NLO Exam Protocol

28.08.2019

1. What is nonlinear in NLO? When can one observe it?

Relationship between **P** and **E.** At electric fields close to interatomic electric fields. ~10^8 V/m.

2. Linear electric polarization in time-invariant local in space media.

Eq. 1.9, explain the terms

3. Can $\chi^{(1)}$ be a scalar? When?

Yes, in isotropic media.

4. How expression of P looks in nonlinear case?

Eq. 2.1, explain a bit.

5. Expression for $P_q^{(2)}$?

Eq. 2.3

6. Professor showed eq. 1.95. Explain terms. How can one come to that equation?

Use SVEA, draw a pulse envelope with carrier inside it, explain.

7. Why do we do SVEA?

To have first-order differential eq. instead of second-order one.

8. How can we simplify eq. 1.95 even more?

Retarded time frame, write expressions for t' and z', explain what this change does and which term in equation cancels out because of it.

9. The phase matching part in the eq. Why do you need phase matching? What is $k_{p,l}$ and k_l?

So that contributions at different points in the media add up constructively. $k_{p,l}$ is the wave number/vector corresponding to contributions from induced P_{NL}, k_l - wave number that corresponds to the generated wave on the left side of eq.

10. Write down phase matching condition for SFG.

Let's say we have type I phase matching, negative uniaxial crystal, collinear interaction. Then in the end we get:

$\omega_1 n_o(\omega_1) + \omega_2 n_o(\omega_2) = \omega_3 n_e(\omega_3)$

11. Explain the principle of Mach-Zehnder modulator.

Draw a sketch, explain. For me a drawing in a complex plane helped to explain how to get only amplitude modulation without chirp and from where the chirp comes.

12. How can you achieve the phase shifts in the arms of the modulator?

Here I drew a z-cut modulator, explained everything how one uses r_{33} coefficient with the help of eqs. 3.23 and 3.24, how the same phase difference with opposite sign is achieved and similar things.

13. How else can you modulate the light?

Fig. 3.11, tell about the purpose of $\lambda/4$ waveplate.

14. What is soliton?

Self-sustaining wave packet. Maintains shape while propagating at a constant speed.

15. What equation would you use to describe the processes happening when soliton occurs?

Nonlinear Schrödinger (NLS) equation. Write out the terms, explain each of them.

16. When does a soliton occur?

Third order nonlinearity needed, GVD compensated by SPM (can be achieved in optical fibers). Draw pulse in time when only dispersion affects it. Take NLS case without GVD term (eq. 5.52), one can then express the phase shift (5.54). Draw pulse shape in time, phase shift in time and the derivative of the phase shift with respect to time (which gives frequency shift). Explain.

17. What pulse shape does a soliton have?

Take NLS without the attenuation term (eq. 5.56). By putting in ansatz you get eq. 5.60. Taking phase factor K into account in the end you obtain:

$$\underline{A}(z,t) = A_1 \operatorname{sech}\left(\frac{t}{T}\right) e^{-\mathrm{j}Kz},$$

18. If one would increase the pulse duration T, what would happen?

Eq. 5.61. Increasing T means less spectral components in the pulse, which leads to less dispersion, therefore one needs less SPM, which means amplitude of the pulse should be decreased.

In the end, the result was good. I would say that you should just try saying what is on your mind, explain it in your way. You can deviate a little bit from what you might think that he really wants to hear as long as everything you say is correct and it helps you to explain the thing you are asked for. It shows that you can think by yourself, not only learn by heart and it does not go unnoticed by prof. Koos. Best of luck in your exam.