Shin-dependent parts of the MS in QED and CED

Outline

1. Imaginary parts of the mass shift in QED and CED

2. Basics of the classical approach

3. The “localizabilty” of the spin-orbital contribution to the self-action for relativistic particles

4. Applications:

    * RP (Sokolov – Ternov effect)

    * The boundaries’ influence

5. Conclusions

Demeur,

Jancovici

Newton

Bayer et al.

Ritus

Schwinger et al.

QED

$$\mathrm{Re}\,\Delta m = \frac{4\alpha m}{3\pi}\chi^2\left(\ln\frac{\sqrt{3}}{\chi} + C - \frac{37}{12}\right) + \ldots$$

$$\mathrm{Im}\,\Delta m = -\frac{5\alpha m}{4\sqrt{3}}\chi\left(1 - \frac{8}{5\sqrt{3}}\chi\right) + \ldots$$

CED

$$\mathrm{Re}\,\Delta m = 0$$

$$\mathrm{Im}\,\Delta m = -\frac{5\alpha m}{4\sqrt{3}}\chi$$

$$\chi^{mag} = \frac{p_\perp}{m}\frac{H}{H_c} \leftrightarrow \chi^{el} = \frac{p_\perp}{m}\frac{E}{E_c} \leftrightarrow \chi^{cr} = \frac{p_-}{m}\frac{H}{H_c}$$

$$H_c = \frac{m^2c^3}{|e|\hbar}, \quad \chi \ll 1, \quad \gamma_\perp \gg 1$$

`Crossed field universality`

(Nikishov, Ritus 1964)

Ritus – crossed
Bayer et al. &
Schwinger et al. –
magnetic,
SL-electric

$$\mathrm{Im}\,\Delta m_\varsigma = \frac{3}{2}\cdot\frac{\alpha m}{4\sqrt{3}}\chi^2\varsigma\left(1 - 4\sqrt{3}\chi + \ldots\right)$$

$$\varsigma = \pm 1$$

$$\mathrm{Im}\,\Delta m_\varsigma = \frac{\alpha m}{4\sqrt{3}}\chi^2\left(-\varsigma_{\vec{H}_R}\right)$$

Particle: electron, $e = -|e|$

Classical self-action:

$$\Delta W = \frac{1}{2}\iint J_\alpha(x)\,\Delta_c^{\alpha\beta}(x,x')J_\beta(x')\,dxdx'\Big|_0^F$$

Ritus, JETP '81

hep-th/0211078

hep-th/0508166

hep-th/0512228

$$J_\alpha = j_\alpha + \partial_\beta M_{\alpha\beta}$$

radiation ⟶ $\exp(-\frac{2}{\hbar}\mathrm{Im}\,\Delta W) < 1$

$$\frac{1}{\hbar}\mathrm{Im}\,\Delta W = \int \frac{dE(\vec{k})}{\hbar\omega_k}$$ ⟵ **spectral radiation power**

$$\Delta W = \Delta W_{or} + \Delta W_{so} + \Delta W_{ss}$$

$$\Delta W_{so} = -\frac{\mu e}{2\pi^2}\int d\tau \int d\tau' \frac{(x-x')\wedge \dot{x}(\tau)\wedge \dot{x}(\tau')\wedge S(\tau')}{[(x(\tau)-x(\tau'))^2]^2},$$

For $\gamma_{\perp} \gg 1$ **formation proper time interval:** $\Delta\tau_f \sim \sqrt{12/\ddot{x}^2} \sim 1/\omega\gamma_{\perp} \to 0$

$$\Delta W_{so} = -\frac{\mu e}{2\pi}\frac{1}{4\sqrt{3}}\int d\tau\, \frac{\dot{x}\wedge\ddot{x}\wedge\dddot{x}\wedge S}{\sqrt{\ddot{x}^2}}$$

$$\left(x(\tau) - x(\tau')\right)^2 = f(\tau - \tau')$$

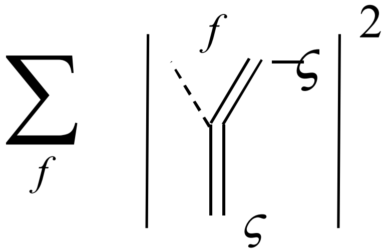
$$\Delta m_{so} = \frac{\mu e}{2\pi}\frac{1}{4\sqrt{3}}\frac{\dot{x}\wedge\ddot{x}\wedge\dddot{x}\wedge S}{\sqrt{\ddot{x}^2}}$$

Constant of the motion

$\ddot{x}$ **-term is responsible for the difference of polarization effects for electron and positron; the dependence on the sign of the charge comes from**

$$\ddot{x} = \frac{e}{m} F\cdot\dot{x}$$

Sokolov, Ternov et al. 60's



$$w^{\uparrow\downarrow} = \frac{1}{2T_{QED}}\left(1+\zeta_3\frac{8\sqrt{3}}{15}\right),\ \zeta_3 = \pm 1$$

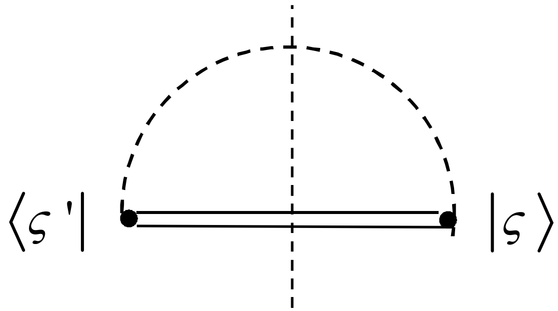
$$T_{QED} = \frac{8\sqrt{3}}{15}\frac{a_B}{c}\gamma^{-2}\left(\frac{H_c}{H}\right)^3$$

Bayer et al. Late 60 ÷73's **Quasiclassical consideration**

Jackson, '76: $\frac{\Delta n}{n} \square 10^{-6},\ \Delta n \square 10^{11}$

? : $i)\ \frac{8\sqrt{3}}{15},\ ii)$ ***Incomplete polarization degree ↑-/0.924↓***

Schwinger et al.
Beginning of 70's



Parameters' domain

$$\chi = \frac{e\hbar}{m^3c^4}\sqrt{(F_{\mu\nu}p_\nu)^2} = \gamma_\perp\frac{F}{F_c}$$

$$\chi \cong \frac{\hbar\omega_{ph}}{E} \quad \square\ 2\cdot 10^{-6}$$

$$\chi \square\ 1,\ \gamma_\perp \square\ 2\cdot 10^3 \square\ 1$$

$?:\ T_{QED} \square\ \hbar/\mu_B^2 \quad , \qquad \mu_B = e\hbar/2mc$

Unitarity: $$\operatorname{Im}\Delta m < 0$$

Total radiation probability rate (SQS'05; hep-th/0512228)

$$\lambda_{class} = -\frac{c^2}{\hbar} 2\operatorname{Im}(\Delta m_{or} + \Delta m_{so} + \Delta m_{ss}) =$$

$$= \frac{c}{a_B}\chi\left[\frac{5}{2\sqrt{3}} + \zeta_3 \frac{1}{2\sqrt{3}}\chi + \frac{29}{48\sqrt{3}}\chi^2 - \zeta_3^2 \frac{15}{32\sqrt{3}}\chi^2 - \zeta_v^2 \frac{1}{32\sqrt{3}}\chi^2 \ldots\right]$$

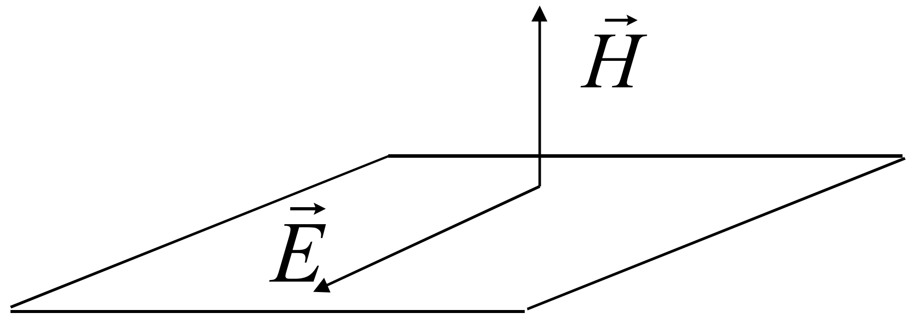
$$T_f \,\square\, \frac{1}{\omega_c} = \alpha \frac{a_B}{c}\left(\frac{H_c}{H}\right); \;\; T_{orb} \,\square\, \frac{a_B}{c}\left(\frac{H_c}{H}\right);$$

$$T_{so} \,\square\, \frac{a_B}{c}\gamma^{-1}\left(\frac{H_c}{H}\right)^2; \;\; T_{ss}^{(1)} = 4T_{QED} \,\square\, \frac{a_B}{c}\gamma^{-2}\left(\frac{H_c}{H}\right)^3; \;\; T_{ss}^{(2)} = 15T_{ss}^{(1)}$$

$$\square \;\; \frac{\lambda_{ss}^{(1)}}{\lambda_{ss}^{(1)} + \lambda_{ss}^{(2)}} = \frac{15}{16} \,\square\, 0.938$$

It would be hardly sensible to expect, in addition, the coincidence of coefficients : there is no `big quantum numbers limit` for spin

Boundary effects



1. **Crossed field**
2. **Plane motion**
3. **Ideal metal BC**

$$\Delta W_{so} = -\frac{\mu e}{2\pi^2}\int d\tau \int d\tau' \left[\frac{(x - x') \wedge \dot{x}(\tau) \wedge \dot{x}(\tau') \wedge S(\tau')}{[(x(\tau) - x(\tau'))^2 + i0]^2} - \frac{(\tilde{x} - x') \wedge \dot{\tilde{x}}(\tau) \wedge \dot{x}(\tau') \wedge S(\tau')}{[(x(\tau) - \tilde{x}(\tau'))^2 + i0]^2} \right]$$

$$\mathrm{Im}\Delta m^{cr}_{so}\Big|_{R\to\infty} = -\frac{\alpha}{m}\frac{\ddot{x}^2}{4\sqrt{3}}\,\varsigma_{\vec{H}_R}$$

$$\mathrm{Im}\Delta m^{cr}_{so}\Big|_{R\to 0} = -\frac{\alpha}{m}R\frac{\ddot{x}^2\sqrt{3}}{8}(\ddot{x}\cdot S)$$

$$\mathrm{Im}\Delta m^{cr}_{or}\Big|_{R\to\infty} = -\frac{5\alpha}{4\sqrt{3}}\sqrt{\ddot{x}^2}$$

$$\mathrm{Im}\Delta m^{cr}_{or}\Big|_{R\to 0} = -\frac{13}{120}\frac{5\alpha}{4\sqrt{3}}\sqrt{\ddot{x}^2}\cdot(R^2\ddot{x}^2)$$

SL, JETP'94

Spin relative to orbital boundary effect

$$\left.\frac{\mathrm{Im}\,\Delta m_{so}^{cr}}{\mathrm{Im}\,\Delta m_{or}^{cr}}\right|_{R\to 0} \sim \frac{3}{mR}\frac{(\ddot{x}\cdot S)}{\sqrt{\ddot{x}^2}} \quad \sim \lambda_C / R$$

Not depending on particle's energy

Real part:

$$\left.\mathrm{Re}\,\Delta m_{so}^{cr}\right|_{R\to 0} = -\frac{\alpha}{4}\chi(\ddot{x}\cdot S) + O(R) \quad \mathbf{< 0}$$

One more χ sits here

Conclusions

1. **`Crossed field universality` for the MS was justified for the electric field case as well as the correspondences between quantum and quasiclassical radiation probabilities at three different field configurations were established**
2. **Relative simplicity of the classical spin model in conjunction with the possibility to consider variety of particular examples makes this model a reasonable method to consider radiation processes at different surroundings of the particle**
3. **The problem of correspondence in sign between QED and CED MS remains. Unfortunately, there is no direct indication in literature on that connection between the better or less radiating spin states and the electron-positron option [NB: speaking is about the total radiation probability!]**
4. **The terms responsible for different sign of polarization effects in the electron versus positron cases has their origin in spin-orbital self-interaction**
5. **Boundary effects in spin radiation (generally small) manifest themselves through the relative growth of spin light radiation probability w.r.t. charge one and through the appearance of the negative real part of the MS, being the particle accelerated in a proximity to the boundary.**