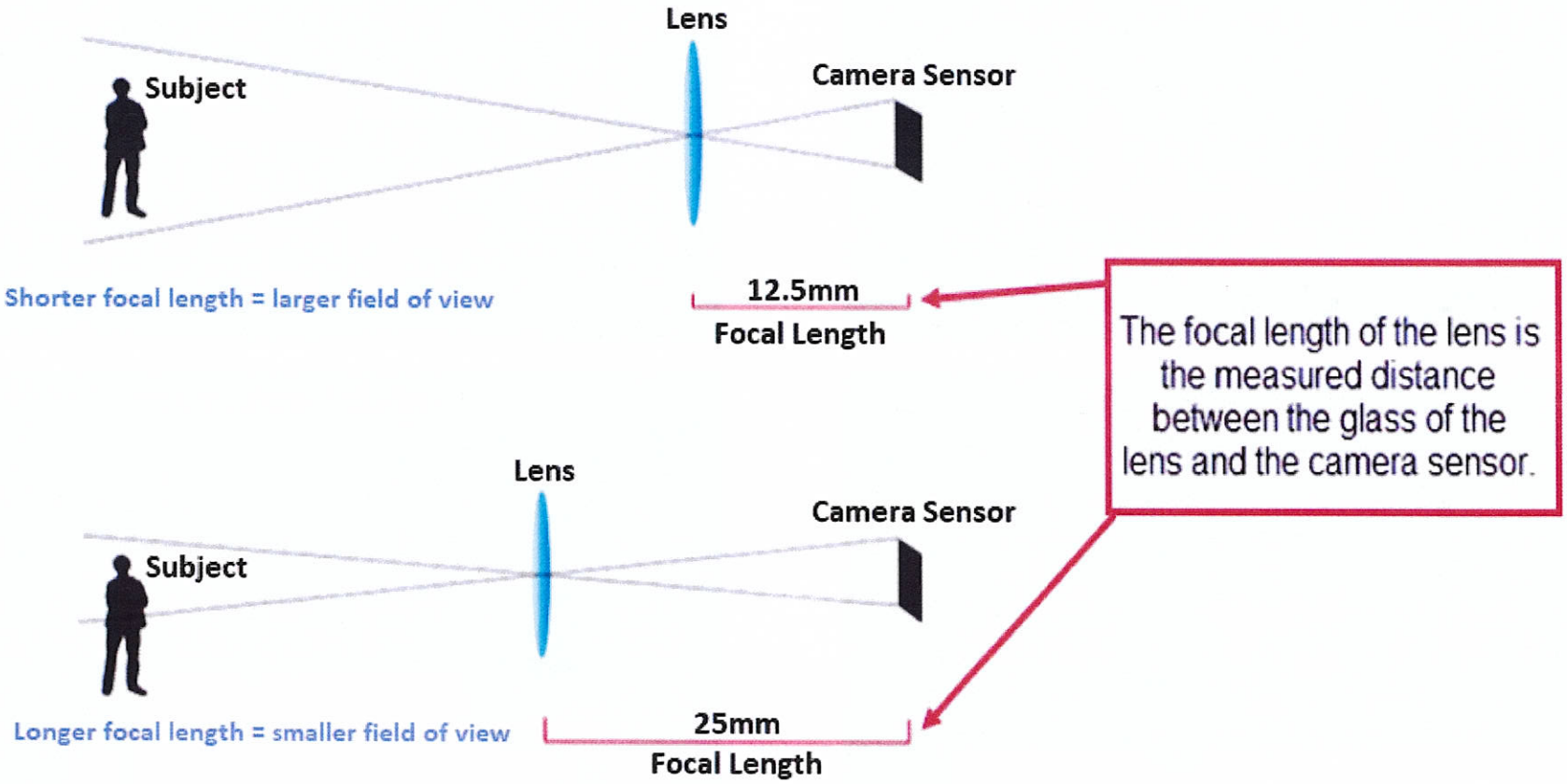
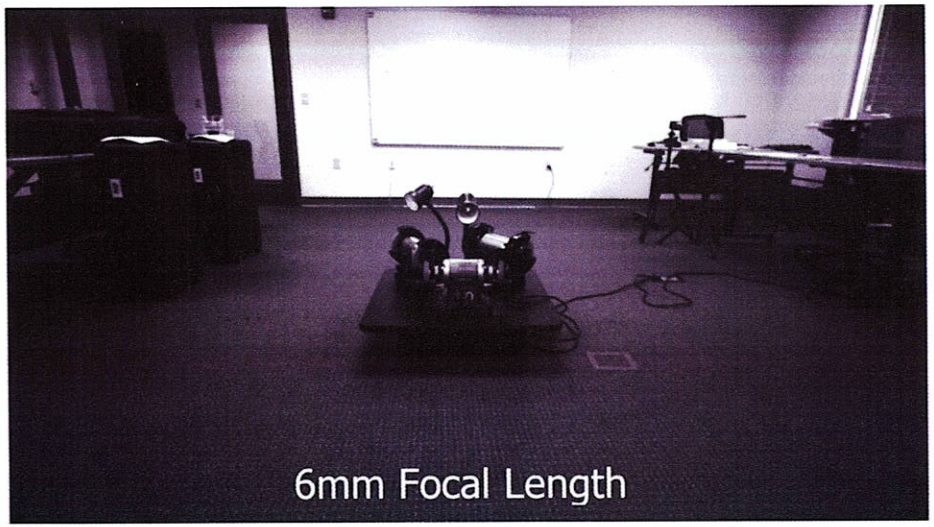
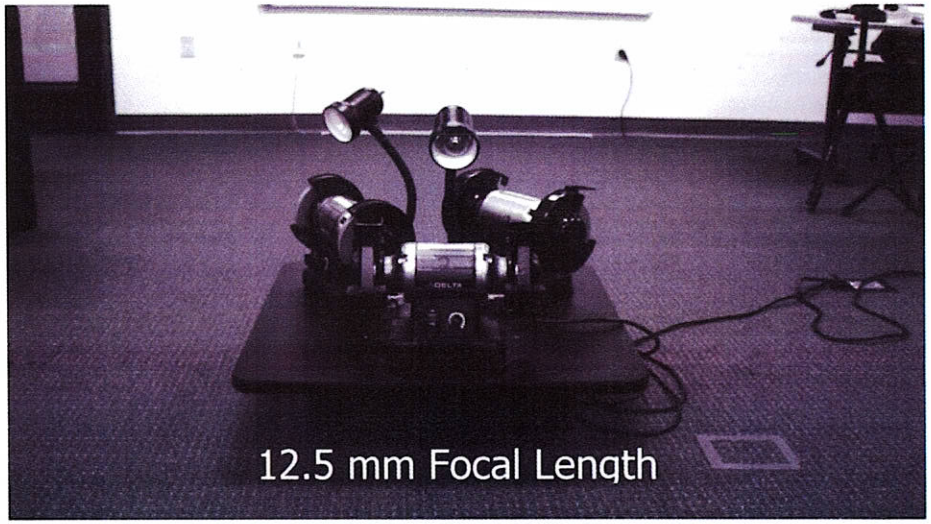
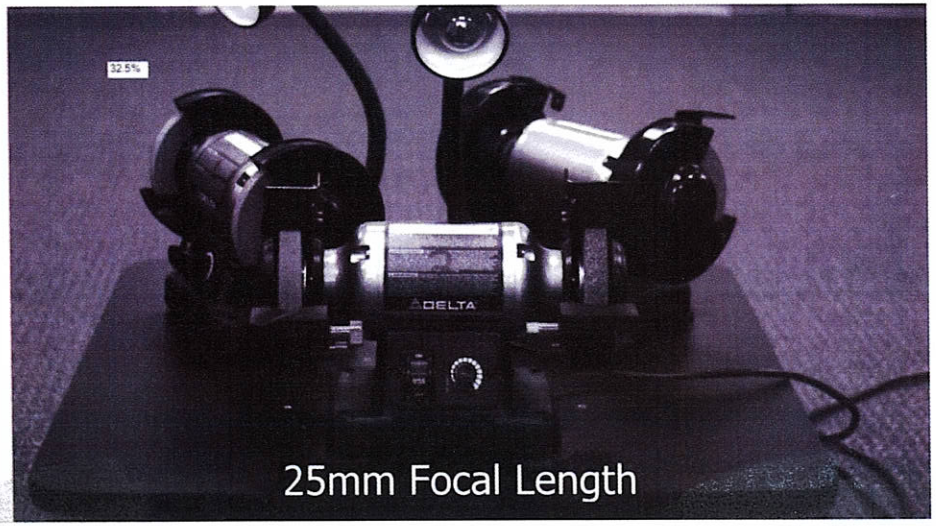


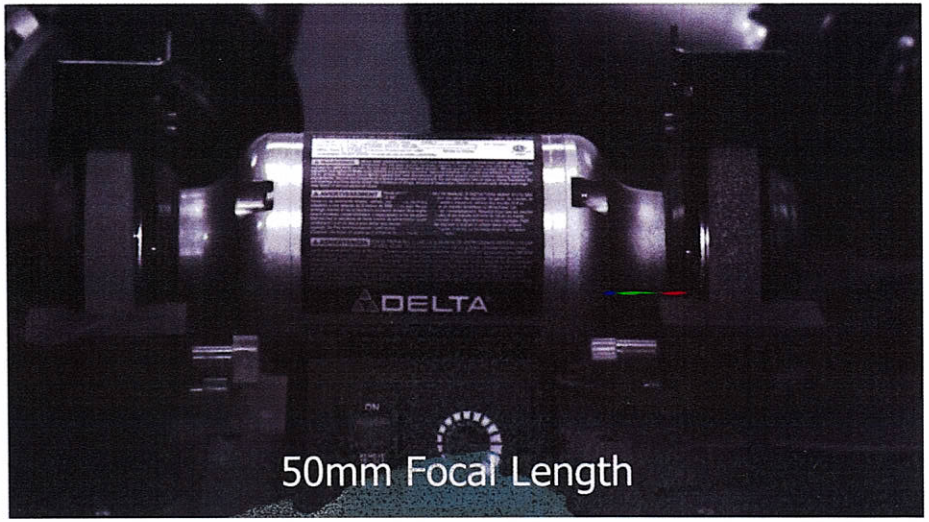
- ***Focal length determines field of view and magnification.***

Focal Length Comparison (Camera 10’ from asset)

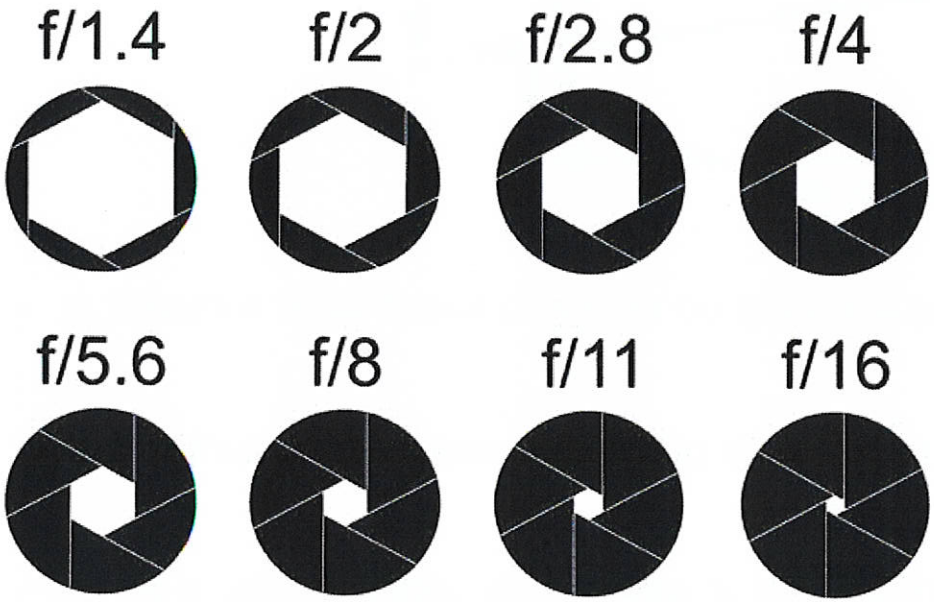








Aperture Adjustment



- Controls diameter of lens opening.
- Vary on most lenses from f/1.4 to f/22
- In this example – f/1.4 allows most light f/16 allows least.
- Each setting displayed here represents either halving or doubling amount of light.
- f/2.8 allows half amount of light as f/2, but double as much as f/4.

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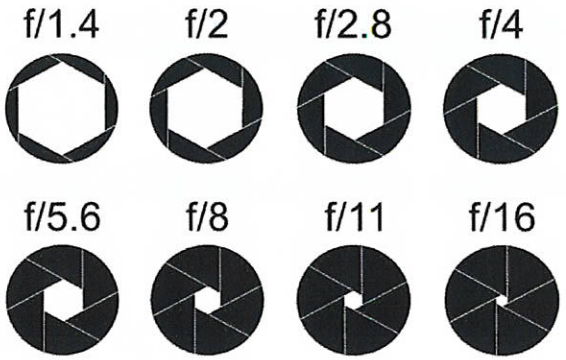
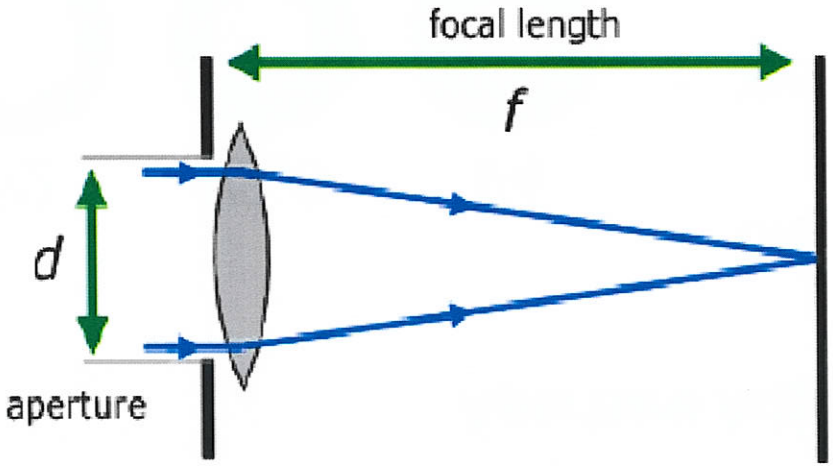
F Ratio



- Notice aperture values get higher as aperture opening decreases.
- Value is ratio between focal length of lens and diameter of aperture opening.
- If aperture opening was 50mm and focal length was 50mm, f-ratio would be f/1.
- If aperture were closed to 25mm on the same lens, f-ratio would be f/2.



$$\text{F Ratio} = \frac{\text{focal length (f)}}{\text{aperture diameter (d)}}$$

RDI TECHNOLOGIES

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Depth of Field and Aperture

- Aperture adjustments effects Depth of Field.
- ***Depth of Field is distance between closest and farthest points in image that are in focus.***
- Shallow Depth of Field - smaller amount of image in focus - Portrait photography.
- Wide Depth of Field – entire image (all distances) in focus - Landscape photography.

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f/1.4

F Ratio = f/1.4

Shallow Depth of Field

Larger aperture.

Closest and farthest object in focus not far apart.

Portrait photography.

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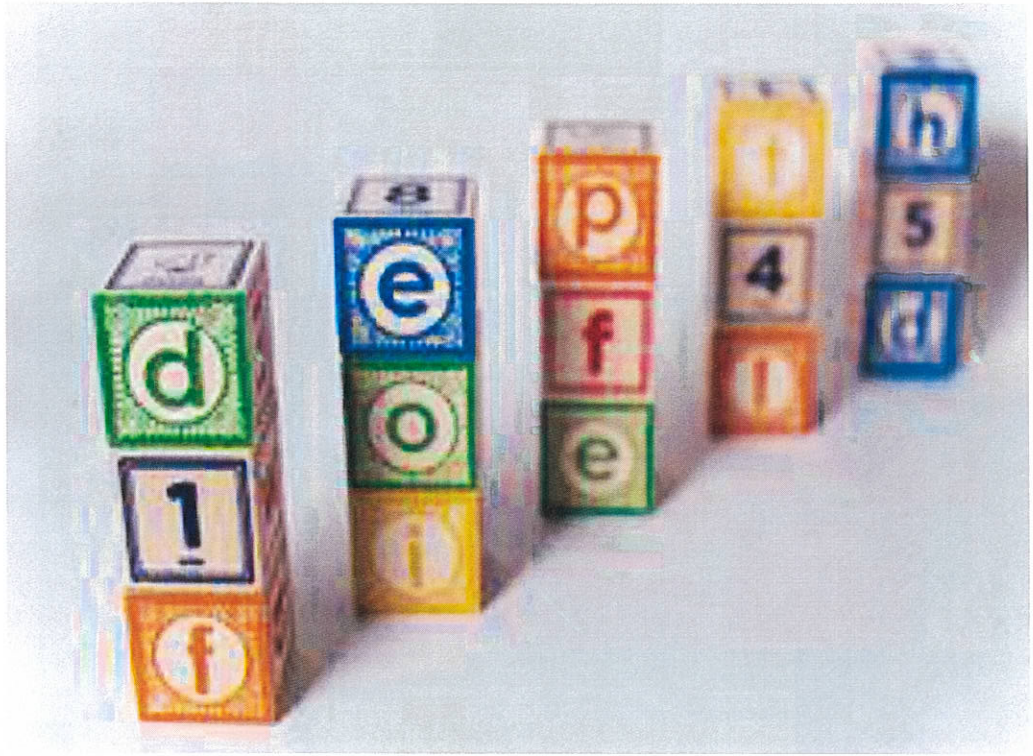
F Ratio = f/4.0



f/4

Medium Depth of Field

Closing aperture a bit makes depth of field larger.

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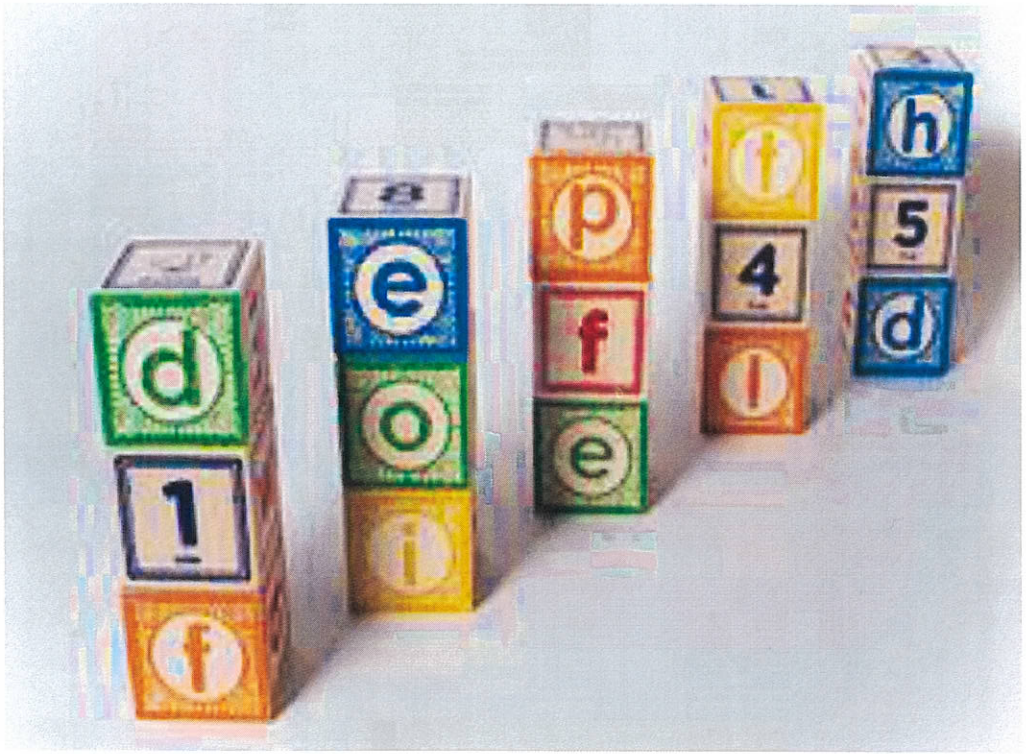
F Ratio = f/22



Wide Depth of Field

Setting to f/22, depth of field is now much larger.

Closest and farthest object in focus are farther apart.

Landscape photography.

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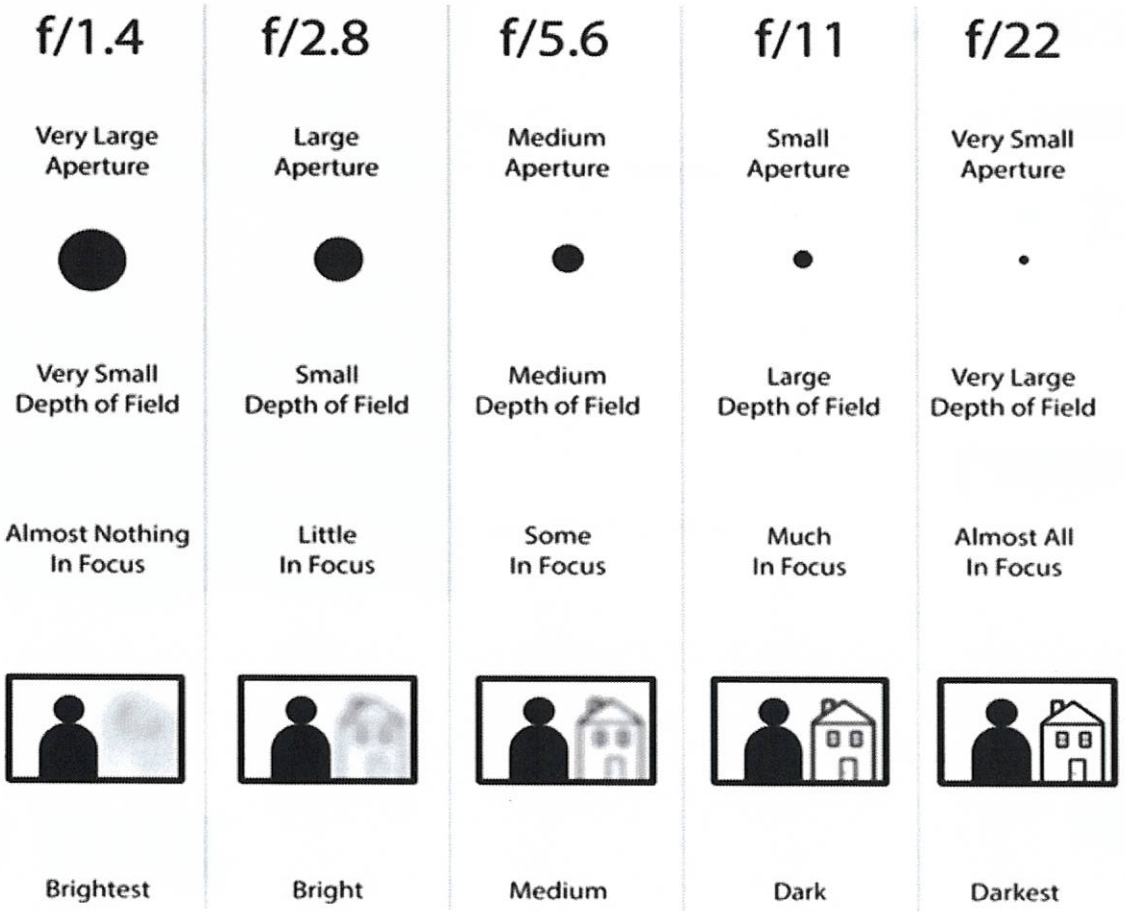
- Closing aperture for larger depth of field allows less light to enter camera's sensor, resulting in darker image.

- If larger depth of field is needed for an image, more light may be needed.



RDI TECHNOLOGIES

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Acquisition Unit

Microsoft Surfacebook 3

or

Dell Latitude Rugged

- 1 TB
- 32 Gb RAM
- Transport Case
- Preloaded with RDI Software Applications

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Tripod Use

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- Tripod designed to provide virtually any camera angle.
- ***Most important consideration, next to safety, is camera stability.***
- Best way to get usable recordings is to eliminate camera shake at the source.
- "Best Practices" that should always be observed…

RDI TECHNOLOGIES

Tripod Use – Best Practices

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- ***Always use vibration pads***
- **Move camera away from vibration source**
- **Extend thicker portions of legs first**
- **Avoid extending center rod**

RDI TECHNOLOGIES

USB 3.0 Cable

- A special USB 3.0 cable is supplied with the IRIS M camera.
- Provides camera power and carries data from camera to Acquisition Unit.
- ***When connected to camera, screw locks must be utilized.***
- Longer cable can be ordered if needed.

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Lighting

Many situations require additional light

- IRIS M accessory kit includes a DC powered LED light.
- 135,000 lux - dimmable (10%-100%) onboard controls or wireless remote.
- AC 110 V – 240 V or Lithium Ion battery.
- Battery life at full intensity approximately 23 minutes.

RDI TECHNOLOGIES

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Section 2
Review

1. What is the maximum framerate of the Iris M camera?
2. Do the supplied lenses in the Iris M/MX camera kit have adjustable zoom?
3. What is the maximum framerate of the Iris MX camera?
4. When should the supplied vibration pads be used with the camera tripod?
5. When should the screw locks on the USB3 cable be used?

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Section 2
Review

6. Which aperture setting would allow exactly half as much light to enter the camera sensor as the f/4.0 setting?

7. Which aperture setting would give a larger depth of field: f/5.6 or f/22?

8. What does FPS stand for?

9. Which focal length would result in a larger field of view? 25mm or 50mm?

IRIS M

Enhancing Vision

Section 3

Introduction to Motion Explorer

Objectives:

1. Introduce the four MA software applications
2. Build a database hierarchy using Motion Explorer
3. Launch the Acquisition and Motion Amplification applications directly from Motion Explorer

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RDI Software Applications

IRIS M Acquisition Unit comes preloaded with four software applications.

RDI Motion Explorer

- Create database structure
- Organize/store raw data, mp4 videos, and images
- Launch other three applications

RDI Acquisition

- Recording/data acquisition
- Application only works when camera is connected

RDI Motion Amplification

- View/edit recordings
- Analysis
- Create mp4 videos and images

RDI Motion Studio

- Video editing
- Build movies
- Titles can be included
- Helps tell a complete story

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Motion Explorer

Motion Explorer allows user to:

- Create hierarchy of folders and assets.
- Organize links to recordings, Exported MP4 videos, and other files

- Assets have one or more associated collections
- Collections are where recordings, MP4 videos and images reside.

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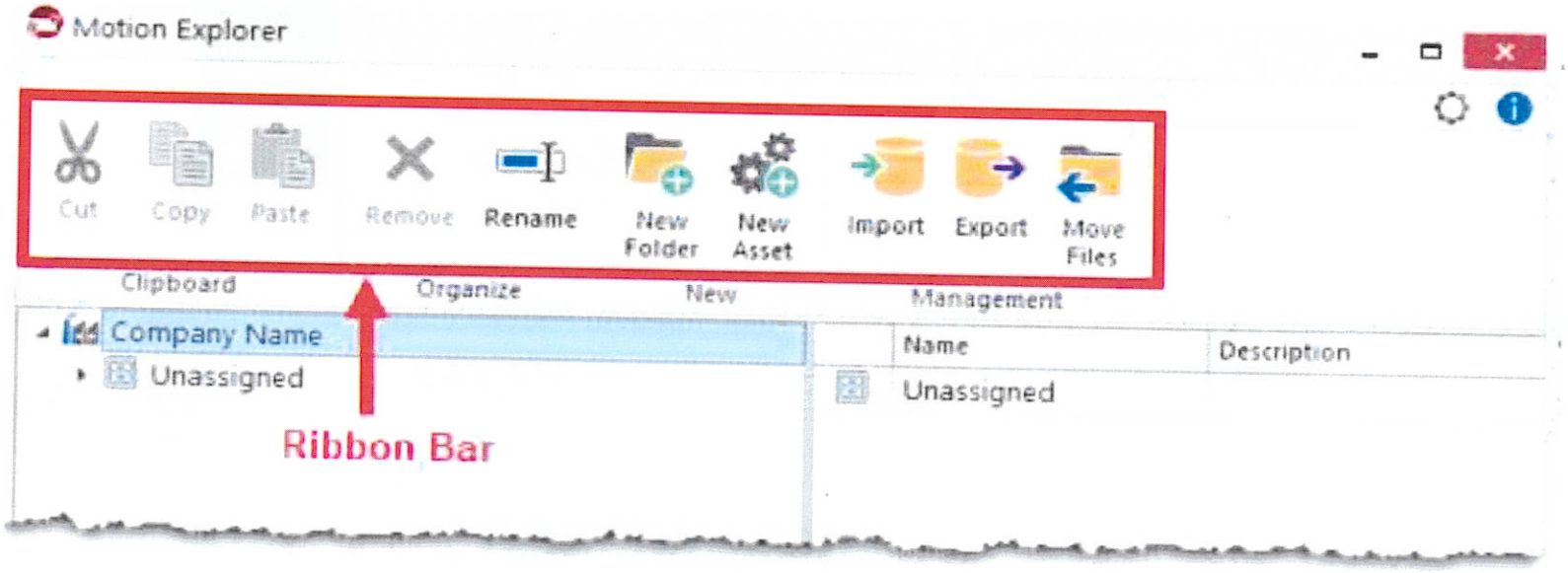
Getting Started

When Motion Explorer is launched for first time, hierarchy contains only an item representing the company and an Unassigned folder.

- Company name can be renamed.
- Folders, Assets and Collections can be added.

Ribbon Bar



Context sensitive - shows only functions that can be performed on currently selected item.

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Adding Items to Hierarchy

- When Company selected - Folders and Assets can be added.
- When Folder selected - Folders and Assets can be added.
- When Asset selected - Collections can be added.

Cut/Copy/Paste

- Cut/Paste
- Copy/Paste
- Recordings, MP4's, and other files <u>can't</u> be copied from within Motion Explorer.

Remove

- Any item except Company can be removed.

Rename

- Any item can be renamed.

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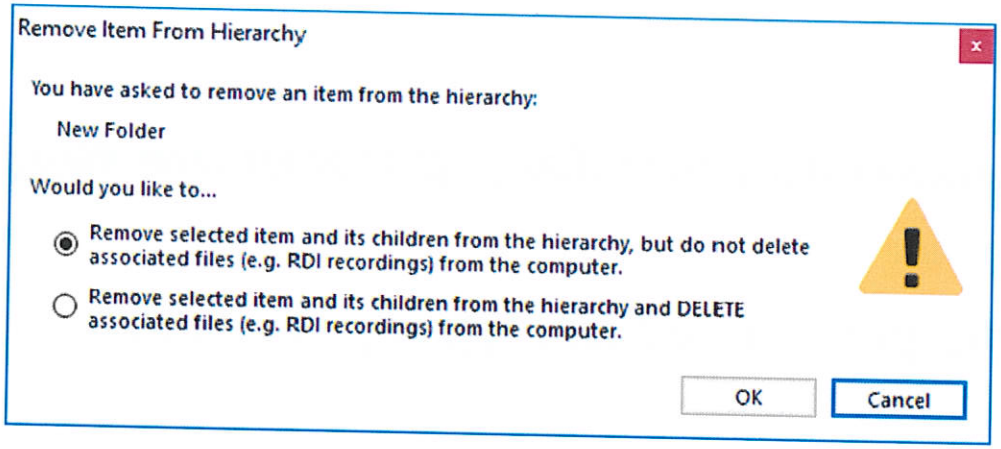

Important: When removing an item a dialog will be displayed asking, Would you like to…

- Remove selected item and its children from the hierarchy, but do not delete associated files.

- Remove selected item and its children from the hierarchy and DELETE any associated files.

RDI TECHNOLOGIES

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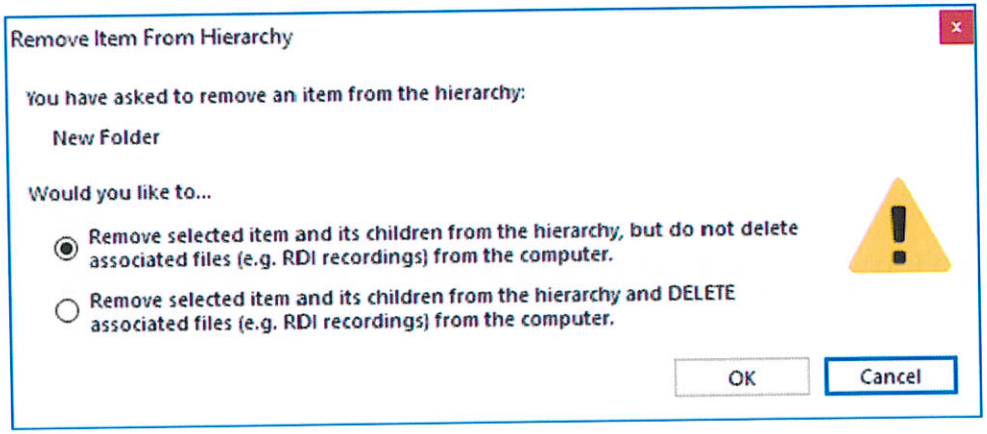

- Recordings, MP4's, and other files are not stored in RDI Hierarchy Database.
- Stored in Windows File System and linked to storage location in Hierarchy.
- Choice to remove just link to file OR remove link and delete associated files.

If files are deleted, they can't be recovered.

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Exercise 1 - Create a Hierarchy

Step 1 - Open IRIS M Acquisition Unit and turn on power.

Step 2 - Launch **Motion Explorer** application. 

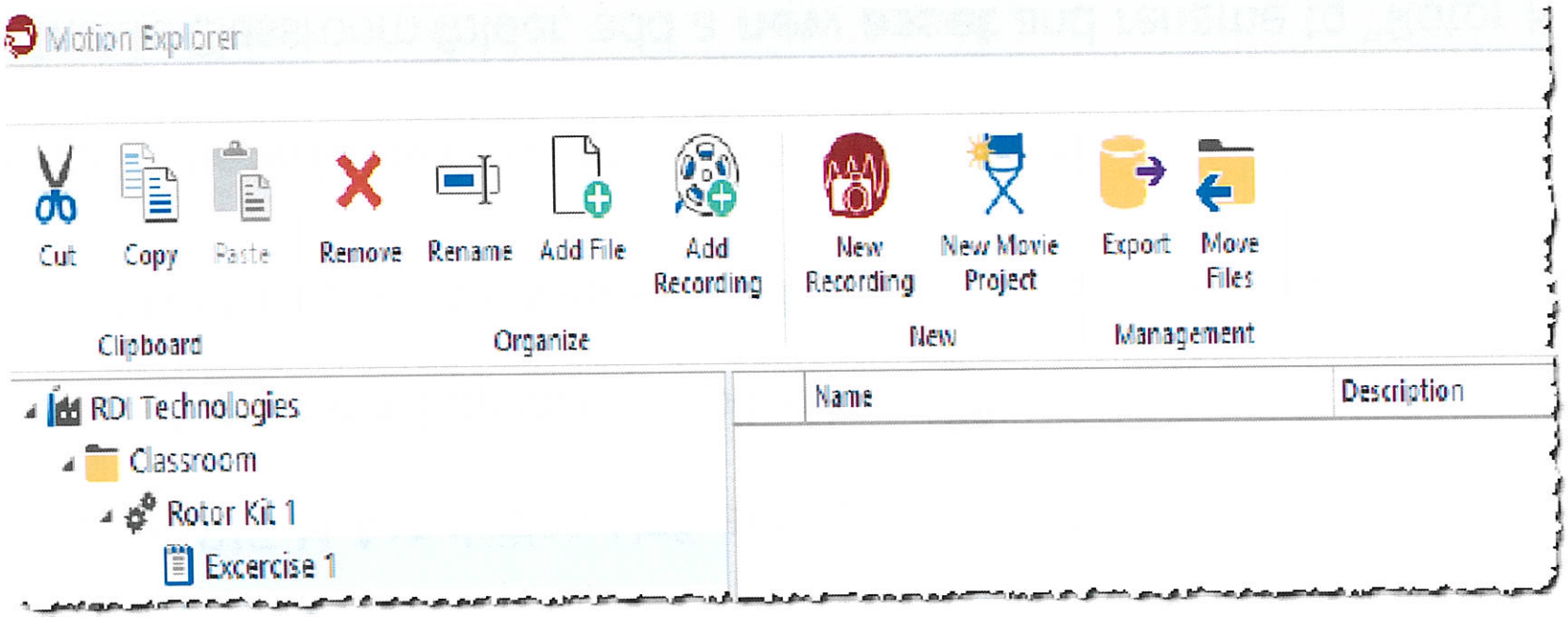
Step 3 - Highlight **Company Name** in left pane and rename to your company name.

Step 4 - Add a **new folder** and rename to "Classroom".

Step 5 - Inside Classroom folder, add a **new asset** and rename to "Rotor Kit 1".

Step 6 - Inside Rotor Kit 1, add a **new collection** and rename to "Exercise 1".

Result should look like this:



RDI TECHNOLOGIES

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Exercise 2 - Store a Recording in Motion Explorer

Step 1 – Connect USB 3.0 cable to camera. ***Make sure to fully seat screw connectors into camera.***

Step 2 – Connect USB 3.0 cable to Acquisition Unit. Green LED at back of camera should light.

Step 3 – Select 25mm lens from kit and attach to camera.

Step 4 – Highlight collection under Rotor Kit 1 and use ***New Recording*** button on Ribbon Bar to launch RDI Acquisition application.

A live image should appear on the screen.

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Exercise 2 - Store a Recording in Motion Explorer

Step 5 – Aim camera lens at rotor kit so rotor kit can be seen on acquisition screen.

Focus lens by following below procedure:

- Use Digital Zoom Button to zoom closer to rotor kit.
- Once image is zoomed it is easier to see focus quality.

Digital Zoom & Pan Controls 

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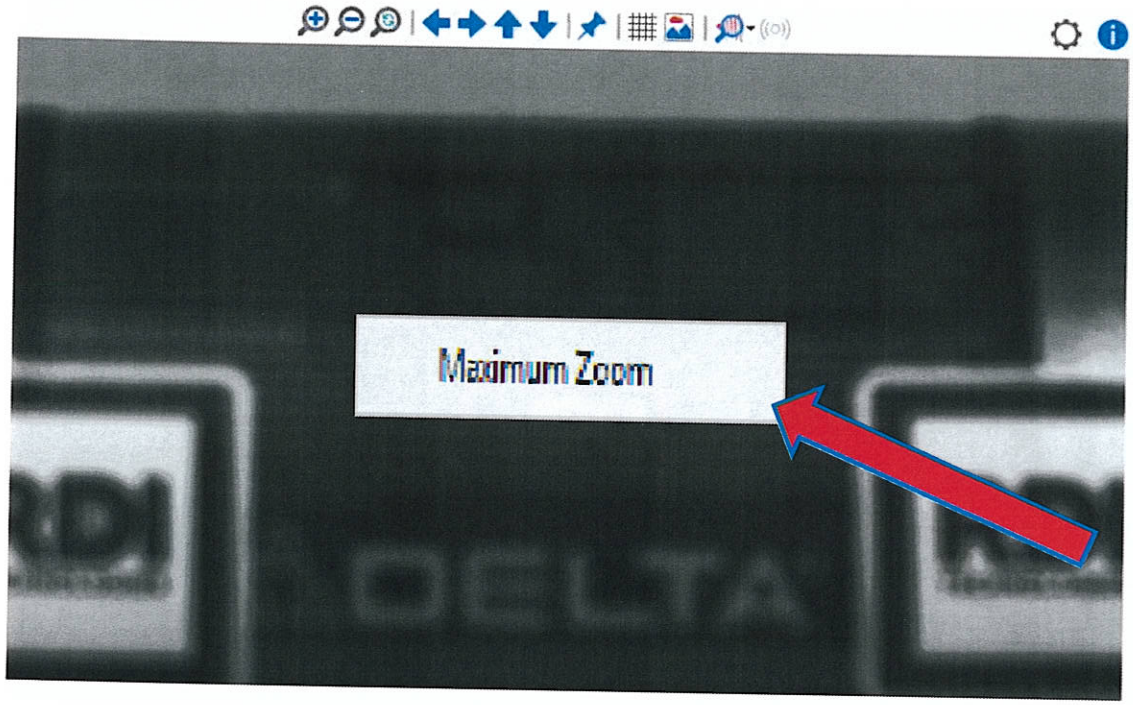
Exercise 2 - Store a Recording in Motion Explorer



- It can be helpful to zoom into an area where there is small print.
- In this case camera is zoomed to motor information tag.

An alternate zoom method is to right click inside image and click **"Maximum Zoom".**

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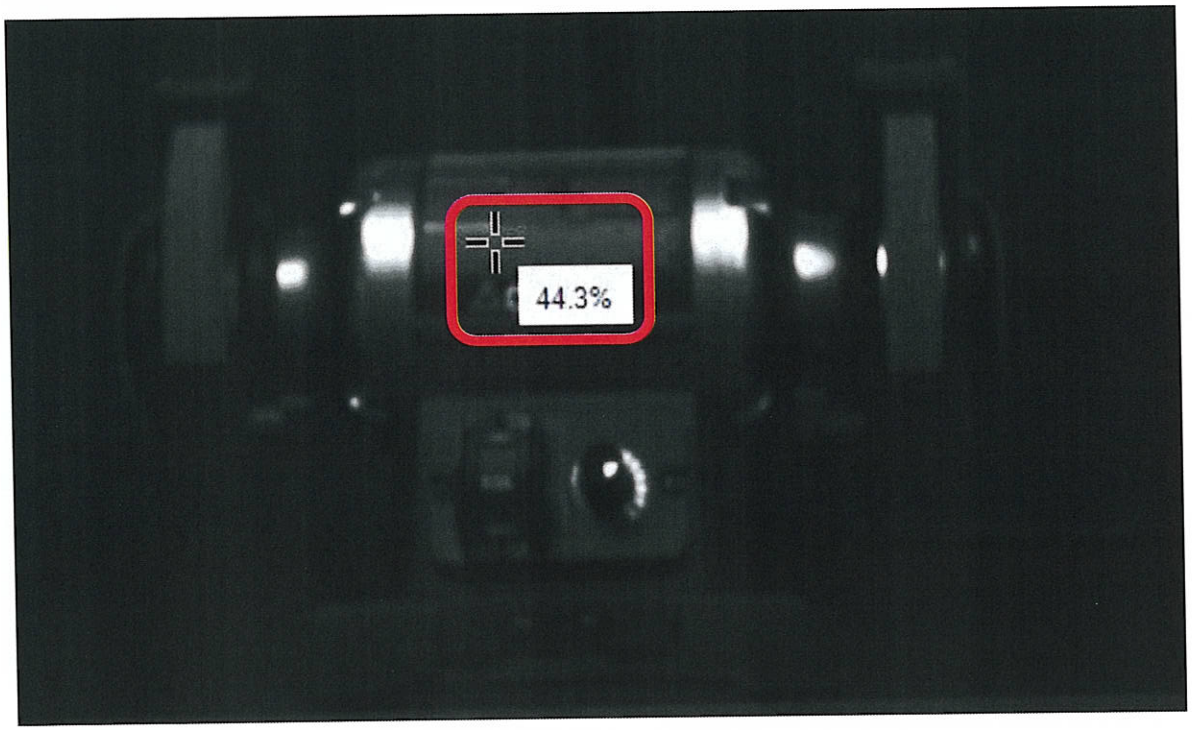
Exercise 2 - Store a Recording in Motion Explorer



Position cursor and click where desired center of zoomed image is to be.

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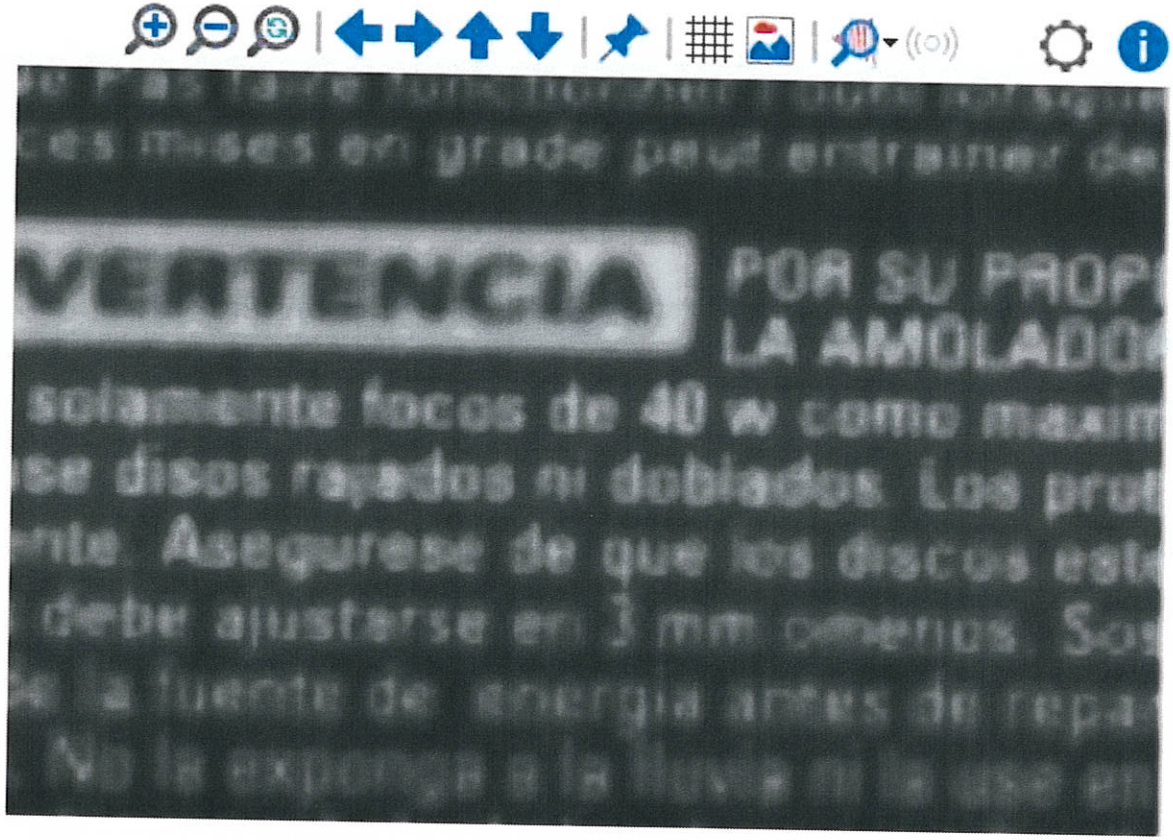
Exercise 2 - Store a Recording in Motion Explorer



Focus lens while at maximum zoom.

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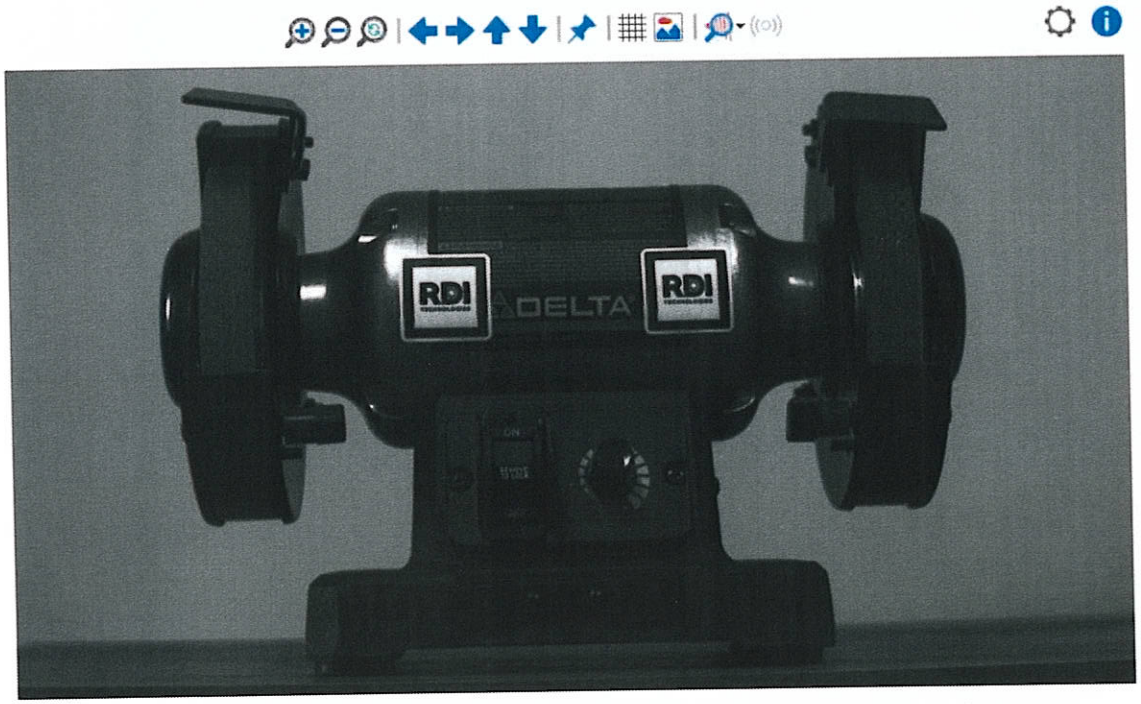
Exercise 2 - Store a Recording in Motion Explorer



Zoom back out to original setting.

Image is now focused as well as possible.

These steps should be taken each time prior to capturing a recording:

- Digital zoom
- adjust focus
- zoom back out

RDI TECHNOLOGIES

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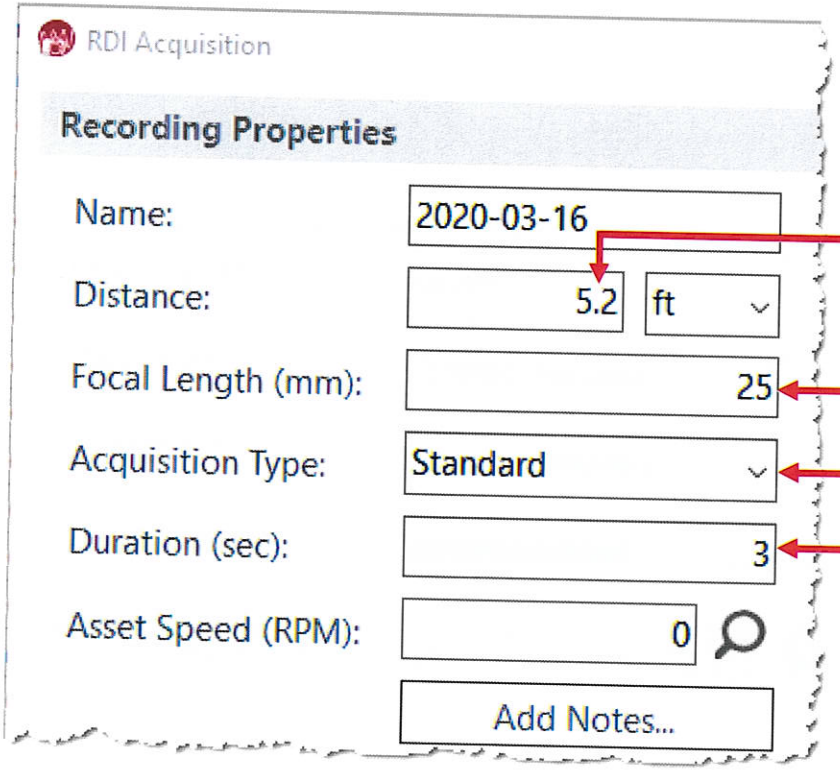
Exercise 2 - Store a Recording in Motion Explorer



Step 6 – Use laser rangefinder to measure distance to rotor kit and enter value.

Step 7 – Enter 25mm for Focal Length.

Step 8 – Set Acquisition Type to Standard.

Step 9 – Enter 3 for a 3 second acquisition time.

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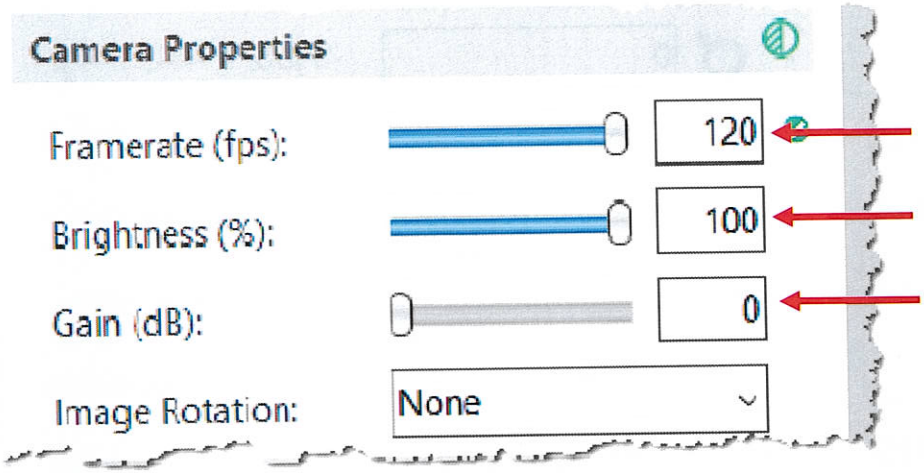
Exercise 2 - Store a Recording in Motion Explorer



Step 10 – Set Framerate (fps) to 120.

Step 11 - Adjust Brightness to 100.

Step 12 – Set Gain to 0.

RDI TECHNOLOGIES

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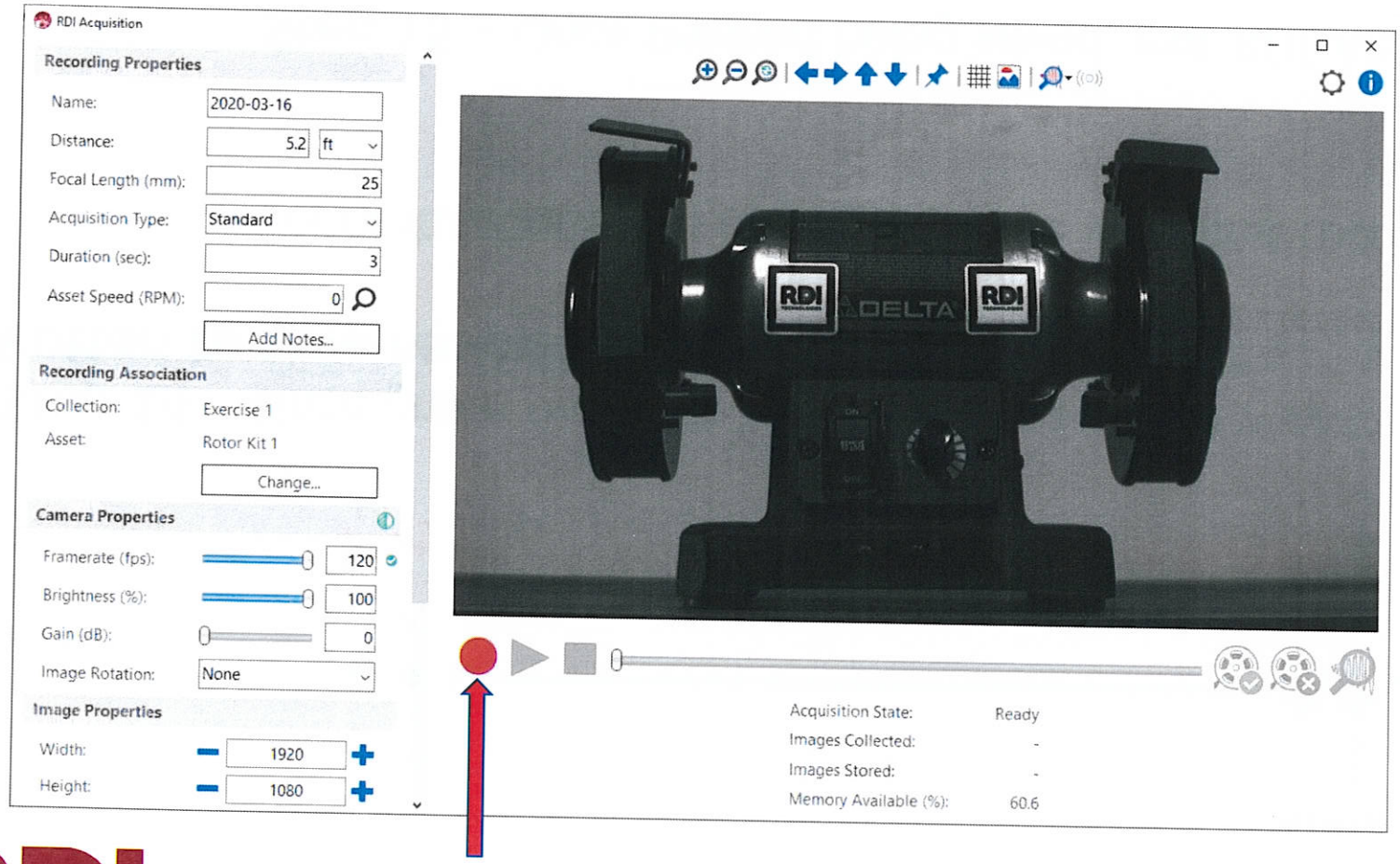
Exercise 2 - Store a Recording in Motion Explorer



Screen should look like this.

Step 13 – Press Record Button to acquire a recording.

RDI TECHNOLOGIES

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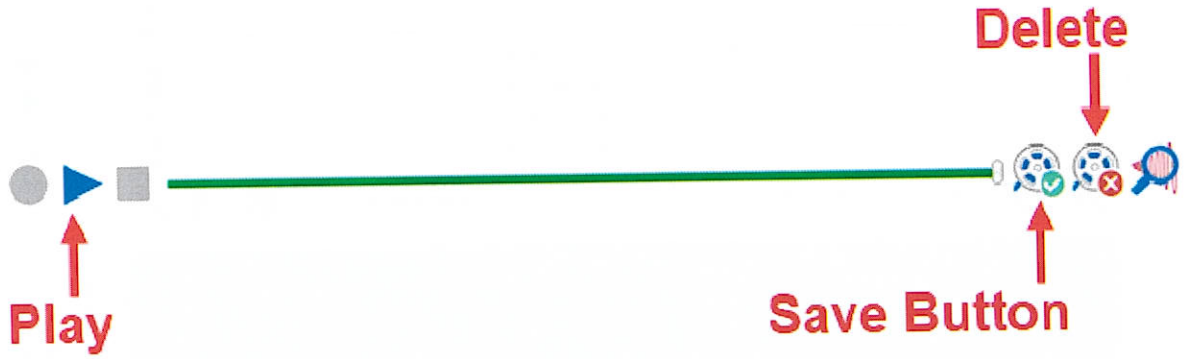
Exercise 2 - Store a Recording in Motion Explorer



Step 14 – Once green progress bar has moved all the way to right **Press Save Button to save recording.**

Congratulations you have just saved your first recording!

Step 15 – Once finished being saved, exit RDI Acquisition application.

RDI TECHNOLOGIES

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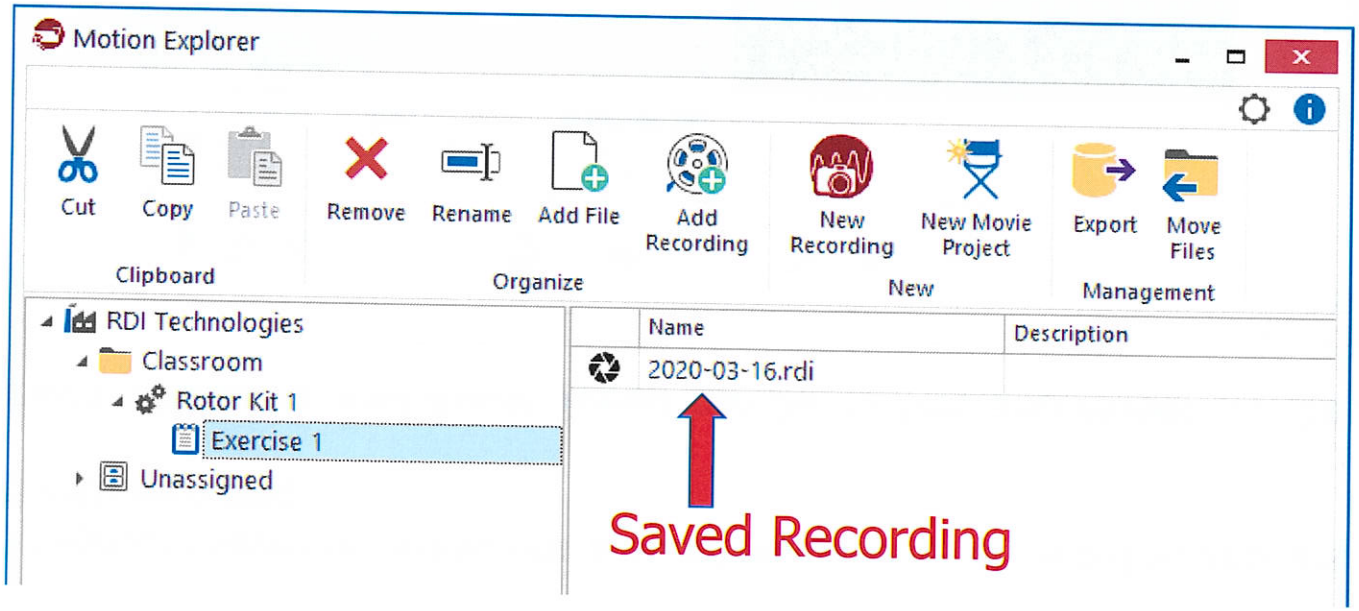
Exercise 2 - Store a Recording in Motion Explorer

Step 16 - With Motion Explorer open, highlight Exercise 1 under Rotor Kit 1 and the saved recording should be listed in center panel of screen.

Recording will automatically be named with date of acquisition ending with .rdi



RDI TECHNOLOGIES

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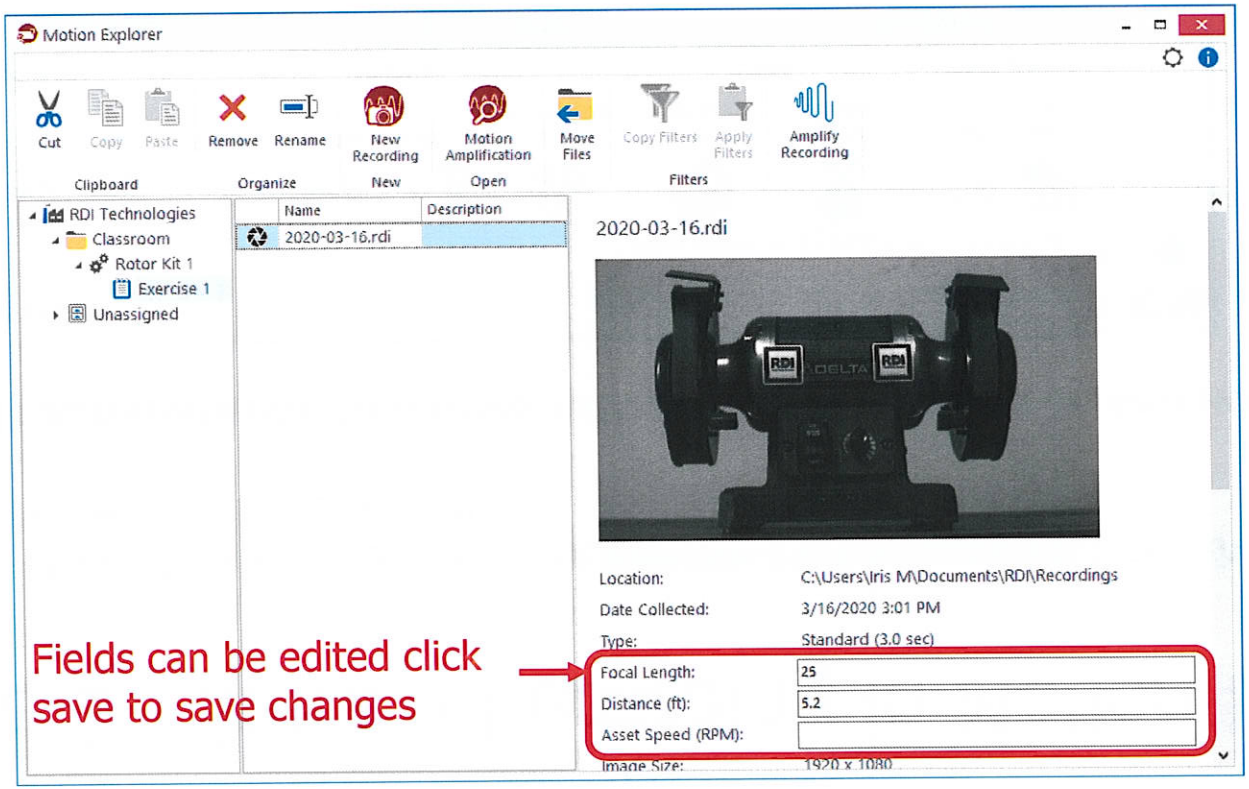
Exercise 2 - Store a Recording in Motion Explorer

Step 17 - Highlight saved recording and a thumbnail preview of recording appears along with properties associated with recording.

Focal Length, Distance, and Asset Speed can be edited, and Notes can be added.



RDI TECHNOLOGIES

Section 3 Review

1. Which MA software application allows the user to create a database hierarchy?
2. Can user notes be stored with the Motion Amplification recording?
3. The Motion Amplification raw data is stored as which file type?
4. Are Motion Amplification recordings stored automatically?

Section 3 Review

5. In Motion Explorer, which button in the Ribbon Bar initiates recording acquisition?

6. If the delete button is pressed after acquisition, is there any way to recover the deleted recording?

7. What should be done prior to capturing a recording to get a better-focused image?

IRIS M

Enhancing Vision

Section 4

RDI Acquisition

Objectives:

1. Discuss RDI Acquisition settings and their impact on video quality.
2. Discuss how settings impact vibration data quality.
3. Learn proper lighting techniques.

RDI TECHNOLOGIES

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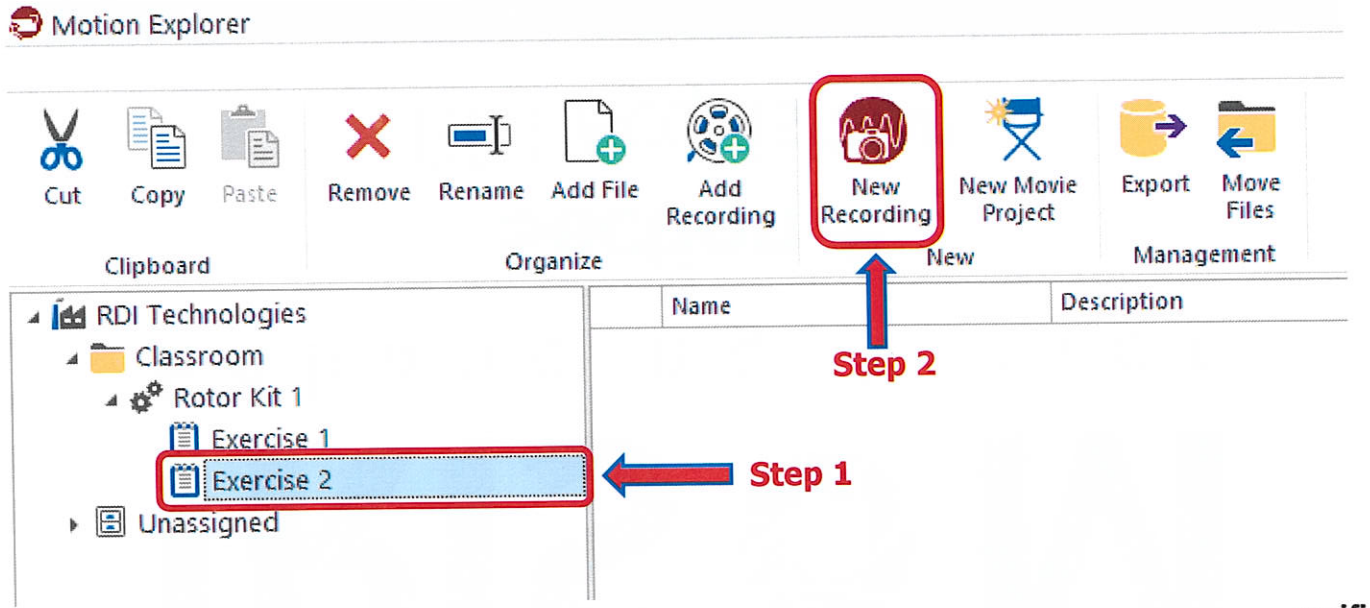
Mini Exercise

Step 1 – In Motion Explorer, create a new collection and name it "Exercise 2".

Step 2 – Highlight new collection and launch RDI Acquisition application by clicking "New Recording" button on Ribbon Bar.



RDI TECHNOLOGIES

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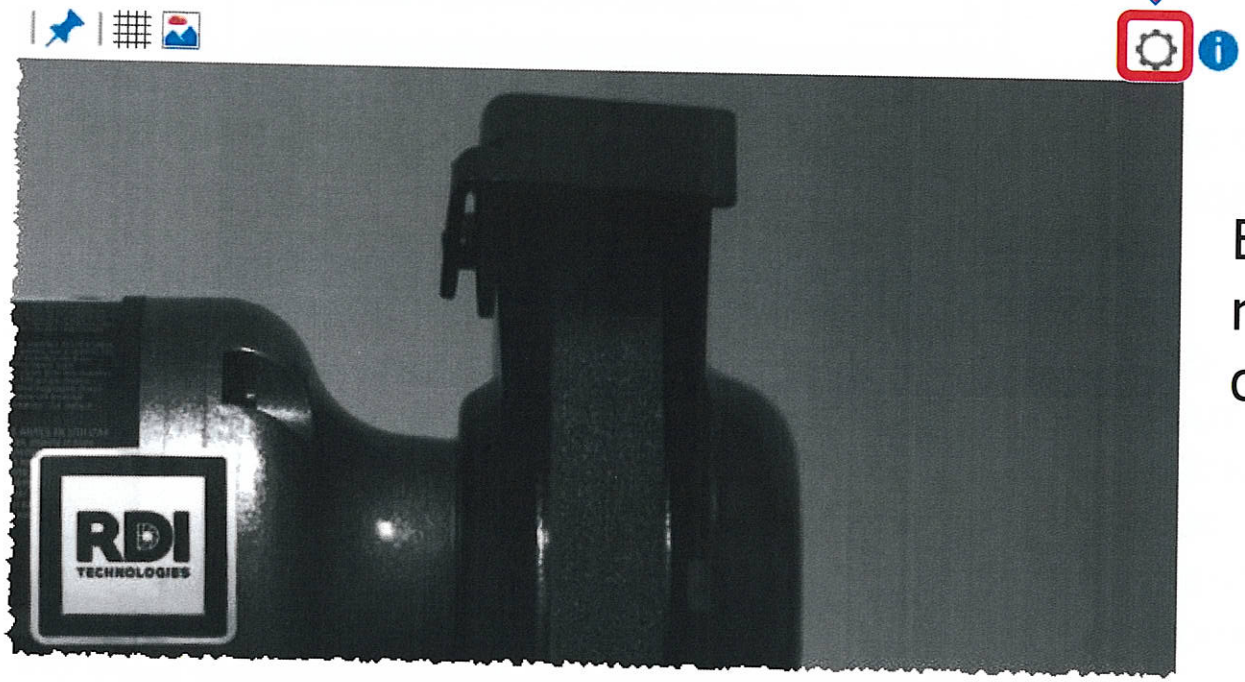
RDI Acquisition

Application Options



Before making acquisition settings, review Application Options by clicking Gear Wheel button.

RDI TECHNOLOGIES

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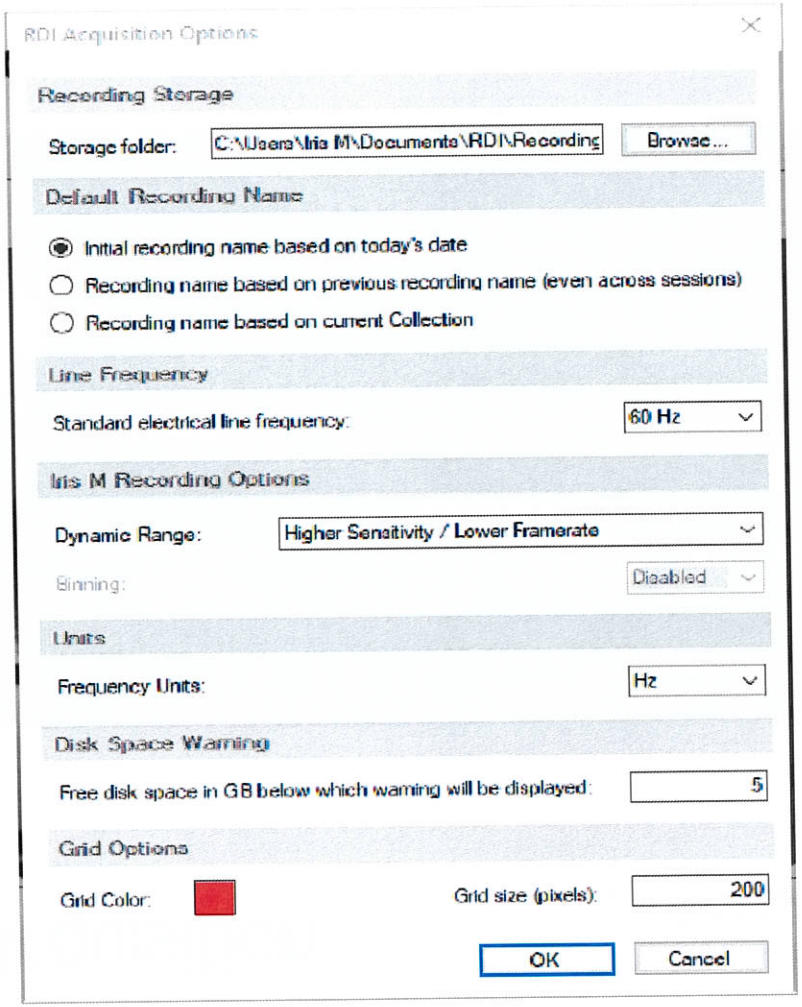
RDI Acquisition – Recording Properties



<u>RDI Acquisition Options:</u>

- Storage Location
- Default Recording Name
- Line Frequency
- Recording Options
- Units
- Disk Space Warning Value

Recording options - used to select Dynamic Range and if Binning is enabled for Iris MX.

Frequency Units (Hz or CPM)

RDI TECHNOLOGIES

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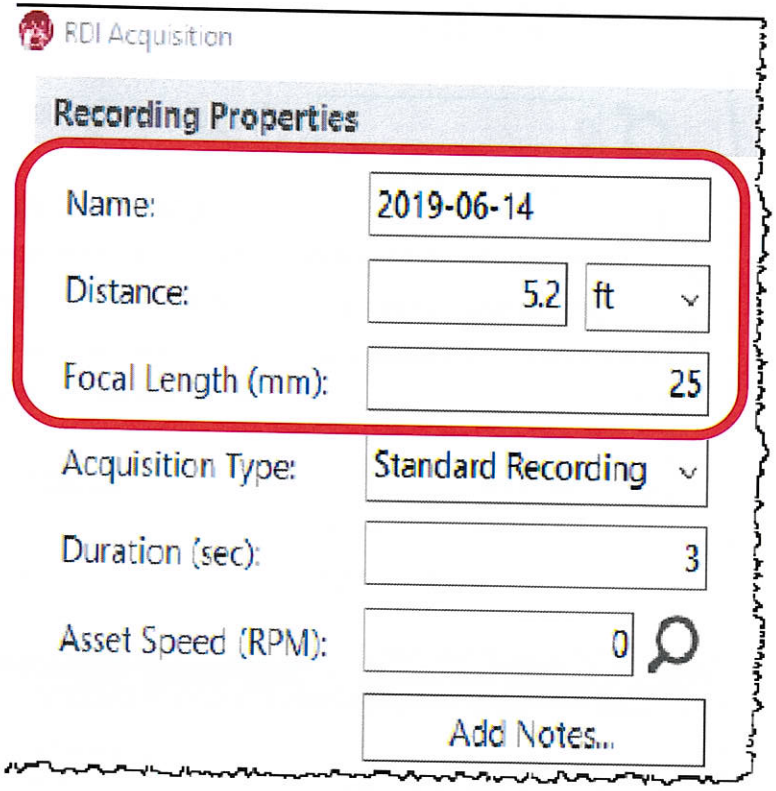
RDI Acquisition – Recording Properties



Name – Sets filename of recording.

If file name already exists software appends an auto advance number at end of filename.

Example: if filename "motor.rdi" next file "motor_01.rdi".

Distance – Stores distance from lens to object.

Value extremely important - vibration amplitude accuracy is directly related to distance accuracy.

Focal Length (mm) - Stores focal length of lens.

Value extremely important – Vibration amplitude accuracy is directly related to properly recording focal length.

RDI TECHNOLOGIES

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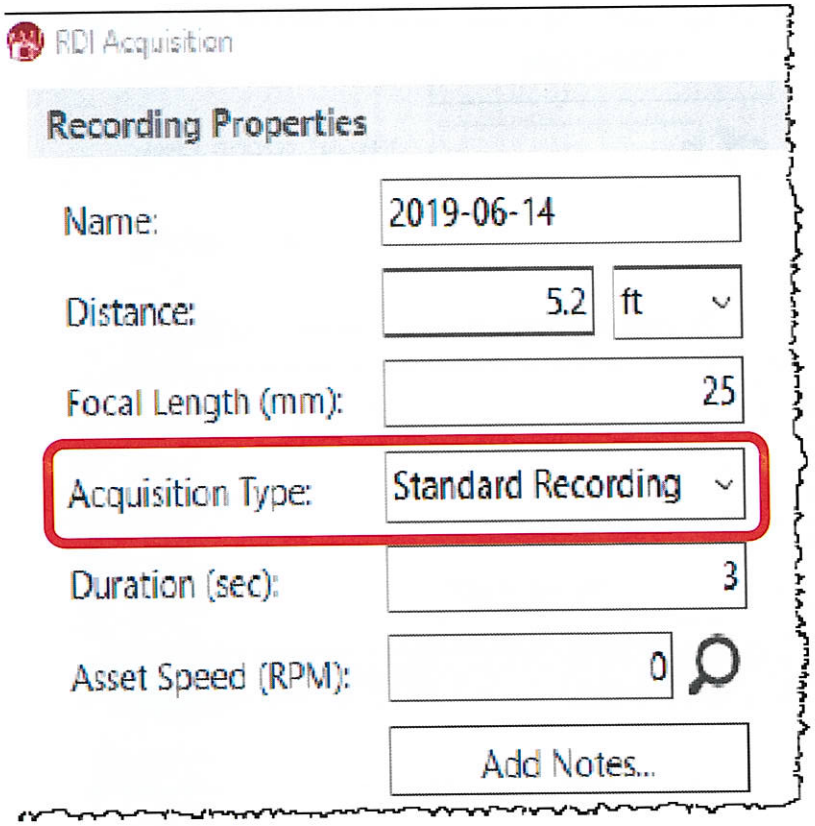
RDI Acquisition – Acquisition Type



- **Standard Recording -** Standard Motion Amplification
- **Shaft Inspection -** Acquire recording of rotating component – for visual inspection.

  Asset Speed needs to be entered - Amplification not used.
- **Triggered –** User must arm the triggered before initiating recording in order to catch quick event occuring temporarily
- **Long term** – Record long-term structural changes which result from the thermal expansion of the materials
- **Ext Sync** – Capture one frame per revolution

  Working only with laser tacho

RDI TECHNOLOGIES

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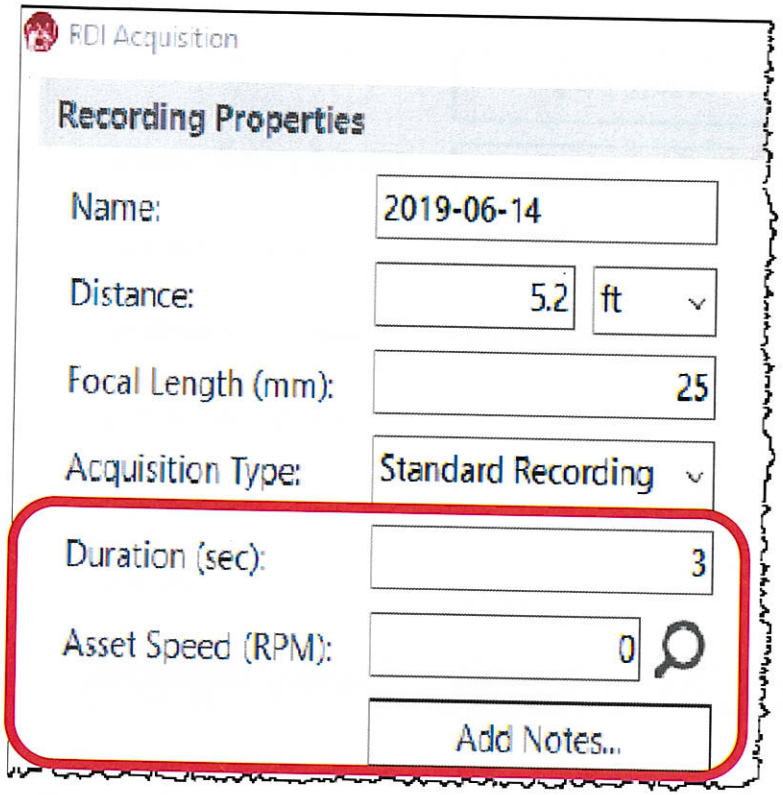
RDI Acquisition – Recording Properties



Duration (sec) – Recording duration in seconds.

Asset Speed (RPM) – Entering asset speed enables order based functionality in vibration analysis.

Add Notes – Notes can be entered.

RDI TECHNOLOGIES

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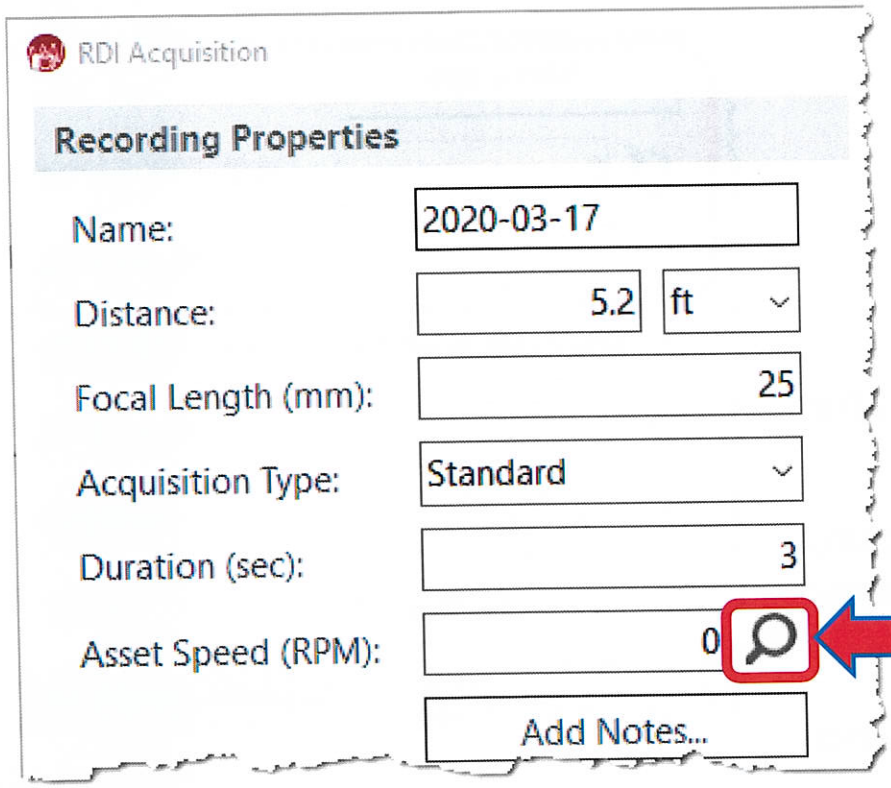
Exercise 3 – Measure the RPM



Step 1: Click Calculate Speed Button for Asset Speed (RPM).

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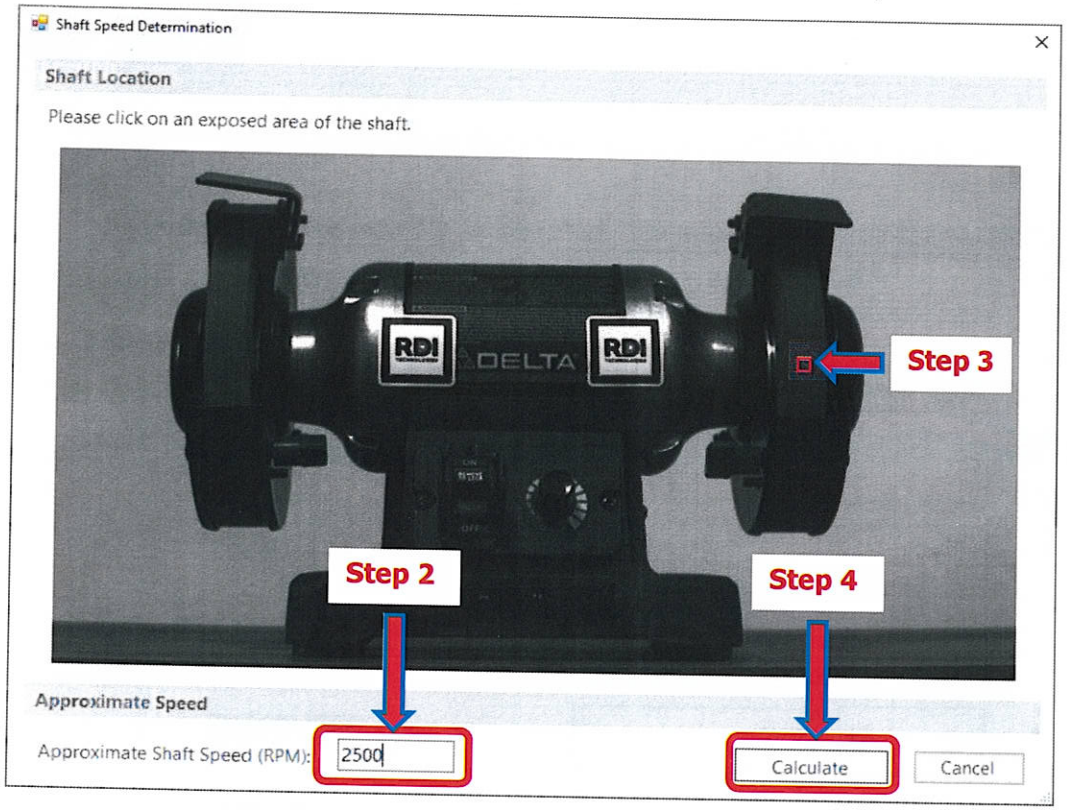
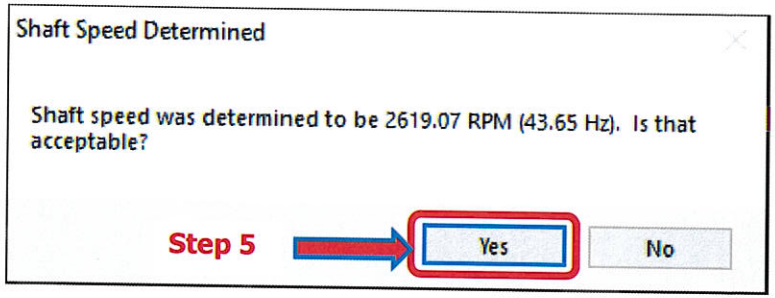
The Shaft Speed Determination window opens



Step 2 – Enter Approximate Shaft Speed

Step 3 – Click on exposed area of shaft or rotor.

Step 4 – Click **Calculate.**



Step 5 – If calculated RPM is acceptable, click Yes.

RDI TECHNOLOGIES

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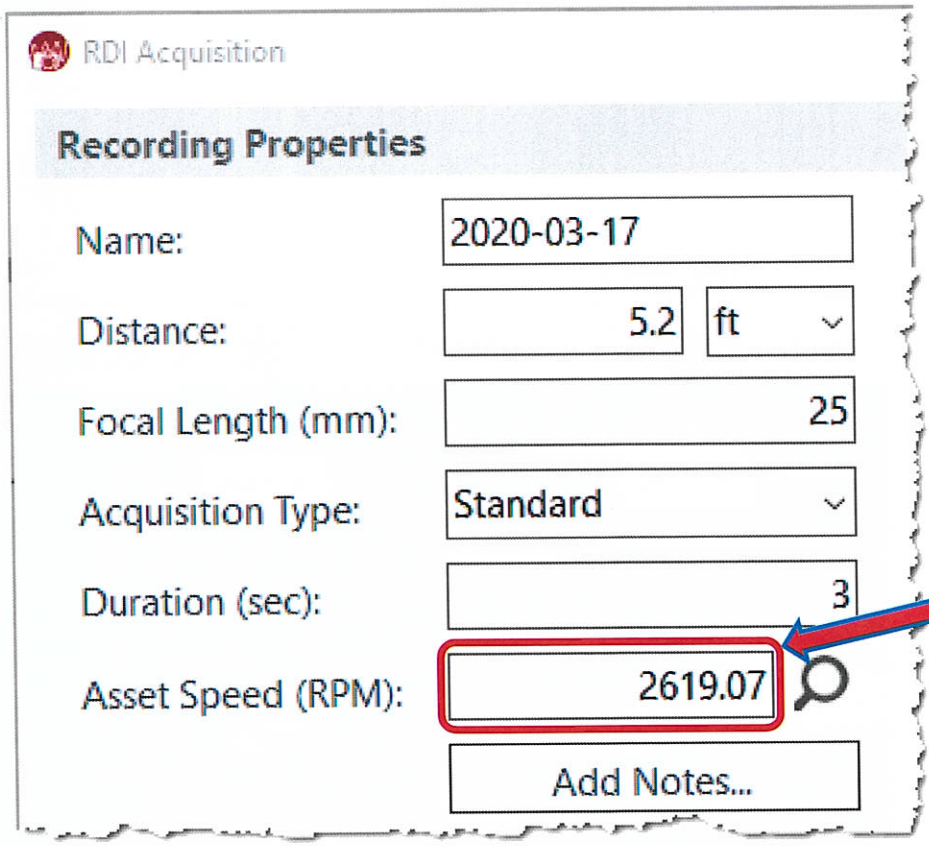

Measured RPM now appears in Asset Speed (RPM) Field

RDI TECHNOLOGIES

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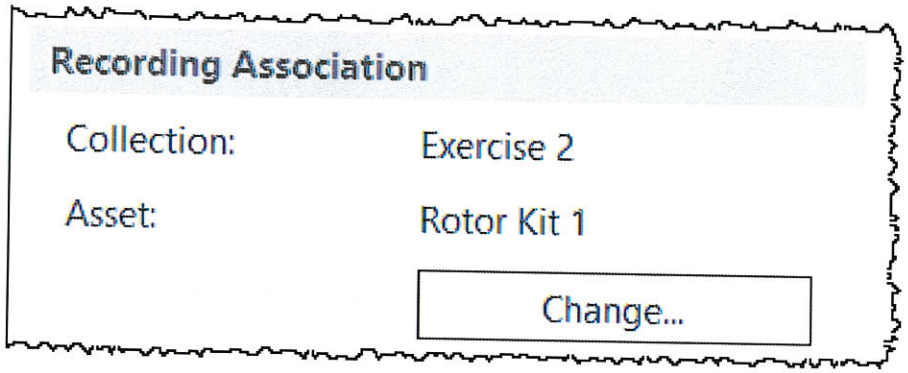
RDI Acquisition – Recording Association



Collection – Specifies collection recording will be associated with.

Asset – Determines asset under which recording will be associated.

RDI TECHNOLOGIES

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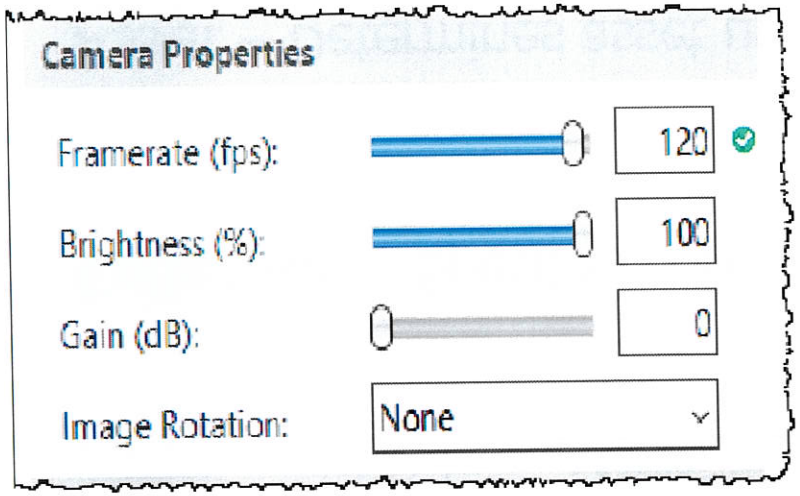
RDI Acquisition – Camera Properties



Framerate (fps) – Frames per second for recording.

- **Iris M:** 121 fps default - up to 1,300 fps @ reduced resolution.
- **Iris MX:** 211 fps default - up to 29,000 fps @ reduced resolution.

RDI TECHNOLOGIES

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RDI Acquisition – Camera Properties

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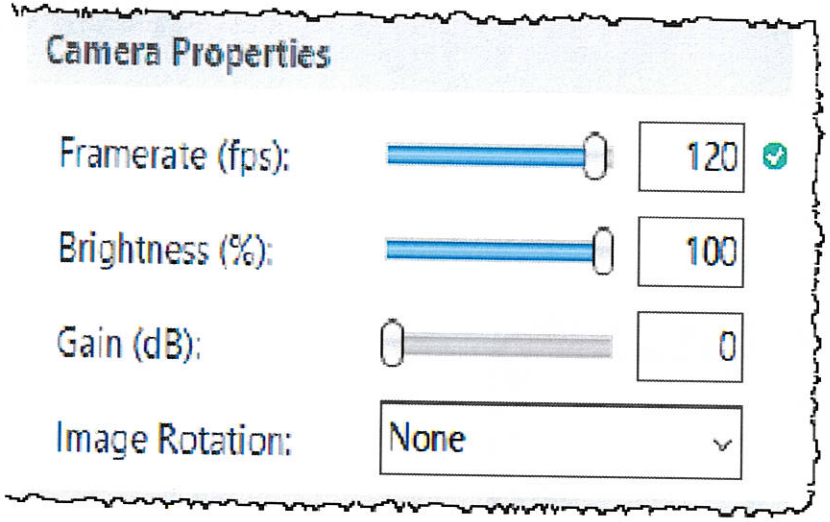


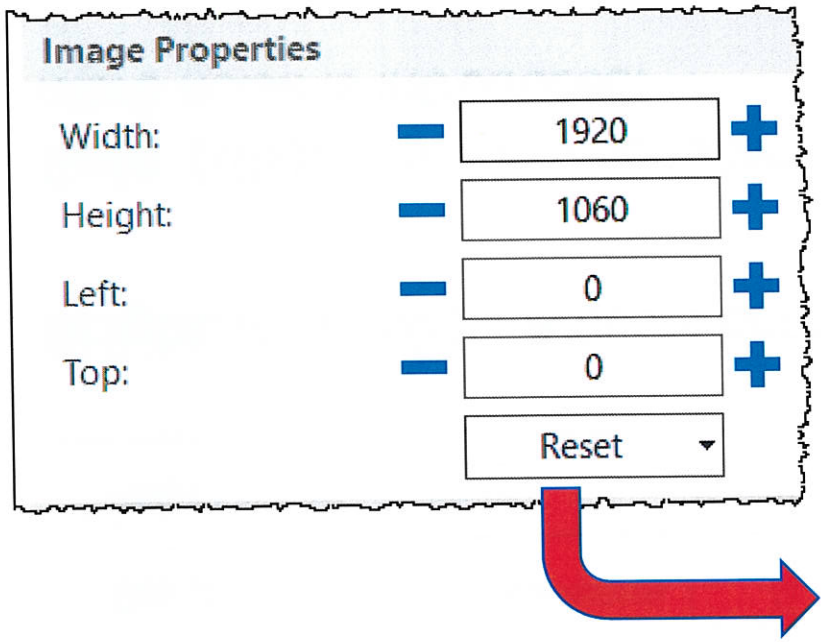
Brightness (%) - Adjusts brightness by changing exposure time. Scaled 0 - 100%.

Gain (dB): - Adjusts sensitivity of camera's sensor. Increasing brightens image, but more noise is introduced.

RDI TECHNOLOGIES

Image Rotation – Rotates image in Viewer Window - 90° or 180°.

RDI Acquisition – Image Properties



Width - Adjusts width of image in pixels.

Height - Adjusts height of image in pixels.

Left – Offset of image from left.

Top – Offset of image from top.

Reset – Dropdown list of preset image resolutions.

RDI TECHNOLOGIES

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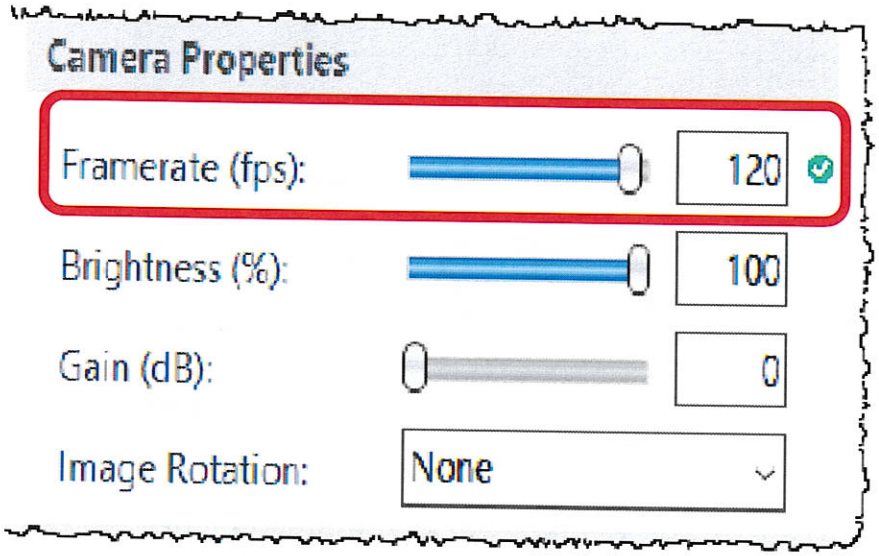
RDI Acquisition – Framerate Considerations



Framerate (fps) – Very important setting.

Framerate responsible for or linked to:

- Indoor Lighting Flicker
- Vibration Spectrum F-Max
- Available Image Brightness
- Vibration Waveform Sample Rate

In most cases, framerate default is 120 fps, because many indoor applications are recorded under AC lighting.

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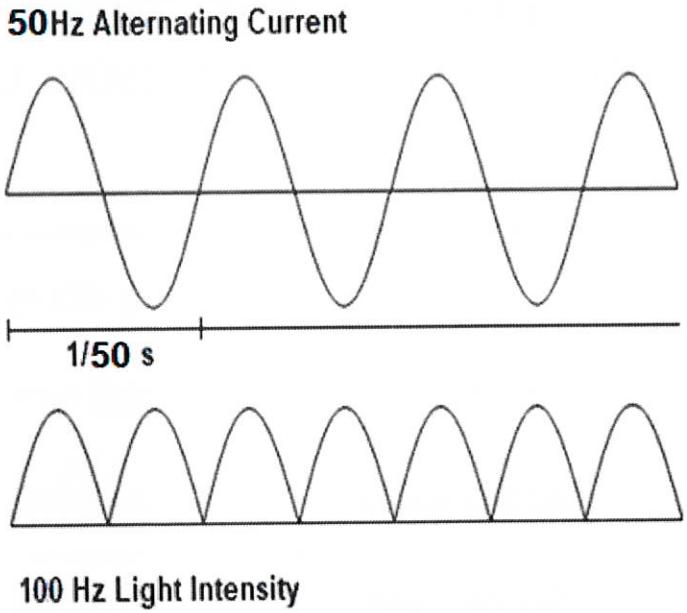
Framerate and Indoor AC Lighting



- EU AC is 50 Hz - voltage changes from "+" to "-" 50 times/sec.
- From "+" to "-" peak, voltage decreases.
- Light intensity is less than when voltage is near either "+" or "-" peak.

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Framerate and Indoor AC Lighting

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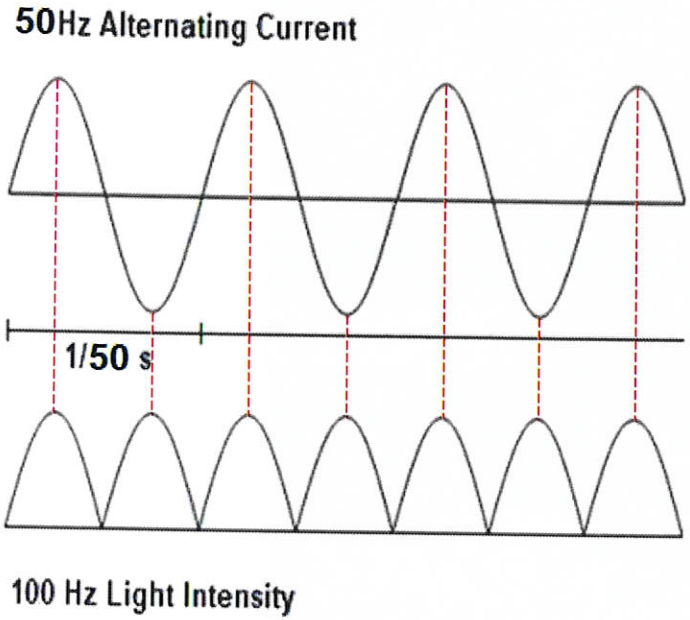

- EU AC is 50 Hz - voltage changes from "+" to "-" 50 times/sec.
- From "+" to "-" peak, voltage decreases.
- Light intensity is less than when voltage is near either "+" or "-" peak.
- Changing light intensity or "flicker", at 100 Hz.
- Flicker typically not perceptible to human eye.

RDI TECHNOLOGIES

Framerate and Indoor AC Lighting

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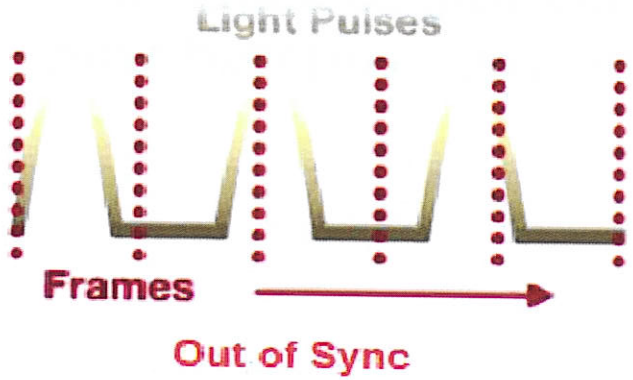
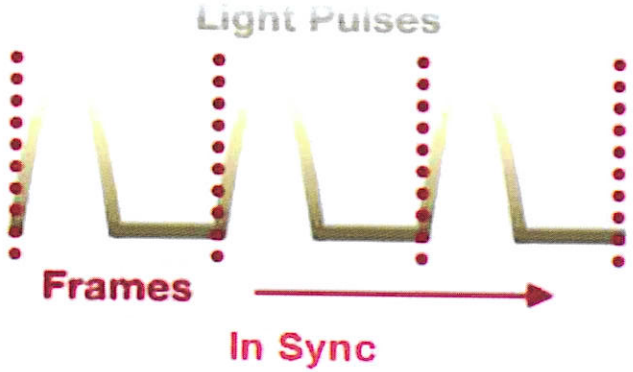
RDI TECHNOLOGIES

Framerate and Indoor AC Lighting



In MA amount of change is amplified.

Can occur when framerate is out of sync with pulsation rate of lighting.



R*ecommend setting framerate to either 100 fps or 50 fps* to be in sync with AC pulsation rate.

Will greatly reduce chance that flicker will be apparent.

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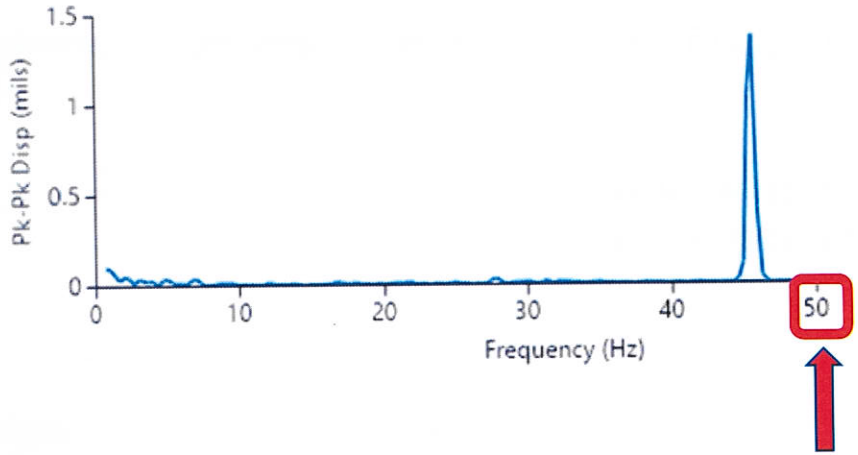
Framerate vs Fmax



Fmax of 50 Hz from Acquisition Framerate of 100 fps.

Fmax (max freq) of vibration spectrum is determined by Framerate.

Fmax of spectrum is exactly half framerate.

Fmax (in Hz) = fps ÷ 2

Example: If framerate is 100 fps, Fmax will be 50 Hz.

But a spectrum with an Fmax of 50 Hz would not be able to properly resolve a peak at exactly 50 Hz.

Best practice - Set *minimum Framerate to 2.5x highest vibration frequency of interest*.

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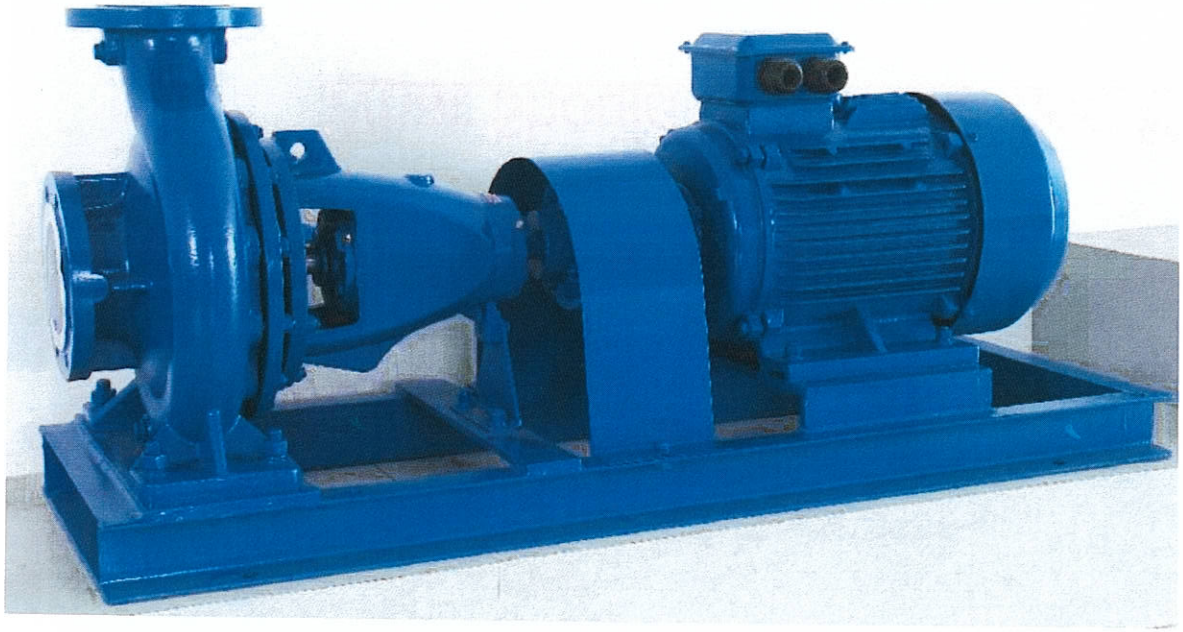
Minimum Framerate Example



- Motor/Pump = 1500 RPM
- Offset misalignment (2X)
- Highest Frequency of interest = 3000 CPM (50 Hz.)

What Should Recommended Minimum Framerate Be?

RDI TECHNOLOGIES

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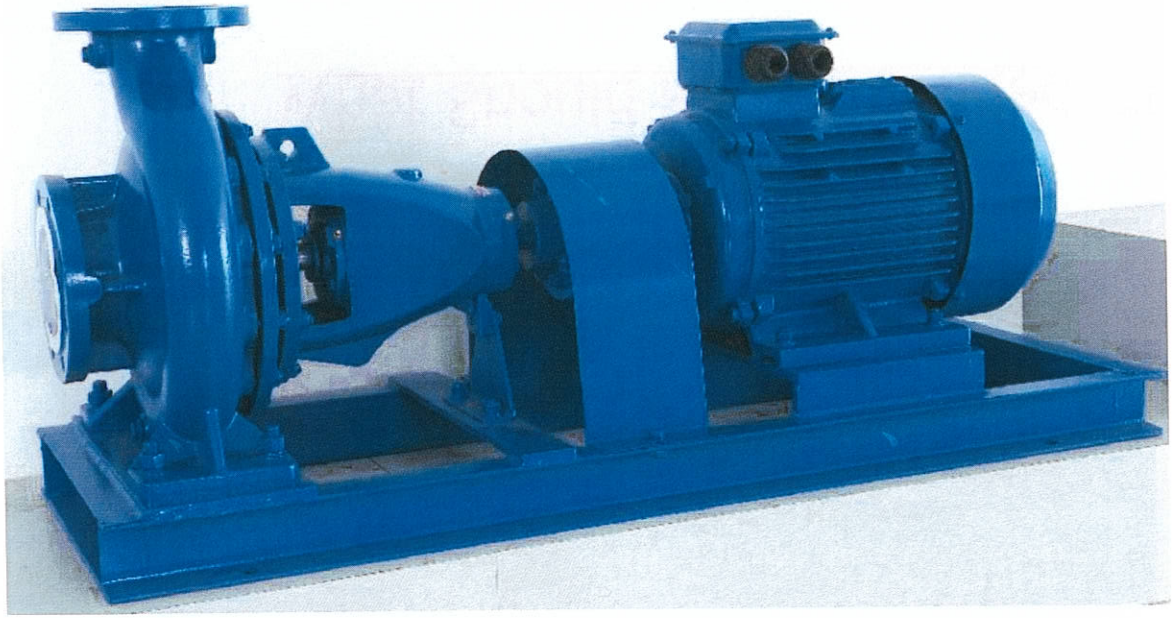
Minimum Framerate Example



- Motor/Pump = 1500 RPM
- Offset misalignment (2X)
- Highest Frequency of interest = 3000 CPM (50 Hz.)

What Should Recommended Minimum Framerate Be?

2.5 x 50 Hz = 125 fps

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Relationship - Framerate and Brightness

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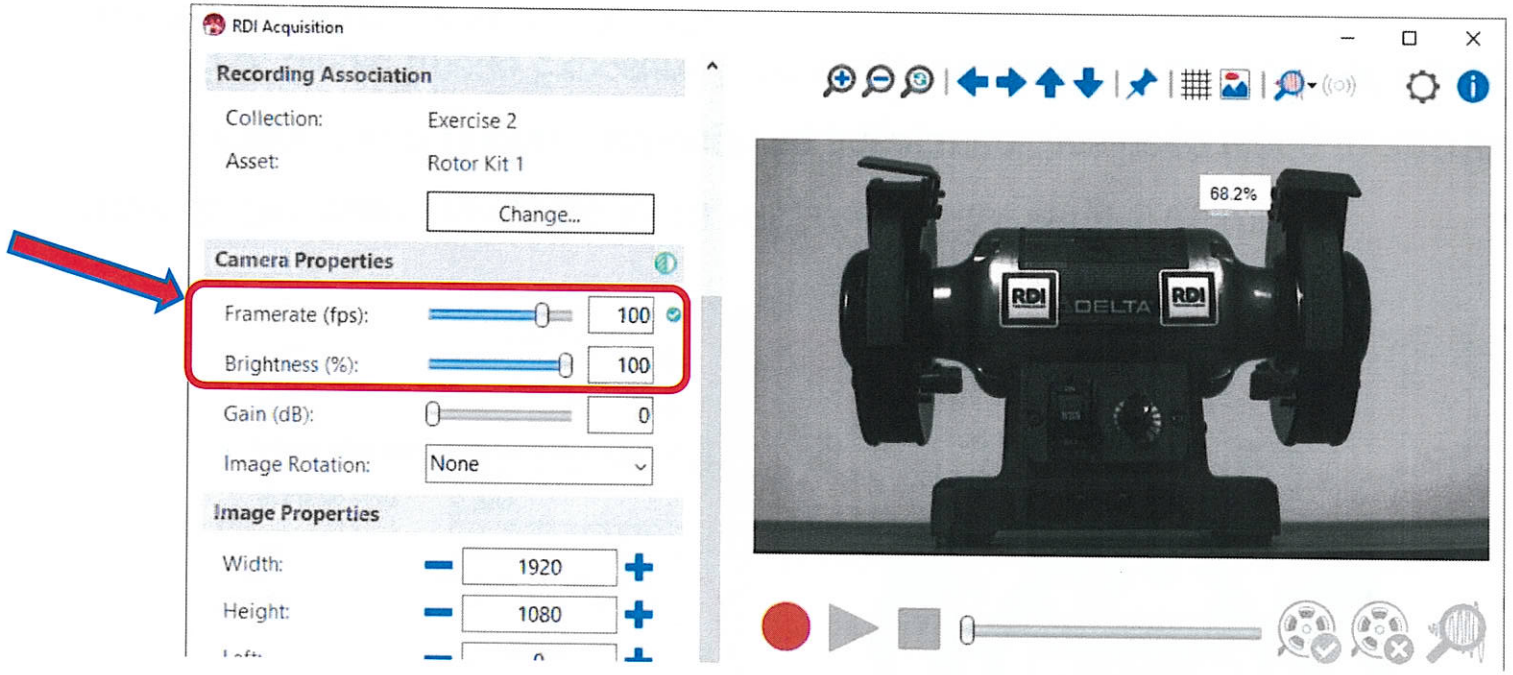
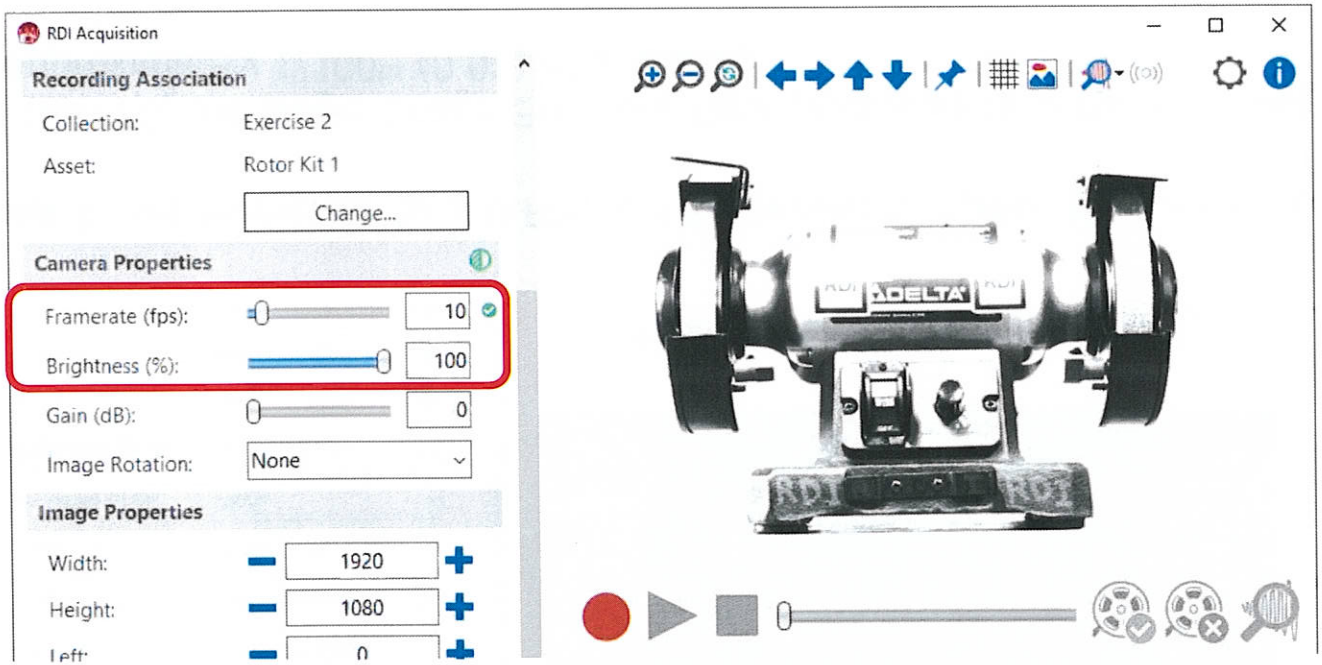
Exercise 4 – Adjust Framerate and Brightness



Step 1: Set Framerate to 100 FPS and Brightness to 100%. Note image brightness.

At 100 FPS, the Single Image Exposure Time (exposure time for each single image) is approximately 1/100th (0.01) of a second.

RDI TECHNOLOGIES



Step 2: Decrease Framerate to 10 FPS. (Return brightness to 100%).

Notice image much brighter although no adjustment has been made to aperture or Brightness setting.

At 10 FPS, Single Image Exposure Time is approximately 1/10th (0.1) of a second, which is **10 times more** than what it was at 100 FPS.

Results in image that is **approximately 10 times brighter**

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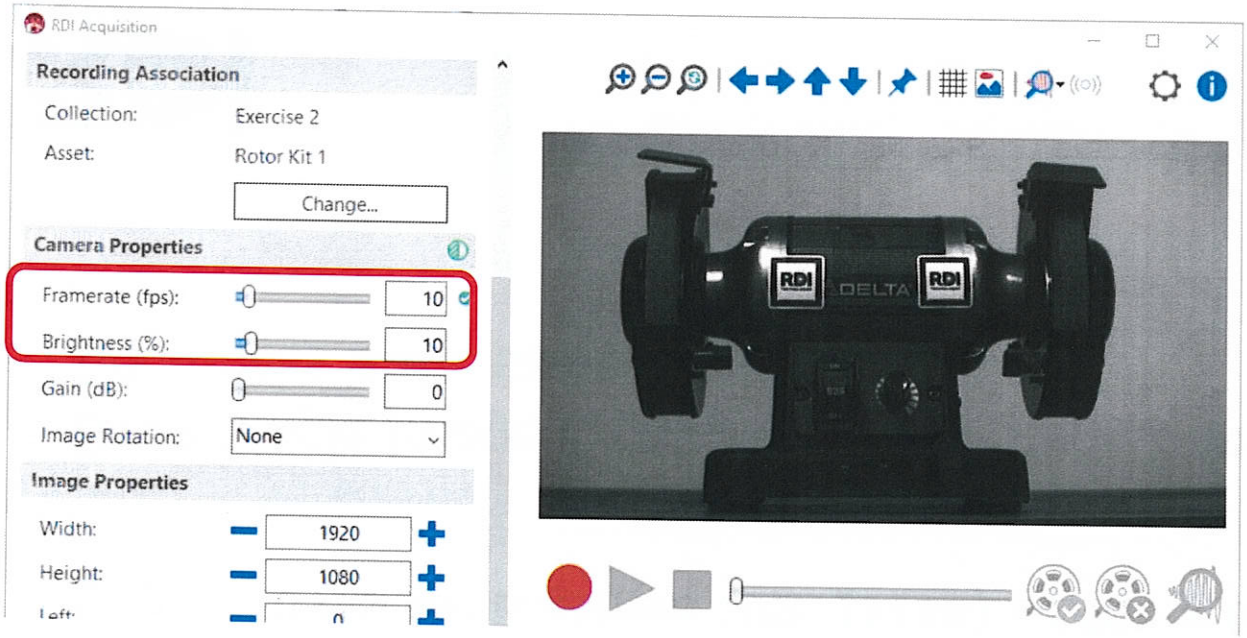

Step 3: Move Brightness slider to 10%.

Notice image brightness is same as when framerate was 100 FPS and Brightness at 100%.

When Brightness % is lowered, that % is applied to Single Image Exposure Time.

10 FPS sets single image exposure time to approx. 1/10th of a second.

But brightness is now at 10%, this lowers single image exposure time to 10% of 0.1 seconds, which is 0.01 seconds.

Explains why image brightness is same as when framerate is set to 100 FPS and Brightness is at 100%.

RDI TECHNOLOGIES

Brightness setting percentage is applied to Single Image Exposure Time

Single Image Exposure Time (in seconds):

Single Image Exposure Time = (1/Framerate) x Brightness %

Step 1 - 100 FPS and Brightness 100%, single image exposure time: **(1/100) x 100% = 0.01 sec**

Step 2 - 10 FPS and Brightness 100%. **(1/10) x 100% = 0.1 sec**

Step 3 - 10 FPS and Brightness 10%. **(1/10) x 10% = 0.01 sec**

Since Single Image Exposure Time in Steps 1 and Steps 3 are the same, their screen brightness is the same.

Single Image Exposure Time (in seconds):

Gain

In previous steps Gain setting was set to zero.

Increasing gain makes image brighter but has no effect on Single Image Exposure Time.

Gain adds brightness to image by making camera sensor more sensitive to light.

Addition of Gain can make image grainier.

Lighting

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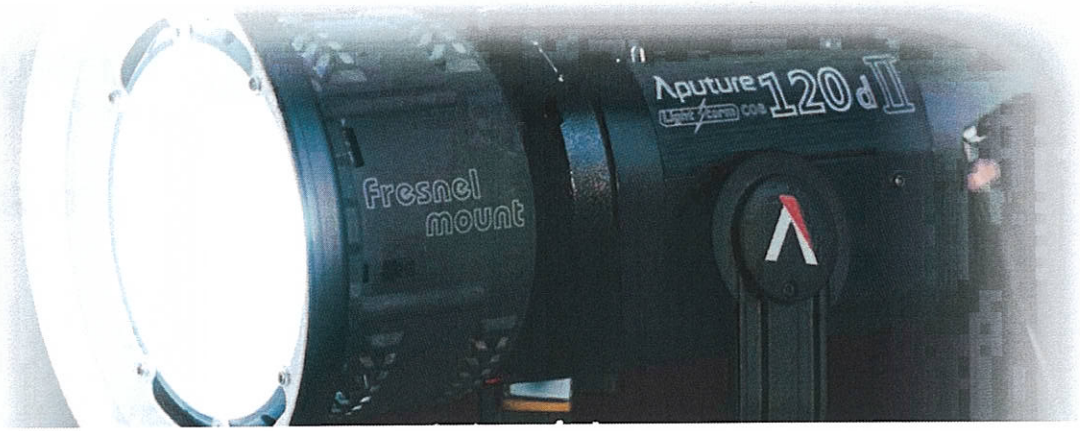
Proper lighting is essential for Motion Amplification.

<u>Makes recording:</u>

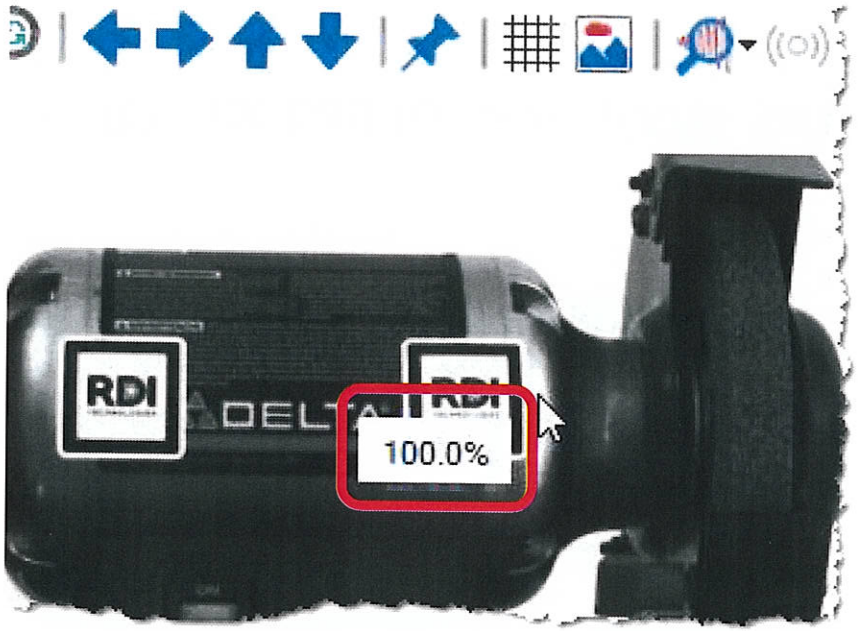
- Easier to See
- Easier to Analyze
- More Professional Quality

Remember, in MA the video is the report.



RDI TECHNOLOGIES

Saturation



Pointer in RDI acquisition lists percentage of saturation.

Here point referenced is 100% saturated.

Pixel is completely full of light photons and can hold no more.

If at 100% it is impossible to know how much light is coming into this pixel.

RDI TECHNOLOGIES

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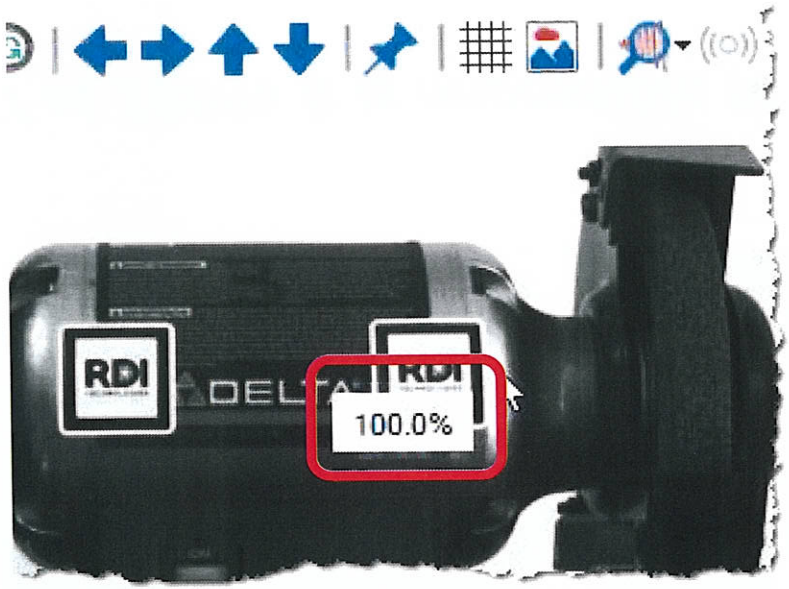
Saturation



Pixels that are 100% saturated will not get amplified and cannot provide an accurate time waveform.

- Depending on subject, it may be impossible to avoid portions of image that are 100%.
- Reflective surfaces are especially prone to oversaturation.
- It's not bad to have 100% saturated areas in image if they aren't areas of interest.

RDI TECHNOLOGIES

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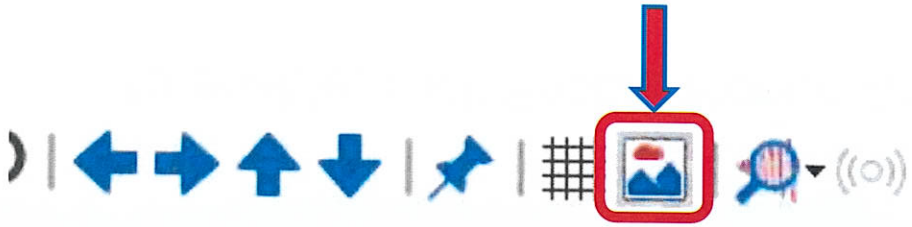
Saturation Tool



Saturation Tool

Allows users to quickly identify areas that are 100% saturated.

100% saturated areas appear red.

RDI TECHNOLOGIES

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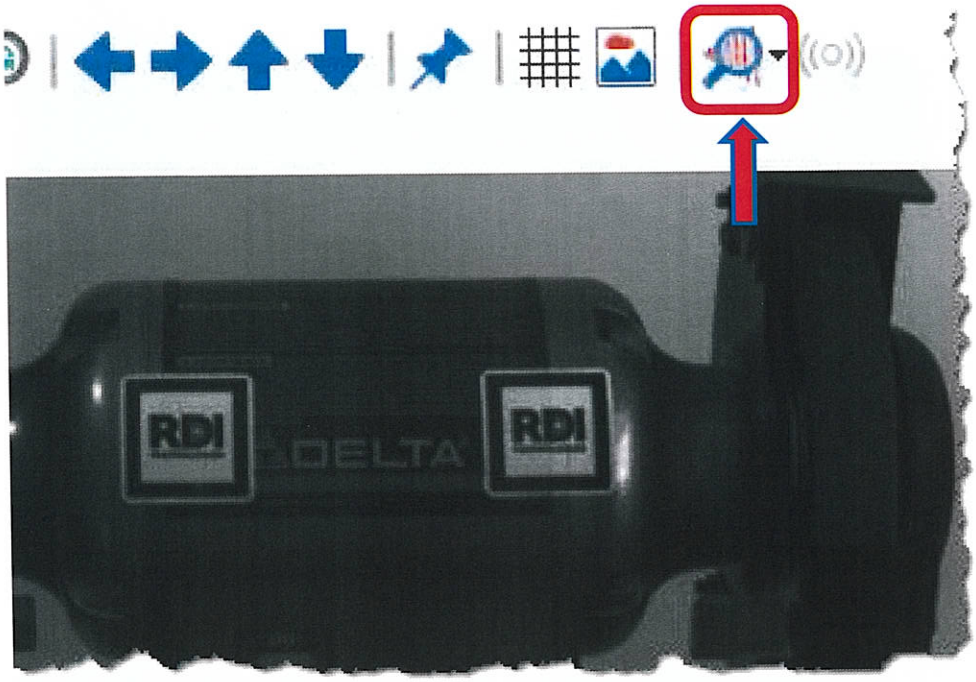
Live Motion Amplification



Enable/Disable Motion Amplification button in RDI Acquisition allows user to see live MA.

To enable, click Enable Motion Amplification Button on acquisition screen.

RDI TECHNOLOGIES

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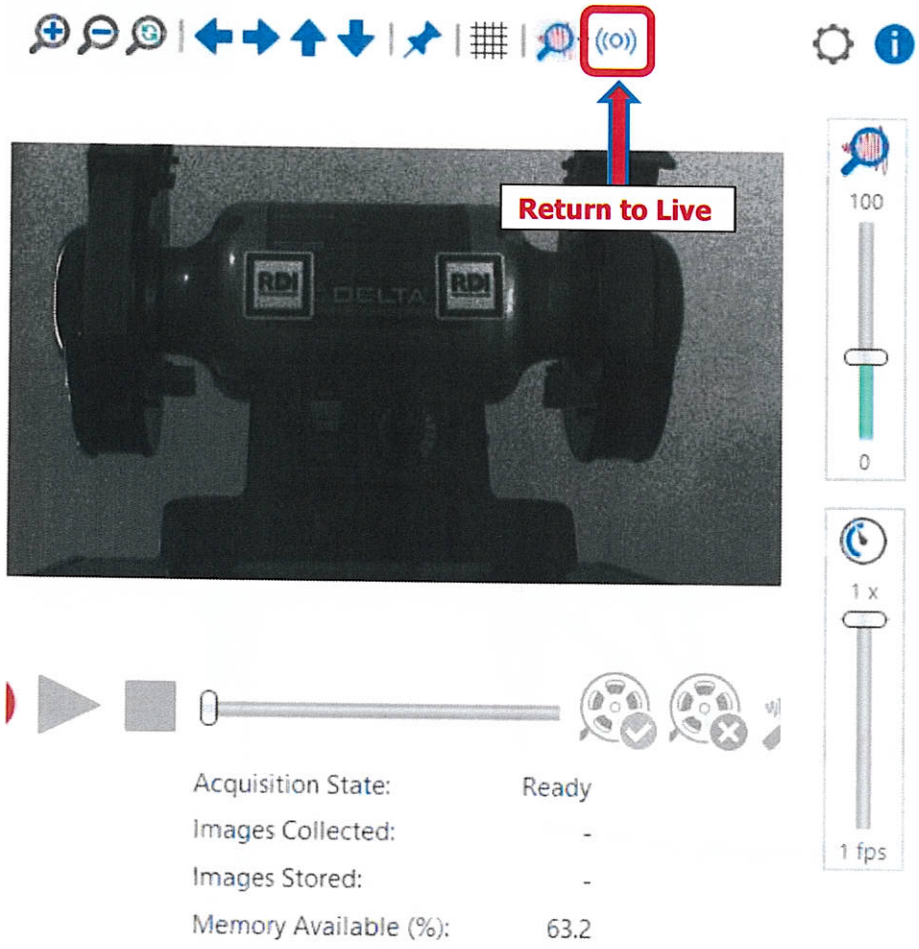

Amplification and Playback Speed sliders can be adjusted while image is being amplified live.

There will be some lag in live video, especially if playback speed is lowered.

To restart playback from live, click **Return to Live** button.

To end live MA, click Disable Motion Amplification button.

RDI TECHNOLOGIES

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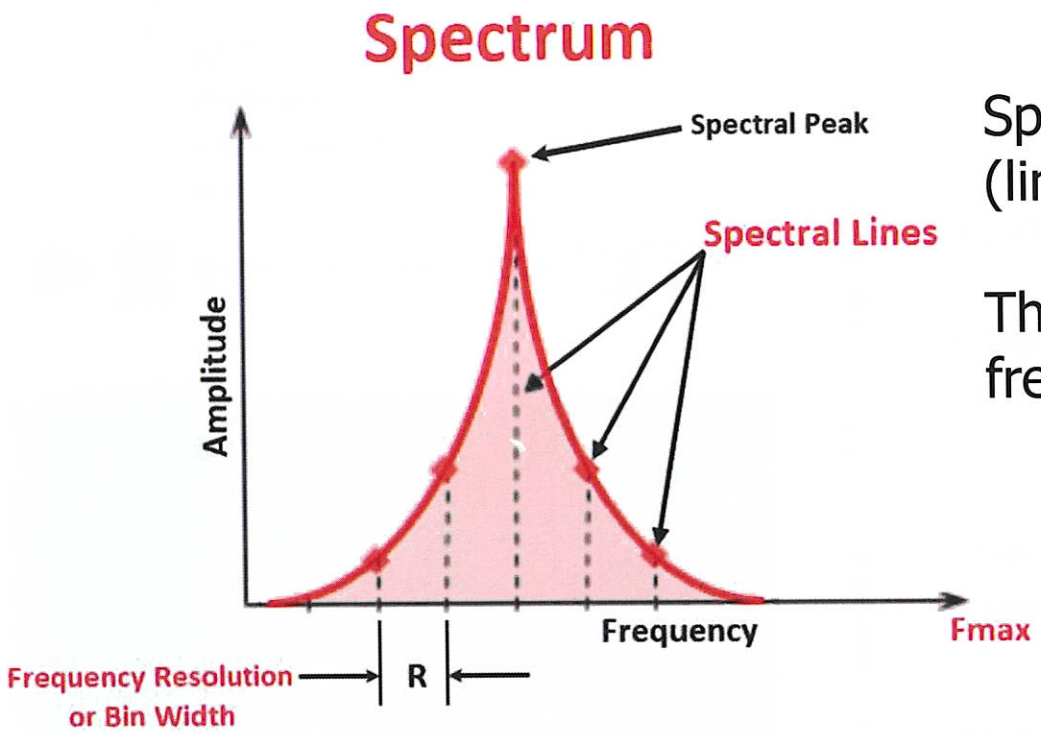
Spectral Resolution



Spectral Resolution is defined by number of bins (lines) in spectrum, or by width of each bin.

The smaller the bin width, the more accurate frequency and amplitude of any peak will be.

Smaller bins increase ability to separate closely spaced peaks within spectrum.

RDI TECHNOLOGIES

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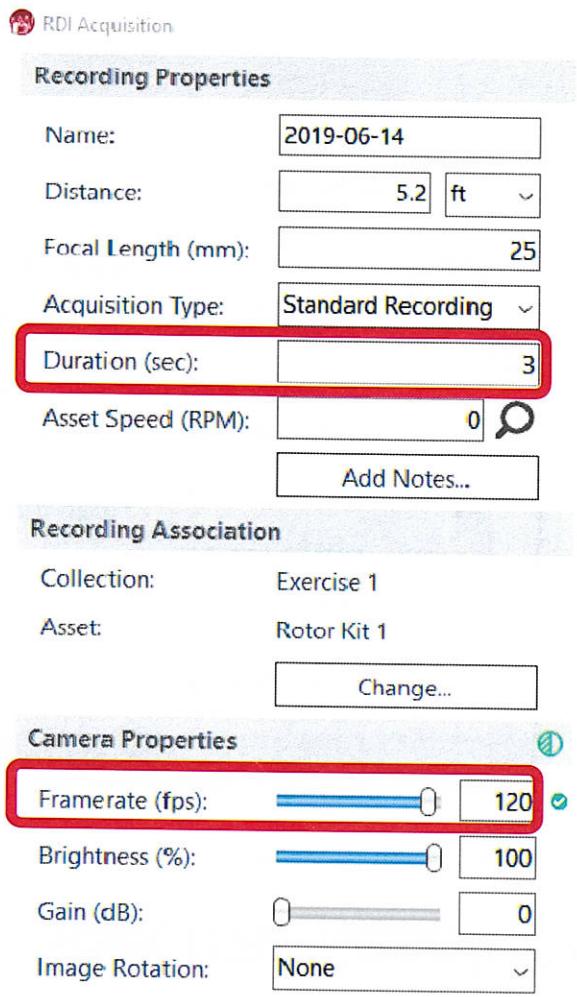
Spectral Resolution



Number of lines = Total number of frames/2.

<u>In this example:</u>

- Duration = 3 seconds
- Framerate = 120 fps.
- Result in <u>360 total frames</u>.

Number of lines of resolution is 360/2, or <u>180</u>.

Based on Framerate, Fmax will be 60 Hz.

Bin Width calculation is:

60 Hz ÷ 180 = 0.33 Hz

RDI TECHNOLOGIES

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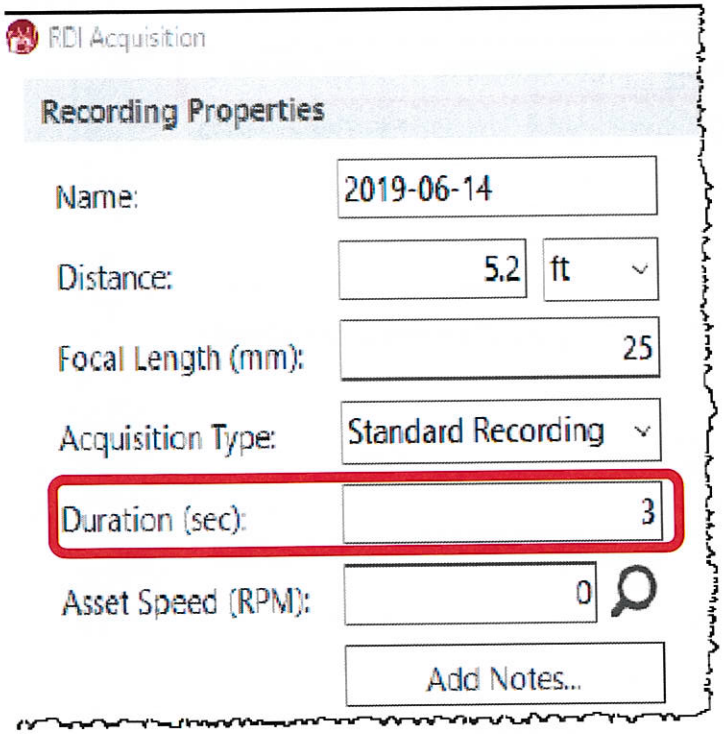
Spectral Resolution



An easier way to calculating Bin Width is to calculate inverse of Duration.

Recording Duration is 3 seconds.

Inverse of 3 is 1 ÷ 3, or 0.33 Hz.

RDI TECHNOLOGIES

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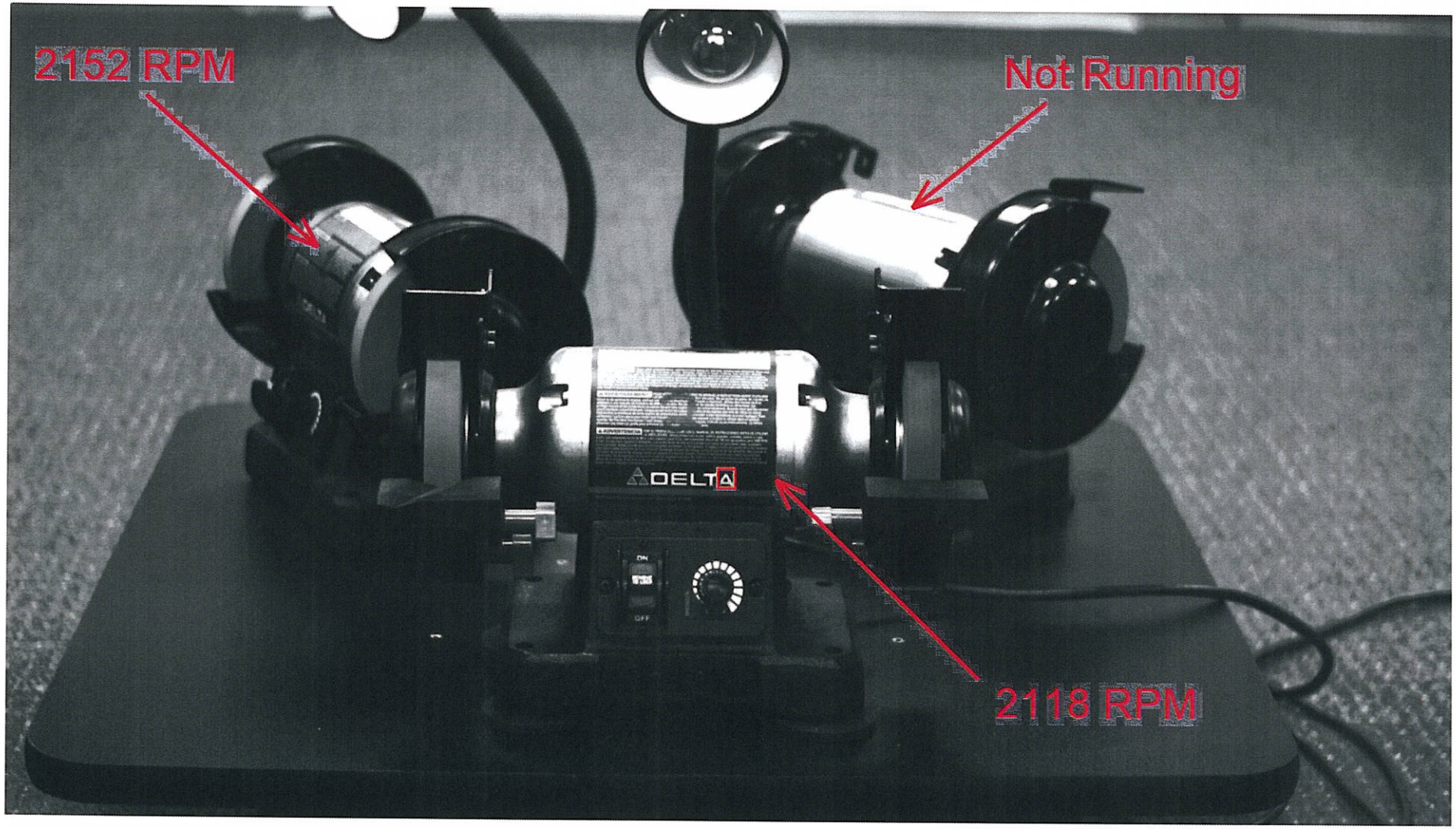
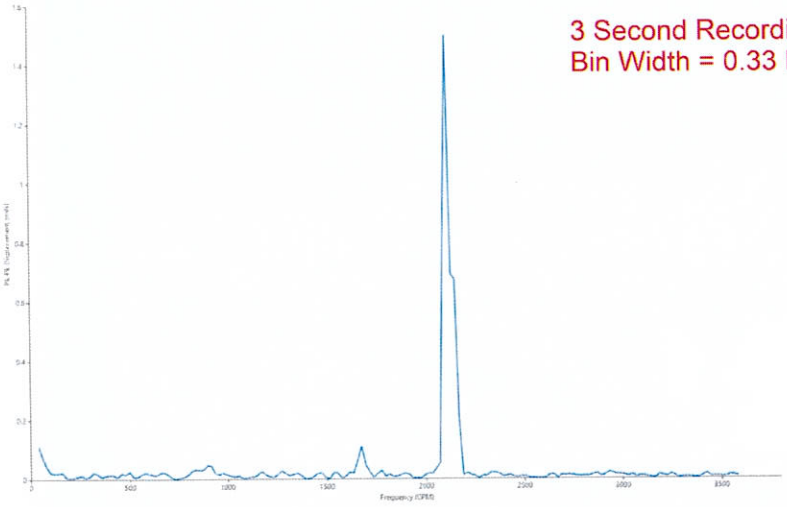
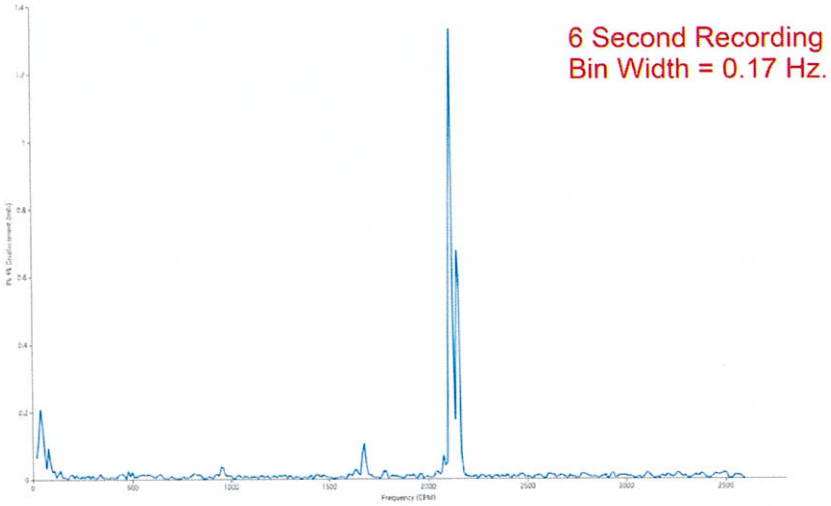
Spectral Resolution



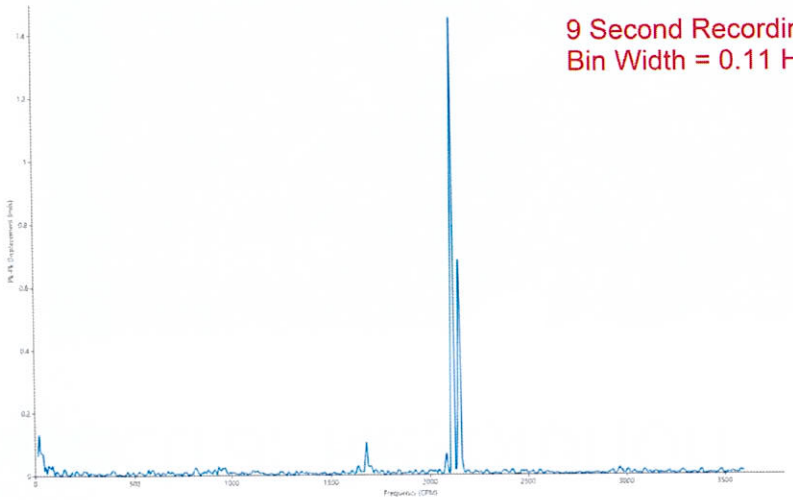
Spectral Resolution



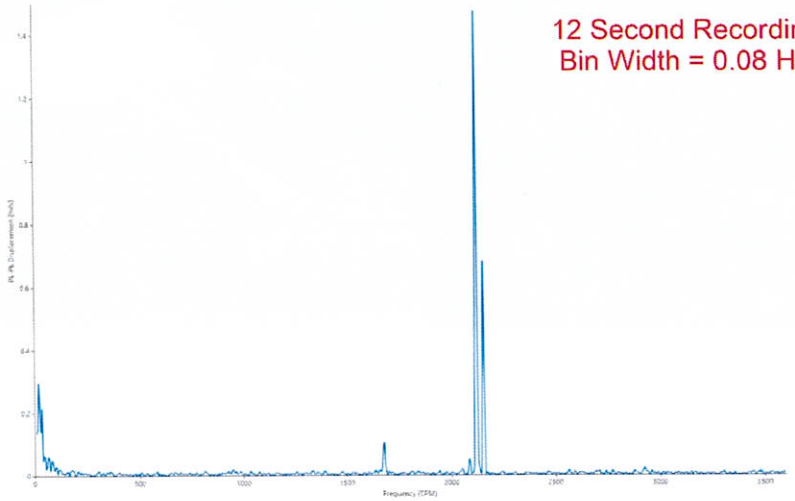
3 Second Recording
Bin Width = 0.33 Hz.



6 Second Recording
Bin Width = 0.17 Hz.



9 Second Recording
Bin Width = 0.11 Hz.



12 Second Recording
Bin Width = 0.08 Hz.

Calculations

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Frequency Resolution or Bin Width (in Hz)

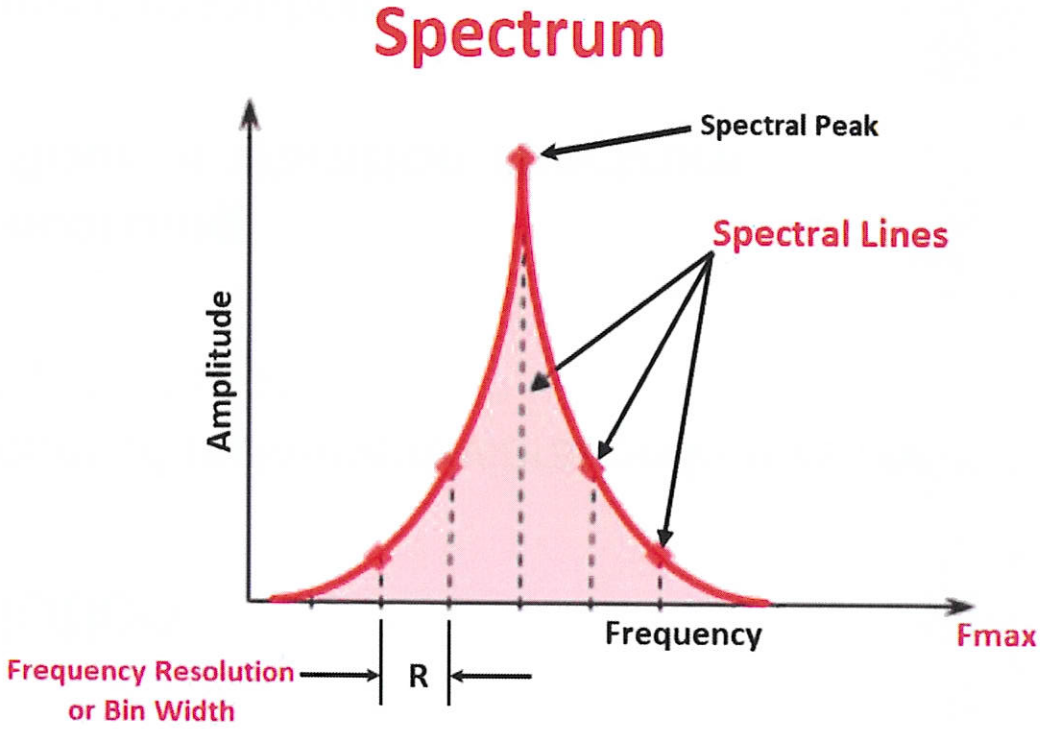
BW = 1/Duration

Number of Lines (or Bins) of Resolution

 # Lines = Total Number of Frames/2

Frequency Range or Fmax

Fmax = Framerate (fps)/2



RDI TECHNOLOGIES

Minimum Displacement Resolution

Minimum Displacement Resolution is amount of movement/vibration in mils (or microns) that needs to occur for two things to happen:

1. **Motion to be visible in amplified recording**
2. **For a peak to appear above noise floor in vibration spectrum**

Two things that affect minimum displacement resolution:

- Distance of camera from asset.
- Focal length of lens.

RDI TECHNOLOGIES

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Calculating Minimum Displacement Resolution

$$R = \frac{D}{F} \times 0.5 \frac{mils*mm}{meter} \quad \textbf{-or-} \quad R_u = \frac{D}{F} \times 12.5 \frac{microns*mm}{meter}$$

Where:

R = Minimum Displacement Resolution (mils)

Rμ = Minimum Displacement Resolution (microns)

D = Distance from the lens to the object (meters)

F = Focal Length of Lens (mm)

Note: 0.5 $\frac{mils*mm}{meter}$ and 12.5 $\frac{microns*mm}{meter}$ are empirical based conversion factors.

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How Focal Length and Distance Affect Displacement Resolution

Distance to Object (D)	Focal Length of Lens (F)	Displacement Resolution (R)
2 m	25mm	0.04 mils (1 micron)
2 m	50mm	0.02 mils (0.5 microns)
1 m	50mm	0.01 mils (0.25 microns)

RDI TECHNOLOGIES

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Cropping Image

Max framerates: Iris M 1,300 fps (Iris MX 29,000 fps).

Currently Framerate slider: Iris M Max 121 fps (Iris MX 211 fps).

Transfer speed has limitations - based on resolution and framerate.

Iris M ***USB 3.0 cable can only accommodate a certain amount of data flow.***

Acquisition application allows user to crop image.

When image is cropped, only pixels in cropped area used, making faster framerates possible.

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Cropping Image

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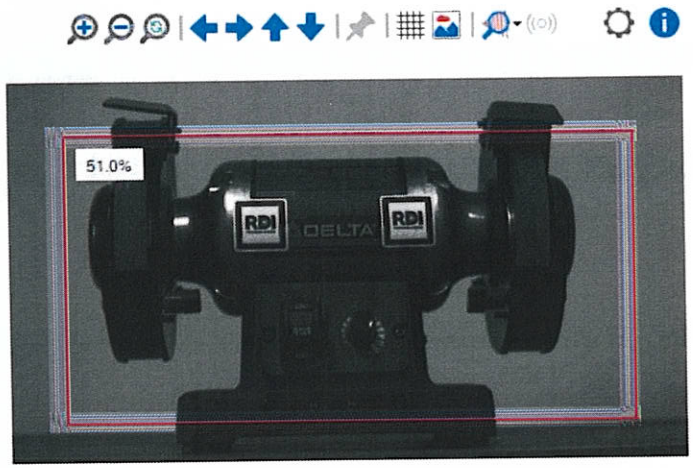
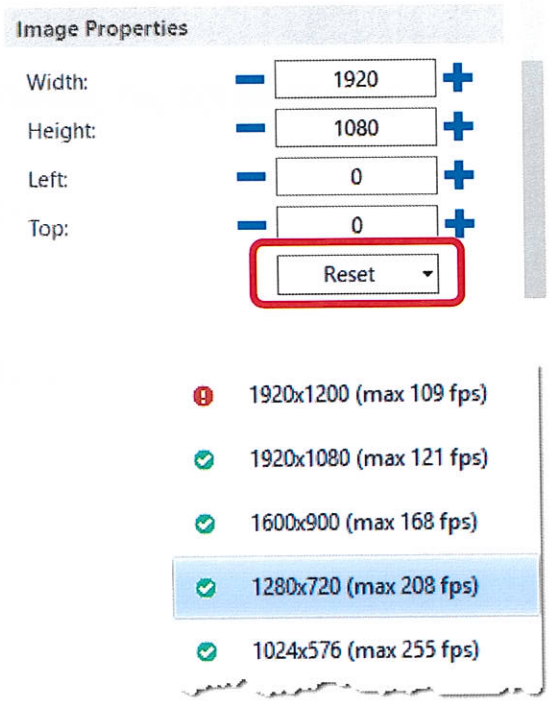
Two ways to crop an image:

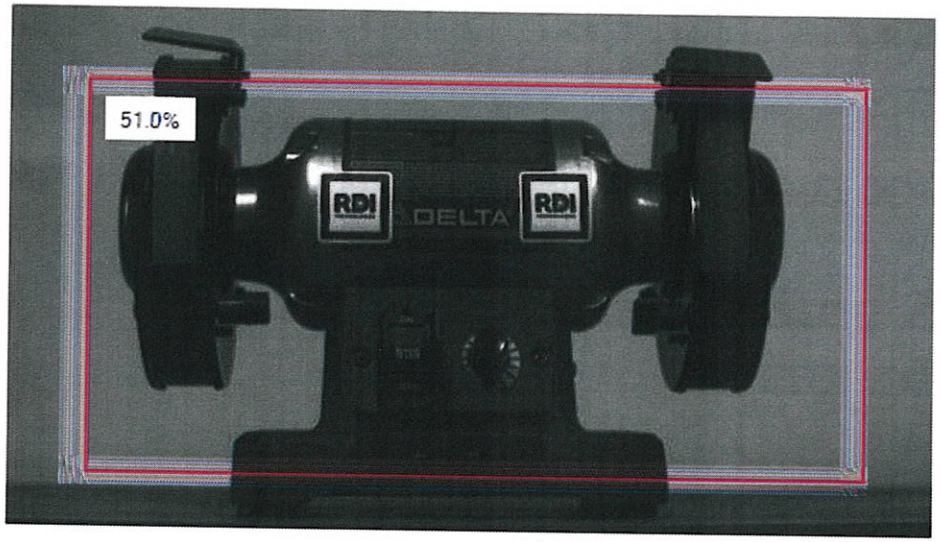
1. Manually draw area on image to crop.
2. Selecting a preset value by clicking on "Reset" in "Image Properties".





RDI TECHNOLOGIES

Exercise 5a – Manual Cropping

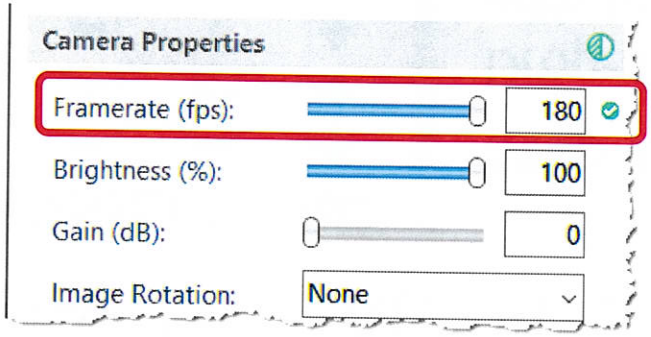


Step 1: At corner of desired crop area in image, left click and hold mouse button down while moving cursor.

A crop window will be drawn in red.

Step 2: Release mouse button when desired crop size has been reached.

Image resizes, showing only cropped area.



Step 3: Framerate can now be increased.

RDI TECHNOLOGIES

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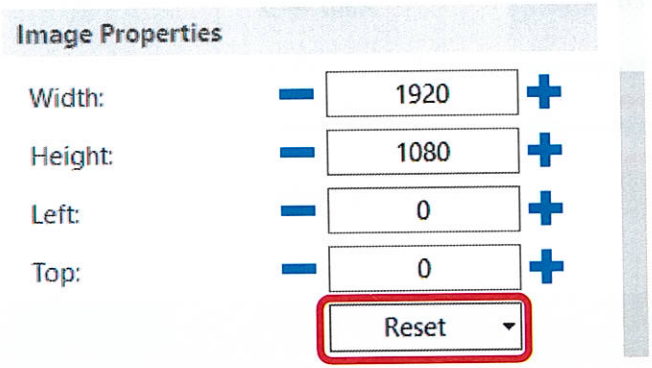
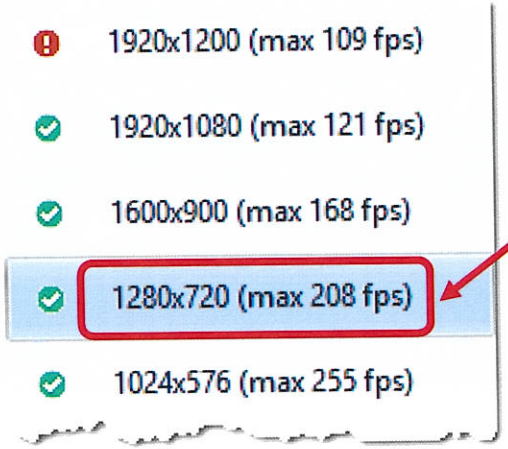
Exercise 5b – Automatic Cropping



Step 1: Click Reset button under Image Properties.

Drop-down menu appears with preset image sizes along with their max available framerates.



Step 2: Select 1280x720 (max 208 fps).

RDI TECHNOLOGIES

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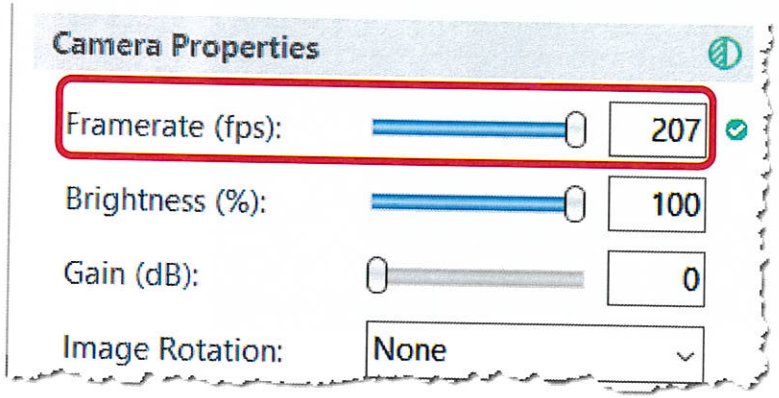

Cropped image now has higher max available framerate.

Higher framerate comes at a cost.

Image is smaller and darker, even though brightness setting is still 100%.

Increased framerate leaves less exposure time for each image, resulting in darker image.

RDI TECHNOLOGIES

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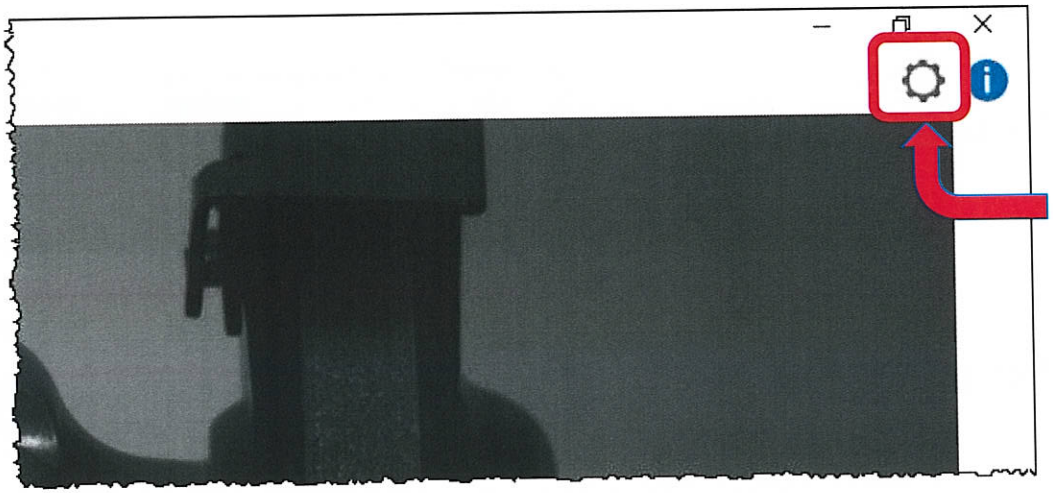
Dynamic Range

- Another way to achieve higher framerates is to lower sensitivity of camera by changing dynamic range.
- Iris M/MX utilize a 12-bit CMOS sensor, however there's an option to change dynamic range to an 8-bit sensor.
- Changing 12-bit to 8-bit results in higher framerate, however this affects image quality.



<u>To change dynamic range:</u>

Click "RDI Acquisition Options" gear wheel in Acquisition software.

RDI TECHNOLOGIES

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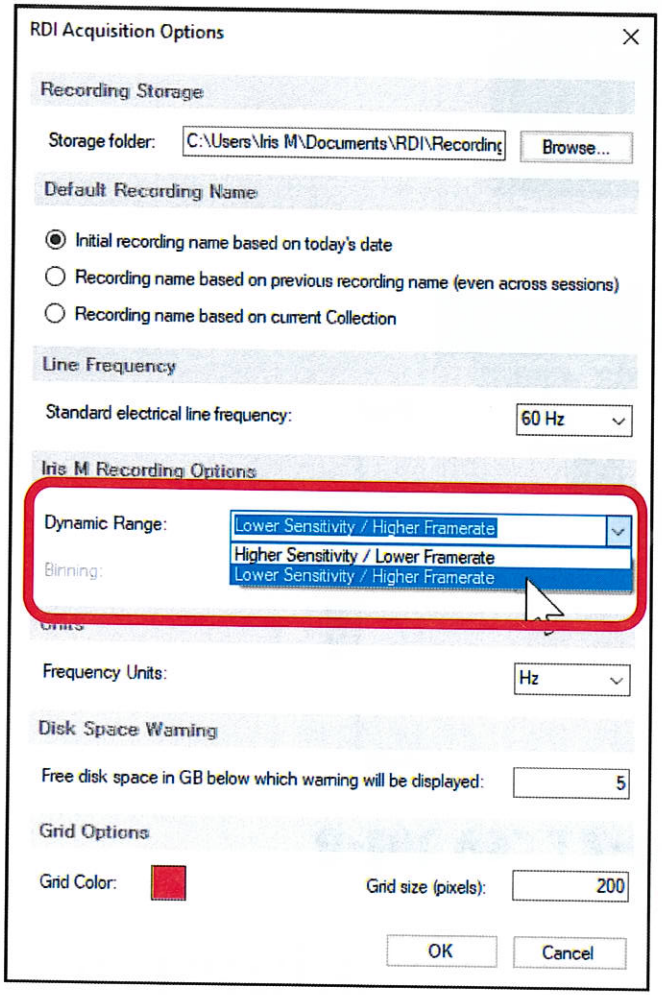
Dynamic Range



Click dropdown box for "Dynamic Range".

<u>Provides a selection</u>:

"Higher Sensitivity / Lower Framerate" (12-bit)

and

"Lower Sensitivity / Higher Framerate" (8-bit)

RDI TECHNOLOGIES

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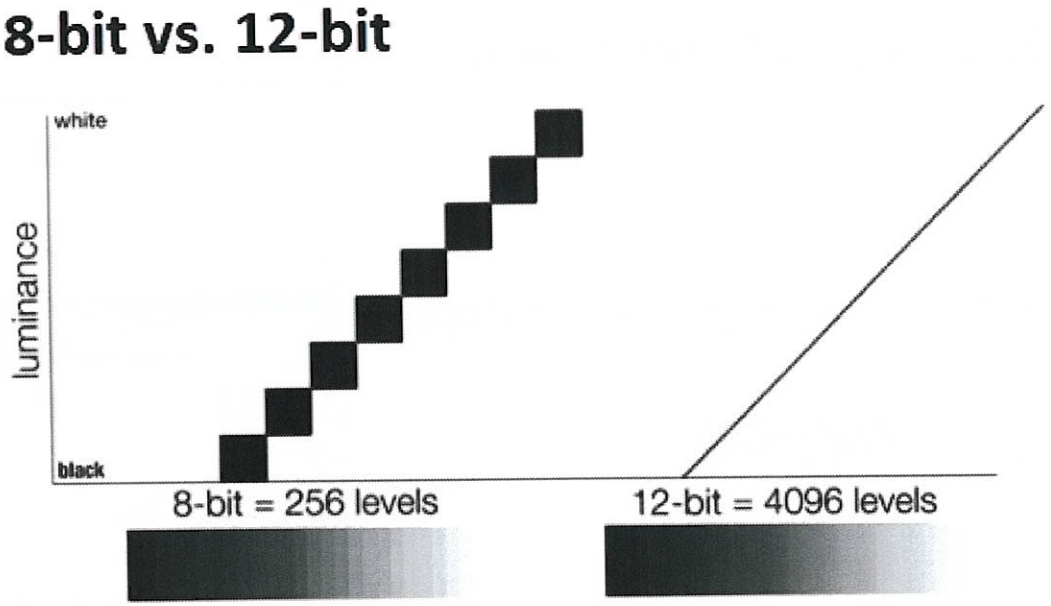
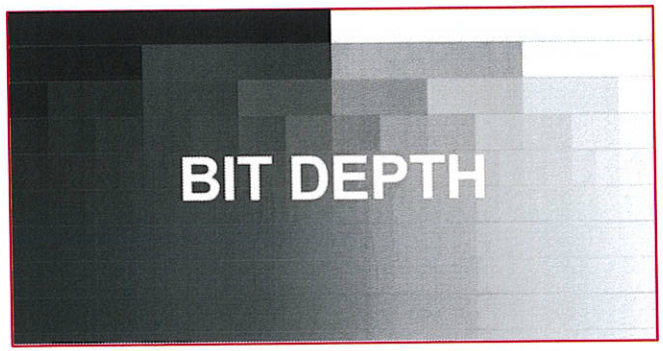
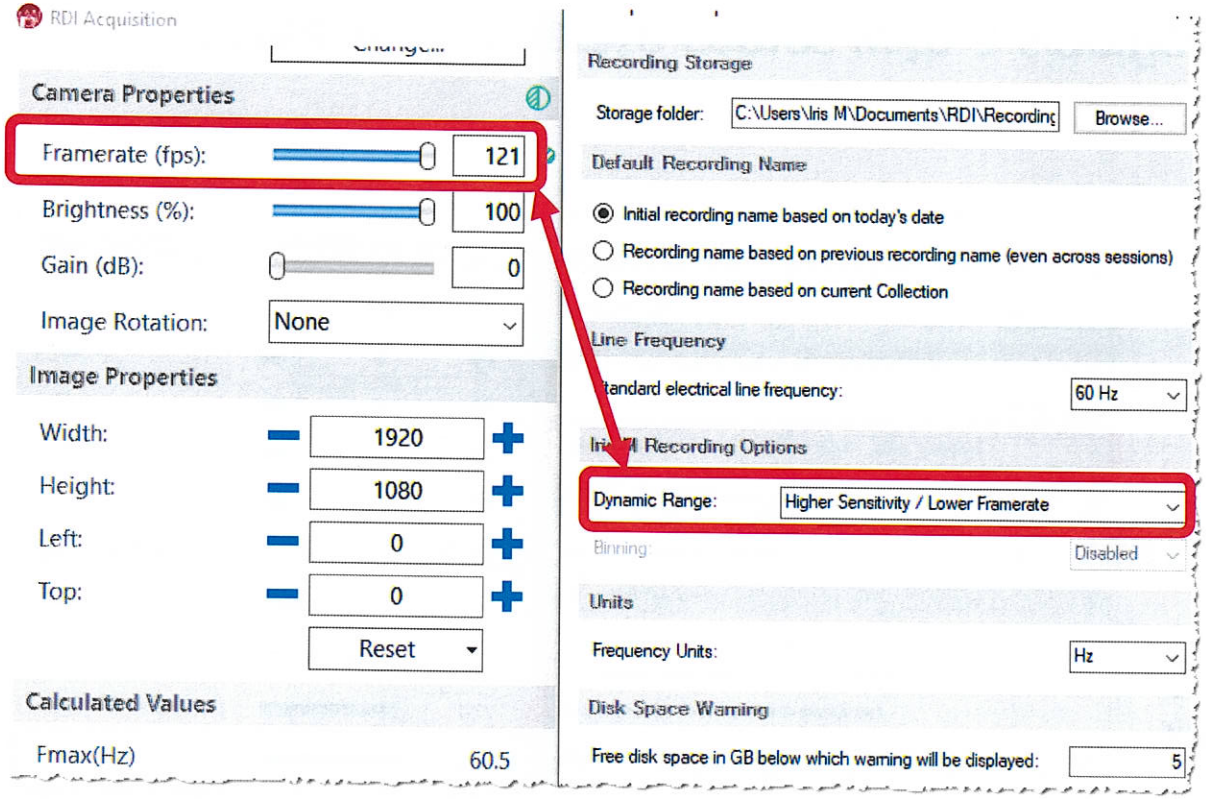
Dynamic Range





Dynamic Range



Here "Dynamic Range" is "Higher Sensitivity/Lower Framerate" (12-bit).

With this dynamic range and image properties max framerate is 121 fps.

RDI TECHNOLOGIES

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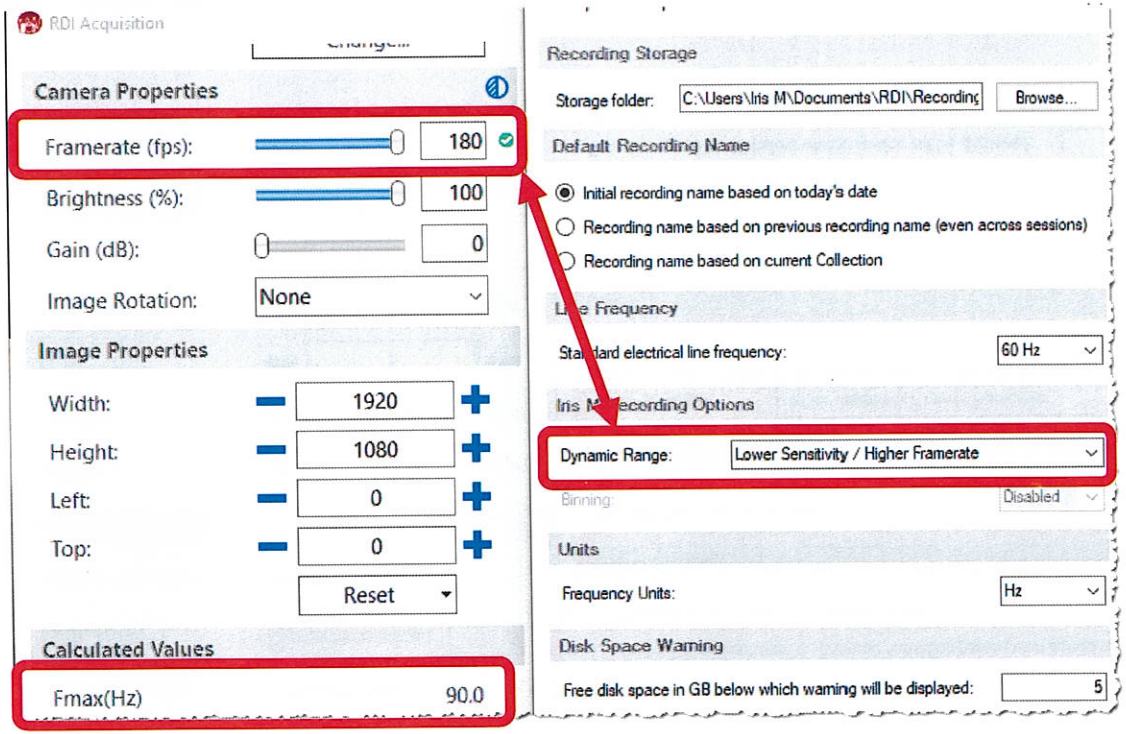
Dynamic Range



Here "Dynamic Range" is "Lower Sensitivity/Higher Framerate"(8-bit).

Max framerate is now 180 fps.

Increased framerate comes with a significantly higher spectral Fmax.

RDI TECHNOLOGIES

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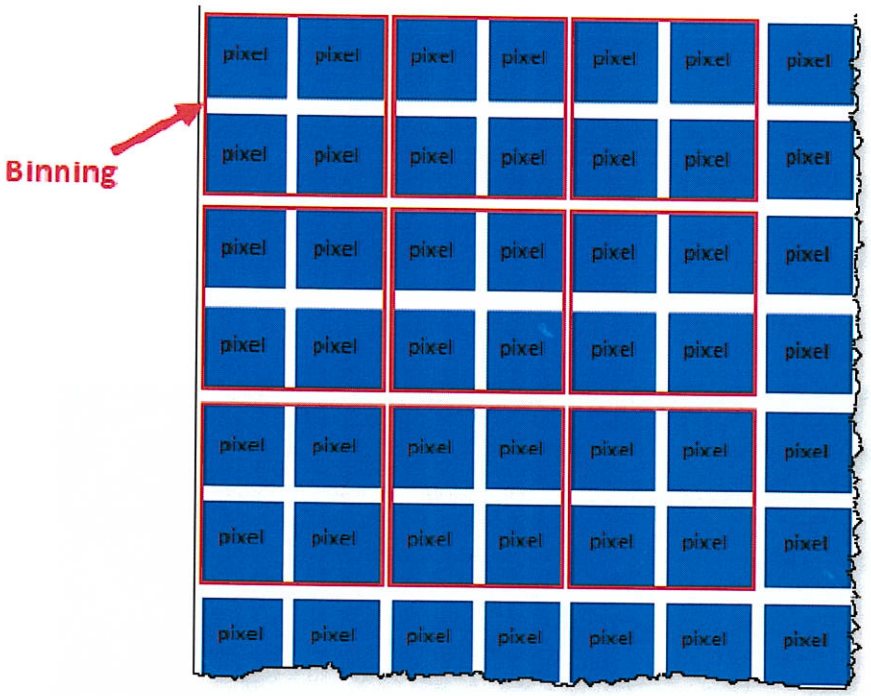
Iris MX Binning



Iris MX camera allows for adjustment of image size by a process called binning.

Binning merges 2x2 pixels to create 1 larger pixel.

Allows sensor to read out one pixel instead of 4. Results in higher framerate while maintaining same field of view.

Image resolution is reduced by a factor of 2 both horizontally and vertically.

For example, a 2560x2048 image become 1280x1024.

RDI TECHNOLOGIES

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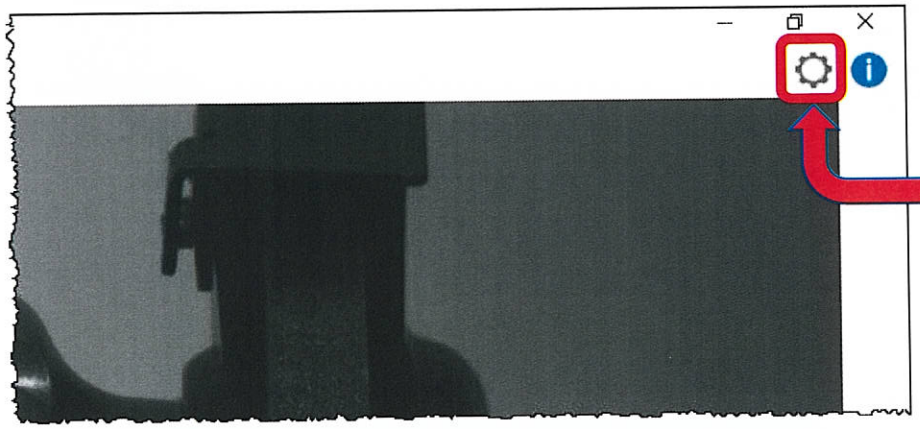
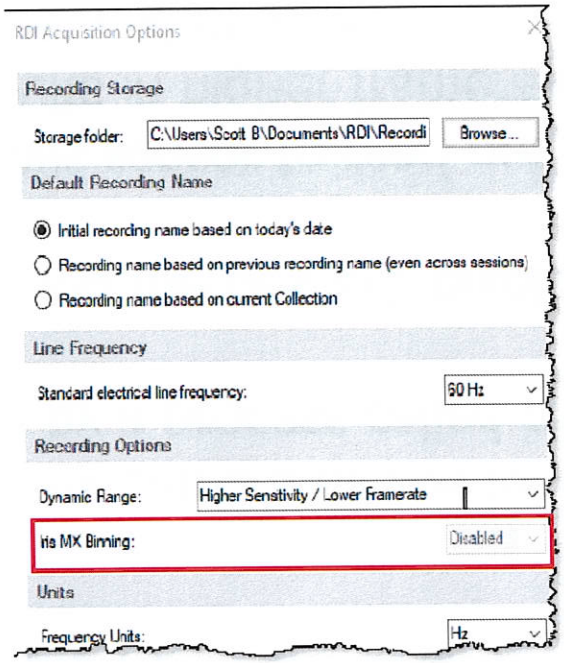
Iris MX Binning



To enable binning click gear wheel in RDI Acquisition.



Under "Recording Options" click dropdown box for "Iris MX Binning" and select enable.

RDI TECHNOLOGIES

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Rotating Component Inspection Using Shaft Inspection Acquisition Mode

- Shaft Inspection Acquisition makes it easy to acquire a recording for purpose of visually inspecting a rotating shaft or element while machine is in operation.

- Useful in performing visual inspections of rotating components such as shafts, couplings, sheaves, and belts.

RDI TECHNOLOGIES

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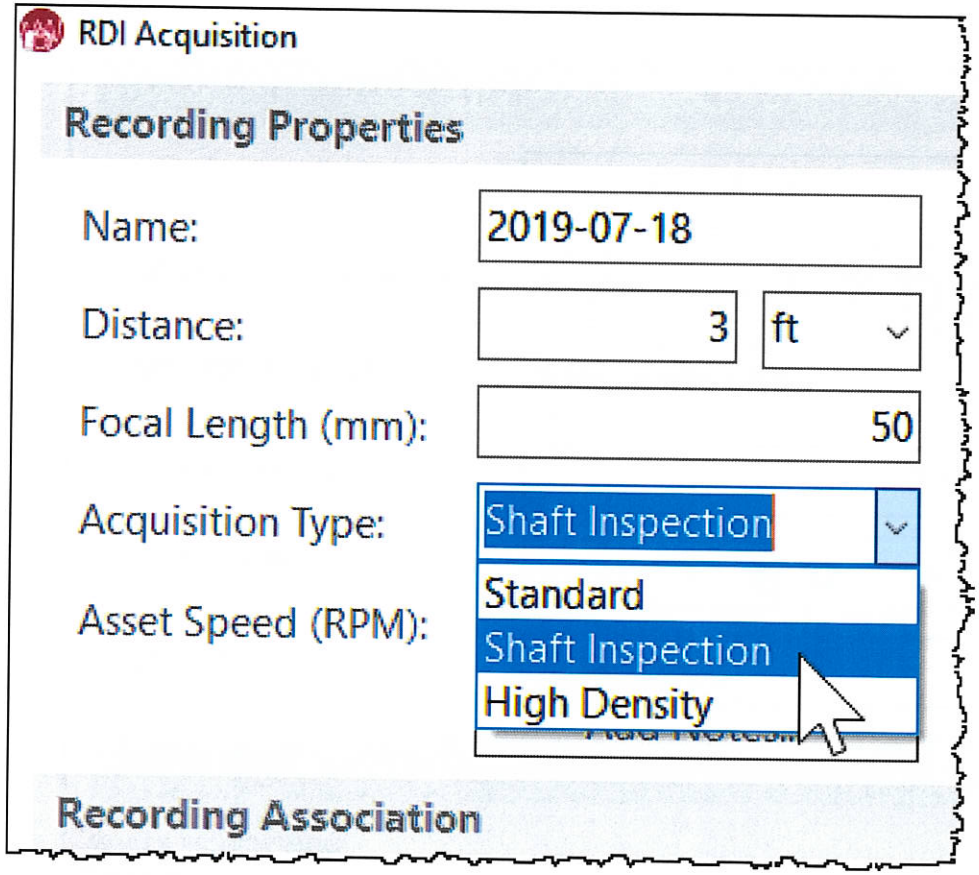
Shaft Inspection

Exercise 6 – Shaft Inspection Acquisition



Step 1: In RDI Acquisition select "Shaft Inspection" under Acquisition Type in Recording Properties.

RDI TECHNOLOGIES

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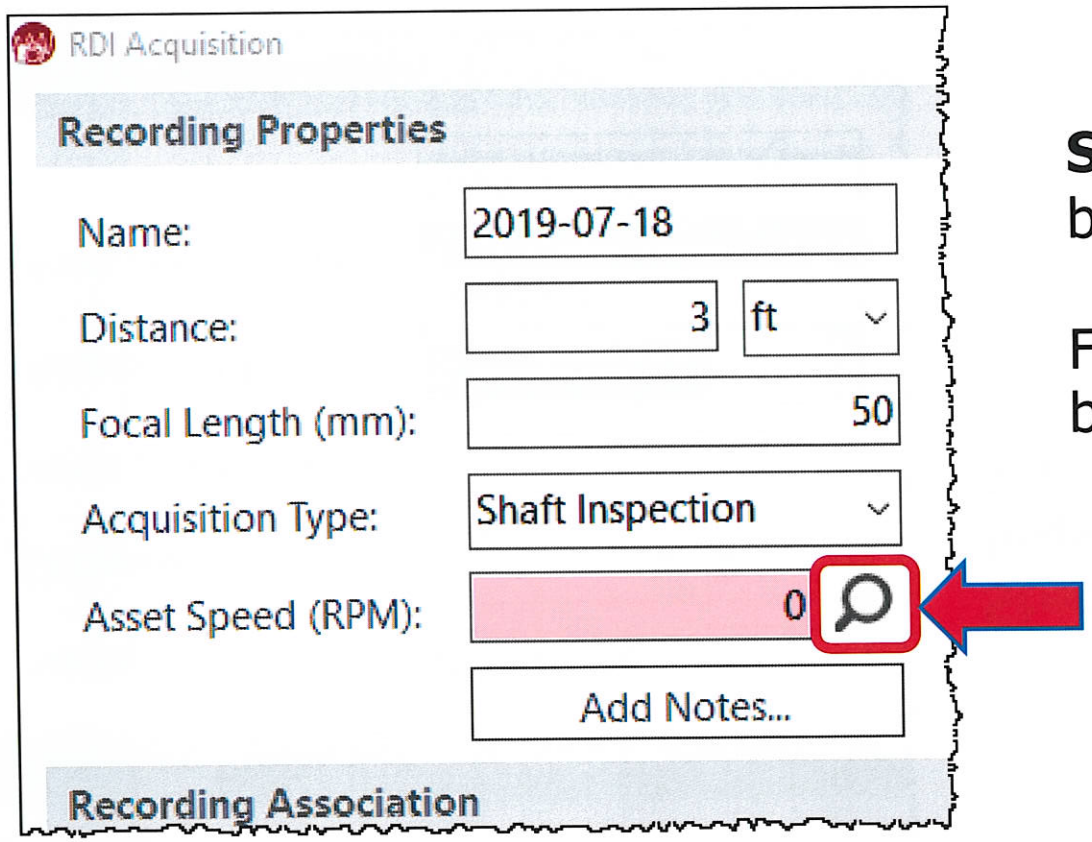
Exercise 6 – Shaft Inspection Acquisition



Step 2: Click Measure Asset Speed button to measure rotor RPM.

For best result, Asset Speed needs to be as accurate as possible.

RDI TECHNOLOGIES

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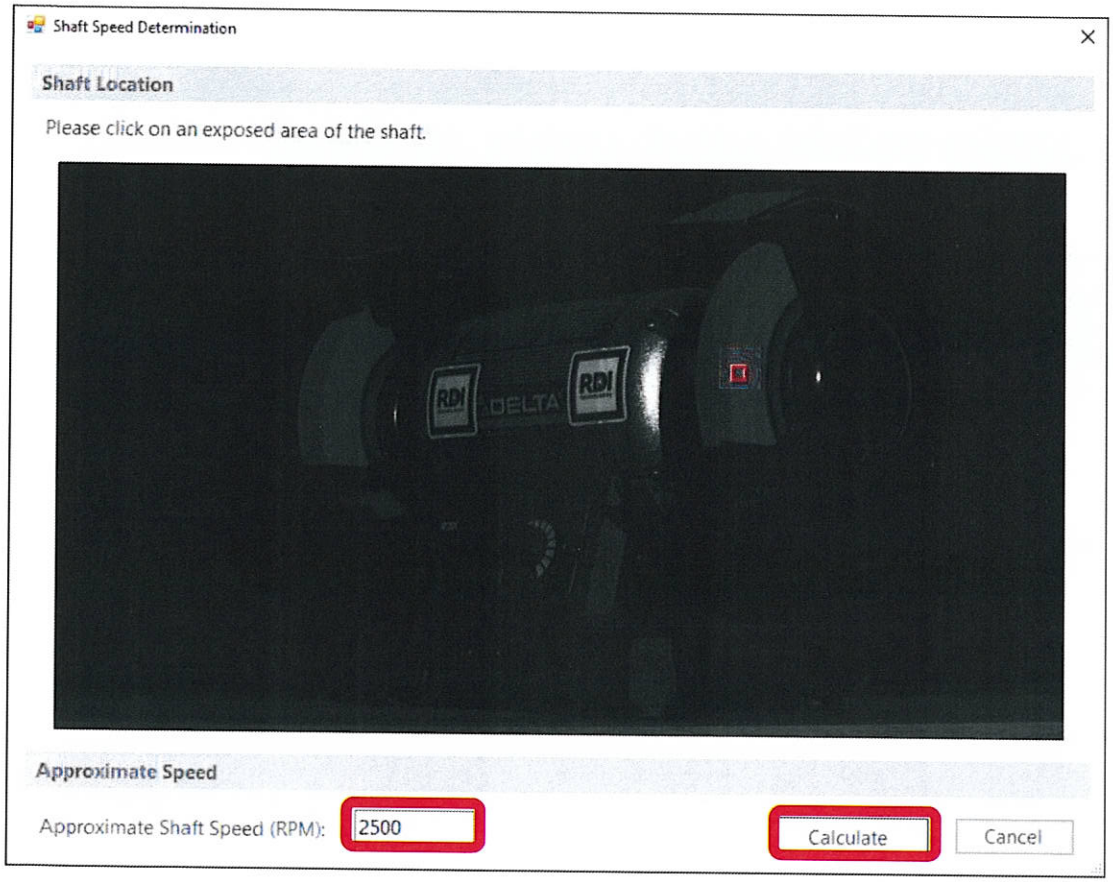
Exercise 6 – Shaft Inspection Acquisition



Step 3: In Approximate Shaft Speed (RPM) field type approximate RPM.

Step 4: Using cursor, click on shaft or rotating element.

Step 5: Click Calculate

RDI TECHNOLOGIES

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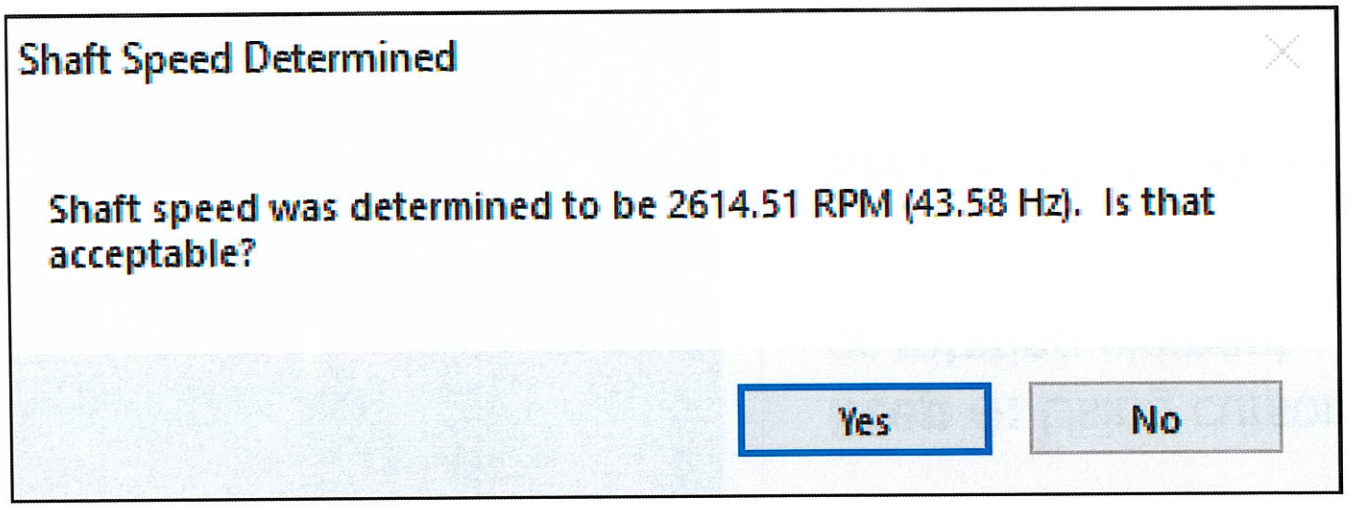
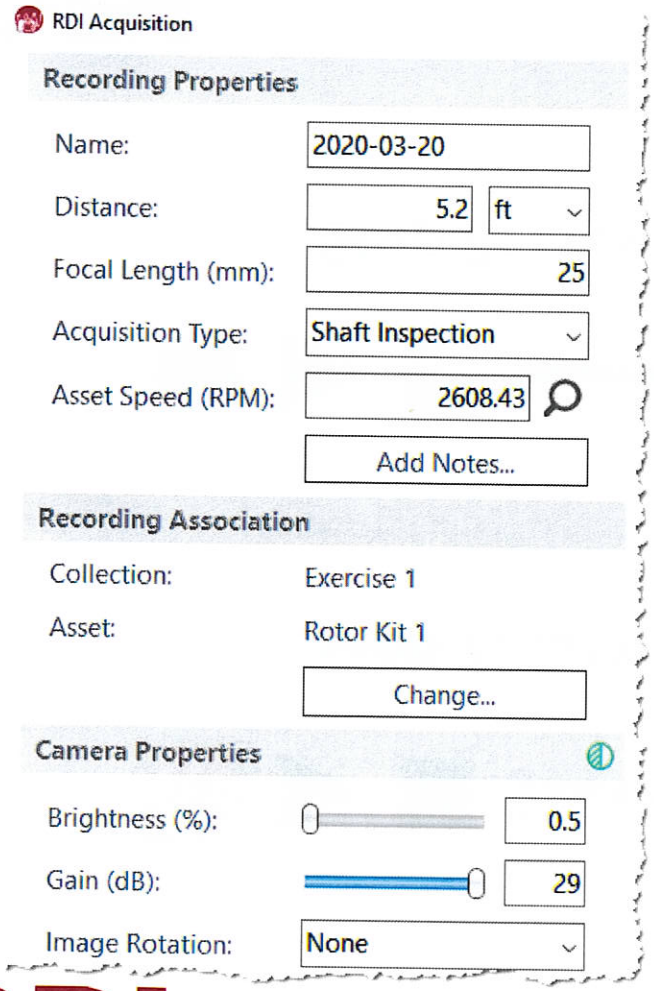
Exercise 6 – Shaft Inspection Acquisition



Step 6: When Shaft Speed Determined window opens, click Yes

Exercise 6 – Shaft Inspection Acquisition



Measured RPM appears in Asset Speed (RPM) window.

Brightness and Gain automatically set.

Most cases - Brightness less than 1 and Gain at 29.

Important to leave Brightness and Gain settings at automatically set values.

RDI TECHNOLOGIES

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Exercise 6 – Shaft Inspection Acquisition

Step 7: Click Record button to begin data acquisition.

Step 8: Click Launch Motion Amplification Button to view recording.

RDI TECHNOLOGIES

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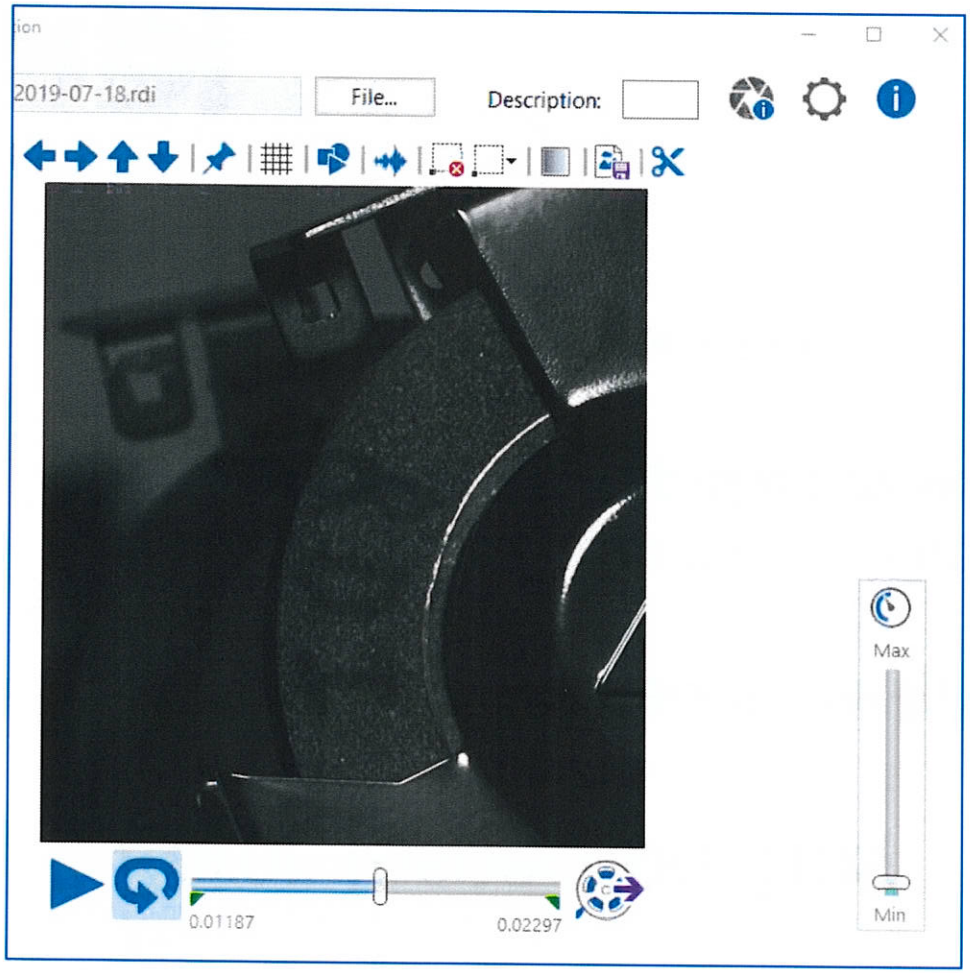

In Motion Amplification file can be edited and played.

- Playback speed can be adjusted.
- Length of recording is approximately one shaft revolution.

Standard analysis/editing tools are available except for spectrum and orbit functions.

Amplification not available.

RDI TECHNOLOGIES

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Rotor Inspection Tips

- Prepare to provide additional lighting.
- Single Image Acquisition time needs to be very short in order to produce a clear image. Accomplished by setting brightness as low as possible.
- RPM needs to be consistent.

RDI TECHNOLOGIES

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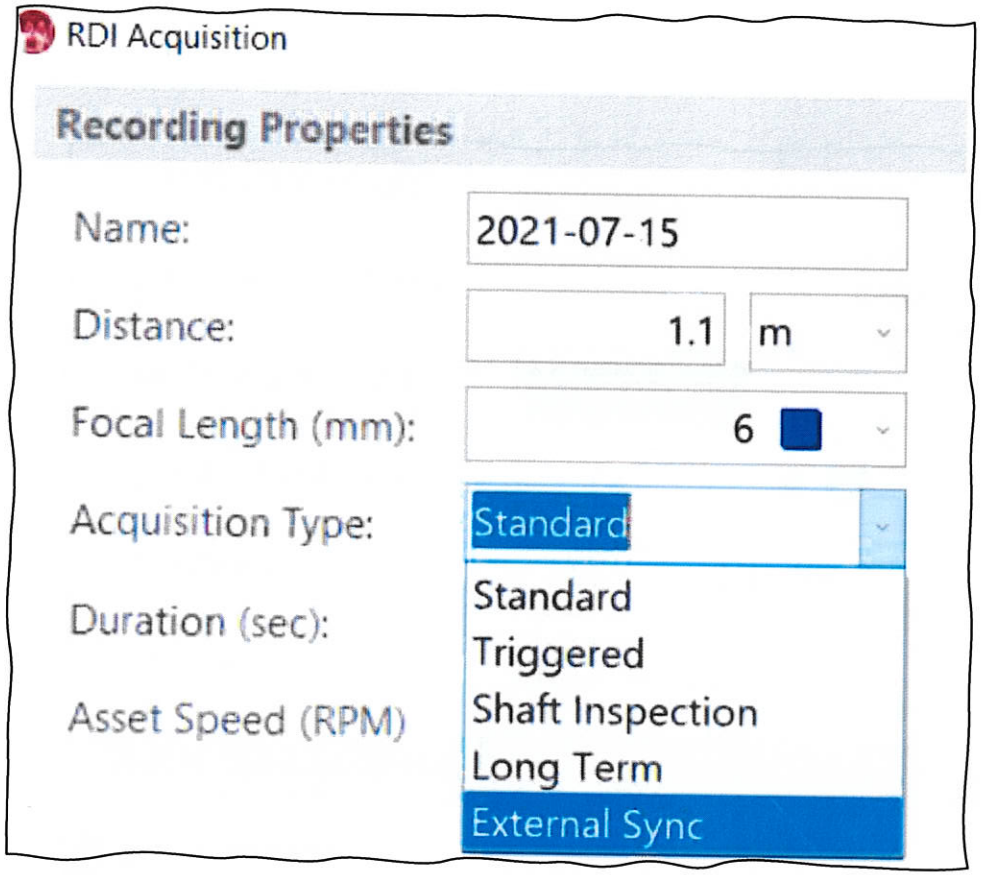
Exercise 7 – External Sync



Step 1: In RDI Acquisition select "External Sync" under Acquisition Type in Recording Properties.

RDI TECHNOLOGIES

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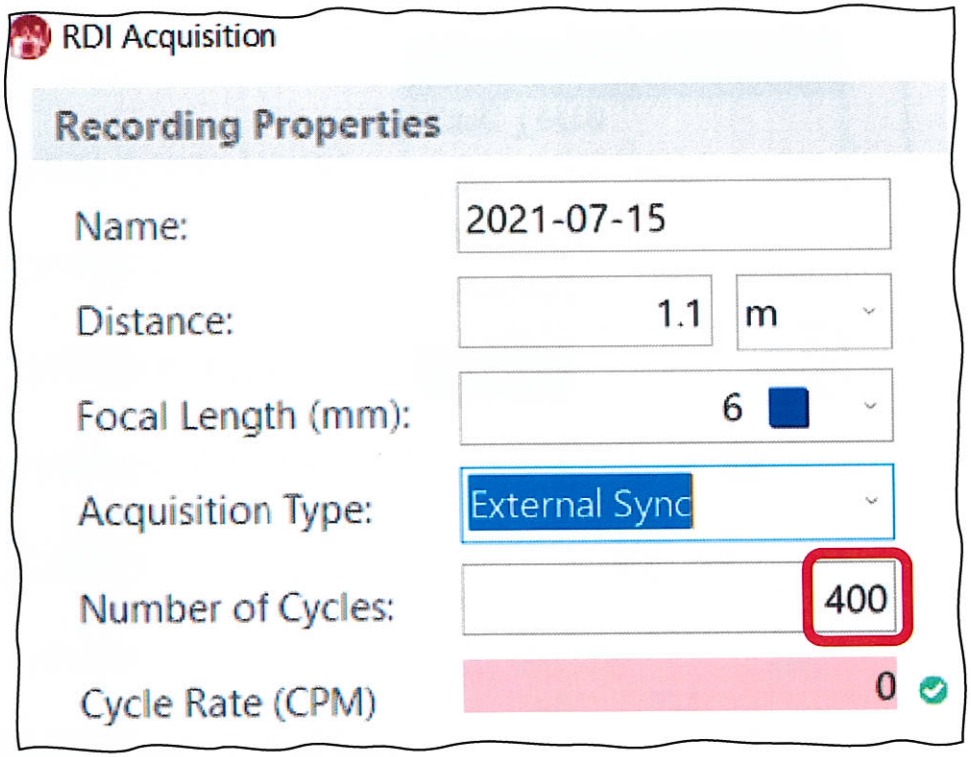
Exercise 7 – External Sync



Step 2: Enter number of revolution.

Cycle Rate – will present speed of the shaft measured by the tacho.

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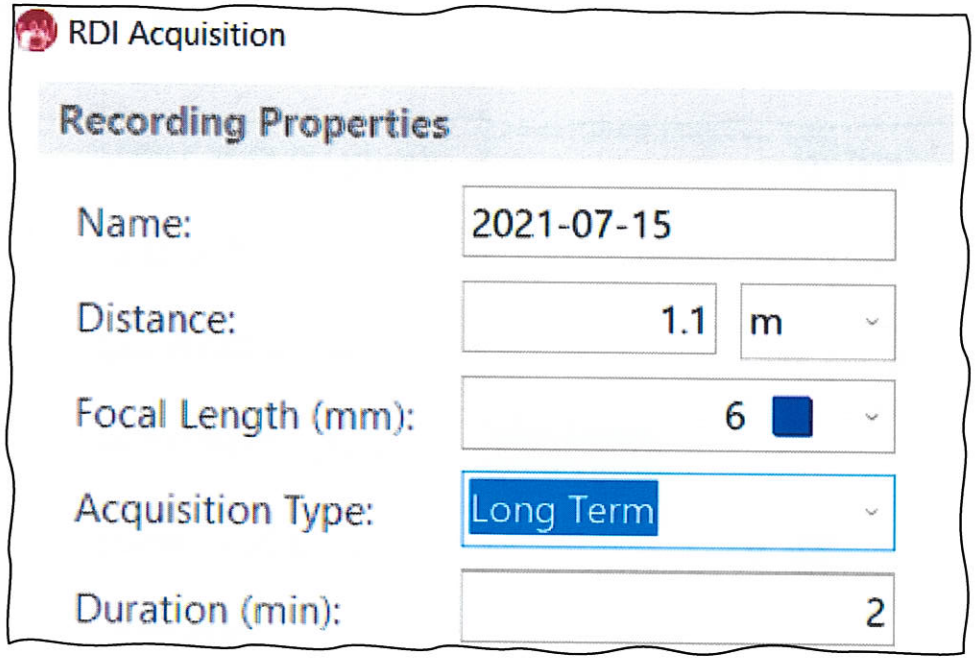
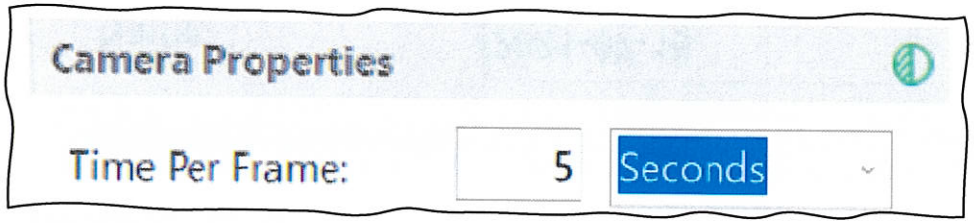
Exercise 8 – Long Term



Step 1: Enter duration in minutes.



Step 2: Determine duration between frames

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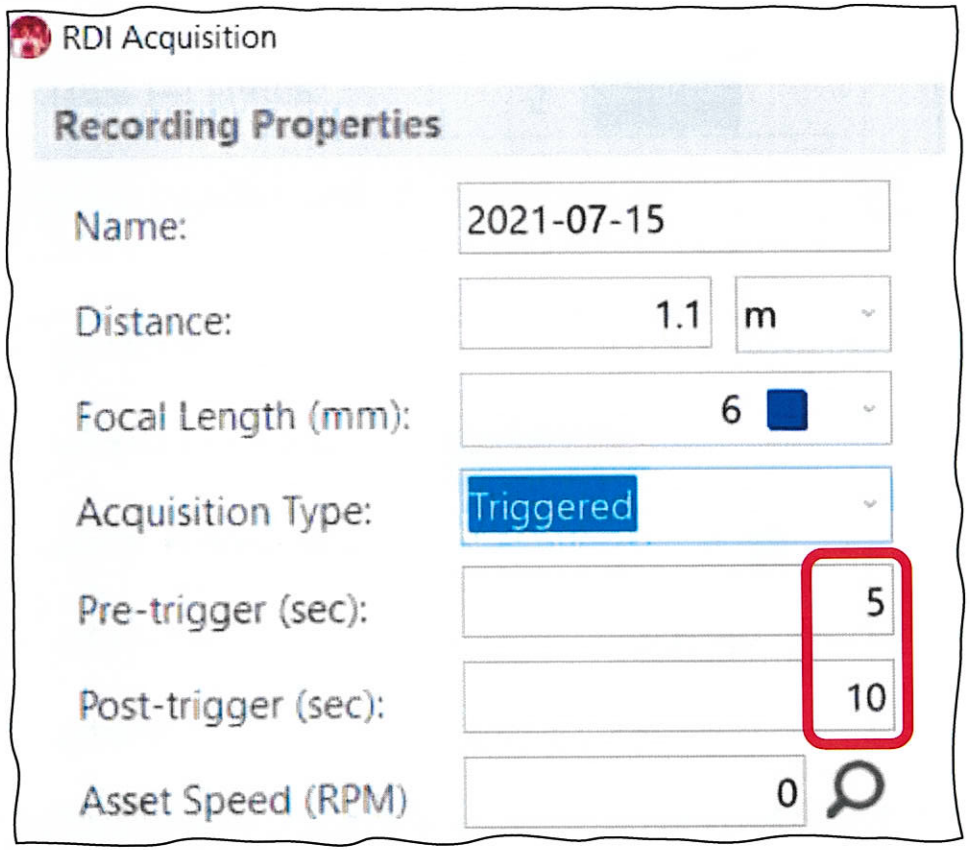
Exercise 9 – Triggered



Step 1: Time before trigger apers.

Step 2: Time after triger

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Before Acquiring a Recording

The "Nower Never" 5 things to remember before pressing the red button:

1. **Lens** - Accurately record Lens focal length
2. **Distance** – Accurately measure and enter distance to asset
3. **Lighting** - Set correctly for environment and subject
4. **Focus** – Zoom in, focus, then zoom out
5. **Stability** – to avoid camera shake use vibration isolation pads under tripod legs and ensure that the tripod is tightened at all joints.

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Section 4 Review

1. What would be the minimum displacement resolution if the camera is located 5 meters from the machine using a 25mm lens?

2. In camera properties, the Framerate (fps) maximum value is 121. Name two ways to raise the framerate above 121 fps.

3. What can be done to reduce lighting flicker when recording indoors?

4. True or False: For best results when using Shaft Inspection Acquisition, the Brightness setting is automatically lowered and needs to be manually raised to 100%.

Section 4 Review

5. In regard to the Dynamic Range settings for the camera if "Higher Sensitivity" is selected, how is the maximum framerate affected?

6. Can digital zoom be used to increase framerate?

7. What does increasing the Gain do to the image?

8. Calculate the Single Image Exposure Time for the following Acquisition settings:
   Framerate = 150 FPS Brightness = 50%

IRIS M

Enhancing Vision

Section 5
Motion Amplification

Objectives:

1. Identify and discuss Motion Amplification tools
2. Generate vibration data from Motion Amplification data
3. Complete classroom exercises to practice Motion Amplification skills

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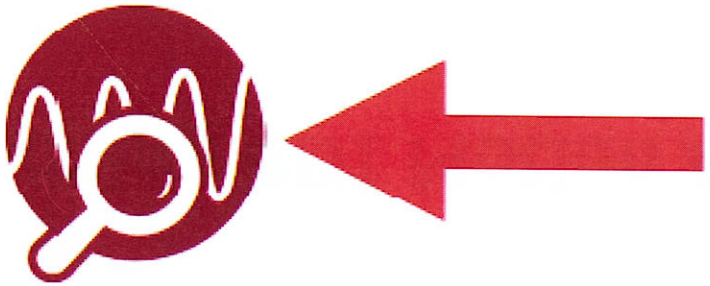
Launching RDI Motion Amplification

Motion Amplification software is used to:

- Amplify
- Analyze
- Create mp4 videos of .RDI recordings

Can be launched a few different ways:

1. Clicking Motion Amplification shortcut on desktop



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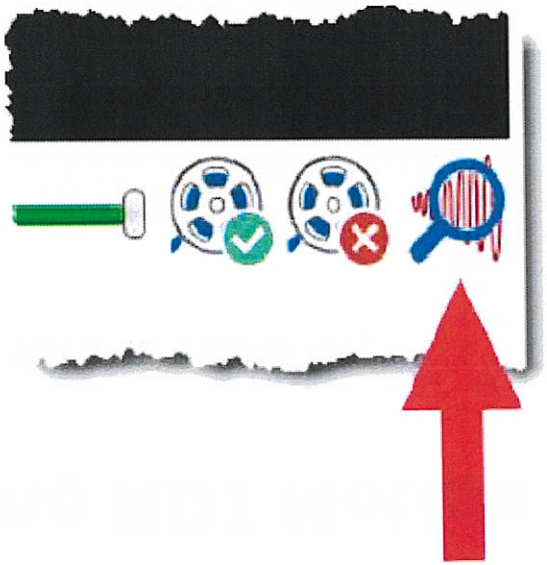
Launching RDI Motion Amplification

2. Clicking Motion Amplification button in Acquisition after acquiring a recording.



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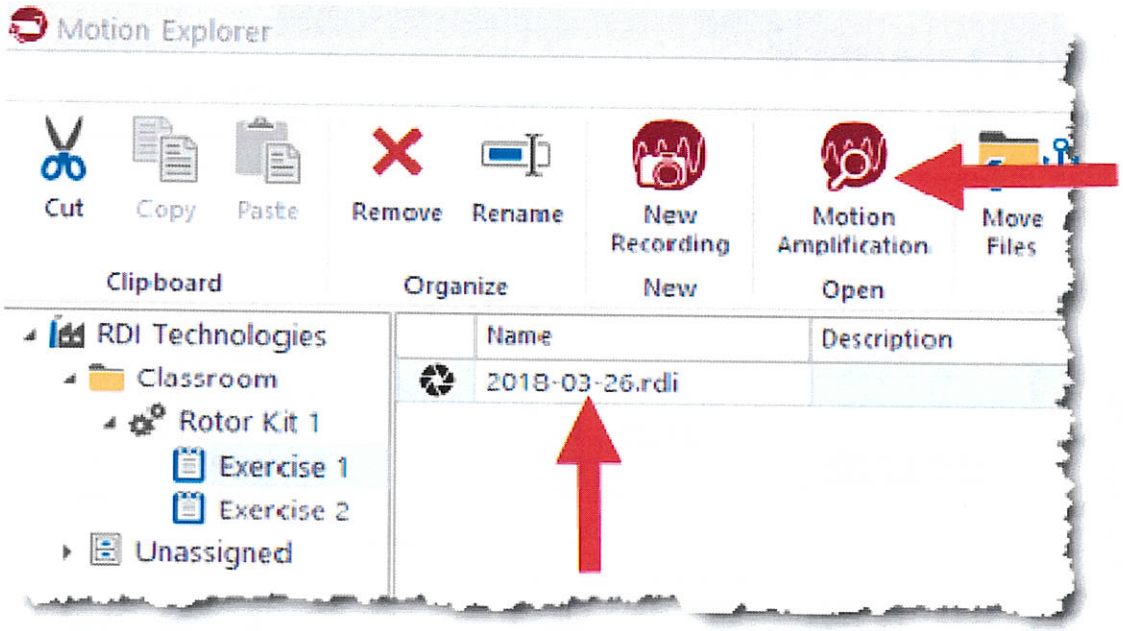
Launching RDI Motion Amplification



3. From Motion Explorer, either:

   Double-clicking any .rdi recording

   or

   Highlight recording and click Motion Amplification button in Ribbon Bar.

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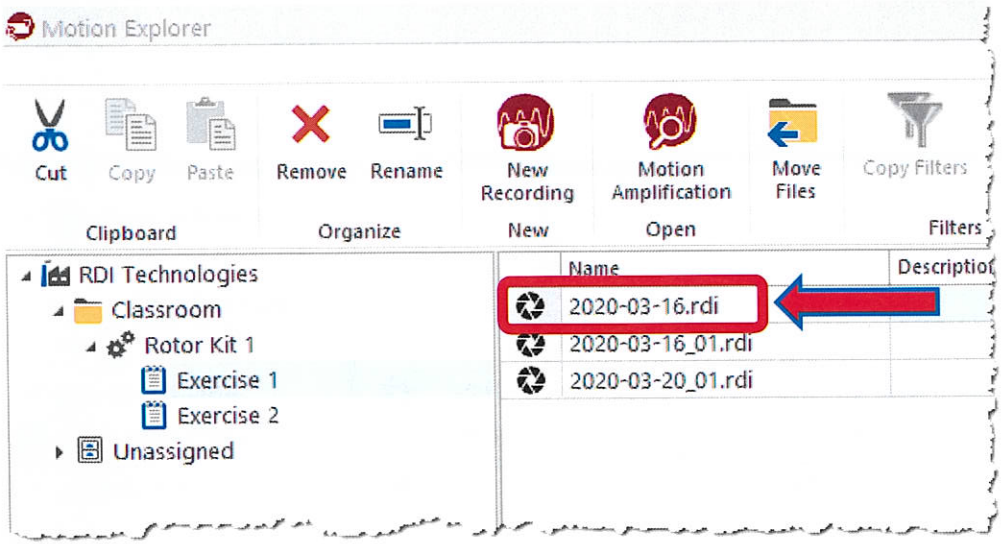
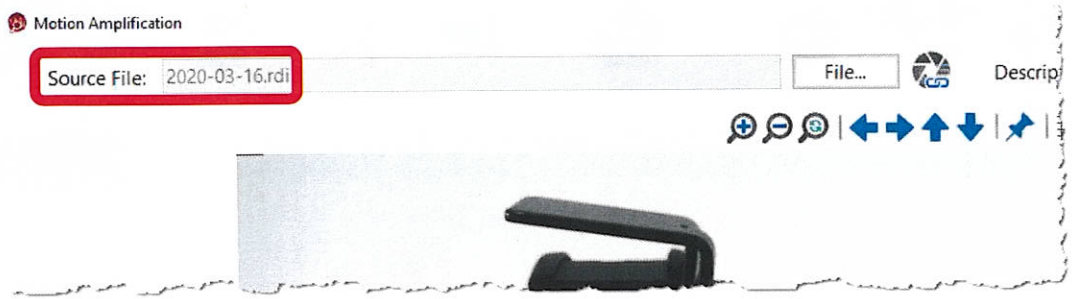
Exercise 8 - Launch Motion Amplification



Step 1 - Launch Motion Explorer.

Step 2 - Highlight .rdi file from Exercise in Section 3 and launch Motion Amplification.



Motion Amplification opens showing recording captured in exercise 1.

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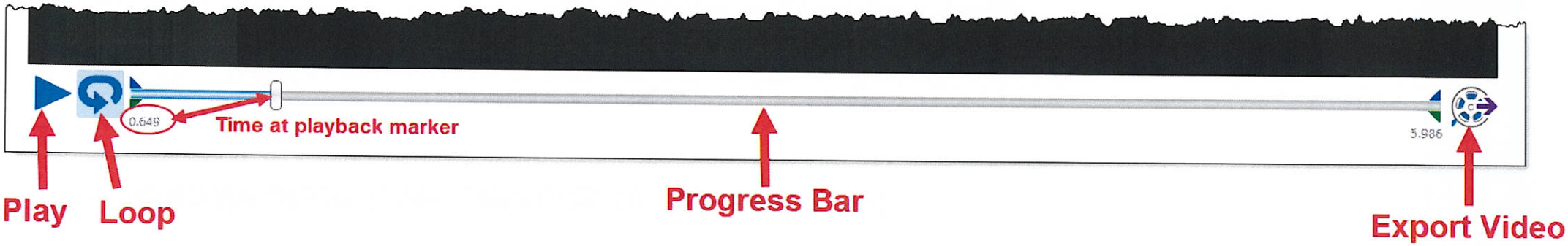
Basic Playback



Play Recording and Loop Playback controls.

Progress bar - see recording playback progress and go directly to desired location.

Manual time can be entered for playback marker - click on time at left side to enter desired time.

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Amplification Slider

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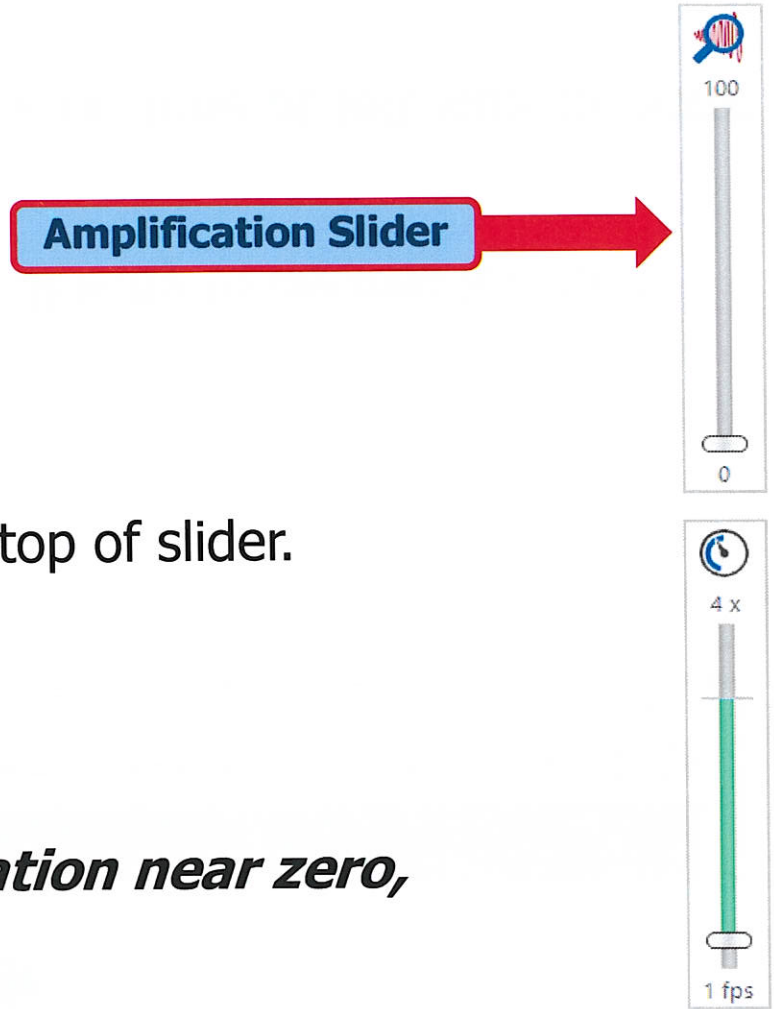
Slider adjustment:

- Drag slider
- Left click at desired location
- Right click, specify value.



- Amplification - 0 to 100X.
- *Extreme Amplification* to 500X – right click icon, top of slider.
- Amplification level defaults to last value set.

Recommended: begin with amplification near zero, increase as needed.

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Playback Speed Slider

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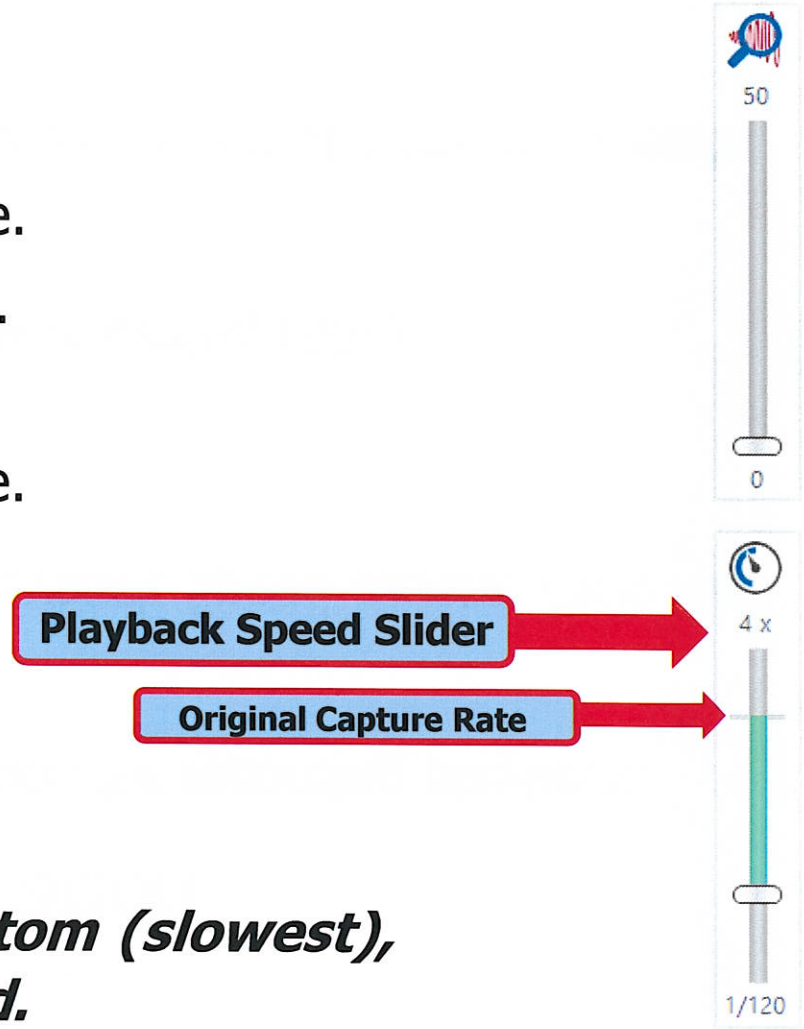
Line near top indicates original capture rate.

- When set here - playback is capture rate.
- When below - playback slower than capture rate.
- When above - playback faster than capture rate.

- Defaults to starting at 10% original capture rate.



RDI TECHNOLOGIES

Recommended to start near bottom (slowest), increase as to find suitable speed.

Exercise 9 - Basic Motion Amplification

Step 1 – Click Loop button to enable loop function for recording playback.

Step 2 – Without adjusting Amplification or Playback Speed sliders, click Play button to view Unamplified recording.

Step 3 – Drag Amplification slider up to its highest setting (50x).

Step 4 – Adjust Playback Speed slider and observe motion at different speeds. Start from bottom of the bar and work upwards.

Why is recording so grainy?

All digital images contain inherent digital noise.

More noticeable in low light conditions, where ratio of light to noise is lower.

When gain is used image gets brighter, but also increases noise in image.

Motion Amplification also amplifies amount of noise.

RDI TECHNOLOGIES

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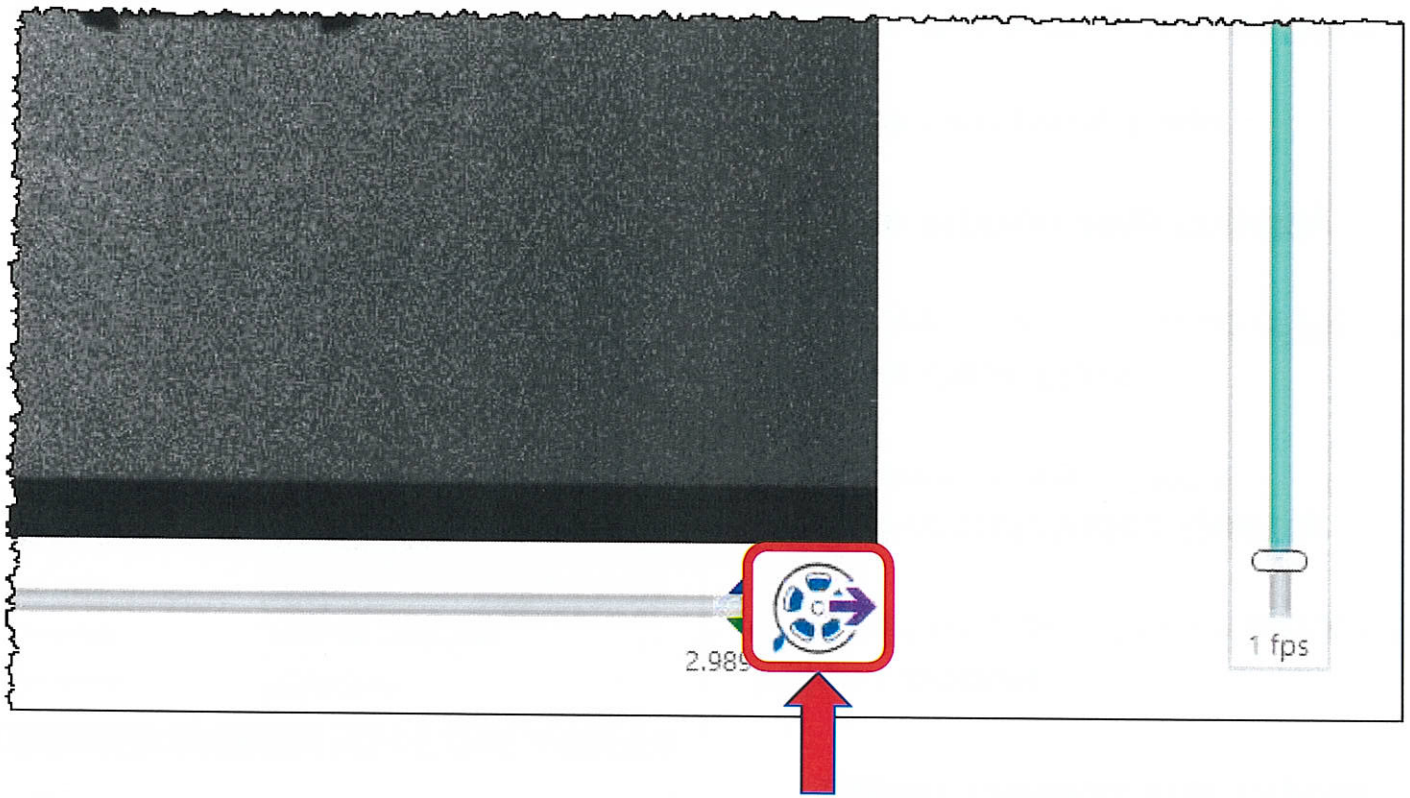
Exercise 10 - Basic Video Export

Once amplification and playback speed have been adjusted to desired levels, recording can be exported in .mp4 format.

Important step because original .rdi data files are not viewable outside of Motion Amplification software application.

.mp4 video often serves as most important file used for reporting.

Exercise 10 - Basic Video Export



Step 1 – Click Export Video button.

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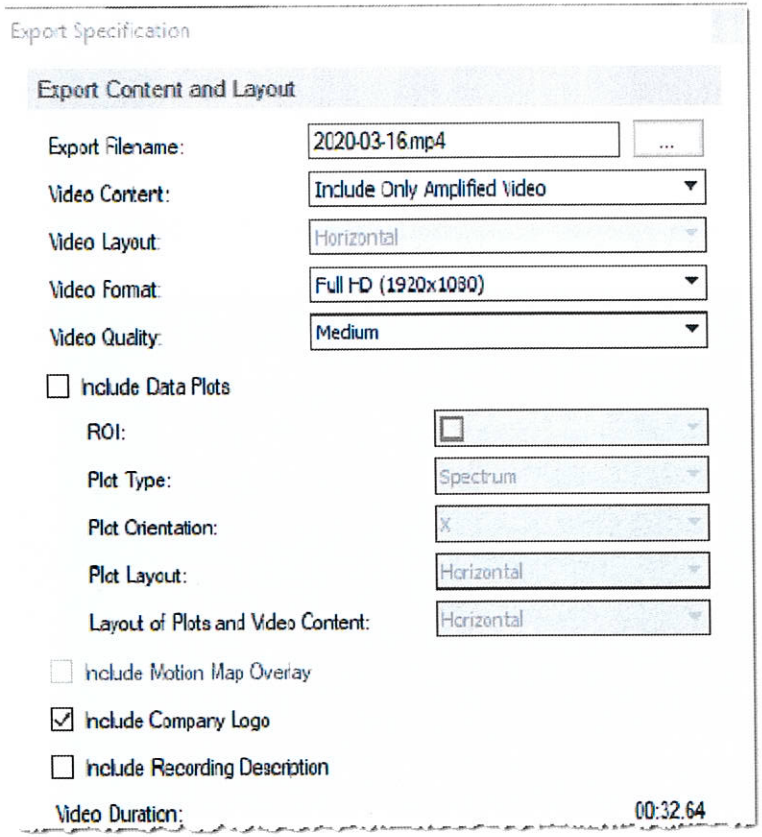
Exercise 10 - Basic Video Export



"Export Content and Layout"

Video Content
- Amplified Video Only or Include Unamplified Video

Video Format/Video Quality
- Can reduce size of MP4

Include Data Plots
- In addition to or instead of Plot Annotations

Include Motion Map Overlay

Include Company Logo

Include Recording Description

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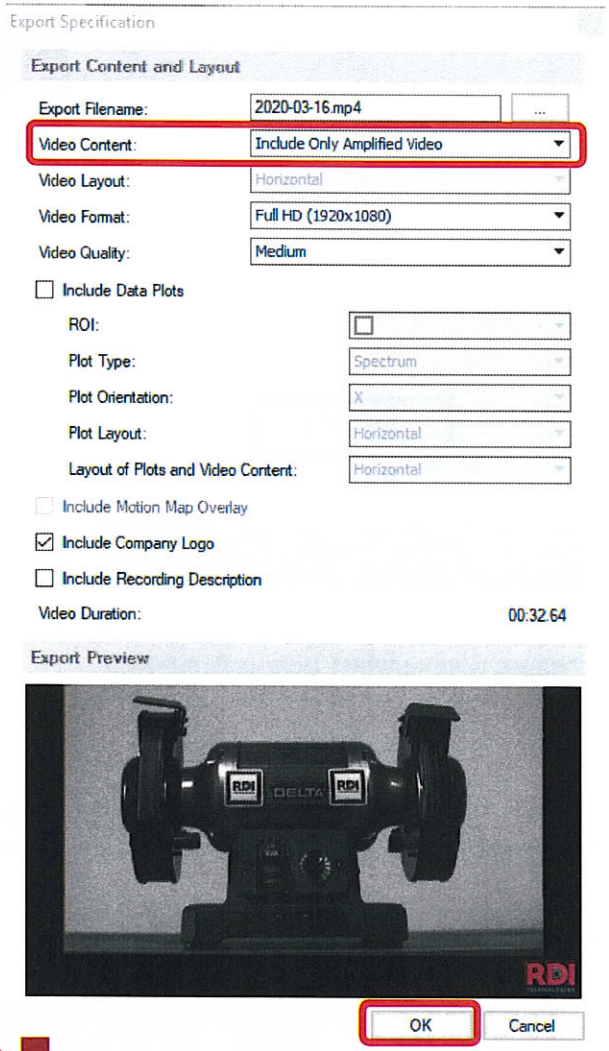

Step 2 – In "Video Content" box select **Include Only Amplified Video,** click "OK".

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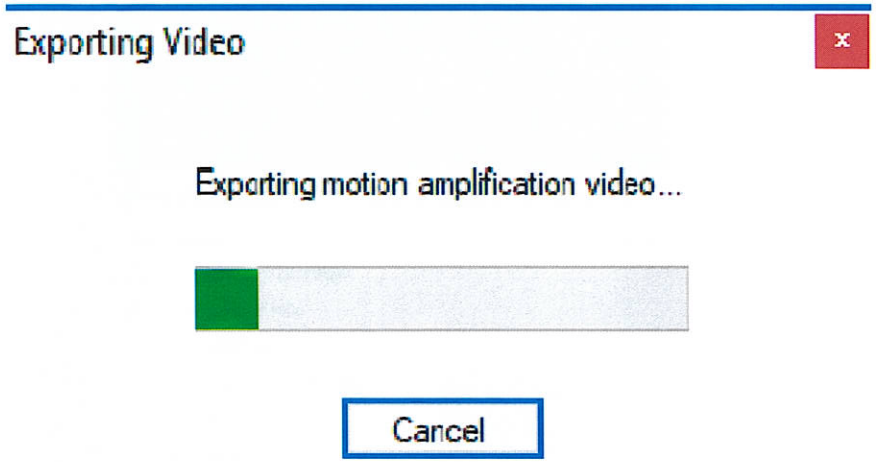
Exercise 10 - Basic Video Export



Video export progress window appears.

Time needed varies based on number of frames and image size.

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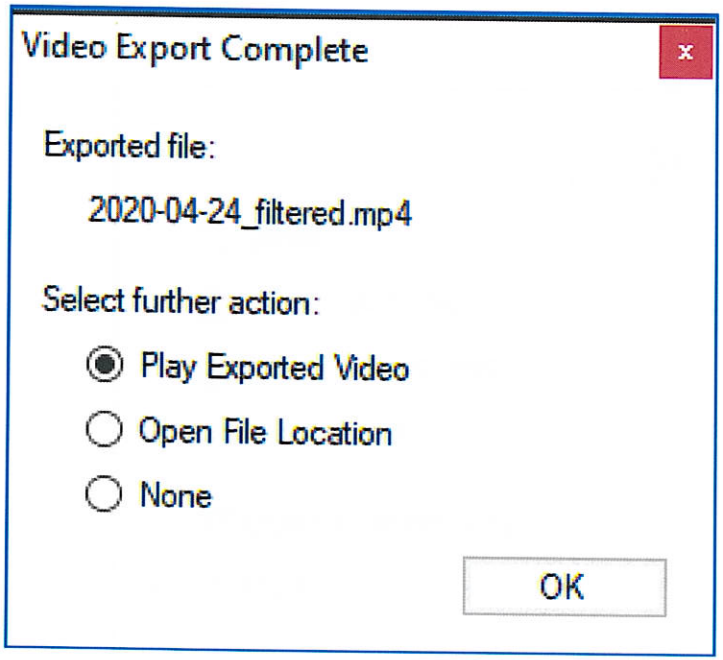
Exercise 10 - Basic Video Export



"Play Exported Video"

- Opens .mp4 video using user's selected mp4 playback application.

"Open File Location"

- Opens Windows Explorer application to location of file on Acquisition Unit hard drive.

"None"

- No immediate action – back to MA.

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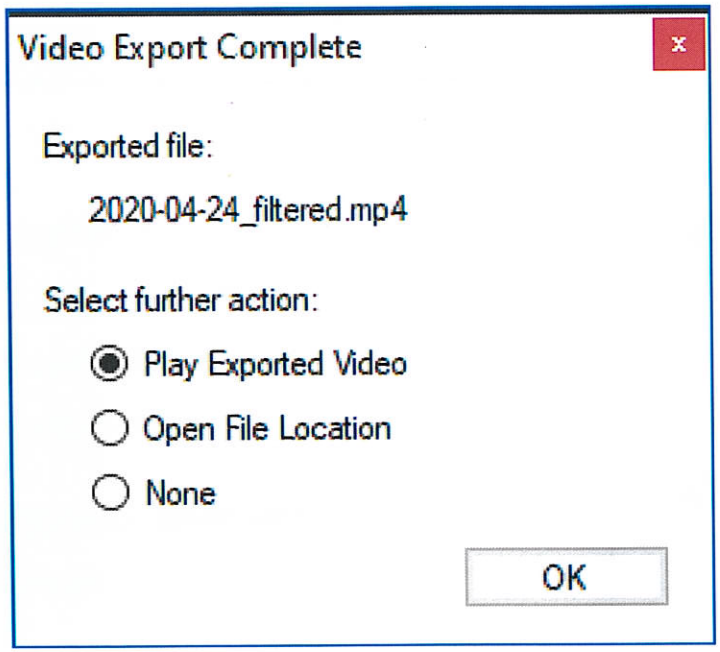
Exercise 10 - Basic Video Export



Step 3 - Select "Play Exported Video", click "OK".

Step 4 – Allow mp4 video to play.

If video is satisfactory, close mp4 playback window and proceed to step 5.

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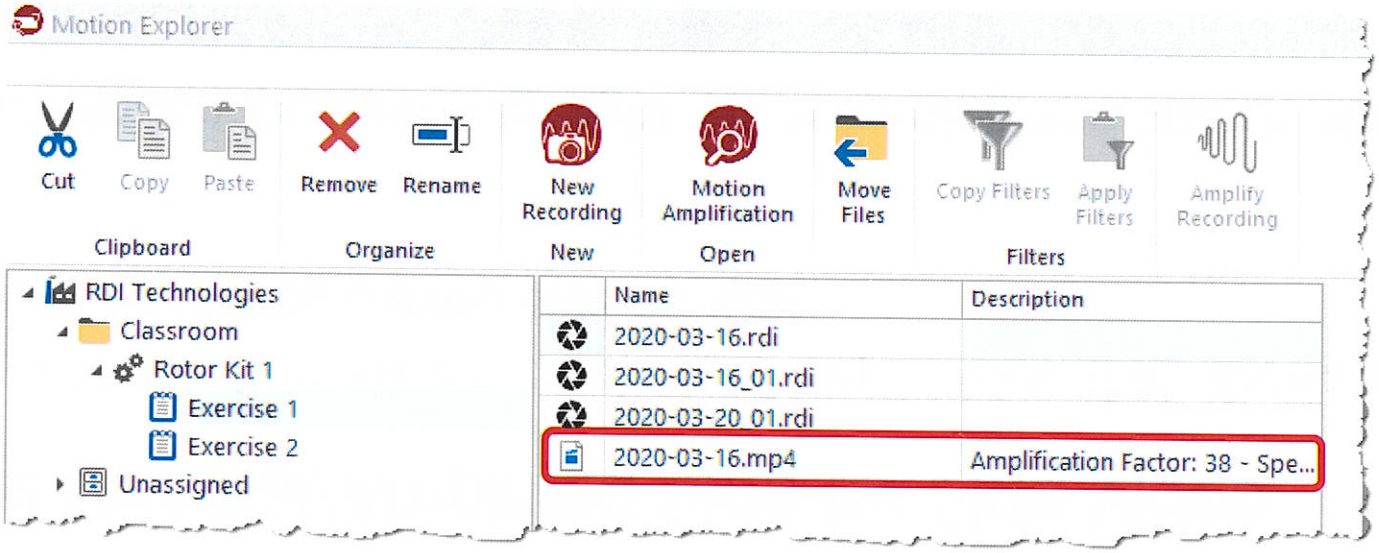
Exercise 10 - Basic Video Export

Step 5 – Close Motion Amplification and verify that stored mp4 video appears in Motion Explorer hierarchy.



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Exercise 11 - Advanced Video Export

Create Original/Amplified Side-By-Side Video

Motion Amplification allows creation of .mp4 video that shows both unamplified and amplified videos played side by side.

Step 1 – In Motion Explorer, highlight .rdi recording and launch Motion Amplification.

Step 2 – Set amplification to desired level and click Export Video button. 

RDI TECHNOLOGIES

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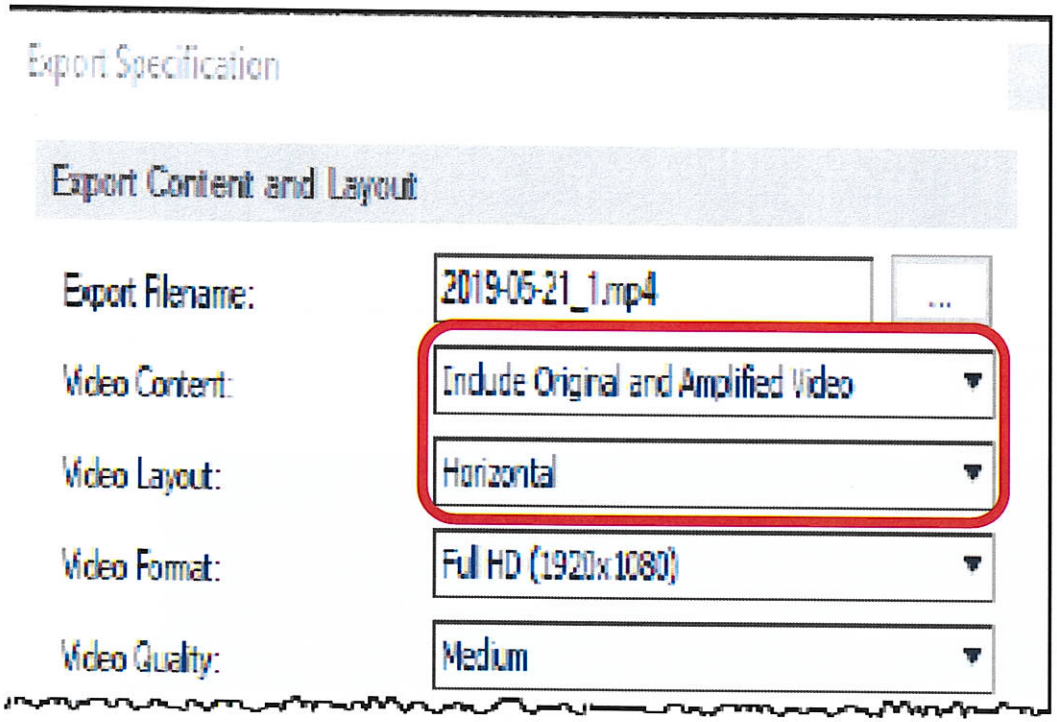
Exercise 11 - Advanced Video Export



Step 3 – In "Video Content" box select Include original and Amplified Video.

Step 4 – Click selection arrow for "Video Layout", select Horizontal.

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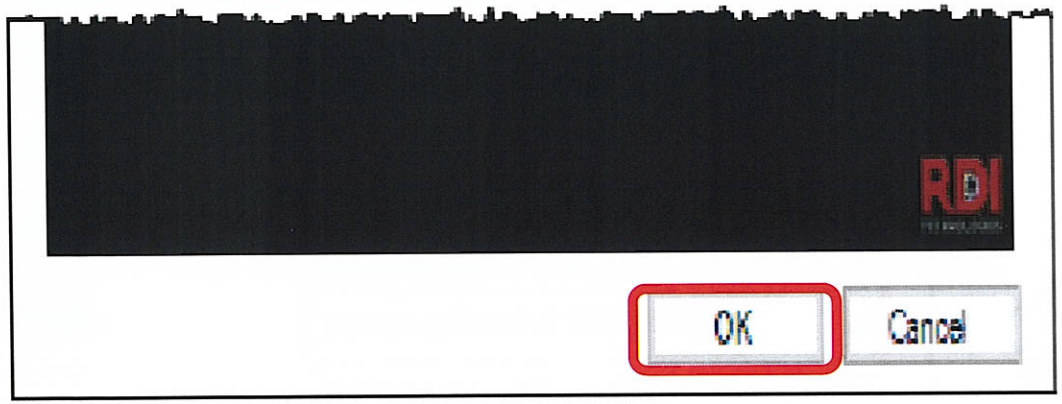
Exercise 11 - Advanced Video Export



Step 5 – Click OK at bottom of the Export Specification window.

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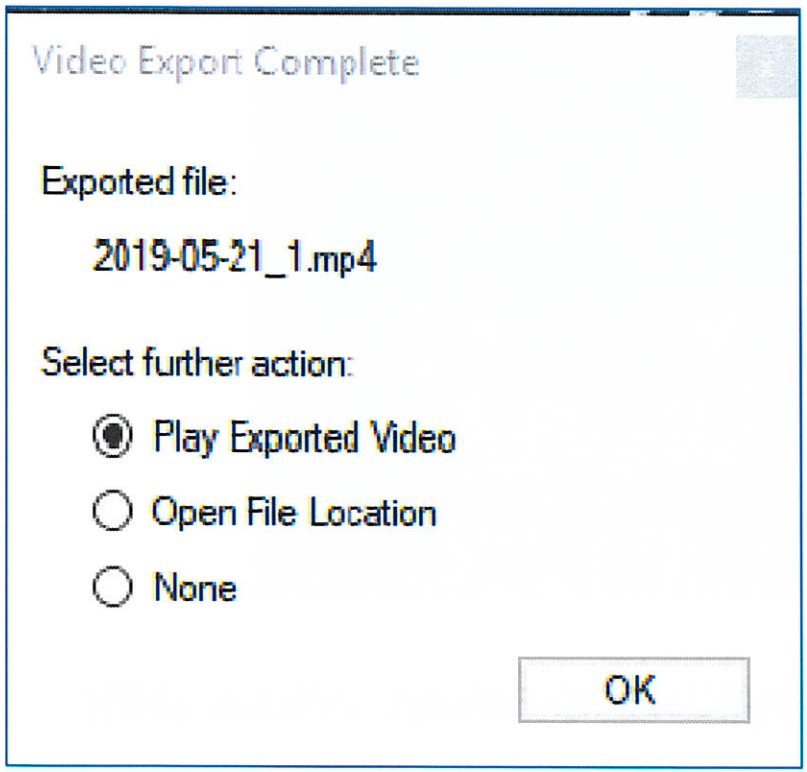
Exercise 11 - Advanced Video Export



Step 6 – When Video Export Complete window appears, select **Play Exported Video.**

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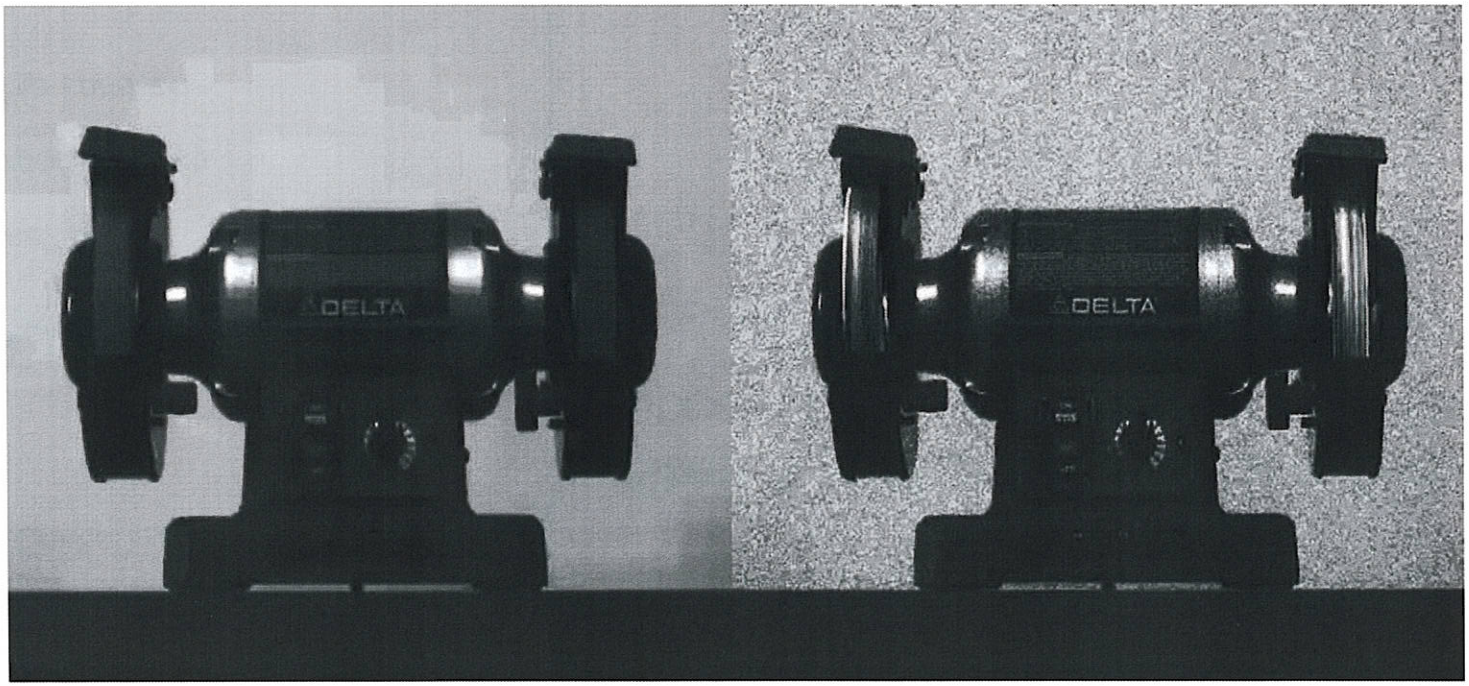
Exercise 11 - Advanced Video Export

Split screen shows unamplified and amplified videos playing simultaneously.



RDI TECHNOLOGIES

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Exercise 11 - Advanced Video Export

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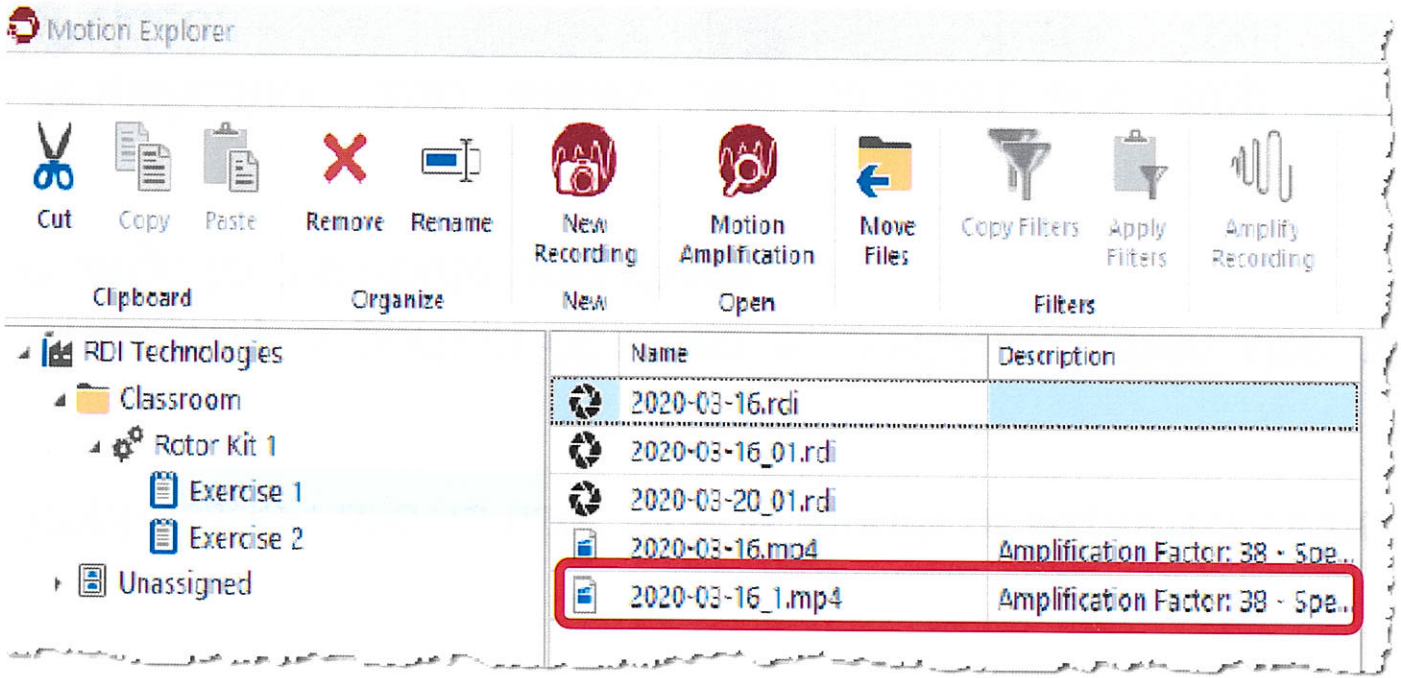
Step 7 – Exit mp4 player and exit Motion Amplification.



RDI TECHNOLOGIES

The new mp4 file is now listed in Exercise 1 collection.

Exercise 12 – Modify Video Playback

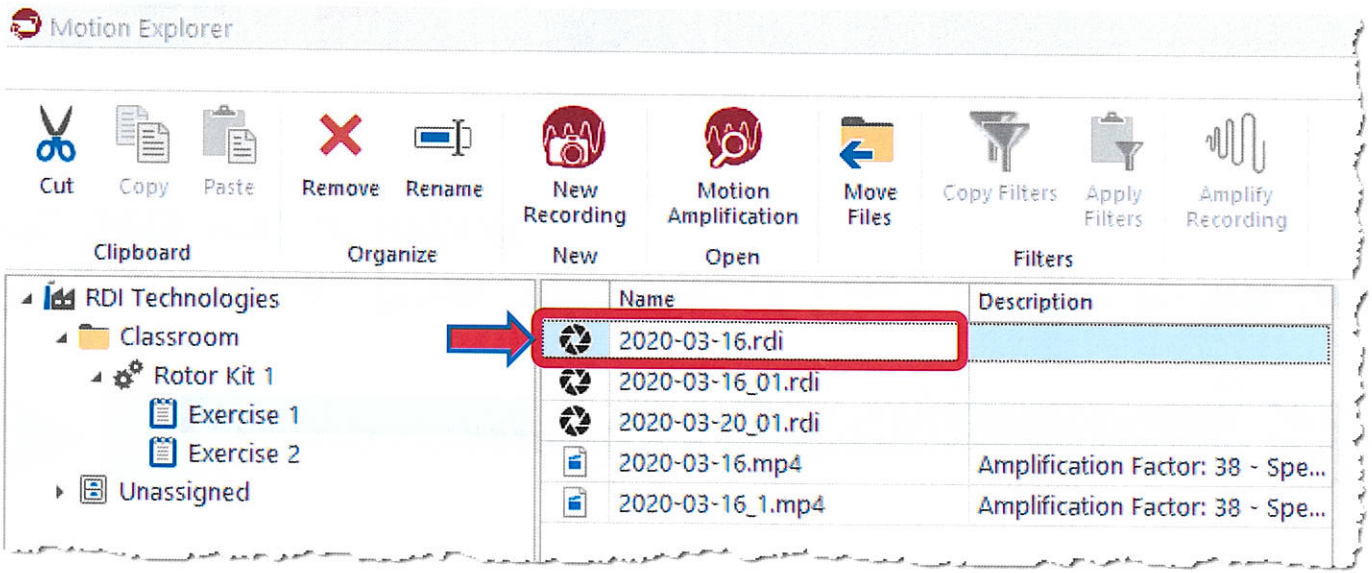
Motion Amplification allows user to edit length of exported videos.

Helpful when only a portion of video is useful, or when size of exported file is too large to distribute and share.

Motion Amplification also allows user to start and stop the amplified portion of video.

Exercise 12 – Modify Video Playback

Step 1 – In Motion Explorer, highlight .rdi file and launch Motion Amplification.



RDI TECHNOLOGIES

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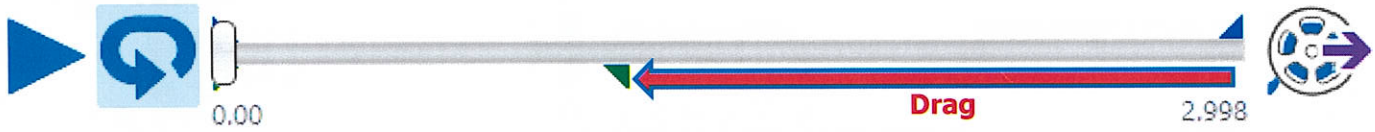
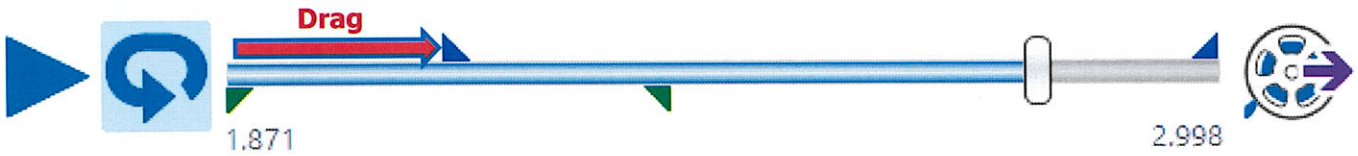
Exercise 12 – Modify Video Playback



Step 2 – Drag green flag from right side of Playback Bar to left to about the one second mark. Sets end of export.



Step 3 – Drag blue flag from left side of Playback Bar to right to halfway between green flags. Resets area of amplification.

RDI TECHNOLOGIES

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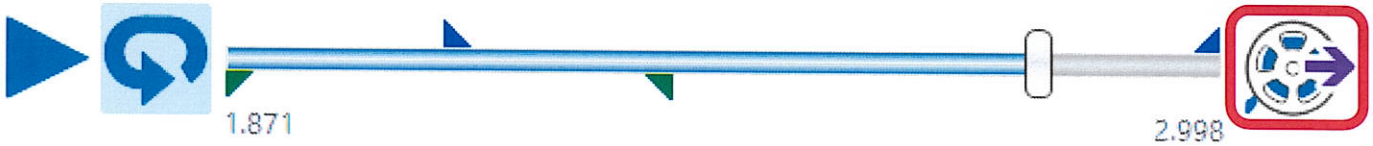
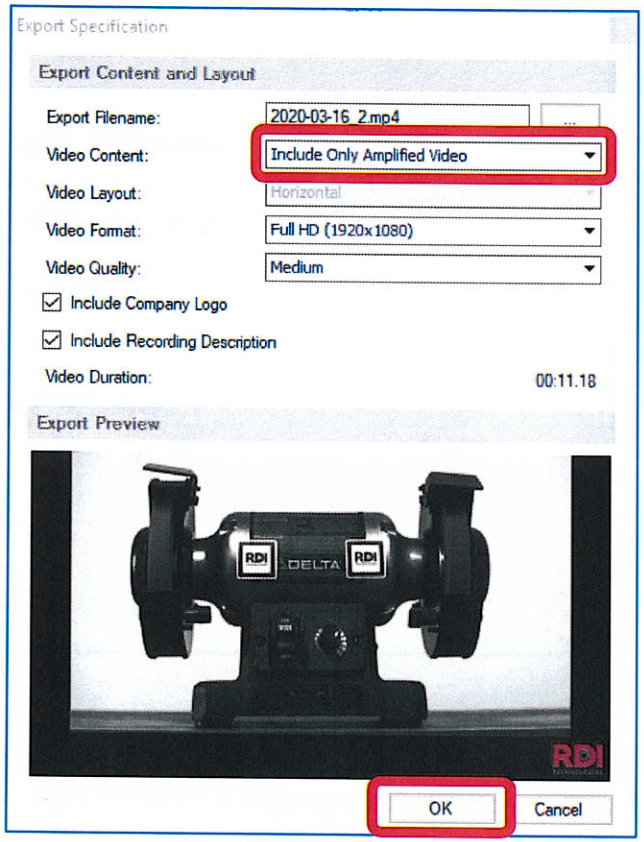


Step 4 – Click Export button.



Step 5 – Select **Include Only Amplified Video** in Video Content box, click **OK**

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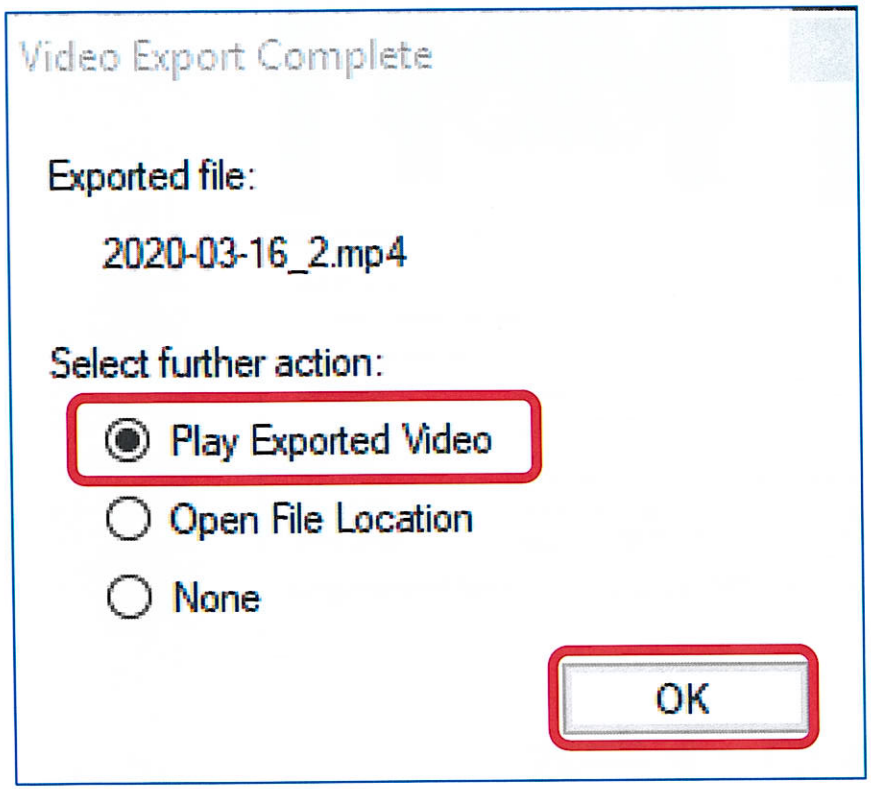
Exercise 12 – Modify Video Playback



Step 6 – Select **Play Exported Video**, click **OK**.

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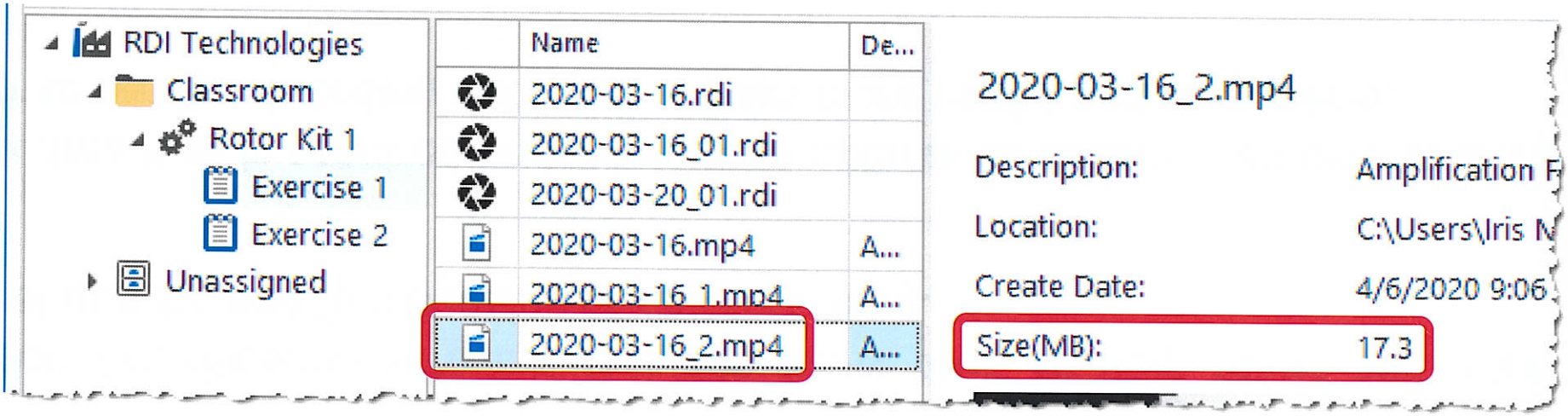
Exercise 12 – Modify Video Playback

Step 7 – Play exported video. When finished, close mp4 player and exit Motion Amplification



Note file size of exported Mp4 is significantly smaller than first two Mp4 files.

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Recording Editing Tools

Motion Amplification software includes many tools to help refine and improve visual quality, and functionality of raw recording.

Raw data that is acquired under less than optimal conditions, can be manipulated later to render recording data that is even more useful and compelling.

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Transient/Standard Amplification

Default method for amplification is known as Transient Amplification.

<u>Advantages to Transient Amplification:</u>

- Processing time much less than Standard. Live Amplification only possible with Transient Amplification.
- Makes transient motions in amplified recording appear much more natural.
- Allows measurement/analysis of both periodic and non-periodic motions.

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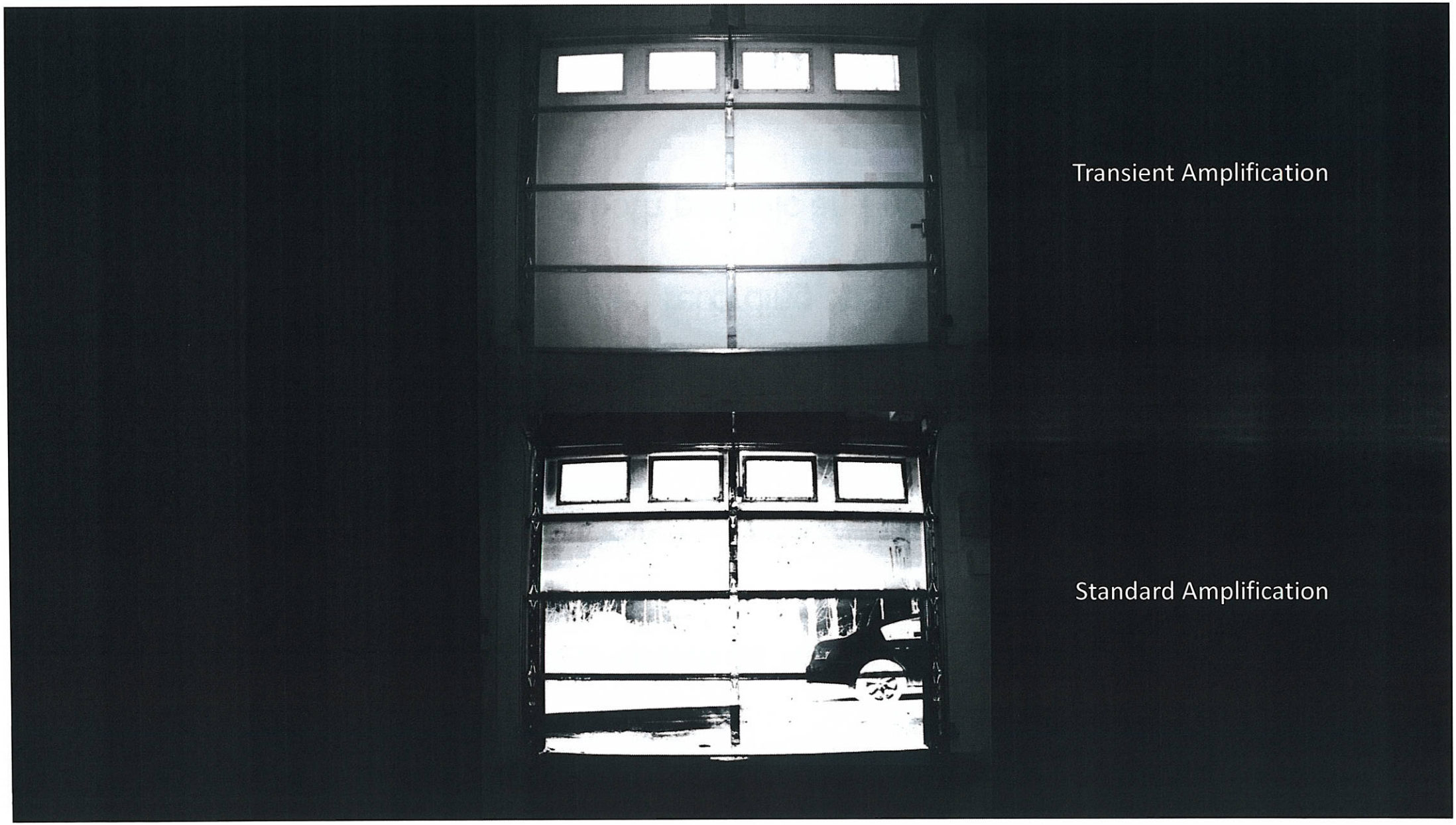
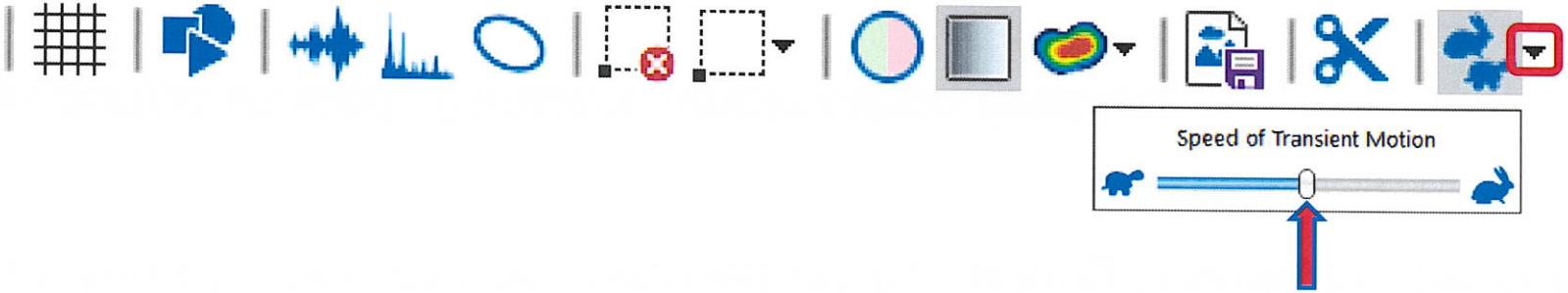

Transient Amplification
Standard Amplification

Speed Adjustment for Transient Motion

If transient motion looks washed out or grainy when amplified, speed of transient motion can be adjusted.

Click down arrow just to right of Transient Amplification Mode button in Toolbar.



Adjust slider position to left or right until desired effect is seen in playback.

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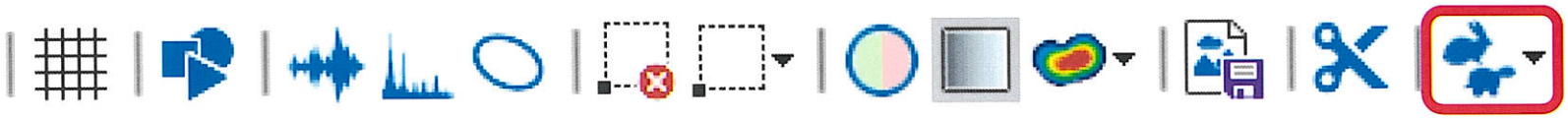

Transient Amplification can be switched off by clicking Disable/Enable button.

- When button shaded, Transient Amplification Enabled.
- When button clear, Transient Amplification Disabled.

In most cases Transient Amplification recommended.

Motion Map

Motion Map - analysis tool, makes locating areas of significant motion easier/faster. Especially useful when many components are captured in single recording.

To enable, click Motion Map button.

Settings include:

- Display Frequency Specific Motion Contours
- Autoscale
- Color scale
- Transparency scale
- Single Color/Multi color

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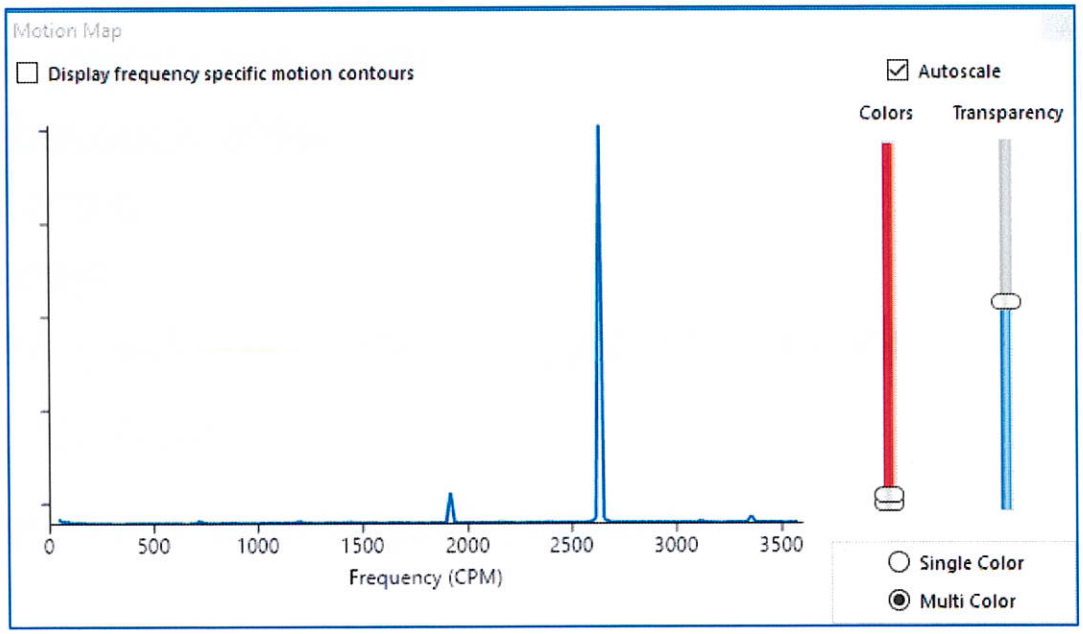

Spectrum appears with various settings.

Peaks in spectrum generated based on combination of two factors:

- Total number of pixels in image that are moving at any given frequency
- Amount of amplitude at any given frequency

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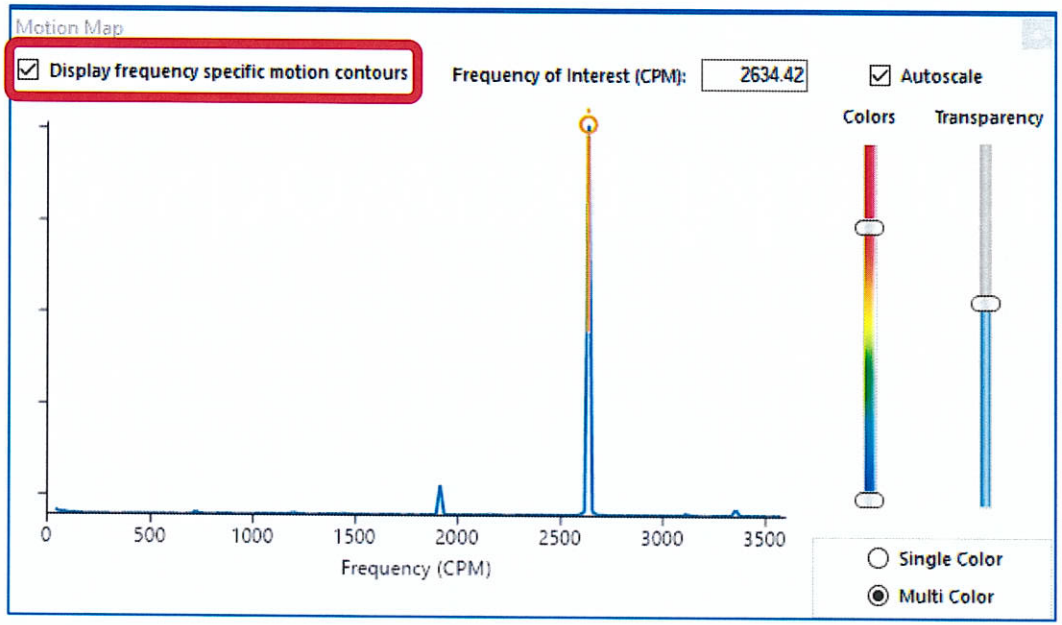
3 things happen when **Display frequency specific motion contours** box is checked.

1) Marker is automatically located at largest peak in spectrum.

2) Frequency of Interest field appears listing exact frequency.

3) Colored overlay is applied to image.



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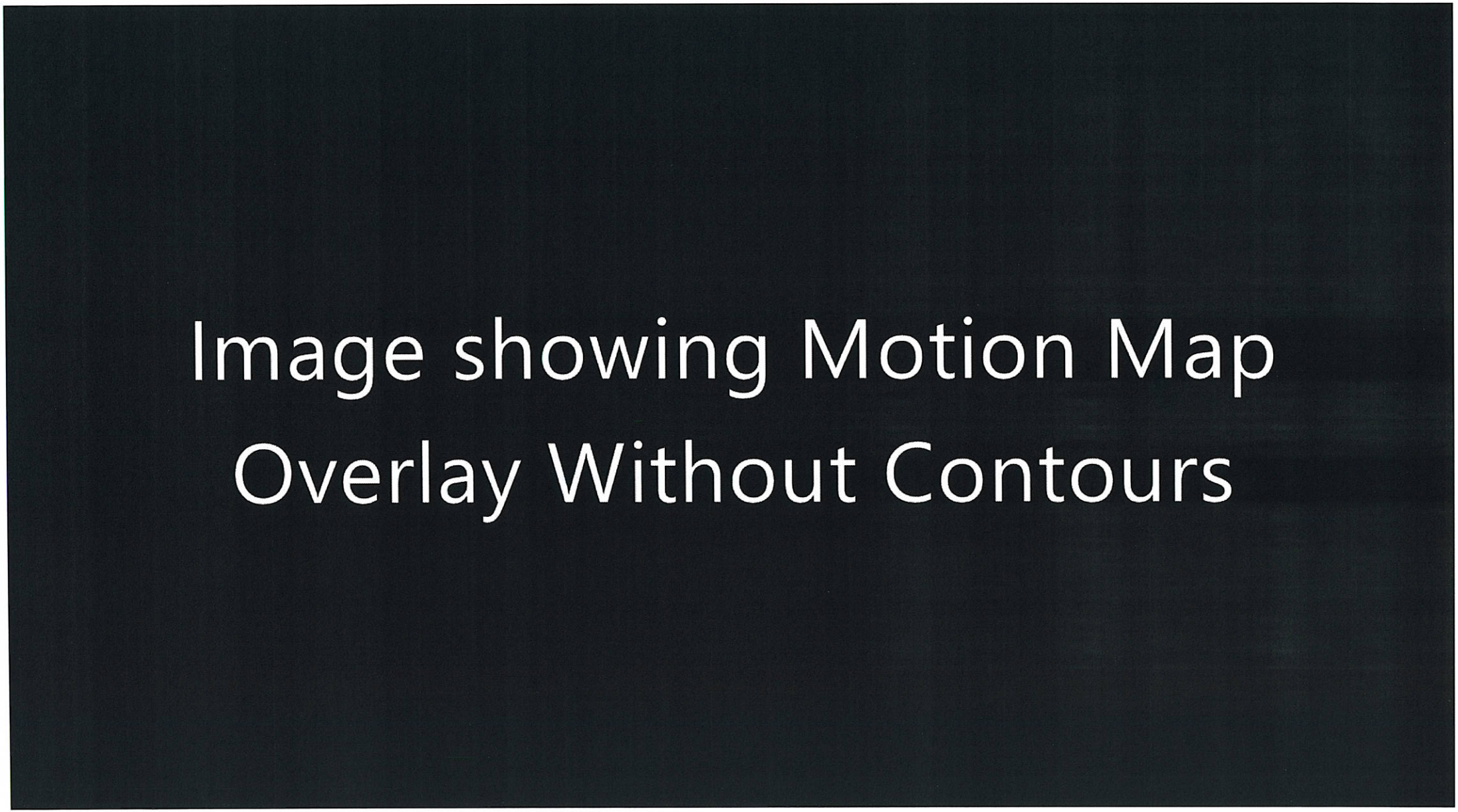
Image showing Motion Map
Overlay Without Contours