# Laser Pulse Temporal Envelopes

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**Introduction**

PIC codes like OSIRIS allow different models for the temporal profile of a laser pulse, namely sin(t)^2, polynomial and Gaussian. There is usually much confusion on what definition of FWHM to use (whether it is for the field or for intensity). In this notebook we derive these quantities in a systematic way, such that it becomes easy to convert from one form to the other.

Also for reference:

$x[c/\omega p] = x/(c/\omega p)\ \mu m/\mu m = 2\pi\ x[\mu m]/\lambda[\mu m]$

$t[1/\omega p] = t/(1/\omega p)\ fs/fs = t[fs]\ \omega p[1/fs]$

$\Delta t[1/\omega p] = \Delta x[c/\omega p]$

$\omega p[1/fs] \sim 1.884/\lambda[\mu m]$

In[ ]:=
```
Clear[Esin2, fwhmEsin2, fwhmIsin2, Egauss, Epoly]
```

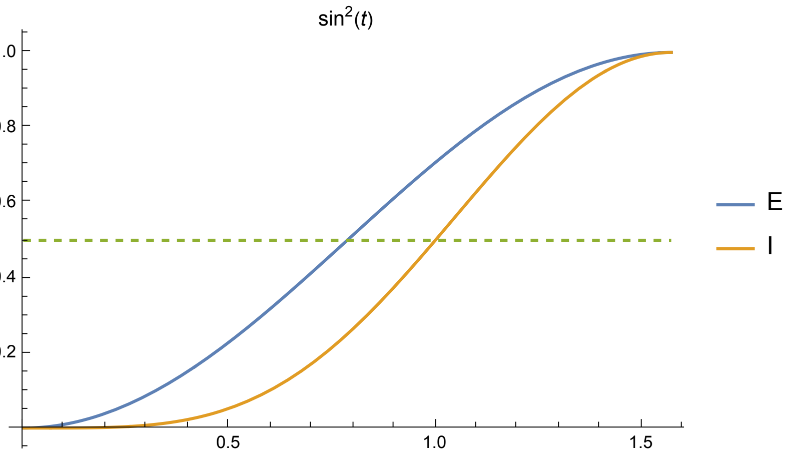
# Profile Sin2

In[•]:=
```
Esin2 = Sin[t]^2;

(*fwhm for field is π/2 *)
Plot[{Esin2, Esin2^2, 0.5}, {t, 0, π/2}, PlotStyle → {Default, Default, Dashed},
 PlotLegends → {"E", "I"}, PlotLabel → Esin2]

fwhmEsin2 = π/2 // N
(* (sin(x)^2)^2=0.5 → x=arcsin( (0.5)^0.25 ) *)
x12 = NSolve[Esin2^2 == 0.5, t][[4, 1, 2]] // Quiet;
π - 2 x12;
fwhmIsin2 = π - 2 ArcSin[(0.5)^0.25]

fwhmIsin2 / fwhmEsin2
```

Out[•]=



Out[•]= 1.5708

Out[•]= 1.14372

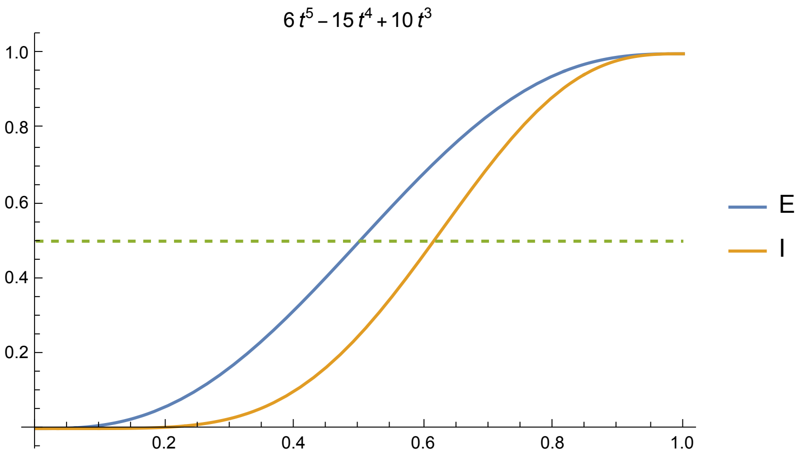
Out[•]= 0.728113

# Profile Polynomial

In[∘]:=
```
Epoly = 10 t^3 - 15 t^4 + 6 t^5;
Plot[{Epoly, Epoly^2, 0.5}, {t, 0, 1}, PlotStyle → {Default, Default, Dashed},
 PlotLegends → {"E", "I"}, PlotLabel → Epoly]

fwhmEpoly = 1
x12 = NSolve[Efld^2 == 0.5, t, Reals][[2, 1, 2]];
fwhmIpoly = 2 × (1 - x12)

fwhmIpoly / fwhmEpoly
```

Out[∘]=



Out[∘]= 1

Out[∘]= 0.771229

Out[∘]= 0.771229

# Profile Gaussian

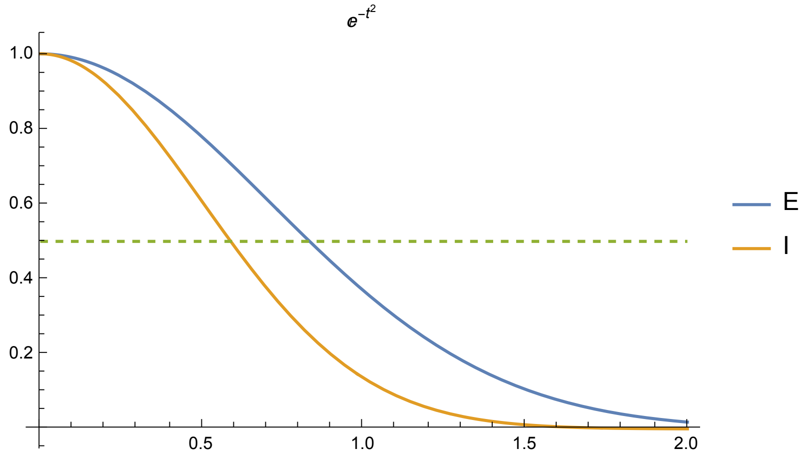
In[∘]:=
```
Egauss = Exp[-t^2]
Plot[{Egauss, Egauss^2, 0.5}, {t, 0, 2}, PlotStyle → {Default, Default, Dashed},
 PlotLegends → {"E", "I"}, PlotLabel → Egauss]

fwhmEgauss = 2 NSolve[Egauss == 0.5, t, Reals]⟦2, 1, 2⟧
fwhmIgauss = 2 NSolve[Egauss^2 == 0.5, t, Reals]⟦2, 1, 2⟧

fwhmIgauss / fwhmEgauss (*Sqrt[2]*)
```

Out[∘]= $e^{-t^2}$

Out[∘]=




Out[∘]= 1.66511

Out[∘]= 1.17741

Out[∘]= 0.707107

# Results (normalized to some characteristic time $\tau$)

In[∘]:=
```
TableForm[{{"", "tmax", "FWHM E", "FWHM I", "FWHM I/FWHM E"},
  {"sin^2", π, fwhmEsin2, fwhmIsin2, fwhmIsin2 / fwhmEsin2},
  {"poly", 2, fwhmEpoly, fwhmIpoly, fwhmIpoly / fwhmEpoly},
  {"gauss", ∞, fwhmEgauss, fwhmIgauss, fwhmIgauss / fwhmEgauss}}]
```

Out[∘]//TableForm=

| | tmax | FWHM E | FWHM I | FWHM I/FWHM E |
|---|---|---|---|---|
| sin^2 | π | 1.5708 | 1.14372 | 0.728113 |
| poly | 2 | 1 | 0.771229 | 0.771229 |
| gauss | ∞ | 1.66511 | 1.17741 | 0.707107 |