Steady-state and Transient Measurements of 0.8-2.0 μm Luminescence of PbS Quantum Dots

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Abstract

We describe a new experimental setup developed for luminescence measurements in the near-infrared region. The setup let us obtain spectral and time-resolved parameters of nanostructure's luminescence in spectral range 0.8–2 μm for stationary analysis with spectral resolution of 7 nm and 0.8–1.7 μm for time-resolved luminescence measurements with time resolution of 2 ns. We discuss technical parameters of the setup and demonstrate its capabilities on the example of PbS quantum dots (QDs) luminescence measurements.

Spectral luminescence analysis and luminescence decay measurements are important for understanding of charge carrier dynamics, energy levels structure and processes of energy relaxation in semiconductor QDs [1]. However there is a lack of sensitive commercial equipment for such experiments. Because our setup is mainly intended for PbS QDs luminescence analysis, we took into account some features of this objects' luminescence: wide spectral range, long decay times and difficulties with signal receiving as consequence. At the same time powerful sources of excitation radiation should not be used to avoid a photobleaching and multiple electron-hole pair generation.

We use conventional 90 degree detection geometry (fig. 1). The setup consists of continuous and pulsed lasers, monochromators, InGaAs photodiodes, amplifiers, an oscilloscope, and auxiliary optical elements. For stationary measurements 532 nm and 633 nm continuous lasers, an Acton monochromator, cooled Hamamatsu InGaAs photodiodes, and self-made FET preamplifier are used [2]. Spectral sensitivity has been calibrated using a black body source [3]. In time-resolved mode a 635 nm and 980 nm PiqoQuant pulsed lasers are used. Collected radiation is sent through the self-made monochromator or bandpass filters and focused on Femto high-speed InGaAs photoreceiver with build-in preamplifier. The received signal is additionally amplified by Stanford Research amplifier and then registered by PiqoScope hi-speed PC oscilloscope [4]. A purpose-built computer program accumulates the results of measurement to get reliable signal/noise ratio. Signal acquisition rate is above 10^5 waveforms per minute, therefore up to tens of millions waveforms can be accumulated.

The setup capabilities and features are demonstrated on PbS QDs luminescence. The setup lets us to carry out spectral measurements in a wide range of QDs sizes (2.7–7.6 nm) and establish size dependencies of its optical properties [1]. Luminescence lifetimes can be measured in the time range 20 ns – 10 μs that makes us able to obtain luminescence decay curves for PbS QDs in solutions and embedded into the porous matrix.

Acknowledgement

The authors thank financial support from the RFBR (Grants 12-02-01263 and 12-02-00938) and the Ministry of Education and Science of the Russian Federation (Projects 11.519.11.3020, 11.519.11.3026, № 14.B37.21.0741 and 14.B37.21.1954).

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Figures

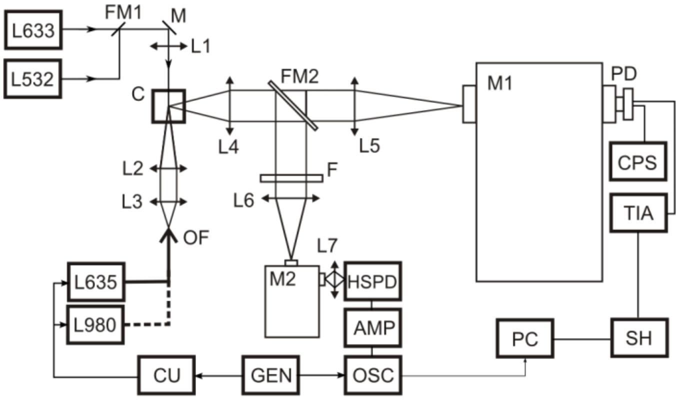

Fig. 1 Functional diagram of the setup for PbS QDs luminescence analysis: (L532, L633) 532 and 633 nm continuous lasers; (L635, L980) 635 and 980 nm PicoQuant pulsed lasers; (FM1,FM2) flipping mirrors; (M) a mirror; (L1–L7) lenses; (C) a cuvette or a sample holder; (OF) an optical fiber; (F) an optical filter; (M1) Acton SP-2558 monochromator; (M2) a compact monochromator with f/3 aperture; (PD) Hamamatsu G5852-21 or G8605-21 photodiodes; (CPS) a cooler power supply; (TIA) a transimpedance amplifier; (SH) Acton SpectraHub; (HSPD) Femto HCA-S-200M-IN hi-speed photodiode; (AMP) Stanford Research SR445A amplifier; (OSC) PicoScope 3206A oscilloscope, (GEN) a frequency generator; (CU) PicoQuant PDL-800B laser control unit; and (PC) a computer.