

Introduction

Applications involving photoluminescence (PL) measurements in NIR have been rapidly growing in recent years. The demand comes mainly from several areas in materials science, such as fiber optics telecommunication, solar energy conversion, lasing media, LED and OLED technologies and development of upconversion nanoparticles for biomedical analyses and bioimaging. Most of these applications involve rare earth ions (lanthanides), many of which emit in NIR. Often these ions are used with ligand photosensitizers which improve their light absorption properties as lanthanide ions themselves are very weak absorbers. They are used as dopants in lasing media and glasses and are made into nanoparticles of varying size and shape in order to control their optical properties. The PL lifetime is the key parameter in assessing the optical efficiency of devices involving lanthanides as well as in quality control during their manufacturing.

QuantaMaster™ NIR Lifetime Option

The PL lifetimes of lanthanides fall into the microsecond to millisecond time range. PTI QuantaMaster™ Series includes specially optimized solid-state NIR detectors, such as TE-cooled InGaAs, PbS and others, which are combined with pulsed light sources (xenon pulsed lamp, PTI tunable nitrogen/dye laser and 3rd party Q-switched lasers, such as tunable Opolette laser) to provide an efficient system for PL decay measurements in NIR. The NIR lifetime option utilizes PTI proprietary Single-Shot Transient Digitizer (SSTD) technique, which affords extremely rapid signal accumulation and highly accurate lifetime determination with included lifetime analysis software package. In line with PTI philosophy, the NIR lifetime option is fully modular and can be used either in a stand-alone instrument or combined with any QuantaMaster™ or TimeMaster™ system as an upgrade. With existing systems, the NIR detector can be added to the 2nd exit port of the emission monochromator and a NIR-optimized grating will be also added together with the dual grating turret to the monochromator. Alternatively, a new emission monochromator with the NIR grating and NIR lifetime detector can be added to the instrument converting it into a T-format system. A Xe pulsed lamp can be added to the 2nd entrance port of the excitation monochromator or a pulsed laser can be attached via fiber optics to the unused side of the sample compartment. The same NIR lifetime detector works as the steady-state detector with a xenon arc lamp or a cw laser source and appropriate detection electronics, which for the best performance should include a chopper and lock-in amplifier. The data presented in this note were obtained with a QM-50 NIR system featuring both the lifetime and the steady state mode.

Results

The PL decays and spectra of several glass samples doped by Nd^{3+} , Er^{3+} , Tm^{3+} , Ho^{3+} and Pr^{3+} ions were measured with the QM-50 NIR photoluminescence spectrometer equipped with the lifetime option comprising PTI pulsed nitrogen/dye laser combo and TE-cooled InGaAs photodiode operating in the SSTD mode with a specially-designed preamplifier. For the steady state spectra a standard 75 W xenon lamp with a built-in chopper and a double excitation monochromator (300 nm blazed, 1200 l/mm gratings) were used for excitation. The steady-state emission was measured with the same InGaAs photodiode with the signal being fed to a lock-in amplifier. A single emission monochromator with a 1250 nm blazed, 600 l/mm grating was used for both lifetime and steady-state measurements. The combination of steady state and lifetime modes in the QM-50 system operating by powerful Felix GX software allows for complete and rapid characterization of lanthanide photoluminescence.

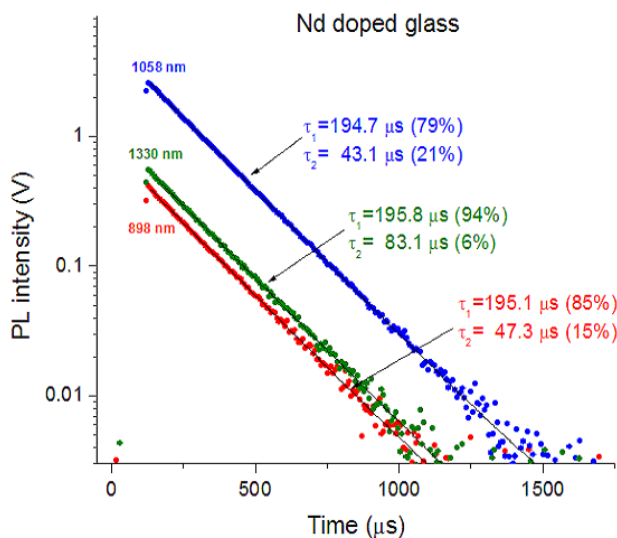


Fig 1. PL decays of Nd^{3+} doped glass measured with the QM-50 NIR system operating in the lifetime mode.

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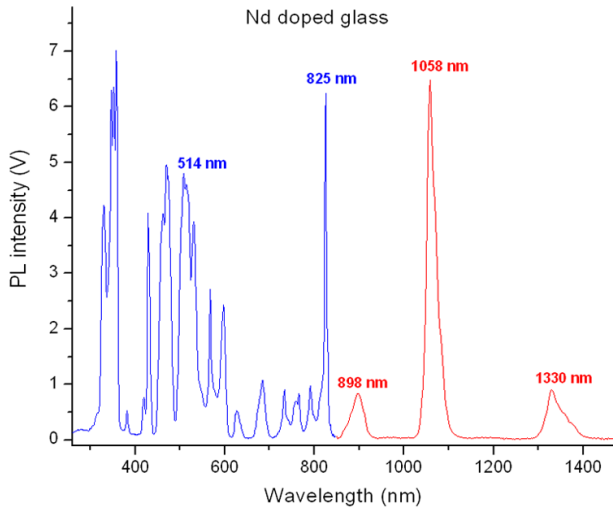


Fig. 2. PL excitation and emission spectra of neodymium ions measured with the QM-50 NIR in the steady state mode.

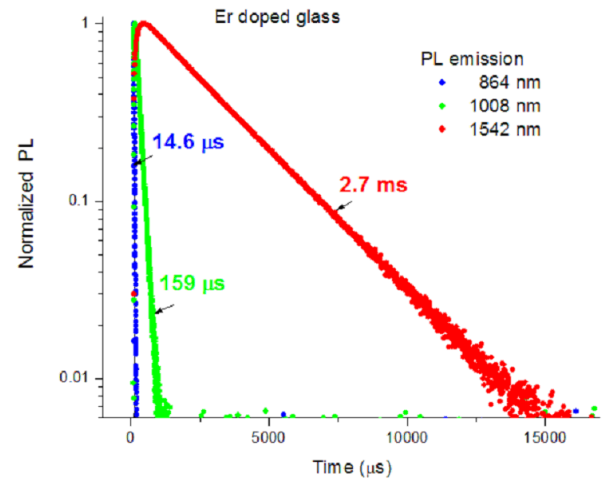


Fig. 3. PL decays of Er³⁺ doped glass measured with the QM-50 system operating in the lifetime mode. Note the dramatic decrease of PL lifetime with the transition energy.

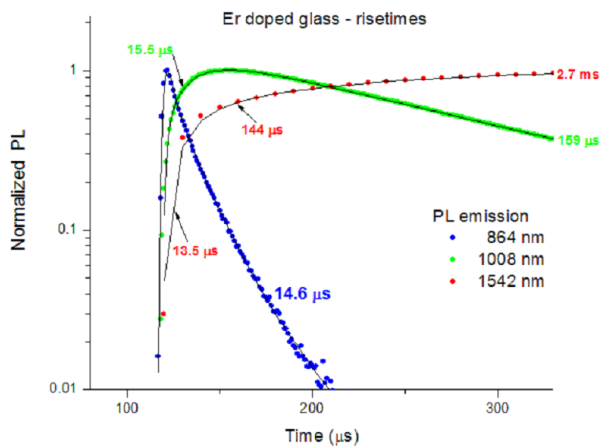


Fig. 4. PL decays of erbium ions from Fig. 3 with expanded timescale. Note the presence of risetimes for transitions at 1008 and 1542 nm and good agreement of the risetimes with decay times of higher energy transitions. IRF not shown.

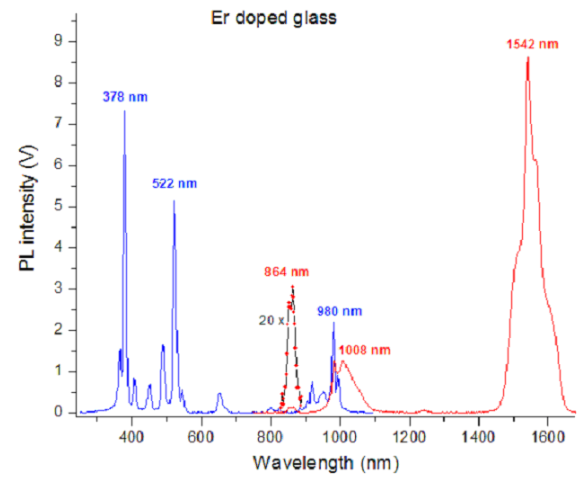


Fig. 5. PL excitation and emission spectra of Er³⁺ doped glass measured with the QM-50 NIR in the steady state mode.

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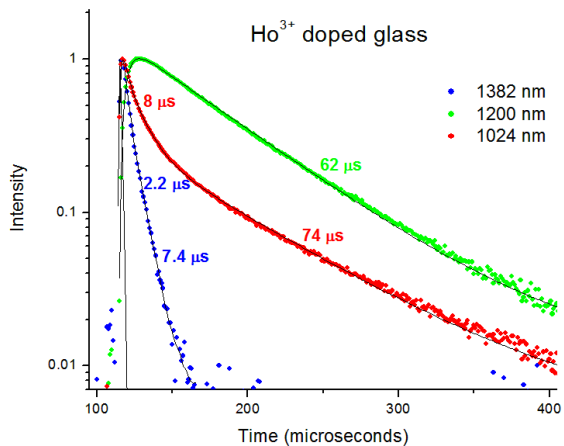


Fig. 6. PL decays of Ho³⁺ doped glass measured with the QM-50 system operating in the lifetime mode. Note that the decays are very different for different transitions. The decay at 1200 nm also shows a rise time of 2.4 μs.

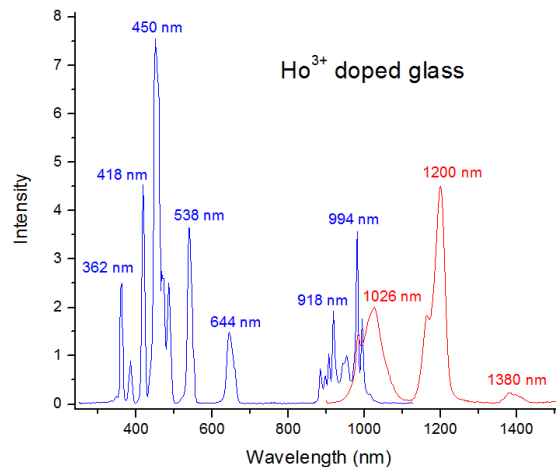


Fig. 7. PL excitation and emission spectra of holmium doped glass measured with the QM-50 NIR in the steady state mode.

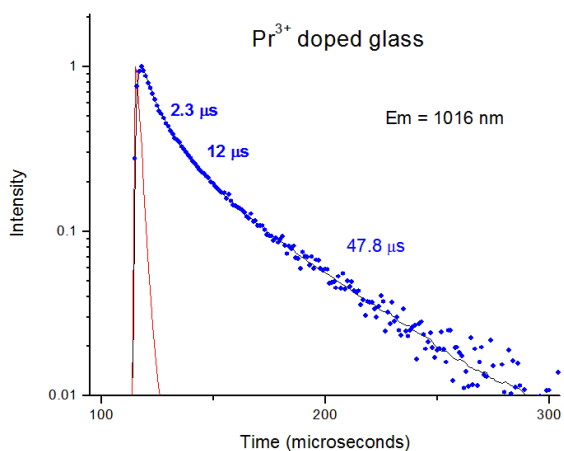


Fig 8. PL decays of praseodymium doped glass measured with the QM-50 NIR system operating in the lifetime mode.

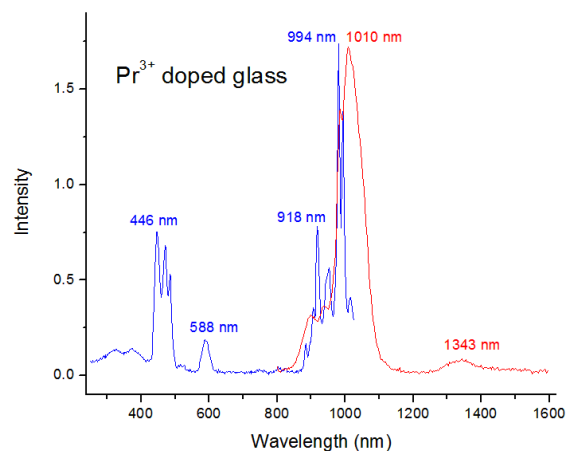


Fig. 9. PL excitation and emission spectra of Pr³⁺ doped glass measured with the QM-50 NIR in the steady state mode.



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