

A glowing vacuum photodiode tube is the central focus, set against a warm, orange-toned background. The tube is illuminated from within, creating a bright, hazy glow that fades into the surrounding color. The text is overlaid on this background.

Long-Term Stability of Bi-Planar Vacuum Photodiodes

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- **ACKNOWLEDGMENT**

This project was supported in part by an appointment to the Internship/Research Participation Program for the U.S. Army Center for Health Promotion and Preventive Medicine administered by the Oak Ridge Institute for Science and Education through an agreement between the U.S. Department of Energy and the USACHPPM.

- **DISCLAIMER**

The opinions or assertions herein are those of the authors and should not be construed as official positions of the U.S. Department of the Army or the U.S. Department of Defense.

Topics

- Background
- Visible Radiation Detectors (S20)
- NIR Radiation Detectors (S1)
- UV detectors (S5)
- VIS-NIR detectors (Si PIN)
- Comparison
- Identifying Problems
- Current Availability
- Questions
- References

Background

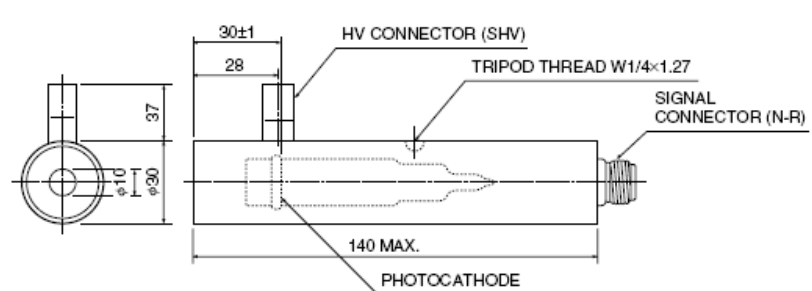
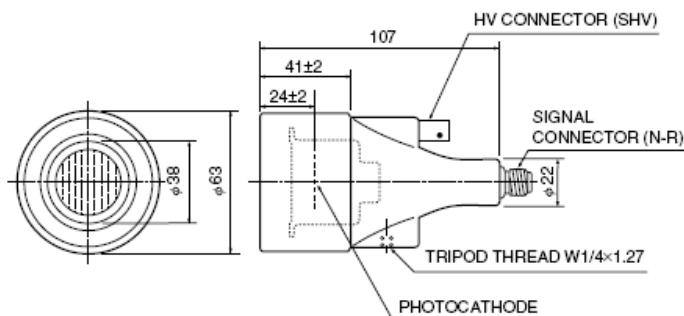
- USACHPPM Laser/Optical Radiation program determines hazards from lasers systems and high intensity optical sources for the U.S. Army to prevent injuries.
- Radiometers containing biplanar vacuum photodiodes have been the work-horse of our program for >30 years.
- Originally, radiometer was designed to measure optical radiation from nuclear fireball.
- Routinely shipped and subjected to field measurements conditions (rough handling, environmental extremes).

Background

- Biplanar Vacuum Photodiode
 - *Biplanar vacuum photodiodes* or *phototubes* consist of a plane wire mesh anode and a plane opaque cathode separated by a few mm.
 - Radiation on anode causes electron to be ejected by photoelectric effect.



Background



Background

- In General:
 - Rise/fall times in 10's ps currently available
 - Phototubes show virtually no fluctuation with changes in the ambient temperature
 - no problems with surface linearity
 - RCA phototube handbook, 1950: “negligible drop in sensitivity values for different degrees of illumination and over long periods of use”

Background

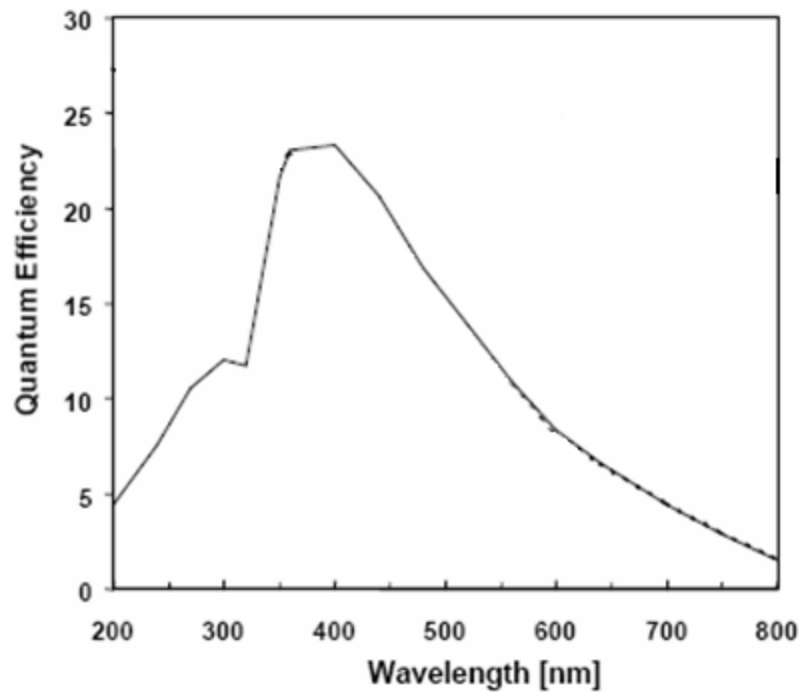
- Our program has retained calibration data for S1 (Ag-O-Cs, 350 – 1150 nm), S20 (Na₂KSb:Cs, 350 – 800 nm), and S5 (Cs₃Sb, 200-750 nm) biplanar vacuum photodiodes.
- Detectors have proven to be rugged, reliable, and stable over long periods of extensive use.
- Rise/fall times ~ 1 ns.

Background

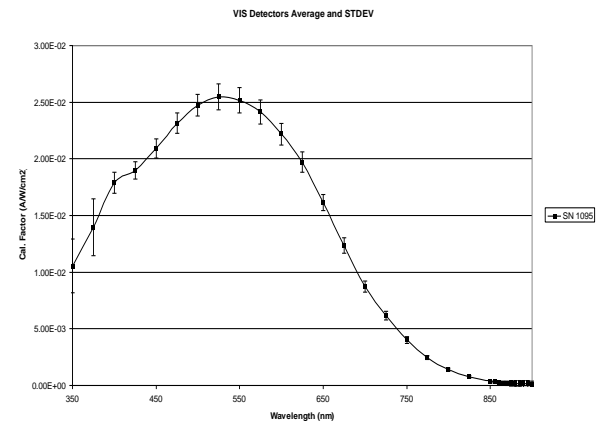
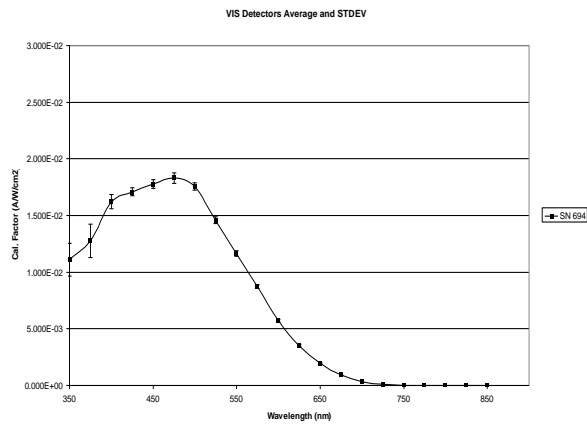
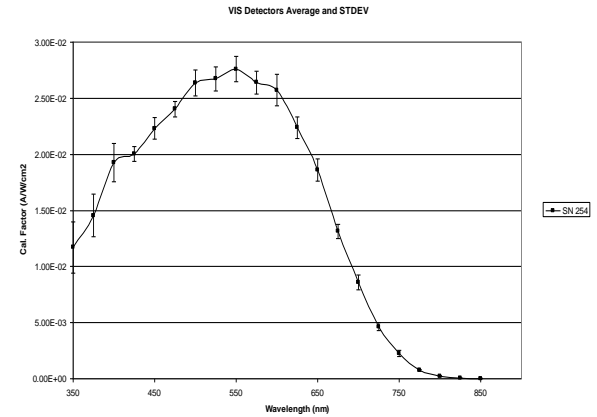
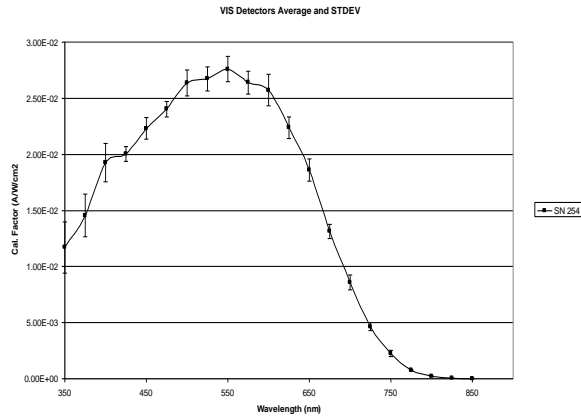
- Linear Dynamic Range of 12 orders of magnitude.
- Accuracy of $\pm 8\%$ in visible and NIR, $\pm 15\%$ in UV; $< 1\%$ error in precision
- 14° acceptance cone

Visible Radiation Detectors (S20)

- 350 – 850 nm

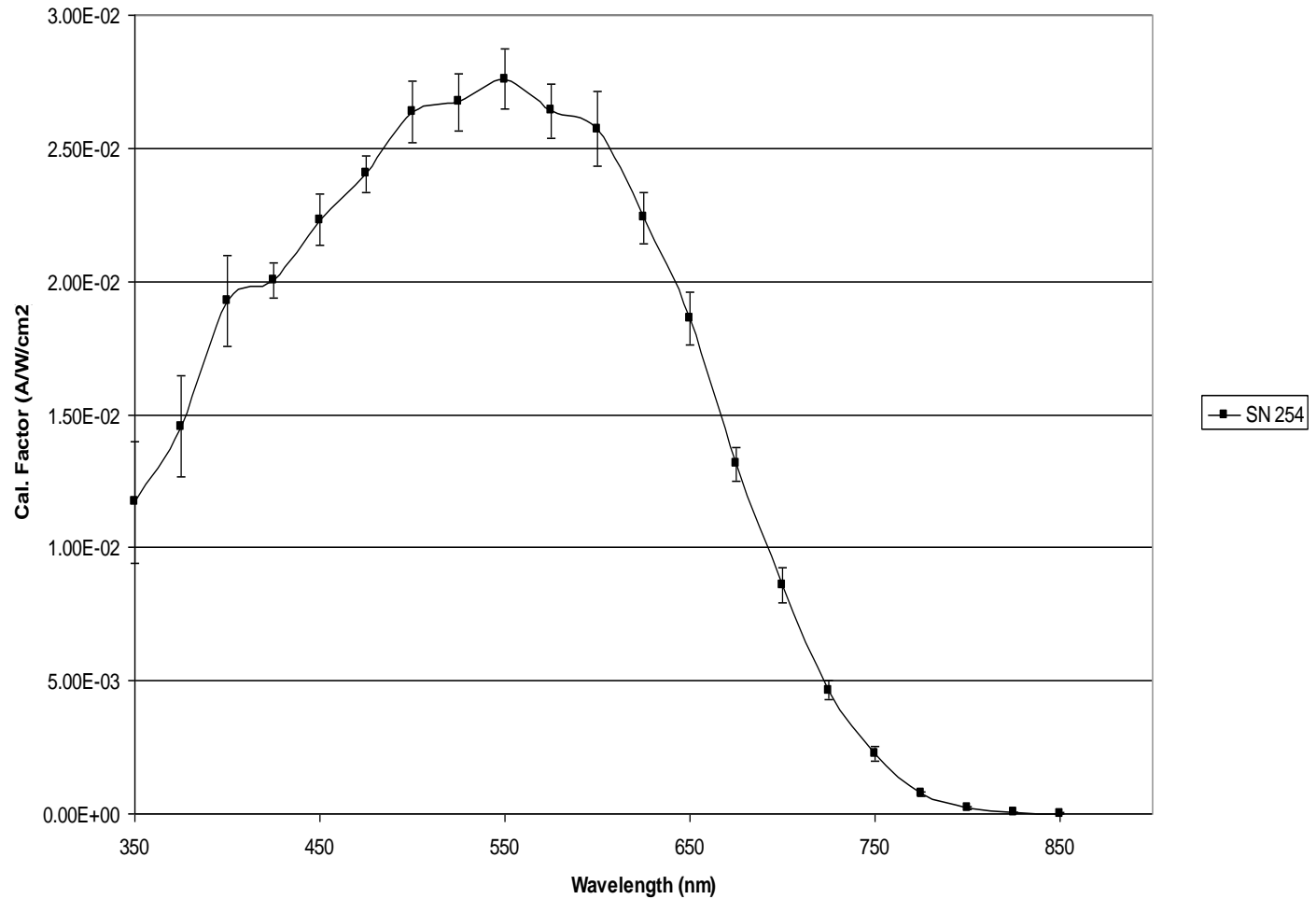


Visible Radiation Detectors (S20)



Visible Radiation Detectors (S20)

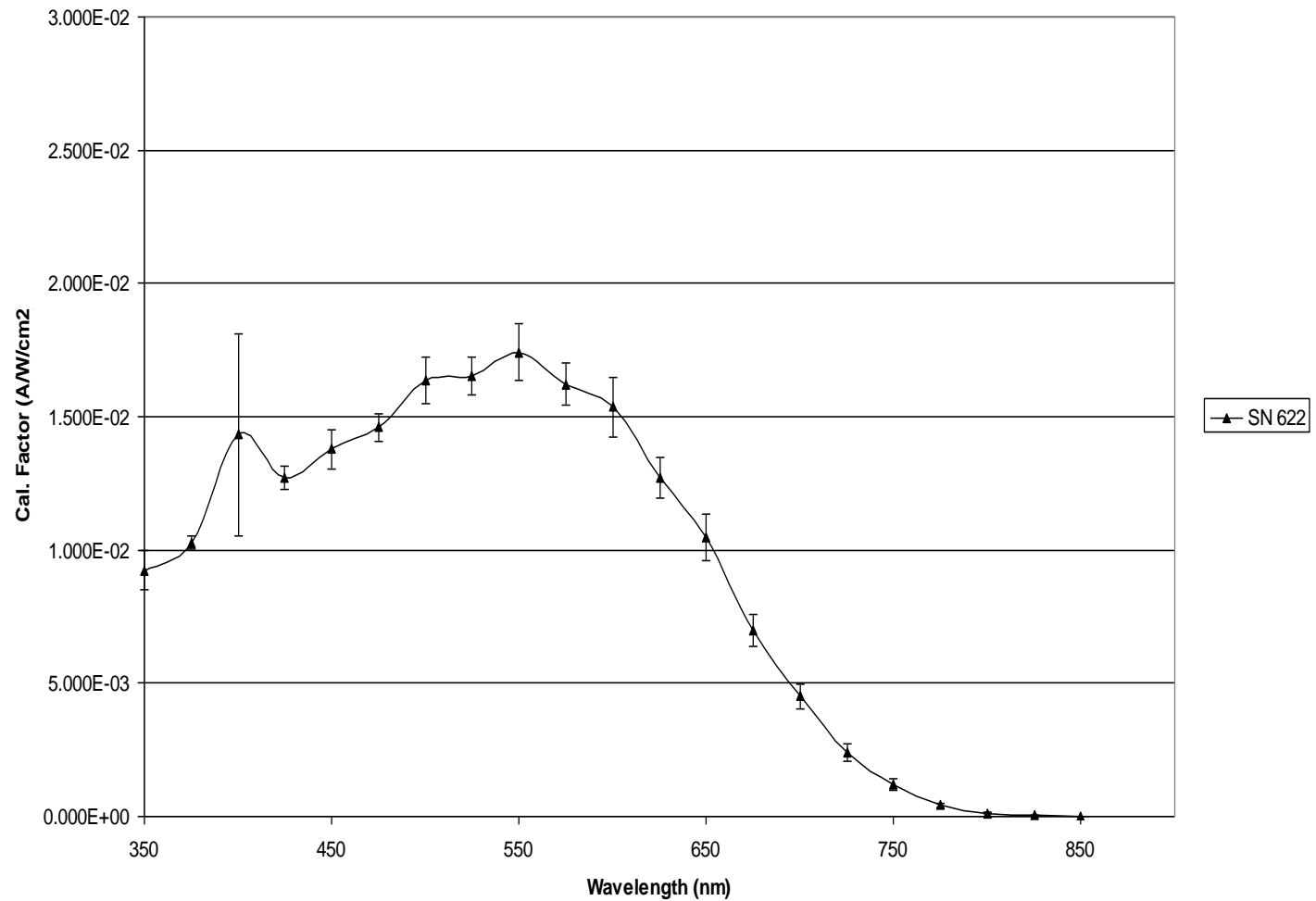
VIS Detectors Average and STDEV



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Visible Radiation Detectors (S20)

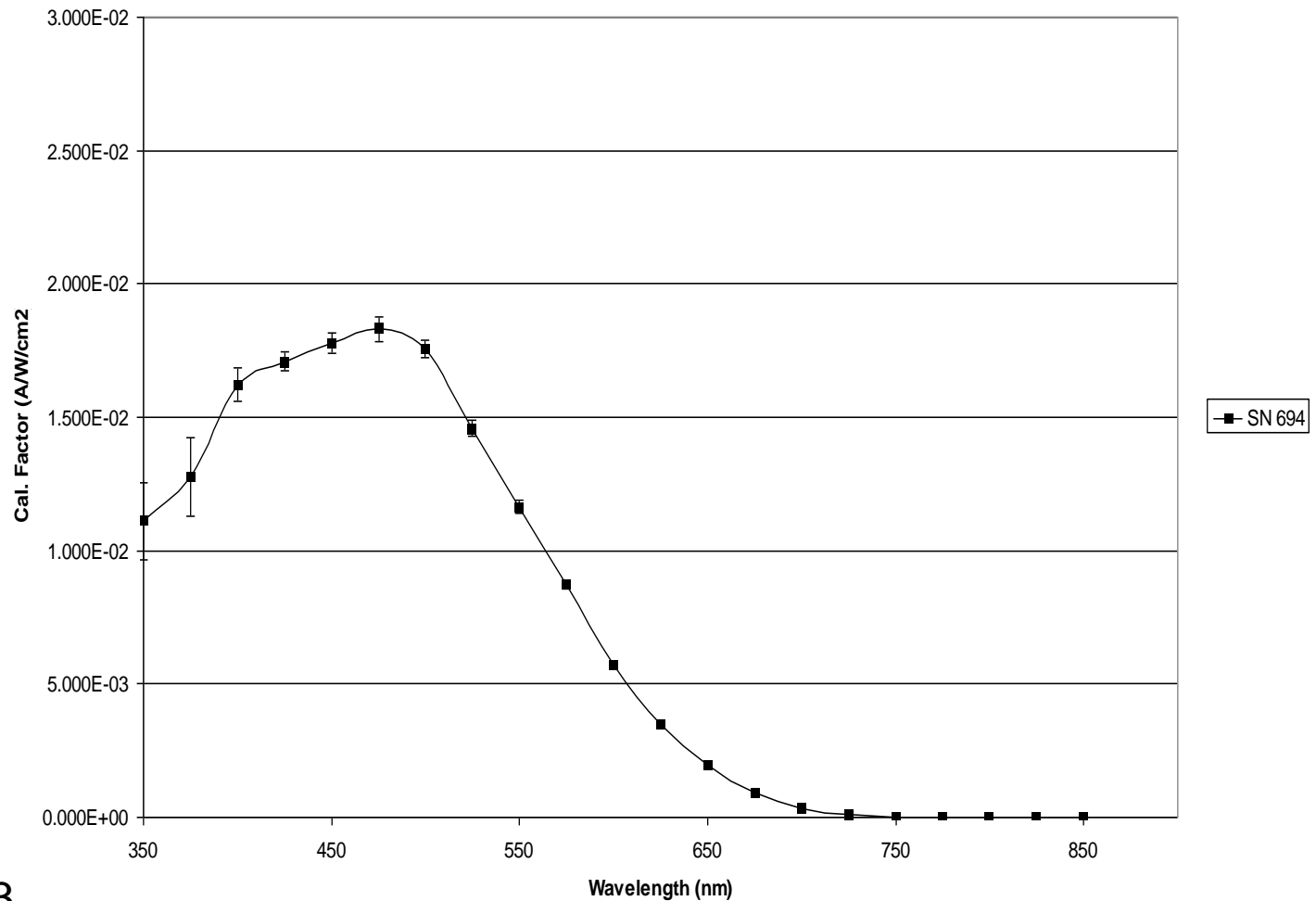
VIS Detectors Average and STDEV



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Visible Radiation Detectors (S20)

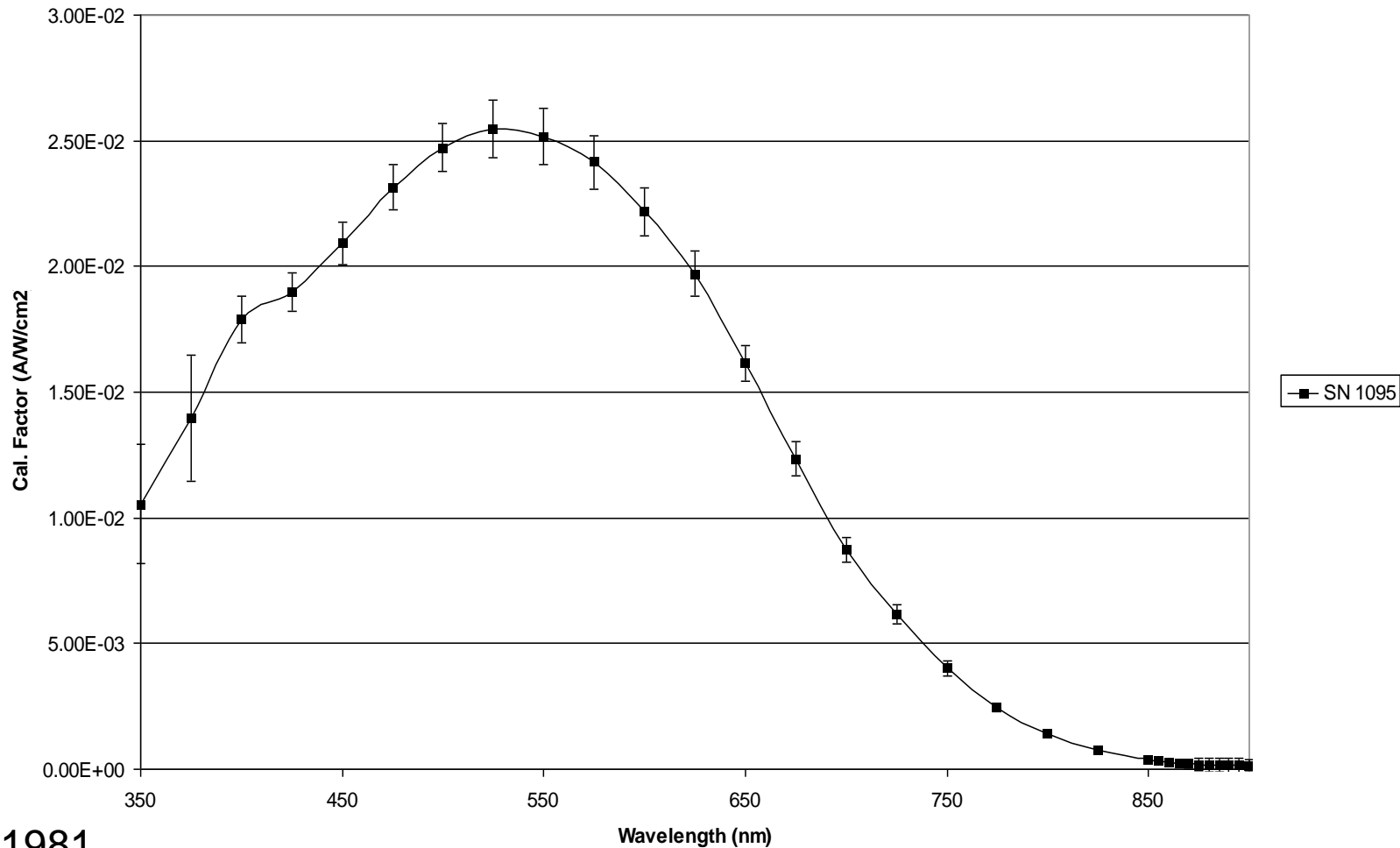
VIS Detectors Average and STDEV



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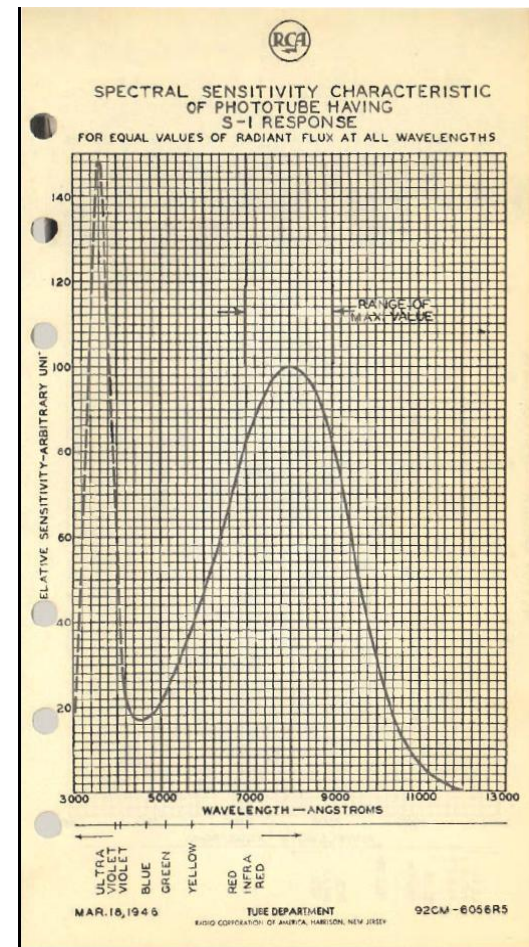
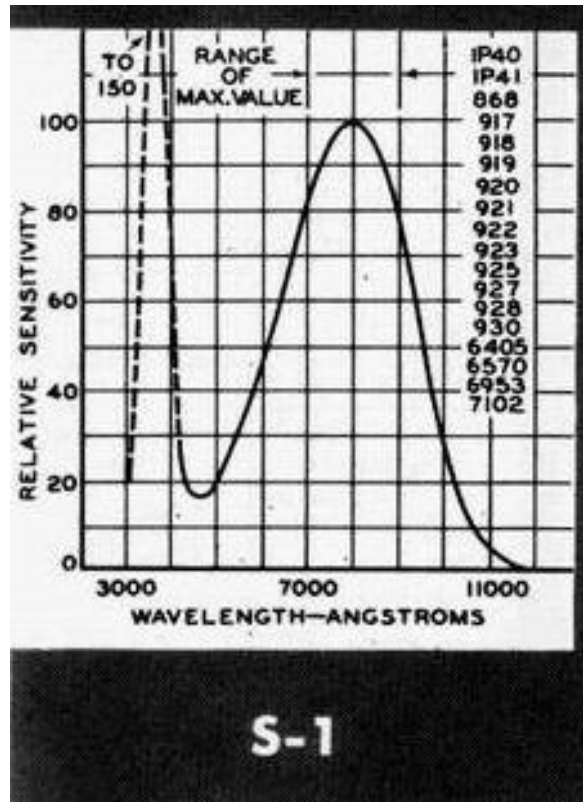
Visible Radiation Detectors (S20)

VIS Detectors Average and STDEV

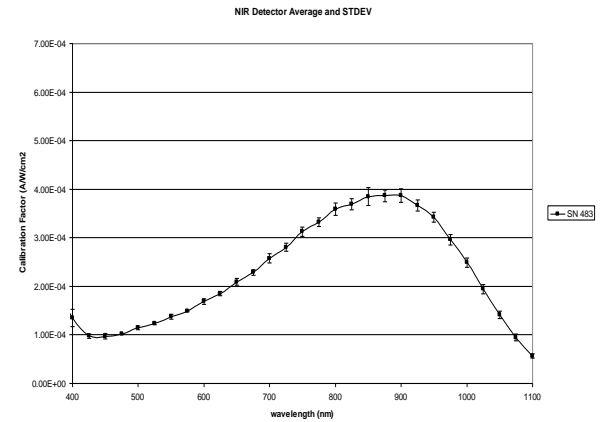
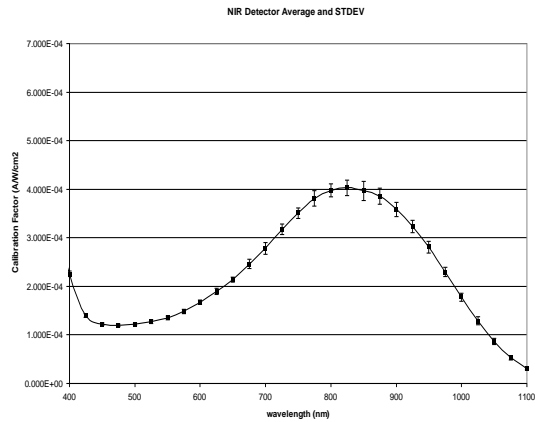
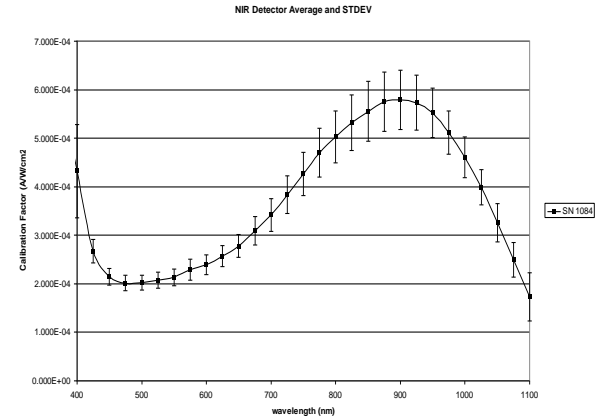
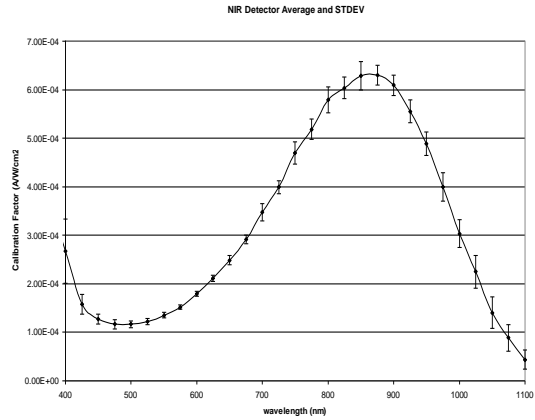


NIR Radiation Detectors (S1)

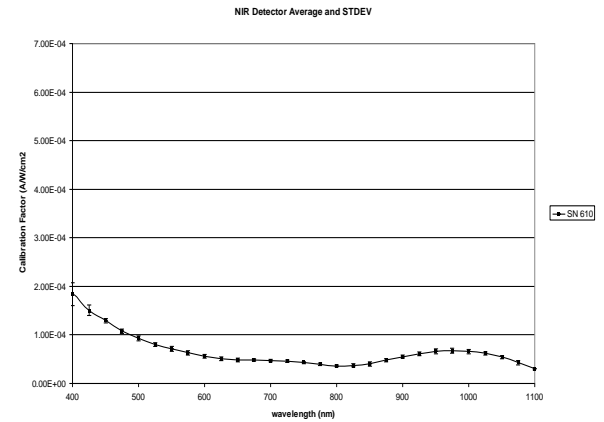
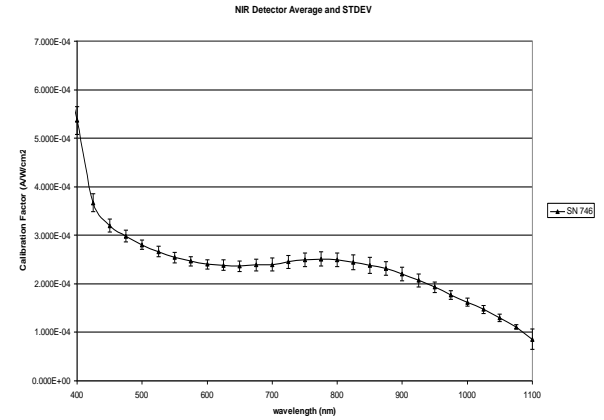
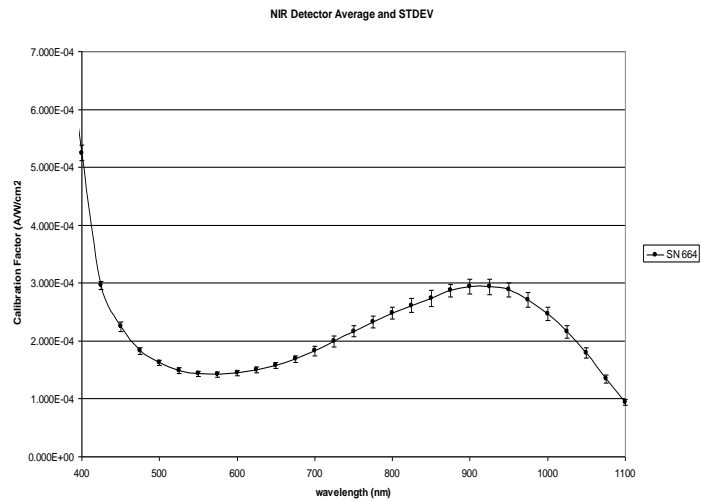
- 350 – 1150 nm



NIR Radiation Detectors (S1)

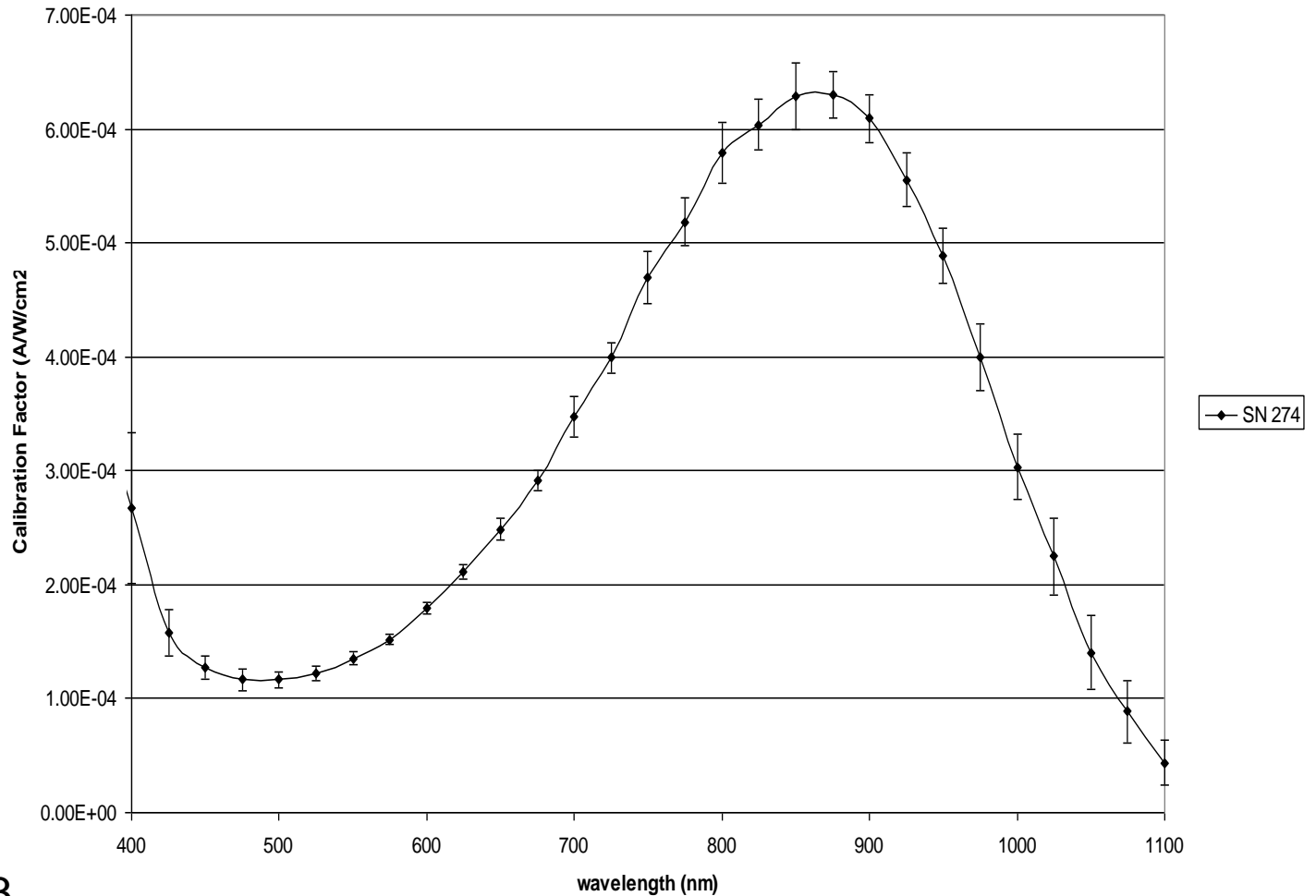


NIR Radiation Detectors (S1)



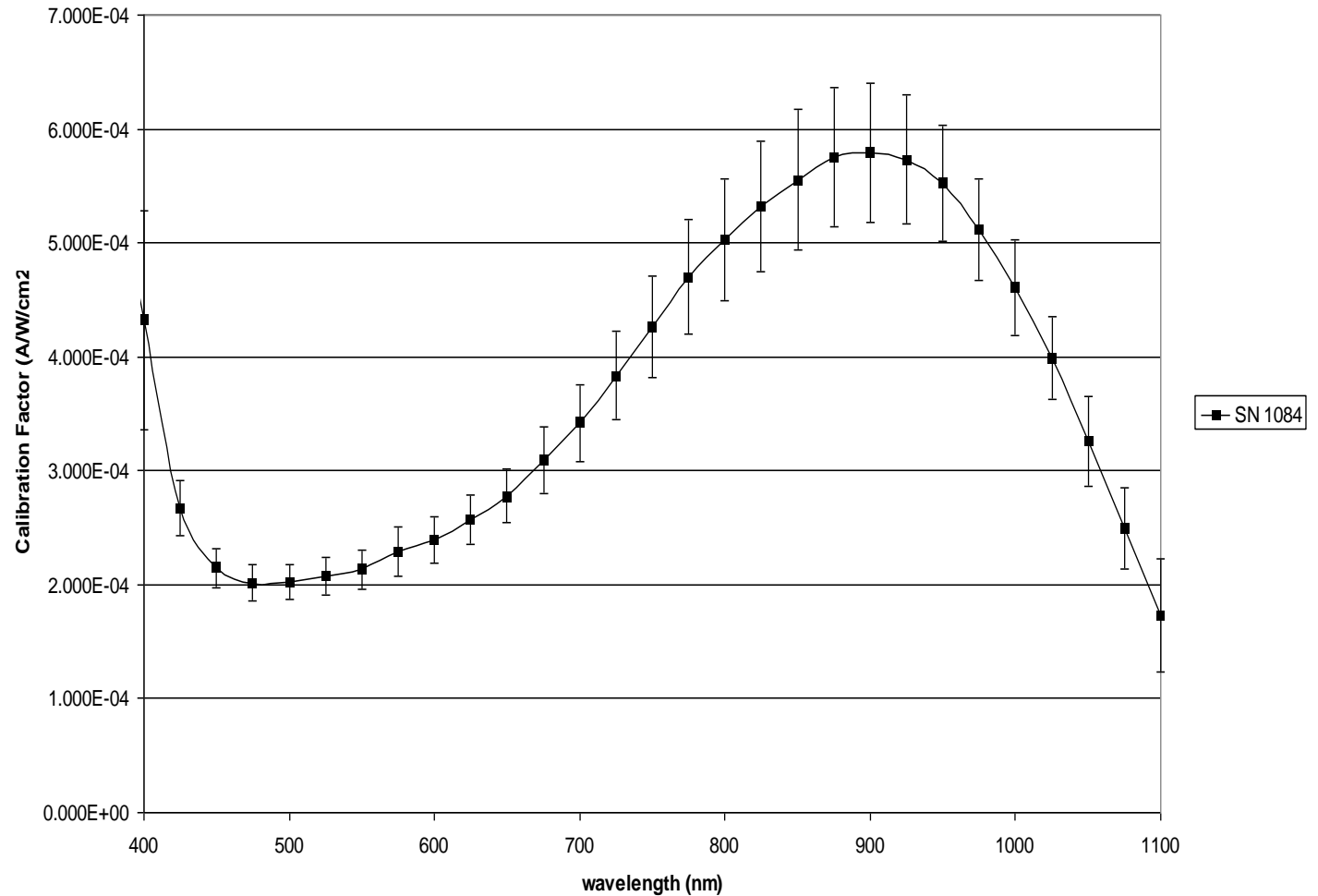
NIR Radiation Detectors (S1)

NIR Detector Average and STDEV



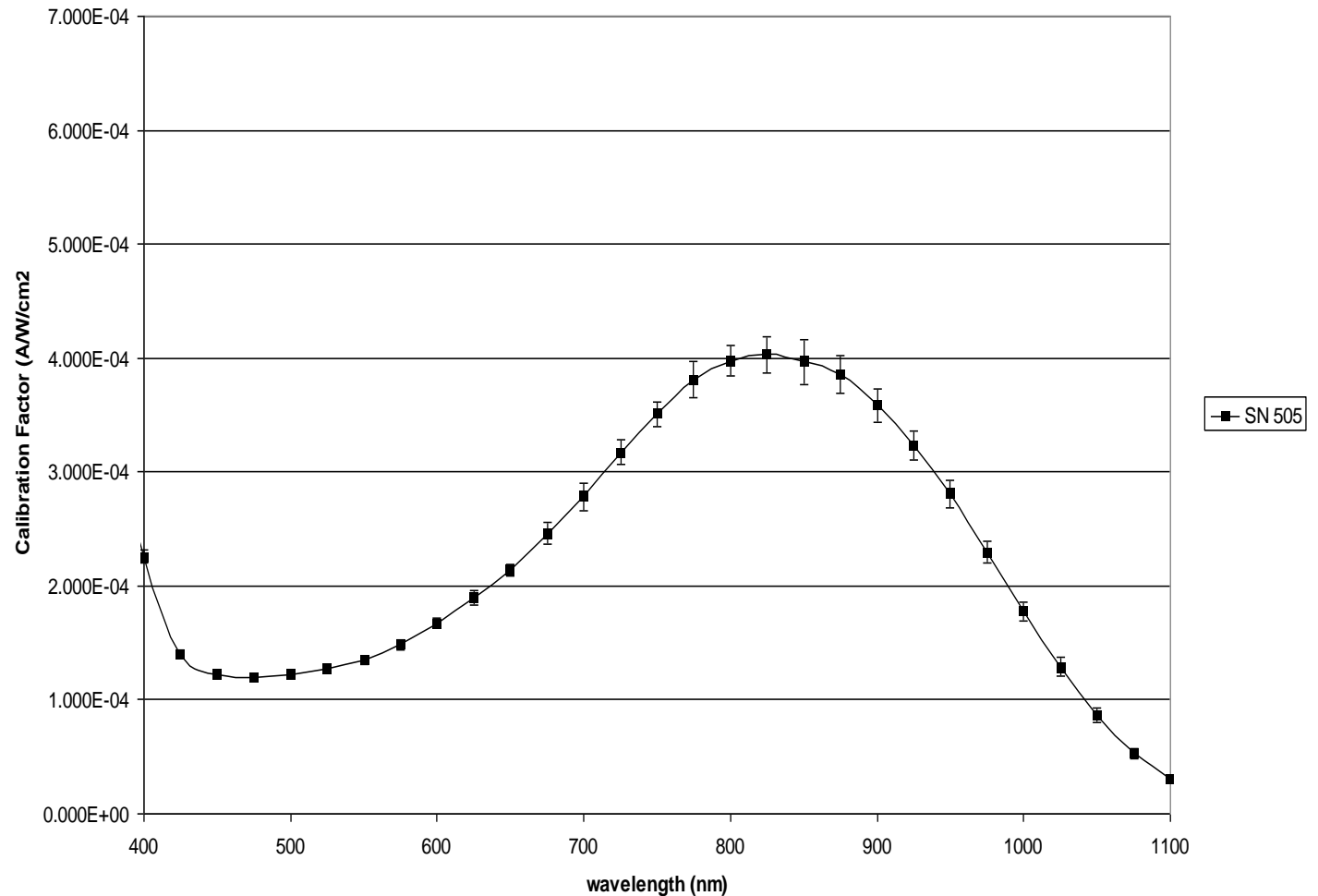
NIR Radiation Detectors (S1)

NIR Detector Average and STDEV



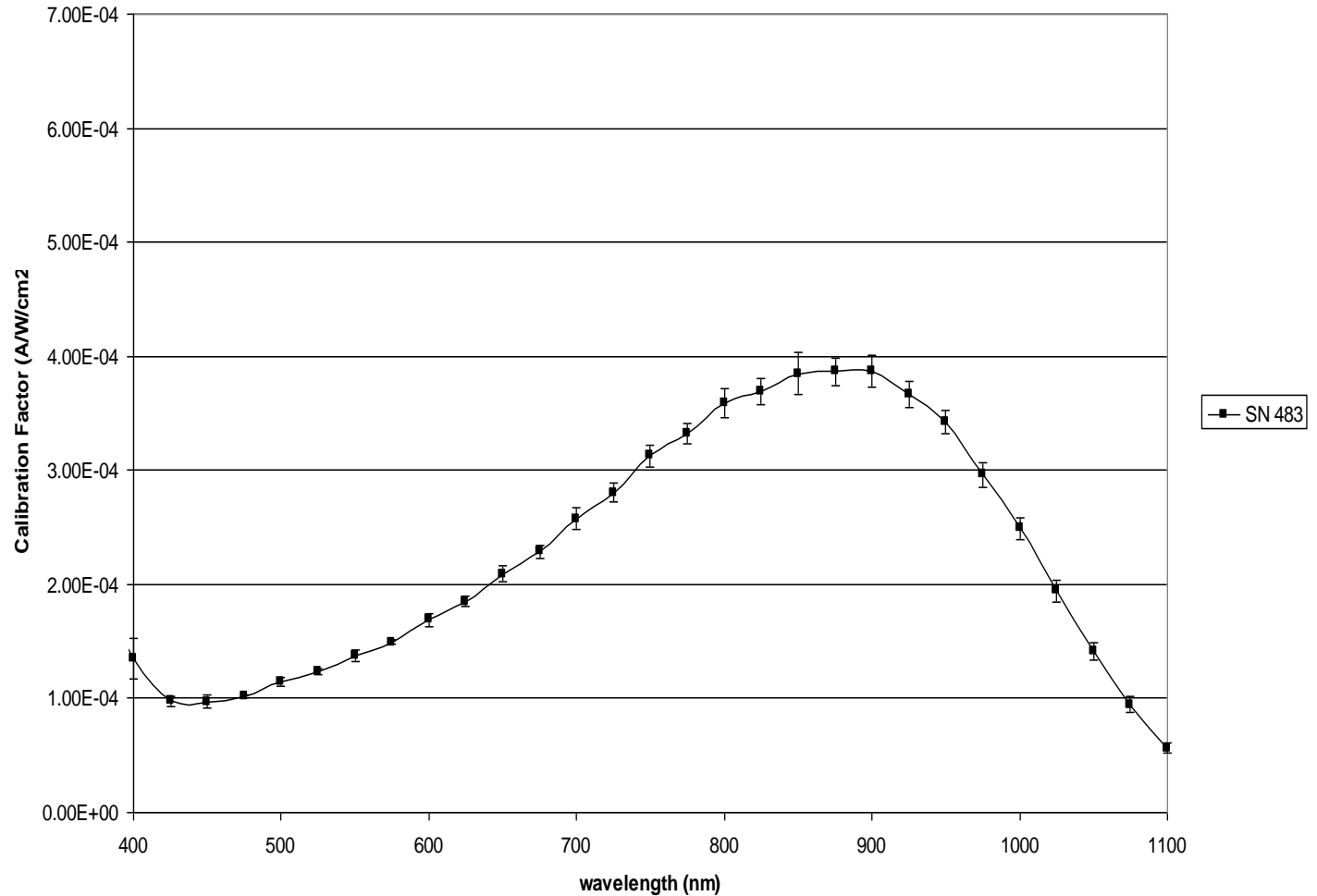
NIR Radiation Detectors (S1)

NIR Detector Average and STDEV



NIR Radiation Detectors (S1)

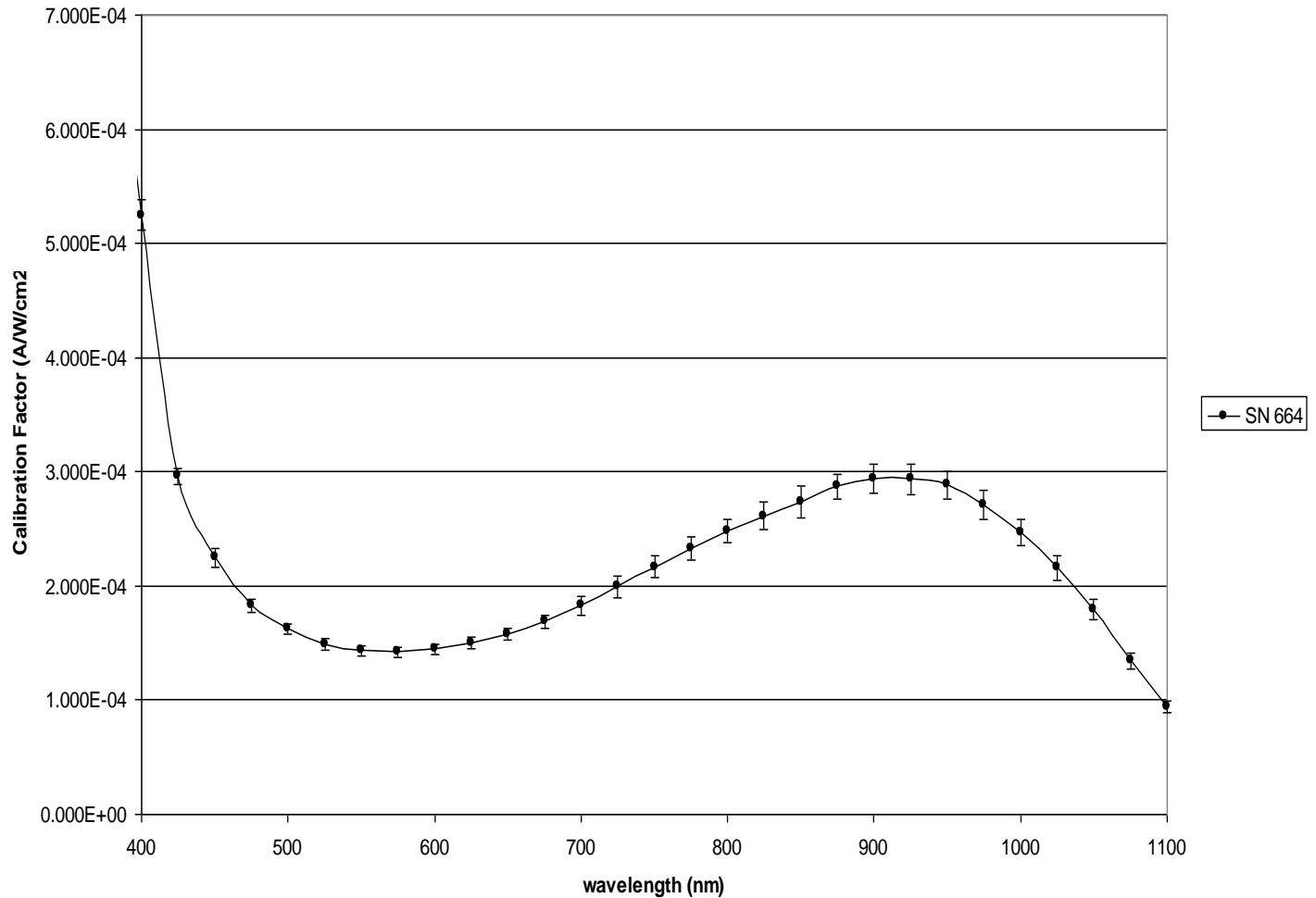
NIR Detector Average and STDEV



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NIR Radiation Detectors (S1)

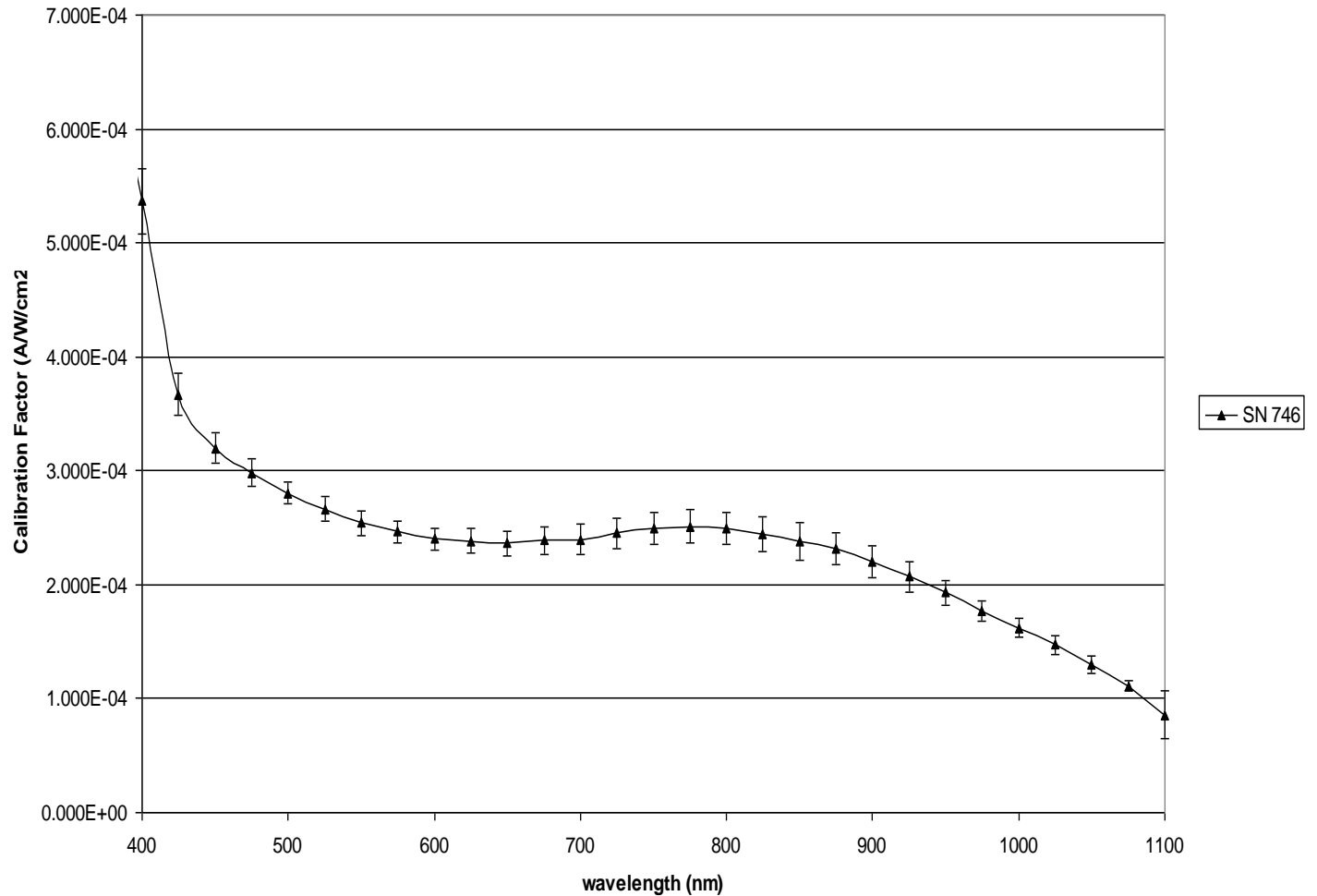
NIR Detector Average and STDEV



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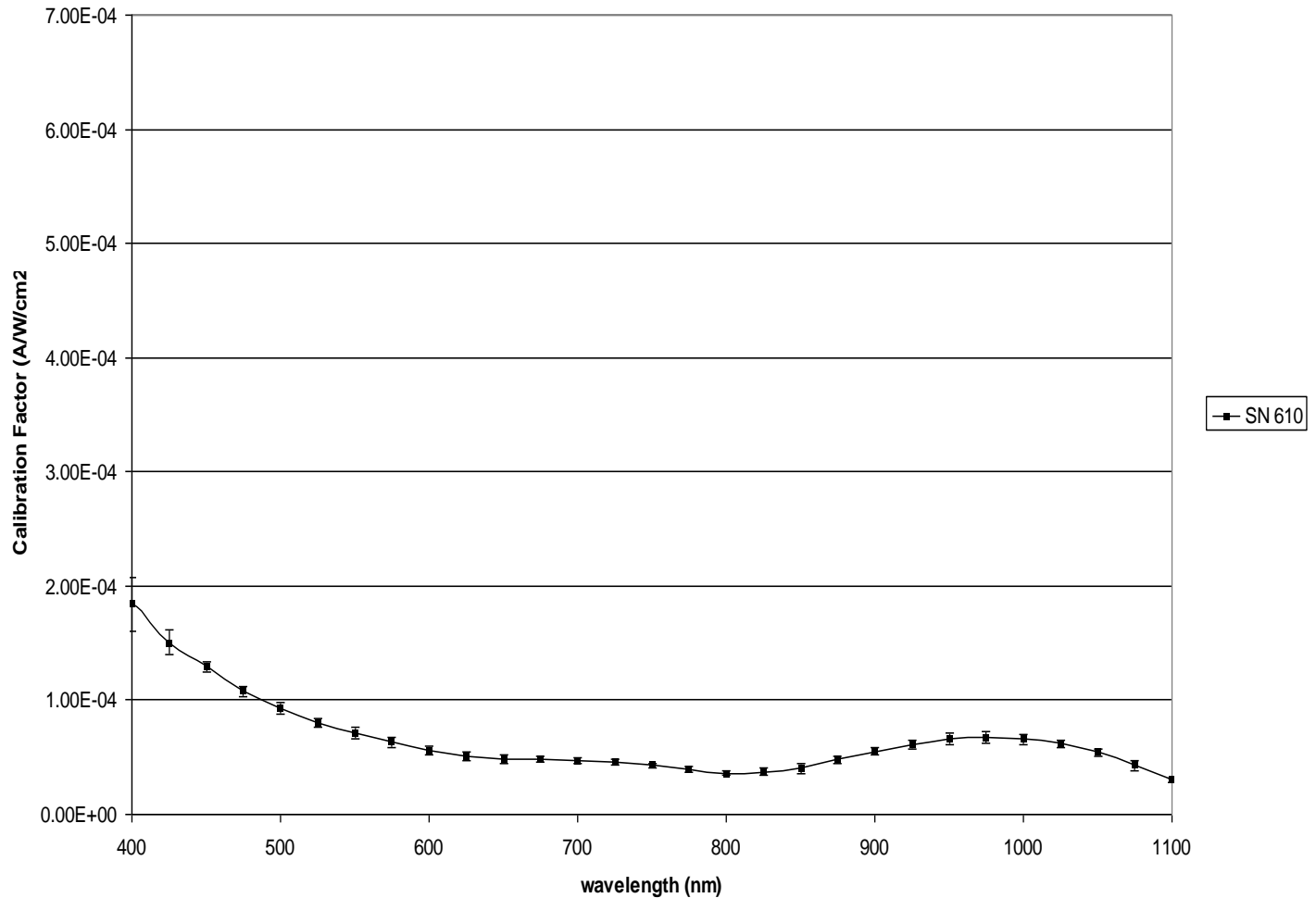
NIR Radiation Detectors (S1)

NIR Detector Average and STDEV



NIR Radiation Detectors (S1)

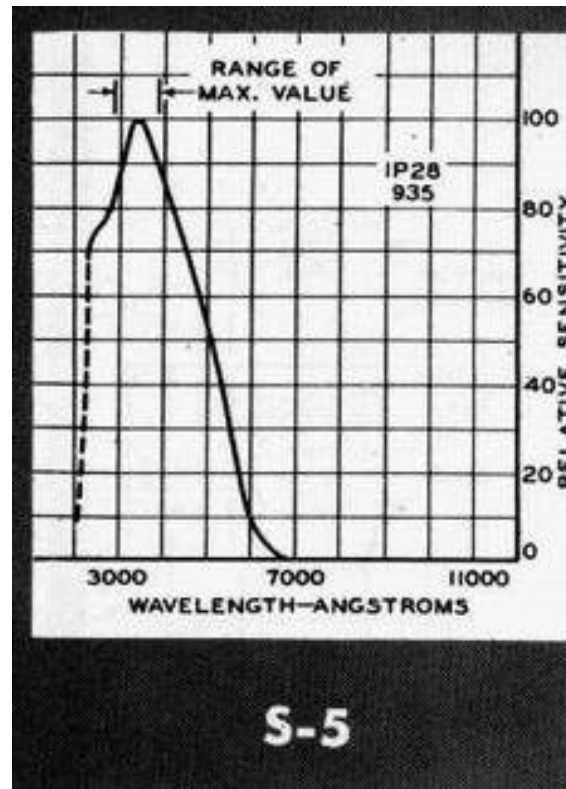
NIR Detector Average and STDEV



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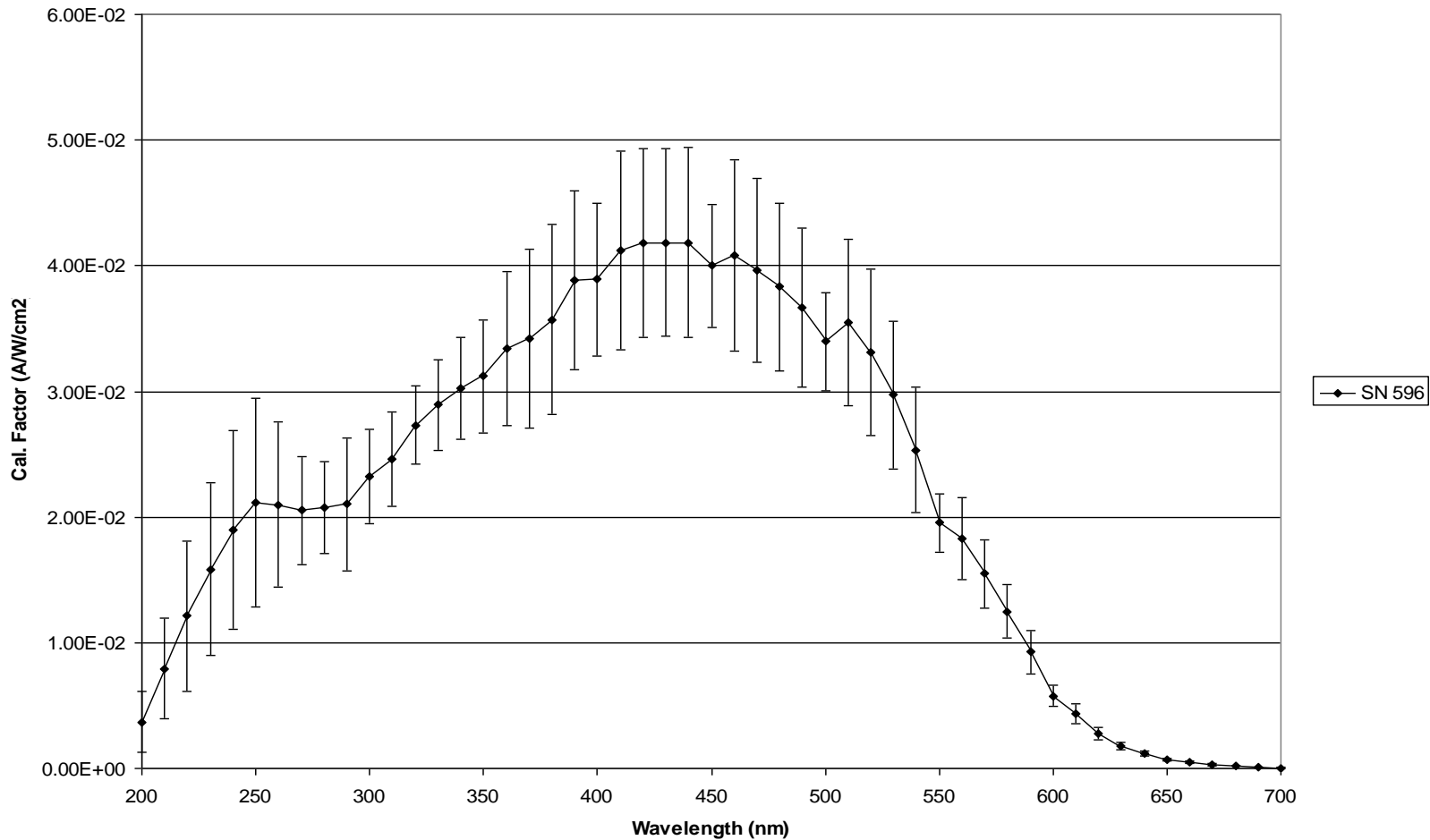
UV detectors (S5)

- 200 – 750 nm



UV detectors (S5)

UV Detector Ave and STDEV



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VIS-NIR Si PIN

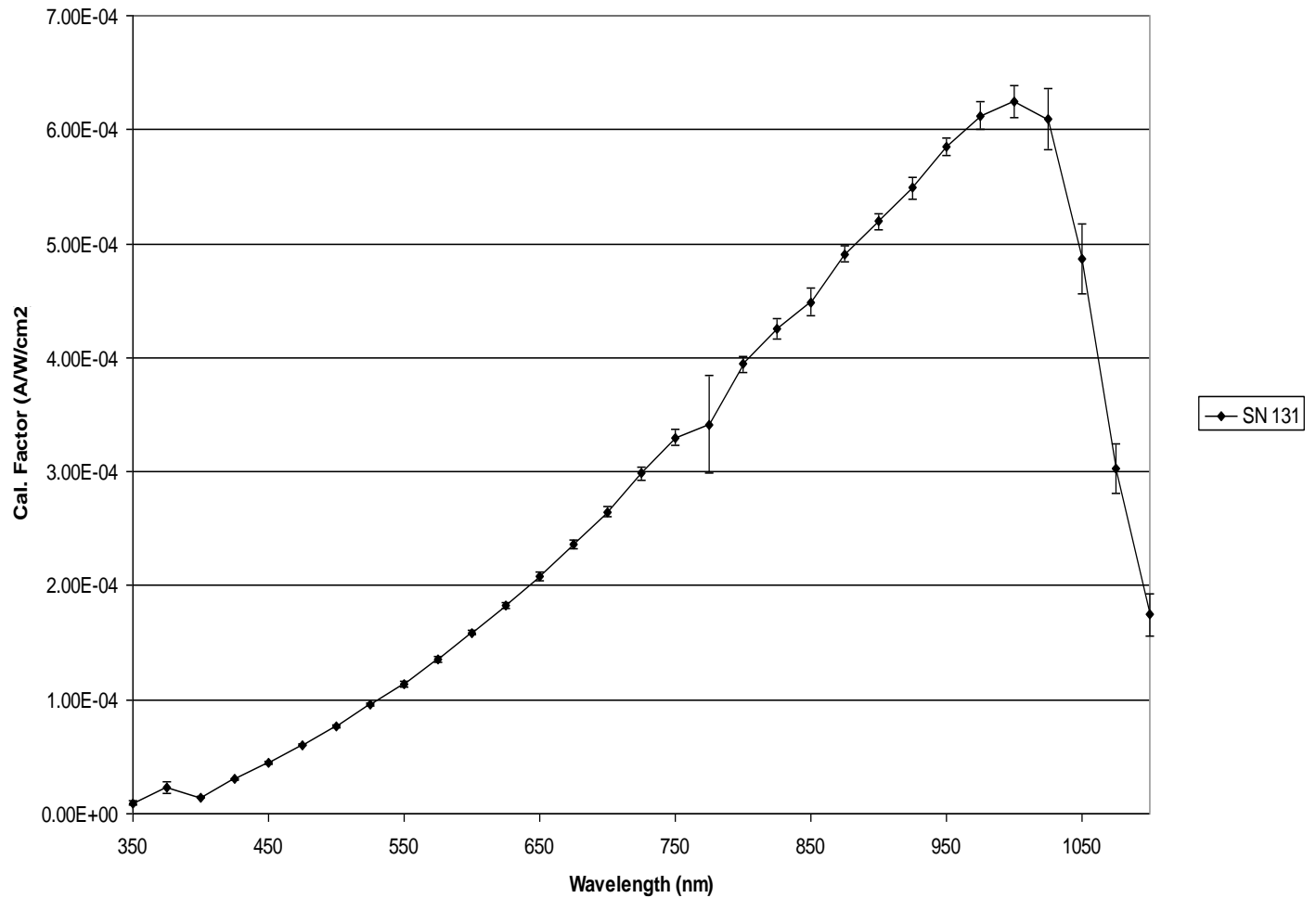
- Next generation of the radiometers in use by our program replaced the bi-planar vacuum photodiode with Si PIN.
- VIS-NIR Si PIN radiometers are less sensitive in visible spectrum than most of our S1, S20, and S5 phototubes.

VIS-NIR Si PIN

- Range of 10 orders of magnitude – “highly theoretical”
- Typically ~ 6 orders of magnitude
- ~ 8 ns rise time

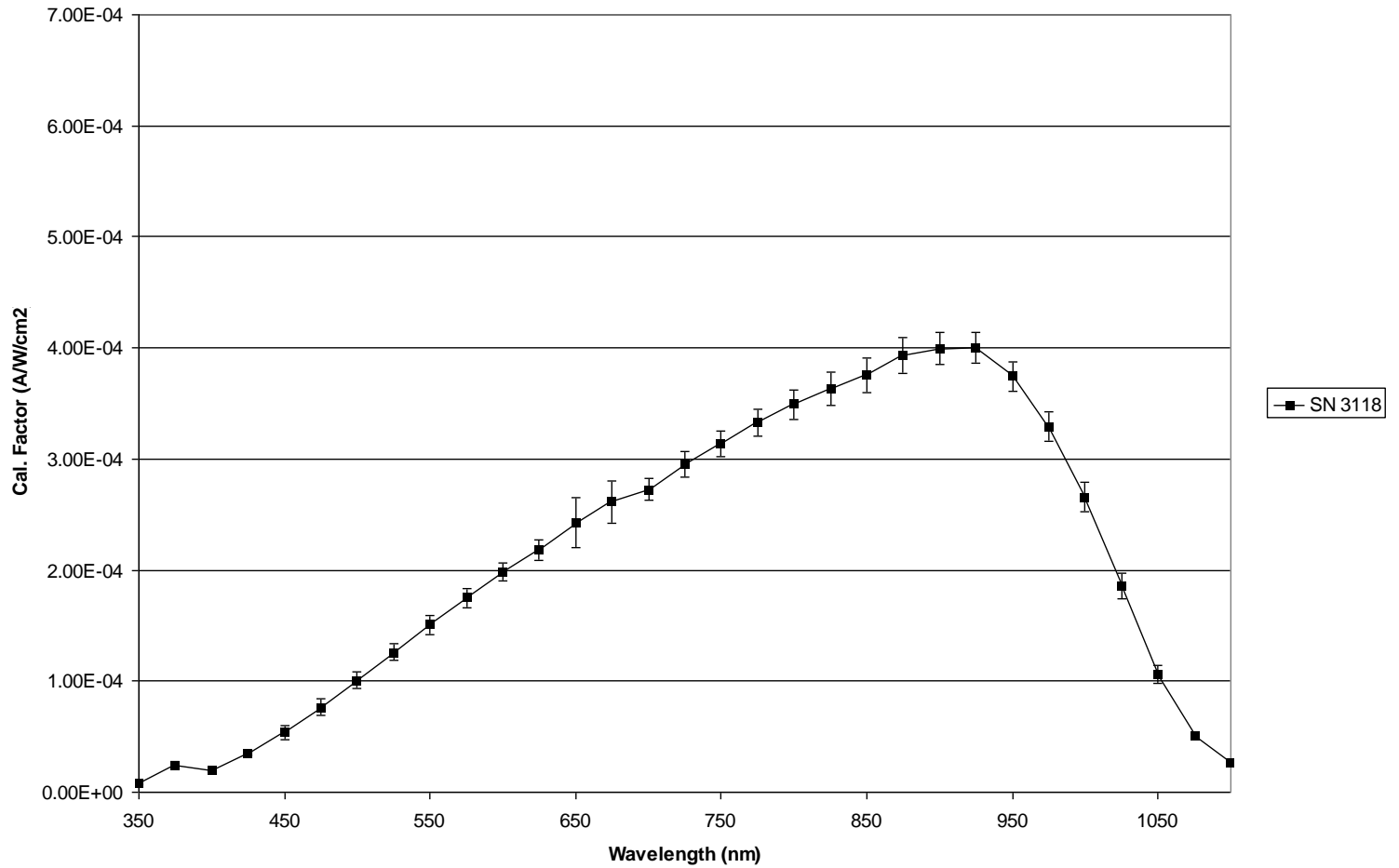
VIS-NIR Si PIN

VIS-NIR Detector Ave and STDEV



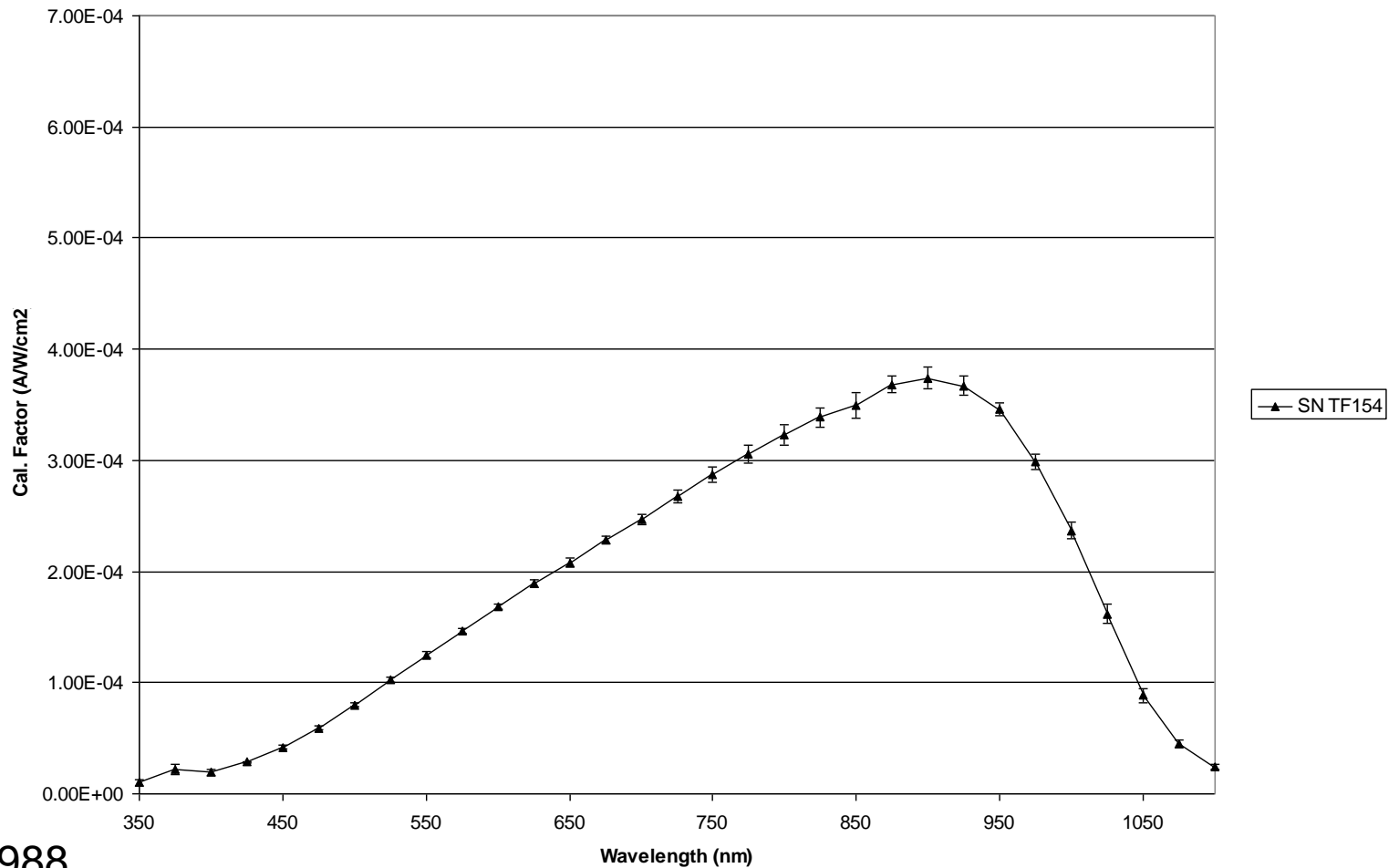
VIS-NIR Si PIN

VIS-NIR Detector Ave and STDEV



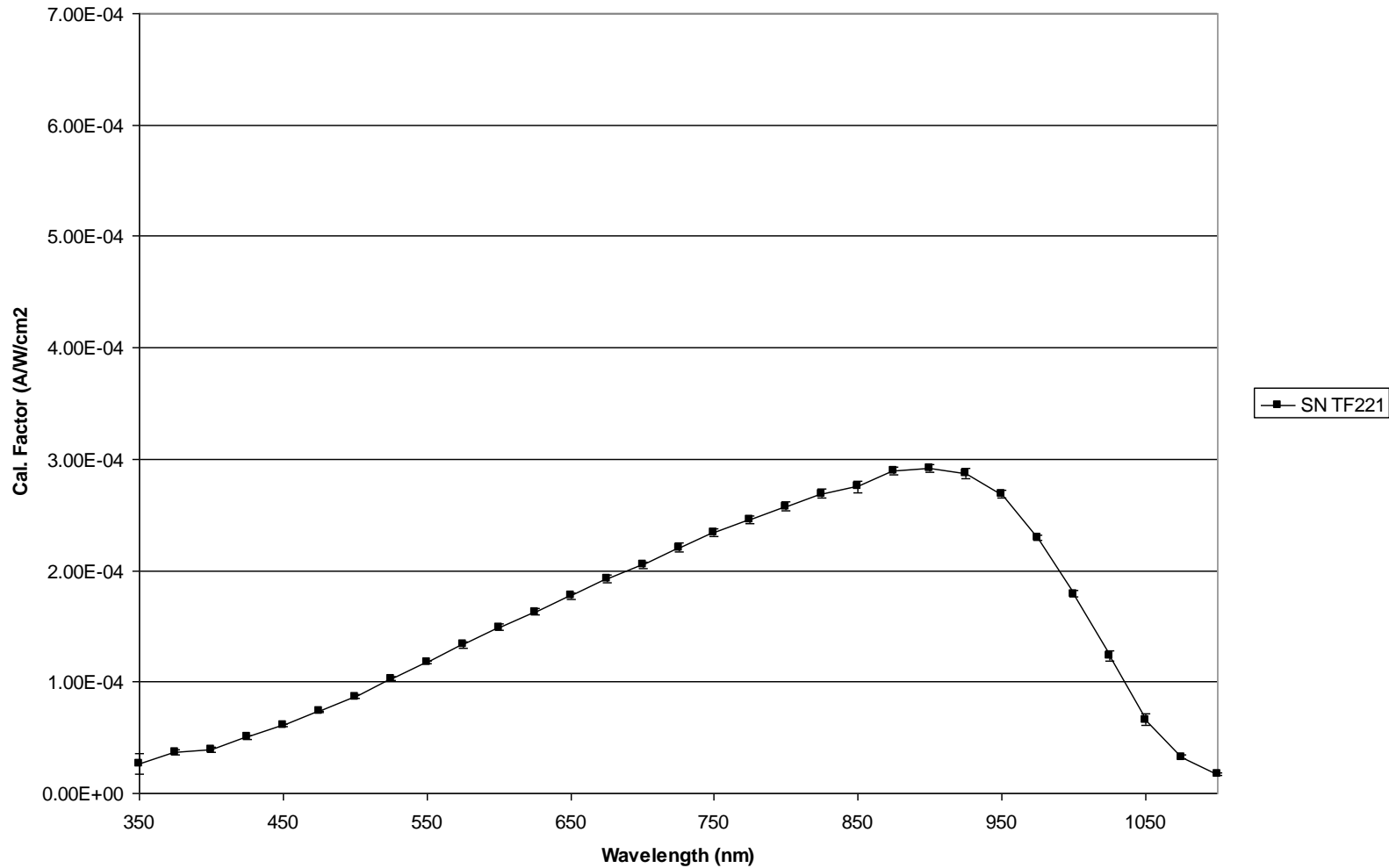
VIS-NIR Si PIN

VIS-NIR Detector Ave and STDEV



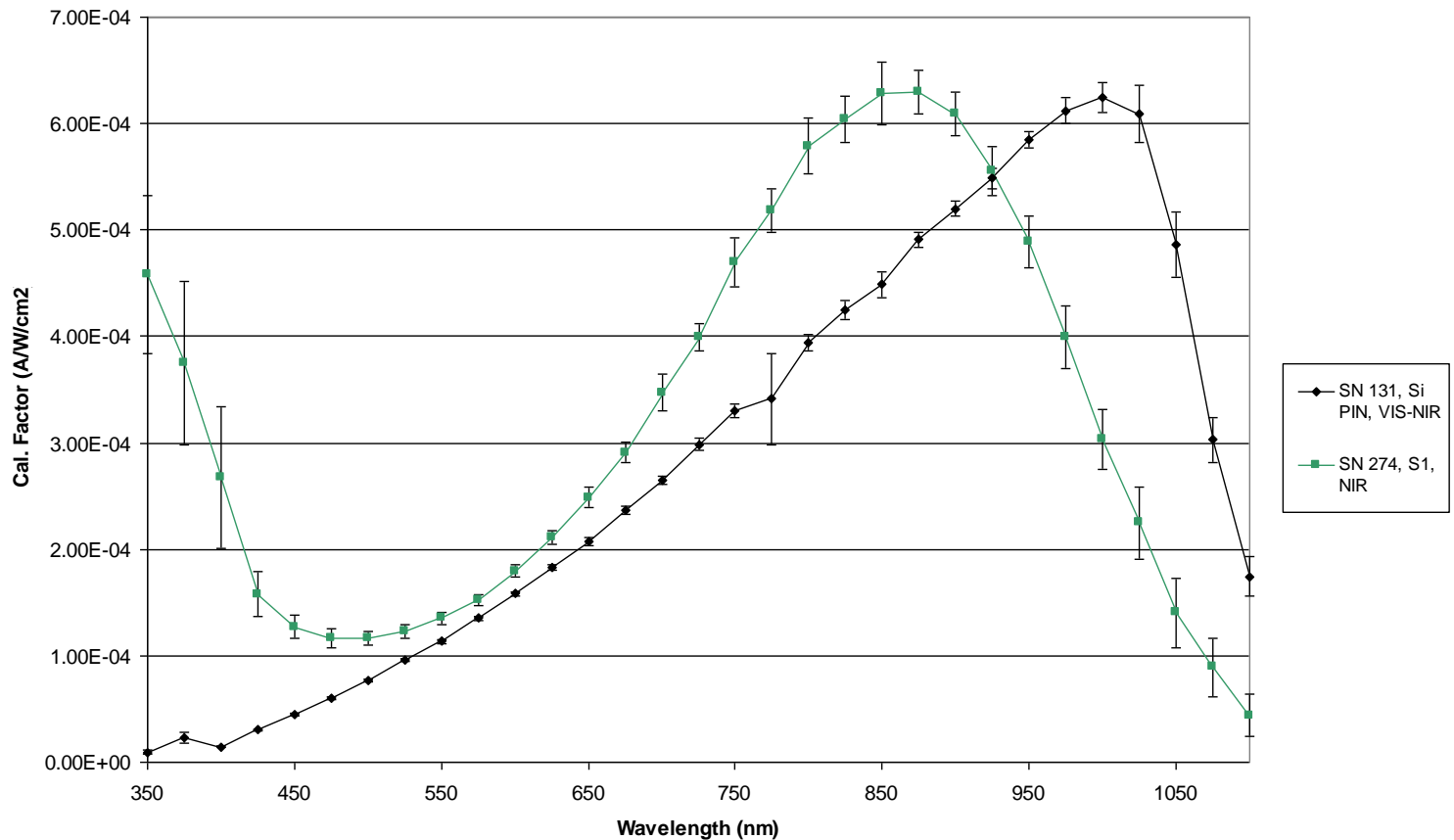
VIS-NIR Si PIN

VIS-NIR Detector Ave and STDEV



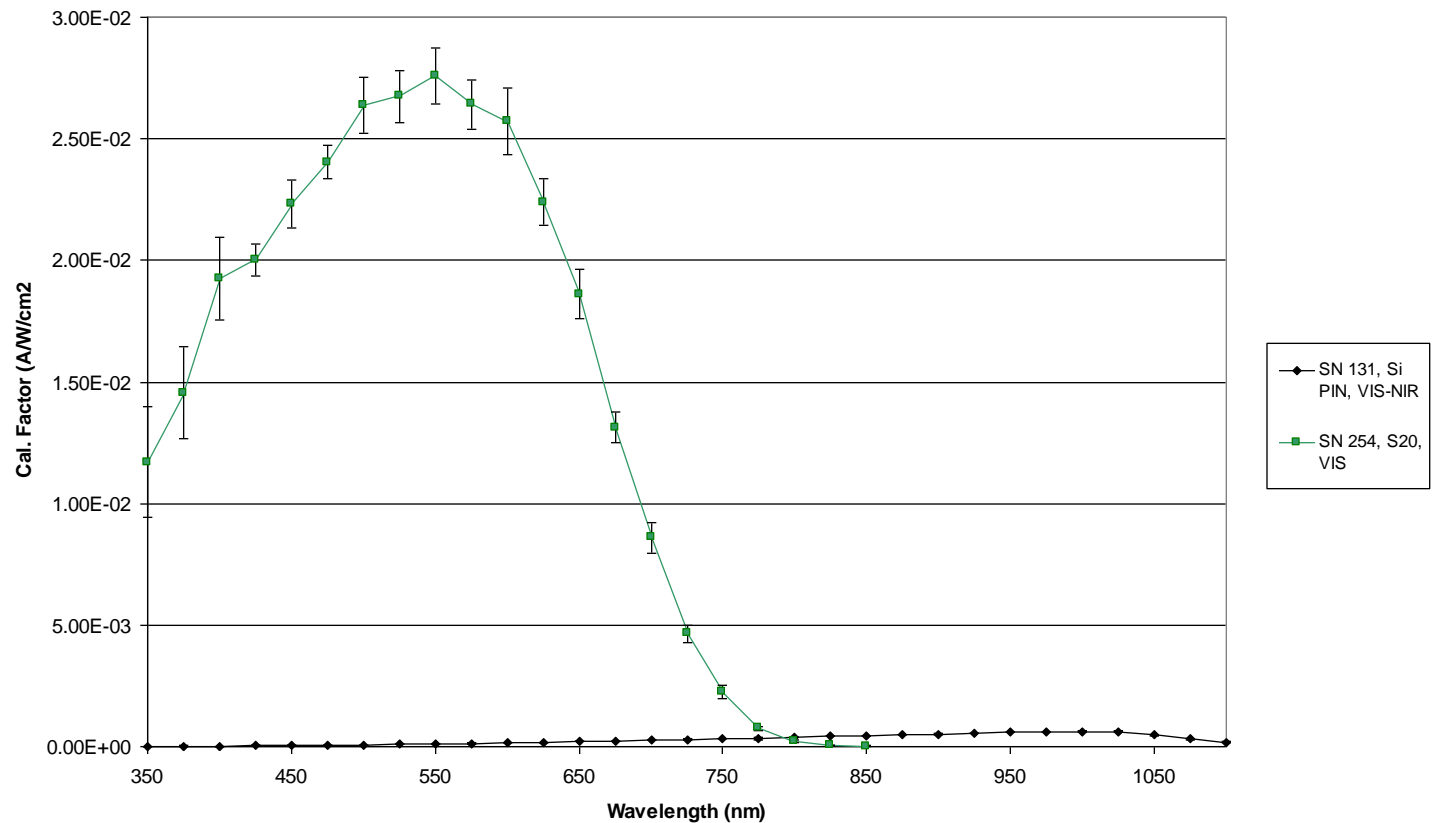
Comparison

- Si PIN (VIS-NIR) & S1 (NIR)



Comparison

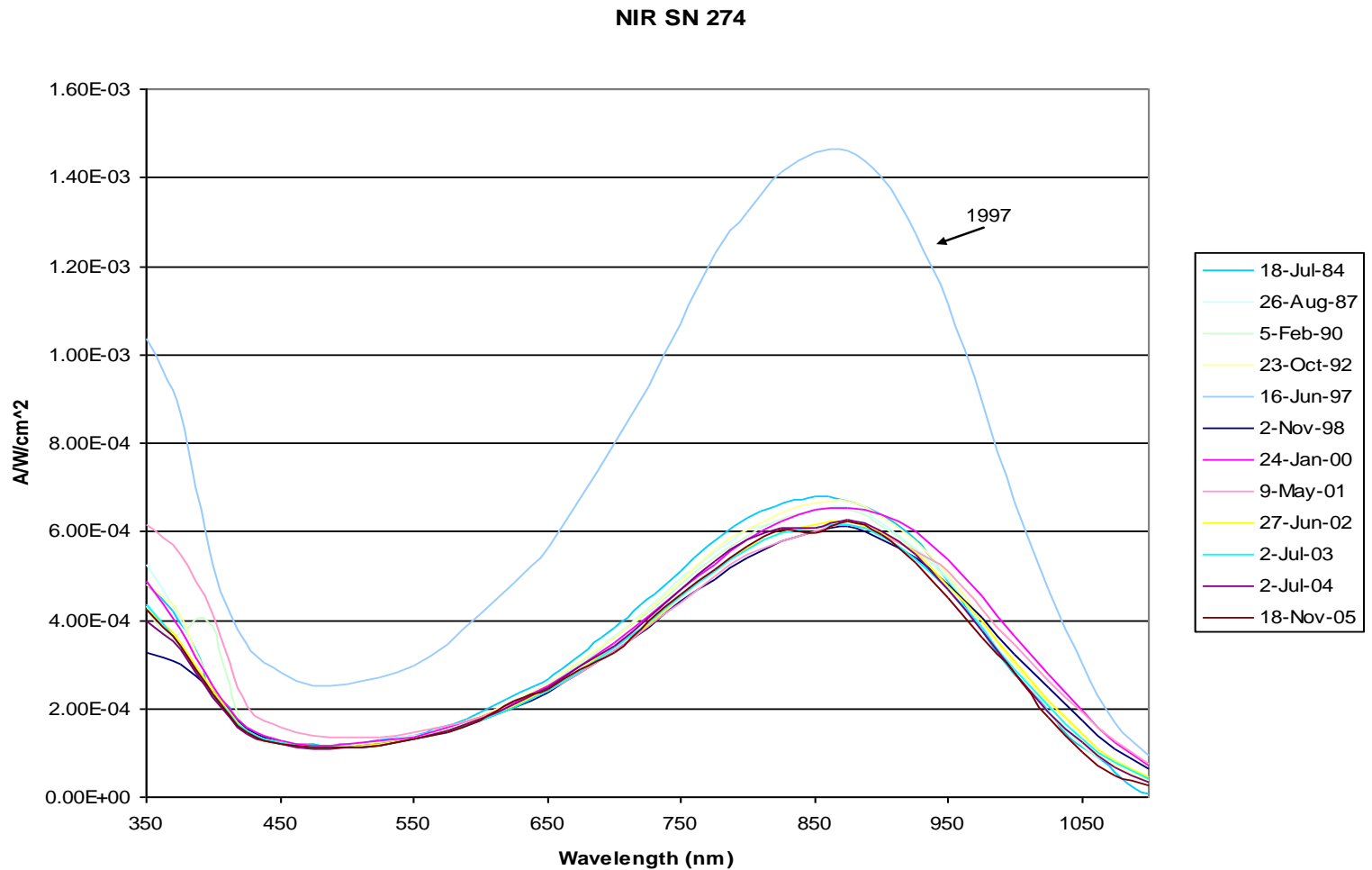
- Si PIN (VIS-NIR) & S20 (VIS)



Identifying Problems

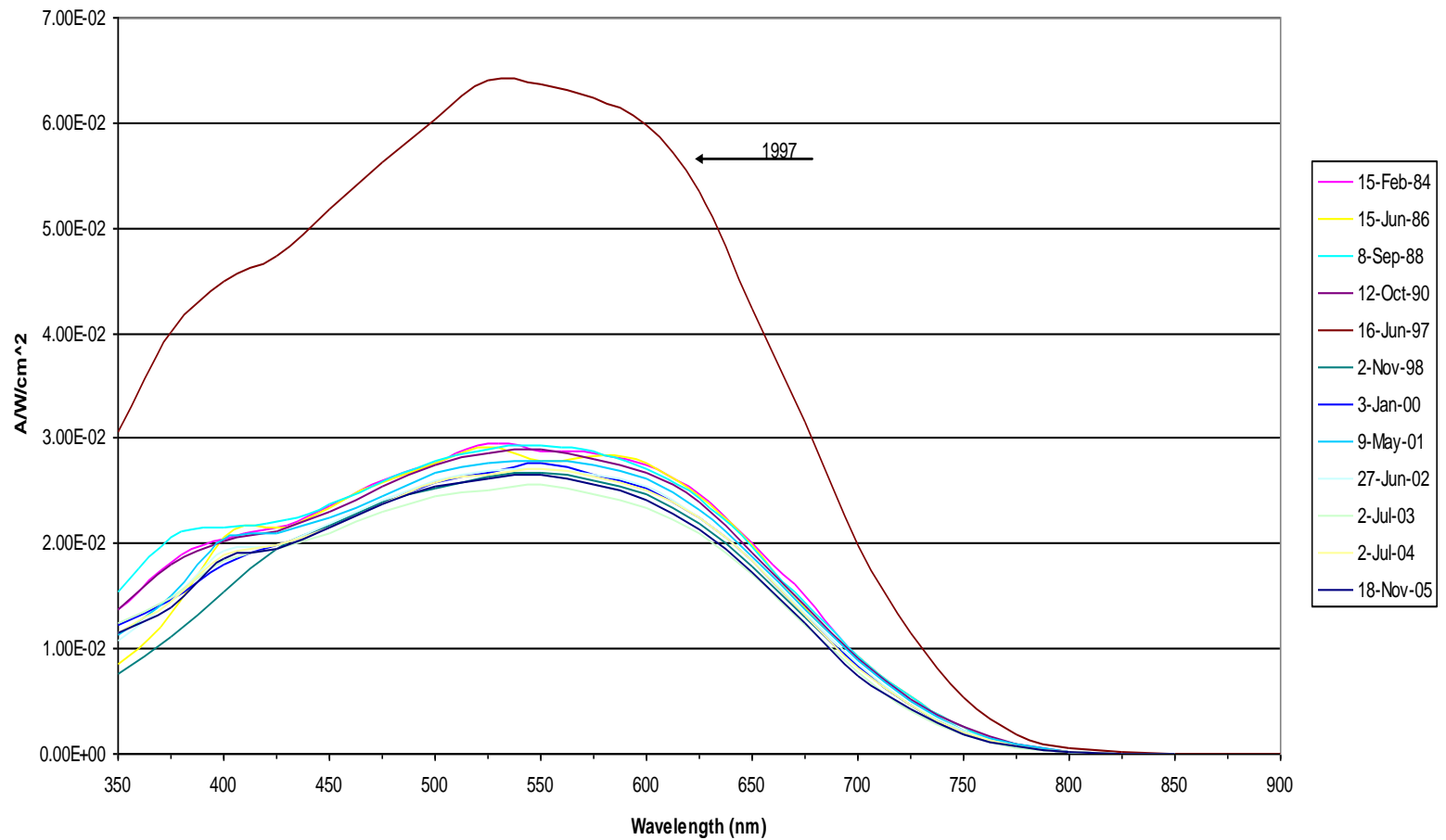
- Long-term stability of detector allows calibration errors to be obvious.
- A few extreme cases...

Identifying Problems



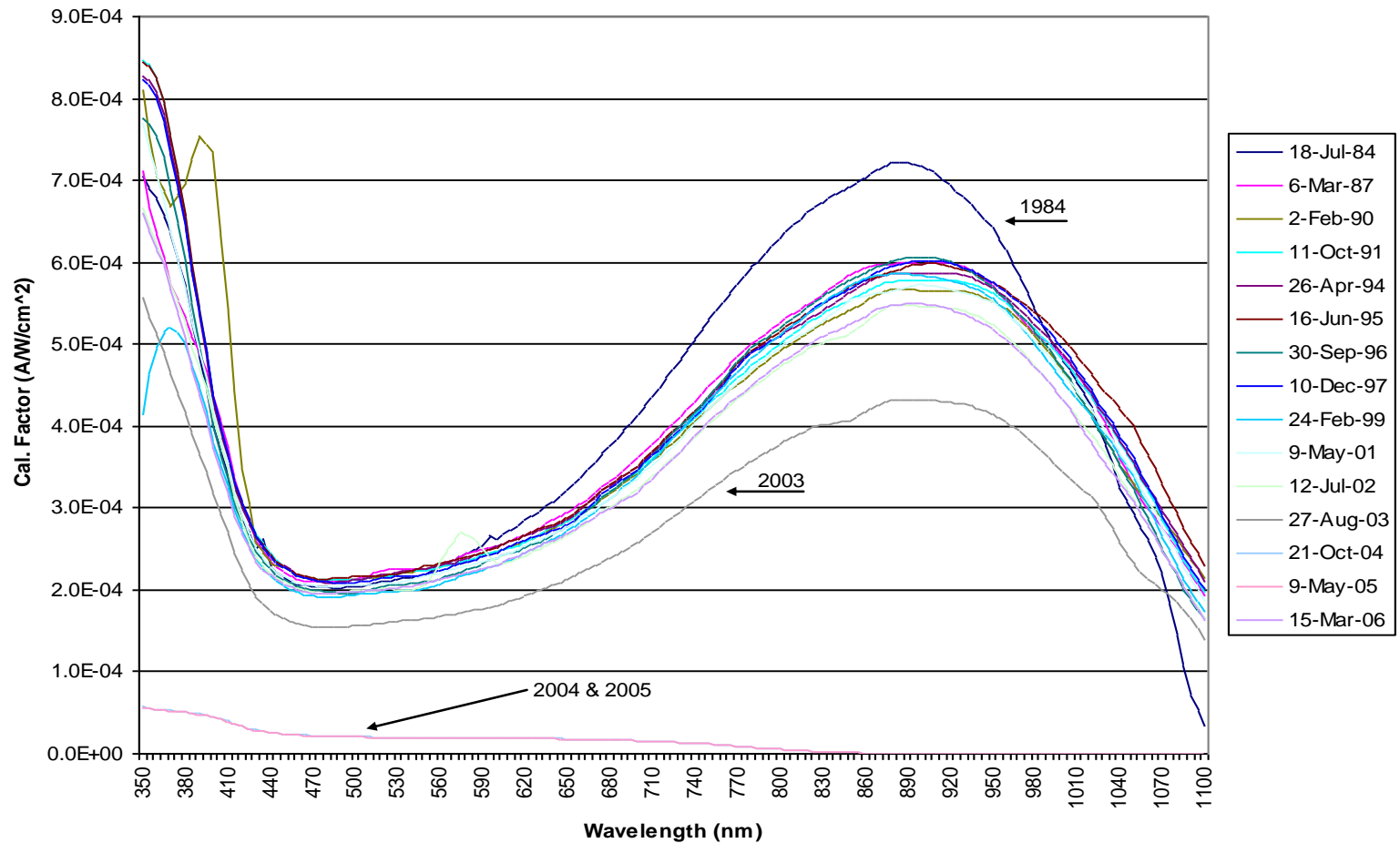
Identifying Problems

VIS Detector SN 254



Identifying Problems

NIR Detector SN 1084



Current Availability

- The bi-planar vacuum photodiode detector is no longer routinely used in instruments
- Difficult to find
- Valuable as a “one size fits all” detector
 - small to large beam diameters
 - CW to sub-ns pulses
 - immediate results, no waiting for thermal equilibrium
 - one instrument can measure VIS-NIR or detector can be chosen for high sensitivity at wavelength of interest

Current Availability

- Currently available detectors from one company:

| | Large Area Biplanar Vacuum Photodiode (S1) | Fast Response Biplanar Vacuum Photodiode (S1) | Fast Response Precision Photometry Si Photodiode | Large Area Precision Photometry Si Photodiode |
|--------------------------------|---|--|---|--|
| Rise/Fall Time | 270/100 ps | 60/55 ps | 0.4 μs | 33 μs |
| Sensitivity at Peak | ~3 mA/W | ~3mA/W | 0.6 A/W | 0.58 A/W |
| Active Area | 3.14 cm² (min) | 0.785 cm² (min) | .012 cm² | 1 cm² |
| Spectral Response | 300-1100 nm | 300-1100 nm | 320-1100 nm | 320-1100 nm |



Questions?

References

- RCA Tube Handbook HB-3, Phototube Section
- RCA Electro-Optics Handbook
- Hamamatsu Phototubes catalogue, June 2005
- EG&G Model 580 Radiometer Instruction Manual, Number B-4365B, Reissued May 1980
- EG&G Model 581 Laser Radiometer System Instruction Manual, Number B-4544, 1 August 1979

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