Pyrene Fluorescence Studies for Noble Liquid Detectors

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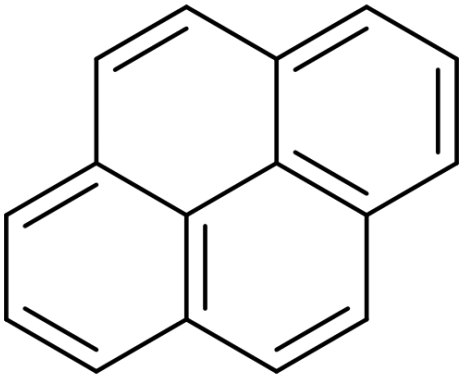
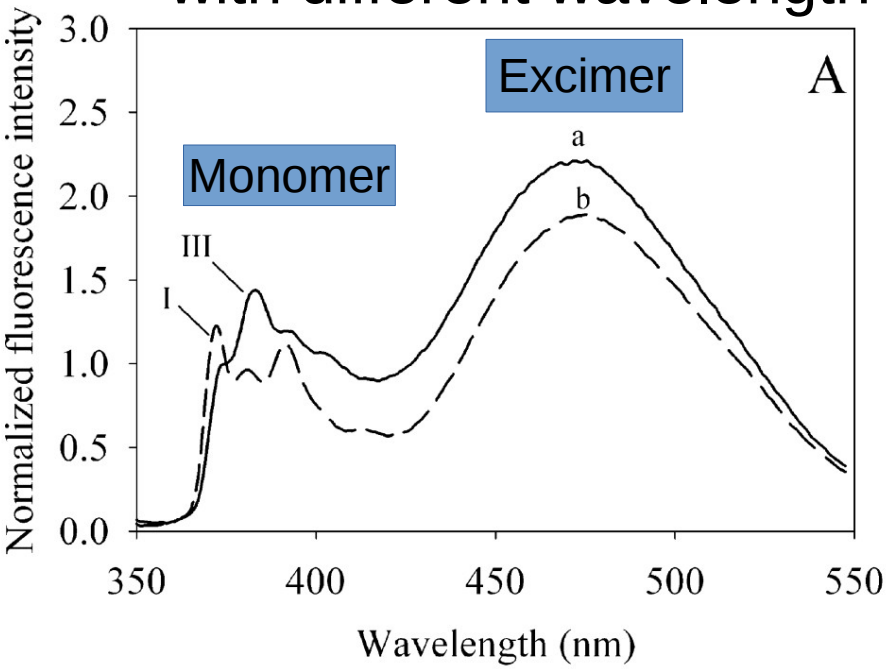
Pyrene



- Aromatic Compound C16H10
- Absorbs UV light and forms excited dimer (excimer) states which emit light in visible spectrum during de-excitation
- Excited monomer can also emit light, but with different wavelength



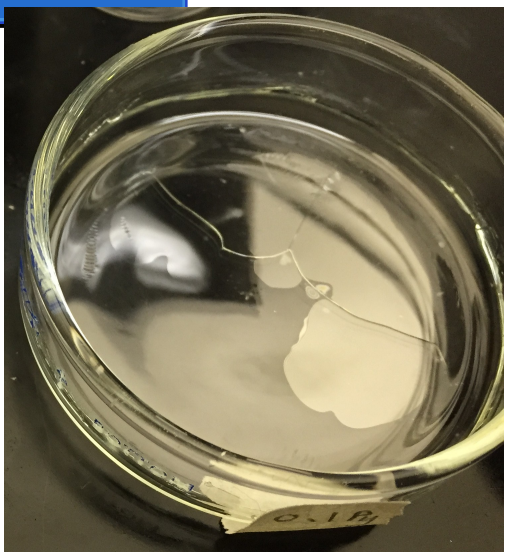
Gursharan et al., Biochemistry, (2012)

Motivation

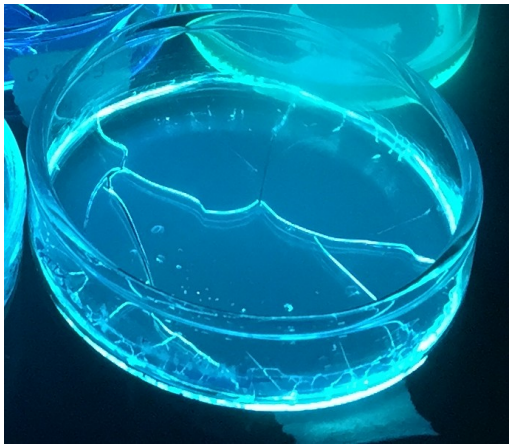
- Possible wavelength shifting material for future noble liquid detectors (eg. Next-gen DEAP)
- Different time structure -> discrimination from other wavelength shifters (TPB)
- Important to know scintillation properties at noble liquid temperatures vs. room temperature

Sample Preparation

- Vapour pressure of pyrene causes it to evaporate under vacuum needed for cooling, so it must be contained
- Dissolve pyrene into acrylic (PMMA) with varying concentration, and dry to form homogeneous thin films
- >10% concentration films did not remain homogeneous, with pyrene separating and crystallizing

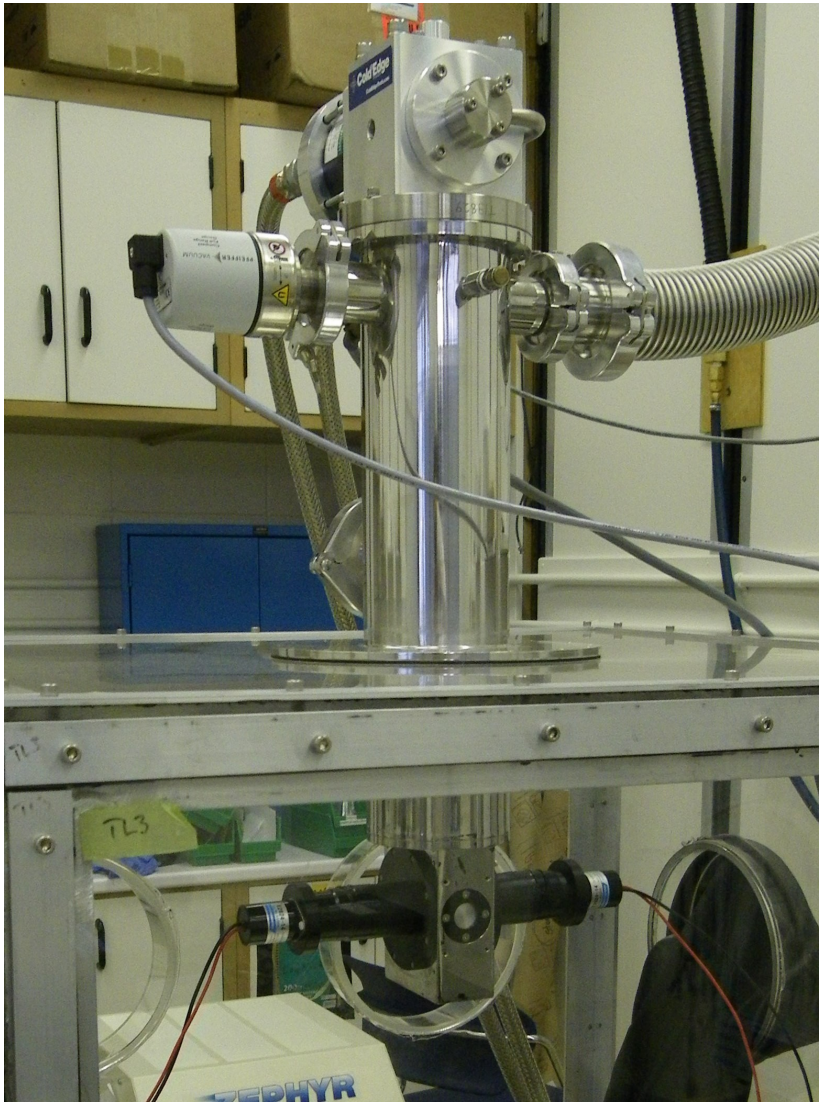


10% Pyrene Film



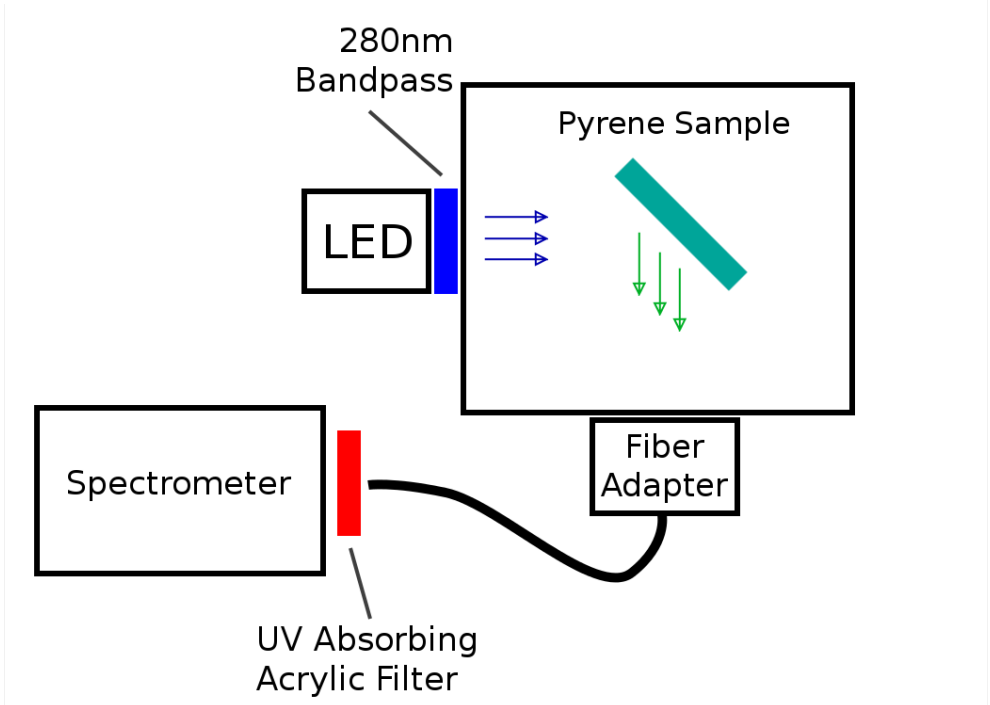
Experimental Methods

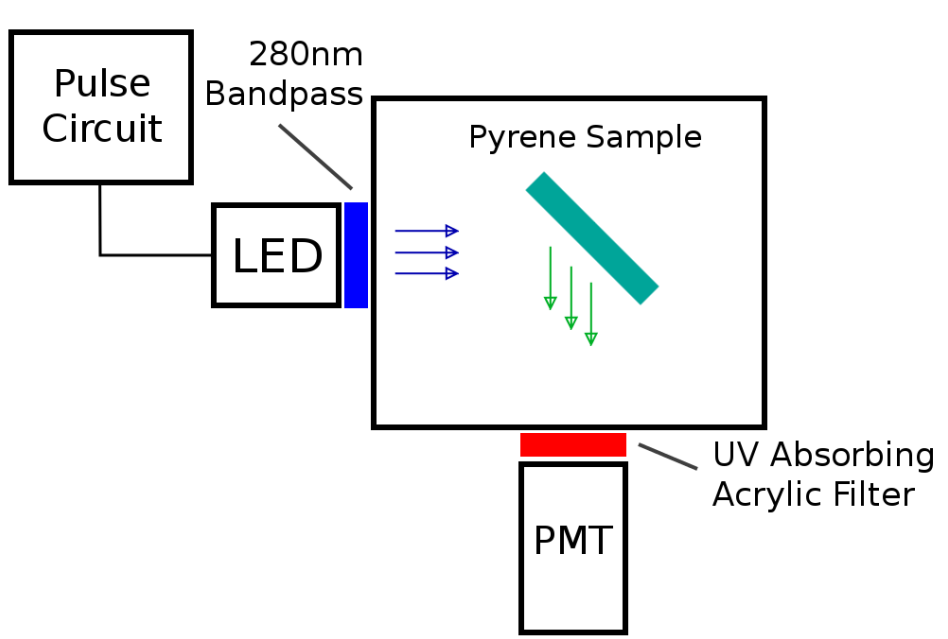
- Cool pyrene samples in optical cryostat at Queen's[1]
  - Temperature range (300K – 3.4K)
  - Previous studies on TPB[2], CaWO4[3], and other scintillators
- Illuminate pyrene samples with UV LED (280 nm) and observe resulting light with two separate measurements to evaluate time structure and wavelength spectrum as a function of temperature



[1]P.C.F. Di Stefano et al., NIM A 700 (2013)
[2]M. Von Sivers et al., J. Appl. Phys 118 (2015)
[3]L. Veloce et al., JINST 11 (2016)

Experimental Methods



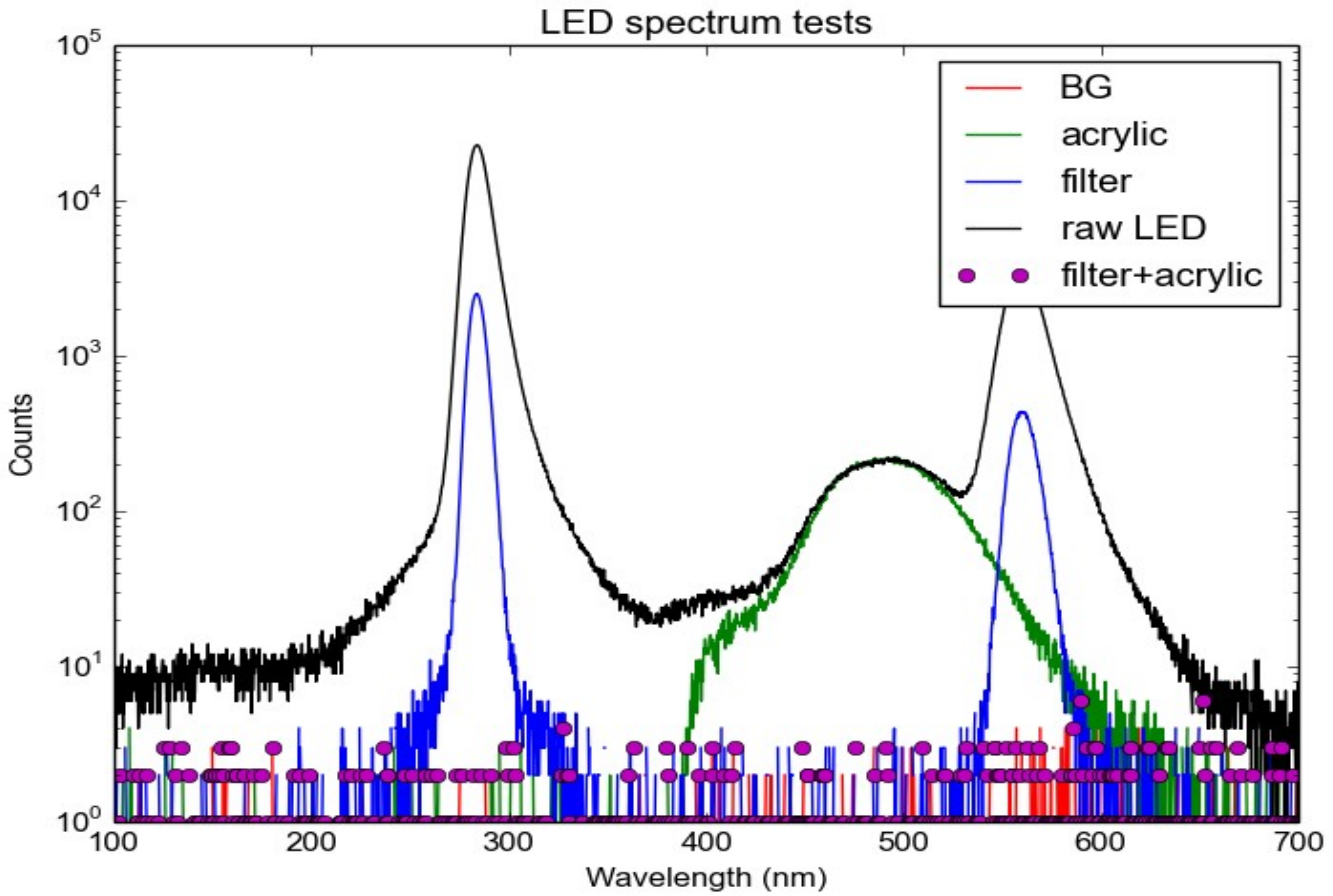


<u>Spectroscopic Measurement</u>
Study wavelength spectrum as a function of temperature

<u>Time-Resolved Measurement</u>
Study fluorescence decay time and structure

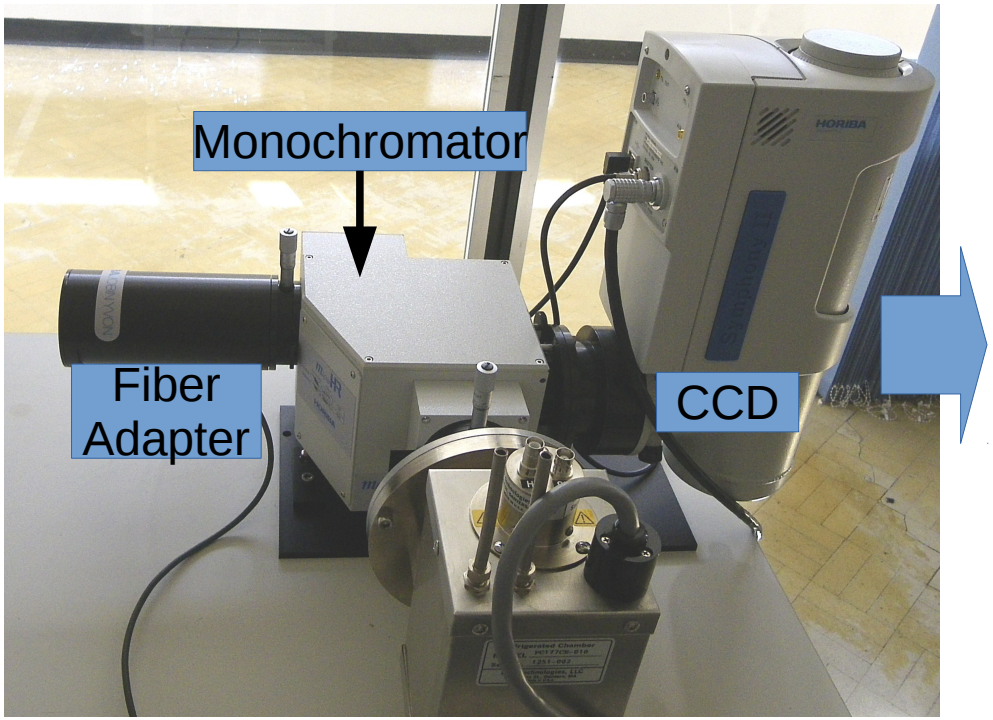
Raw LED Spectrum

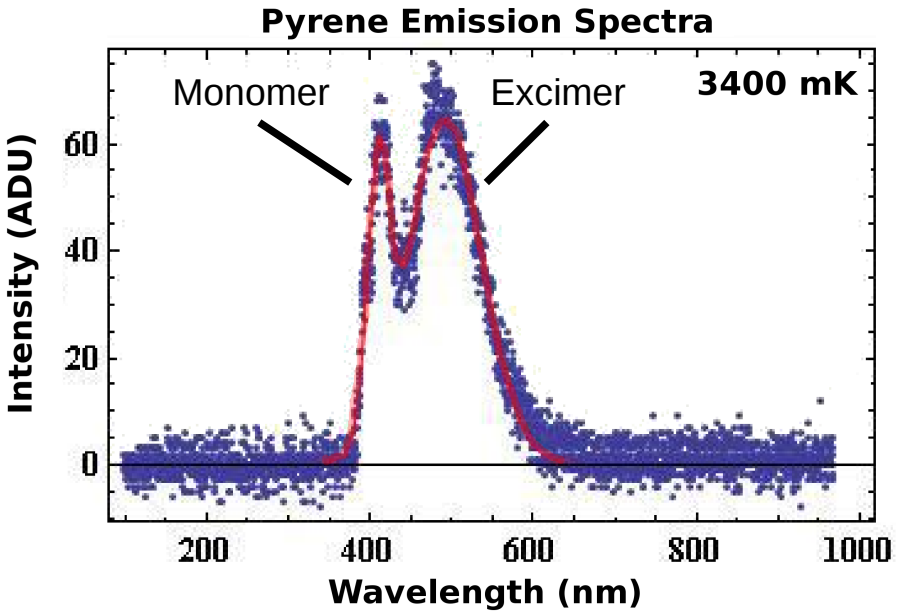
- Filters needed to clean up the 280 nm LED spectrum
  - 280nm Bandpass on LED, UV absorbing filter on Spectrometer



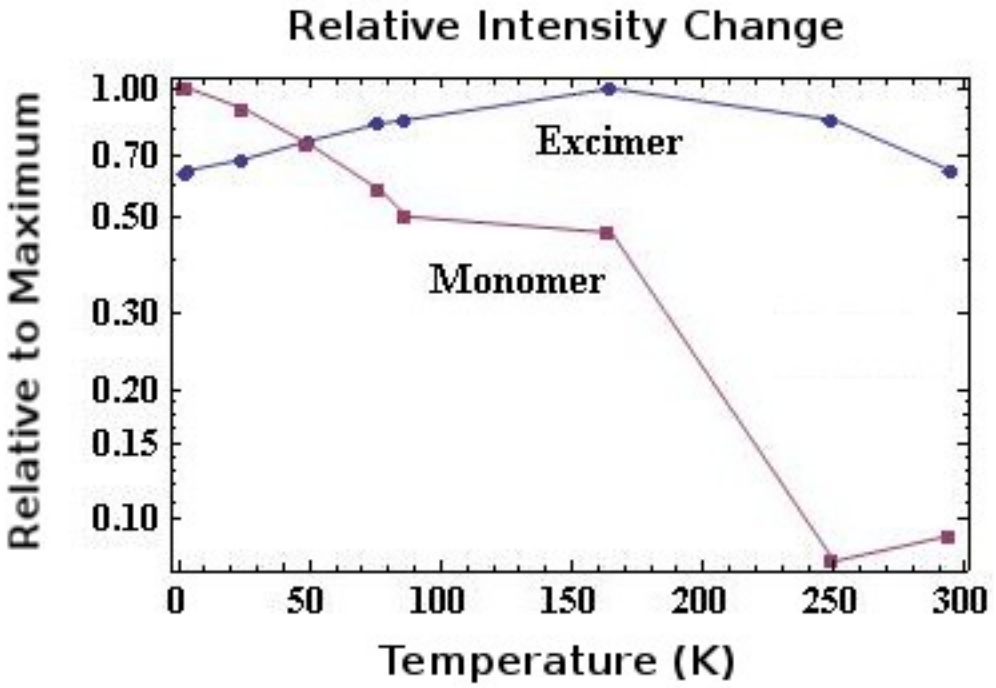
Spectroscopic tests

- Observe Pyrene fluroescence at different temperatures using HORIBA monochromator, evaluate the contribution of both monomer and excimer peaks using Gaussian fits

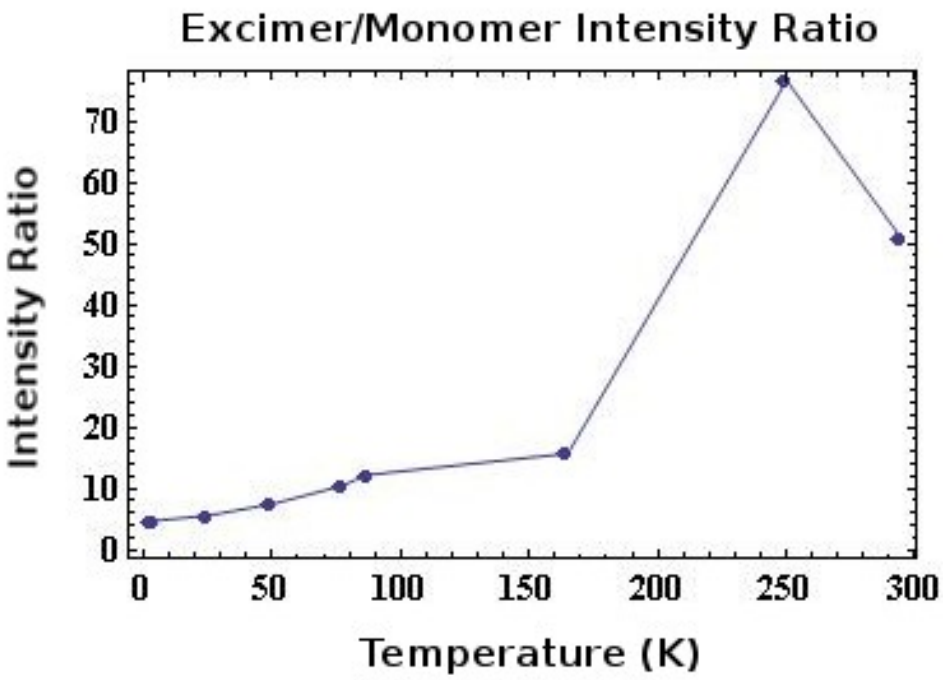




Spectroscopic Results



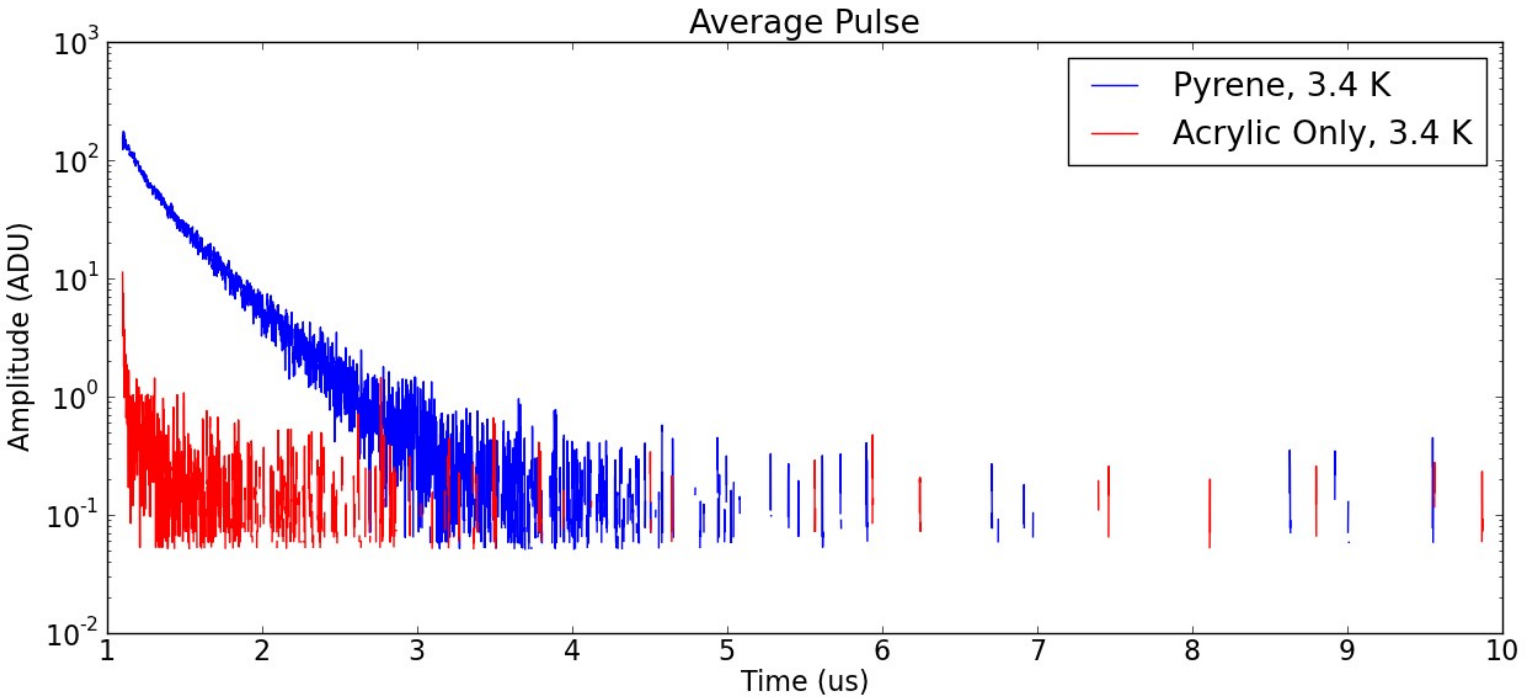
Relative change of monomer and excimer peak amplitudes



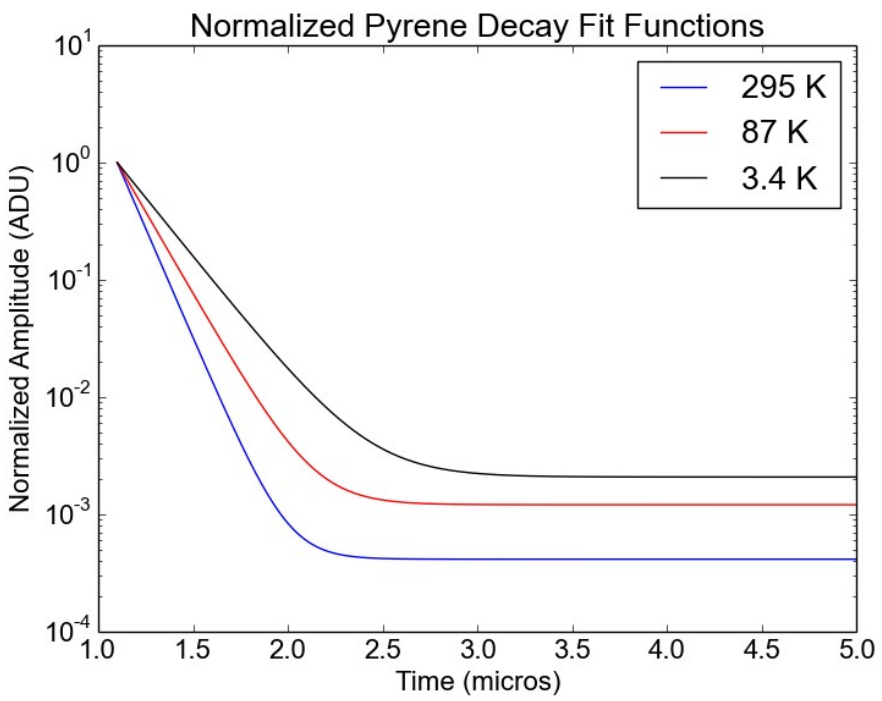
Ratio of excimer to monomer peak intensity

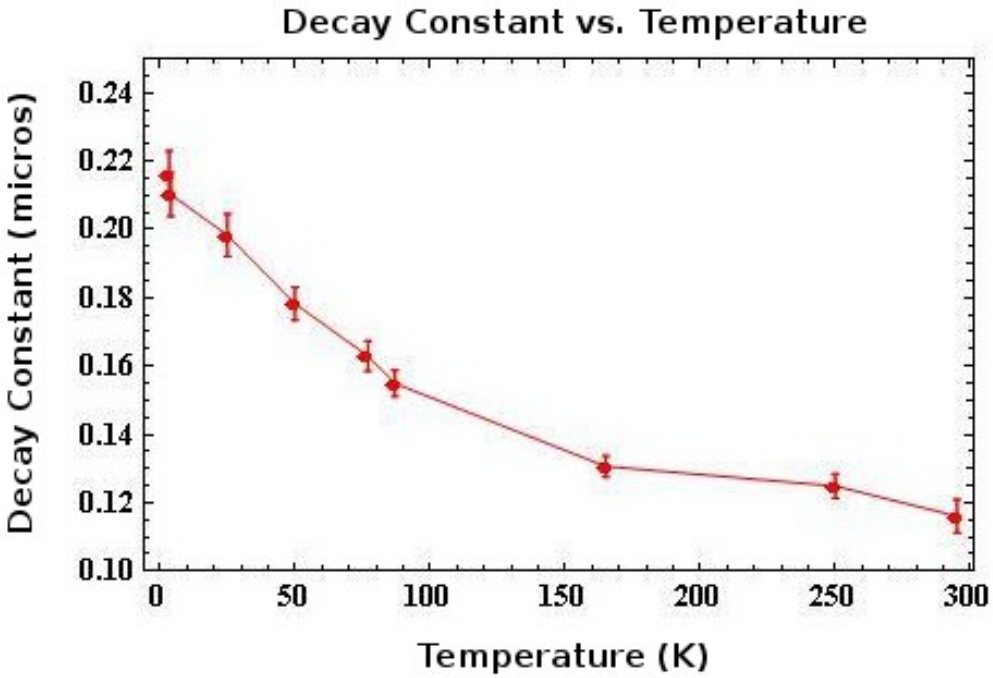
Time-Resolved tests

- Observed light using Hamamatsu R6095 PMT to evaluate the fluorescence decay at different temperatures
- LED pulsed with 4ns pulses, and resulting light is observed over a 10 us window
- Sum of individual photons from many events form an average pulse



Fluorescence Decay





- Decay constant increases as temperature decreases
- 160 ns at 87K, compared to TPB time constant of ~1 ns

Flourney et al.,
NIM A, 1994

Conclusion

- Successfully dissolved pyrene into acrylic at low concentrations, with observable UV fluorescence
- Observed change in proportion of monomer to excimer emission and fluorescence decay constant as T decreases
- Work to be done to increase concentration in the films for increased light yield

Backup Slides

LED Pulser Circuit

Parameter	Value
λ	470 nm
Rise Time	<2 ns
Pulse width	<4.5 ns
Photons per flash	$\sim 10^8$
Operating Voltage	-24 V
Operating Frequency	<20 kHz

Table 5.1: Pulse and operational specifications of the Sheffield LED pulser.

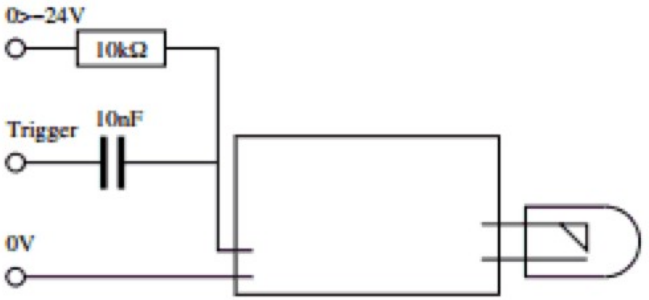
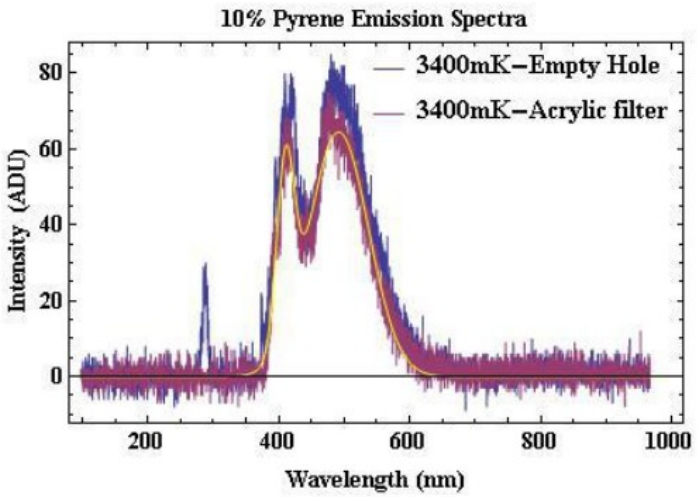
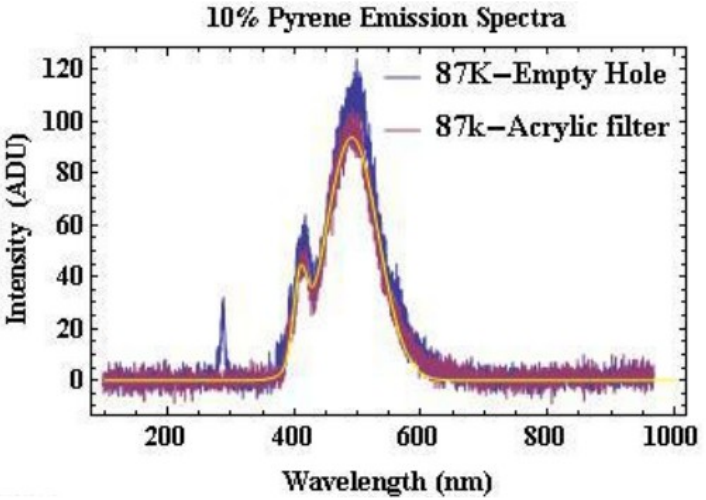
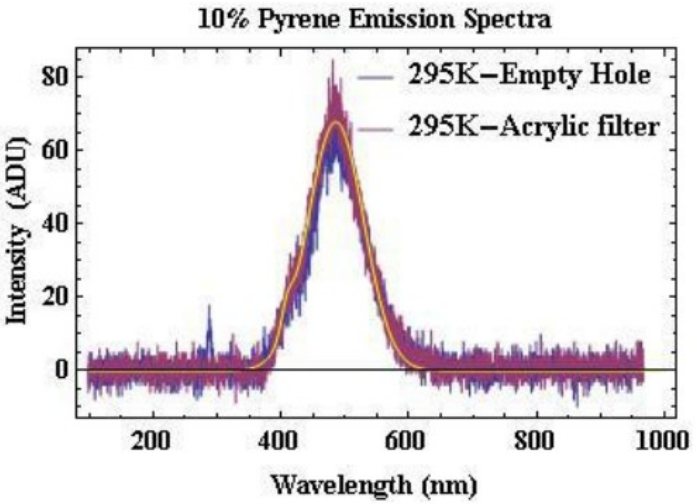


Figure 5.12: External circuit required to operate the Sheffield LED Pulser

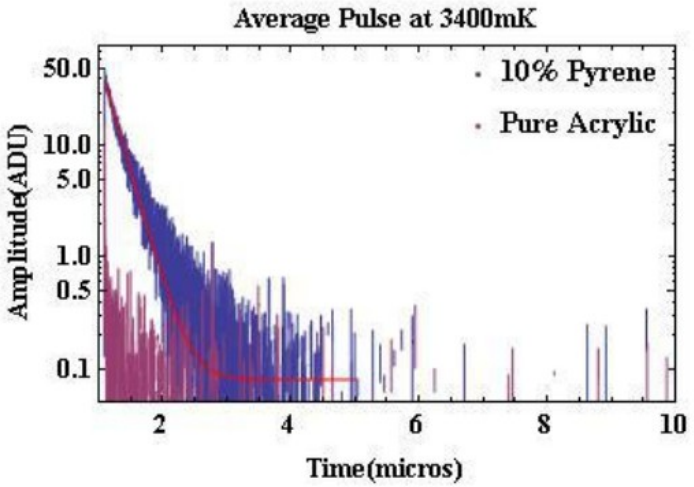
Spectrum Fits

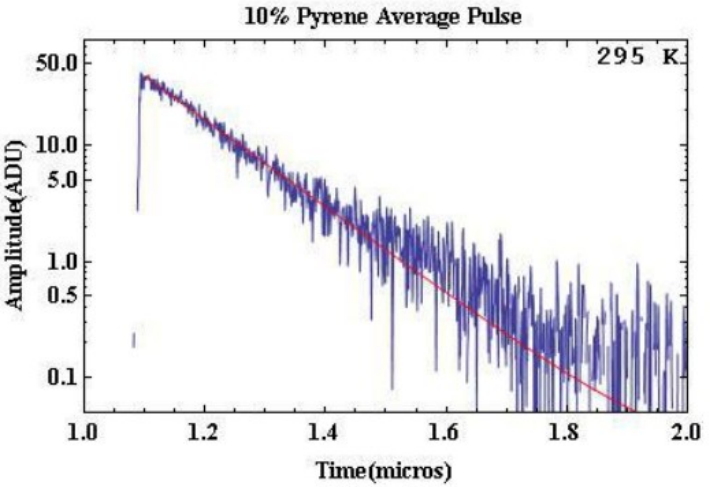


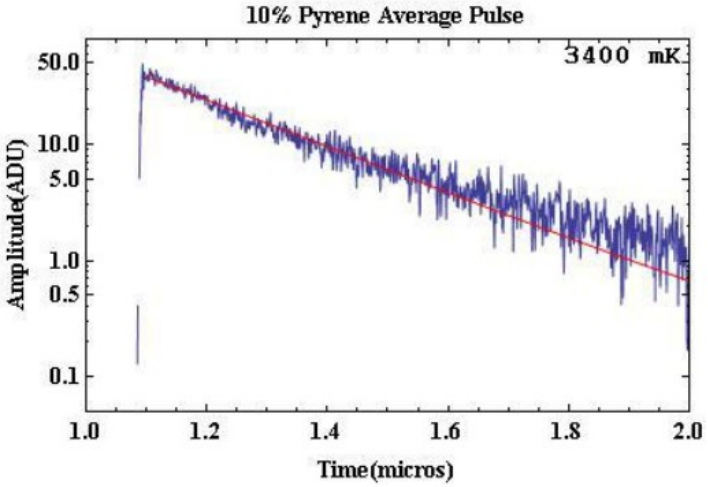


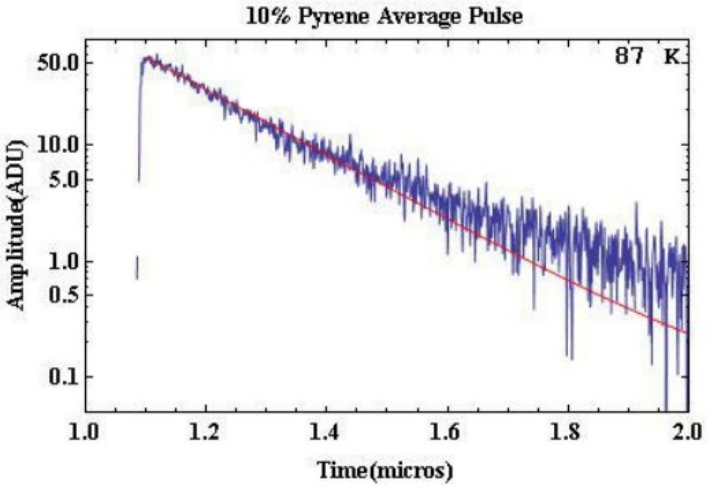


Pulse Fits


Average Pulse at 3400mK
10% Pyrene
Pure Acrylic
Amplitude(ADU)
50.0
10.0
5.0
1.0
0.5
0.1
2
4
6
8
10
Time(micros)


10% Pyrene Average Pulse
295 K
Amplitude(ADU)
50.0
10.0
5.0
1.0
0.5
0.1
1.0
1.2
1.4
1.6
1.8
2.0
Time(micros)


10% Pyrene Average Pulse
3400 mK
Amplitude(ADU)
50.0
10.0
5.0
1.0
0.5
0.1
1.0
1.2
1.4
1.6
1.8
2.0
Time(micros)


10% Pyrene Average Pulse
87 K
Amplitude(ADU)
50.0
10.0
5.0
1.0
0.5
0.1
1.0
1.2
1.4
1.6
1.8
2.0
Time(micros)