

Analyze the obtained photoluminescence spectra:

1. Extract the measured photoluminescence spectra's linewidth by fitting a Gaussian and Lorentzian function.
2. Explain which fitting gives better results and why.
3. Correlate the measured photoluminescence spectrum of individual quantum dots with their images.

Analyzing the photoluminescence spectra of individual quantum dots (QDs) involves extracting the linewidth, performing fitting using Gaussian and Lorentzian functions, and correlating the spectral data with the corresponding images.

Step 1. Extracting Linewidth:

- Begin by selecting a representative photoluminescence spectrum from an individual QD. This spectrum represents the emission of photons from that specific QD.
- To extract the linewidth, you can perform a peak fitting analysis. This typically involves fitting the spectrum with both a Gaussian and a Lorentzian functions, as QD emission often exhibits characteristics of both broadening mechanisms.

Step 2. Peak Fitting with Gaussian and Lorentzian Functions:

Use commercial software (Origin) or Python (MATLAB) designed for spectral analysis to fit the selected spectrum with both Gaussian and Lorentzian functions. These functions are often characterized as follows:

- Gaussian Function (for homogeneously broadened lines):
 - Gaussian function: $F(x) = A * \exp(-(x - x_0)^2 / (2 * \sigma^2))$
 - A: Amplitude
 - x_0 : Peak position
 - σ : Standard deviation (related to the linewidth)
- Lorentzian Function (for inhomogeneously broadened lines):
 - Lorentzian function: $F(x) = (A / \pi) * [\Gamma / ((x - x_0)^2 + \Gamma^2)]$
 - A: Amplitude
 - x_0 : Peak position
 - Γ : Half-width at half-maximum (related to the linewidth)

Step 3. Comparison and Evaluation:

After fitting with both functions, compare the results obtained from the Gaussian and Lorentzian fits. Consider factors such as:

- a. Quality of Fit: Evaluate the quality of the fit for both functions. This can be assessed by examining the residuals (the differences between the data and the fitted curves) and the χ^2 statistic. Lower χ^2 values indicate better fits.

b. Physical Considerations: Consider the physical properties of QDs. Inhomogeneous broadening due to size and composition variations may favor the Lorentzian fit, while Gaussian broadening may represent homogeneous broadening more accurately.

c. Nature of the Spectrum: Observe the shape of the emission spectrum. The Gaussian fit might provide a better representation if the spectrum appears more symmetrical. While the Lorentzian fit may be more suitable if the spectrum is skewed or asymmetric.

Step 4. Reporting: Document the extracted linewidth values of different quantum emitters under different sample temperatures (4K, 10K, and 15K), the chosen fitting functions, and discuss your observations in your report.

Analyze the histogram and extract the lifetime:

1. Extract the radiative lifetime of the emitters by fitting an exponential function.
2. Explain the constraints you had to implement in the fitting and discuss the underlying mechanisms governing this process.
3. Correlate the lifetime spectra with the corresponding PL spectra you have collected in the previous section and comment on them.

Step 1. Collect the data from your measurements (different QDs / varying temperatures).

Step 2. Extract lifetime of the different emitters by using either commercial software (e.g. OriginLab) or coding languages like Python (MATLAB). The fitting could be done by using a single exponential function:

- $F(x) = F_0 + A_1 \cdot \exp(-(t - t_0) / \tau_1)$

$F(x)$ = observed signal or intensity at time t .

F_0 = offset or baseline at time $t=0$. It represents the initial value of the signal when the decay process begins.

A_1 = amplitude or the difference between the baseline F_0 and the peak signal.

t_0 = is the time offset or the time at which the decay process begins. It's the time at which the decay or emission process starts influencing the signal.

τ_1 = is the decay constant or the characteristic time constant of the exponential decay process. It determines how quickly the signal decays from its initial value F_0 to $1/e$ of that initial value.

Step 3. Compare your results with each other (different QDs or different temperatures). Comment on the confidence of your fitting. This can be assessed by examining the residuals (the differences between the data and the fitted curves) and the χ^2 statistic.

Step 4. Document your results and report the extracted lifetimes of your emission spectra, your fitting functions and your confidence in them. Discuss your observations.