

# CALiPER Exploratory Study: Flicker in SSL Integral Replacement Lamps

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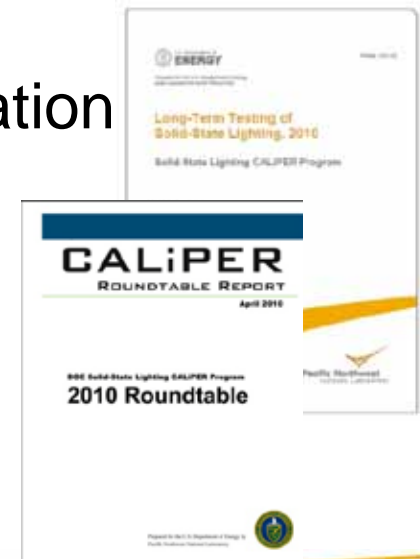
# CALiPER Exploratory Testing

## ▶ Primary focus of CALiPER

- Commercially available SSL luminaires and integral lamps
- Anonymously purchased samples
- LM-79 testing using qualified independent labs
- Posting and analyzing test results

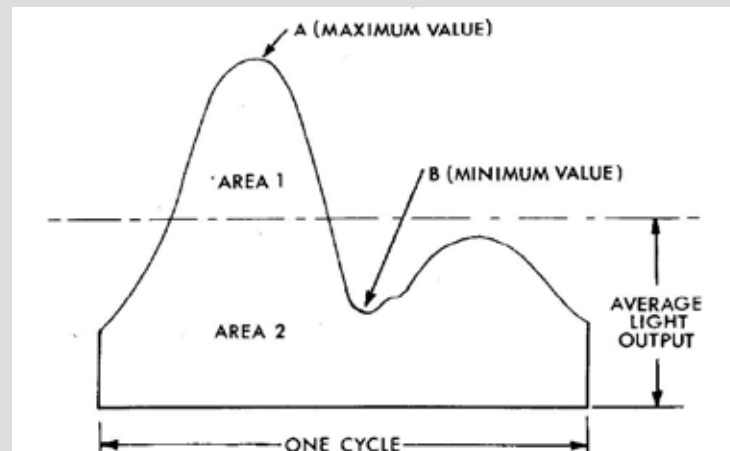
## ▶ Additional CALiPER testing, studies, coordination

- Testing and Standards Roundtable Meeting
- Long-term testing of luminaires and integral lamps
- Dimming
- Reliability
- Flicker
- Glare



# Background: Reminders

- ▶ Commercial electric light sources running on AC power modulate light output
- ▶ Many names for light modulation
  - Flicker (most common)
  - Flutter, shimmer
- ▶ Measurement of light modulation, or photometric flicker, is not a standard practice for commercially available light sources
- ▶ IES has defined two metrics for flicker
  - Percent flicker
    - 0-100% scale
    - Simple computation
  - Flicker index
    - 0-1.0 scale
    - More complex computation



$$\text{Percent Flicker} = 100\% \times (A - B) / (A + B)$$

$$\text{Flicker Index} = \text{Area 1} / (\text{Area 1} + \text{Area 2})$$

Periodic waveform reference  
for traditional flicker metrics

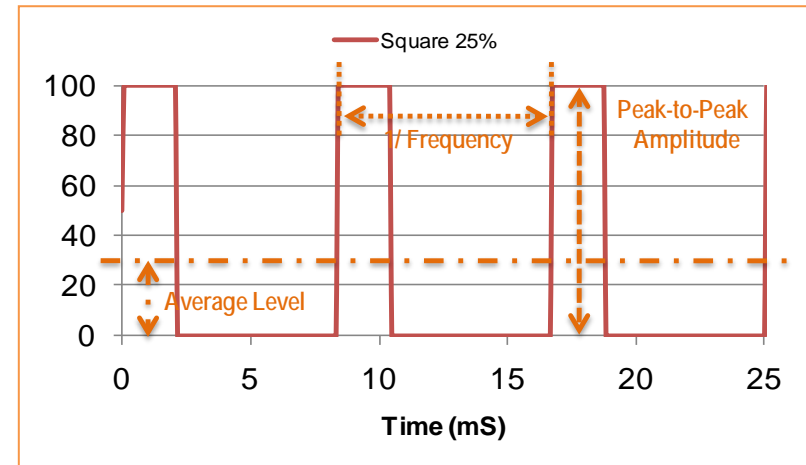
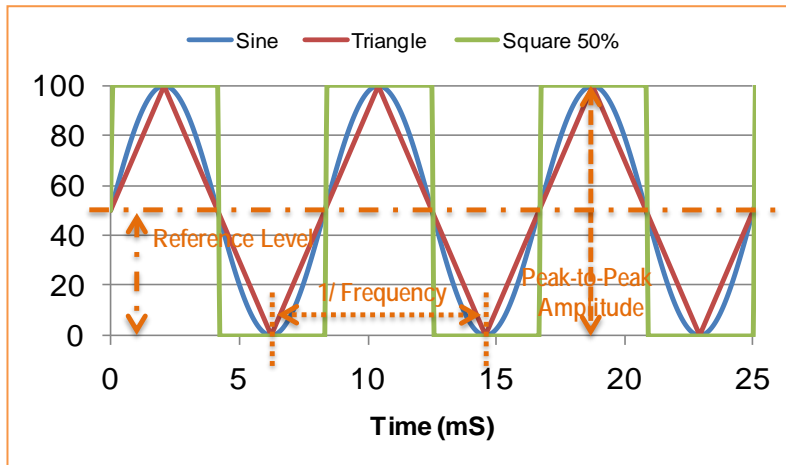
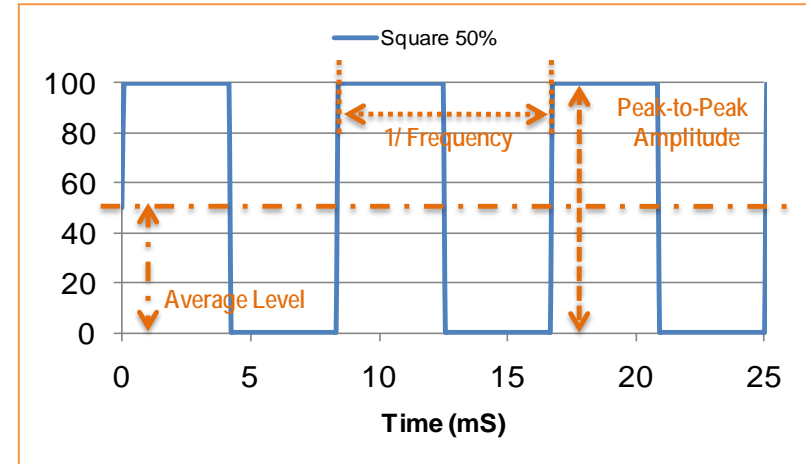
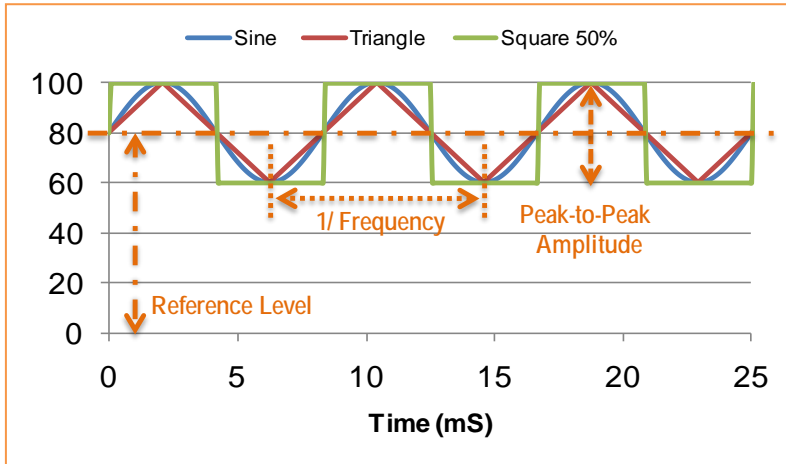
Source: IESNA Lighting Handbook, 9<sup>th</sup> Edition



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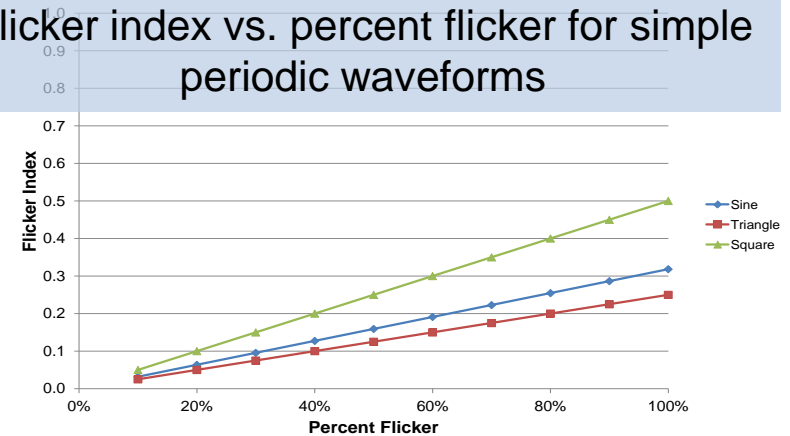
# Waveform characteristics: shape, offset, peak-to-peak, frequency, duty cycle



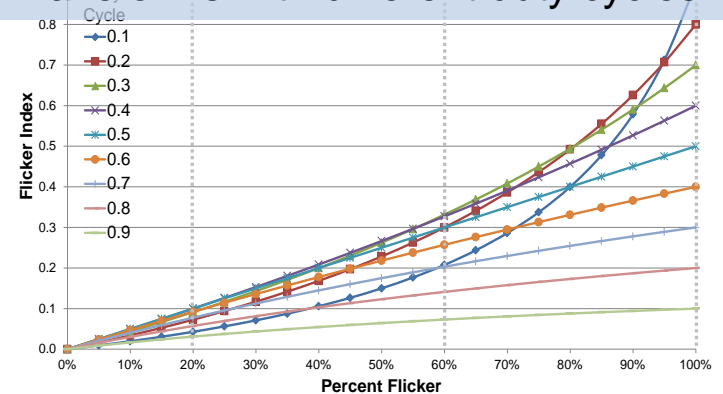
# Background: Flicker Metric Characteristics

	Percent Flicker	Flicker Index
Average	Yes	Yes
Peak-to-peak amplitude	Yes	Yes
Shape/Duty Cycle	No	Yes
Frequency	No	No
Complexity of calculation	Simple	Moderate

Flicker index vs. percent flicker for simple periodic waveforms



Flicker index vs. percent flicker for square waveforms with different duty cycles



# Photometric Waveform Measurement Nuances

## ▶ Basic Configuration

- Environment (e.g., black box)
- Photosensor
- Transimpedance amplifier
- Digital Oscilloscope
- Software

## ▶ Nuances & Choices

- Frequency response
- Integration time
- Number of waveform periods
- Sampling rate
- Filtering
- Analytic methods (i.e. to implement integration, etc)



# Basic Initial Question

- ▶ Do solid-state lighting sources modulate light output any differently than other commercial electric lighting technologies?
- ▶ Focused comparison
  - Traditional lighting sources, selected to represent breadth of technologies, and include examples known/expected to have most light modulation/flicker
  - Solid-state lighting sources, selected to include a variety of form factors, and demonstrate breadth of modulation approaches

*Incandescent, Halogen, Metal Halide*



*Magnetically-ballasted fluorescent*



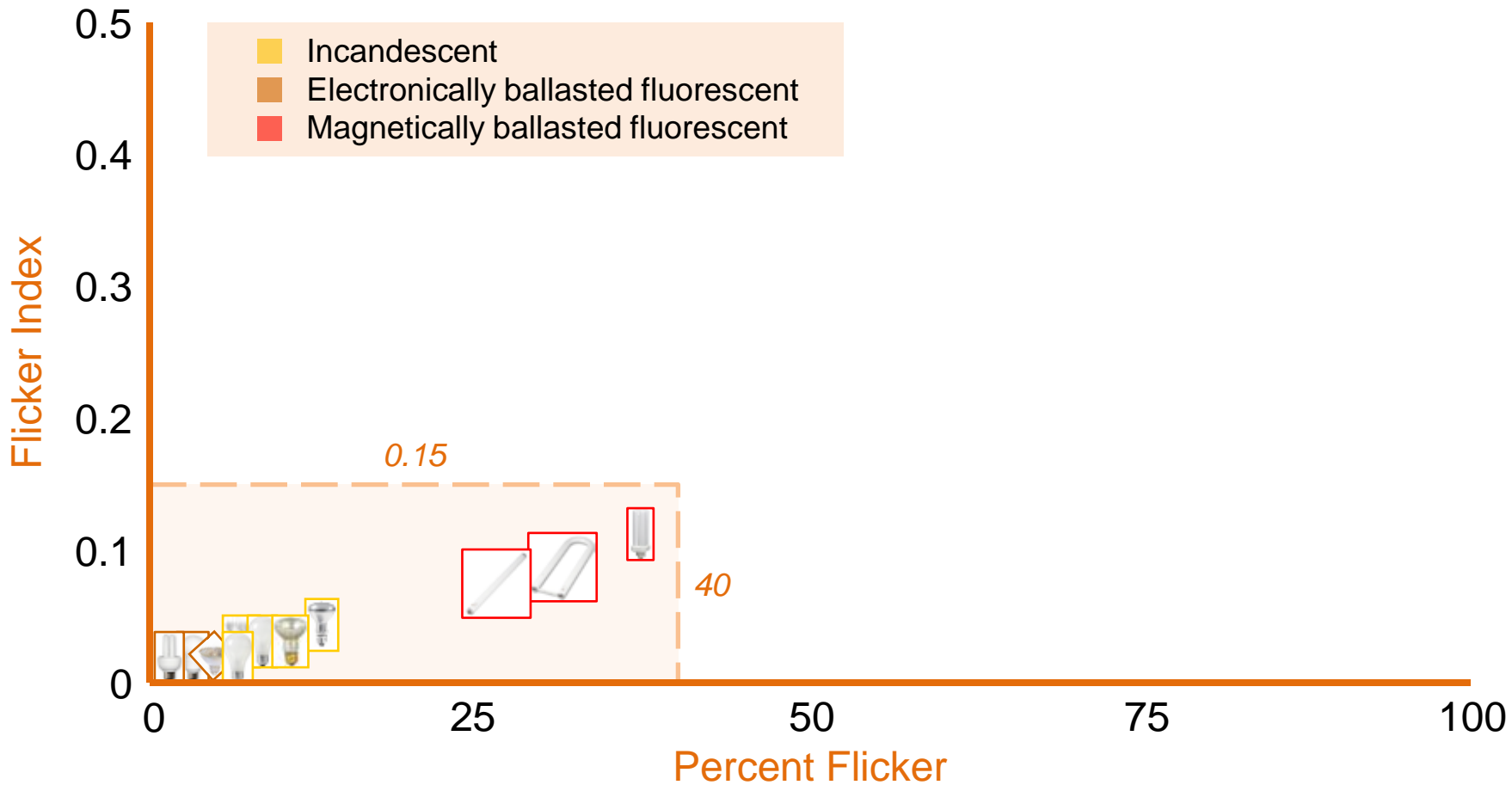
*Electronically-ballasted fluorescent*



*Solid-State*

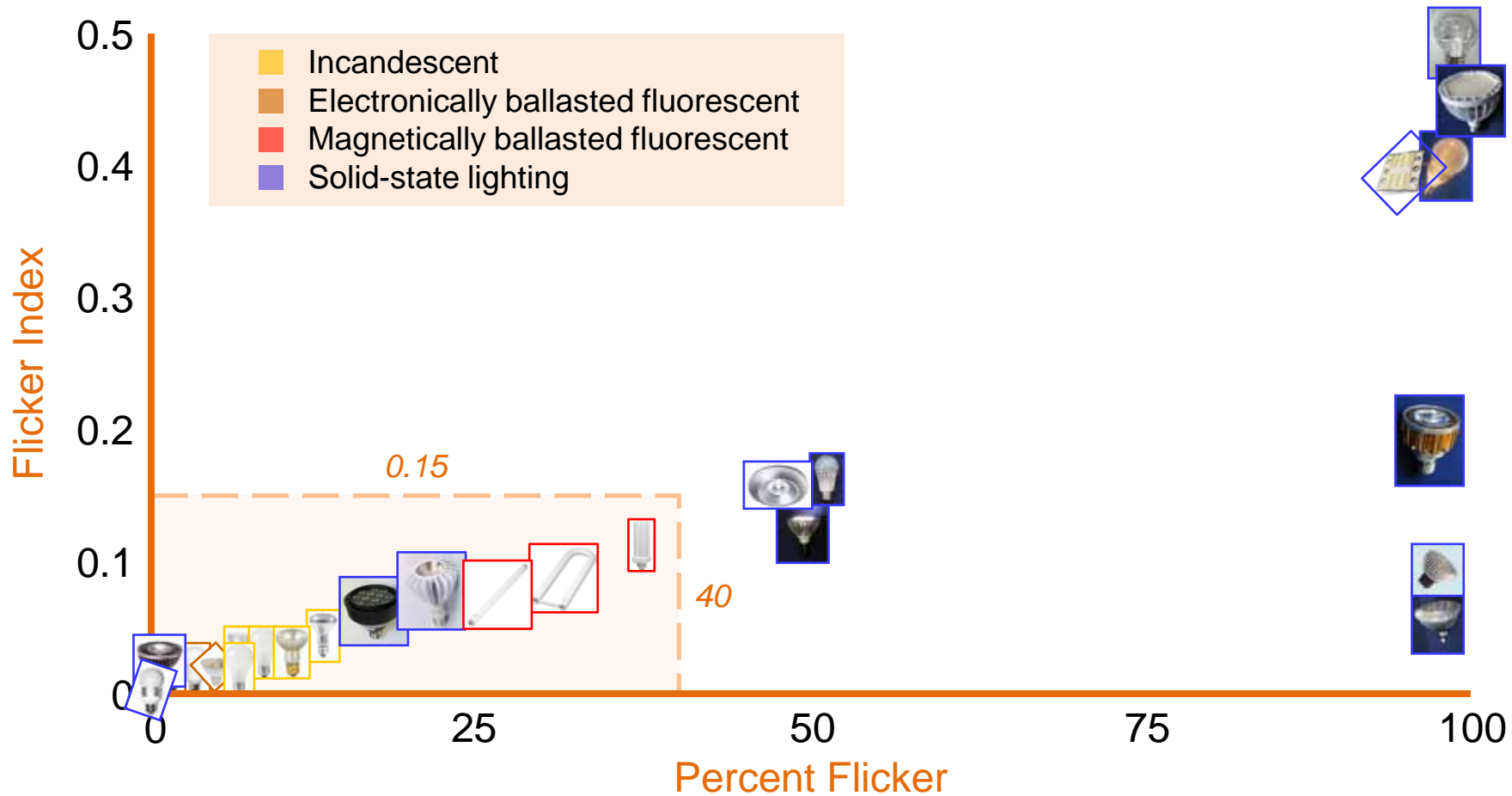


# Flicker Results: Frame of reference



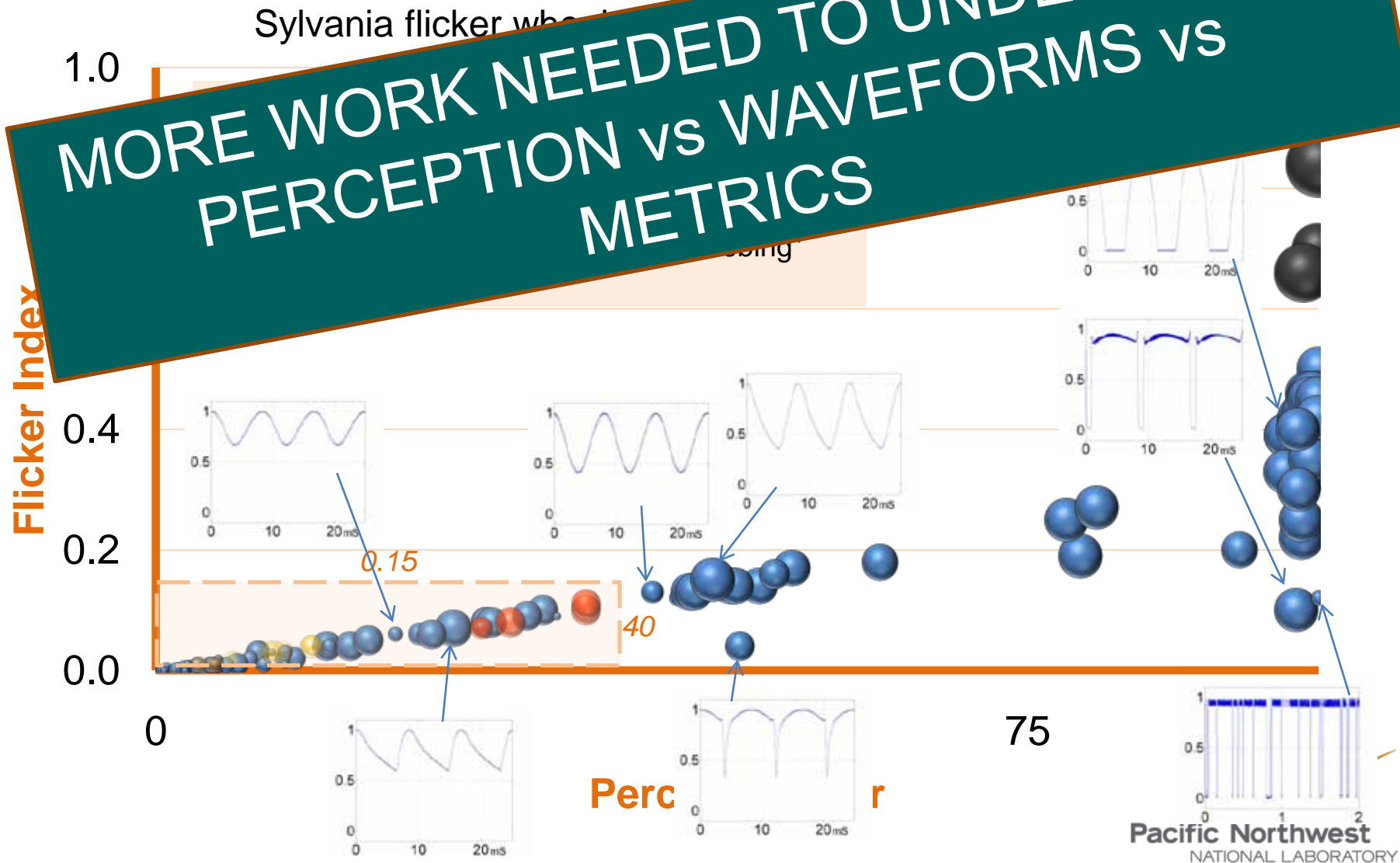


# Solid-state lighting on the frame of reference



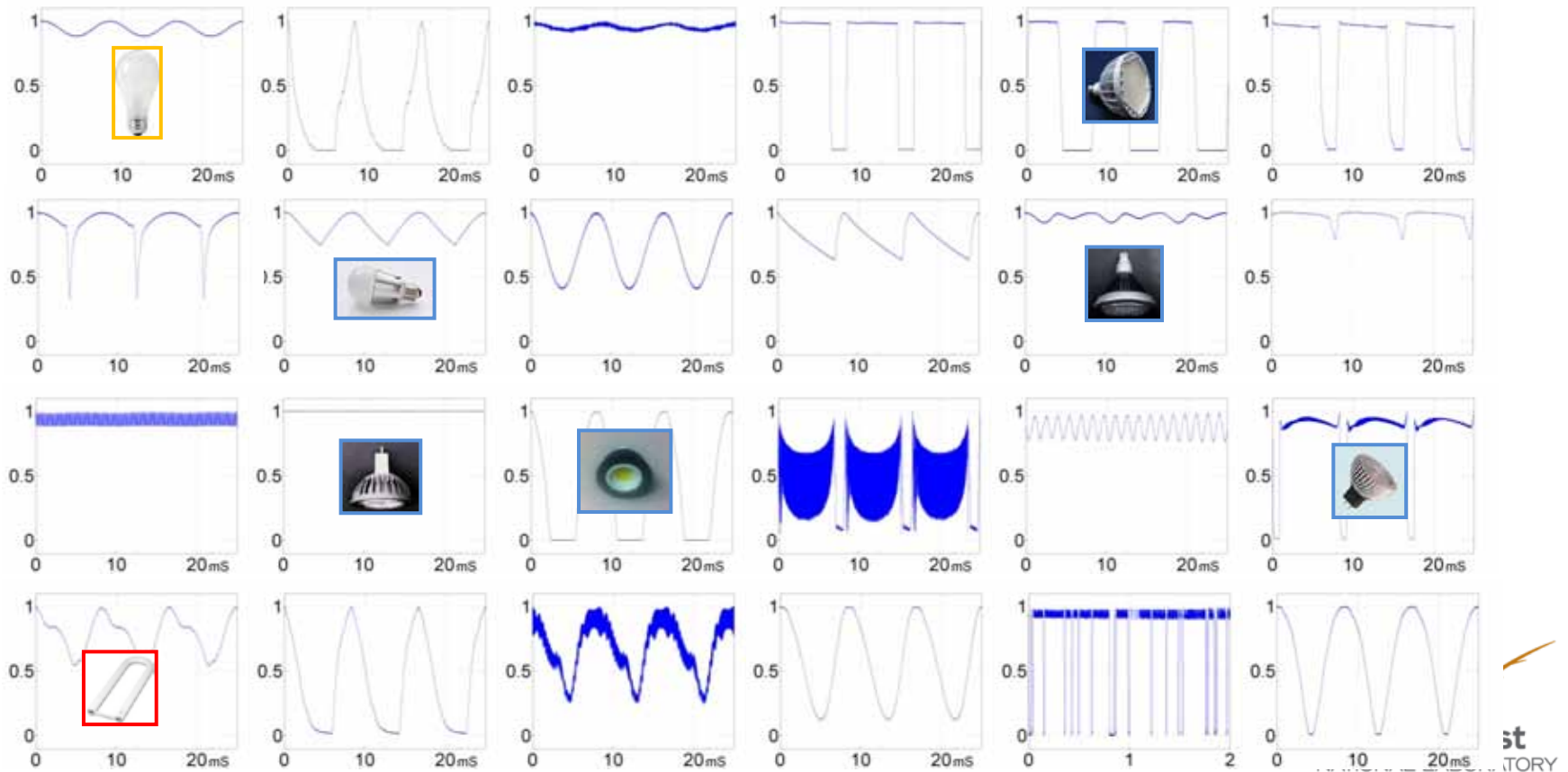
# Qualitative Assessment: Perceived Flicker

**MORE WORK NEEDED TO UNDERSTAND PERCEPTION vs WAVEFORMS vs METRICS**



# Compendium of Photometric Waveforms

- ▶ Report assembles photometric waveforms and metrics for
  - Over 30 benchmark samples (incandescent, halogen, metal halide, fluorescent)
  - Over 100 SSL samples (primarily integral replacement lamps)



# More Questions

- ▶ Do the currently defined flicker metrics accurately represent solid-state light sources?
  - Yes and no
  - Percent flicker accounts for average, amplitude; does not account for duty cycle/shape, frequency
  - Flicker index accounts for average, amplitude, duty cycle/shape; does not account for frequency
- ▶ Does the type and amount of flicker in solid-state light sources correlate to and/or trade-off with other performance metrics?
  - Yes and no
  - Specific designs impose some constraints
- ▶ How does line-voltage (phase) dimming affect light modulation?
  - Get ready to see even more variation
- ▶ Do we need to define a new flicker metric that more accurately represents all lighting technologies/sources?
  - Maybe
- ▶ What further studies of physiological impacts of flicker are needed?
  - Perception of flicker varies across people, conditions, and nature of the photometric waveform.
  - How do various flicker metrics relate to perceived flicker?

# Needs

- ▶ Standard flicker measurement method
  - Commercially available independent third-party resources
  - IES working group S408-10 “Photometric Waveform/Flicker Measurement Methodology”
- ▶ Standard flicker metric
  - Simple quantitative indicator of flicker performance
  - IEEE PAR1789 subcommittee “Defining Measures for Flicker”
- ▶ Risk assessment
  - Probability of known hazards arising from exposure to a variety of flicker types/levels in specific lighting applications
  - Development of risk matrix
  - IEEE PAR1789 subcommittee “Risk Assessment for Flicker”
- ▶ Recommended practices
  - Correlation of standard flicker metric to risk matrix thresholds
  - IEEE PAR1789 TBD



# THANK YOU

- [-] Complete flicker report should be available for distribution shortly
- [-] Michael Poplawski, PNNL
- [-] Mia Paget, PNNL
- [-] Benton Russell, PNNL