Fluorescence

Selection Guide for Solid State NIR Detectors on the Fluorolog-QM™

Application Note
Rare Earth Sciences
FL-2021-05-06

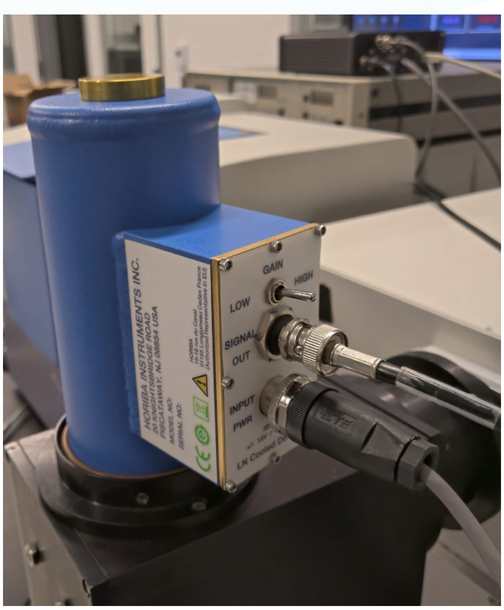
Introduction

Solid state NIR detectors (NIR DSS) are an attractive alternative to NIR photomultipliers. In fact, they can be considered superior in many respects, as they offer much higher upper wavelength limits, are much less prone to damage when exposed to light, are not limited by dark counts when used for long lifetimes, and are considerably less expensive than NIR photomultipliers.

This technical note serves as a guideline to selecting the best solid state detector with the Fluorolog-QM™ modular research spectrofluorometer for a given series of photoluminescence experiments.

Although these NIR detectors cannot be used for fluorescence lifetimes using TCSPC detection electronics, they are perfectly suited for phosphorescence lifetimes in the microsecond to millisecond time scale. For this reason, these solid state detectors can be ideal solutions for rare earth studies, where the lifetime range of rare earths is in the microsecond to millisecond time-scale, and, for most rare earths, their emissions are in the NIR wavelength region.

In 2021 HORIBA introduced an entirely new family of NIR DSS detectors for the Fluorolog-QM spectrofluorometer, manufactured by our world famous multichannel camera group at at our center of excellence in Piscataway, NJ. They include four types of InGaAs (IGA), one InAs and one InSb diode. All these detectors have been optimized to deliver top performance with continuous light sources for steady state spectral measurements, as well as for time-resolved studies with various pulsed sources, taking full advantage of HORIBA's proprietary Single Shot Transient Digitizer (SSTD) technique available on all Fluorolog-QM spectrofluorometers. These new NIR detectors are liquid nitrogen cooled for ultimate sensitivity, with a 140 ml capacity, which when filled with liquid nitrogen, will hold the detector at LN temperature for approximately 6-8 hours. All of these NIR detectors are coupled to an emission monochromator exit slit with an all-reflective mount to ensure the best possible sensitivity and chromatic aberration-free measurements over their entire spectral ranges.



NIR DSS Detector

New NIR DSS detectors in final QC at the HORIBA NJ Optical Spectroscopy Center in Piscataway, NJ.

Common Rare Earth Wavelengths and Lifetimes

	Excitation Wavelengths (nm)	Emission Wavelengths (nm)	Lifetime Range	Possible Detectors
Erbium (Er)	380, 522, 980	1008, 1540, 2720	15 to 8,000	InGaAs, InAs, InSb
Terbium (Tb)	265, 353, 370	489, 545, 583, 621	420	PMT
Holmium (Ho)	454, 538, 644	760, 1027, 1198, 1384, 2060	7 to 1,000	PMT, InGaAs, InAs, InAs, InSb
Neodymium (Nd)	358, 470, 508, 825	898, 1054, 1330	150 to 220	PMT
Europium (Eu)	395, 470, 540	593, 615	110	PMT, InGaAs, InAs, InSb
Thulium (Tm)	358, 468, 686, 800, 1220, 1600	813, 1023, 1200, 1480, 1630,1850	20 to 200	PMT
Praseodymium (Pr)	446, 588, 994	1010, 1343, 1540, 2010	2 to 50	InGaAs, InAs, InSb
Ytterbium (Yb)	875 to 1025	980 to 1000	2,000	InGaAs

All NIR DSS detectors feature 2 mm sensors and come with low and high gain amplification settings, which are selected by a toggle switch. The choice of gain will depend on a particular detector and a type of measurement:

- For steady state measurements, the high gain should always be used with all detectors for the best sensitivity.

- For time-resolved measurements with InGaAs 1.7 and InGaAs 1.9, the low gain should be used due to a very slow time response in the high gain mode for these two diodes.

- All other detectors can be used with either high or low gain setting for lifetimes. The low gain improves temporal resolution but also lowers the sensitivity.

- The InSb detector in the low gain setting is the fastest of all, with a response below 1 µs. If combined with a fast Q-switched OPO laser (e.g. Opolette) and an optional GHz digital oscilloscope, it can be used for measuring lifetimes in the range of hundreds of nanoseconds or lower in the wavelength range from 900 to 5,500 nm!

The sensitivity of NIR detectors generally decreases with the increase of the spectral range as noted in the D* specifications. The sensitivity of the HORIBA InGaAs 1.7 and 1.9 are so good that they do not require an optical chopper and lock-in amplifier, even for detection of Rose Bengal by signet oxygen, which is a weak emission.

For the InGaAs 2.1 and 2.6, the chopper/lock-in option is highly recommended, but optional, and you can see from the Table above and Figure 1 that the InGaAs 2.1 with the chopper/lock-in offers much better sensitivity than the 1.7 version.

The chart below provides a comparison of these new NIR detectors with respect to their spectral range, relative sensitivity and time-resolved (SSTD) performance when used with the Fluorolog-QM.

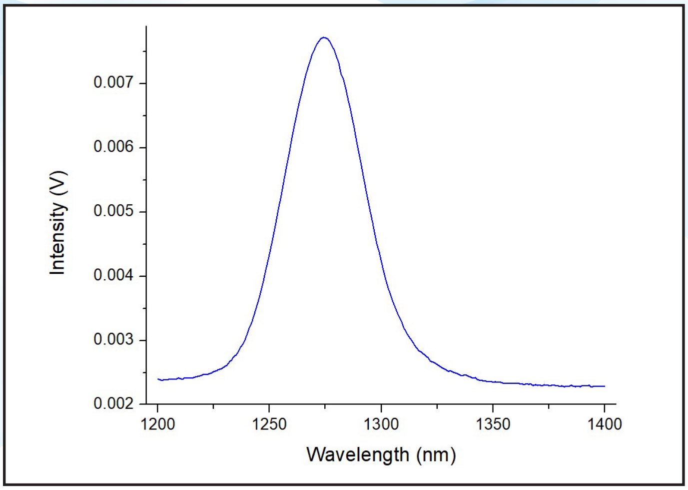


Figure 1: Rose Bengal by singlet oxygen acquired on Fluorolog-QM with IGA 1.7 detector (no chopper/lock-in)

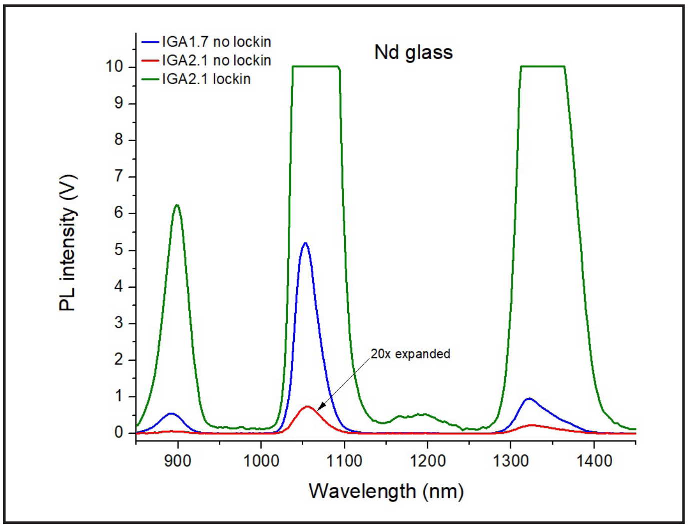


Figure 2: IGA 1.7 (no chopper/lock-in) compared to IGA 2.1 with and without chopper/lock-in. Note that the spectrum for the red IGA 2.1 with lock-in was multiplied by a factor of 20, to be able to see it better on this graph, but, in fact, the signal intensity relative to the other curves is 20 times lower.

Fluorolog-QM NIR DSS Detector Performance									
Detector type	Fluorescence Part Number	Detectivity D* (cm Hz1/2/W) T = 77K	Chopper/ Lock-In	Spectral range (nm) at liquid nitrogen (LN) and room temperature (RT)	Approximate relative sensitivity at 1,324 nm at High Gain with continuous excitation	Temporal response in µs (FWHM of IRF)		Approximate shortest lifetime (µs)	
						Low Gain	High Gain	Low Gain	High Gain
InGaAs 1.7	FL-QM-NIR-IGA(1.7)P	$7.3x10^{16}$	Not required	800 to 1,550 (LN) 800 to 1,700 (RT)	1	7.0	NA	1.0	NA
InGaAs 1.9	FL-QM-NIR-IGA(1.9)P	$3.2x10^{15}$	Not required	800 to 1,750 (LN) 800 to 1,900 (RT)	0.03	14.0	NA	2.0	NA
InGaAs 2.1	FL-QM-NIR-IGA(2.1)P	$1.9x10^{14}$	NO	850 to 1,900 (LN) 850 to 2,100 (RT)	0.001	8.0	17.0	1.0	2.0
InGaAs 2.6	FL-QM-NIR-IGA(2.6)P	$1.3x10^{13}$	NO	850 to 2,300 (LN) 850 to 2,600 (RT)	0.000036	13.0	19.0	2.0	2.0
InAs	FL-QM-C-InAs	3.0×10^{11}	Included	900 (LN)	0.74	6.0	12.0	1.0	2.0
InSb	FL-QM-C-InSb	1.5×10^{10}	Included	900 (LN)	0.09	<1.0	4.0	1.0	1.0

Due to the lower sensitivity of the InAs and InSb detector options, these detectors always include an optical chopper and a lock-in amplifier to improve steady state fluorescence measurements.

An important feature of HORIBA DSS detectors is their ability to work with pulsed light sources in SSTD mode, providing a unique capability of PL lifetime measurements in NIR up to 5500 nm, which far exceeds the spectral range of NIR photomultipliers. The amplification stage and signal conditioning is carefully designed to provide a proper response and bandwidth for the operation with pulsed lasers and microsecond Xe flash lamps. Below is an example of a PL decay of an Nd^{3+} doped glass sample measured with the InGaAs 2.1 detector.

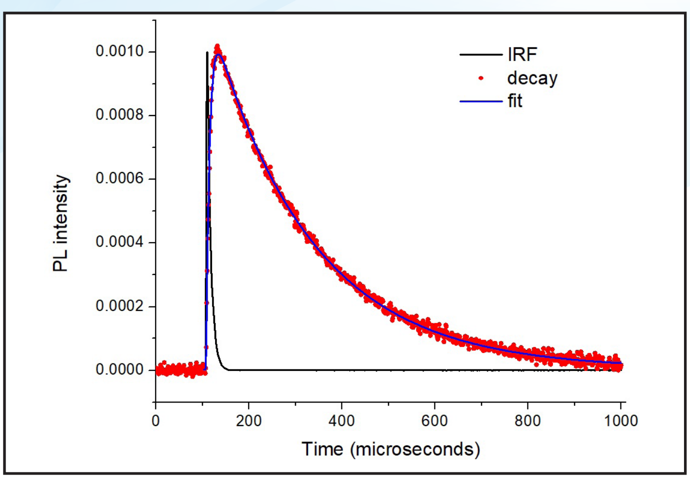


Figure 3: PL decay of Nd^{3}+ doped glass with InGaAs 2.1 detector resulting in a lifetime of 213.7 ± 0.4 µs.

The time response is optimized for each type of detector and varies between the low gain (fast, high bandwidth) and high gain (slow, low bandwidth) settings. Typical Instrument Response Functions (IRF) for each detector are shown on the graphs following.

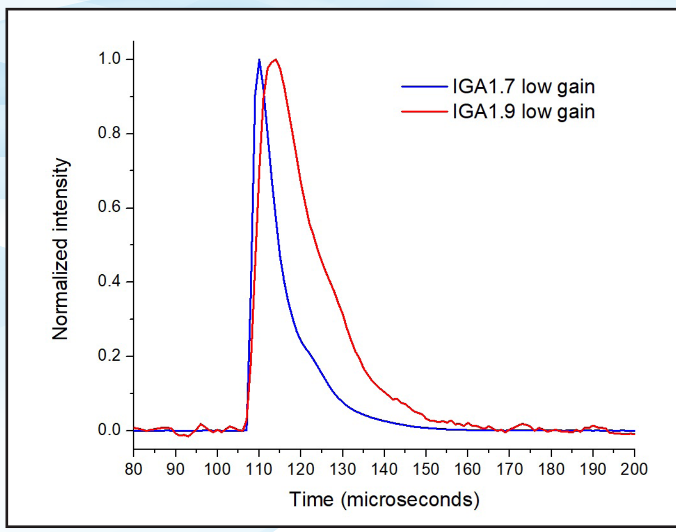


Figure 4: IRF for IGA 1.7 and 1.9 in low gain.

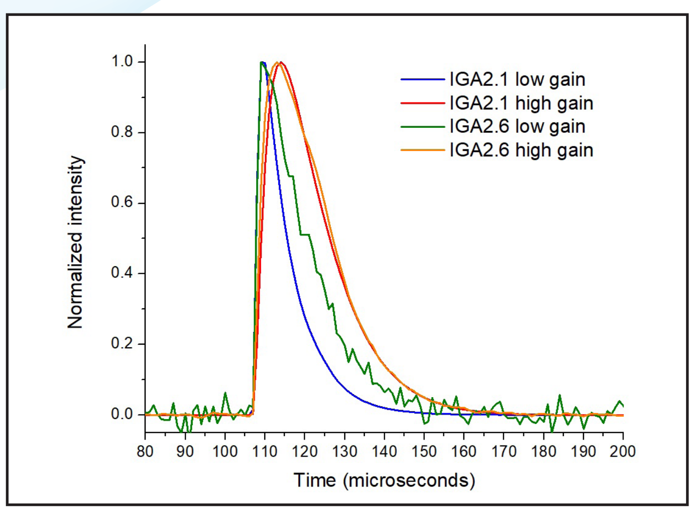


Figure 5: IRF of IGA 2.1 and IGA 2.6 in low and high gain.

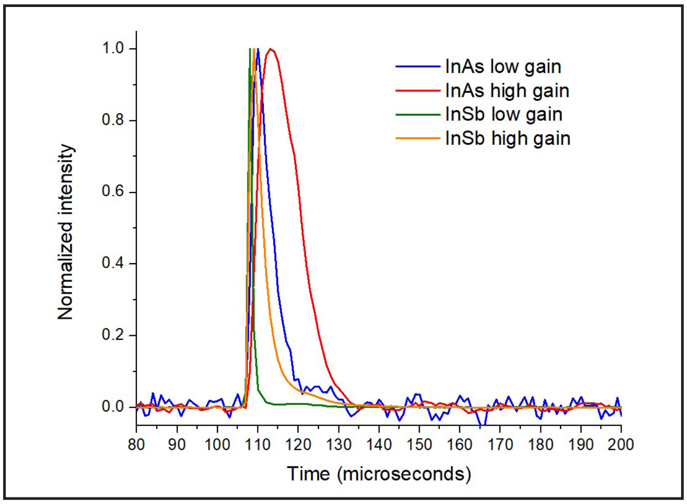


Figure 6: IRF of InAs and InSb in low and high gain. For InSb in low gain FWHM < 1 µs, so it is suitable for lifetimes in the range of tens to hundreds of ns when used with an optional digital oscilloscope and a Q-switched/OPO laser.

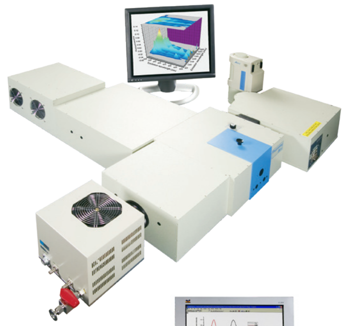
These new NIR DSS detectors are excellent options to expand the capabilities of the Fluorolog-QM into NIR fluorescence spectroscopy.

For Use with Fluorolog-QM™

All of these NIR DSS detectors are available as optional detectors for the Fluorolog-QM modular research spectrofluorometer for steady state NIR spectral detection. If the Fluorolog-QM is equipped with a pulsed source (Xe lamp, or laser), then these detectors will also operate in phosphorescence lifetime mode and time-resolved phosphorescence spectral mode.

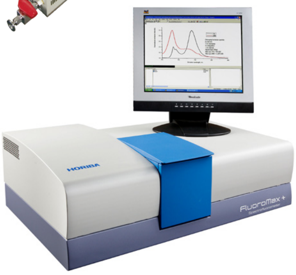
For Use with Nanolog®

All these NIR detectors can be used with the Nanolog platform for steady state spectral measurements, but they cannot be used for lifetime measurements since the Nanolog does not include the SSTD detection mode that is included in the Fluorolog-QM.



For Use with FluoroMax® Plus

The InGaAs 1.7 and 1.9 are available with FluoroMax Plus for the steady state measurements, but again, not for lifetimes.



Contact HORIBA for correct detector part numbers for the Fluorolog-QM, Nanolog and FluoroMax Plus.

HORIBA Scientific

info.sci@horiba.com

www.horiba.com/scientific

USA: +1 732 494 8660
UK: +44 (0)1604 542 500
China: +86 (0)21 6289 6060
Taiwan: +886 3 5600606
France: +33 (0)1 69 74 72 00
Italy: +39 06 51 59 22 1
India: +91 80 41273637
Brazil: +55 (0)11 2923 5400
Germany: +49 (0) 6251 8475 0
Japan: +81(75)313-8121
Singapore: +65 (0)6 745 8300
Other: +33 (0)1 69 74 72 00