ON SYNCHROTRON RADIATION POLARIZATION FROM RUNAWAY ELECTRONS IN TOROIDAL MAGNETIC FIELDS

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The formation of synchrotron radiation polarization of runaway electrons is studied. The radiated power and directions of polarization in the synchrotron radiation spot in the dependence of pitch angles of emitting electrons are estimated. The polarization measurements can give additional diagnostics for the radiating relativistic electrons.

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INTRODUCTION

Synchrotron radiation provides information about the runaway electrons in tokamaks. Polarization measurements will give extra features.

In [1 - 3], the synchrotron radiation from runaway electrons in tokamaks was observed. The synchrotron spectra of runaway electrons in tokamak were analyzed in [4, 5]. In [6, 7] the polarization pattern of the synchrotron radiation of runaway electrons in tokamak has been calculated.

Analysis of experimental data has shown that the description of the synchrotron radiation of runaway electrons in tokamaks is the case when you need to take into account the curvature of magnetic field lines [8 - 10].

In this paper, we will continue to study the polarization of synchrotron radiation in a toroidal magnetic field configuration taking more attention to forming the polarization pattern.

The topology of toroidal magnetic fields, the electron energies take values that are typical for medium-size tokamaks. The nested circle tori for magnetic fields and drift trajectories are considered.

The compact formulas that describe the coordinates of the radiation points are given. The synchrotron radiation formulae for an electron moving along a circle are used to describe the radiation of ultrarelativistic electrons from a small arc of its trajectory. The mechanism of the appearance of linear polarization in the synchrotron radiation spot is elucidated.

The paper is organized as follows. The formulas for coordinates of particles emitting to the detector are given in Section 2. The contribution to radiation from two different regions on the torus is described. The merging of these two areas into one is described.

In Section 3, the formulae for calculating the directions of polarization and power of synchrotron radiation from electrons with drift trajectories on the torus are considered.

In Section 4, the polarization and power in synchrotron radiation spot is calculated for the range of pitch angles of the runaway electrons.

1. TOROIDAL MAGNETIC FIELDS AND ELECTRON TRAJECTORIES

Cartesian coordinates are taken as shown in Fig. 1. The torus is described with coordinates (r,ϑ,φ): coordinates (r,ϑ) with centre at major radius R and the toroidal angle φ, $\mathbf{e}_r,\mathbf{e}_\vartheta,\mathbf{e}_\varphi$ are the corresponding orts, $\mathbf{e}_\varphi=[\mathbf{e}_r,\mathbf{e}_\vartheta]$. Magnetic surfaces and drift surfaces have a toroidal topology. The major radius of nested magnetic surfaces is $R=R_0$, the major radius of drift surfaces is $R=R_0+\delta$.

So, there are two coordinate systems (r,ϑ,φ) and $(r_f,\vartheta_f,\varphi)$ corresponding to drift and magnetic torus, respectively.

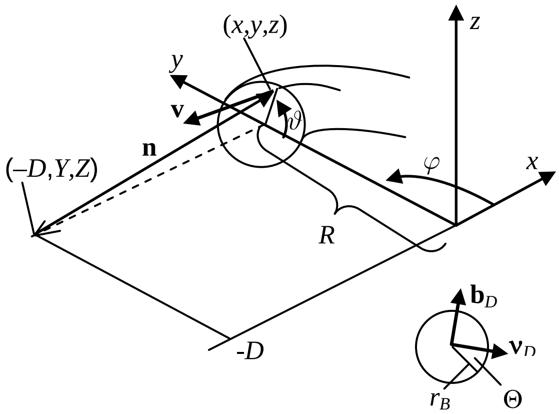

Fig. 1. Coordinate systems. Cartesian coordinates (x,y,z) of the emitting electron; coordinates of the torus (r,ϑ,φ); cylindrical coordinates (ρ,φ,z), $\rho=R-r\cos\vartheta$; cartesian coordinates of the detection point $(-D,Y,Z)$; Larmor's circumference and trihedron orts of the drift trajectory $\boldsymbol{\tau}_D,\mathbf{v}_D,\mathbf{b}_D$ (bottom right corner)

Suppose, the toroidal magnetic field $\mathbf{B}_\varphi$ and plasma current $\mathbf{I}$ are clockwise, radiating electrons are moving counterclockwise.

Magnetic fields take the form [11, 12]

$$\mathbf{B}(r_f,\vartheta_f)=\frac{-B_0}{1-r_f\cos\vartheta_f/R_0}\left[\frac{r_f}{q(r_f)R_0}\mathbf{e}_{\vartheta f}+\mathbf{e}_{\varphi f}\right], \quad (1)$$

here r_f,ϑ_f are the radius and poloidal angle of magnetic surface, $q(r_f)$ the safety factor.

Suppose that the safety factor of the magnetic field lines $q(r_f)$ is equal that of the particle drift orbits $q_D(r)$ when equal radii of magnetic field line surface r_f and drift surface r are considered [1].

The guiding center is moving along drift trajectory with speed $v_\parallel$. The electron pitch angle is

$\alpha \approx v_\perp / v_\parallel << 1$, with respect to the drift trajectory, where $v_\perp = \omega_B r_B$, $\omega_B = eB/(\gamma mc)$, $B = B(r, \vartheta)$ the magnetic field at the point with drift coordinates r, ϑ, $\gamma >> 1$ is the Lorentz factor.

The electron velocity vector is given by [7]

$$\mathbf{v} = v_\parallel \boldsymbol{\tau}_D + v_\perp \left(-\sin\Theta \mathbf{v}_D - \cos\Theta \mathbf{b}_D\right), \quad (2)$$

here $\boldsymbol{\tau}_D, \mathbf{v}_D, \mathbf{b}_D$ are the tangent, normal, and binormal to the drift path, the angle Θ is measured from the normal $\mathbf{v}_D$ to the direction of vector $-\mathbf{b}_D$, $\dot{\Theta} = \omega_B$, Fig. 1.

We note that the position of the electron on the Larmor circle is described by an angle Θ, which is measured from the direction of the normal $\mathbf{v}_D$ to the drift trajectory.

1.1. RADIATION POINTS

The detector is located at the point P_O with Cartesian coordinates $(-D, Y, Z)$, Fig. 1. The line of sight is directed from the detection point P_O to the radiation point P_e, denote unit vector in the direction $P_O P_e$ as $\mathbf{n}$. The high energetic electrons emit their synchrotron radiation practically along their velocity vector (2), Fig. 1.

The coordinates of radiation point are founded out after equating components $-n_y, -n_z$ to the directional cosines of velocity vector, i. e., equations $v\mathbf{n} + \mathbf{v} = 0$ are solved.

For any r, ϑ the third coordinate of radiation point takes a value $\varphi = \pi/2 + \Delta\varphi$, where $\Delta\varphi$ is the first-order correction with respect to $r/R << 1$, $\alpha << 1$.

The electron position in Larmor circle, angle Θ, is given by [6, 7]

$$\cos\Theta = \frac{r}{\alpha q_D(r) R \cos\vartheta_0} \cos(\vartheta - \vartheta_0) - \frac{Z}{\alpha D}, \quad (3)$$

where $\cos\vartheta_0 = D \Big/ \sqrt{D^2 + (q_D R)^2}$.

From equation $v_y + v n_y = 0$ follows[1]

$$\Delta\varphi = \frac{r}{q_D R} \frac{\sin(\vartheta - \vartheta_0)}{\cos\vartheta_0} + \alpha \sin\Theta + \frac{R - Y}{D}, \quad (4)$$

here $q_D(r) = (n+1) q_0 \dfrac{r^2/a^2}{1 - \left(1 - r^2/a^2\right)^{n+1}}$ models the safe factor of drift path, $n = 1...7$, a is the small tokamak radius [11]. Larmor radius r_B is not taken into account because of its smallness.

Formulas (3) and (4) can be illustrated by visual geometric constructions.

The formulae (3), (4) are consistent with eqs. (9), (10) in [12], only you need to pay attention to the fact that our angle Θ is measured from the normal to the drift trajectory. As, the unit vector $\mathbf{v}_D$ has almost constant orientation along the unit vector $-\mathbf{e}_y$, this simplifies calculations.

Further, we assume $Z = 0$, $Y - R = 0$.

The range of angles ϑ depends on pitch-angles α. As can see from eq. (3), there are constraints on acceptable angles ϑ when $\alpha < r/(q_D R_D \cos\vartheta_0)$, Fig. 2.

The angle ϑ_0 specifies the direction of the line AA' to the vertical axis (Z-axis), Fig. 2.

Using (3), we obtain $\Theta = \pi/2$ at the point $A(r, \vartheta_0 + \pi/2)$. At this point, the drift velocity vector is directed to the detector (the projection to the (x, z) plane, more correctly).

Suppose, the radiation point is in the line OC then the point C has coordinates (r_0, ϑ_0). There are not radiation points for $r > r_0$ along this direction. From eq. (3) we obtain $r_0 = \alpha q_D(r_0) R \cos\vartheta_0$. The larger pitch-angles α give larger values of the radius r_0, (the dash-dotted curve in Fig. 2)

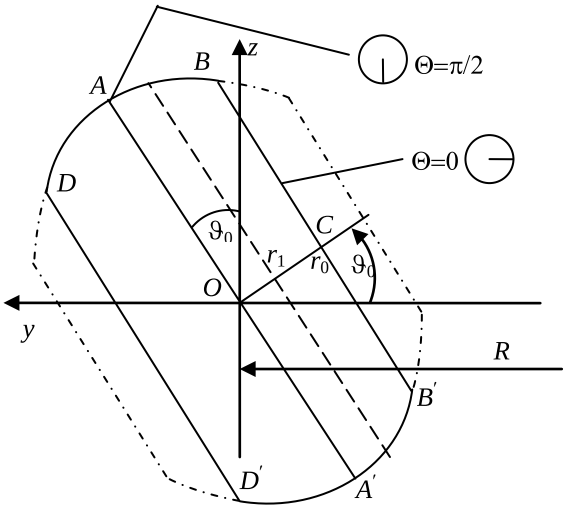

Fig. 2. Scheme of the synchrotron radiation spot. Z=0, R=Y

If $\alpha = 0$ the radiation spot is converted into line AA', which has an angle $\vartheta_A = \vartheta_0 + \pi/2$, where $\mathrm{tg}\,\vartheta_0 = \mathrm{ctg}\,\vartheta_A = qR/D$, [12].

There are two solutions of eq. (3), i. e. $\pm\Theta$.

Substituting $\Theta_1 = \Theta$ and $\Theta_2 = -\Theta$ into eq. (4), we obtain azimuthal coordinates φ_1 and φ_2 of two radiation points. The angular difference between these points is $\varphi_1 - \varphi_2 = 2\Delta\varphi$,

$$2\Delta\varphi = 2\alpha \sqrt{1 - \left(\frac{q_D(r_0)}{q_D(r)}\right)^2 \left(\frac{r}{r_0}\right)^2 \cos^2(\vartheta - \vartheta_0)}.$$

The maximum value of the angle $2\Delta\varphi$ is reached on the line AA' whenever $\Theta = \pm\pi/2$, then $\Delta\varphi = \alpha$.

Along the dashed line in Fig. 2, as follows from (4) for $q_D(r) = const$, we obtain $2\Delta\varphi = 2\alpha\sqrt{1 - (r_1/r_0)^2}$, where $r_1 \in (-r_0, r_0)$ is the minimum distance between the dashed line and the point O. $l \approx 2 r_{beam} \sqrt{1 - (r_1/r_{beam})^2}$ is the dashed line length, r_{beam} is the radius of electron beam.

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[1] In [7, eq. 5] should be $r/(q_D R)\sin\vartheta$ instead of $r/(q_D R)\cos\vartheta$.

There is one radiation point at lines BB' and CC', $\Delta\varphi = 0$ for these lines of sight. The line BB' is described by $r\cos(\vartheta - \vartheta_0)/q(r) = r_0/q(r_0)$ as it follows from eq. (3).

The distance $\Delta r = r_0 - r_1$ from the boundary line BB' to the point, for which the angular distance between the radiation points decreases to $1/\gamma$, $\Delta\varphi \sim 1/\gamma$, can be estimated as $\Delta r = 0.5 r_0/(\alpha\gamma)^2$.

The ultrarelativistic electron radiates into a narrow cone along the instantaneous velocity vector, the angular width of the cone is of the order $1/\gamma$. From the vector product, $-[\mathbf{n}, \mathbf{v}/v]_z \sim 1/\gamma$, we can estimate that corrections to the rhs of (4) are of the order $1/\gamma$.

The electron passes the distance $l_{SC} \approx v_{\|} 2\pi/\omega_B$ in one revolution around magnetic field line. This distance corresponds to an angle $\alpha_{SC} \approx 2\pi v_{\|}/(\omega_B R)$. Then, the ratio of the angle between the radiation points to the angle α_{SC} is $q_{SC} = 2\Delta\varphi/\alpha_{SC} = \alpha\omega_B R \sin\Theta/\pi v_{\|}$, or $q_{SC} = q_a \sin\Theta/\pi$, where q_a is given by (7).

2. SYNCHROTRON RADIATION FORMULAE

The synchrotron radiation of an ultrarelativistic electron moving along a circle is formed on a small segment of circle with an angular opening $2/\gamma$. For an ensemble of electrons we integrate the spectral angular distribution over the solid angle assuming that the magnetic field is not strong anisotropic in angles $\sim 1/\gamma$ [13, 1].

The spectral power density of synchrotron radiation emitted by an relativistic electron moving along a circular path with a curvature radius R_{curv} at wavelength λ is expressed by [13, 14]

$$\frac{dP_i(\lambda)}{d\lambda} = \frac{2\pi}{\sqrt{3}} \frac{e^2 c}{\lambda^3 \gamma^2} \left(\int_y^{\infty} K_{5/3}(x)dx \pm K_{2/3}(y) \right), \quad (5)$$

where $y = \lambda_c/\lambda$, $\lambda_c = 4\pi R_{curv}/(3\gamma^3)$ is the characteristic wavelength, $i = \sigma, \pi$ denote the cases of π and σ-polarization, "plus" corresponds to σ-polarization, "minus" corresponds to π-polarization, $\mathbf{e}_\sigma = [\mathbf{e}_\pi, \mathbf{k}]$ is the unit vector of σ-polarization, $\mathbf{k}$ is the unit wave vector, K_ν is the Macdonald function. Linearly polarized radiation is described by eq. (5) [13].

As shown in [8 - 10], the curvature radius of the trajectory, which is formed by the motion of an electron with guiding center on a circle of radius R (R_D for the trajectory (2)), is equal to

$$R_{curv} = \frac{R_D}{\sqrt{1 - 2q_a \cos\Theta + q_a^2}}, \quad (6)$$

where $\cos\Theta$ is given by eq. (3), $q_a = \alpha\omega_B R_{curv}/v_{\|}$.

At each point of radiation, there are electrons with $\Theta \in (0, 2\pi)$, but radiation is detected from the electron with a definite Θ. This angle defines the direction of acceleration of the radiating electron.

In this case, the radius of curvature is greater on the side of the small circle closer to the center of the large circle of torus.

The parameter q_a is defined as the quotient of the acceleration of the particle motion in the small Larmor circle to the centrifugal acceleration due to movement in the larger circumference of radius equal to the curvature radius of drift trajectory. Also, it is the ratio of Larmor's speed $\omega_B r_B$ to the speed of centrifugal drift.

Available coordinates (r, ϑ, φ) of the guiding center of electron are given by (3), (4). At the point, the curvature radius $R_D(r, \vartheta, \varphi)$ of the drift trajectory is calculated. Further, the value $B(r, \vartheta)$ of magnetic field is found at this point.

The parameter q_a can be written as

$$q_a = \frac{e}{mc^2} B(r_f, \vartheta_f) R_D(r, \vartheta) \frac{\alpha}{\gamma}, \quad (7)$$

where $R_D = R_0 + \delta + \left(-1 + \frac{1}{q_D^2} \right) r\cos\vartheta$ is the curvature radius of drift trajectory in a first-order approximation.

To calculate the magnetic field at the point $P_e = \left(r, \vartheta, \frac{\pi}{2} \right)$ the displacement δ in equatorial plane of the drift torus with respect to magnetic torus is taken into account, then $r_f = \sqrt{r^2 + \delta^2 - 2\delta r\cos\vartheta}$ and $\cos\vartheta_f = \frac{r\cos\vartheta - \delta}{r_f}$. ($\delta = q_f \gamma mc^2/(eB)$ see in [1, 4]).

Therefore, the magnetic field value is expressed by

$$B = B_0 \left(1 + \frac{r\cos\vartheta - \delta}{R_0} \right). \quad (8)$$

2.1. POLARIZATION VECTOR

To describe the polarization properties we use the Stokes parameters I, Q, U, V. According [13, eq. (3.13)] the Stokes parameters for the radiation from an individual electron are given by

$$I_e = \frac{dP_\sigma}{d\lambda} + \frac{dP_\pi}{d\lambda}, \quad (9)$$

$$Q_e = \left(\frac{dP_\sigma}{d\lambda} - \frac{dP_\pi}{d\lambda} \right) \cos 2\chi, \quad (10)$$

$$U_e = \left(\frac{dP_\sigma}{d\lambda} - \frac{dP_\pi}{d\lambda} \right) \sin 2\chi, \quad V_e = 0, \quad (11)$$

where $\chi \in (0, \pi)$ is the angle between some arbitrary fixed direction, axis $0z$ in our case, and the major axis of the ellipse of polarization. The angle χ is measured clockwise from the selected direction if the coordinate axes is taken as in Fig. 2. $dP_i/d\lambda$ is given by eq. (5).

As consequence of the integration the synchrotron radiation formulae over the solid angle, the parameter V, which indicates the presence of elliptically polarized radiation, is equal zero, $V = 0$ [13].

For the ensemble of particles, the Stokes parameters are equal to the sum of the parameters of the individual particles.

Then the degree of polarization is defined as [13]

$$\Pi(\lambda) = \frac{\sqrt{Q^2 + U^2}}{I}, \qquad (12)$$

and the angle χ

$$\operatorname{tg} 2\chi = \frac{U}{Q}. \qquad (13)$$

The rule according [13] is "from two values of the angle $0 \le \chi \le \pi$ we choose that which lies in the first quadrant if $U > 0$ and in the second if $U < 0$."

As known, the direction of the larger axis of polarization ellipse (σ-component) for synchrotron emission of relativistic electrons moving on a circular orbit coincides with the direction of particle's acceleration [14]. Let χ be an angle between the axis $0z$ and the electron acceleration $\mathbf{a}$. Taking into account the smallness of angle between the line of sight and axis $0x$, we find that $\sin\chi = \frac{a_y}{a}$, $\cos\chi = \frac{a_z}{a}$.

Then

$$\sin\chi = \frac{-1 + q_a \cos\Theta}{\sqrt{1 - 2q_a \cos\Theta + q_a^2}}, \qquad (14)$$

and

$$\cos\chi = \frac{q_a \sin\Theta}{\sqrt{1 - 2q_a \cos\Theta + q_a^2}}. \qquad (15)$$

Here, corrections of the first order of smallness, as in [7], are not given,

It follows from (3) that each ϑ corresponds to two values of Θ. Substituting them into (4) we get two values of the angle φ. It turns out that electrons radiate from two different places.

We add up Stokes parameters for these two emitting regions, $Q = Q_1 + Q_2$, $U = U_1 + U_2$. Expressions (14), (15) are substituted for $\sin\chi$, $\cos\chi$ in trigonometric formulas for doubled angles in (10), (11).

Using Eqs. (3)-(15) we will calculate the distributions of the total intensity I, degree of polarization Π and polarization directions χ in the synchrotron radiation spot from a homogenous electron beam with radius $r \in [r_{\min}, r_{\max}]$.

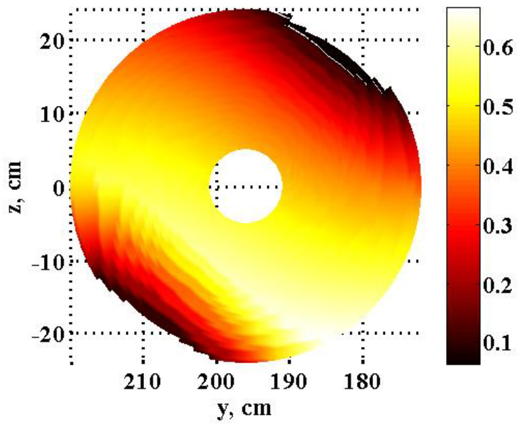

Fig. 3. Total radiated power at pitch angles α = 0.08…0.15 rad: λ = 5 μm, R_0 = 186 cm, δ = 10 cm, r = 5…24 cm, D = 186 cm, $B_0 = 2{\cdot}10^4$ G, $|\gamma$ = 80, q_0 = 1, n = 2, a = 45 cm

3. DISCUSSION

We take a small arc of the electron path and use integrated over solid angle the classical synchrotron radiation formulae (5).

The distribution of total power I in the area of synchrotron spot is shown in Fig. 3 if electrons uniformly distributed in a limited range of angles The radiation point coordinates are plotted in (y, z)-plane. The color (gray colormap) shows the radiation power (in arbitrary units) at a given wavelength λ (in this case, the wavelength λ = 5 μm), the range of pitch angles is from 0.08 to 0.15 rad. One can see the broadening of the spot with increasing pitch angles α. The increased brightness is observed inside the spot where the emissions of particles with different α are summed.

The radiation will be strongly influenced by the distribution of electrons over the pitch angle. The presence of particles with different pitch angles and inhomogeneity of magnetic field directions will cause the radiating hollow cone with an opening angle α to become filled, or partially filled. Then, we can integrate eqs. (5) over angles Θ to obtain formulae from [8 - 10].

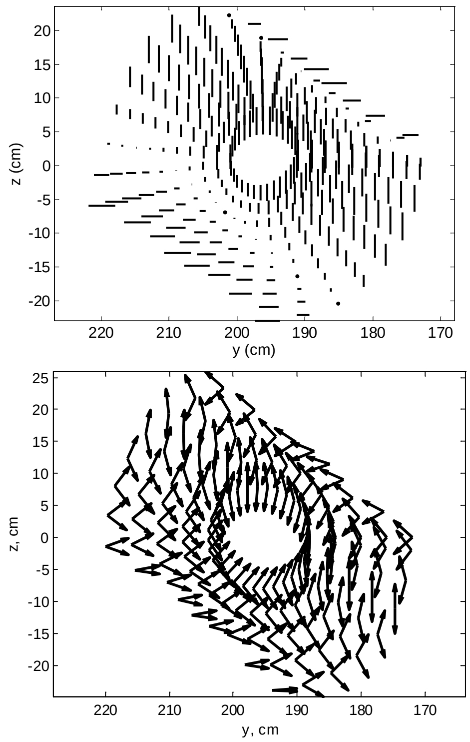

Fig. 4. Polarization of the synchrotron spot (poloidal projection) at the wavelength λ = 5 μm (top), the normals to the trajectory (2) that correspond $\pm\Theta$ (bottom). Parameters: $B_0 = 2{\cdot}10^4$ G, $|\gamma$ = 80, α = 0.12 rad, r = 6…24 cm, R_0 = 186 cm, δ = 10 cm, D = 186 cm, q_0 = 1, n = 2, a = 45 cm

The directions of polarization in the synchrotron radiation spot are shown in Fig. 4. The length of dashes is proportional to the degree of polarization. In the upper part of the figure, a case when the contribution to the polarization comes from two emission points has been considered. The degree of polarization varies from 0 to 72%. This range of values depends on α and γ. Polarization directions are orthogonal. There are regions with small and zero polarization.

To understand how such polarization pattern is formed, the particle accelerations (directions of normal to the trajectory (2)) are shown in the lower part of Fig. 4. Two arrows at each point correspond to two values of the angle $\pm\Theta$ in eq. (3). The contribution to radiation comes from two waves of equal intensity linearly polarized along these directions. The radiation of two waves of equal intensity linearly polarized along these directions is added at each point. The Stokes parameter $U = 0$ in this case. The degree of polarization of the total wave vanishes if the initial waves have orthogonal directions of polarizations. For the range of pitch angles, these regions of zero polarization expand.

It should be noted the change of the polarization direction on 90°. The polarization from 'horizontal' parallel to the *y* axis becomes 'vertical' parallel to the Z axis.

An important result is the presence of regions of zero polarization. Their presence allows us to speak of contributions to radiation from two different regions, which in turn will speak of the stability of the magnetic field directions.

Also, one can talk about the directions of the magnetic field having a polarization pattern.

New relationships between the parameters of the emitting electrons and the magnetic field obtained from measurements of polarization can give additional data for the diagnostics of electron beams.

They will complement the ratios obtained from measurements of the total intensity of the synchrotron radiation of runaway electrons.

REFERENCES

1. I. Entrop, R. Jaspers, N.J. Lopes Cardozo, K.H. Finken. Runaway snakes in TEXTOR-94 // *Plasma Phys. Control. Fusion*. 1999, v. 41, p. 377-398.
2. Y. Shi, J. Fu, J. Li, Y. Yang, et al. Observation of runaway electron beams by visible color camera in the Experimental Advanced Superconducting Tokamak // *Rev. Sci. Instrum.* 2010, v. 81, p. 033506.
3. A.C. England, Z.Y. Chen, D.C. Seo, et al. Runaway Electron Suppression by ECRH and RMP in KSTAR // *Plasma Sci. Technol.* 2013, v. 15, p. 119-122.
4. R.J. Zhou, I.M. Pankratov, L.Q. Hu, et al. Synchrotron radiation spectra and synchrotron radiation spot shape of runaway electrons in Experimental Advanced Superconducting Tokamak // *Physics of Plasmas.* 2014, v. 21, p. 063302.
5. M. Xiao, R.J. Zhou, L.Q. Hu, et al. Analysis of synchrotron radiation spectra of runaway electrons in Tokamak // *Physics of Plasmas.* 2017, v. 24, p. 124504.
6. Ya.M. Sobolev. Polarization of synchrotron radiation from relativistic electrons moving within toroidal magnetic fields // *Problems of Atomic Science and Technology. Series "Plasma Electronics and New Acceleration Methods".* 2013, v. 4, p. 108-111. http://vant.kipt.kharkov.ua/ARTICLE/VANT_2013_4/article_2013_4_108.pdf
7. Ya.M. Sobolev. Synchrotron radiation and its polarization from runaway electrons in toroidal magnetic fields // *Problems of Atomic Science and Technology. Ser. "Plasma Electronics and New Acceleration Methods".* 2015, v. 4, p. 135-139. http://vant.kipt.kharkov.ua/ARTICLE/VANT_2015_4/article_2015_4_135.pdf
8. K.S. Cheng, J.L. Zhang. General radiation formulae for a relativistic charged particle moving in curved magnetic field lined: The synchro-curvature radiation mechanism // *Astrophys. J.* 1996, v. 463, № 1, p. 271-283.
9. I.M. Pankratov. Towards analyses of runaway electrons synchrotron radiation spectra // *Plasma Physics Reports.* 1999, v. 25, № 2, p. 145-148.
10. Ya.M. Sobolev. Influence of magnetic line curvature on spectrum and polarization of synchrotron radiation of a charged particle // *Radio Physics and Radio Astronomy*. 2001, v. 6, № 4, p. 277-290. http://journal.rian.kharkov.ua/index.php/ra/article/view/868/731.
11. J. Wesson. *Tokamaks*. Oxford: "Clarendon Press", 2004, 762 p.
12. I.M. Pankratov. Analysis of the synchrotron radiation emitted by runaway electrons // *Plasma Physics Reports.* 1996, v. 22, p. 535-538.
13. V.L. Ginzburg, S.I. Syrovatskii. Cosmic Magnetic Bremsstrahlung (synchrotron Radiation) // *Soviet Physics Uspekhi.* 1966, v. 8, p. 674-701.
14. A.A. Sokolov, I.M. Ternov. *Radiation from relativistic electrons.* New York, AIoP, 1986, 324 p.

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О ПОЛЯРИЗАЦИИ СИНХРОТРОННОГО ИЗЛУЧЕНИЯ УБЕГАЮЩИХ ЭЛЕКТРОНОВ В ТОРОИДАЛЬНОМ МАГНИТНОМ ПОЛЕ

Я.М. Соболев

Рассмотрены условия формирования поляризации синхротронного излучения убегающих электронов. Оценена излучаемая мощность и направления поляризации в пятне синхротронного излучения убегающих электронов в зависимости от питч-углов излучающих электронов. Измерение поляризации синхротронного излучения может быть дополнительным средством для диагностики излучающих релятивистских электронов.

ПРО ПОЛЯРИЗАЦІЮ СИНХРОТРОННОГО ВИПРОМІНЮВАННЯ УТІКАЮЧИХ ЕЛЕКТРОНІВ У ТОРОЇДАЛЬНОМУ МАГНІТНОМУ ПОЛІ

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Розглянуто умови формування поляризації синхротронного випромінювання утікаючих електронів. Надані оцінки потужності випромінювання і напрями поляризації в плямі синхротронного випромінювання утікаючих електронів у залежності від пітч-вуглів випромінюючих електронів. Вимірювання поляризації синхротронного випромінювання може слугувати додатковим засобом для діагностики релятивістських електронів.