Photosynthesis Course Note

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July 11, 2016

Contents

Abstract

This is a note of the course *An Introduction to Light Harvesting in Bacteria and Plants*. The course is more of a academic than of a pedagodic nature: ideas and methods are only mentioned, with reference to the published paper available in the corresponding PDF page. Therefore, this note aims to provide a guidance to read the PDFs. Note that the page numbers in this note are the page numbers of each individual PDFs, not necessarily the page numbers displayed on the bottom-right corner inside the PDFs.

1 June 29th

In this lecture, the teacher presents backgroud for light-harvesting mechanism in biology systems:

- **pp.1 to 9 of PPT** General backgroud to Biophysics.
- **pp.10 to 18 of PPT** Review of several mechanisms of light harvesting in different species.
- **pp.19 to 20 of PPT** The central topics of this course
  - The natrual of exciton in biological ligth harvesting system. Is it of Frenkel (short-ranged) of Wannier (long-ranged) type?
  - The transfer mechanism. (pp.20) It was mentioned that the transfer is much more efficient than predicted by a classical diffusion model.
  - How is active self-regulation archieved. (pp.20)

Then after a review of Quantum Mechanics (**pp. 22 to 32**)[1], the teacher illustrated a model to calculate the excitation energy of a dimer.(**pp.33 to 36**) Note that here it is expected that only one of the dimer is excited, becuase this energetically eaiser to achieve. Note also that the symble "†" denotes neither conjugation nor creation operator, but simply a label for an excited state's wavefunction.

Afterwards, the result on **page 36** expressed the excitation energy as a function of transition dipole moment and the speration length of two molecules.

2 July 1th

pp.1 of PPT It begins with a review of two modes of excitons in organic biology.

pp.2 of PPT

3 July 8th

In the previous lecture, the *master equation* for density matrix [2] could lead to problematic result. When the density matrix propagates as described by the master equation, the eigenvalues for it might evolve into comprising negative values. This is because the added terms are not rigorously derived, but just an approximation. On **page 2** the teacher mentioned a specific case.[3] Therefore, one introduces the **Lindblad equations** (**pp.3**). This equation ensures that the density matrix $\rho \geq 0$ (i.e. having all positive eigenvalues). However, this operator sometimes breaks down the symmetries of the system. That is, a system started with translation symmetry at t_0 might not have translation symmetry at $t > t_0$.

The teacher wrote an example for the V_m term on ppt on blackboard:

Considering the case of a harmonic oscillator.

$$H = w_0 a^\dagger a$$

If we add an interaction between the oscillator and other excitons:

$$A^\dagger A(a^\dagger + a) = \text{extra} \otimes \text{bath}$$

Then $A^\dagger A$ is V_m in ppt.

[1] Interestingly, the teacher mentioned Bohmian Mechanics, an alternative model of Quantum Mechanics that features determinism and nonlocality. A comprehensive discussion of this model could be found here: `http://plato.stanford.edu/entries/qm-bohm/`

[2] Reference not found.

[3] Digression: in the article PRE 65 056120, we can find something about the entanglement between two oscillators.

Digression In two Spin system. One way to judge whether the two particles are entangled or not, is to do partial transpose: transposing only part of the density matrix corresponding to only one particle of the system.

Next, the author provided a specific model of energy transfer. [4]

pp.5 shows diagramatically the exciton transport process. External influence to the system includes trapping, decaying and disspation. Here k_t characterizes the trapping rate. And k_d characterizes the decay rate.

pp.6 of PPT explains some notations. Here τ_n characterize the life time of exciton in on state n. [5] We hope that the total life time $\langle t\rangle = \sum \tau_n$ is small, because the shorter an exciton is fixed on a state, the more random the system is and the more likely that the exciton is trapped.

Following are a series of toycases that has been calculated.

pp.8 to 9 are the $\rho(t)$ for these simple cases.

pp.10 of PPT [6] This ring with 16 sites shows that there is always a peek Max population in the opposite site(See upper-right plot). This is because there is always two channels of equal length for excitons to get to the opposite site.

pp.11 of PPT is a two ring case, with 8 sites on each ring. The initial configuration is that excitons are evenly excited in the left ring. The right ring comprised of trapping sites.

pp.12 of PPT is another two ring case, with a change in the right ring's number of trapping sites. It shows that a asymmetric design would somehow imporve the efficiency, since the plot on the right has a maximum region while the left one has none. The next slide shows similar result.

Caution: I am quite confused by the following content, from pp.16 to the end of PPT. Erogo the following notes are note well organized. It is advised that one should look at the original literature instead.

pp.15 to 16 shows a more advanced calculation of excited states.

pp.16 of PPT Calculating the absorption spectrum, showing that only one level is acceptable.

pp.17 of PPT Changing the configuration of laser could result (in generally) more acceptable levels. However, these laser configurations are not practically achievable.

[4] **Note**: This section's material could be found in *Excitonic energy transfer in light-harvesting complexes in purple bacteria. JChemPhys_136_245104.pdf*

[5] Here $\rho_n \equiv \rho_{nn}$.

[6] Could be found on *Efficient energy transfer in light-harvesting systems. Cao and Silbey et al New J Phys (2010)*

pp.19 of PPT Using Frankel-Exciton Model and find very good fit, balabala.