Mert Ercan

Peer Review On Felipe Mazzi's Code Project – Anisotropy Assisted Quasi-Phase Matching (AA-QPM)

This project makes use of an original method called "Anisotropy-Assisted Quasi-Phase Matching" for on-chip second harmonic generation. In this method, the effective nonlinear susceptibility is modulated by changing the path shape of the guiding structure. This project provides a detailed comparison between the "conventional" quasi-phase matching methods and results that can be obtained by a given shape of the guiding structure.

I will be listing a few things that are not necessarily important for the physics but would make the notebook look better for coherency and simplicity. These are mostly because I think we are aiming with these notebooks to be useful to someone who does not have prior experience, so from the point of view of an experienced reader these will not be so important.

AA-QPM INTRODUCTION:

1) I don't really know if we require the introduction to be in Jupyter notebook. I would rather have it as a pdf (opening pdfs are slightly easier for the user) since the actual code is in Mathematica. You can even opt to merge mathematica pdf with this.

Point taken, thank you! I will include a PDF version in the Drive folder.

2) 1. Overview of Chi-2 Nonlinear Susceptibility Tensor, can be written in equation format χ as that is how you proceed under.

Good point, altered.

3) I think it would be better if you took a slower approach as you did in your presentation, that is to say, go through each term and its meaning if any (like phase matching). Especially in the first equation you laid out. I think the rest would then be complete. In my opinion, this would also show users that they can expect to understand even the most useless terms in this notebook.

Excellent point, I added a few paragraphs to improve this discussion.

4) Perhaps you could expand a little bit more as to why 3m group materials have these properties in a sentence. Same for what Kleimann Symmetry is, however, I think that is more apparent to many people.

This is indeed necessary for completeness. However I believe that a proper explanation could be a deviation from the main topic, so now I included references specific to this part.

readme:

1) You can put the title, the aim of the notebook/code very shortly. Date of the code, versions used would be a nice addition as well.

Done, thank you!

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AA-QPM Code:

1) Modelling QPM and calculating its efficiency -⟶ Susceptibility Modulation: The period of susceptibility modulation comes out as negative; you may want to put an absolute value.

Thank you for pointing it out. I added the absolute value to represent the condition. In reality, this sign will depend on whether I am looking at the condition for the forward or reverse project, which are optimal at the same values for k_1 and k_2.

2) I did not quite understand the relative efficiency plots. I think just a sentence to clear it out as good. Especially when the user is not familiar with the programming language used, it gets harder to understand.

Good point, thank you! I just added a few short sentences on that. Indeed, the reader should be instructed to compare this plot to the previous one to get more meaning out of it.

3) To me it looks like you look at the ratio at each propagation distance between the phase-matched and the methods (QPM, or AA-QPM, or phase mismatched). However, I do not understand why there is a strange behaviour at the start for QPM where efficiency seems to increase wildly at start and is worse than phase-mismatched which is counter intuitive. Aren't they all supposed to start from 1 at 0 propagation? It may be a numerical artifact or something physical; however, some explanation with text would be good.

Very good point. Indeed the green and blue curves (mismatched and quasi-phase matched) should be identical up to the first coherence length, and then slowly diverge. As you pointed out, this is a numerical artifact. The mismatched case can be solved exactly, but the Mathematica solver had some issues with solving the numerical equation at z=0, so I started it at z = 0 + dz. Since we are only interested in the "final" (steady-state) value, I omitted this part to avoid confusion and added a note.

4) In accordance with my last comment, I find it easier to go through the notebook if the author keeps referring to the equations solved at each specific section, also accompanied by text (I am not sure if it is possible to show equations in this format in Mathematica). For instance, your text at `rotating the frame of reference` is a good example, and you do this occasionally, but it feels like there is still space for this. This is subjective of course!

I tried to improve this by adding explicit references to equations (repeating them directly instead of just referring to them) . I hope it is better now.

5) Extracting Effective Nonlinearity from a Path Shape –> Susceptibility Tensor and the Overlap Integral: There is a reference to starthere.pdf (which was not send in the files) which is probably the old file name for the introduction.ipynb.

That is correct, thank you! I just changed it.

6) Some conclusion would be in place, which you seem to have in mind from your introduction page but perhaps could not find time yet.

Good point, I added this conclusion and some "future perspectives" in the file

7) To me it looks like there is a legend mismatch in `Calculating the efficiency of AA-QPM` section where phase matched seem to be oscillating and mediocre, where as

quasi-phase matching is perfect. Which color represents which process also seems to have changed in this plot, so it is probably good to take a look.

Excellent point, the order was in fact inverted, I just changed it.

8) Ultimately this conclusion may touch upon why this method is introduced. Is it better? What is the conclusion out of this simulation, is this method worth going after? Is it perhaps much easier to do in the lab so even if it is worse, it could be more practical in some cases? I think a few sentences from your presentation could be a good finish.

Yes, thank you, I also addressed this in the conclusion paragraph suggested above. I reproduce it here:

A model was introduced and implemented to quantify the efficiency of anisotropy-assisted quasi-phase matching (AA-QPM). The results indicate that nonlinear conversion can in fact be achieved between initially mismatched modes simply by modulating the optical path in the two-dimensional plane. Obtaining the optimal path to achieve this is an open question, as a trade-off must be considered between maximum theoretical efficiency according to this model, and the actual efficiency in a device where the curvature radius, dispersion characteristics and cross-talk effects will be relevant. Nevertheless, this model itself can be used for an iterated "inverse design"-like process of searching for the ideal path shape.

Overall, the central advantage of AA-QPM is that it can reduce fabrication complexity significantly. In comparison of electric-field induced poling, for example, If the reduced efficiency is acceptable, this technique can eliminate an additional step of aligned lithography, the deposition, lift-off and removal of metal contacts (which often contaminate the sample and lead to increased optical loss) and the cumbersome process of applying electric pulses with the correct waveform and at the correct temperature.

Typos (ones that have drawn my attention)

Rotating the frame of reference

First sentence, “matching requires both the susceptibility *anistropy”*

Second sentence, “Thus, it is *pnly* feasible” “...and for interactions between *quasei*-TE mode”

Fourth sentence , “or the optical mode, we can adopt a frame of reference *thaat*…”

Simulating AA-QPM

First sentence, “…to estimate the efficiency of AA- QPM with a *sinuisoidal* path.”

Thank you! I fixed these.

Overall, I think this is a really good project. It is very nice to see that you came up with such an idea!