PHY340 Data Analysis Feedback:

Group P06 doing Problem P6

# Data Analysis

You determined the visibility values by selecting the highest and lowest 27 points and taking the “mean average” (as opposed to the generous average? This is a silly expression: if you mean “the arith­metic mean” as I imagine you do, then *say* that). This seems very likely to overestimate the visibility, since it will preferentially select points that are fluctuations upwards or downwards (respectively) from the true peak. In cases where some peaks are higher than others, it will also preferentially sam­ple the higher peaks. You seem to be aware of these issues, since you explain that you went from 9 to 27 points in order to reduce their effect, and you discuss the problem further at the end of your report, but you do not present any quantitative studies and you do not provide error bars on your visibility data points. Statistical errors could be calculated from the error on the mean; systematic errors could be investigated by considering the difference in your calculated visibilities for 9 and 27 points.

 *Figure 1: Fringes from the 0 mm RF run. The red solid lines correspond to the 9th highest/lowest intensities, and the dashed lines to the 27th highest/lowest.*

I suspect that in some cases, the systematic error introduced by your technique is rather large. Consider the 0 mm RF dataset plotted in figure 1, which admittedly is fairly pathological: most of the runs are nicer-looking than this one. The visibility calculated from the 9 highest and lowest points is 0.269±0.006, whereas for the top and bottom 27 it’s 0.246±0.003. Looking at figure 1, I would argue that the former value is completely meaningless, because the top and bottom 9 points not only do not sample all the peaks, they are not even a fair sample of the peaks they do belong to. It’s clear that you are taking only upward/downward fluctuations, and are therefore significantly overestimating the visibility. You were definitely correct to reject this methodology. However, in this particular (not necessarily typical) dataset, even taking the top/bottom 27 points is not safe: you are still not sam­pling all the peaks, and because there is a systematic overall trend you are not sampling the *same* peaks in both datasets: you are missing the maxima of the outer fringes, and the minima of the central ones. Therefore, again, you are systematically overestimating the fringe visibility. There are ways to correct for this: for example, you could fit a polynomial to the entire dataset, to describe the overall trend, and then subtract this off to “flatten” your baseline. The effect of this can be seen in figure 2: the top and bottom 9 points still sample only statistical fluctuations, but the top and bottom 27 sample nearly all the fringes and seem much safer. The calculated visibility is now 0.243±0.003, a decrease of one error bar compared to the raw data—probably not a significant change in terms of the overall fit, but worth investigating. This is still likely to be an overestimate: it is clear from figure 2 that even the top 27 points systematically miss downward fluctuations in points near the peaks, such as the red points near the maxima of the 4th, 5th and 7th fringes in figure 2.

*Figure 2: as figure 1, but with quadratic fit to overall trend subtracted off. Note that the top 27 points systematically exclude downward fluctuations, such as the points picked out in red.*

One effect of this overestimating is that you will calculate a non-zero visibility even in cases where there really are *no* visible fringes, such as the dataset in figure 3. There is no fringe pattern here, but the visibility calculated using your method comes out to 0.0360±0.0010: small, but non-zero.

*Figure 3: PL 0 mm data, with top and bottom 27 points indicated by dashed lines.*

The effect of this is seen in your figure 2: instead of going to zero at times far from the fringe maxi­mum, your visibilities tail off to a constant non-zero value. This will adversely affect your fit quality if you do not take account of it: the simplest procedure is to fit a Gaussian plus a constant, , instead of just a Gaussian.

Proceeding *to* the fits, we seem to have a serious problem: although the caption to your figure 2 cor­rectly states that the PL data should be fitted to a Gaussian, the function you show does not look in the least like a Gaussian. I am reasonably confident that this is in fact an exponential, as shown in figure 4.

 
*Figure 4: fits to the PL data. Left, fit to Gaussian plus constant, giving t0 = 369.9±2.0 ps and T2 = 179±5 ps; right, fit to exponential, giving t0 = 368.2±3.2 ps and T2 = 142±8 ps.*

The caption to figure 3 states that you have fitted a Lorentzian line shape. If this were true, it would be completely wrong: the RF data are expected to produce a Lorentzian line shape,
***in frequency space***, but you are not working in frequency space and so this is irrelevant. You should be fitting an exponential,
In fact, looking at your figure 3, it does not appear that you have fitted either a Lorentzian or an expo­nential: this actually looks like a Gaussian, badly distorted by your failure to take into account your constant offset. In other words, *you have fitted your functions the wrong way round!*



*Figure 5: Fits to the RF data. Solid line, fit to , yielding A = 0.387± 0.009, t*0 *= 317±11 ps and T2 = 594 ±33 ps, with an RMS of 0.013 and an ad­jus­ted coefficient of determination of 0.981. Dashed line, Gaussian fit (with con­s­tant background, which fits as 0.118±0.010), yielding t*0 *= 296±15 ps, σ = 244± 21 ps (hence T2 = 432±37 ps), with an RMS of 0.013 and an adjusted coefficient of deter­mination of 0.979. The two fits are es­sen­tially equally good.*

In fact, the RF data fit quite well to a Gaussian, as shown in figure 5, *but only if you include a constant offset*, which for my visibility values (calculated using a method not dissimilar to yours) turned out to be 0.118±0.010 (yours looks as though it would be a bit larger than that). Because you did not do this, your Gaussian fit is clearly terrible, and the *T*2 value is too large by about a factor of 2 and has a very large error.

This brings up a key point: you can fit *any* function to *any* set of data, but if the function is not appro­priate the fit will not mean anything. Even though you have made no attempt to calculate error bars for your data points—which you should have done, as with your method it’s not difficult—it should be immediately apparent from looking at your figure 3 that *your function is the wrong shape*. Clearly your data have a narrower central peak and wider wings than your fit. This might have caused you to re­cog­nise that you’d got the wrong function, but in fact the same thing would probably have happened if you’d fitted a Gaussian to your PL data, because they also have this constant background (though there are more points, so it might not have had quite such a bad effect). It is less obvious that your function in your figure 2 is the wrong shape, but there are still clear hints: the peak is too sharp, and the data points are systematically lower than the curve at first, then systematically high, then low again. If you compare the two plots in figure 4 above, you can see that the Gaussian is definitely a better fit than the exponential, and the numbers bear this out: the RMS residual and the adjusted coefficient of deter­mination are 0.0089 and 0.994 respectively for the Gaussian, and 0.020 and 0.972 for the exponential (the former number says that, on average, the points as more than twice as far from the exponential fit as from the Gaussian).

I think your visibility data are quite plausible—they look very similar to mine, which is reas­suring since I used a somewhat different method—but you have effectively thrown away much of this good work by carelessness in your analysis. Your final results are, as far as I can see, both wrong, simply because you did not fit the right function to the right dataset (and, as a contributing factor, that you did not realise that your method would *never* produce zero visibility for data with non-zero statistical noise, and that this should be taken into account in the fit). It looks to me as though you simply did not look hard enough at your data: you surely know what a Gaussian looks like, so whoever wrote the caption to your figure 2 should have stopped and thought, “But this doesn’t *look* like a Gaussian!” Your report should have included some plots like my figures 1−3, and a discussion of the implications of my figure 3; it should also have included a discussion of the quality of your fits, especially the one in your figure 3, which is clearly awful (ideally, you should quote the χ2 of your fits, but I don’t think you can do that, because there is no evidence that you thought at all about the error bars on your data points).

Average mark for this section: 28.5/50

# Data Presentation

The first obvious point to make is that if you are using colour to distinguish the lines in your plots, don’t hand in a black and white print-out! It is quite annoying to be told that the blue curve is the data and the red curve is the fit, when what you actually have is two shades of grey. In general, it is good practice to ensure that your curves are distinguished by more than just colour (e.g. make one a dashed line), because some people *will* print out your work in greyscale (including print versions of journals) and a significant fraction of people (about 10% of men, 1% of women) are colour-blind to some degree and may not see the colours as you intend.

As noted above, there should be plots from the earlier stages of your work, to explain and justify your procedure and to illustrate potential systematic errors. Figures 2 and 3, apart from needing to be in colour and/or have distinctive line styles, should have *points* for the data, preferably with error bars, not just a line.

The axis labels on figures 2 and 3 are rather small, and you should either convert your times from seconds to ns or ps, or find a plotting package that can quote scientific notation properly (10−10, not 1e−10).

Generally, you have quoted numerical values appropriately, but 9.496±1.483 is silly—this should be 9.5±1.5—and you have not propagated the errors in *T*2 to errors in the bandwidths (since in both cases *T*2 ∝ 1/Δν, this is very simple: the fractional error is the same for both, so you should have 3.465 ±0.018 GHz for PL and 0.33±0.05 GHz for RF). I also think that you may have made a factor 10 mistake in copying down the error for your PL fit: my exponential fit gave a *T*2 of 142±8 ps, so I suspect that yours really gave 153±8 rather than 153.0±0.8.

It would be good practice to compare your results with values from the literature, for example 154±5 ps for a Gaussian fit to the PL data, and 640±40 ps for an exponential fit to RF data, from Makhonin et al. (2014). As this is the same group that provided your data, you might feel justifiably concerned that your RF number is a long way out (and lulled into a false sense of security by the good agreement of your PL value!). My values, 179±5 ps and 594±33 ps, look OK for RF but noticeably different for PL; however, Makhonin et al. (2014) do not seem to have fitted the same function that you were told to fit, see figure 6. If they fitted
without the factor of in the equation in the instruction sheet, then my value of *T*2 comes out as 143 ±4 ps, which is fairly consistent with 154±5. Interestingly, Makhonin et al. clearly fitted their Gaussian with a constant background (see figure 6) even though their data do not seem to need one.



*Figure 6: Fringe amplitude against time delay, from Makhonin et al., Nano Lett.* ***14*** *(2014) 6997 −7002 (their figure 3a). Note the presence of a constant offset of about 0.05 in their Gaus­sian fit, though their data do not obviously re­quire this (the last few points are below the fit). Super­imposed on this plot are functions of the form , with T*2 *= 154 ps (dark blue dashes) and 185 ps (dark red dashes): it is clear that T*2 *= 185 ps reproduces the “T*2 *= 154 ps” line in the paper, whereas T*2 *= 154 ps does not. This shows that the function fitted in this paper has a different form from that given in the instructions.*

Average mark for this section: 16.25/30

# Style

You do seem to know what is expected of a scientific report: your report has the correct overall structure and appropriate section headings, and your abstract is a fair summary of the paper. How­ever, the whole report is seriously in need of careful proof-reading, to get rid of confused statements like “Photon emission is a useful property of Quantum Dots and can be used to obtain coherence times further investigate and research properties.” This makes no sense as it stands—and it’s the first sen­tence of the report, so you are not giving a good first impression! The second “sentence” isn’t a sentence at all: I suspect that the “and” in “and understanding” should be “an”, and should be preceded by a comma: at least that way you have something that compiles as a sentence. Later in the intro­duction, we get “This review explores, we explained how light (in the form of a resonant electro­magnetic field) can be absorbed by the quantum dot, and then scattered at the same initial frequency.” This also doesn’t make sense (I really have no idea what this one was supposed to look like). Other careless errors include “is given” in subscript between equations 3 and 4.

These are all issues that would have been fixed by a careful and thorough proof-reading. This whole report looks as though nobody cared enough to really read it: anyone who really *looked* at figures 2 and 3 would notice that the Gaussian doesn’t look Gaussian and the exponential doesn’t look expo­nential, and come to the same conclusion that I did; anyone who read through it carefully would have noticed the sentences that don’t make sense. Maybe you just did not manage your time effectively, and wound up doing it in too much of a hurry. It’s a pity: you have sound initial data, but your careless mistakes have meant that you have not made good use of it. A couple of hours’ more work could easily have given you another 10%.

Average mark for this section: 12/20

Overall average mark: 56.75%