Proc. Indian Acad. Sci. (Chem. Sci.), Vol. 103, No. 3, March 1991, pp. 413–416.

Energy transfer kinetics in the green bacterium *Chloroflexus aurantiacus*

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Abstract. The energy transfer from the main light harvesting complex of green bacteria into the reaction center has been examined by us. The chlorosomes, which are the highly organized antenna system of green bacteria, can perform an extremely efficient capture of light energy which is converted in the reaction center and results in essential electron transfer products. We have carried out some investigations of the energy transfer kinetics in *Chloroflexus aurantiacus* in a two-wavelength fashion. The experiments seem to confirm previously obtained results.

Keywords. Bacterium chlorophyll; chlorosomes; energy transfer kinetics.

1. Introduction

The chlorosomes are the main light harvesting complexes of green bacteria. These membrane associated antenna systems contain large amounts of bacteria chlorophyll *c* (around 10 000 Bchl *c*). The aim of our study was to investigate the energy transfer from the chlorosome to the Bchl 808–866 and the reaction center through the Bchl 795 containing base plate. The chlorosome is an extremely well-organized and efficient antenna system. The large number of Bchl *c* could lead to an annihilation of the excitation energy. Different attempts to reveal such processes have not been successful (Miller *et al* 1990). The results of these experiments indicate that the Bchl *c* is organized in domains of 20–30 Bchl *c* and consequently that the excitation energy is restricted to these Bchl *c*-rods. Investigations of the kinetic energy transfer with a single wavelength pump-probe technique was also done. At $\lambda = 750$ nm Miller *et al* (1990) found a very fast component, $\tau_1 = 11$ ps, which comprises about 80% of the total signal intensity, an intermediate component with a decay time of $\tau_2 = 40$ ps and a signal intensity of 15%–20% of the total intensity. The remaining 5% and less of the signal intensity came from more slowly decaying components. At $\lambda = 800$ nm it was possible to resolve two components of similar intensities; a fast one, $\tau_1 = 40$ and a slower one, $\tau_2 = 300$ ps. A kinetic scheme was then suggested (Miller *et al* 1990).

$$\text{Bchl } c\,740 \xrightarrow{11\text{ps}} \text{Bchl } a\,795 \xrightarrow{40\text{ps}} \text{Bchl } 808\text{–}866 \xrightarrow{300\text{ps}} \text{decay products.}$$

* For correspondence

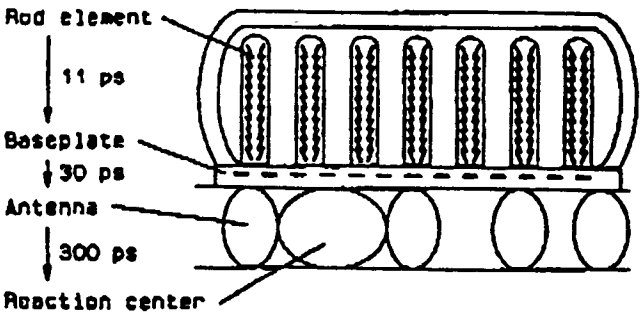

Figure 1. The proposed model for *Chloroflexus aurantiacus.*

Studies of the time resolved anisotropy at $\lambda = 750$ nm indicate a fast decay of the anisotropy from $r = 0{\cdot}4$ to $r = 0{\cdot}2$ within 10 ps (Miller *et al* 1990). The interpretation of this result is that the Bchl *c* transition dipoles are distributed symmetrically about the rod axis at an angle θ. The angle is then given by the following relation:

$$r = r_0(3\cos^2\theta - 1)^2/4.$$

Inserting $r = 0{\cdot}2$ and $r_0 = 0{\cdot}4$ results in $\theta = 22°$. i.e. the mean orientation of the Bchl *c* transition is close to the rod symmetry axis (Miller *et al* 1990). At $\lambda = 800$ nm they found a steady state value of the anisotropy, $r = 0{\cdot}13$. This value is close to a value of $r = 0{\cdot}1$ which is expected if the main Bchl a transition is circularly distributed in the membrane plane ($\theta = 90°$ in the equation above). Studies of the fluorescence anisotropy at $\lambda = 750$ nm results in a value of $r = 0{\cdot}18$, close to a mean value of the absorption anisotropy at $t = 40$ ps, i.e. the anisotropy of an equilibrated system. At $\lambda = 800$ nm however, the emission is only a fraction of the absorption anisotropy; $r = 0{\cdot}01$. This loss of anisotropy is interpreted as if there is a different orientation of the Bchl a transitions relative to the Bchl *c* transitions. Thus, Miller *et al* (1990) could propose a model for the chlorosome organization in *Chloroflexus* (figure 1).

2. Materials and methods

Chloroflexus aurantiacus was grown and prepared according to Miller *et al* (1990). The picosecond experiments were performed using 2 wavelengths, i.e. the sample was excited with one wavelength ($\lambda_1 = 750$ nm) and probed with another ($\lambda_2 = 795$ nm). The advantage with this technique is the possibility of not only measuring the decay of the excitation energy in a complex, but also the rise time of the excitation energy in the same complex. The recorded kinetic traces were fitted to a kinetic exponential model, using a modified Marqaurdt algorithm, consisting of the rise time-component of excitation energy in a complex (τ_r) and two components describing the migration of excitation energy from the specific complexes (τ_1 and τ_2). The kinetic traces were deconvoluted with the cross-correlation produced by the two light pulses of different wavelengths, λ_1 and λ_2, representing the picosecond pulse. The experimental set-up is shown in figure 2.

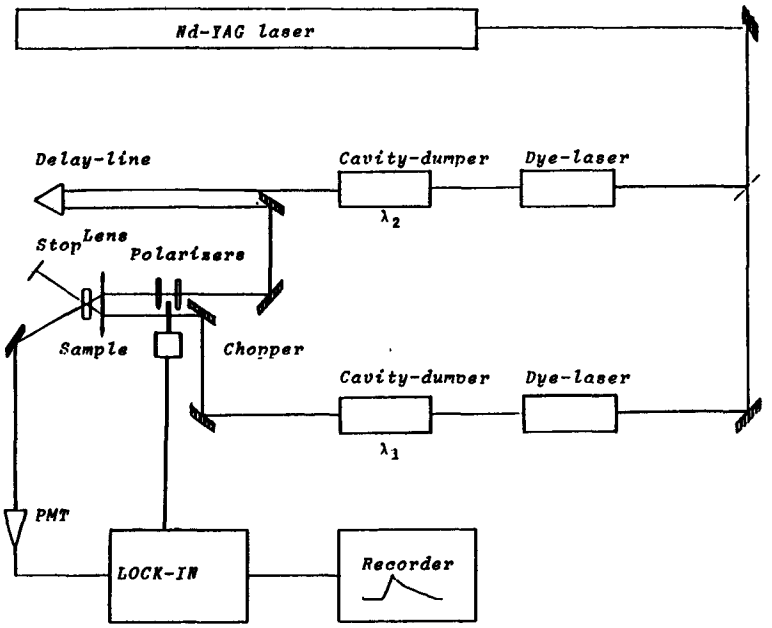

Figure 2. The experimental set-up.

3. Results and discussion

With the obtained results it was possible to study the energy migration from the Bchl a containing base plate further on into the system.

$$\cdots \xrightarrow{\tau_r} \text{Bchl}\,a\,795 \xrightarrow{\tau_1} \cdots.$$

The mean values of the obtained results were:

$$\langle \tau_r \rangle = 23{\cdot}9 \pm 9{\cdot}5\,\text{ps},$$

$$\langle \tau_1 \rangle = 66{\cdot}4 \pm 10{\cdot}0\,\text{ps},$$

$$\langle \tau_2 \rangle = 2800 \pm 1000\,\text{ps}.$$

Concerning the relative amplitudes of the decaying components, τ_1 comprised nearly all of the total amplitude, $A_1(\tau_1) = 95\%$. The value of the rise time, τ_r, is in agreement with what has been reported by other groups and previously obtained results (Miller *et al* 1990). The somewhat higher value of the rise time and the relatively large error might be explained by the difficulty in resolving components with a lifetime shorter than approximately 15 ps i.e. the width of the cross-correlation function used in the deconvolution procedure.

Furthermore, a more proper procedure of treating the rise time-component might be to include yet another component. For instance, Müller *et al* (1990) has observed

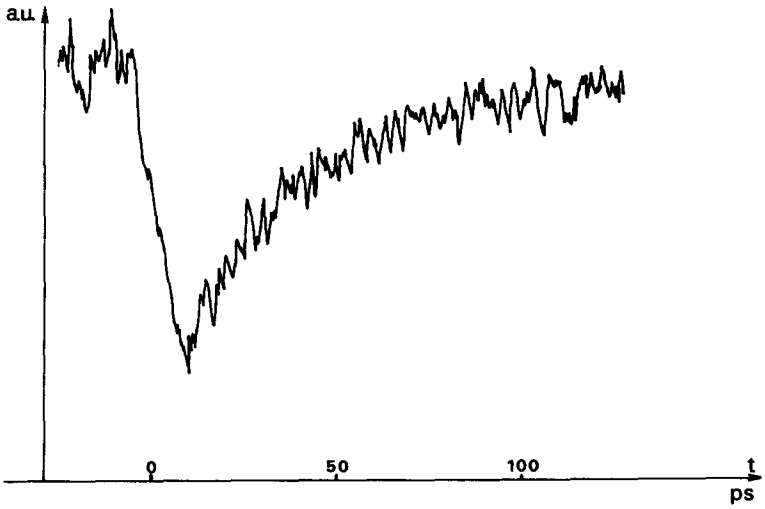

Figure 3. Absorption recovery decay from *Chloroflexus aurantiacus.*

two rise time-components responsible for the growth of excitation energy in the Bchl a pigments. The first decaying component, τ_1, we believe, represents the migration of excitation energy from the Bchl a containing base plate into the *B* 808–866 complex, i.e. open reaction centers. The second decaying component, τ_2, represents most likely Bchl a fluorescence from disconnected Bchl a. The large errors in all the results is caused by the in general unfavorable signal to noise ratio. One of the scans is shown in figure 3.

References

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