Fluorescence Efficiency and Visible Re-emission Spectrum of Tetraphenyl Butadiene Films at Extreme Ultraviolet Wavelengths

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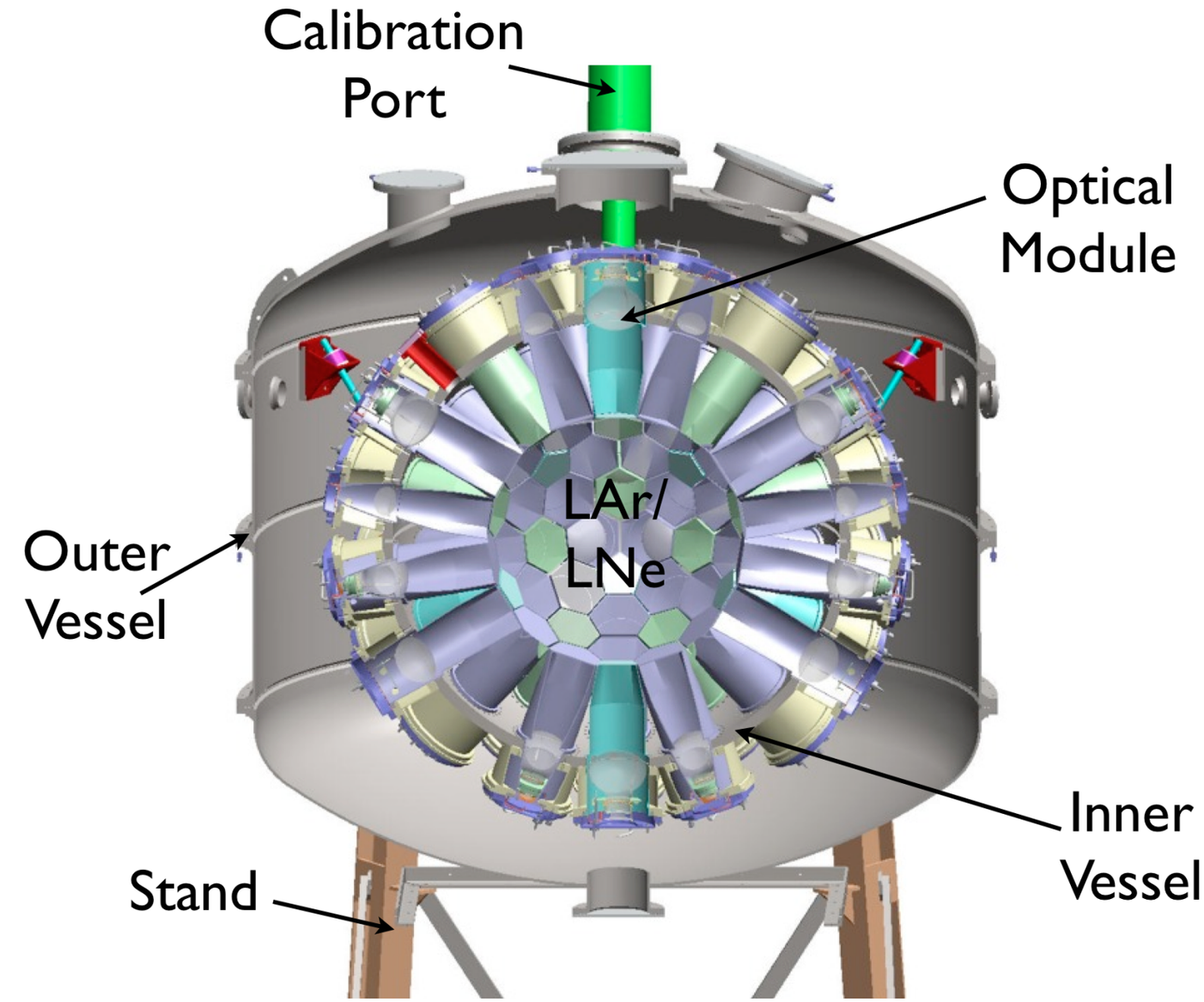
arXiv:1104.3259v1 [astro-ph.IM]

MiniCLEAN (in one slide...)

- Single-phase LAr/LNe dark matter search
- Reads out *only* scintillation light
- Uses difference in time structure (PSA) to distinguish nuclear recoils from electron recoils
- Detailed understanding of optical propagation is important



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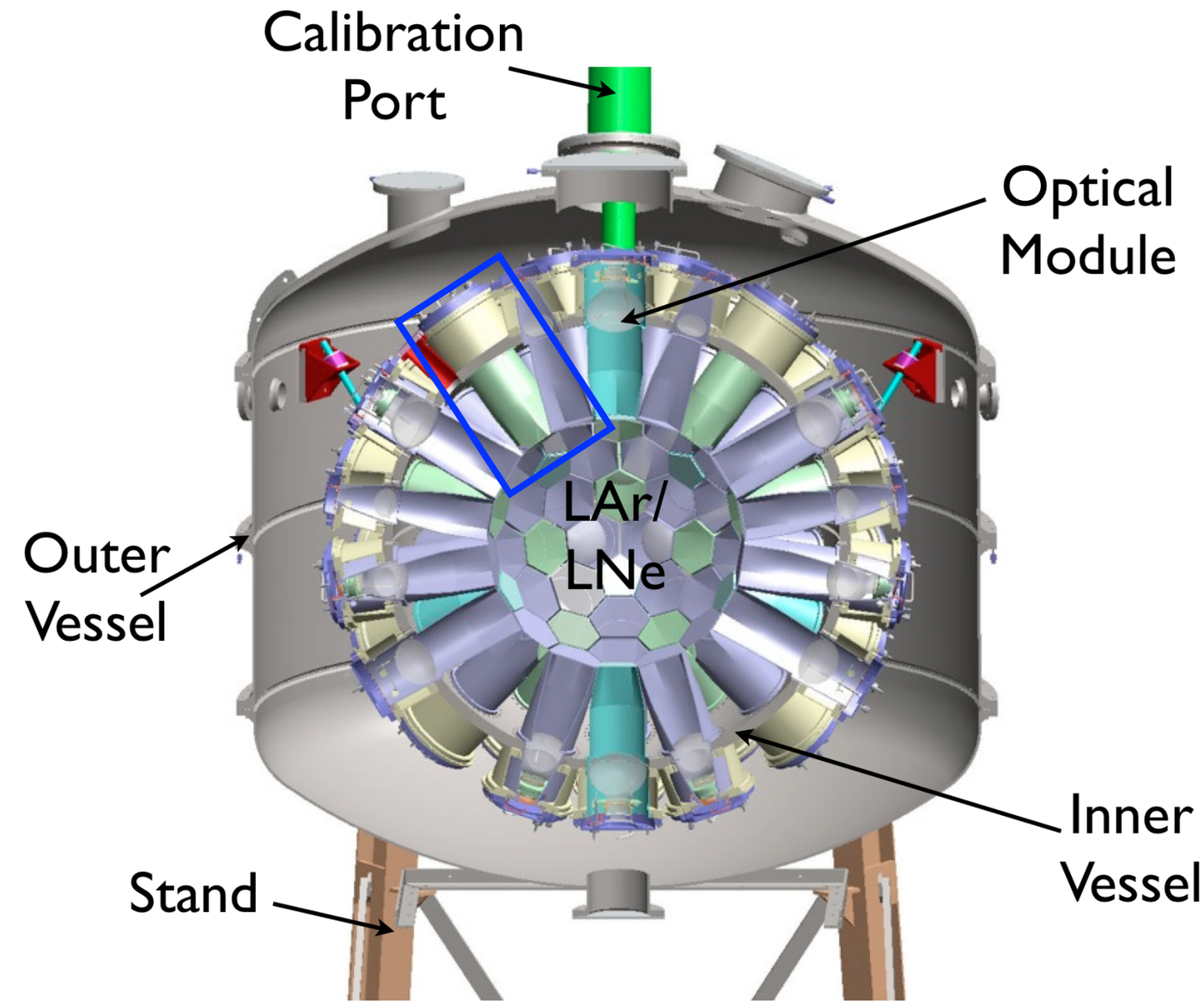

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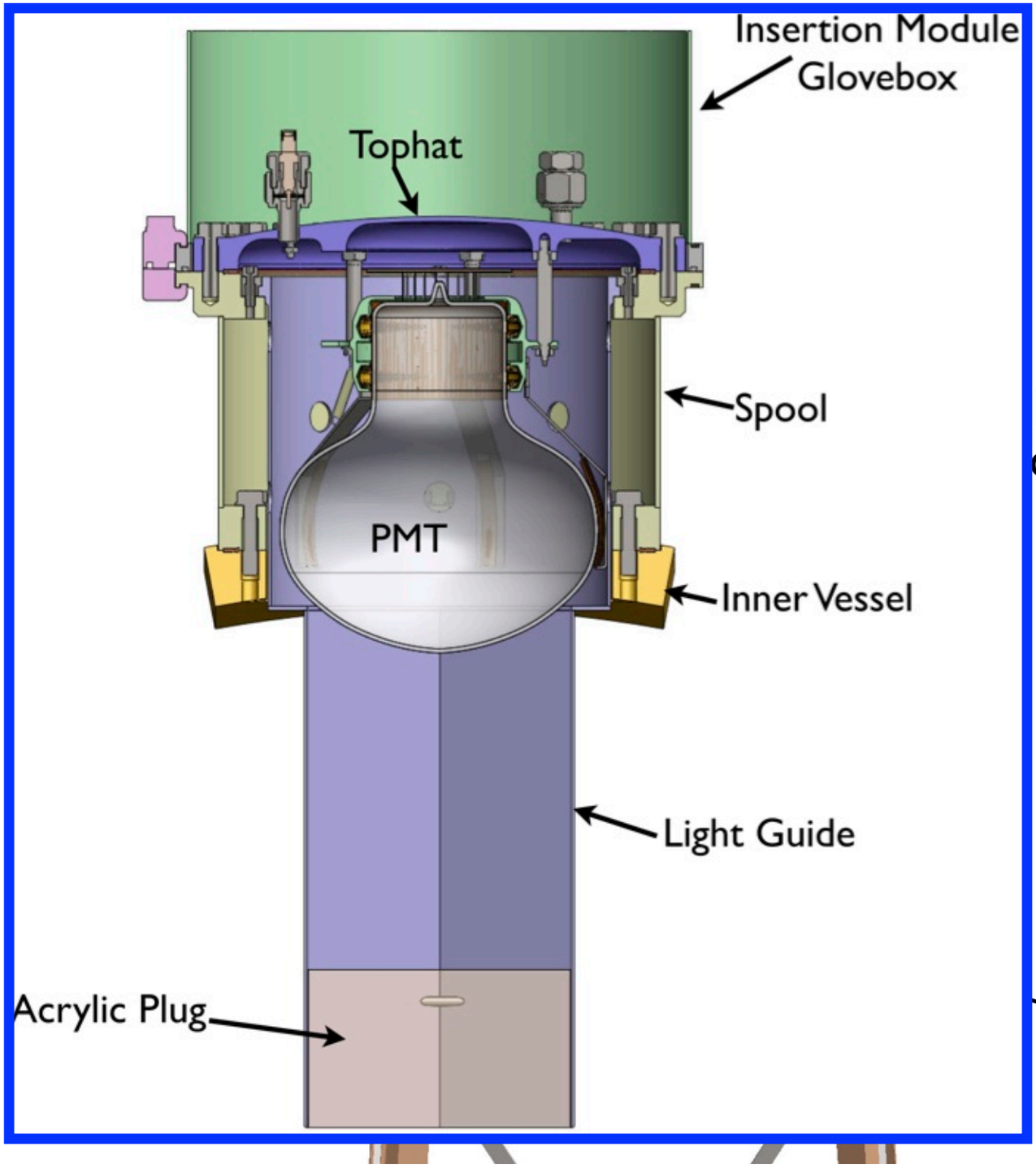
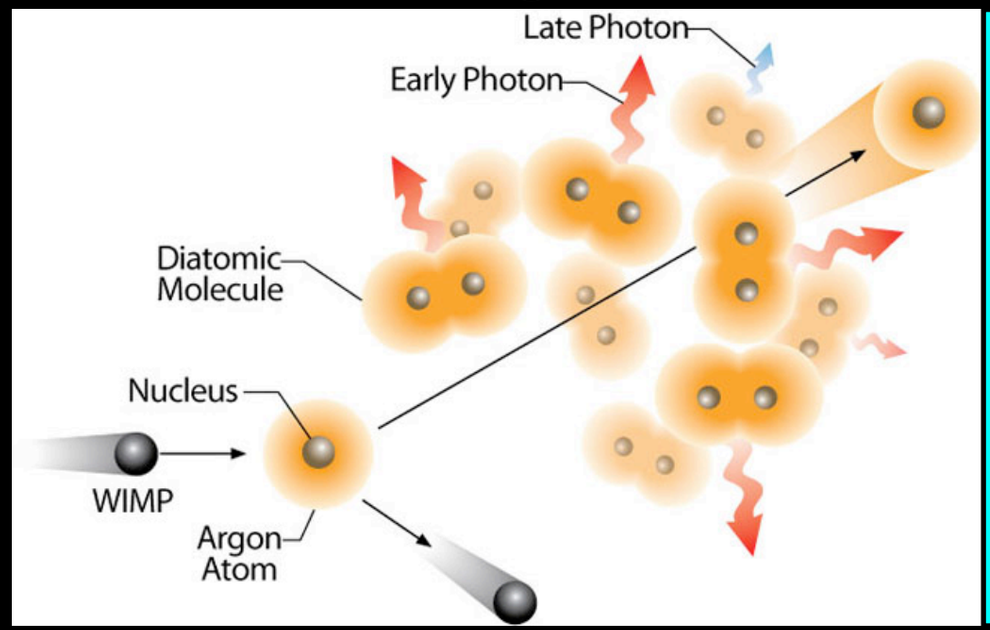
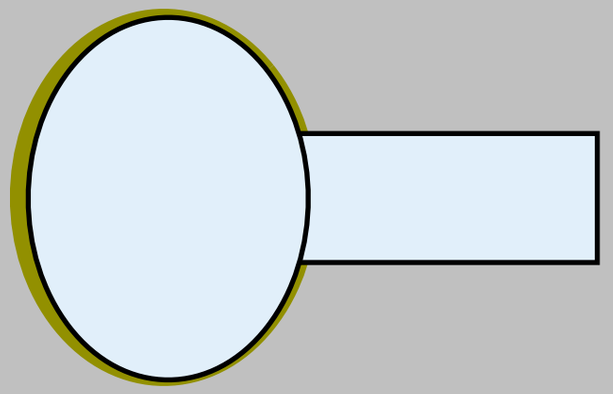


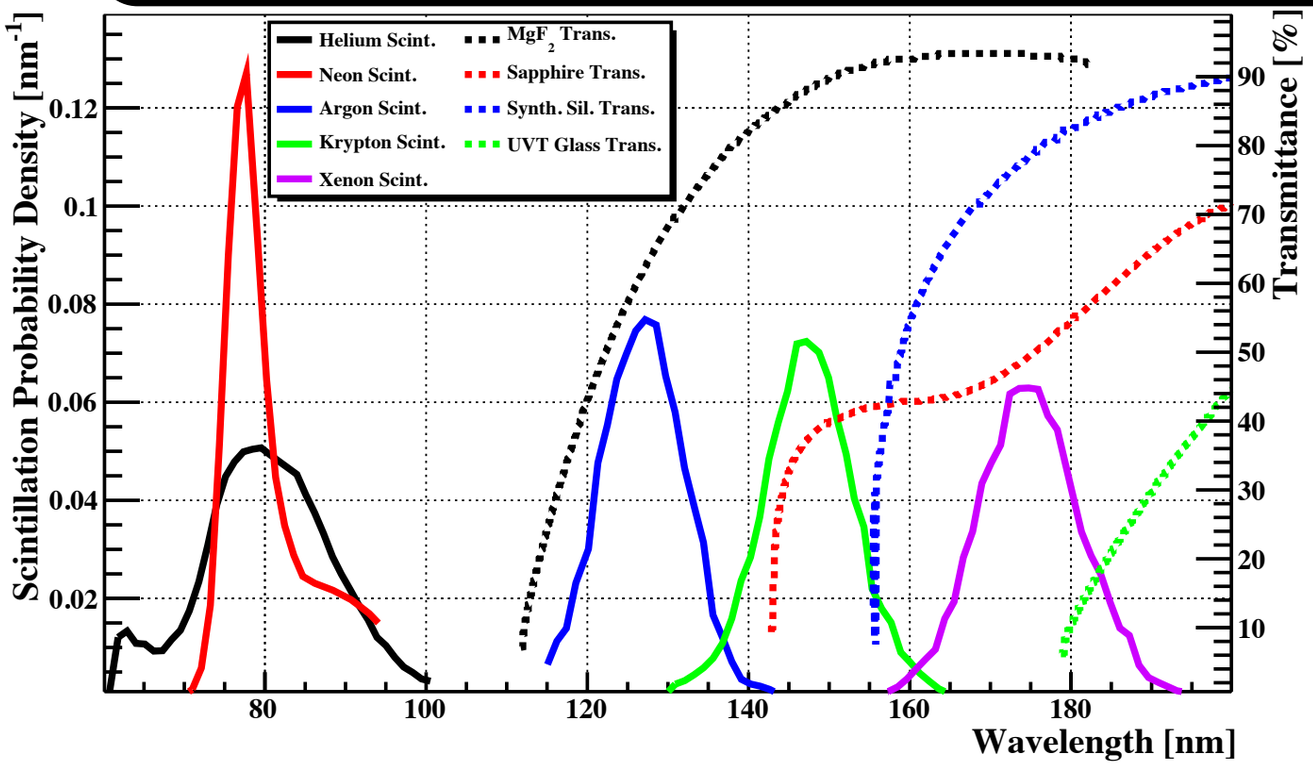
Detector Response

EUV Light → WLS → Visible Light → Charge





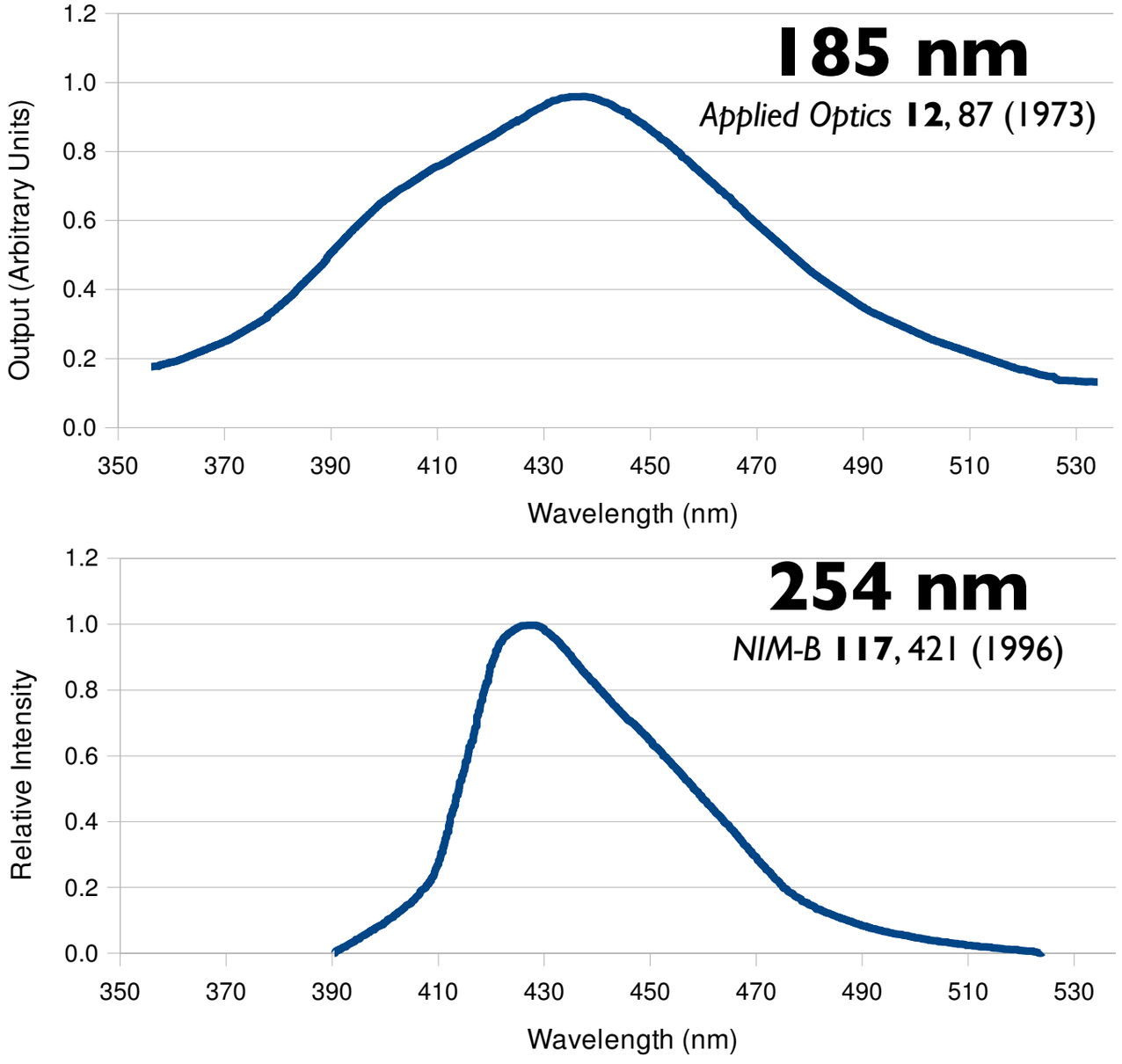
Argon/Neon → TPB → Acrylic/Ar/Ne → PMT



- Noble Elements scintillate in extreme ultraviolet (EUV)
- Essentially no fast, sensitive, big and cheap photon detectors are directly sensitive to EUV
- Characterizing WLS behavior is very important!

Hasn't Someone Done This Already?

- Yes, but…
- There was a lot of ambiguity in the shape of the re-emission spectrum as a function of input wavelength
- Previous efficiency measurements were made relative to other fluors whose absolute efficiency was uncertain to about a factor of two!



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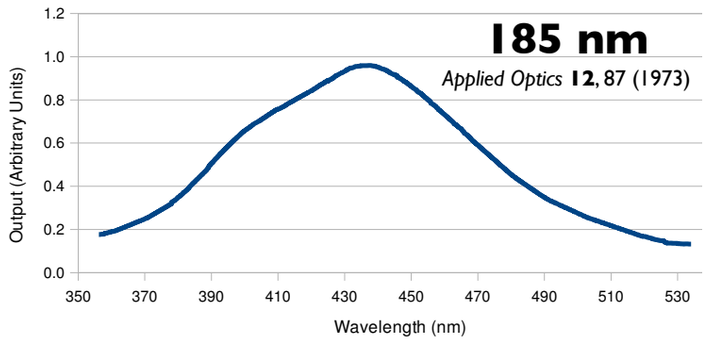

Absolute Efficiency [%]			Layer Thickness
2537 Å	1216 Å	304 Å	[mg / cm^2]
99	94		2–4
	62–80	41	5
65	38		2
50			1–2
64			6
25			?
60			2 mm[a]

[a]Sample was a plaque pressed 2 mm thick

Table reproduced from "Techniques of Vacuum Ultraviolet Spectroscopy," James A. R. Samson, ©1967

Experimental Apparatus

Since we are observing individual photons, we care about the efficiency as a ratio of photon rates.

$$\epsilon(\lambda) = \frac{I_{\mathrm{TPB}} - I_{\mathrm{dark}}}{I_{\mathrm{lamp}} - I_{\mathrm{dark}}} \times g \frac{\int d\lambda' \frac{hc}{\lambda'} C(\lambda') S(\lambda - \lambda')}{\int d\lambda'' \frac{hc}{\lambda''} C(\lambda'') R(\lambda'')}$$

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- Measured by us
- Measured by IRD/NIST
- Calculated from our measurements

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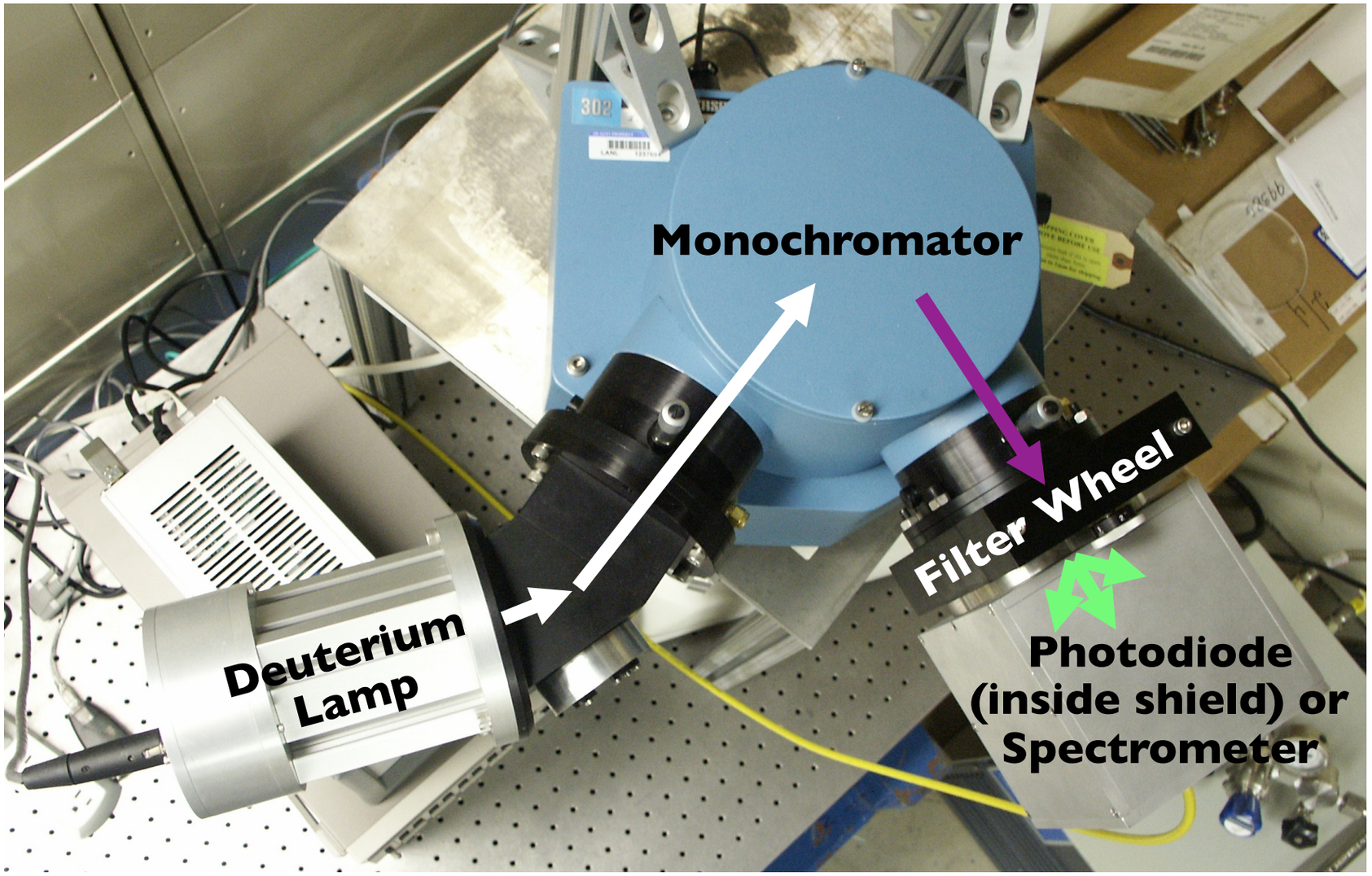

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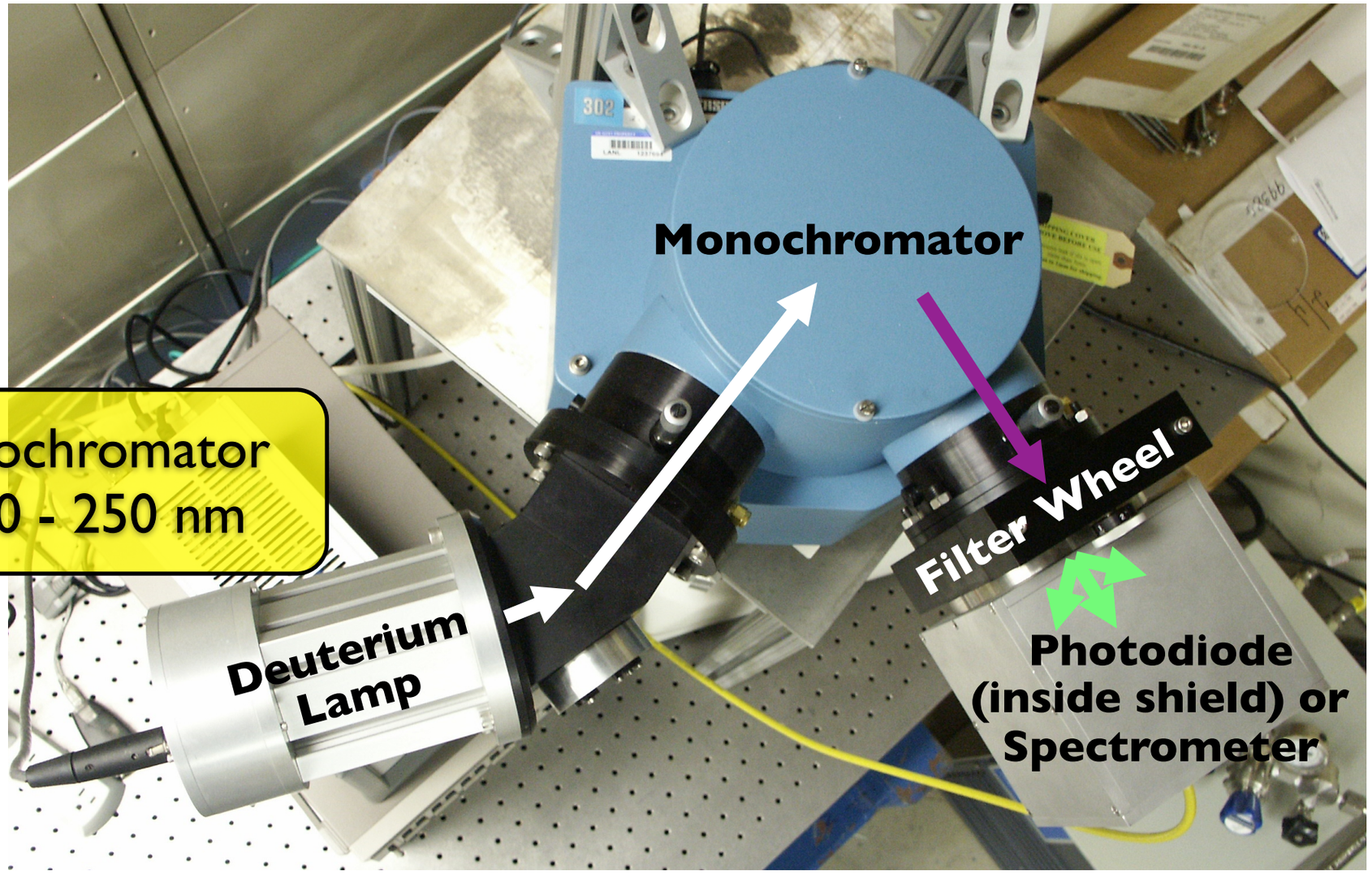

Lamp/Monochromator covers 110 - 250 nm

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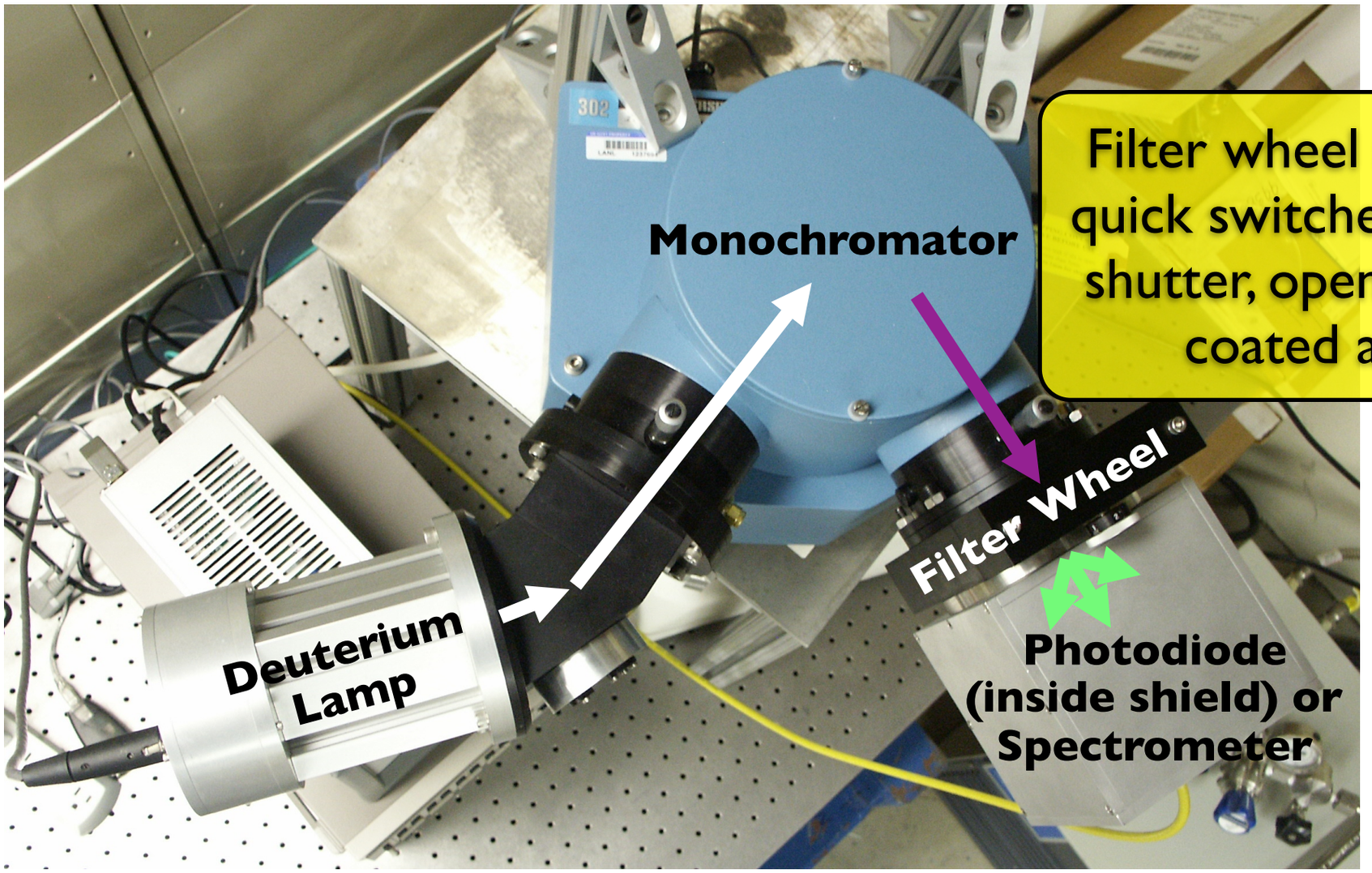

Filter wheel allows for quick switches between shutter, open and TPB-coated acrylic

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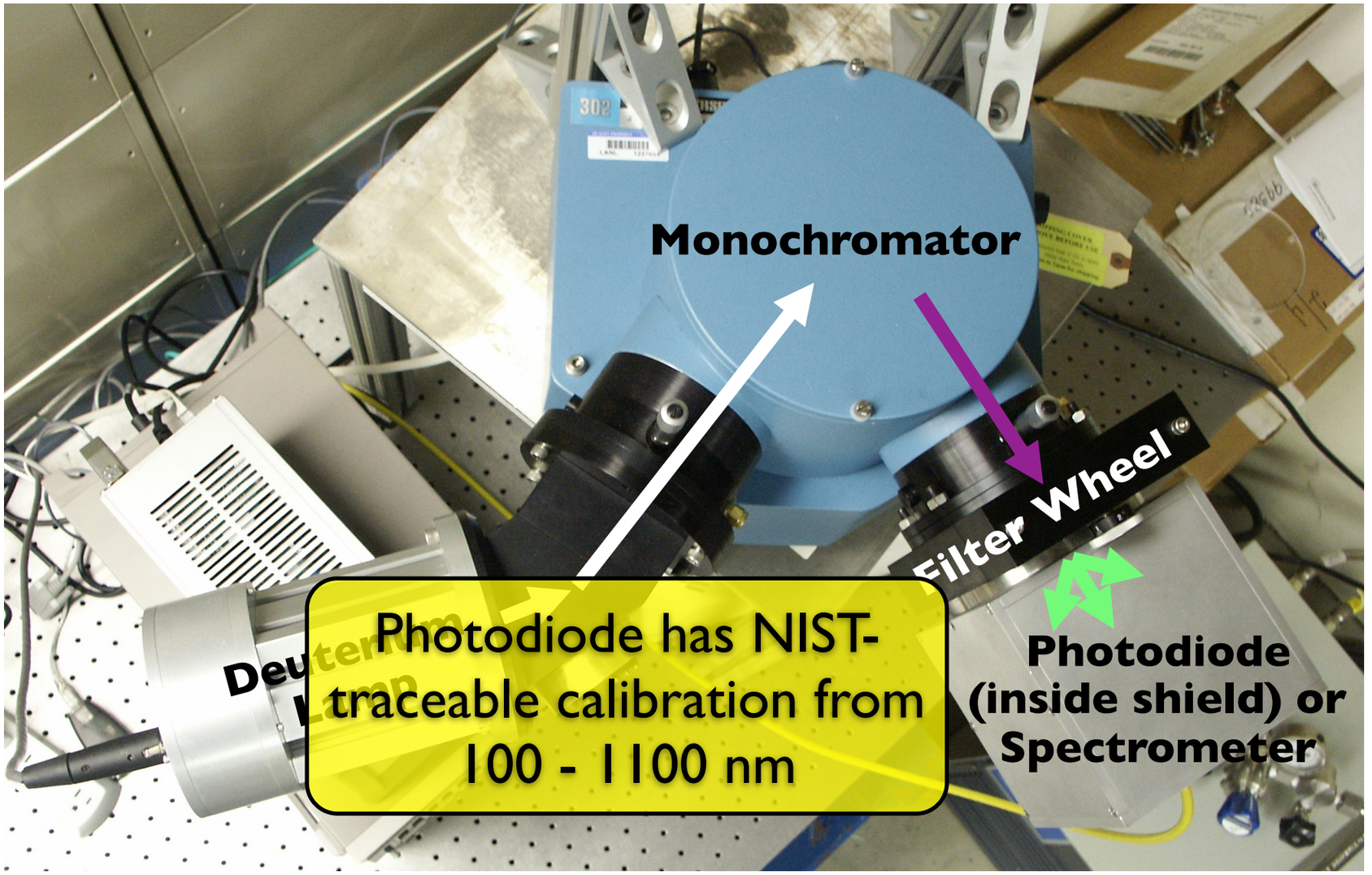

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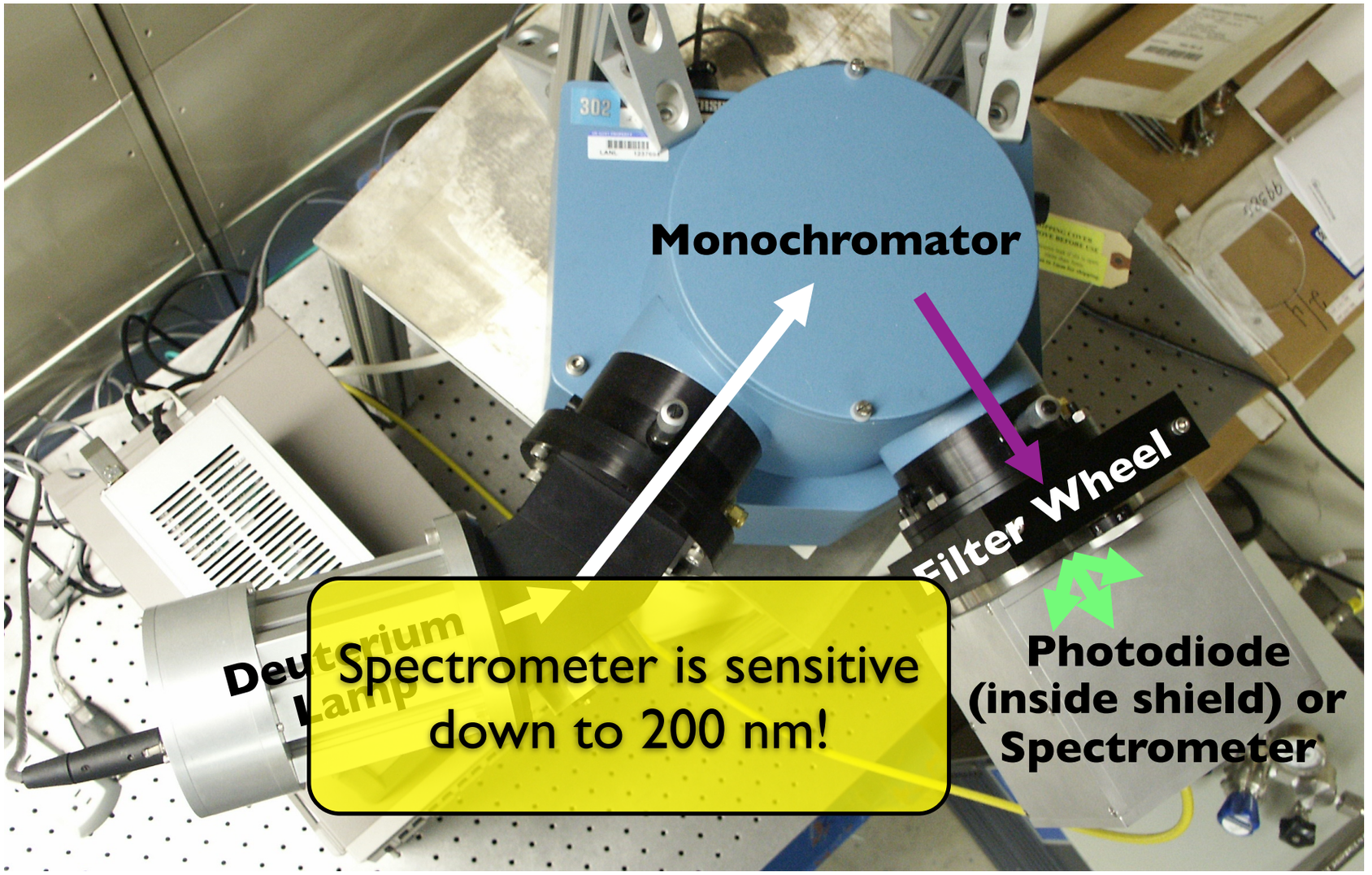
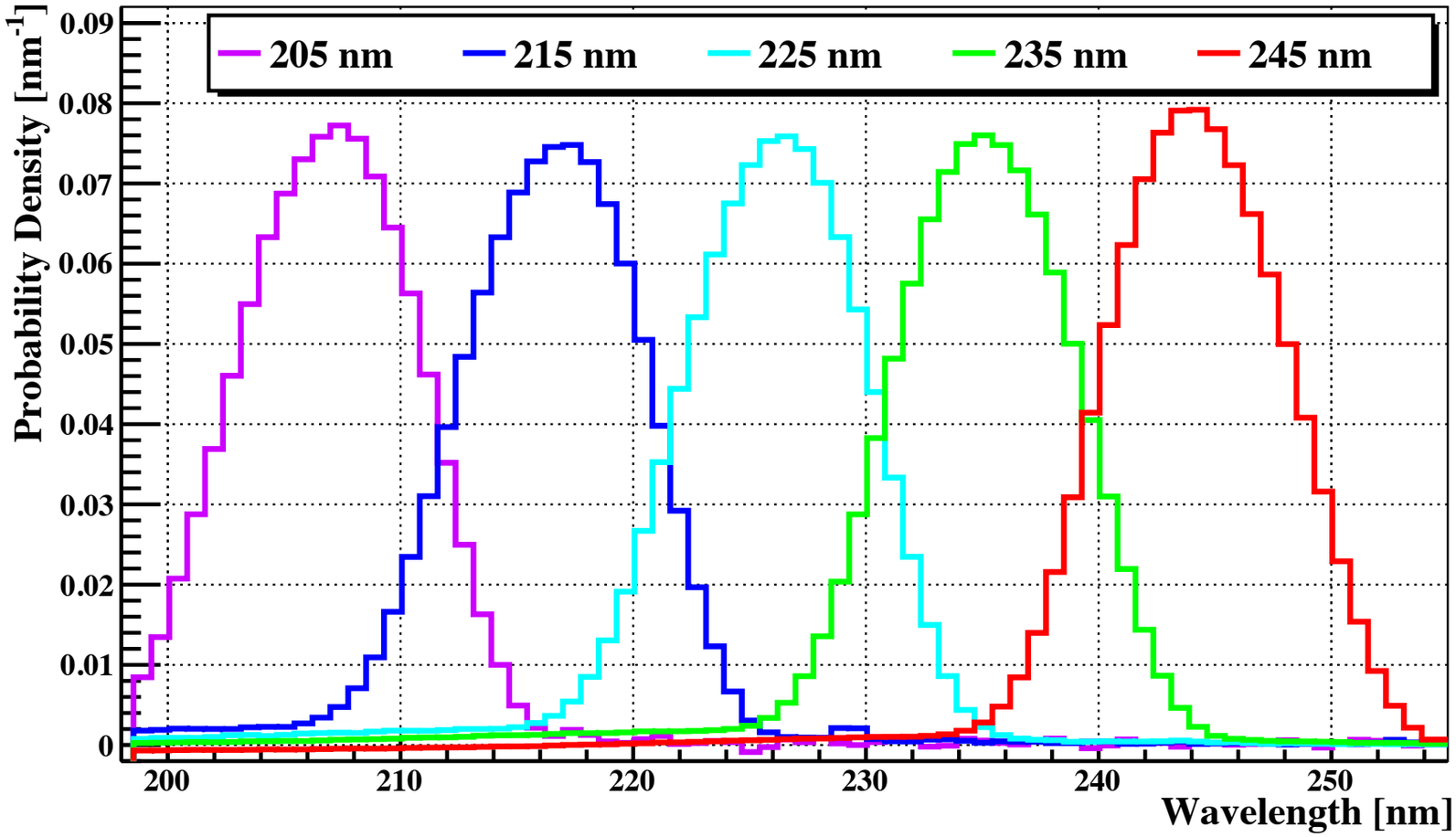


Systematic Checks

- Light source resolution: 8.5 ± 0.5 nm
- TPB film thickness: 1.5 ± 0.05 μm (thin film reflectometry)
- Acrylic (substrate) transmittance
- Optical train (lens, fibers, feedthroughs) transmittance
- Photodiode response (measured by IRD and NIST)



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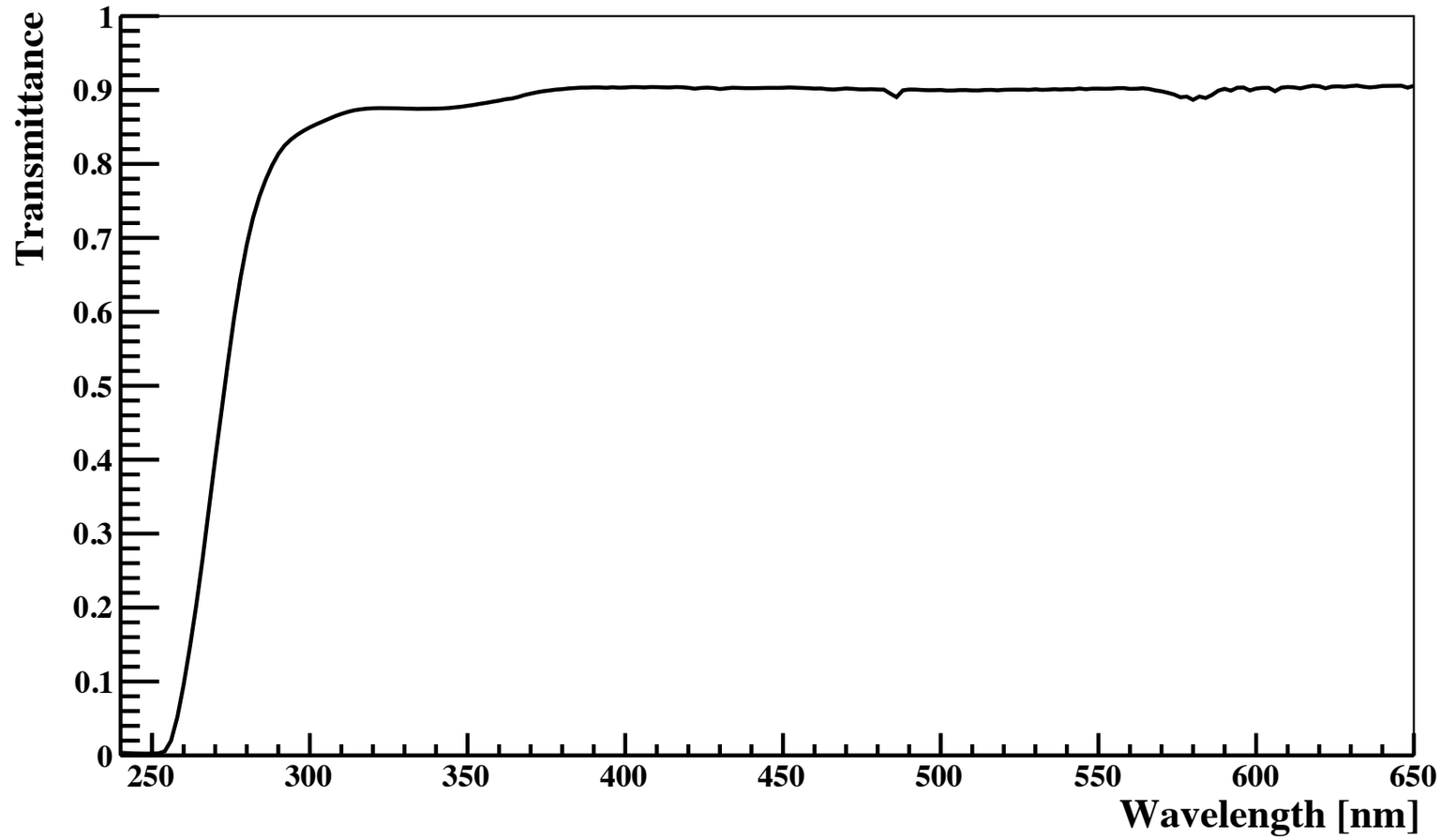

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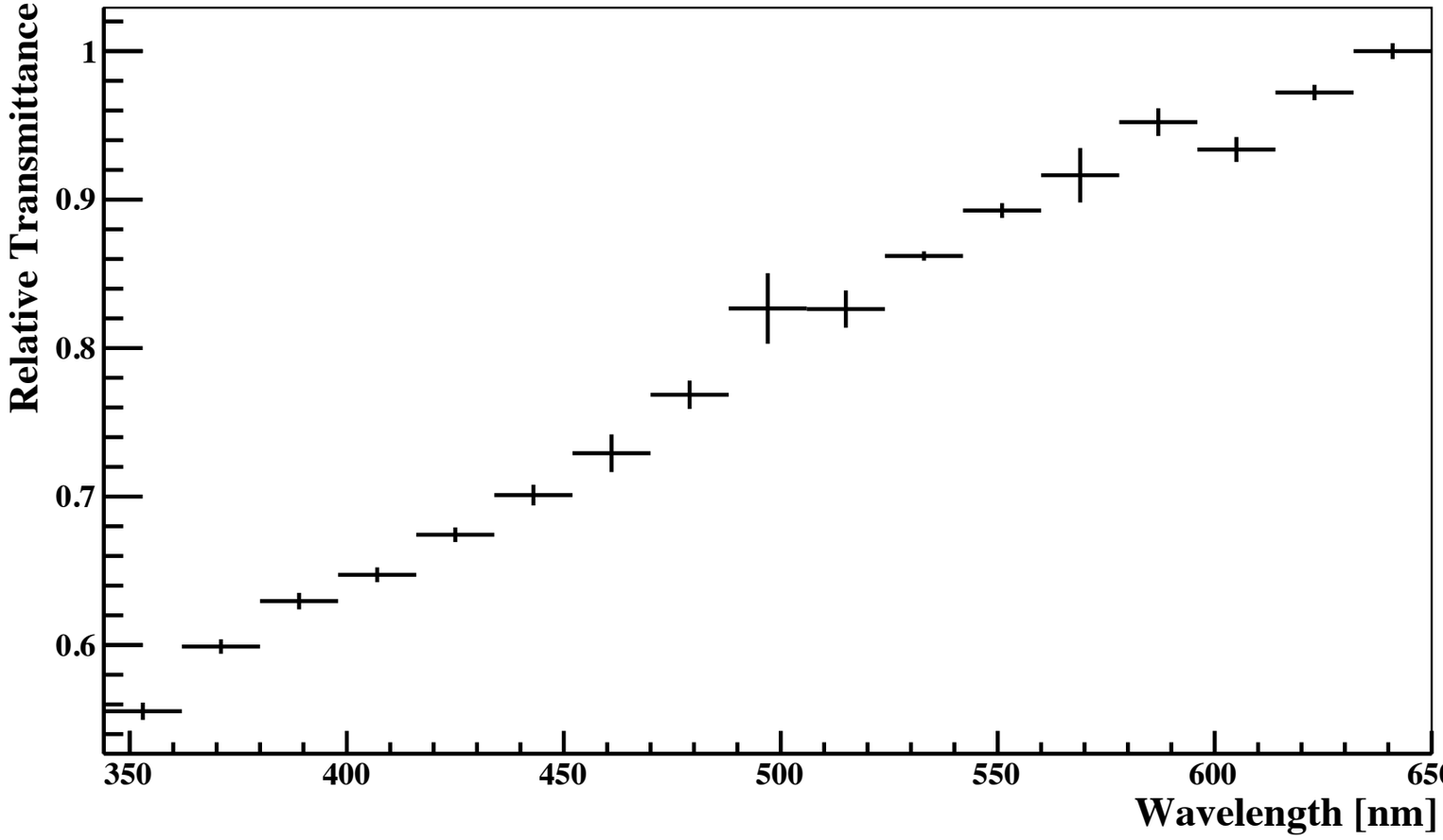

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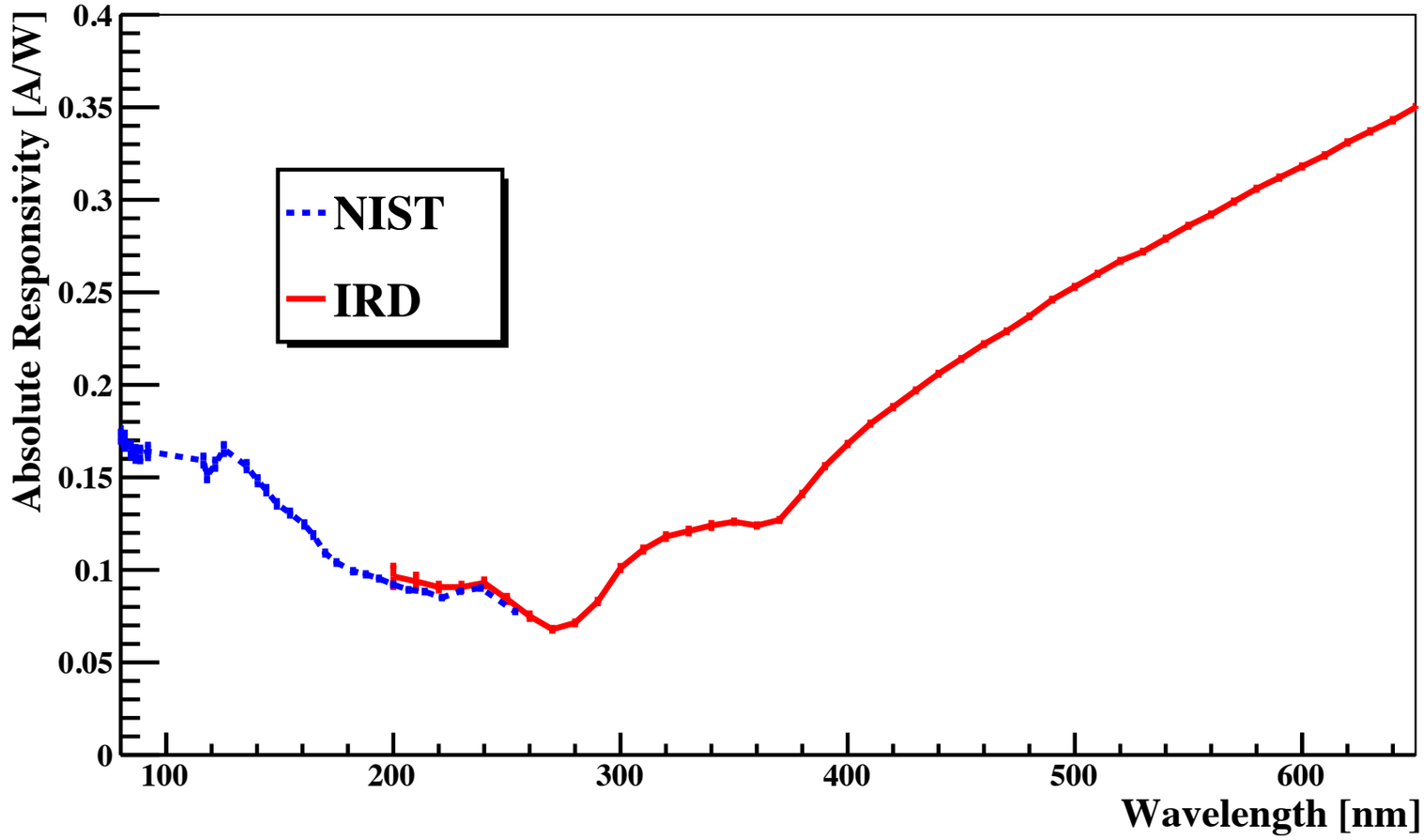
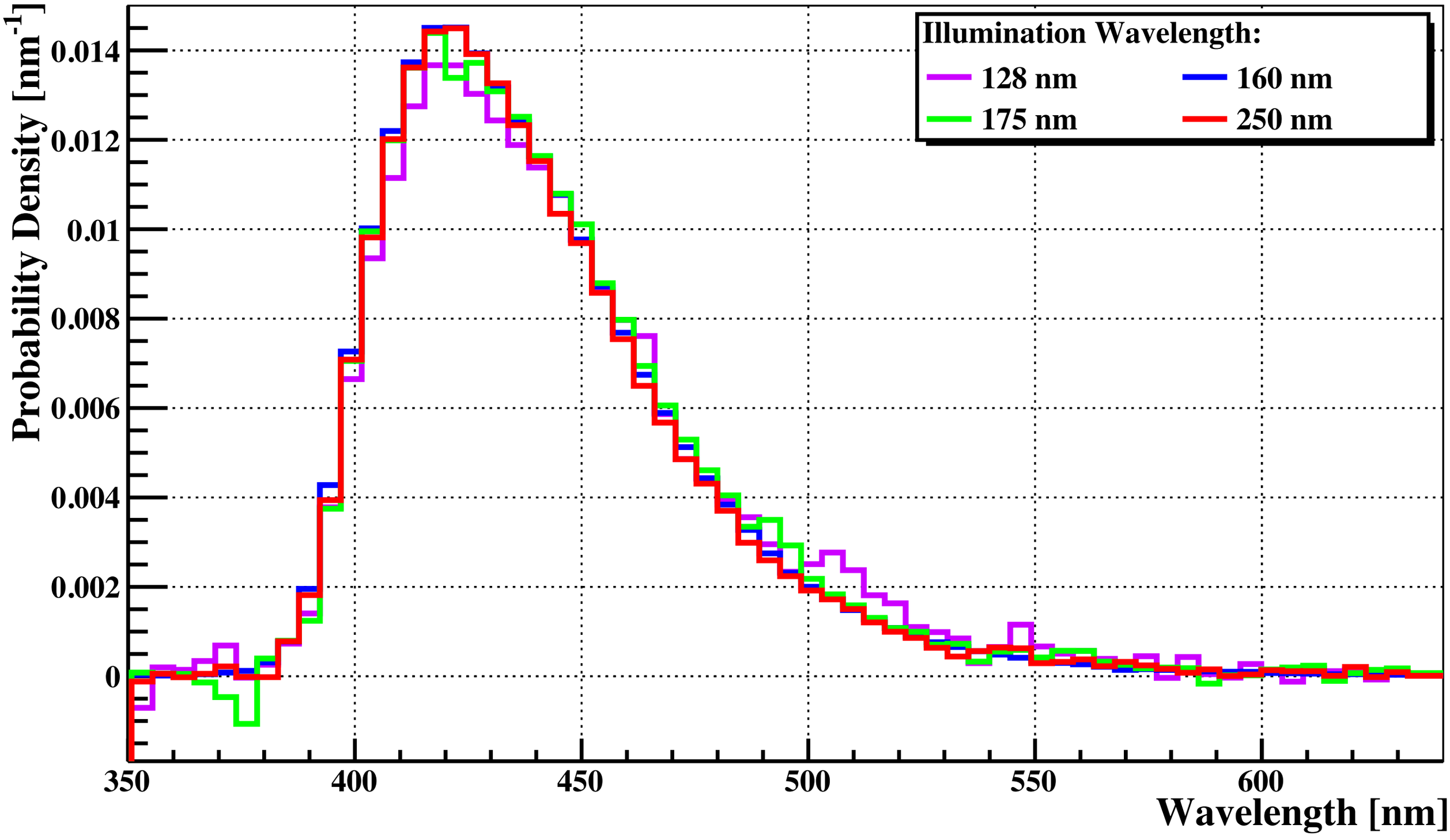


Visible Re-emission Spectrum

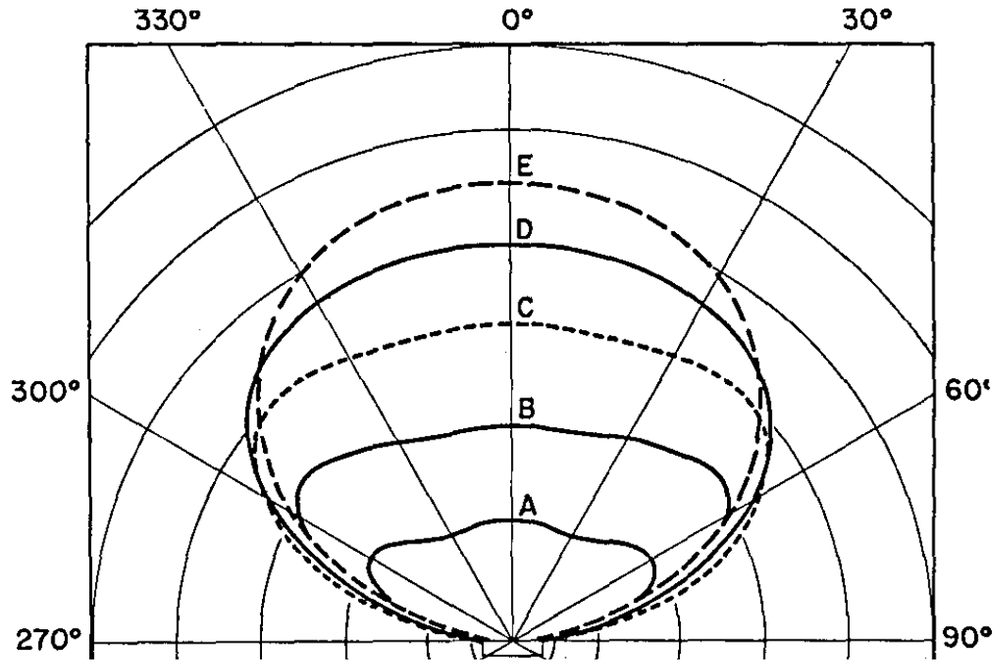


No strong wavelength dependence!

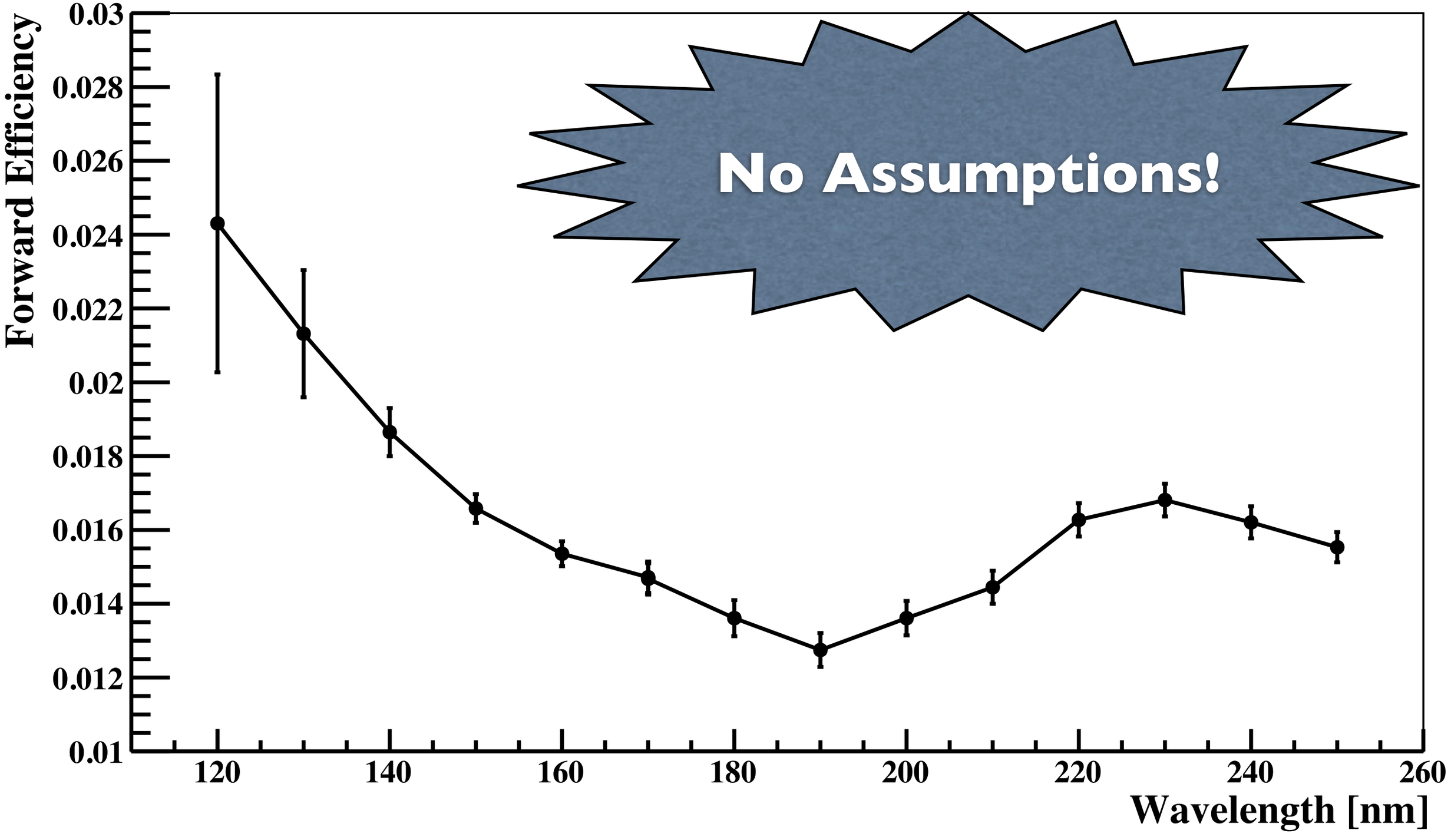
Fluorescence Efficiency

- The absolute efficiency calculation adds one more ambiguity: *angular distribution of re-emission light*
  - No published measurements for TPB!
  - Most naive assumption (isotropic re-emission) gives unphysically high efficiencies
- Found published angular distribution for *Sodium Salicylate* (the "other fluor" from Slide 4)
- Follows Lambertian (cosine) distribution
- Calculated "Forward Efficiency" (re-emission at 0°, no assumptions) and total efficiency (more useful, requires Lambertian assumption)

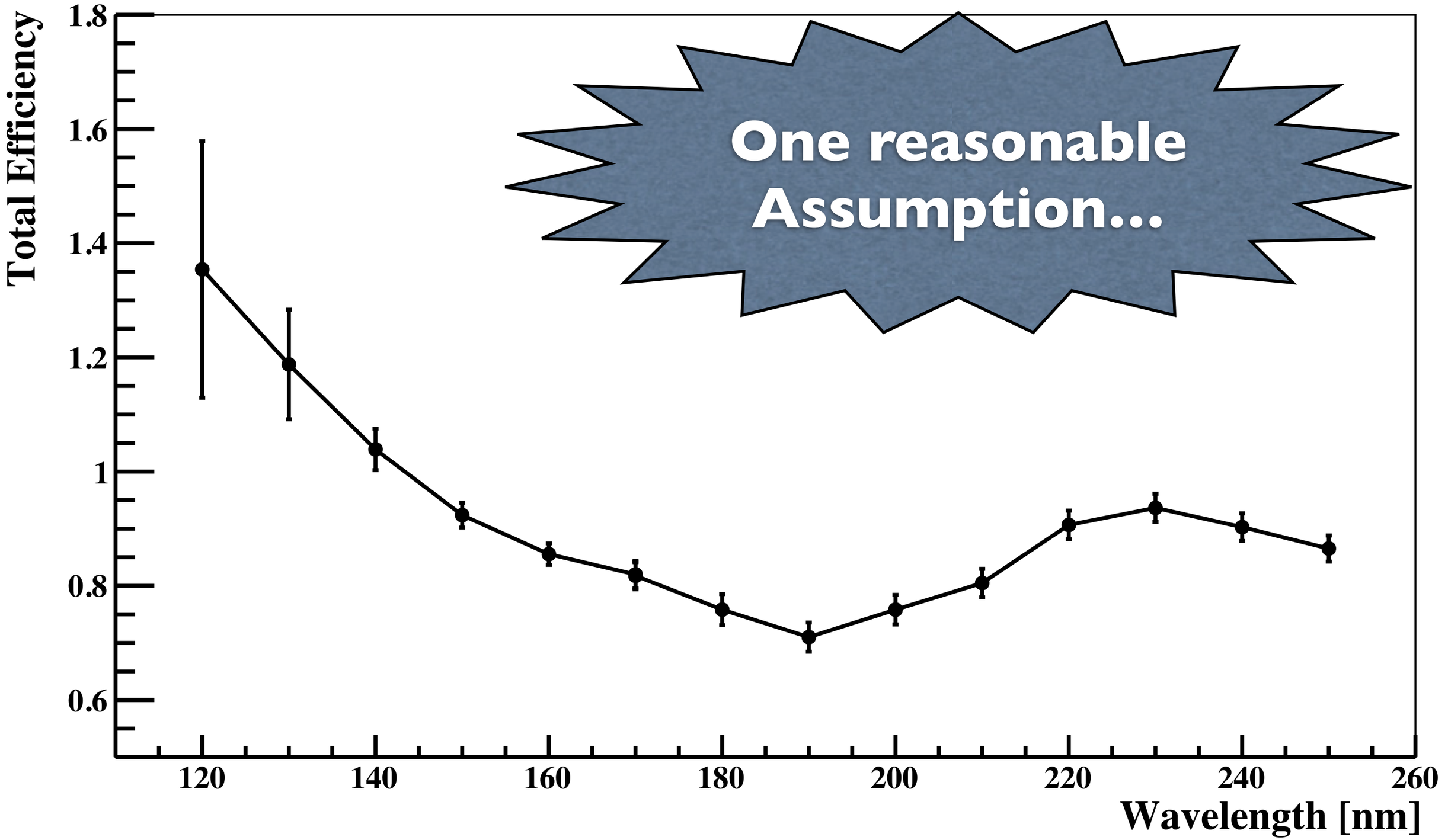
J. Opt. Soc. Am., **54**, 747 (1964), Fig. 3



Forward Fluorescence Efficiency



Total Fluorescence Efficiency



Thank you for your attention!

Any questions?

You can also read the preprint:
arXiv:1104.3259v1 [astro-ph.IM]