Measuring the boiling point of the vacuum of quantum electrodynamics

Anthony Hartin, Andreas Ringwald, and Natalia Tapia, Phys Rev D 99, 036008 (2019)
Notebook: Óscar Amaro, November 2022 @ GoLP-EPP

Introduction

In this notebook we reproduce some results from the paper.

Figure 2: dimensionless function F$\gamma(\xi,\chi)$

This computation might take a long time...

```
In[•]:= Clear[α, me, Ee, EeGeV, χ, X, X0, ΓBPPP14, θ, ξ, e, Fγ8, Fγ9, Fγ, n, n0, vn, zv]

(* eq 6 *)
Fγ[ξ_, χ_] := Module[{vn, zv, n0, n, v},
  (* eq 7 aux functions *)
  n0 = 2 ξ (1 + ξ^2)/χ;
  vn = χ n/(2 ξ (1 + ξ^2));
  zv = (4 ξ^2 Sqrt[1 + ξ^2])/χ (v (vn - v))^(1/2);
  Return[Sum[NIntegrate[(2 BesselJ[n, zv]^2 +
        ξ^2 (2 v - 1) (BesselJ[n + 1, zv]^2 + BesselJ[n - 1, zv]^2 - 2 BesselJ[n, zv]^2)) /
      (v Sqrt[v (v - 1)]), {v, 1, vn}, AccuracyGoal → Infinity],
    {n, Ceiling[n0], Ceiling[n0] + 40, 1}]]
 ]

(* eq8 ξ<<1 *)
Fγ8 = 2 ξ^2 (Log[2 χ/ξ] - 1);
(* eq9 ξ>>1 *)
Fγ9 =
  3/4 Sqrt[3/2] χ Exp[- 8/(3 χ) (1 - 1/(15 ξ^2))];

(* plot *)
Show[{LogLogPlot[{Fγ[ξ, 1.5], Fγ[ξ, 1], Fγ[ξ, 0.5]},
   {ξ, 10^-2, 10^1}, PlotStyle → {{Black}, {Blue}, {Red}},
   PlotRange → {{10^-2, 10^1}, {5 × 10^-4, 5 × 10^-1}}, Frame → True,
   FrameLabel → {"ξ", "Fγ(ξ,χ)"}, PlotPoints → 3,
   PlotLegends → {"χγ=1.5", "χγ=1", "χγ=0.5"}],
  LogLogPlot[{Fγ8 /. {χ → 1.5}, Fγ8 /. {χ → 1}, Fγ8 /. {χ → 0.5}}, {ξ, 10^-2, 10^-1},
   PlotStyle → {{Black, Dotted}, {Blue, Dotted}, {Red, Dotted}}],
  LogLogPlot[{Fγ9 /. {χ → 1.5}, Fγ9 /. {χ → 1}, Fγ9 /. {χ → 0.5}}, {ξ, 10^0, 10^1},
   PlotStyle → {{Black, Dashed}, {Blue, Dashed}, {Red, Dashed}}]}]
```

Out[∘]=

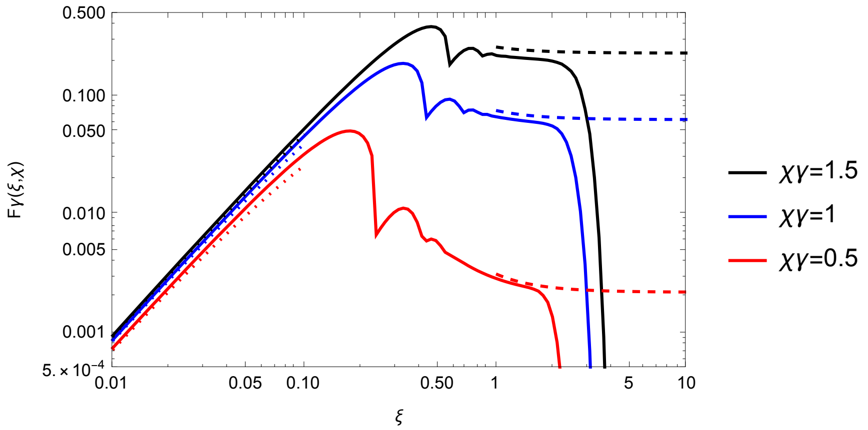

Figure 5

In[∘]:=

```
Clear[α, me, Ee, EeGeV, χ, X, X0, ΓBPPP14, θ, ξ, e, I]
(* "circularly polarized infinite plane wave (IPW)", before equation 6 *)

(* a0 of CP laser and 0.8 μm optical laser*)
ξ = 0.855 Sqrt[I/10^18] 0.8 / √2 ;
(* equation 16 *)
χ = 0.1576 × (1 + Cos[θ]) EeGeV/17.5 (I/10^19)^(1/2) ;(*[]*)
(* parameters *)
EeGeV = 17.5;(*[GeV]*)
θ = π / 12;(*[]*)

LogLinearPlot[{ξ, χ}, {I, 10^18, 10^20}, PlotRange → {0, 5},
 Frame → True, FrameLabel → {"I[W/cm^2]", ""}, PlotLegends → {"ξ", "χ"},
 PlotStyle → {{Dashed, Black}, {Dashed, Blue}}]
```

Out[∘]=

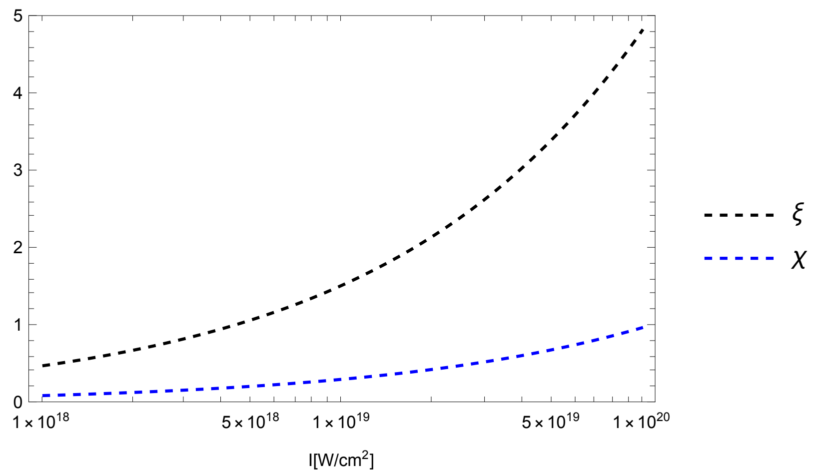

Figure 6

In[1325]:=
```
Clear[α, me, Ee, EeGeV, χ, X, X0, ΓBPPP14, θ, ξ, e]
(* equation 14 *)
```
$$\Gamma BPPP14 = \frac{\alpha\, me^2}{Ee} \frac{9}{128} \mathrm{Sqrt}\left[\frac{3}{2}\right] \chi^2 \mathrm{Exp}\left[-\frac{8}{3\,\chi}\left(1-\frac{1}{15\,\xi^2}\right)\right] \frac{X}{X0};$$
```
(* equation 16 *)
```
$$\chi = 0.1576 \times (1 + \mathrm{Cos}[\theta]) \frac{EeGeV}{17.5} \left(\frac{I}{10^{19}}\right)^{1/2};$$
```
θ = π / 12;(*[]*)

(* parameters *)
```
$e = 1.6 \times 10^{-19}$;(*[C]*)

$me = 9.1 \times 10^{-31}$;(*[Kg]*)

α = 1 / 137;(*[]*)

$I = 5 \times 10^{18}$; (*[W/cm²]*)

X = 0.01 X0; (*[]*)

(*λ=0.8;*)

$$\xi = 0.855\ \mathrm{Sqrt}\left[\frac{I}{10^{18}}\right] 0.8 / \sqrt{2};$$

$Ne = 6 \times 10^9$;(*[] number of electrons of energy Ee *)

LogPlot[{$10^{54.4}$ Ne ΓBPPP14 /. {Ee → 10^9 e EeGeV}},
{EeGeV, 10, 18}, PlotStyle → {{Red, Dashed}}, Frame → True,
FrameLabel → {"Energy[GeV]", "e⁺e⁻ pairs"}, PlotRange → {10^{-4}, 10^2}]

Out[1334]=