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DNA Elasticity at Different Architecture

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ABSTRACT
Mechanical properties of DNA (deoxyribonucleic acid) attracted interest of both physicist and biologists because it is important in numerous mechanical and biological processes. Physical model in static and dynamics of DNA was presented by us as a very thin helicoidal strip. Similar strip in straight form is used in many precision measuring instruments and well presents DNA model properties. It may have different circular architecture with different elasticity especially at action of light. In this article we present mathematical expressions for pressure of light and elasticity of DNA in straight form for linear and nonlinear versions under pressure, and elasticity of curved circular DNA model which is found by biologists in the eyes of nocturnal animals as tiny light-collecting lenses. The circular model of DNA under pressure is presented in this article first time that required experimental verification in the future. In conclusion, we see that further research in the field of DNA architecture connected with radiation pressure of light is required both in physics and biology with special technique and instrumentation. Pressure of light depends onthe mean value of spatial density of incidence light, coefficient of light reflection, the incident angle of light, the concentration of photons in incidence light, Plank's constant, and the frequency of light in the medium which depends on its refractive index. These important features should be carefully estimated in experimental studies of DNA elasticity at different architecture

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I. INTRODUCTION

Physical model in static and dynamicsof DNA was presented by us[1] as a very thin helicoidal strip. Similar strips withappropriate dimensions were used in sensitive mechanical and electro-mechanical transducers and measuring heads[2] (microkators, opticators, micators, photoelectric sorting transducers,microchators with the frequency output, etc.). Resolution of these measuring devices may be up to nanometer. These systems very sensitive to environmental parameters including the pressure of light. From another hand, researchers have discovered an important element for making night vision possible in nocturanal mammals (cats, bats, mice): the DNA within their eyes photoreceptor rod cells responsible for low light vision is packaged in a very unconventional way, according to a report issue of Cells[3, 4].That special DNA architecture turns the rod cell nuclei themselves into tiny light-collecting lenses, with millions of them in every nocturanal eye.

Let us consider this phenomenon in respect of light pressure acting on DNA physical models.

II. PRESSURE OF LIGHT

Let us recall[1] that pressure of light p_{it}can be expressed by the following formula:

$p_{it}=<w>(1+R_{ref})\cos^2 i_{\varphi}.$

where $<w>= 2\pi\hbar n_0 \nu_{igt}$ is the mean value of the spatial density of incidence light, R_{ref} is the coefficient of light reflection , i_{φ}. is the incident angle of light on flat surface, n_0 is the concentration of photons in incidence light, $2\pi\hbar$is Plank's constant, and

$\nu_{igt}=cn_{ref.i}(\lambda_{vac})^{-1}$ is the frequency of light in the medium.

In the latter expression, the velocity of light c= 299, 792.458, $\lambda_{vac}$is the wave-length of light in vacuum, and $n_{ref.i}$is the refractive index of the medium.

III. ELASTICITY OF STRAIGHT DNA MODEL

Regular DNA model presented by us asa straight beam of pretwisted strip [1]with central hole under extension with width of section $b=2b_1$, its thickness $h=2h_1$, number of section rotations$n_o$in the length $l$of the strip as $r=2\frac{\pi}{l}n_0$ .Force F_Q pressure on the aria of cross section A_{csec}provides extension s of the strip in accordance with the following formula

$F_Q/sAcsec= E(1+01786b^2r^2/\lambda)/2003l(1+0.32b^2r^2/\lambda)$, (1)

whereλ =(h/b)^2, E is the Young's modulus ofthe model's material, $F_Q/A_{csec}=p$is the pressure.

In nonlinear version we have in accordance with Eq 6.34 in Ref.1 the following relations:

$F_Q(S_{\gamma 1})=57.3L'_i\psi_2 j_{\theta\eta}L_c\theta_\gamma(S_\gamma)\, S_{\gamma 1,}$(2)

whereS_γ=s/L_c, $S_{\gamma 1}$=2 S_γ, ψ_2=0.25, $L_c$is the molecular length,$\theta_\gamma=\theta/L_c$,whereθ istheangle of the strip's end rotationin radians at its extension s,L'_i is the experimental scale factor, and

$j_{\theta\eta} =F_Q/\theta=0.698GA_{csec}(1.4)^n/\lambda(1+\nu_{jf}\chi_{kp})L_c k_{po,}$ (3)

where 1.4 ≅√2, G is the shear modulus of strip's material, A_{csec} is the area of strip's crossection.

4. Cantilever ring segment schematic in Fig. 1represents loading of special circular DNA (as in the eyes of nocturanal mammals) in the perpendicular to its plane direction by distributed load with the intensity p. Displacement of thissegment in the perpendicular direction u represents by corresponding formulafrom Table 6.10in Ref.1

$u=\frac{pR^4}{EJ}[(1-cos\alpha)^2+\lambda_k(\alpha\text{-}\sin\alpha)^2]$, (4)

where$\lambda_k=EJ/GJ_k$and EJ, $GJ_k$are the flexural and twisting stiffness of the ring's (circular beam's) cross section with the Poisson's ratio $\nu_p=\frac{E}{2G}$-1.

Calculation of elastic rings displacement under applied forces requires knowledge of section's moment of inertia ***J*** which for our DNA model withhelical pretwisted strip (Fig. 2a, b) is equal in each section to:

$J=J_\eta \sin\varphi+J_\xi\cos\varphi$,

where$\varphi=(2\pi/S_o)x$, $J_\eta=b^3h/12$, $J_\xi=bh^3/12$.

We see (Fig. 2) that $J_\eta>>J_\xi$. Therefore we accept $J=J_\eta\sin\varphi$and the average value of J in the helix pitch is equal to

$\hat{J}=\frac{1}{So}\int_{-So/2}^{So/2}J\eta\, sin(2\pi/So)dx=J_\eta/\pi$

Explicit helical model has naturally pretwisted strip, with outer (o) and inner (i) elliptical surfaces. Therefore, its section's moment of inertia is equal to

$J\eta=\frac{1}{2}(J\eta o\text{-}J\eta i) = (b_o{}^3h_o)\text{-}(\pi b_{1i}{}^3h_{1i}/128)$

and corresponding average moment of inertia equals

$\hat{J}==J_\eta/\pi$

In conclusion, we see that for night visionfurther research in the field of DNA architecture connected with radiation pressure of light is required bothin physics and biology, because area light action in this case is larger than the crossection in the straight DNA.

Data openly available in a public repository that does not issue DOIs	The data that support the findings of this study are openly available in the article references.

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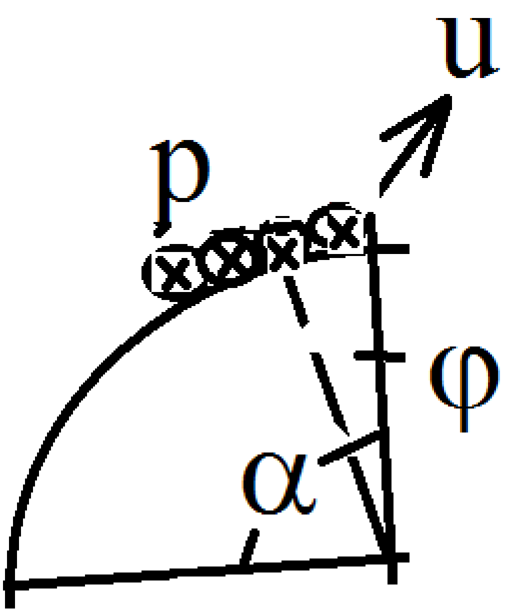

Fig.1. loading of special cantileverring-circular DNA

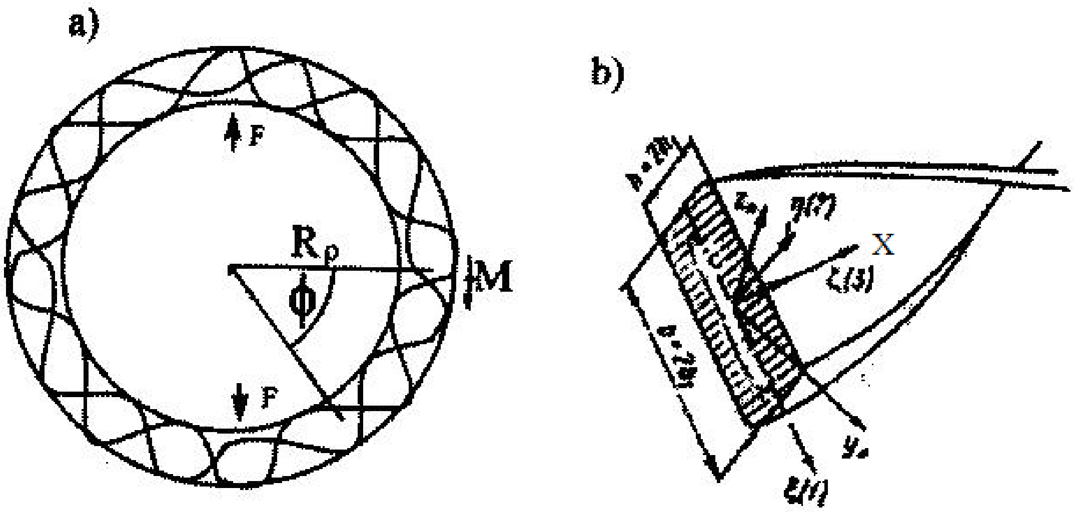

Fig.2. DNA chain in elastic ring (a) and its helicoidal model fragment of twisted strip with central hole(b). Reprint fromPrecision elasticity [1] with permission.

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