Characterizations of a KHz Pulsed Laser Detection system

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Content

- Motivation
- System Description
- Characterization Set Up
- Characterization Procedure
- Results and Discussion

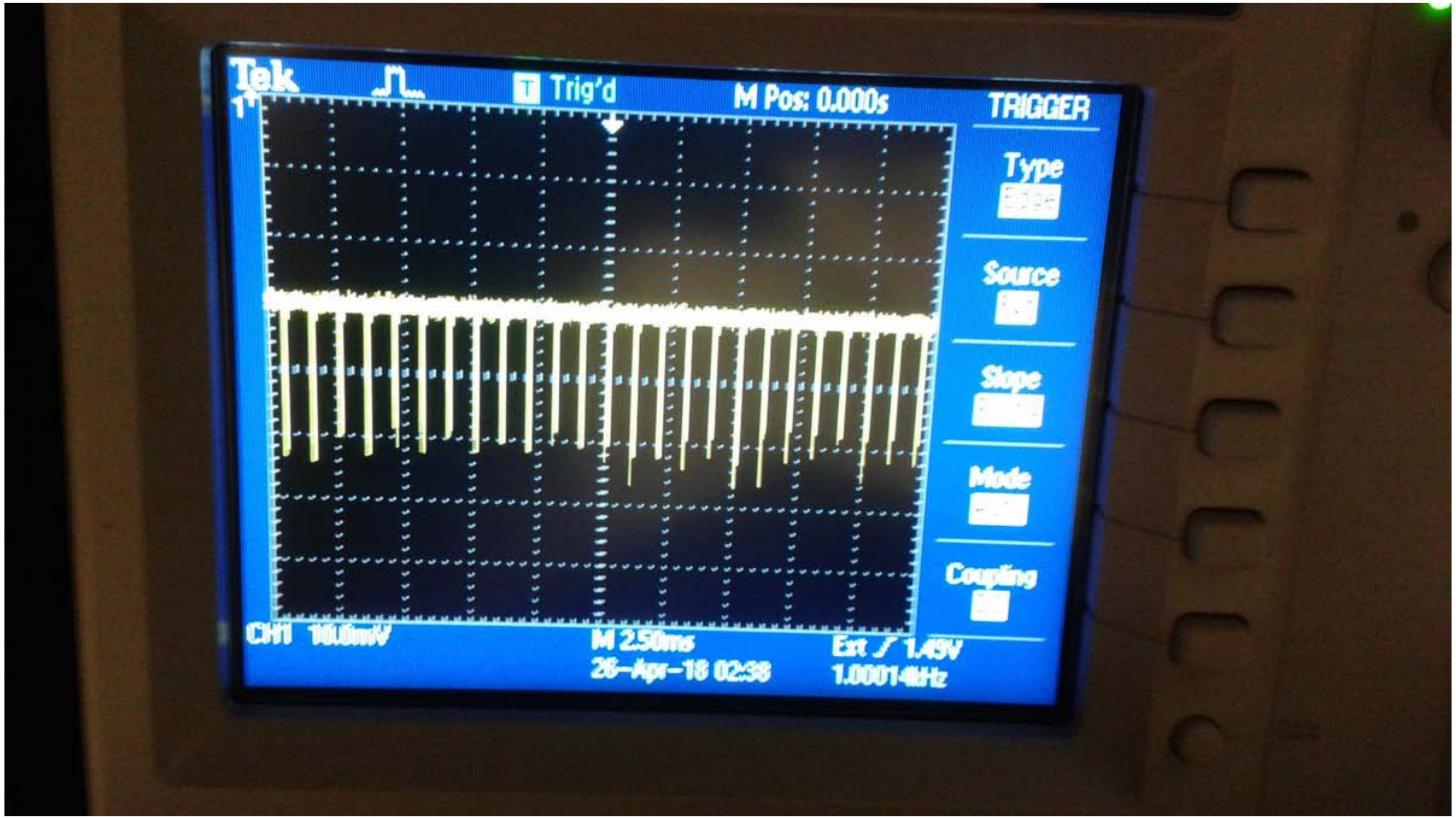
Motivation

- Traditional double-monochromator based irradiance and radiance responsivity calibration comes with two major shortcomings: low radiant power and wide bandpass, and the calibration uncertainty can hardly reach sub-percentage;
- SIRCUS laser and detector based calibration uncertainty can reach sub-quarter percentage, but the system is expensive and difficult to automate.

Motivation

- The kilohertz (KHz) pulsed optical parametric oscillator (OPO) based tunable lasers are commercially available, e.g. Ekspla NT242 series. They are much more affordable and fully automated over a wide spectral range (210 nm ~ 2600 nm);
- KHz repetition rate – 300 Km pulse-to-pulse distance
- 3 ~ 6 ns pulse duration – about 1.5 m pulse width
- Which yield an approximate 10^{-5} duty cycle and a 10^{+5} peak/average power ratio – hard to stretch and extend by integrating sphere and fiber optics, and theoretically may cause saturation problem to conventional current-to-voltage converter based detection systems
- More than 10% pulse-to-pulse fluctuation

Motivation



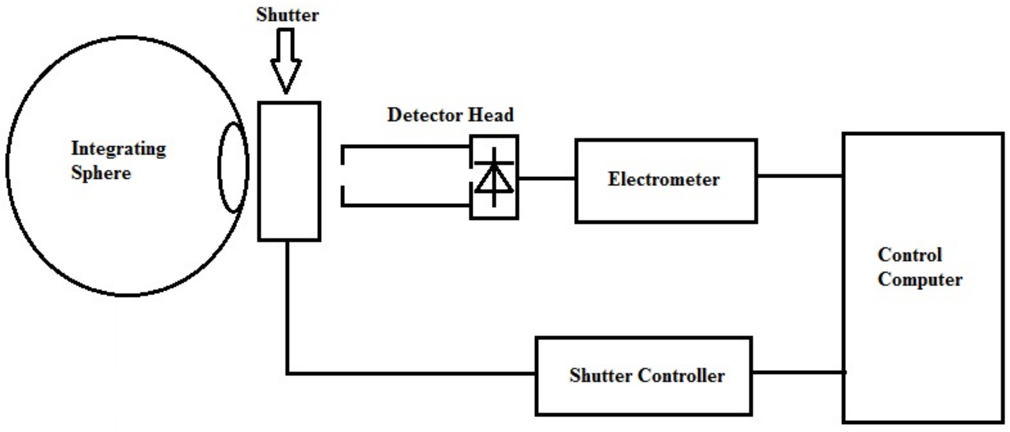
Tek
Trig'd
M Pos: 0.000s
TRIGGER
Type
Source
Slope
Mode
Coupling
CH1 10.0mV
M 2.50ms
26-Apr-18 02:38
Ext ∕ 1.45V
1.00014kHz

Motivation

- Our work here is to develop a KHz pulsed laser detection system, which can overcome the pulse-to-pulse fluctuation and the possible saturation problem;
- Further explore the possibility to put the Ekspla laser into the EOS remote sensing calibration work, like BRDF measurements, in-band and out-band characterizations, etc.

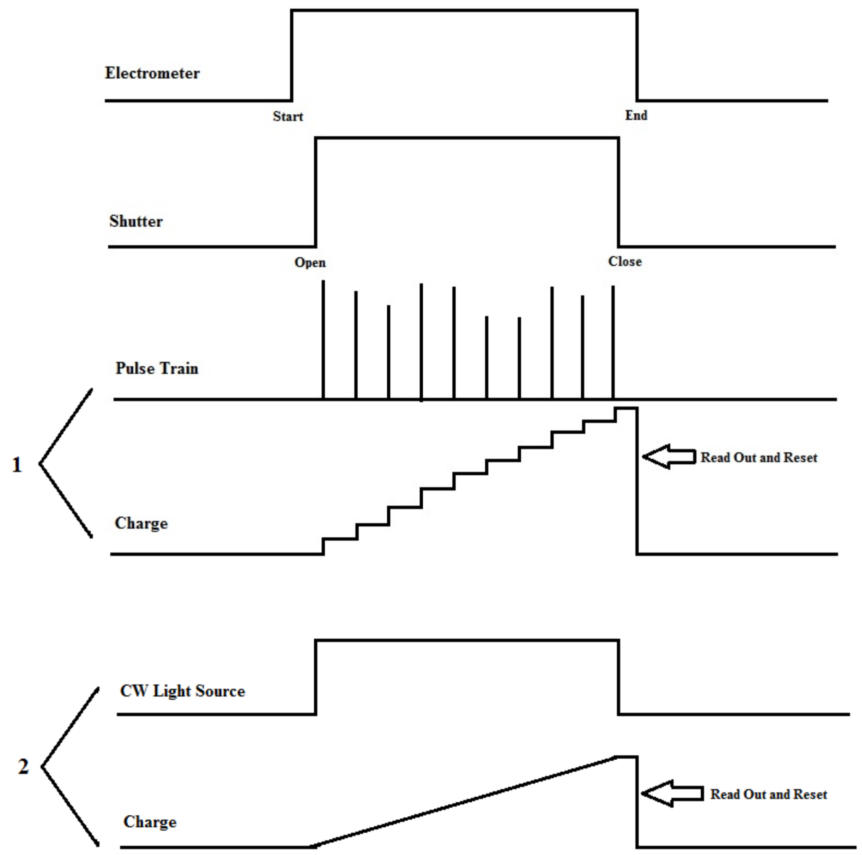
System Description

- This detection system employs the concept of charge integration
- Consists of an electrometer, a UV-enhanced Si detector and a computer controlled laser shutter system
- Keithley 6514, Hamamatsu S2281, Uniblitz CS45S3ZM1 shutter and VCM-D1 controller



System Description

- Electrometer starts slightly earlier than shutter opens, and ends slightly later than shutter closes – Synchronization
- Situation 1 is for pulsed laser light source
- Situation 2 is for CW light source
- This system works with either pulsed laser light source or CW light source

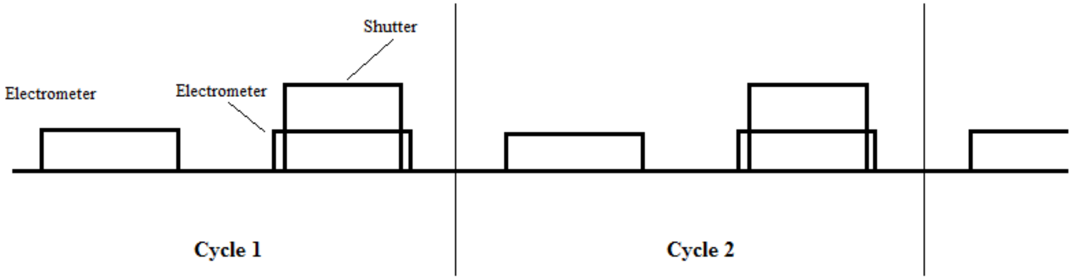


System Description

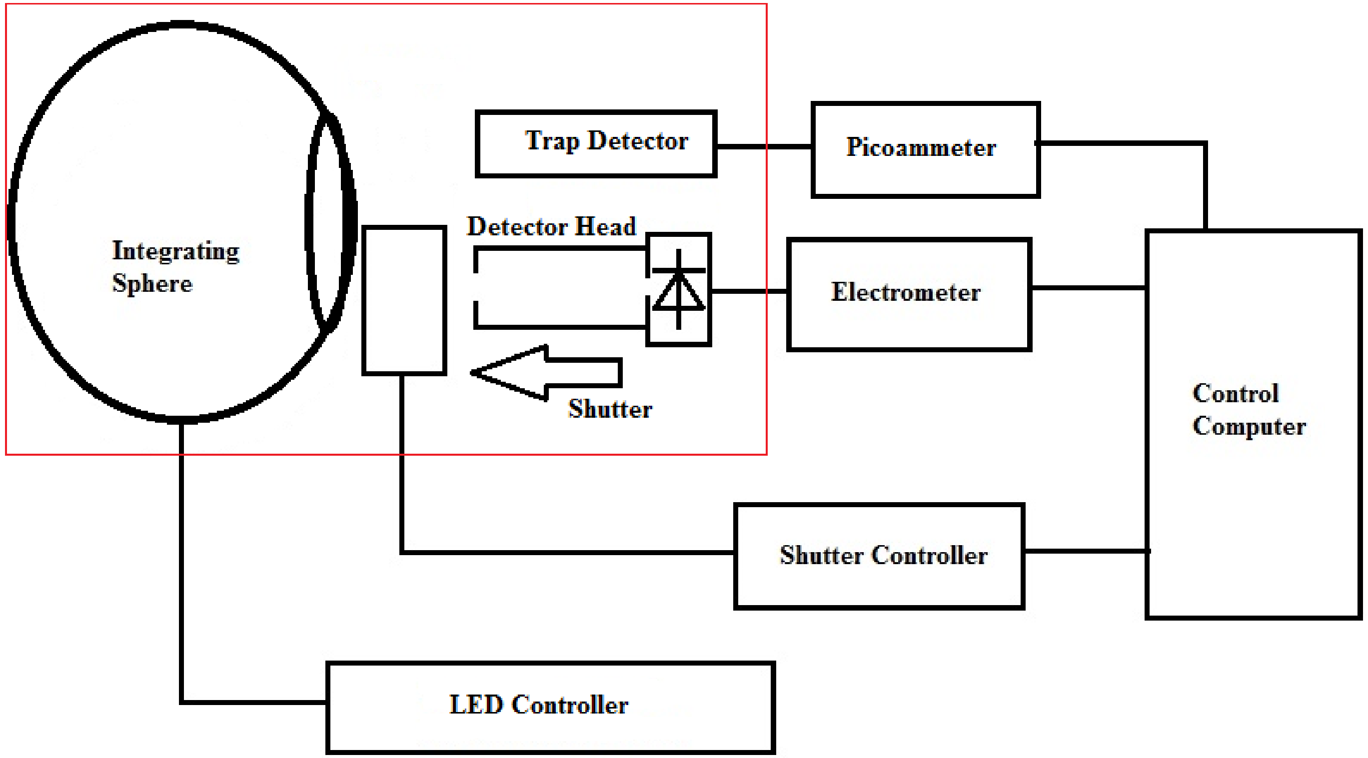
- We are to start characterization with a CW light source, which is a LED-based stable uniform light source;
- After we have gained some knowledge and confidence with the pulsed laser detection system, we then use it to characterize the Ekspla laser light source

System Description

- Two measurements in each cycle;
- First measurement was made with the laser shutter closed (DARK);
- Second measurement was made with laser shutter open;
- The incoming light energy was calculated by subtracting the first measurement from the second measurement;
- Also define “window time” as from shutter open to shutter close in unit of millisecond (ms)



System Description(CW)



System Description (CW)

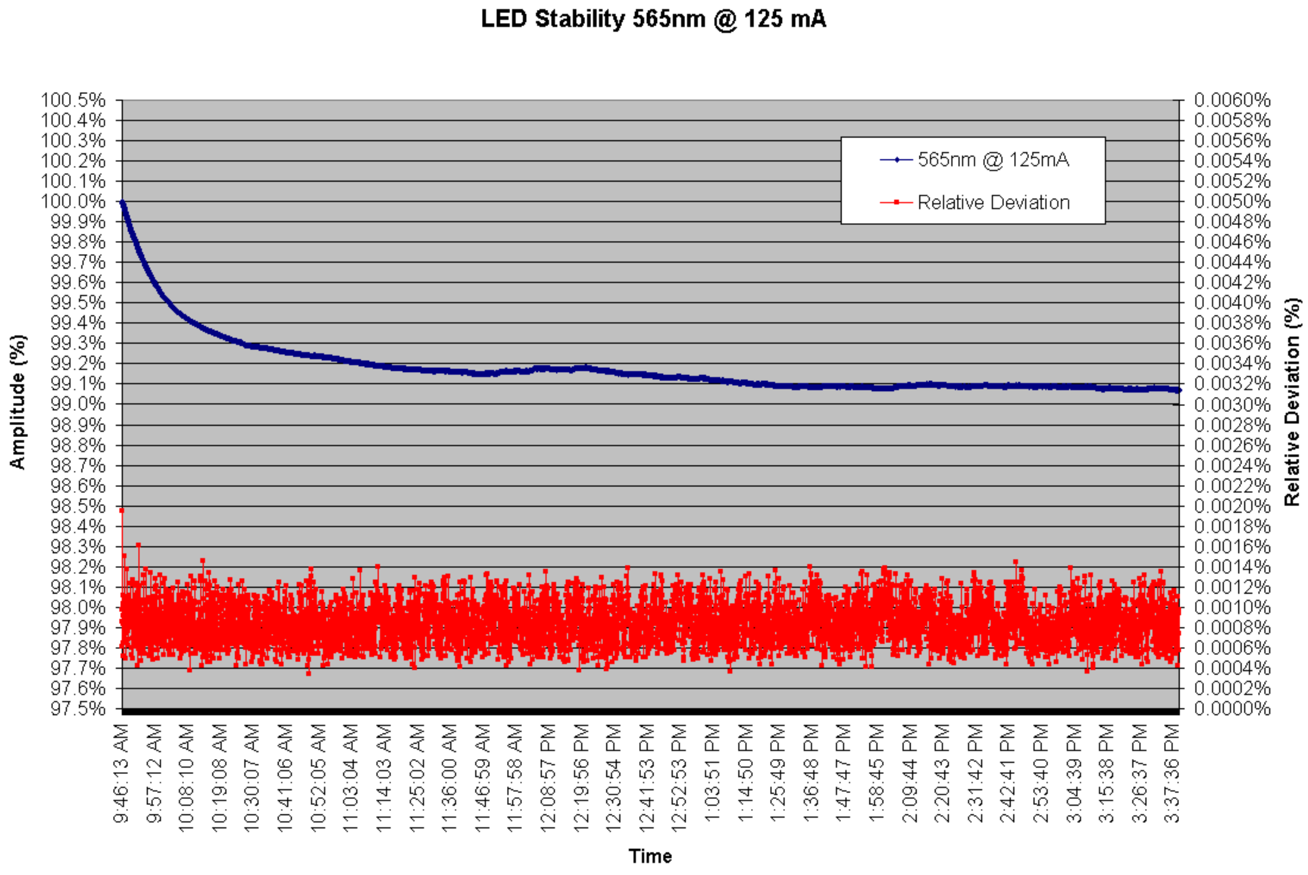
- A trap detector and a Keithley 6485A picoammeter was used as the reference instrument;
- This reference instrument was calibrated by NIST in the spectral range from 300 nm to 1100 nm;
- Gershun tube was used in front of the trap detector elements to ensure it works in radiance mode

System Description (CW)

- LED-based stable uniform light source;
- Integrating sphere 30.5 cm (12”) in diameter;
- Lined with Spectralon;
- 10 cm (4”) opening;
- 4 ports for mounting LEDs (405, 565, 735 and 850 nm)

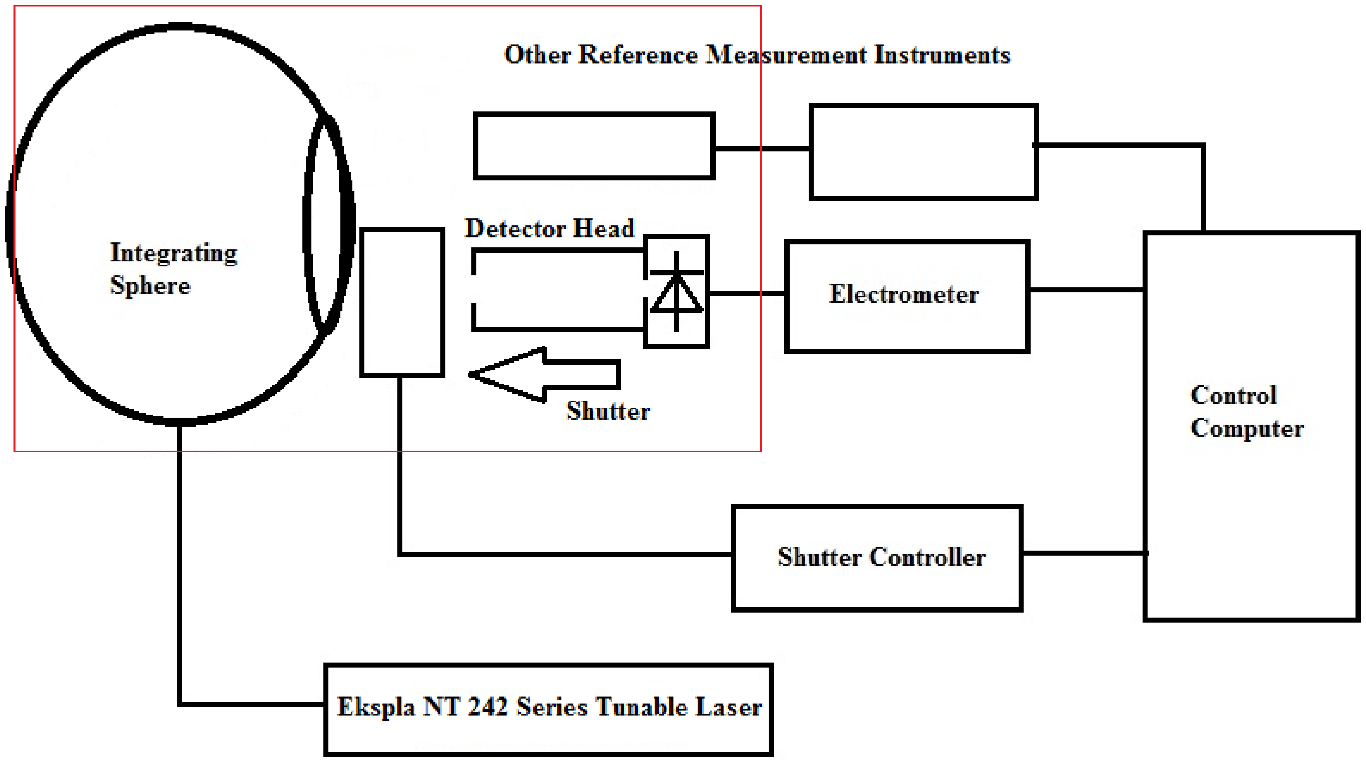
System Description (CW)

- Stability of LED output was measured by the trap detector
- The fluctuation level is less than 0.1% after half hour warm up
- Suitable for characterizing other instruments



System Description (CW)

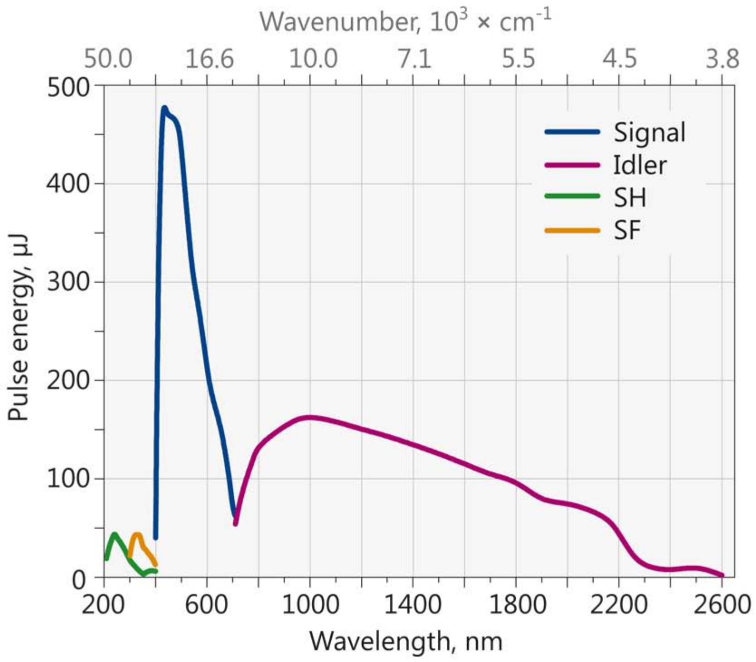
System Description (Ekspla)

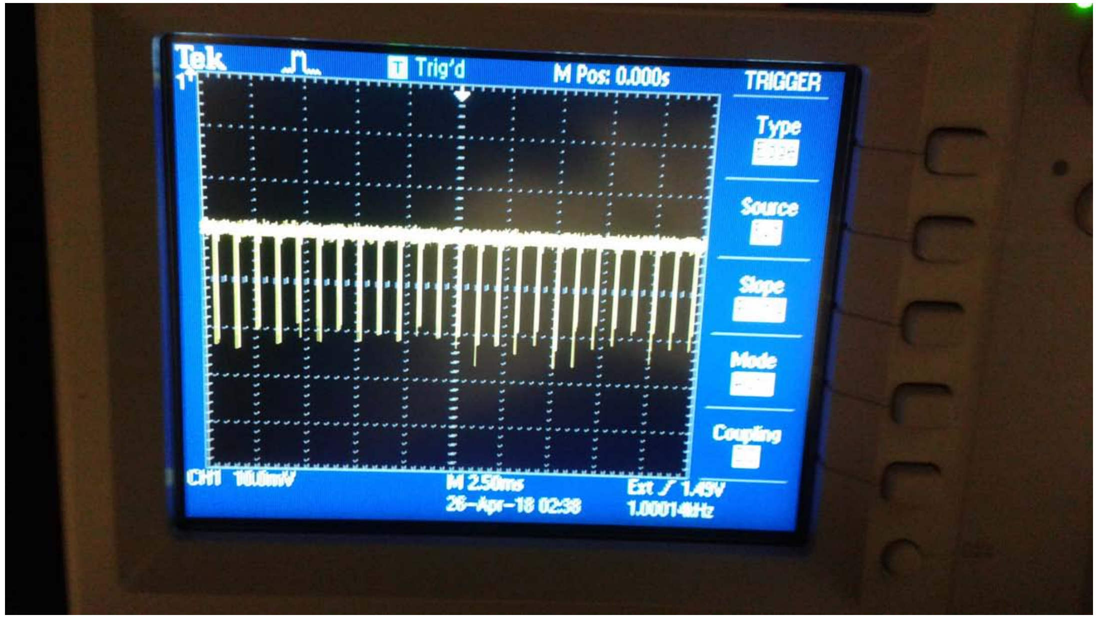


System Description (Ekspla)

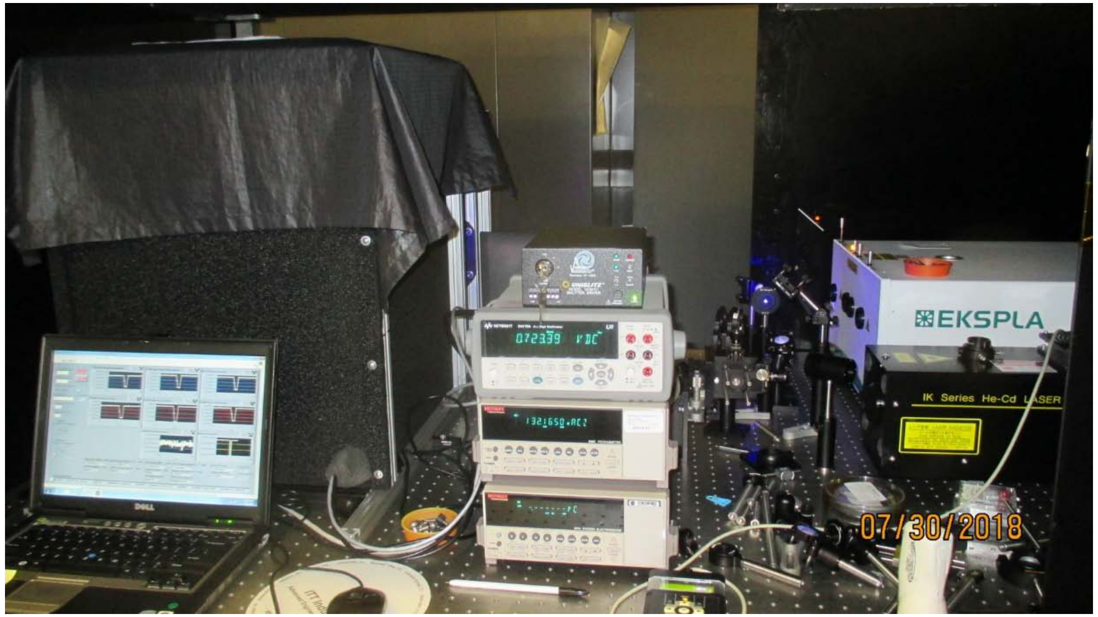
- Participating measurement instruments:
  - Trap detector with Keithley 6485A picoammeter
  - Oriel Merlin lock-in amplifier with a chopper controller, a Si detector head consisting of a UV-enhanced Si detector and a trans-impedance current-to-voltage converter. The final readout is from the lock-in amplifier
  - Filter Radiometer Monitoring System (FRMS), the primary filtered monitoring system at our calibration lab. Filter wheel contains 1 opaque blocking element and 11 specific bandpass filters. Its pre-amp is also a trans-impedance current-to-voltage converter. The voltage readout is from a digital voltage multi-meter (DVM)

System Description (Ekspla)

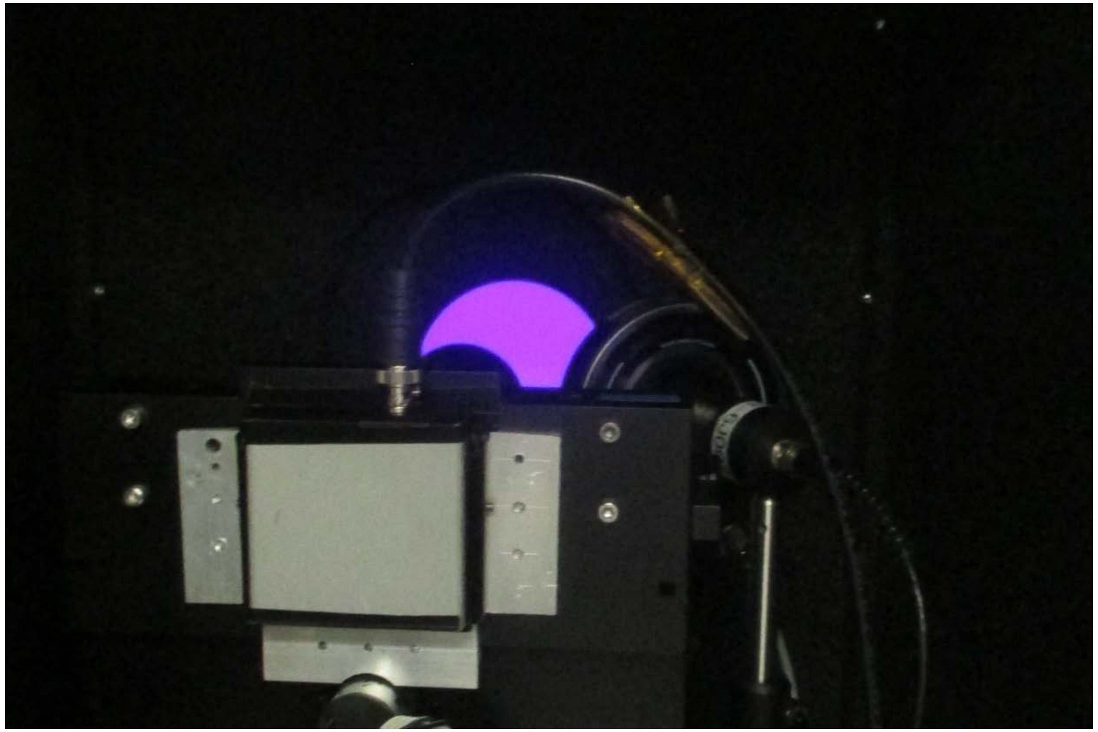


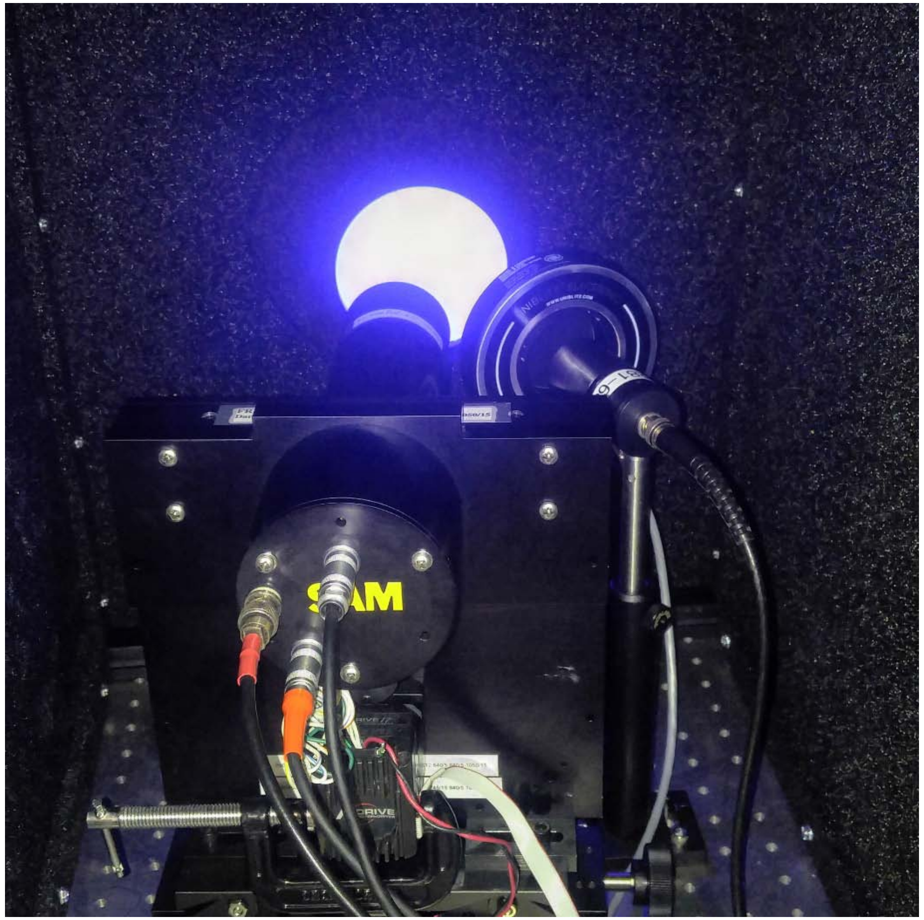


System Description (Ekspla)



System Description (Ekspla)





Characterization Procedure

- For both of light sources, the first step is to characterize the Window Time non-linearity and associated noise and uncertainty;
- To do so, we set the light source a constant power level, then gradually increased the Window Time from 100 ms to up to 60,000 ms (1 minute)*. We measured the charge outputs correspondingly, to check if the charge outputs are proportional to Window Time

* We used 10,000 ms (10 seconds) as maximum in CW light source measurements

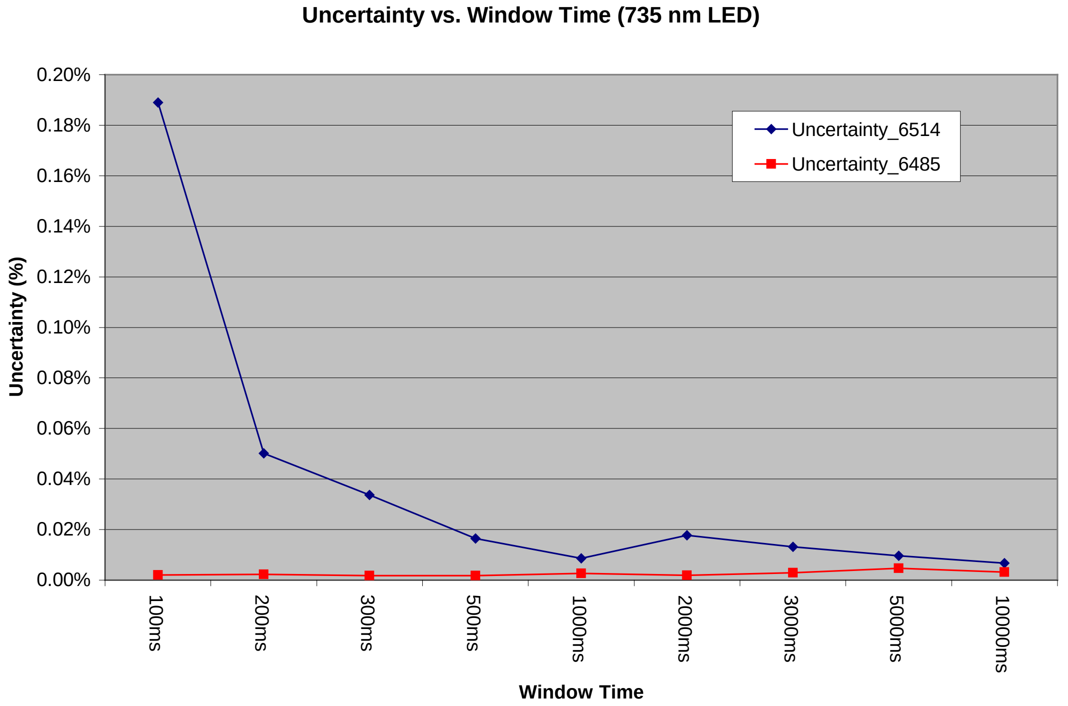
Characterization Procedure

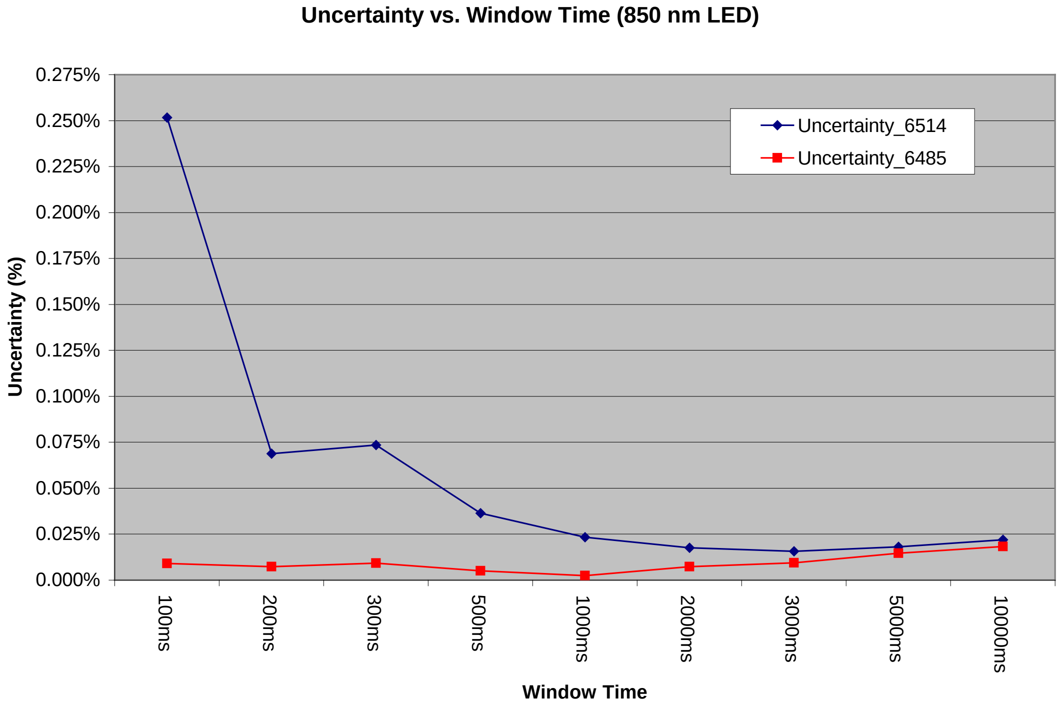
- Second step is to characterize the system responsivity linearity
- We set the Window Time a constant, e.g. 1000 ms; with the LED light source, by changing the LED driving current, so that changed the input light level, we recorded both the outputs from the pulsed laser detection system and trap detector, to check if the changing ratios are matched to each other;
- After we checked the responsivity linearity of the pulsed laser detection system, we use it as the reference to check other measurement instruments' responsivity linearity with the Ekspla laser light source, to find out if there is any saturation associated with the traditional measurement instruments. Two ND filters were used to attenuate the input laser level: ND50% and ND25%.

Results (CW—Window Time)

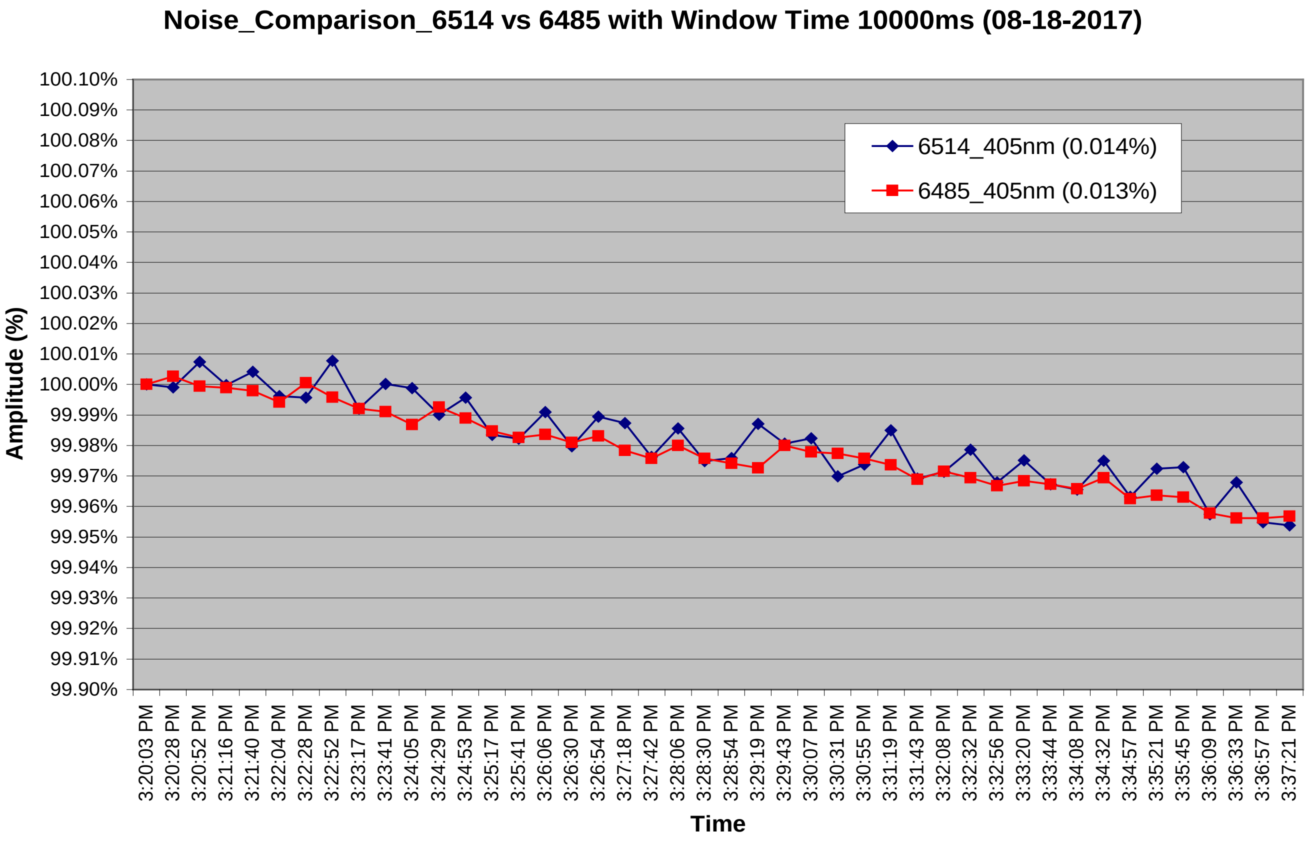
850 nm@50 mA	Window Time	Reference Number	Measurement Coefficient	Non-Linearity
	100ms	1	1	
	200ms	2	2.002343425	0.1172%
	300ms	3	2.997005187	0.0998%
	500ms	5	4.990355715	0.1929%
	1000ms	10	9.973954649	0.2605%
	2000ms	20	19.93891292	0.3054%
	3000ms	30	29.90320303	0.3227%
	5000ms	50	49.82745716	0.3451%
	10000ms	100	99.62442357	0.3756%

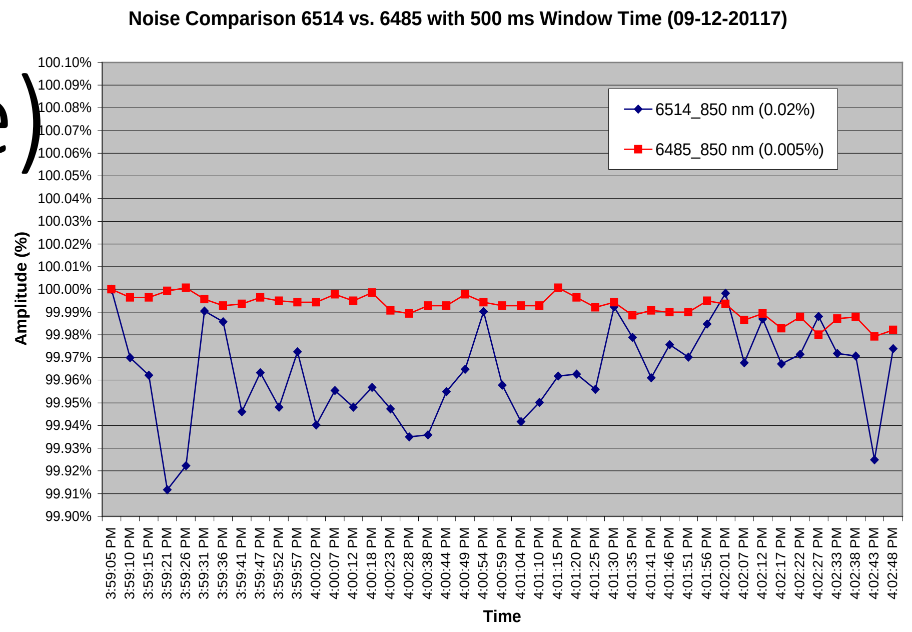
Results (CW—Window Time)

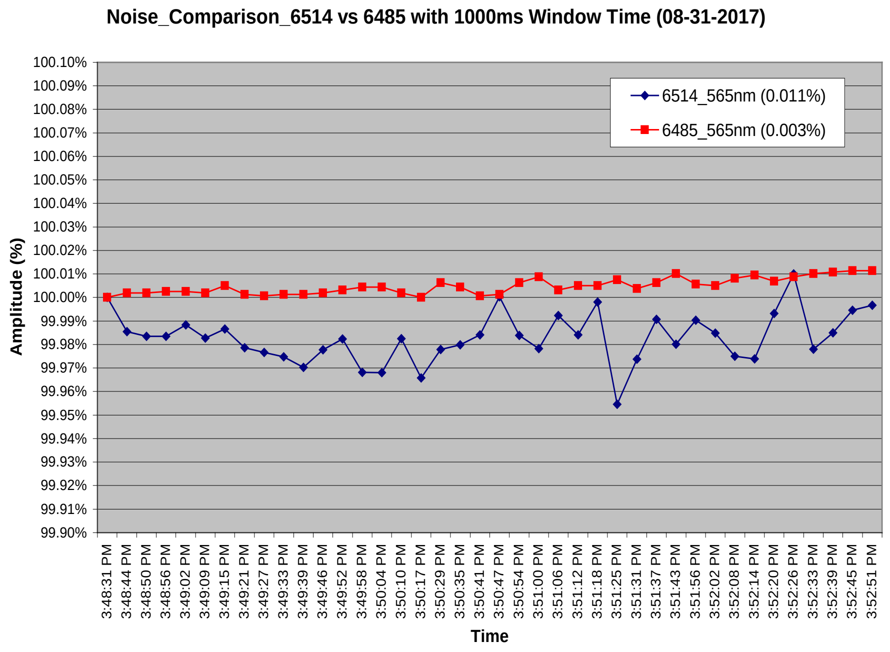




Results (CW—Window Time)

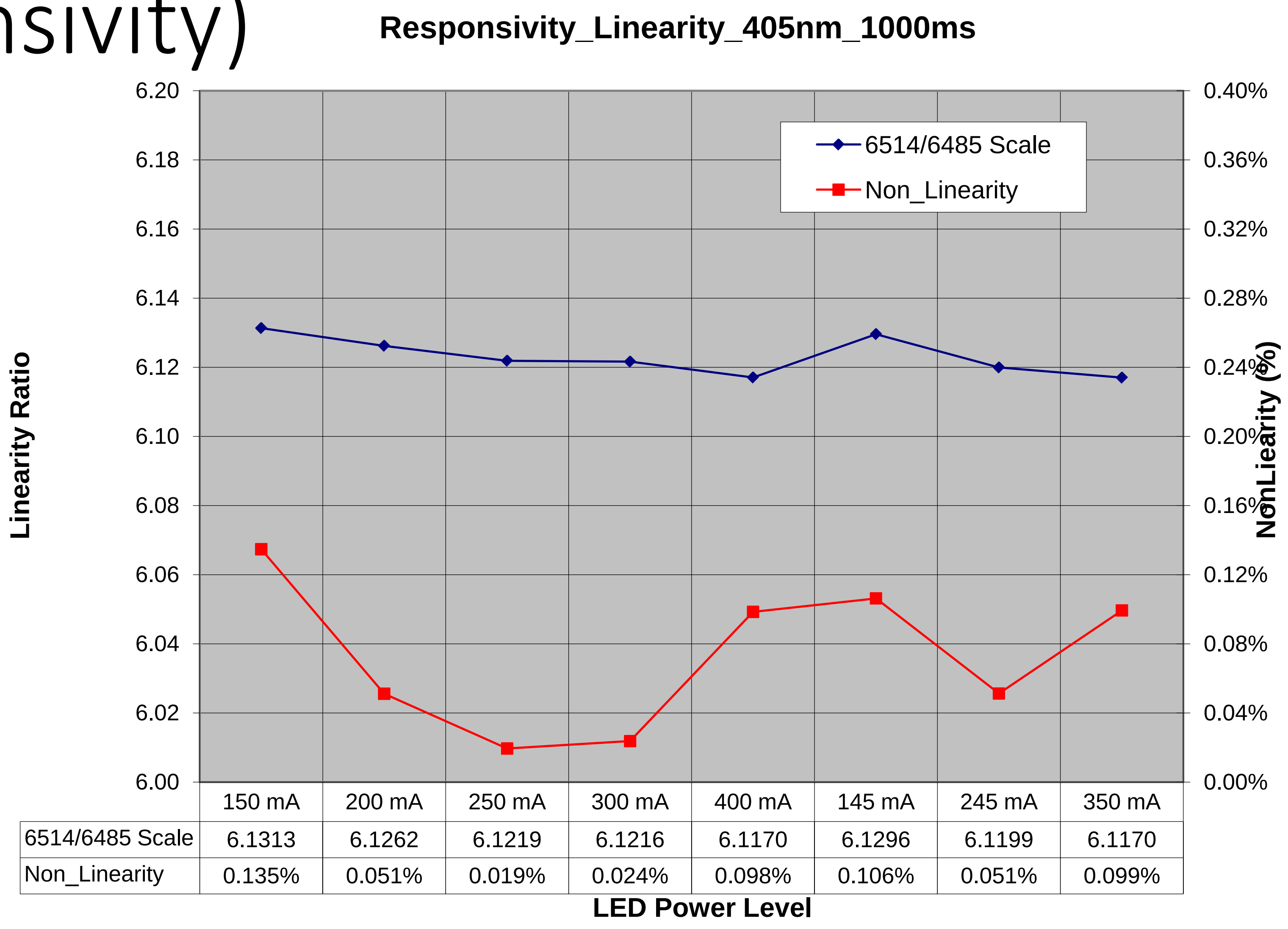






Results (CW--Responsivity)

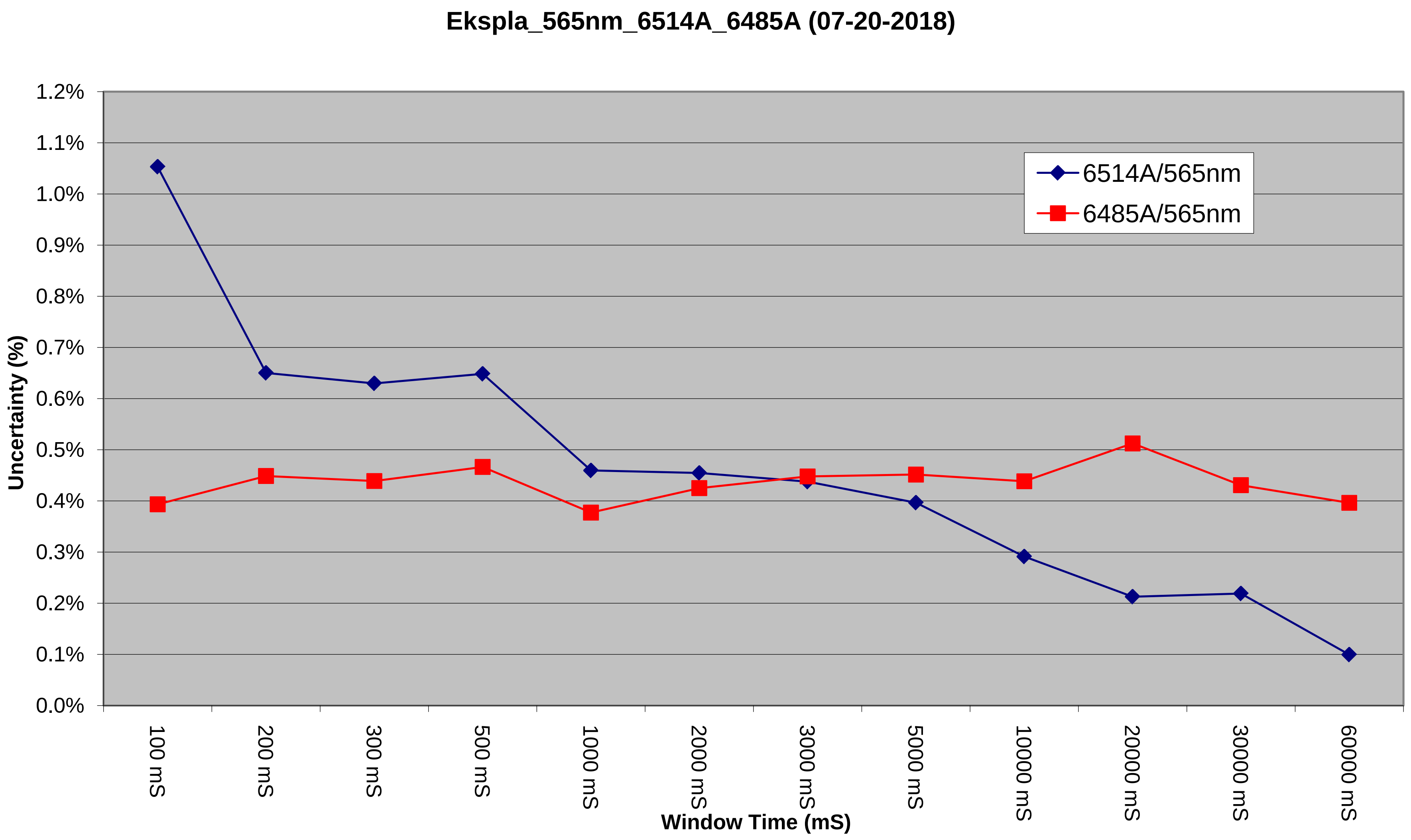
405 nm	6514	6485	6514/6485 Ratio	Nonlinearity
150 mA	5.15076E-07	8.40E-08	6.1313	0.135%
200 mA	7.37144E-07	1.20E-07	6.1262	0.051%
250 mA	9.62287E-07	1.57E-07	6.1219	0.019%
300 mA	1.19079E-06	1.95E-07	6.1216	0.024%
400 mA	1.63532E-06	2.67E-07	6.1170	0.098%
149 mA	5.14407E-07	8.39E-08	6.1296	0.106%
249 mA	9.59452E-07	1.57E-07	6.1199	0.051%
350 mA	1.41261E-06	2.31E-07	6.1170	0.099%
Average			6.1231	



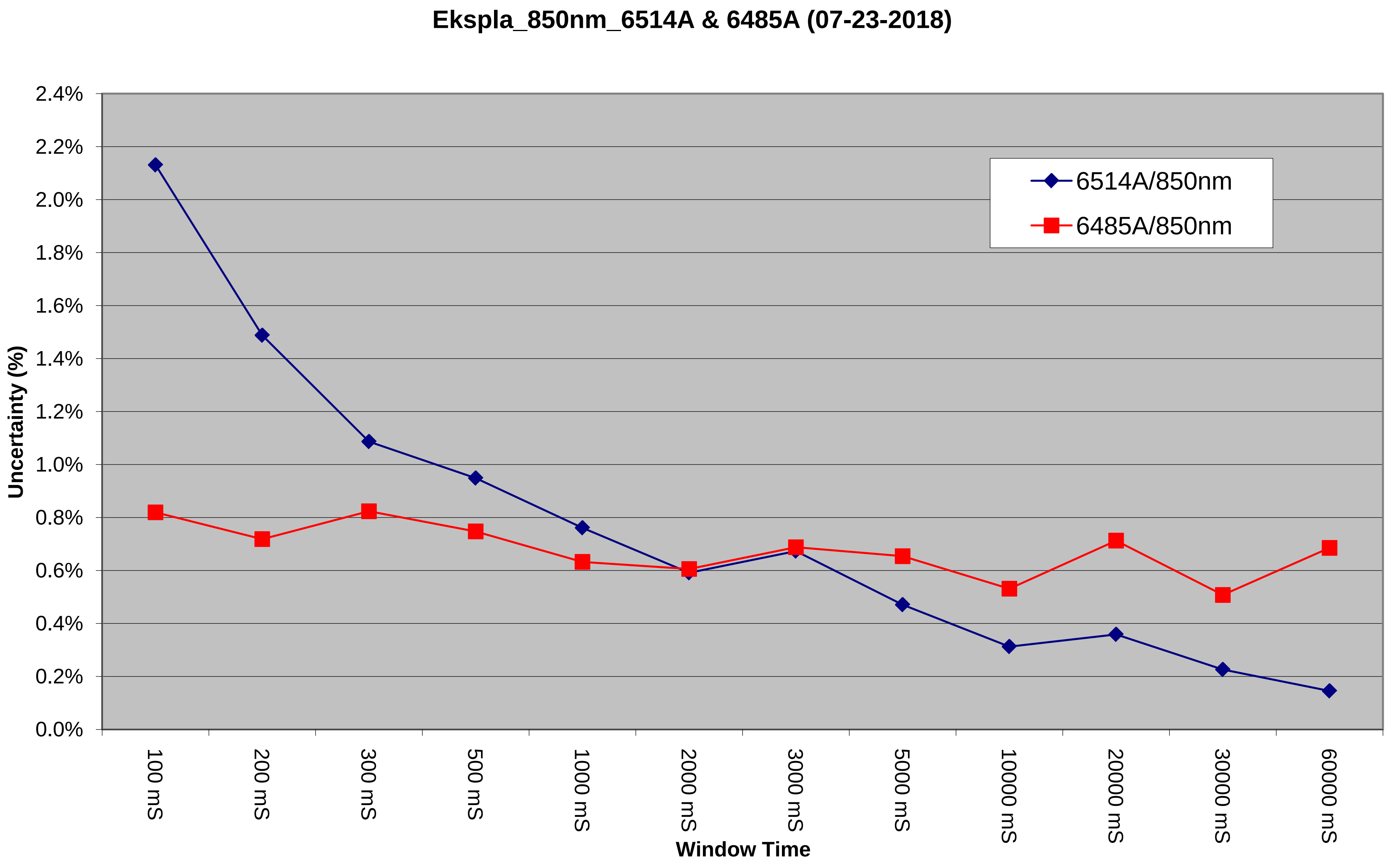
Discussion on CW Results

- The LED-based stable uniform light source demonstrated its liable capability as a characterization light source;
- With CW light source, the measurement uncertainty quickly drops as the Window Time (integration time) increases;
- With shorter integration time, e.g. 1000 ms or less, the shutter is the main source of measurement uncertainty, as it is the only mechanical part in the system

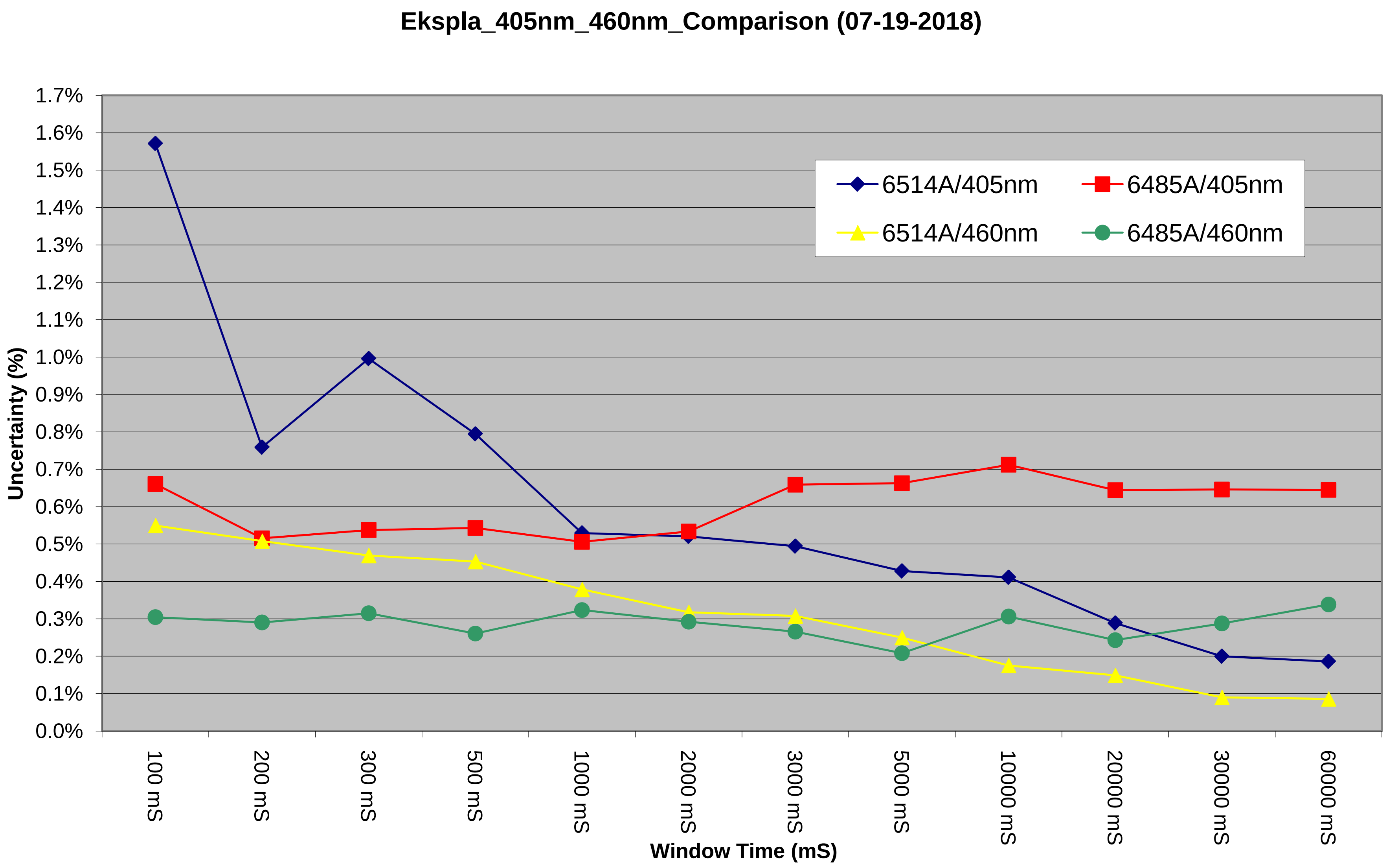
Results (Ekspla—Window Time)



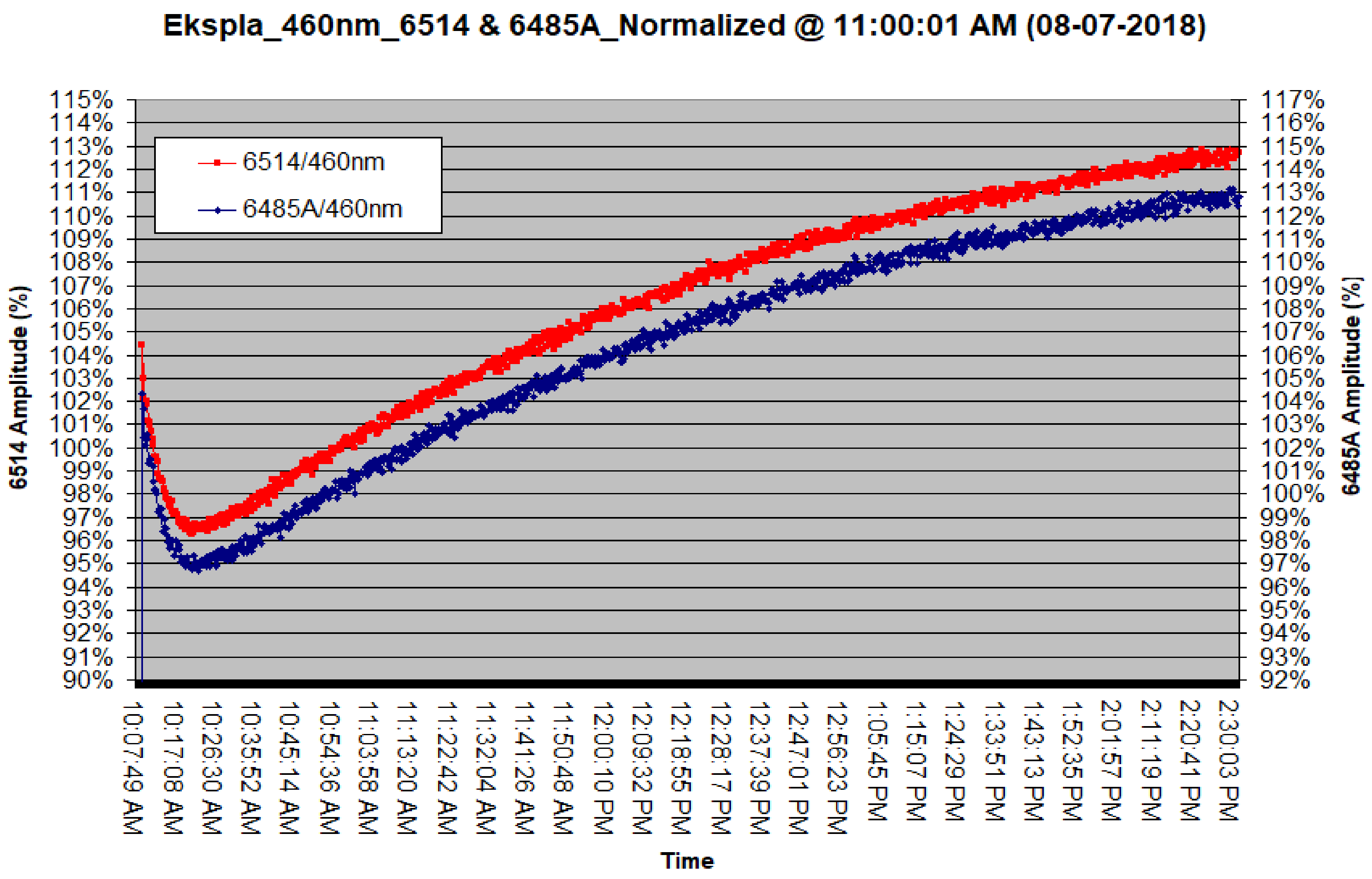
Results (Ekspla—Window Time)



Results (Ekspla—Window Time)



Results (Ekspla—Responsivity)



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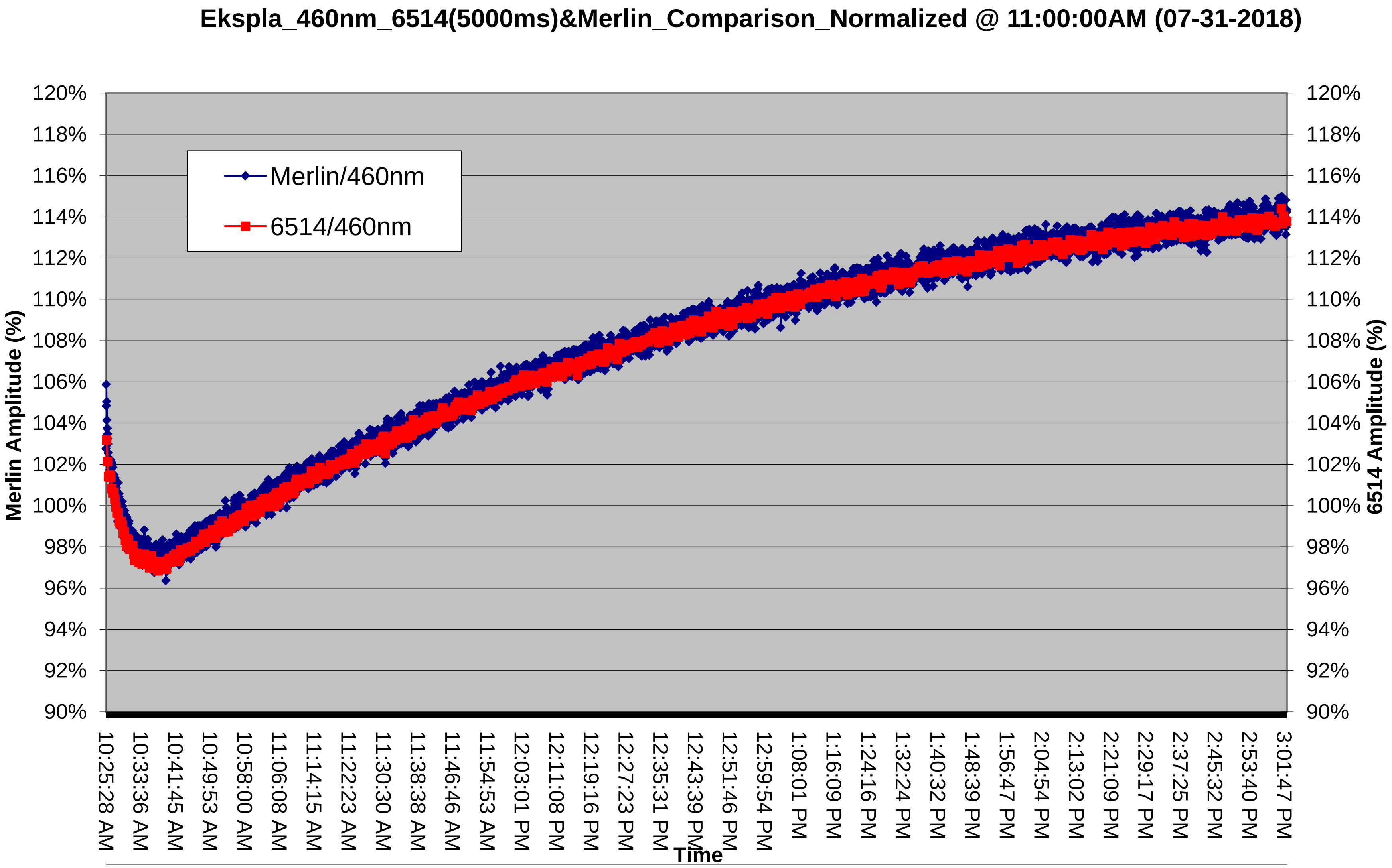
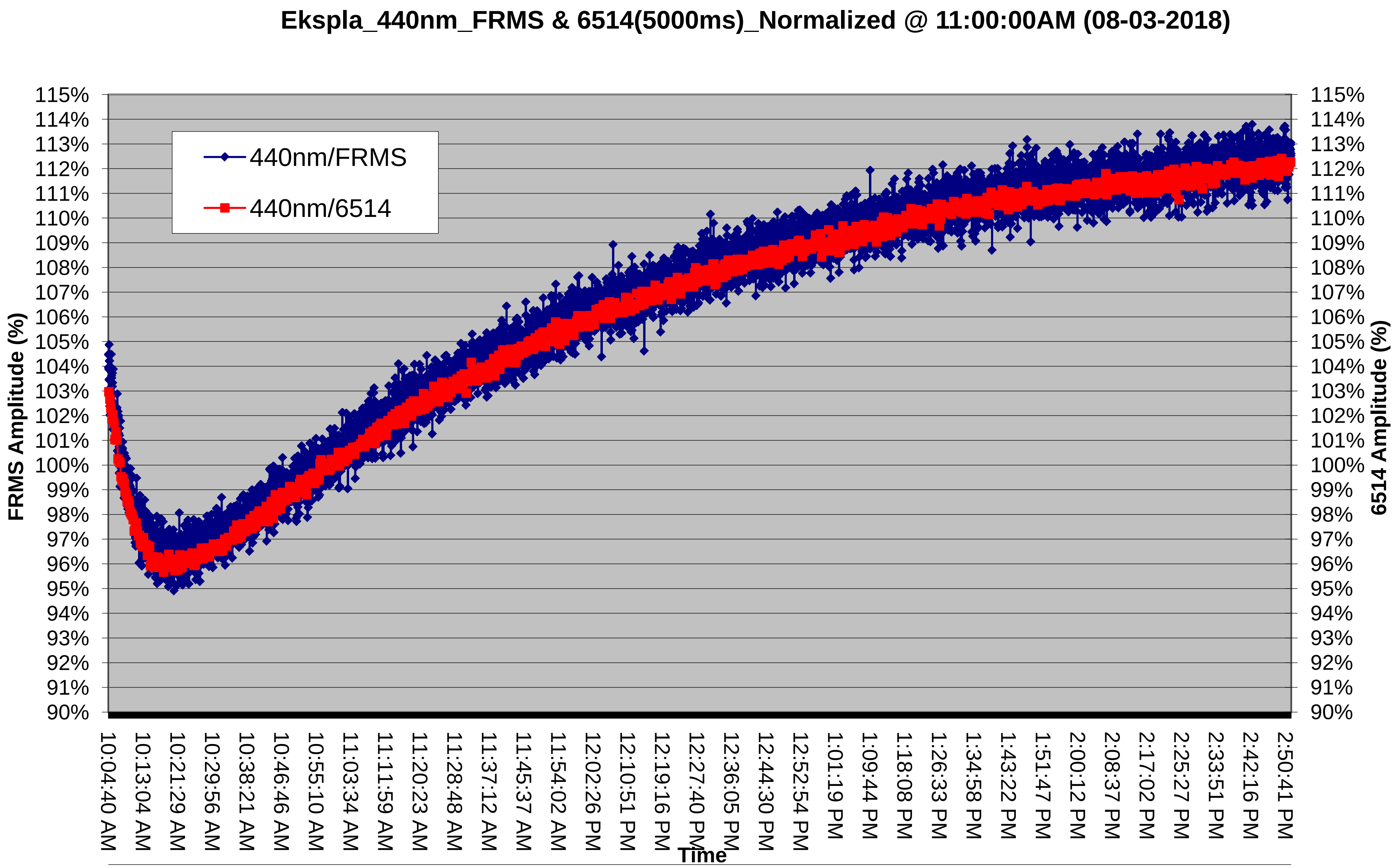


Results (Ekspla—Responsivity)



Results (Ekspla—Responsivity)

440 nm	6514	FRMS
Open 440 nm	**1**	**1**
ND50 440 nm	**52.17%**	**52.03%**
ND25 440 nm	**27.83%**	**27.74%**
ND50+25 440 nm	**14.47%**	**14.42%**

460 nm	6514	6485 (Trap)
Open 460 nm	**1**	**1**
ND50 460 nm	**52.48%**	**52.40%**
ND25 460 nm	**27.86%**	**27.85%**
ND50+25 460nm	**14.55%**	**14.55%**

460 nm	6514	Merlin 10^{+6}
Open 460 nm	**1**	**1**
ND50 460 nm	**52.38%**	**52.26%**
ND25 460 nm	**27.92%**	**27.82%**
ND50+25 460 nm	**14.51%**	**14.49%**

460 nm	6514	Merlin 10^{+5}
Open 460 nm	**1**	**1**
ND50 460 nm	**52.44%**	**52.29%**
ND25 460 nm	**28.34%**	**28.34%**
ND50+25 460 nm	**14.73%**	**14.80%**

Discussion on Ekspla Results

- The expected saturation problems with Ekspla laser did not show in our measurements; traditional instruments seem to work responsively
- Measurement data from traditional instruments exhibit much noisier behavior, but we know that was caused by the Ekspla laser
- Ekspla laser can still be used as a handy calibration light source with traditional instruments, depending on the uncertainty requirement (wavelength dependent)
  - Picoammeter based instruments: 0.25~1.0%;
  - Lock-in amplifier based instruments: 0.5~1.0%
  - DVM based instruments: 1.5~2.0%
- Reference instrument is needed when use Ekspla laser as a calibration light source

Discussion on Ekspla Results (con.)

- The pulsed laser detection system performed better as the Window Time (integration time) increases; with 5000 ms integration time, its measurement uncertainty is around 0.25%; with 60 seconds integration time, its measurement uncertainty can reach or less than 0.1%.
- Based on our experiments, Ekspla laser and the pulsed laser detection system can be possibly used in BRDF measurement
- And finally, we would like to hear any applications with Ekspla laser from the society, so that we can improve or expand the usage of Ekspla laser

Comments and Questions

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