Front edge velocity of ultra-intense circularly polarized laser pulses in a relativistically transparent plasma

https://iopscience.iop.org/article/10.1088/1361-6587/ab98e0

Notebook: Óscar Amaro, June 2021 @ GoLP-EPP
Contact: oscar.amaro@tecnico.ulisboa.pt

Introduction

In this notebook we reproduce results from the paper.

Style

In[ ]:=
```
fntsz = 20;
imgsz = 300;
```

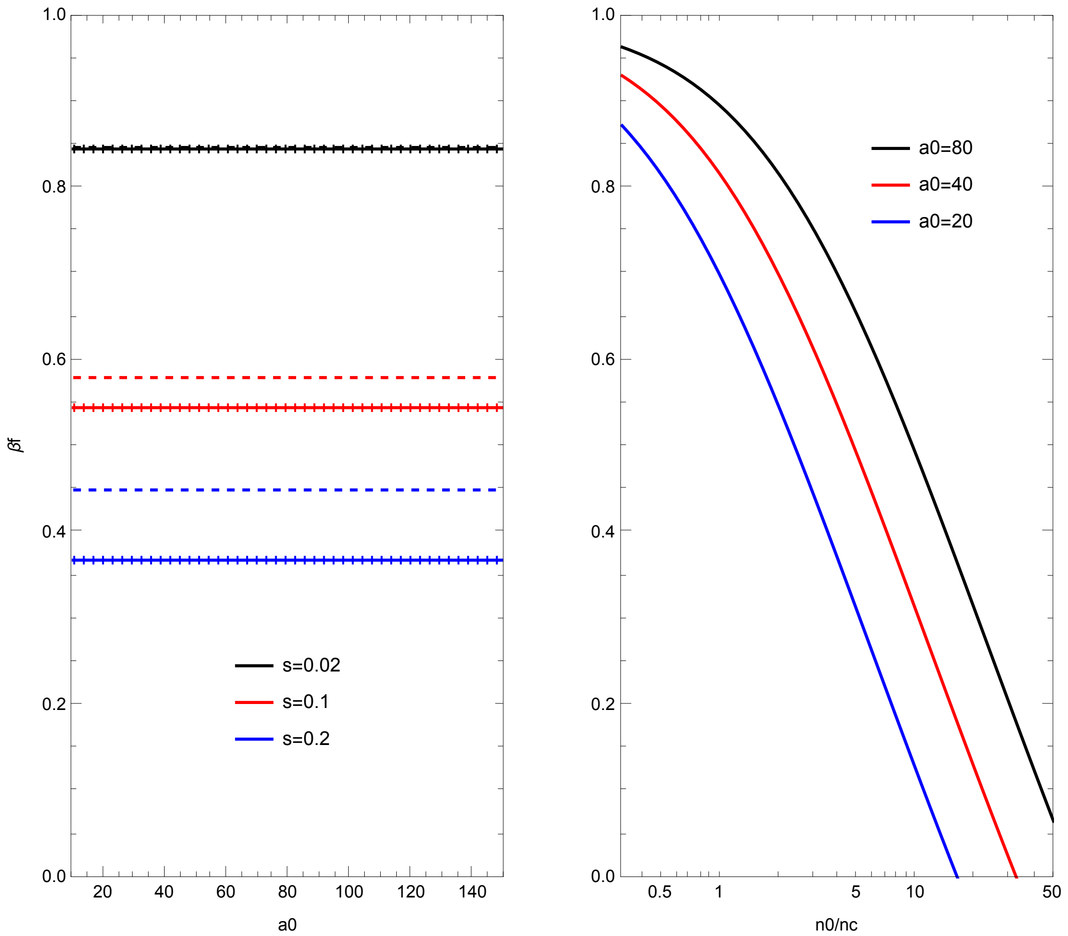
Figure 2

```
In[•]:= Clear[𝒦p, 𝒦m, δ𝒦, s, βf, βf9, βf10, βf11, plta, pltb]
        𝒦p = (8/(π^2 s) (Sqrt[1 + 8/(27 π^2 s)] + 1))^(1/3);
        𝒦m = (8/(π^2 s) (Sqrt[1 + 8/(27 π^2 s)] - 1))^(1/3);
        δ𝒦 = 𝒦p - 𝒦m;
        (* equation 10*)
        βf10 = δ𝒦 - 1;
        (* equation 11 approximation *)
        βf11 = 1/Sqrt[1 + 2 π^2 s];
        (* equation 9 *)
        βf9[s_] := NSolve[(1 - βf)/((1 + βf)^3) == π^2/8 s, βf, Reals][[1, 1, 2]]

        (* equation 10 is a very accurate *)
        ListPlot[Table[{ss, 1 - ((βf10 /. {s → ss}) / βf9[ss])},
            {ss, 0.02, 0.3, 0.02}], Joined → True];

        (* plot *)
        (* line-eq 10, dash-eq 11, dots-eq 9 *)
        plta =
          Plot[{βf10 /. {s → 0.02}, βf10 /. {s → 0.1}, βf10 /. {s → 0.2}, βf11 /. {s → 0.02},
             βf11 /. {s → 0.1}, βf11 /. {s → 0.2}, βf9[0.02], βf9[0.1], βf9[0.2]},
            {a0, 10, 150}, PlotRange → {{10, 150}, {0, 1}}, Frame → True,
            AspectRatio → 2, PlotStyle → {Black, Red, Blue, Directive[Black, Dashed],
              Directive[Red, Dashed], Directive[Blue, Dashed],
              Directive[Black, Dotted, Thickness[0.02]], Directive[Red, Dotted,
               Thickness[0.02]], Directive[Blue, Dotted, Thickness[0.02]]},
            FrameLabel → {"a0", "βf"}, ImageSize → 0.5 imgsz,
            PlotLegends → Placed[{"s=0.02", "s=0.1", "s=0.2"}, {0.5, 0.2}]];
        pltb = LogLinearPlot[{βf10 //. {s → n0nc / a0, a0 → 80},
             βf10 //. {s → n0nc / a0, a0 → 40}, βf10 //. {s → n0nc / a0, a0 → 20}},
            {n0nc, 10^-0.5, 10^1.7}, PlotRange → {{10^-0.5, 10^1.7}, {0, 1}}, Frame → True,
            AspectRatio → 2, PlotStyle → {Black, Red, Blue}, FrameLabel → {"n0/nc", ""},
            PlotLegends → Placed[{"a0=80", "a0=40", "a0=20"}, {0.7, 0.8}],
            ImageSize → 0.5 imgsz];
        GraphicsRow[{plta, pltb}, ImageSize → 2 imgsz]
```

Out[∘]=



In[∘]:=

```
(* proof first term in A6 can be neglected *)
A6 = (1 - βf) ^1.5 / Sqrt[1 + βf] + 4 βf / Sqrt[1 - βf^2];
A7 = 4 βf / Sqrt[1 - βf^2];
Plot[{A6, A7}, {βf, 0.1, 0.99}, PlotLegends → {"A6", "A7"},
 Frame → True, FrameLabel → {"βf", "expression"}]
```

Out[∘]=

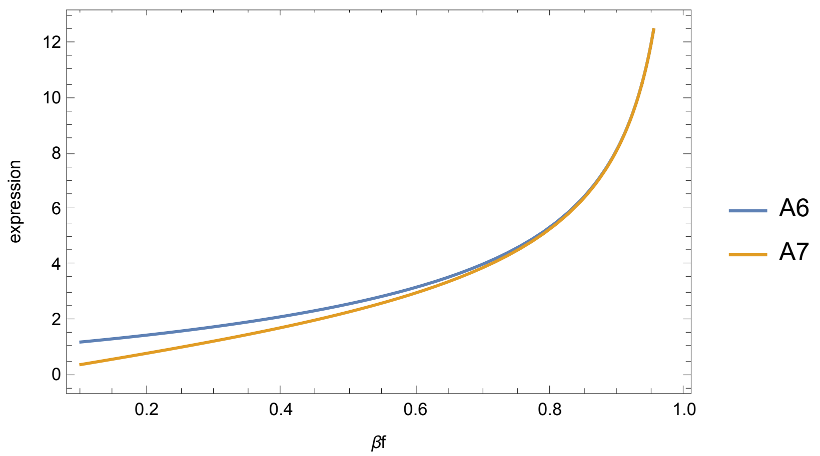


Figure 3

```
Clear[𝒦p, 𝒦m, δ𝒦, s, βf, βf9, βf10, βf11]
𝒦p = (8/(π^2 s) (Sqrt[1 + 8/(27 π^2 s)] + 1))^(1/3);
𝒦m = (8/(π^2 s) (Sqrt[1 + 8/(27 π^2 s)] - 1))^(1/3);
δ𝒦 = 𝒦p - 𝒦m;
(* equation 10*)
βf10 = δ𝒦 - 1;

(* plot *)
Plot[{βf10 //. {s → n0nc / a0, a0 → 20}}, {n0nc, 0.1, 6},
 PlotRange → {{0, 6}, {0, 1}}, Frame → True, AspectRatio → 3 / 4,
 PlotStyle → {Black}, FrameLabel → {"n0/nc", "βf"}, ImageSize → imgsz]

(*ToDo: get green dashed line*)
```

Out[∘]=

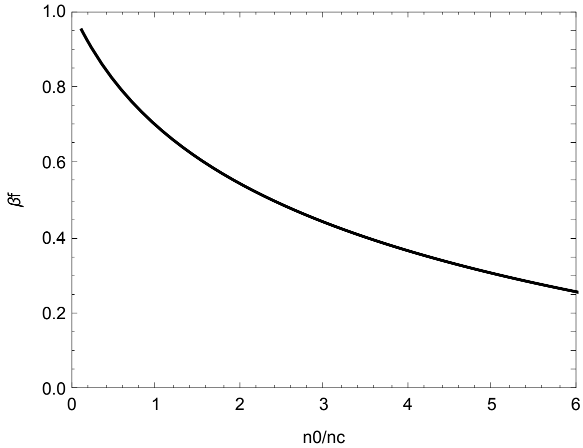
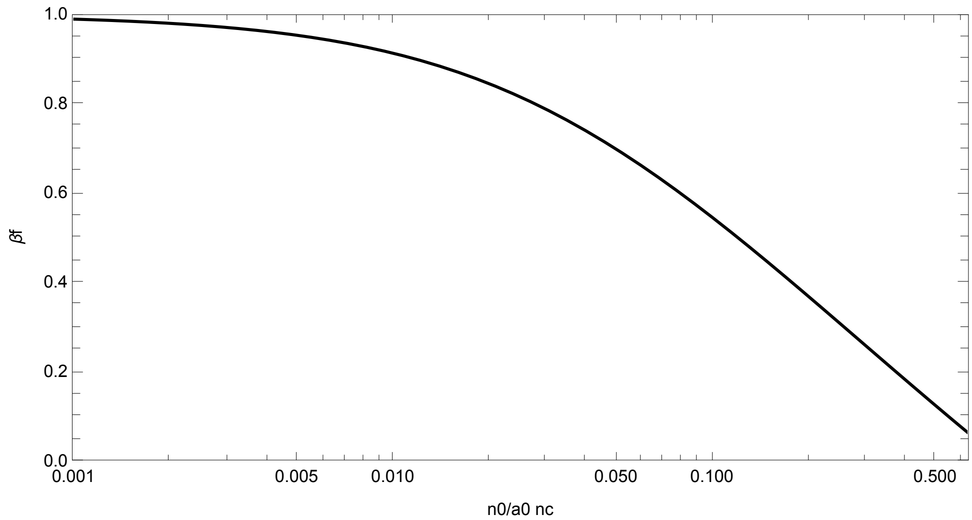


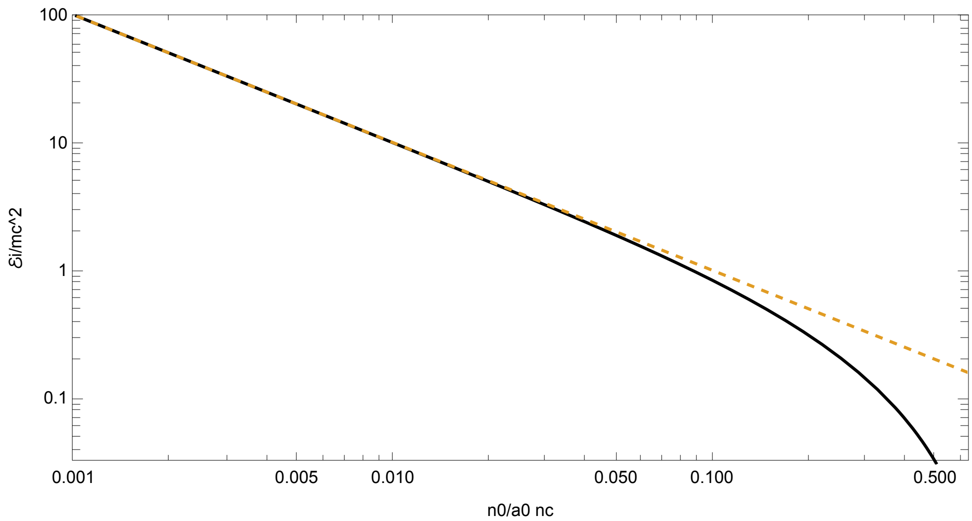
Figure 4

```
In[∘]:= Clear[𝒦p, 𝒦m, δ𝒦, s, βf, βf10, ℰi12, ℰi13, plta, pltb]
𝒦p = (8/(π^2 s) (Sqrt[1 + 8/(27 π^2 s)] + 1))^(1/3);
𝒦m = (8/(π^2 s) (Sqrt[1 + 8/(27 π^2 s)] - 1))^(1/3);
δ𝒦 = 𝒦p - 𝒦m;
(* equation 10*)
βf10 = δ𝒦 - 1;
(* equation 12 *)
ℰi12 = 1/δ𝒦 + 1/(2 - δ𝒦) - 2;
(* equation 13 approximation *)
ℰi13 = 1/(π^2 s);

(* plot *)
plta = LogLinearPlot[{βf10}, {s, 10^-3, 10^-0.2},
   PlotRange → {{10^-3, 10^-0.2}, {0, 1}}, Frame → True, AspectRatio → 1/2,
   PlotStyle → {Black}, FrameLabel → {"n0/a0 nc", "βf"}, ImageSize → imgsz];
pltb = LogLogPlot[{ℰi12, ℰi13}, {s, 10^-3, 10^-0.2},
   PlotRange → {{10^-3, 10^-0.2}, {10^-1.5, 10^2}},
   Frame → True, AspectRatio → 1/2, PlotStyle → {Black, Dashed},
   FrameLabel → {"n0/a0 nc", "ℰi/mc^2"}, ImageSize → imgsz];
GraphicsColumn[{plta, pltb}, ImageSize → 2 imgsz]
```


1.0
0.8
0.6
0.4
0.2
0.0
βf
0.001
0.005
0.010
0.050
0.100
0.500
n0/a0 nc

Out[∘]=


100
10
1
0.1
Ɛi/mc^2
0.001
0.005
0.010
0.050
0.100
0.500
n0/a0 nc