bECAL Kuraray Fiber Tests @Regina

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Presentation to the weekly Barrel ECAL Meeting, July 18, 2023

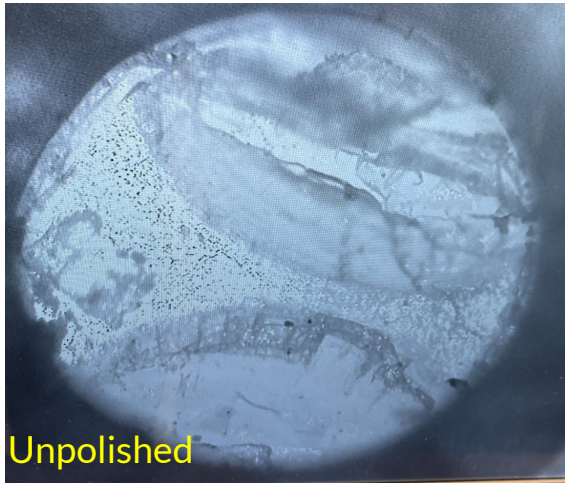
Goals - For Project (July/August)

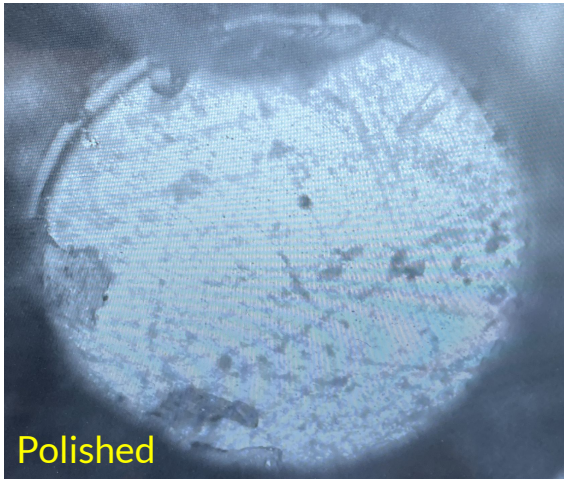
Revive past Zisis' lab + Aram's lab (fiber polishing, SiPM boards, digitizer, and more)

1) Extract attenuation length
   - Comparing
     a) old versus new Kuraray fibers
     b) single versus multi clad Kuraray fibers
     c) (eventually) Kuraray versus Luxium fibers

2) Extract number of photoelectrons (Npe)
   - Using SiPM, PMT, photodiode
   - Coming soon

Fiber Polishing





- Kuraray fibers came unpolished
- RBTX-12B[1] machine used for fiber polishing; from plant imaging lab
- Fibers were polished for 45 min each using 30µ, 9µ, 1µ grinding sheets
  - new fibers were covered with double layer of UV-absorbing film[2] for protection
- Inspected with RBTX-400GM[1] fiber microscope; quick cleaning needed

[1]Shenzhen Rongbang Optical Fiber Equipment Manufacturing Co., Shenzhen, Guangdong Province, China (www.rbtx.cn/EN/)
[2]Window Film Systems, London, ON, Canada (www.windowfilmsystems.com)

Fiber Polishing

Fiber polishing set-up using old GlueX test fibers.
Machine takes 12 fibers at a time.
Programmed polishing time.

Spectrophotometer Set-up

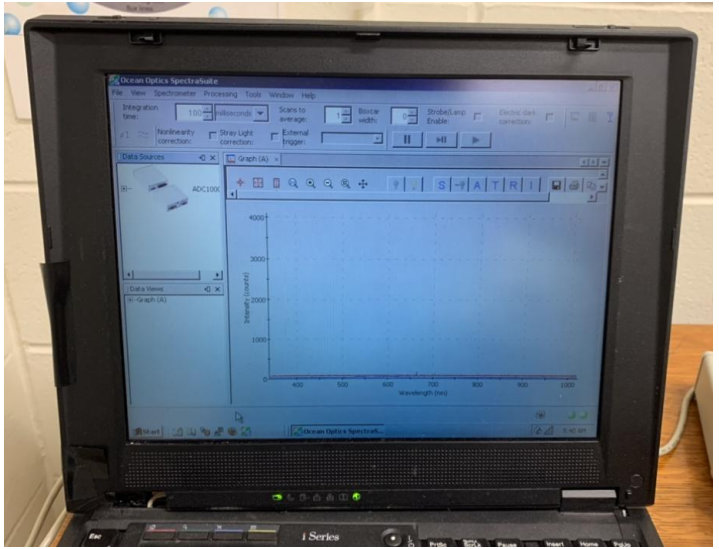
- Single fiber laid in groove of polyethene tray
- Fed into channel 0 of Ocean Optics SD2000[1] spectrophotometer
- SD2000 connected to ADC (Ocean Optics ADC1000-USB Serial[1]), then connected to DAQ laptop via USB plug in
- Measurements predominantly carried out in darkness, otherwise double layer of same UV-absorbing film covered fibers was placed over fibers on the tray

Spectrophotometer with fiber inserted (left); view down the tray holding the fibers (right)

[1]Ocean Insights, Orlando, FL, USA (www.oceaninsight.com)

Analysis Suite

- Ocean Optics OO1Base32 computer software used for analysis
- “Scope Mode” snapshots of spectra saved as .txt files
- Scope plots intensity (in arbitrary unit of “counts”) as a function of wavelength (nm)
    - range of wavelengths for channel 0 is 339.56 nm - 1020.93 nm
- Analysis continued in PyROOT

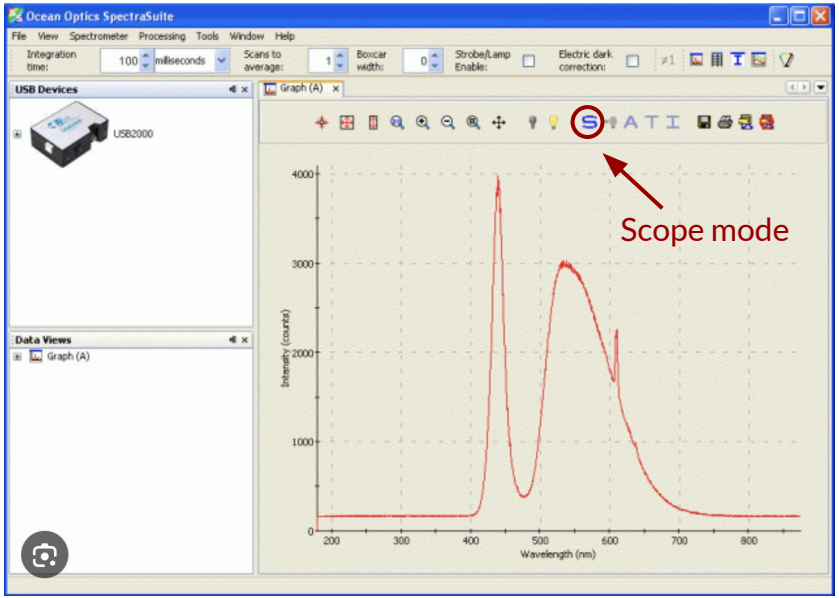


Ocean Optics OOIBase32 home screen.

Spectrophotometer Data Taking

SpectraSuite Data File
++++++++++++++++++++++++++++++++++++
Date: Thu Mar 22 22:39:20 GMT-06:00 2012
User: Administrator
Dark Spectrum Present: Yes
Reference Spectrum Present: Yes
Number of Sampled Component Spectra: 1
Spectrometers: ADUD0370
Integration Time (usec): 500000 (ADUD0370)
Spectra Averaged: 3 (ADUD0370)
Boxcar Smoothing: 10 (ADUD0370)
Correct for Electrical Dark: No (ADUD0370)
Strobe/Lamp Enabled: No (ADUD0370)
Correct for Detector Non-linearity: No (ADUD0370)
Correct for Stray Light: No (ADUD0370)

Not done, but likely not needed



Measurements to Extract Attenuation Length

- DigiKey 380 nm LED light[1] in LS-450[2] housing; mounted on runner above polyethene tray
- Fiber clamped in grove, inserted into channel 0 of spectrophotometer
- Spectra measurements saved at every 10.0 cm interval from 300.0 cm to 10.0 cm
- Fibers being tested are Kuraray plastic scintillating fibers SCSF-78 (single and multi clad)

LED and housing on runner

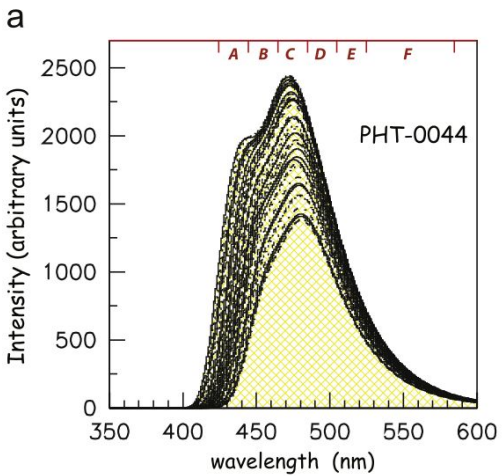
[1]Digi-Key Electronics, Thief River Falls, MN, USA (www.digikey.ca)
[2]Ocean Insights, Orlando, FL, USA (www.oceaninsight.com)

Procedure to Extract Attenuation Length

Once measurements are taken:

1. Fit each spectra with double Moyal function
2. Use fit to extract integral over accepted wavelengths
3. Plot LN scale of integrals as a function of wavelength
4. Fit linear equation, attenuation length is inverse of slope

$$f(\lambda, a_1, \mu_1, \sigma_1, a_2, \mu_2, \sigma_2, b) = a_1 \cdot \exp\left(-\frac{1}{2}\left(\frac{(\lambda-\mu_1)}{\sigma_1}\right) + e^{-(\lambda-\mu_1)/\sigma_1}\right) + a_2 \cdot \exp\left(-\frac{1}{2}\left(\frac{(\lambda-\mu_2)}{\sigma_2}\right) + e^{-(\lambda-\mu_2)/\sigma_2}\right) + b$$



λ - wavelength
a_1, a_2 - scaling terms
μ_1, μ_2 - characteristic wavelength terms
σ_1,σ_1 - width terms
b - background term

Examples of double Moyal functions - Z. Papandreou, B.D. Leverington, G.J. Lolos, Nuclear Instruments and Methods in Physics Research A 596 (2008) 338–346.

Procedure to Extract Attenuation Length

Once measurements are taken:

1. Fit each spectra with double Moyal function
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4. Fit linear equation, attenuation length is inverse of slope

$$I = I_0 \cdot e^{\frac{-\Delta z}{\lambda}}$$

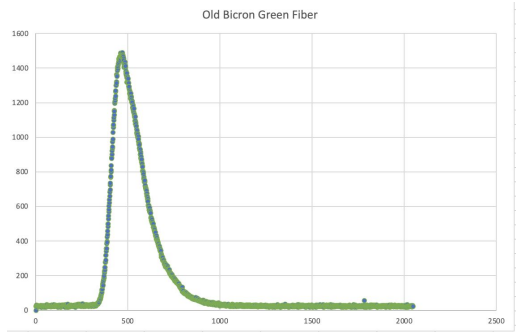
$$\ln\left(\frac{I}{I_0}\right) = \frac{-\Delta z}{\lambda}$$

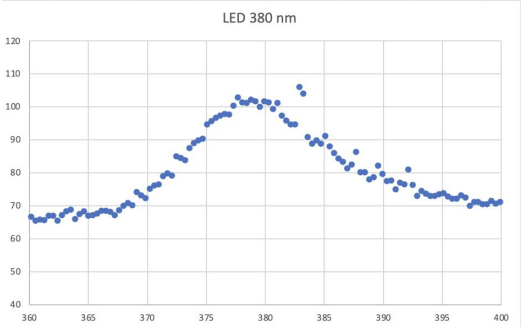
I - intensity
I_0 - initial intensity
Δz - distance from initial to current intensity measurement
λ - attenuation length

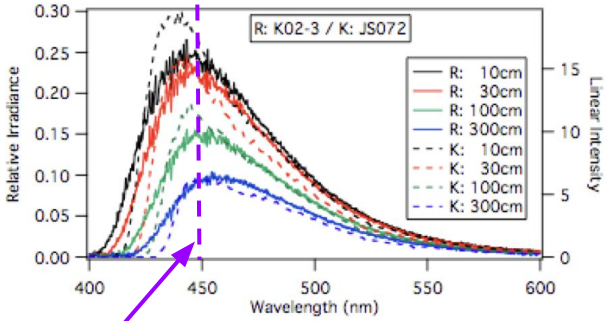
Slope of ln scale (linear) plot is multiplicative inverse of attenuation length

GlueX BCAL Fiber Spectra (ca 2009)

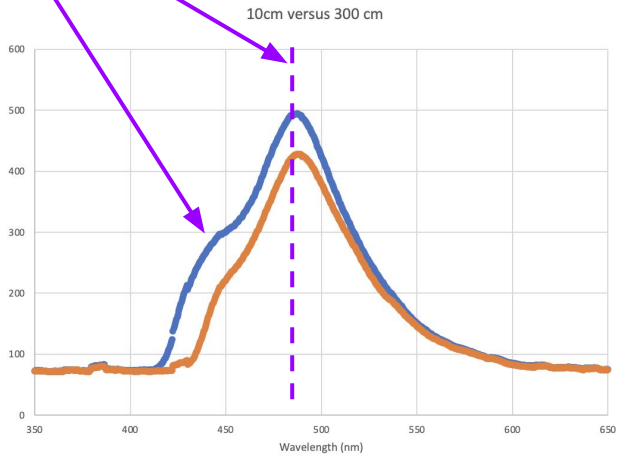
- Kuraray (GlueX):
  - Peak near 450 nm
  - Evolves to 460 nm
  - Single “hump”
- Kuraray (EIC)
  - Peak near 490 nm
  - Double hump
- Bicron Green remeasured
  - Looks right
- LED 380 nm in right spot
- Needs to be resolved



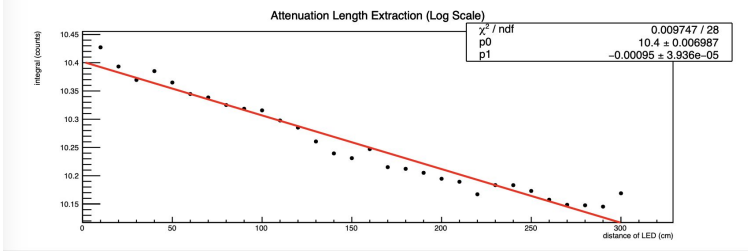


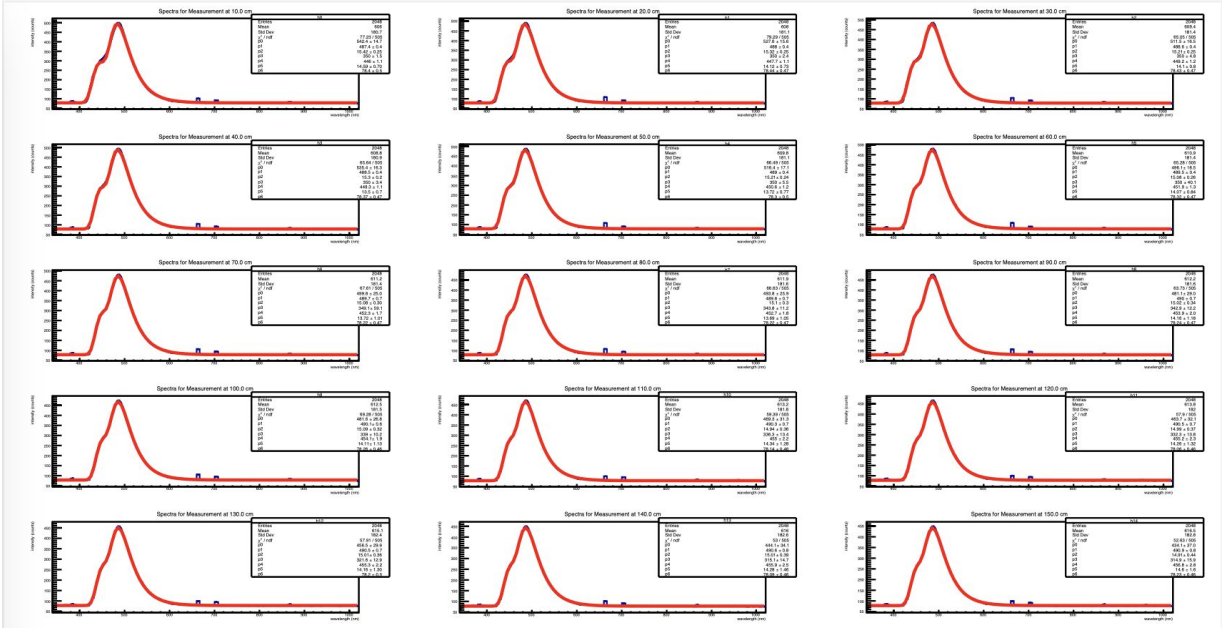


huh?



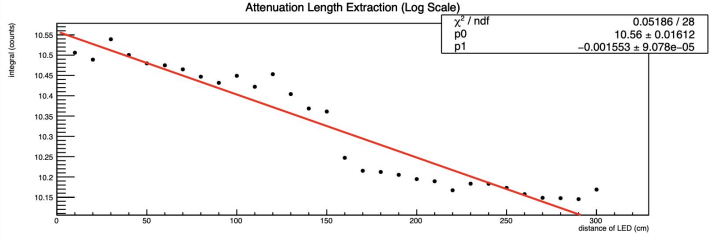
bECAL Single-clad Fiber Spectra

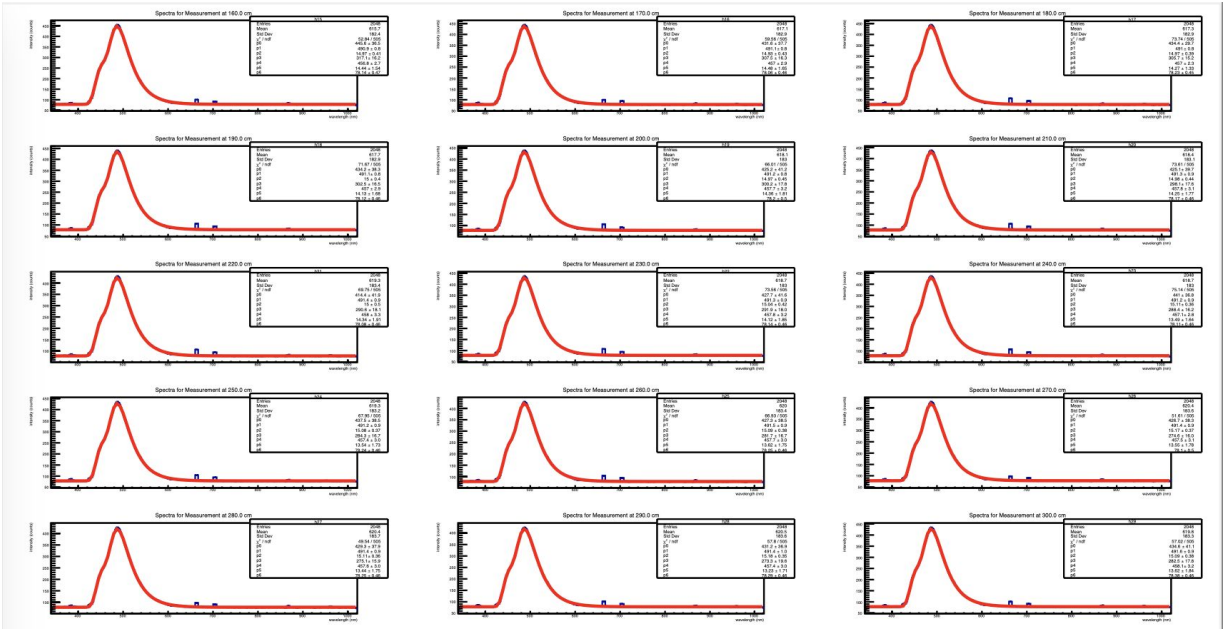




- Spectra shifted to 490 nm (from expected 450 nm)
- Poor quality results (chi squared); fit method might need higher quality data
- Future: study effect in wavelength “zones” (as in NIM 2008 paper)

bECAL Multi-clad Fiber Spectra



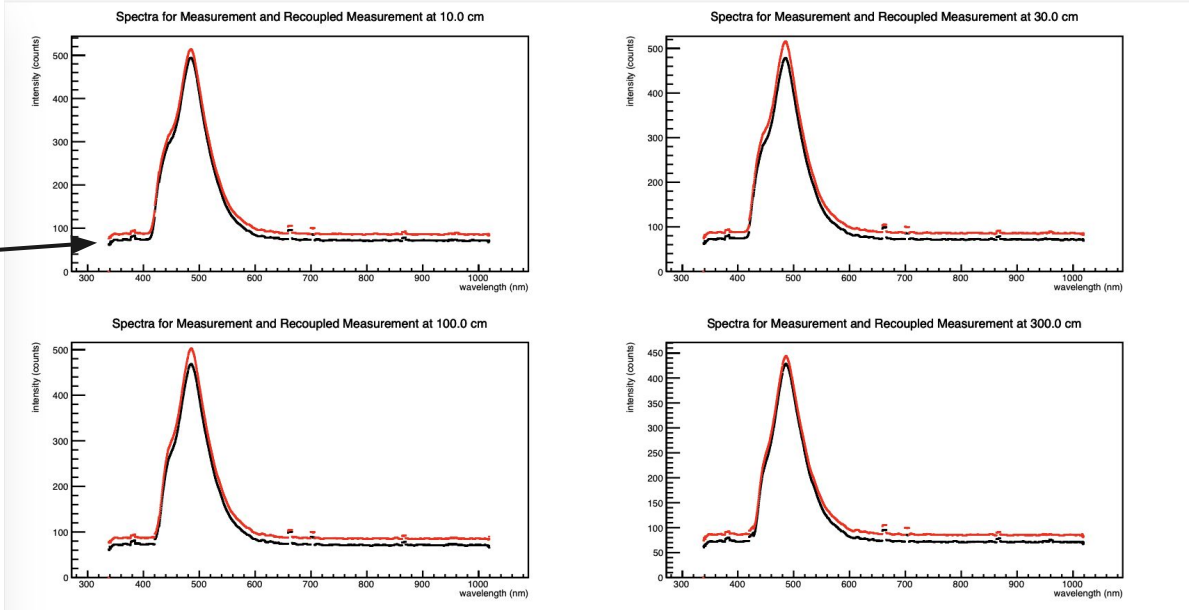


- Spectra shifted to 490 nm (from expected 450 nm)
- Poor quality results (chi squared); fit method might need higher quality data
- Future: study effect in wavelength “zones” (as in NIM 2008 paper)

Fiber Recoupling Checks

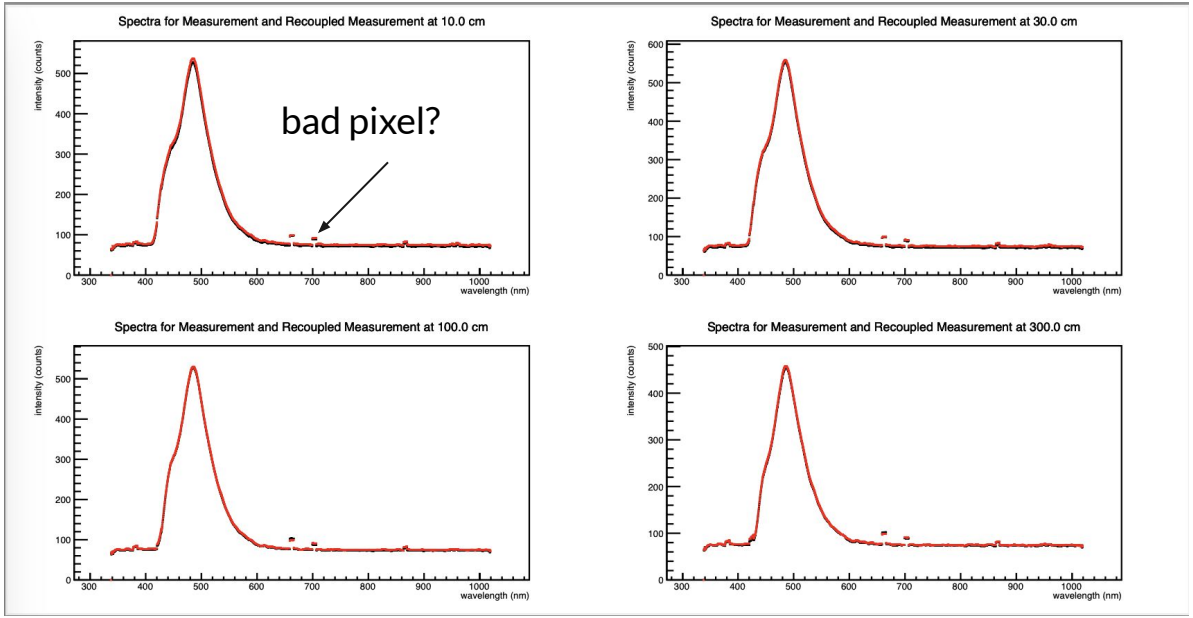
Single clad

baseline?



Fiber Recoupling Checks

Multi clad

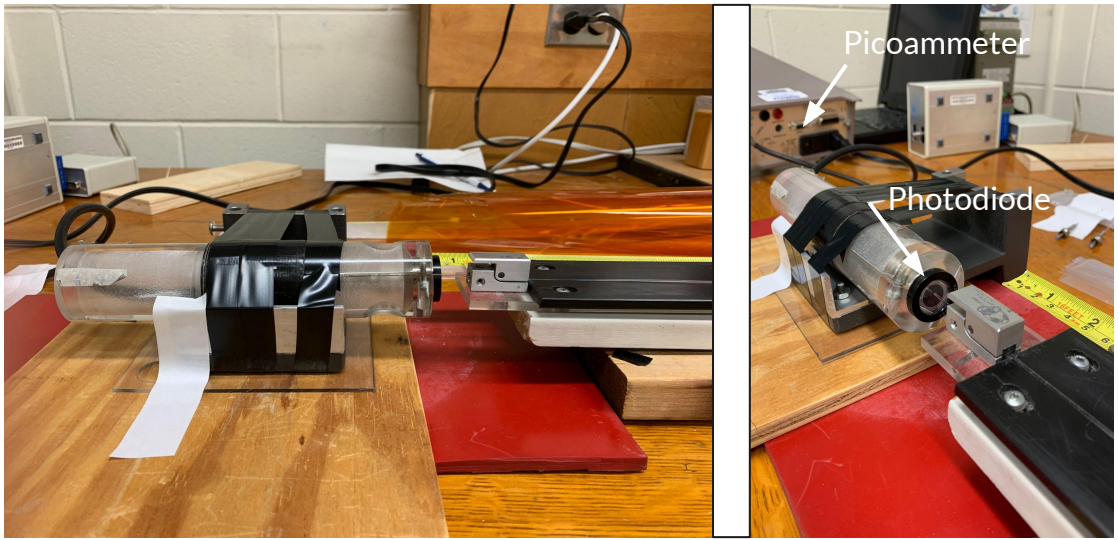


Observations

- Recoupling is robust
- Forward/back scans are the same
- LED is stable to +/-3% over 30 min; scans are usually 15-20 min long
- Spectral shape and peak location not understood using Spectrophotometer
- Go to Plans B (photodiode) and C (SiPM+PMT)

Photodiode Set-up for Attenuation Length Extraction

- New set-up for attenuation length extraction
- Fiber still in groove of tray, but now placed against Hamamtsu S2281 photodiode[1] connected to Keithley 6485 picoammeter[2]



[1]Hamamatsu Photonics, Shizuoka, Japan (www.hamamatsu.com/jp/en.html)
[2]Keithley Instruments, Cleveland, OH, USA (www.tek.com/en/products/keithley)

Photodiode Results

Quick measurement

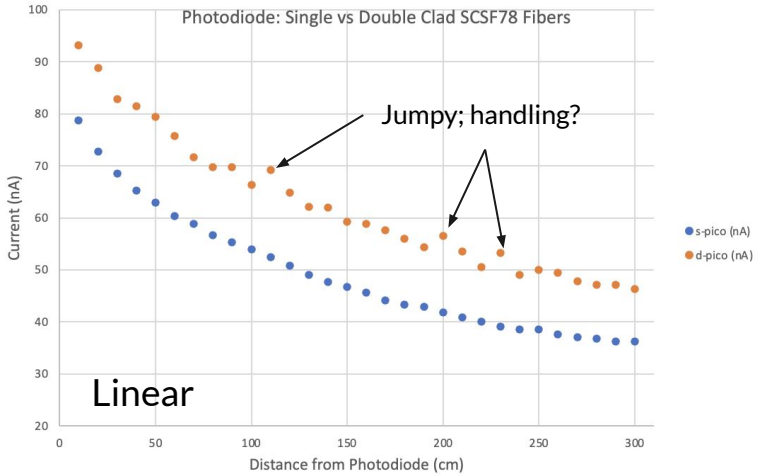
1 single, 1 multi clad

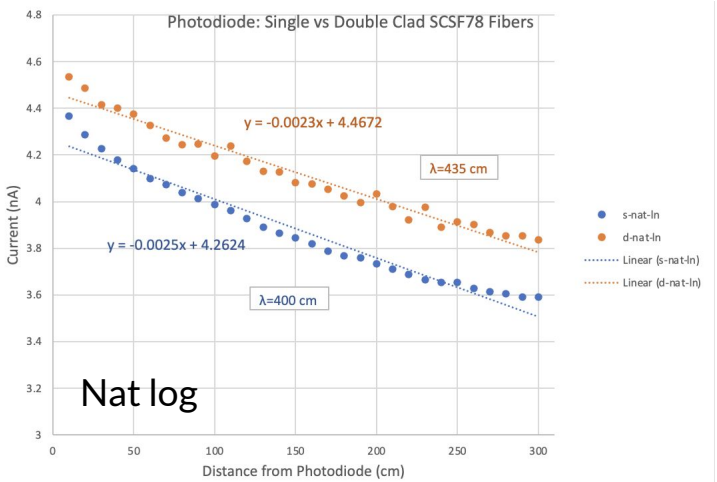
1 end polished (photodiode)

Fiber handling issue?

Stability +/-0.2nA

LED off: 0.1 nA

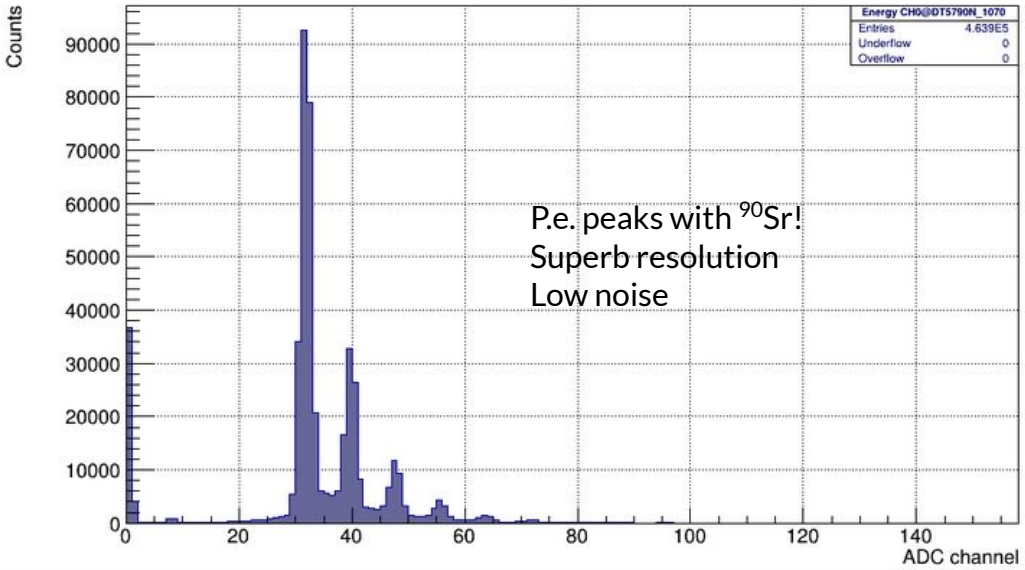


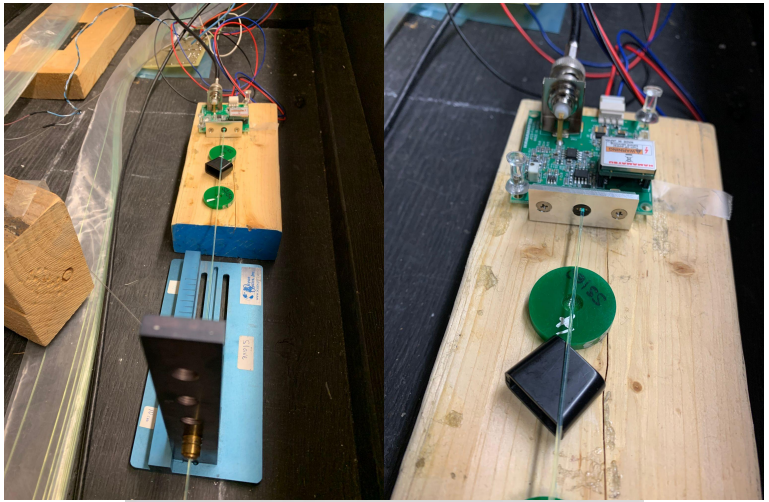


[1]Hamamatsu Photonics, Shizuoka, Japan
(www.hamamatsu.com/jp/en.html)

Hamamatsu Module

- MPPC: S12571-050C/Module: C11205[1]





Next Steps

- Start work on extracting Npe
- Currently configuring SiPM set-up
- Aiming to take initial measurements later today
- Timelines:
  - Photodiode measurements by 7/31?
  - SiPM measurements by 8/7?
- Personnel availability!
- **No Luxium fibers yet**