Analytical analysis of the single photon compression

Photon wavefunction

Spectrum of exponentially decaying single photon waveform.

$\omega 0$ central frequency.
Γ photon bandwidth, corresponding to the FWHM of the lorentzian spectrum.

```
ψ1 = 1/(π Γ - I (ω - ω0));
ψRE = ComplexExpand[Re[ψ1]]
ψIM = ComplexExpand[Im[ψ1]]
```

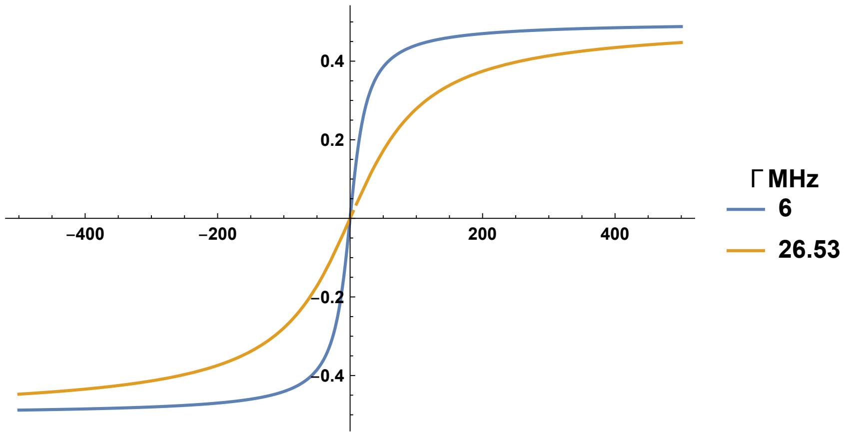
$$\frac{\pi \Gamma}{\pi^2 \Gamma^2 + (-\omega + \omega 0)^2}$$

$$\frac{\omega}{\pi^2 \Gamma^2 + (-\omega + \omega 0)^2} - \frac{\omega 0}{\pi^2 \Gamma^2 + (-\omega + \omega 0)^2}$$

```
ψAbs = FullSimplify[Sqrt[ψRE^2 + ψIM^2]]
ψArg = FullSimplify[ArcTan[ψIM / ψRE]]
Plot[Evaluate[ψArg / π /. {Γ → {6, 26.53}, ω0 → 0}],
 {ω, -500, 500},
 PlotLegends → LineLegend[Table[Γ, {Γ, {6, 26.53}}], LegendLabel → Γ (MHz)]]
```

$$\sqrt{\frac{1}{\pi^2 \Gamma^2 + (\omega - \omega 0)^2}}$$

$$\text{ArcCot}\left[\frac{\pi \Gamma}{\omega - \omega 0}\right]$$



Cavity transformation

Cavity reflection transfer function in frequency.

ωc Cavity resonance frequency

Γc Cavity bandwidth

R1 input mirror reflectance

$$\text{Cavity} = \frac{1 - R1^{\left(\frac{1}{2} + i \frac{\omega - \omega c}{2 \pi \Gamma c}\right)}}{\sqrt{R1} - R1^{\left(i \frac{\omega - \omega c}{2 \pi \Gamma c}\right)}};$$

Taylor expansion around resonance

```
CavityApprox = Normal[Series[Cavity /. (ω - ωc) → Δω, {R1, 1, 1}]];
Refine[%]
CavityRe = ComplexExpand[Re[CavityApprox]]
CavityIm = ComplexExpand[Im[CavityApprox]]
CavityAbs = Simplify[Sqrt[CavityIm^2 + CavityRe^2], Γc > 0];
CavityArg = ArcTan[CavityRe, CavityIm] /. Δω -> (ω - ωc)
```

$$\frac{-\pi\,\Gamma c - i\,\Delta\omega}{\pi\,\Gamma c - i\,\Delta\omega}$$

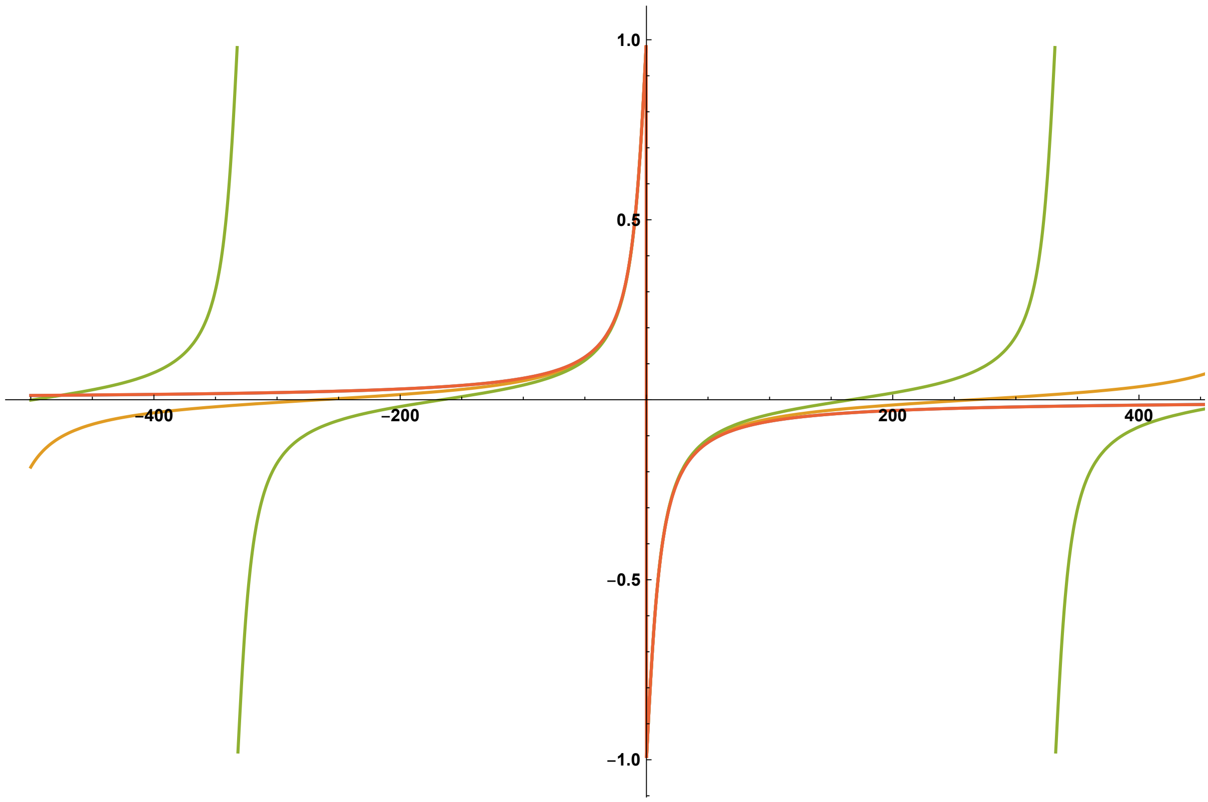
$$-\frac{\pi^2\,\Gamma c^2}{\pi^2\,\Gamma c^2 + \Delta\omega^2} + \frac{\Delta\omega^2}{\pi^2\,\Gamma c^2 + \Delta\omega^2}$$

$$-\frac{2\,\pi\,\Gamma c\,\Delta\omega}{\pi^2\,\Gamma c^2 + \Delta\omega^2}$$

$$\text{ArcTan}\left[-\frac{\pi^2\,\Gamma c^2}{\pi^2\,\Gamma c^2 + (\omega - \omega c)^2} + \frac{(\omega - \omega c)^2}{\pi^2\,\Gamma c^2 + (\omega - \omega c)^2},\ -\frac{2\,\pi\,\Gamma c\,(\omega - \omega c)}{\pi^2\,\Gamma c^2 + (\omega - \omega c)^2}\right]$$

Check the approximation

```
Plot[Evaluate[
   {Arg[Cavity] / π, CavityArg / π} /. {Γc → 3, ωc → 0, R1 → {.98, .8, .7}}],
 {ω, -500, 500},
 PlotRange → All]
```



Wavepacket in the cavity

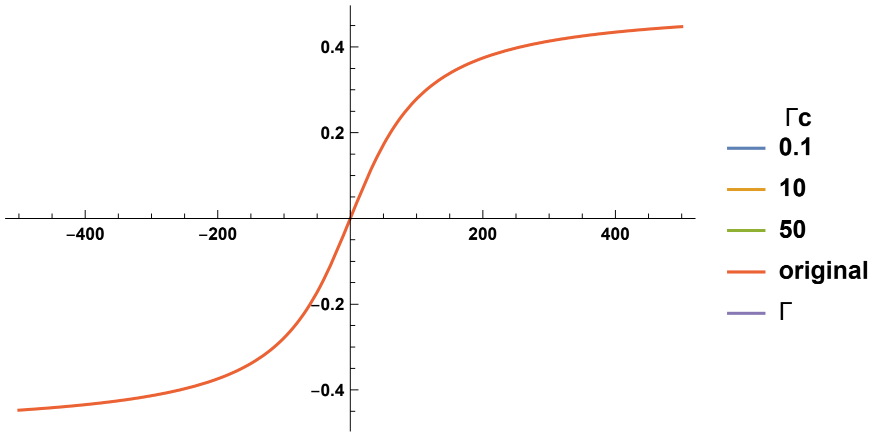
Frequency space

```
PsiCavity = Simplify[CavityApp * ψ1 /. Δω -> (ω - ωc), Γ > 0];
TraditionalForm[%]
(* Check the limit case *)
PsiCavityLimit = NewPsi /. {{Γc → Γ, ωc → ω0}}[[1]];
TraditionalForm[Normal[%]]
```

$$\frac{\text{CavityApp}}{\pi\,\Gamma - i\,(\omega - \omega 0)}$$

NewPsi

```
Plot[{Evaluate@
    Table[Arg[PsiCavity] / π /. {ω0 → 0, ωc → 0, Γ → 26.54}, {Γc, {.1, 10, 50}}],
   Arg[ψ1] / π /. {ω0 → 0, Γ → 26.54},
   Arg[PsiCavityLimit] / π /. {Γ → 26.54, ω0 → 0}},
 {ω, -500, 500},
 PlotLegends →
   LineLegend[Table[Γc, {Γc, {.1, 10, 50, "original", Γ}}], LegendLabel → Γc],
 PlotRange → All,
 AxesOrigin → {0, 0}]
```



Time space

```
PsiCavityT = Simplify[InverseFourierTransform[PsiCavity, ω, t],
   {Γc > 0, Γ > 0, Element[ωc, Reals], Element[ω0, Reals]}];
TraditionalForm[%]
(* Check the limit case *)
PsiCavityLimitT = FullSimplify[InverseFourierTransform[PsiCavityLimit, ω, t],
    {Γc > 0, Γ > 0, Element[ωc, Reals], Element[ω0, Reals]}][[1]];
TraditionalForm[
 %]
```

$$\frac{1}{\sqrt{2\pi}} \text{CavityApp} \left(-\pi \sinh\left(\frac{t(\pi\Gamma + i\,\omega 0)}{\text{sgn}(t)}\right) - i\left(\log(-\omega 0 + i\,\pi\,\Gamma) - \log(\omega 0 - i\,\pi\,\Gamma)\right)\cosh\left(\frac{t(\pi\Gamma + i\,\omega 0)}{\text{sgn}(t)}\right) + \text{sgn}(t)\left(\pi \cosh\left(\frac{t(\pi\Gamma + i\,\omega 0)}{\text{sgn}(t)}\right) + i\left(\log(-\omega 0 + i\,\pi\,\Gamma) - \log(\omega 0 - i\,\pi\,\Gamma)\right)\sinh\left(\frac{t(\pi\Gamma + i\,\omega 0)}{\text{sgn}(t)}\right)\right)\right)$$

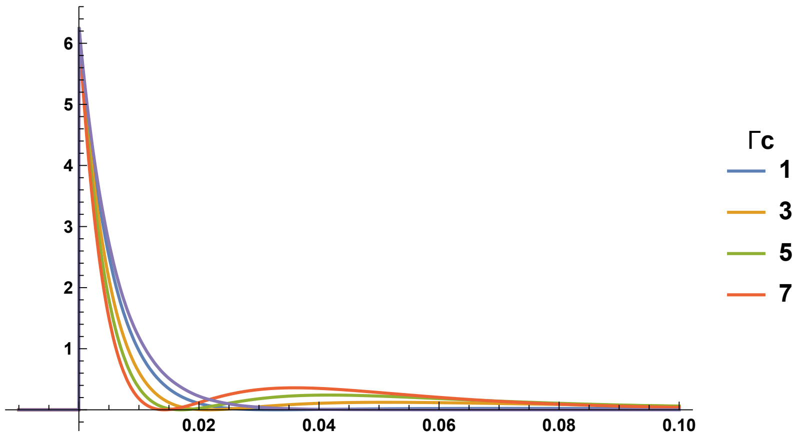
NewPsi

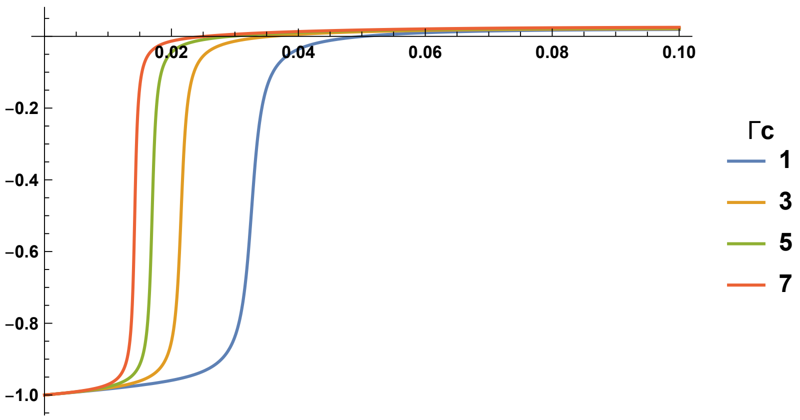
Ignore the fast oscillating part at $\omega 0$ and define $\Delta\omega=\omega 0-\omega c$

```
PsiCavityTSlow =
  -((√(2 π) (2 e^(-t π Γc) π Γc - e^(-t (π Γ+i Δω)) (π (Γ + Γc) + i Δω))) / (π (Γ - Γc) + i Δω))
   HeavisideTheta[t];
TraditionalForm[
 %]
```

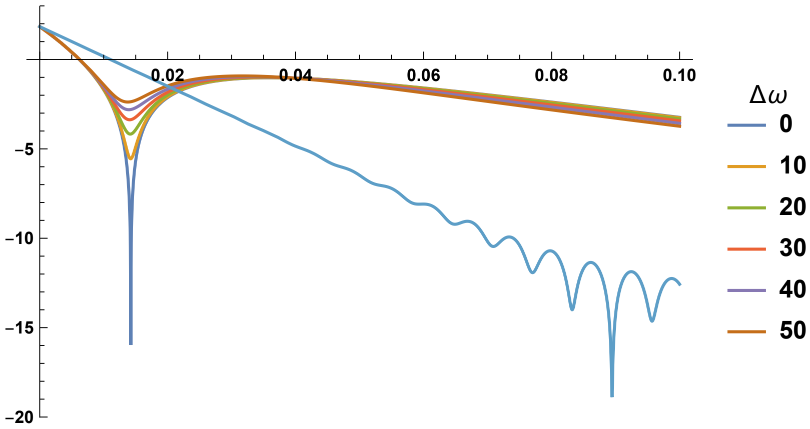
$$-\left(\left(\sqrt{2\pi}\;\theta(t)\left(2\pi\,\Gamma c\,e^{-\pi\,\Gamma c\,t} - (\pi(\Gamma + \Gamma c) + i\,\Delta\omega)\,e^{-t(\pi\,\Gamma + i\,\Delta\omega)}\right)\right)\Big/\left(\pi(\Gamma - \Gamma c) + i\,\Delta\omega\right)\right)$$

```
Plot[
 {Evaluate@Table[Abs[PsiCavityTSlow /. {Γ → 26.53, Δω → 0}]^2, {Γc, 1, 8, 2}],
  Abs[PsiCavityTSlow]^2 /. {Γ → 26.53, Γc → .1, Δω → 1000}}, {t, -.01, .1},
 PlotLegends → LineLegend[Table[Γc, {Γc, 1, 8, 2}], LegendLabel → Γc],
 PlotRange → All,
 AxesOrigin → {0, 0}]
Plot[Evaluate@Table[ArcTan[-Re[PsiCavityTSlow], Im[PsiCavityTSlow]] / π /.
    {Γ → 26.53, Δω → 5}, {Γc, 1, 8, 2}], {t, -.01, .1},
 PlotLegends → LineLegend[Table[Γc, {Γc, 1, 8, 2}], LegendLabel → Γc],
  PlotRange → All,
 AxesOrigin → {0, 0}]
```

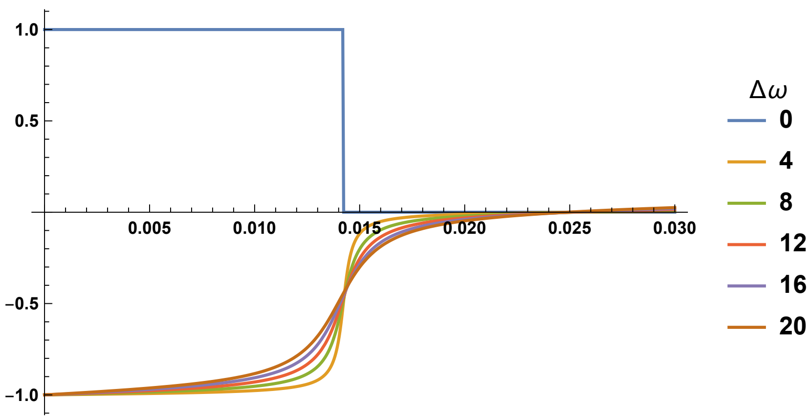




```
Plot[{Evaluate@
   Table[Log[Abs[PsiCavityTSlow]^2] /. {Γ → 26.53, Γc → 7}, {Δω, 0, 50, 10}],
  Log[Abs[PsiCavityTSlow]^2] /. {Γ → 26.53, Γc → .1, Δω → 1000}},
 {t, -.01, .1},
 PlotLegends → LineLegend[Table[Δω, {Δω, 0, 50, 10}], LegendLabel → Δω],
 PlotRange → All,
 AxesOrigin → {0, 0}]
```




```
Plot[Evaluate@
  Table[ArcTan[-Re[PsiCavityTSlow], Im[PsiCavityTSlow]] / π /. {Γ → 26.53, Γc → 7},
   {Δω, 0, 20, 4}], {t, -.1, .03},
 PlotLegends → LineLegend[Table[Δω, {Δω, 0, 20, 4}], LegendLabel → Δω],
 PlotRange → All]
```



Consider only $\Delta\omega = 0$

```
NewPsi = (PsiCavityTSlow /. Δω → 0) (** (Γ-Γc) *)
```

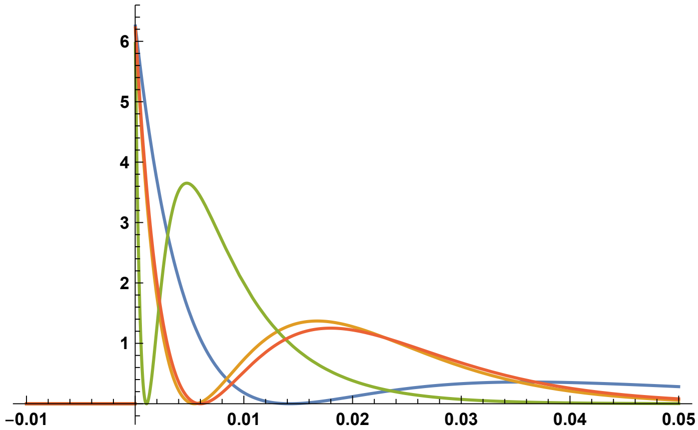
$$-\frac{1}{\Gamma - \Gamma c}\sqrt{\frac{2}{\pi}}\left(2\, e^{-\pi\, t\, \Gamma c}\, \pi\, \Gamma c - e^{-\pi\, t\, \Gamma}\, \pi\, (\Gamma + \Gamma c)\right) \text{HeavisideTheta}[t]$$

```
Series[NewPsi, {Γc, Γ, 2}]
A = Limit[NewPsi, Γc → Γ]
```

$-e^{-\pi t \Gamma}\sqrt{2\pi}\,(-1+2\pi t\Gamma)\,\text{HeavisideTheta}[t] + \sqrt{2}\,e^{-\pi t\Gamma}\pi^{3/2}\,t\,(-2+\pi t\Gamma)\,\text{HeavisideTheta}[t]\,(\Gamma c-\Gamma) - \frac{1}{3}\left(\sqrt{2}\,e^{-\pi t\Gamma}\pi^{5/2}t^2\,(-3+\pi t\Gamma)\,\text{HeavisideTheta}[t]\right)(\Gamma c-\Gamma)^2 + O[\Gamma c-\Gamma]^3$

$-e^{-\pi t \Gamma}\sqrt{2\pi}\,(-1+2\pi t\Gamma)\,\text{HeavisideTheta}[t]$

```
Plot[Evaluate[{NewPsi^2, A^2} /. {Γ → 26.53, Γc → { 7, 30, 200}}],
 {t, -.01, .05},
 PlotRange → All]
```

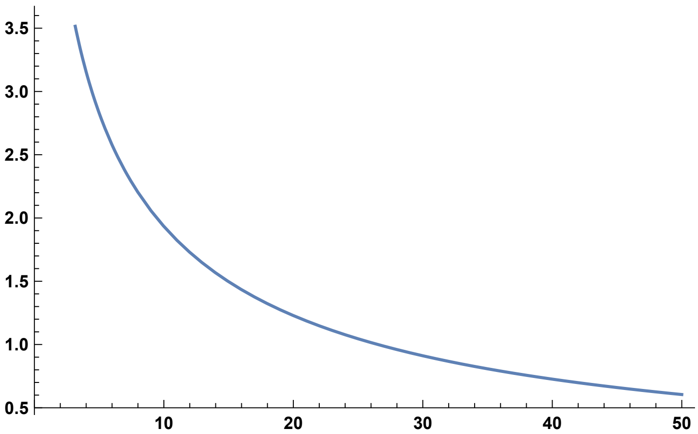


The direct Fourier transform still does not work on the formal definition of Abs of NewPsi. There' s no imaginary unit left, the phase is only associated with the change of sign. I redefine NewPsi to set the phase to zero without using the formal definition of Abs[].

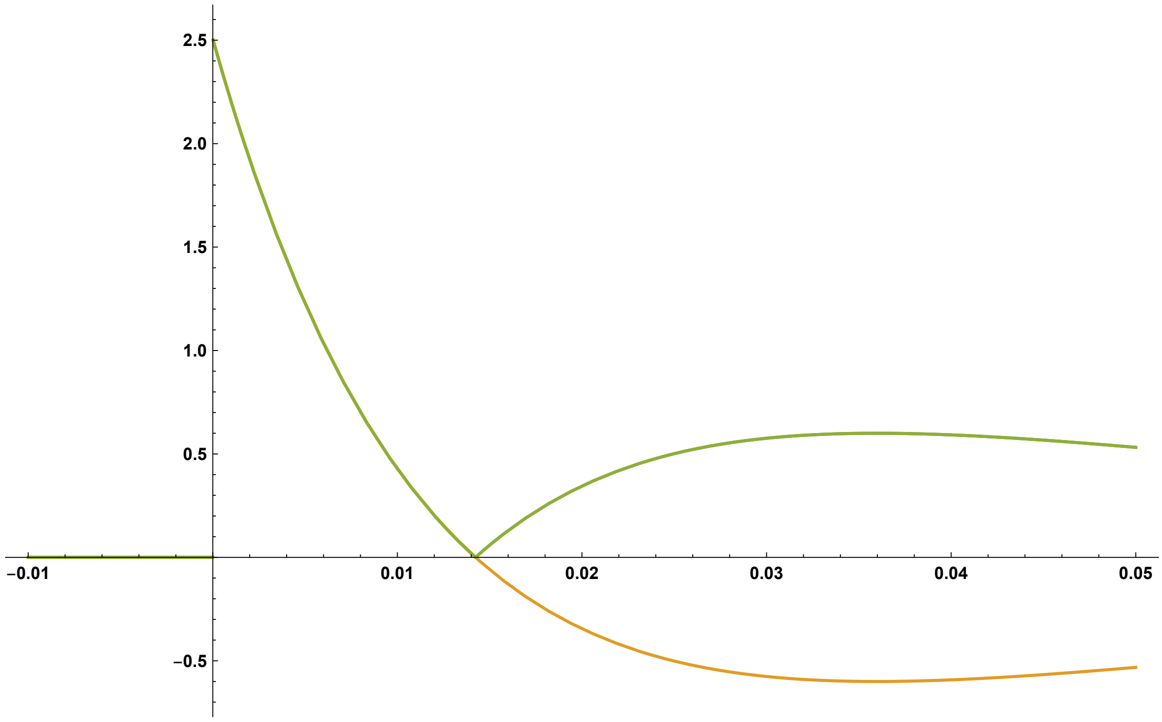
```
SignChangePoint = t /. Solve[NewPsi  == 0 , t][[2]][[1]]
Limit[SignChangePoint, Γc → Γ]
Plot[SignChangePoint * 2 π Γ /. Γ → 26.53, {Γc, 1, 50}]
```

$\frac{\text{Log}\left[\frac{\Gamma+\Gamma c}{2\,\Gamma c}\right]}{\pi\,(\Gamma-\Gamma c)}$

$\frac{1}{2\pi\Gamma}$



```
Plot[Evaluate[{NewPsi * Sign[SignChangePoint - t], NewPsi, Abs[NewPsi]} /.
   {Γ → 26.53, Γc → 7, Δω → 0}], {t, -.01, .05},
 PlotRange →
  All]
```




```
NewPsiF = FourierTransform[
  NewPsi * Sign[SignChangePoint - t], t, ω, Assumptions → {Γc > 0, Γ > Γc}]
```

$$\frac{\Gamma\left(1-2^{\frac{2\pi\Gamma-\pi\Gamma c-i\omega}{\pi\Gamma-\pi\Gamma c}}\left(\frac{\Gamma c}{\Gamma+\Gamma c}\right)^{\frac{\pi\Gamma-i\omega}{\pi\Gamma-\pi\Gamma c}}\right)}{(\Gamma-\Gamma c)\,(\pi\Gamma-i\omega)}+\frac{\Gamma c\left(1-2^{\frac{2\pi\Gamma-\pi\Gamma c-i\omega}{\pi\Gamma-\pi\Gamma c}}\left(\frac{\Gamma c}{\Gamma+\Gamma c}\right)^{\frac{\pi\Gamma-i\omega}{\pi\Gamma-\pi\Gamma c}}\right)}{(\Gamma-\Gamma c)\,(\pi\Gamma-i\omega)}-\frac{2\,\Gamma c\left(1-2^{\frac{\pi\Gamma-i\omega}{\pi\Gamma-\pi\Gamma c}}\left(\frac{\Gamma c}{\Gamma+\Gamma c}\right)^{\frac{\pi\Gamma c-i\omega}{\pi\Gamma-\pi\Gamma c}}\right)}{(\Gamma-\Gamma c)\,(\pi\Gamma c-i\omega)}$$

```
NewPsiFRe = ComplexExpand[Re[NewPsiF]];
NewPsiFIm = ComplexExpand[Im[NewPsiF]];
NewPsiFAbs = Simplify[Sqrt[NewPsiFIm^2 + NewPsiFRe^2], Γc > 0]
NewPsiFArg = ArcTan[NewPsiFRe, NewPsiFIm]
```

$$\sqrt{}\Bigg(\Bigg(\Bigg(4^{-\frac{\Gamma c}{\Gamma-\Gamma c}}\Bigg(-2^{\frac{5\Gamma-\Gamma c}{\Gamma-\Gamma c}}\,e^{\frac{2\omega\,\mathrm{Arg}\left[\frac{1}{\Gamma+\Gamma c}\right]}{\pi\Gamma-\pi\Gamma c}}\,\Gamma c\left(\frac{\Gamma c^2}{(\Gamma+\Gamma c)^2}\right)^{\frac{\Gamma+\Gamma c}{2\Gamma-2\Gamma c}}(\Gamma+\Gamma c)\,(\pi^2\,\Gamma\,\Gamma c+\omega^2)\,\mathrm{Cos}\left[\mathrm{Arg}\left[\frac{1}{\Gamma+\Gamma c}\right]\right]+$$

$$2^{-\frac{\Gamma c}{\Gamma-\Gamma c}}\Bigg(8^{\frac{\Gamma c}{\Gamma-\Gamma c}}\,\pi^2\,\Gamma^2\,\Gamma c^2-2^{\frac{\Gamma+2\Gamma c}{\Gamma-\Gamma c}}\,\pi^2\,\Gamma\,\Gamma c^3+8^{\frac{\Gamma c}{\Gamma-\Gamma c}}\,\pi^2\,\Gamma c^4+$$

$$2^{\frac{4\Gamma+\Gamma c}{\Gamma-\Gamma c}}\,e^{\frac{2\omega\,\mathrm{Arg}\left[\frac{1}{\Gamma+\Gamma c}\right]}{\pi\Gamma-\pi\Gamma c}}\,\pi^2\,\Gamma^2\,\Gamma c^2\left(\frac{\Gamma c^2}{(\Gamma+\Gamma c)^2}\right)^{\frac{\Gamma}{\Gamma-\Gamma c}}+32^{\frac{\Gamma}{\Gamma-\Gamma c}}\,e^{\frac{2\omega\,\mathrm{Arg}\left[\frac{1}{\Gamma+\Gamma c}\right]}{\pi\Gamma-\pi\Gamma c}}\,\pi^2\,\Gamma\,\Gamma c^3\left(\frac{\Gamma c^2}{(\Gamma+\Gamma c)^2}\right)^{\frac{\Gamma}{\Gamma-\Gamma c}}+$$

$$2^{\frac{4\Gamma+\Gamma c}{\Gamma-\Gamma c}}\,e^{\frac{2\omega\,\mathrm{Arg}\left[\frac{1}{\Gamma+\Gamma c}\right]}{\pi\Gamma-\pi\Gamma c}}\,\pi^2\,\Gamma c^4\left(\frac{\Gamma c^2}{(\Gamma+\Gamma c)^2}\right)^{\frac{\Gamma}{\Gamma-\Gamma c}}+2^{\frac{4\Gamma+\Gamma c}{\Gamma-\Gamma c}}\,e^{\frac{2\omega\,\mathrm{Arg}\left[\frac{1}{\Gamma+\Gamma c}\right]}{\pi\Gamma-\pi\Gamma c}}\,\pi^2\,\Gamma^2\,\Gamma c^2\left(\frac{\Gamma c^2}{(\Gamma+\Gamma c)^2}\right)^{\frac{\Gamma c}{\Gamma-\Gamma c}}+$$

$$8^{\frac{\Gamma c}{\Gamma-\Gamma c}}\,\Gamma^2\,\omega^2-2^{\frac{\Gamma+2\Gamma c}{\Gamma-\Gamma c}}\,\Gamma\,\Gamma c\,\omega^2+8^{\frac{\Gamma c}{\Gamma-\Gamma c}}\,\Gamma c^2\,\omega^2+2^{\frac{4\Gamma+\Gamma c}{\Gamma-\Gamma c}}\,e^{\frac{2\omega\,\mathrm{Arg}\left[\frac{1}{\Gamma+\Gamma c}\right]}{\pi\Gamma-\pi\Gamma c}}\,\Gamma^2\left(\frac{\Gamma c^2}{(\Gamma+\Gamma c)^2}\right)^{\frac{\Gamma}{\Gamma-\Gamma c}}\omega^2+$$

$$32^{\frac{\Gamma}{\Gamma-\Gamma c}}\,e^{\frac{2\omega\,\mathrm{Arg}\left[\frac{1}{\Gamma+\Gamma c}\right]}{\pi\Gamma-\pi\Gamma c}}\,\Gamma\,\Gamma c\left(\frac{\Gamma c^2}{(\Gamma+\Gamma c)^2}\right)^{\frac{\Gamma}{\Gamma-\Gamma c}}\omega^2+2^{\frac{4\Gamma+\Gamma c}{\Gamma-\Gamma c}}\,e^{\frac{2\omega\,\mathrm{Arg}\left[\frac{1}{\Gamma+\Gamma c}\right]}{\pi\Gamma-\pi\Gamma c}}\,\Gamma c^2\left(\frac{\Gamma c^2}{(\Gamma+\Gamma c)^2}\right)^{\frac{\Gamma}{\Gamma-\Gamma c}}\omega^2+$$

$$2^{\frac{4\,\Gamma+\Gamma c}{\Gamma-\Gamma c}}\,e^{\frac{2\,\omega\,\mathrm{Arg}\left[\frac{1}{\Gamma+\Gamma c}\right]}{\pi\,\Gamma-\pi\,\Gamma c}}\,\Gamma c^{2}\,\left(\frac{\Gamma c^{2}}{(\Gamma+\Gamma c)^{2}}\right)^{\frac{\Gamma c}{\Gamma-\Gamma c}}\,\omega^{2}-2^{\frac{3\,\Gamma+\Gamma c}{\Gamma-\Gamma c}}\,e^{\frac{\omega\,\mathrm{Arg}\left[\frac{1}{\Gamma+\Gamma c}\right]}{\pi\,\Gamma-\pi\,\Gamma c}}\,(\Gamma-\Gamma c)\,\Gamma c\,\left(\frac{\Gamma c^{2}}{(\Gamma+\Gamma c)^{2}}\right)^{\frac{\Gamma c}{2\,\Gamma-2\,\Gamma c}}$$

$$\left(\pi^{2}\,\Gamma\,\Gamma c-\omega^{2}\right)\,\mathrm{Cos}\left[\left(2\,\pi\,\Gamma c\,\mathrm{Arg}\left[\frac{1}{\Gamma+\Gamma c}\right]-\omega\,\mathrm{Log}\left[\frac{4\,\Gamma c^{2}}{(\Gamma+\Gamma c)^{2}}\right]\right)\Big/\left(2\,\pi\,(\Gamma-\Gamma c)\right)\right]+$$

$$2^{\frac{3\,\Gamma+\Gamma c}{\Gamma-\Gamma c}}\,e^{\frac{\omega\,\mathrm{Arg}\left[\frac{1}{\Gamma+\Gamma c}\right]}{\pi\,\Gamma-\pi\,\Gamma c}}\,\left(\frac{\Gamma c^{2}}{(\Gamma+\Gamma c)^{2}}\right)^{\frac{\Gamma}{2\,\Gamma-2\,\Gamma c}}\,\left(\Gamma^{2}-\Gamma c^{2}\right)\,\left(\pi^{2}\,\Gamma c^{2}-\omega^{2}\right)$$

$$\mathrm{Cos}\left[\left(-2\,\pi\,\Gamma\,\mathrm{Arg}\left[\frac{1}{\Gamma+\Gamma c}\right]+\omega\,\mathrm{Log}\left[\frac{4\,\Gamma c^{2}}{(\Gamma+\Gamma c)^{2}}\right]\right)\Big/\left(2\,\pi\,(\Gamma-\Gamma c)\right)\right]-$$

$$32^{\frac{\Gamma}{\Gamma-\Gamma c}}\,e^{\frac{2\,\omega\,\mathrm{Arg}\left[\frac{1}{\Gamma+\Gamma c}\right]}{\pi\,\Gamma-\pi\,\Gamma c}}\,\pi\,\Gamma^{2}\,\Gamma c\,\left(\frac{\Gamma c^{2}}{(\Gamma+\Gamma c)^{2}}\right)^{\frac{\Gamma+\Gamma c}{2\,\Gamma-2\,\Gamma c}}\,\omega\,\mathrm{Sin}\left[\mathrm{Arg}\left[\frac{1}{\Gamma+\Gamma c}\right]\right]+$$

$$32^{\frac{\Gamma}{\Gamma-\Gamma c}}\,e^{\frac{2\,\omega\,\mathrm{Arg}\left[\frac{1}{\Gamma+\Gamma c}\right]}{\pi\,\Gamma-\pi\,\Gamma c}}\,\pi\,\Gamma c^{3}\,\left(\frac{\Gamma c^{2}}{(\Gamma+\Gamma c)^{2}}\right)^{\frac{\Gamma+\Gamma c}{2\,\Gamma-2\,\Gamma c}}\,\omega\,\mathrm{Sin}\left[\mathrm{Arg}\left[\frac{1}{\Gamma+\Gamma c}\right]\right]-$$

$$2^{\frac{3\,\Gamma+\Gamma c}{\Gamma-\Gamma c}}\,e^{\frac{\omega\,\mathrm{Arg}\left[\frac{1}{\Gamma+\Gamma c}\right]}{\pi\,\Gamma-\pi\,\Gamma c}}\,\pi\,\Gamma^{2}\,\Gamma c\,\left(\frac{\Gamma c^{2}}{(\Gamma+\Gamma c)^{2}}\right)^{\frac{\Gamma c}{2\,\Gamma-2\,\Gamma c}}\,\omega$$

$$\mathrm{Sin}\left[\left(2\,\pi\,\Gamma c\,\mathrm{Arg}\left[\frac{1}{\Gamma+\Gamma c}\right]-\omega\,\mathrm{Log}\left[\frac{4\,\Gamma c^{2}}{(\Gamma+\Gamma c)^{2}}\right]\right)\Big/\left(2\,\pi\,(\Gamma-\Gamma c)\right)\right]+$$

$$2^{\frac{3\,\Gamma+\Gamma c}{\Gamma-\Gamma c}}\,e^{\frac{\omega\,\mathrm{Arg}\left[\frac{1}{\Gamma+\Gamma c}\right]}{\pi\,\Gamma-\pi\,\Gamma c}}\,\pi\,\Gamma c^{3}\,\left(\frac{\Gamma c^{2}}{(\Gamma+\Gamma c)^{2}}\right)^{\frac{\Gamma c}{2\,\Gamma-2\,\Gamma c}}\,\omega$$

$$\mathrm{Sin}\left[\left(2\,\pi\,\Gamma c\,\mathrm{Arg}\left[\frac{1}{\Gamma+\Gamma c}\right]-\omega\,\mathrm{Log}\left[\frac{4\,\Gamma c^{2}}{(\Gamma+\Gamma c)^{2}}\right]\right)\Big/\left(2\,\pi\,(\Gamma-\Gamma c)\right)\right]-$$

$$16^{\frac{\Gamma}{\Gamma-\Gamma c}}\,e^{\frac{\omega\,\mathrm{Arg}\left[\frac{1}{\Gamma+\Gamma c}\right]}{\pi\,\Gamma-\pi\,\Gamma c}}\,\pi\,\Gamma^{2}\,\Gamma c\,\left(\frac{\Gamma c^{2}}{(\Gamma+\Gamma c)^{2}}\right)^{\frac{\Gamma}{2\,\Gamma-2\,\Gamma c}}\,\omega$$

$$\mathrm{Sin}\left[\left(-2\,\pi\,\Gamma\,\mathrm{Arg}\left[\frac{1}{\Gamma+\Gamma c}\right]+\omega\,\mathrm{Log}\left[\frac{4\,\Gamma c^{2}}{(\Gamma+\Gamma c)^{2}}\right]\right)\Big/\left(2\,\pi\,(\Gamma-\Gamma c)\right)\right]+$$

$$16^{\frac{\Gamma}{\Gamma-\Gamma c}}\,e^{\frac{\omega\,\mathrm{Arg}\left[\frac{1}{\Gamma+\Gamma c}\right]}{\pi\,\Gamma-\pi\,\Gamma c}}\,\pi\,\Gamma c^{3}\,\left(\frac{\Gamma c^{2}}{(\Gamma+\Gamma c)^{2}}\right)^{\frac{\Gamma}{2\,\Gamma-2\,\Gamma c}}\,\omega$$

$$\mathrm{Sin}\left[\left(-2\,\pi\,\Gamma\,\mathrm{Arg}\left[\frac{1}{\Gamma+\Gamma c}\right]+\omega\,\mathrm{Log}\left[\frac{4\,\Gamma c^{2}}{(\Gamma+\Gamma c)^{2}}\right]\right)\Big/\left(2\,\pi\,(\Gamma-\Gamma c)\right)\right]\Bigg)\Bigg)\Bigg)\Big/$$

$$\left((\Gamma-\Gamma c)^{2}\,\left(\pi^{2}\,\Gamma^{2}+\omega^{2}\right)\,\left(\pi^{2}\,\Gamma c^{2}+\omega^{2}\right)\right)\Bigg)$$

$$\mathrm{ArcTan}\left[\frac{\pi\,\Gamma^{2}}{(\Gamma-\Gamma c)\,\left(\pi^{2}\,\Gamma^{2}+\omega^{2}\right)}+\frac{\pi\,\Gamma\,\Gamma c}{(\Gamma-\Gamma c)\,\left(\pi^{2}\,\Gamma^{2}+\omega^{2}\right)}-\right.$$

$$\frac{2\,\pi\,\Gamma c^{2}}{(\Gamma-\Gamma c)\,\left(\pi^{2}\,\Gamma c^{2}+\omega^{2}\right)}-\left(2^{\frac{2\,\pi\,\Gamma-\pi\,\Gamma c}{\pi\,\Gamma-\pi\,\Gamma c}}\,e^{\frac{\omega\,\mathrm{Arg}\left[\frac{\Gamma c}{\Gamma+\Gamma c}\right]}{\pi\,\Gamma-\pi\,\Gamma c}}\,\pi\,\Gamma^{2}\,\left(\frac{\Gamma c^{2}}{(\Gamma+\Gamma c)^{2}}\right)^{\frac{\pi\,\Gamma}{2\,(\pi\,\Gamma-\pi\,\Gamma c)}}\,\mathrm{Cos}\left[\frac{\omega\,\mathrm{Log}[2]}{\pi\,\Gamma-\pi\,\Gamma c}\right]\right.$$

$$\left.\mathrm{Cos}\left[\frac{\pi\,\Gamma\,\mathrm{Arg}\left[\frac{\Gamma c}{\Gamma+\Gamma c}\right]}{\pi\,\Gamma-\pi\,\Gamma c}-\frac{\omega\,\mathrm{Log}\left[\frac{\Gamma c^{2}}{(\Gamma+\Gamma c)^{2}}\right]}{2\,(\pi\,\Gamma-\pi\,\Gamma c)}\right]\right)\Big/\left((\Gamma-\Gamma c)\,\left(\pi^{2}\,\Gamma^{2}+\omega^{2}\right)\right)-$$

$$\left(2^{\frac{2\,\pi\,\Gamma-\pi\,\Gamma c}{\pi\,\Gamma-\pi\,\Gamma c}}\,e^{\frac{\omega\,\mathrm{Arg}\left[\frac{\Gamma c}{\Gamma+\Gamma c}\right]}{\pi\,\Gamma-\pi\,\Gamma c}}\,\pi\,\Gamma\,\Gamma c\,\left(\frac{\Gamma c^{2}}{(\Gamma+\Gamma c)^{2}}\right)^{\frac{\pi\,\Gamma}{2\,(\pi\,\Gamma-\pi\,\Gamma c)}}\,\mathrm{Cos}\left[\frac{\omega\,\mathrm{Log}[2]}{\pi\,\Gamma-\pi\,\Gamma c}\right]\right.$$

$$\mathrm{Cos}\left[\frac{\pi\,\Gamma\,\mathrm{Arg}\left[\frac{\Gamma c}{\Gamma+\Gamma c}\right]}{\pi\,\Gamma-\pi\,\Gamma c}-\frac{\omega\,\mathrm{Log}\left[\frac{\Gamma c^2}{(\Gamma+\Gamma c)^2}\right]}{2\,(\pi\,\Gamma-\pi\,\Gamma c)}\right]\Bigg)\Big/\left((\Gamma-\Gamma c)\,\left(\pi^2\,\Gamma^2+\omega^2\right)\right)+$$

$$\Bigg(2^{1+\frac{\pi\,\Gamma}{\pi\,\Gamma-\pi\,\Gamma c}}\,e^{\frac{\omega\,\mathrm{Arg}\left[\frac{\Gamma c}{\Gamma+\Gamma c}\right]}{\pi\,\Gamma-\pi\,\Gamma c}}\,\pi\,\Gamma c^2\,\left(\frac{\Gamma c^2}{(\Gamma+\Gamma c)^2}\right)^{\frac{\pi\,\Gamma c}{2\,(\pi\,\Gamma-\pi\,\Gamma c)}}\,\mathrm{Cos}\left[\frac{\omega\,\mathrm{Log}[2]}{\pi\,\Gamma-\pi\,\Gamma c}\right]$$

$$\mathrm{Cos}\left[\frac{\pi\,\Gamma c\,\mathrm{Arg}\left[\frac{\Gamma c}{\Gamma+\Gamma c}\right]}{\pi\,\Gamma-\pi\,\Gamma c}-\frac{\omega\,\mathrm{Log}\left[\frac{\Gamma c^2}{(\Gamma+\Gamma c)^2}\right]}{2\,(\pi\,\Gamma-\pi\,\Gamma c)}\right]\Bigg)\Big/\left((\Gamma-\Gamma c)\,\left(\pi^2\,\Gamma c^2+\omega^2\right)\right)-$$

$$\Bigg(2^{\frac{2\,\pi\,\Gamma-\pi\,\Gamma c}{\pi\,\Gamma-\pi\,\Gamma c}}\,e^{\frac{\omega\,\mathrm{Arg}\left[\frac{\Gamma c}{\Gamma+\Gamma c}\right]}{\pi\,\Gamma-\pi\,\Gamma c}}\,\Gamma\,\left(\frac{\Gamma c^2}{(\Gamma+\Gamma c)^2}\right)^{\frac{\pi\,\Gamma}{2\,(\pi\,\Gamma-\pi\,\Gamma c)}}\,\omega\,\mathrm{Cos}\left[\frac{\pi\,\Gamma\,\mathrm{Arg}\left[\frac{\Gamma c}{\Gamma+\Gamma c}\right]}{\pi\,\Gamma-\pi\,\Gamma c}-\frac{\omega\,\mathrm{Log}\left[\frac{\Gamma c^2}{(\Gamma+\Gamma c)^2}\right]}{2\,(\pi\,\Gamma-\pi\,\Gamma c)}\right]$$

$$\mathrm{Sin}\left[\frac{\omega\,\mathrm{Log}[2]}{\pi\,\Gamma-\pi\,\Gamma c}\right]\Bigg)\Big/\left((\Gamma-\Gamma c)\,\left(\pi^2\,\Gamma^2+\omega^2\right)\right)-$$

$$\Bigg(2^{\frac{2\,\pi\,\Gamma-\pi\,\Gamma c}{\pi\,\Gamma-\pi\,\Gamma c}}\,e^{\frac{\omega\,\mathrm{Arg}\left[\frac{\Gamma c}{\Gamma+\Gamma c}\right]}{\pi\,\Gamma-\pi\,\Gamma c}}\,\Gamma c\,\left(\frac{\Gamma c^2}{(\Gamma+\Gamma c)^2}\right)^{\frac{\pi\,\Gamma}{2\,(\pi\,\Gamma-\pi\,\Gamma c)}}\,\omega\,\mathrm{Cos}\left[\frac{\pi\,\Gamma\,\mathrm{Arg}\left[\frac{\Gamma c}{\Gamma+\Gamma c}\right]}{\pi\,\Gamma-\pi\,\Gamma c}-\frac{\omega\,\mathrm{Log}\left[\frac{\Gamma c^2}{(\Gamma+\Gamma c)^2}\right]}{2\,(\pi\,\Gamma-\pi\,\Gamma c)}\right]$$

$$\mathrm{Sin}\left[\frac{\omega\,\mathrm{Log}[2]}{\pi\,\Gamma-\pi\,\Gamma c}\right]\Bigg)\Big/\left((\Gamma-\Gamma c)\,\left(\pi^2\,\Gamma^2+\omega^2\right)\right)+$$

$$\Bigg(2^{1+\frac{\pi\,\Gamma}{\pi\,\Gamma-\pi\,\Gamma c}}\,e^{\frac{\omega\,\mathrm{Arg}\left[\frac{\Gamma c}{\Gamma+\Gamma c}\right]}{\pi\,\Gamma-\pi\,\Gamma c}}\,\Gamma c\,\left(\frac{\Gamma c^2}{(\Gamma+\Gamma c)^2}\right)^{\frac{\pi\,\Gamma c}{2\,(\pi\,\Gamma-\pi\,\Gamma c)}}\,\omega\,\mathrm{Cos}\left[\frac{\pi\,\Gamma c\,\mathrm{Arg}\left[\frac{\Gamma c}{\Gamma+\Gamma c}\right]}{\pi\,\Gamma-\pi\,\Gamma c}-\frac{\omega\,\mathrm{Log}\left[\frac{\Gamma c^2}{(\Gamma+\Gamma c)^2}\right]}{2\,(\pi\,\Gamma-\pi\,\Gamma c)}\right]$$

$$\mathrm{Sin}\left[\frac{\omega\,\mathrm{Log}[2]}{\pi\,\Gamma-\pi\,\Gamma c}\right]\Bigg)\Big/\left((\Gamma-\Gamma c)\,\left(\pi^2\,\Gamma c^2+\omega^2\right)\right)+$$

$$\Bigg(2^{\frac{2\,\pi\,\Gamma-\pi\,\Gamma c}{\pi\,\Gamma-\pi\,\Gamma c}}\,e^{\frac{\omega\,\mathrm{Arg}\left[\frac{\Gamma c}{\Gamma+\Gamma c}\right]}{\pi\,\Gamma-\pi\,\Gamma c}}\,\Gamma\,\left(\frac{\Gamma c^2}{(\Gamma+\Gamma c)^2}\right)^{\frac{\pi\,\Gamma}{2\,(\pi\,\Gamma-\pi\,\Gamma c)}}\,\omega\,\mathrm{Cos}\left[\frac{\omega\,\mathrm{Log}[2]}{\pi\,\Gamma-\pi\,\Gamma c}\right]$$

$$\mathrm{Sin}\left[\frac{\pi\,\Gamma\,\mathrm{Arg}\left[\frac{\Gamma c}{\Gamma+\Gamma c}\right]}{\pi\,\Gamma-\pi\,\Gamma c}-\frac{\omega\,\mathrm{Log}\left[\frac{\Gamma c^2}{(\Gamma+\Gamma c)^2}\right]}{2\,(\pi\,\Gamma-\pi\,\Gamma c)}\right]\Bigg)\Big/\left((\Gamma-\Gamma c)\,\left(\pi^2\,\Gamma^2+\omega^2\right)\right)+$$

$$\Bigg(2^{\frac{2\,\pi\,\Gamma-\pi\,\Gamma c}{\pi\,\Gamma-\pi\,\Gamma c}}\,e^{\frac{\omega\,\mathrm{Arg}\left[\frac{\Gamma c}{\Gamma+\Gamma c}\right]}{\pi\,\Gamma-\pi\,\Gamma c}}\,\Gamma c\,\left(\frac{\Gamma c^2}{(\Gamma+\Gamma c)^2}\right)^{\frac{\pi\,\Gamma}{2\,(\pi\,\Gamma-\pi\,\Gamma c)}}\,\omega\,\mathrm{Cos}\left[\frac{\omega\,\mathrm{Log}[2]}{\pi\,\Gamma-\pi\,\Gamma c}\right]$$

$$\mathrm{Sin}\left[\frac{\pi\,\Gamma\,\mathrm{Arg}\left[\frac{\Gamma c}{\Gamma+\Gamma c}\right]}{\pi\,\Gamma-\pi\,\Gamma c}-\frac{\omega\,\mathrm{Log}\left[\frac{\Gamma c^2}{(\Gamma+\Gamma c)^2}\right]}{2\,(\pi\,\Gamma-\pi\,\Gamma c)}\right]\Bigg)\Big/\left((\Gamma-\Gamma c)\,\left(\pi^2\,\Gamma^2+\omega^2\right)\right)-$$

$$\Bigg(2^{\frac{2\,\pi\,\Gamma-\pi\,\Gamma c}{\pi\,\Gamma-\pi\,\Gamma c}}\,e^{\frac{\omega\,\mathrm{Arg}\left[\frac{\Gamma c}{\Gamma+\Gamma c}\right]}{\pi\,\Gamma-\pi\,\Gamma c}}\,\pi\,\Gamma^2\,\left(\frac{\Gamma c^2}{(\Gamma+\Gamma c)^2}\right)^{\frac{\pi\,\Gamma}{2\,(\pi\,\Gamma-\pi\,\Gamma c)}}\,\mathrm{Sin}\left[\frac{\omega\,\mathrm{Log}[2]}{\pi\,\Gamma-\pi\,\Gamma c}\right]$$

$$\mathrm{Sin}\left[\frac{\pi\,\Gamma\,\mathrm{Arg}\left[\frac{\Gamma c}{\Gamma+\Gamma c}\right]}{\pi\,\Gamma-\pi\,\Gamma c}-\frac{\omega\,\mathrm{Log}\left[\frac{\Gamma c^2}{(\Gamma+\Gamma c)^2}\right]}{2\,(\pi\,\Gamma-\pi\,\Gamma c)}\right]\Bigg)\Big/\left((\Gamma-\Gamma c)\,\left(\pi^2\,\Gamma^2+\omega^2\right)\right)-$$

$$\Bigg(2^{\frac{2\,\pi\,\Gamma-\pi\,\Gamma c}{\pi\,\Gamma-\pi\,\Gamma c}}\,e^{\frac{\omega\,\mathrm{Arg}\left[\frac{\Gamma c}{\Gamma+\Gamma c}\right]}{\pi\,\Gamma-\pi\,\Gamma c}}\,\pi\,\Gamma\,\Gamma c\,\left(\frac{\Gamma c^2}{(\Gamma+\Gamma c)^2}\right)^{\frac{\pi\,\Gamma}{2\,(\pi\,\Gamma-\pi\,\Gamma c)}}\,\mathrm{Sin}\left[\frac{\omega\,\mathrm{Log}[2]}{\pi\,\Gamma-\pi\,\Gamma c}\right]$$

$$\mathrm{Sin}\left[\frac{\pi\,\Gamma\,\mathrm{Arg}\left[\frac{\Gamma c}{\Gamma+\Gamma c}\right]}{\pi\,\Gamma-\pi\,\Gamma c}-\frac{\omega\,\mathrm{Log}\left[\frac{\Gamma c^2}{(\Gamma+\Gamma c)^2}\right]}{2\,(\pi\,\Gamma-\pi\,\Gamma c)}\right]\Bigg)\Big/\left((\Gamma-\Gamma c)\,\left(\pi^2\,\Gamma^2+\omega^2\right)\right)-$$

$$\Bigg(2^{1+\frac{\pi\,\Gamma}{\pi\,\Gamma-\pi\,\Gamma c}}\,e^{\frac{\omega\,\mathrm{Arg}\left[\frac{\Gamma c}{\Gamma+\Gamma c}\right]}{\pi\,\Gamma-\pi\,\Gamma c}}\,\Gamma c\,\left(\frac{\Gamma c^2}{(\Gamma+\Gamma c)^2}\right)^{\frac{\pi\,\Gamma c}{2\,(\pi\,\Gamma-\pi\,\Gamma c)}}\,\omega\,\mathrm{Cos}\left[\frac{\omega\,\mathrm{Log}[2]}{\pi\,\Gamma-\pi\,\Gamma c}\right]$$

$$\mathrm{Sin}\left[\frac{\pi\,\Gamma c\,\mathrm{Arg}\left[\frac{\Gamma c}{\Gamma+\Gamma c}\right]}{\pi\,\Gamma-\pi\,\Gamma c}-\frac{\omega\,\mathrm{Log}\left[\frac{\Gamma c^2}{(\Gamma+\Gamma c)^2}\right]}{2\,(\pi\,\Gamma-\pi\,\Gamma c)}\right]\Bigg)\Big/\left((\Gamma-\Gamma c)\,\left(\pi^2\,\Gamma c^2+\omega^2\right)\right)+$$

$$\Bigg(2^{1+\frac{\pi\,\Gamma}{\pi\,\Gamma-\pi\,\Gamma c}}\,e^{\frac{\omega\,\mathrm{Arg}\left[\frac{\Gamma c}{\Gamma+\Gamma c}\right]}{\pi\,\Gamma-\pi\,\Gamma c}}\,\pi\,\Gamma c^2\,\left(\frac{\Gamma c^2}{(\Gamma+\Gamma c)^2}\right)^{\frac{\pi\,\Gamma c}{2\,(\pi\,\Gamma-\pi\,\Gamma c)}}\,\mathrm{Sin}\left[\frac{\omega\,\mathrm{Log}[2]}{\pi\,\Gamma-\pi\,\Gamma c}\right]$$

$$\mathrm{Sin}\left[\frac{\pi\,\Gamma c\,\mathrm{Arg}\left[\frac{\Gamma c}{\Gamma+\Gamma c}\right]}{\pi\,\Gamma-\pi\,\Gamma c}-\frac{\omega\,\mathrm{Log}\left[\frac{\Gamma c^2}{(\Gamma+\Gamma c)^2}\right]}{2\,(\pi\,\Gamma-\pi\,\Gamma c)}\right]\Bigg)\Big/\left((\Gamma-\Gamma c)\,\left(\pi^2\,\Gamma c^2+\omega^2\right)\right),$$

$$\frac{\Gamma\,\omega}{(\Gamma-\Gamma c)\,\left(\pi^2\,\Gamma^2+\omega^2\right)}+\frac{\Gamma c\,\omega}{(\Gamma-\Gamma c)\,\left(\pi^2\,\Gamma^2+\omega^2\right)}-\frac{2\,\Gamma c\,\omega}{(\Gamma-\Gamma c)\,\left(\pi^2\,\Gamma c^2+\omega^2\right)}-$$

$$\Bigg(2^{\frac{2\,\pi\,\Gamma-\pi\,\Gamma c}{\pi\,\Gamma-\pi\,\Gamma c}}\,e^{\frac{\omega\,\mathrm{Arg}\left[\frac{\Gamma c}{\Gamma+\Gamma c}\right]}{\pi\,\Gamma-\pi\,\Gamma c}}\,\Gamma\,\left(\frac{\Gamma c^2}{(\Gamma+\Gamma c)^2}\right)^{\frac{\pi\,\Gamma}{2\,(\pi\,\Gamma-\pi\,\Gamma c)}}\,\omega\,\mathrm{Cos}\left[\frac{\omega\,\mathrm{Log}[2]}{\pi\,\Gamma-\pi\,\Gamma c}\right]$$

$$\mathrm{Cos}\left[\frac{\pi\,\Gamma\,\mathrm{Arg}\left[\frac{\Gamma c}{\Gamma+\Gamma c}\right]}{\pi\,\Gamma-\pi\,\Gamma c}-\frac{\omega\,\mathrm{Log}\left[\frac{\Gamma c^2}{(\Gamma+\Gamma c)^2}\right]}{2\,(\pi\,\Gamma-\pi\,\Gamma c)}\right]\Bigg)\Big/\left((\Gamma-\Gamma c)\,\left(\pi^2\,\Gamma^2+\omega^2\right)\right)-$$

$$\Bigg(2^{\frac{2\,\pi\,\Gamma-\pi\,\Gamma c}{\pi\,\Gamma-\pi\,\Gamma c}}\,e^{\frac{\omega\,\mathrm{Arg}\left[\frac{\Gamma c}{\Gamma+\Gamma c}\right]}{\pi\,\Gamma-\pi\,\Gamma c}}\,\Gamma c\,\left(\frac{\Gamma c^2}{(\Gamma+\Gamma c)^2}\right)^{\frac{\pi\,\Gamma}{2\,(\pi\,\Gamma-\pi\,\Gamma c)}}\,\omega\,\mathrm{Cos}\left[\frac{\omega\,\mathrm{Log}[2]}{\pi\,\Gamma-\pi\,\Gamma c}\right]$$

$$\mathrm{Cos}\left[\frac{\pi\,\Gamma\,\mathrm{Arg}\left[\frac{\Gamma c}{\Gamma+\Gamma c}\right]}{\pi\,\Gamma-\pi\,\Gamma c}-\frac{\omega\,\mathrm{Log}\left[\frac{\Gamma c^2}{(\Gamma+\Gamma c)^2}\right]}{2\,(\pi\,\Gamma-\pi\,\Gamma c)}\right]\Bigg)\Big/\left((\Gamma-\Gamma c)\,\left(\pi^2\,\Gamma^2+\omega^2\right)\right)+$$

$$\Bigg(2^{1+\frac{\pi\,\Gamma}{\pi\,\Gamma-\pi\,\Gamma c}}\,e^{\frac{\omega\,\mathrm{Arg}\left[\frac{\Gamma c}{\Gamma+\Gamma c}\right]}{\pi\,\Gamma-\pi\,\Gamma c}}\,\Gamma c\,\left(\frac{\Gamma c^2}{(\Gamma+\Gamma c)^2}\right)^{\frac{\pi\,\Gamma c}{2\,(\pi\,\Gamma-\pi\,\Gamma c)}}\,\omega\,\mathrm{Cos}\left[\frac{\omega\,\mathrm{Log}[2]}{\pi\,\Gamma-\pi\,\Gamma c}\right]$$

$$\mathrm{Cos}\left[\frac{\pi\,\Gamma c\,\mathrm{Arg}\left[\frac{\Gamma c}{\Gamma+\Gamma c}\right]}{\pi\,\Gamma-\pi\,\Gamma c}-\frac{\omega\,\mathrm{Log}\left[\frac{\Gamma c^2}{(\Gamma+\Gamma c)^2}\right]}{2\,(\pi\,\Gamma-\pi\,\Gamma c)}\right]\Bigg)\Big/\left((\Gamma-\Gamma c)\,\left(\pi^2\,\Gamma c^2+\omega^2\right)\right)+$$

$$\Bigg(2^{\frac{2\,\pi\,\Gamma-\pi\,\Gamma c}{\pi\,\Gamma-\pi\,\Gamma c}}\,e^{\frac{\omega\,\mathrm{Arg}\left[\frac{\Gamma c}{\Gamma+\Gamma c}\right]}{\pi\,\Gamma-\pi\,\Gamma c}}\,\pi\,\Gamma^2\,\left(\frac{\Gamma c^2}{(\Gamma+\Gamma c)^2}\right)^{\frac{\pi\,\Gamma}{2\,(\pi\,\Gamma-\pi\,\Gamma c)}}\,\mathrm{Cos}\left[\frac{\pi\,\Gamma\,\mathrm{Arg}\left[\frac{\Gamma c}{\Gamma+\Gamma c}\right]}{\pi\,\Gamma-\pi\,\Gamma c}-\frac{\omega\,\mathrm{Log}\left[\frac{\Gamma c^2}{(\Gamma+\Gamma c)^2}\right]}{2\,(\pi\,\Gamma-\pi\,\Gamma c)}\right]$$

$$\left.\mathrm{Sin}\left[\frac{\omega\,\mathrm{Log}[2]}{\pi\,\Gamma-\pi\,\Gamma c}\right]\right)\Big/\left((\Gamma-\Gamma c)\left(\pi^2\,\Gamma^2+\omega^2\right)\right)+$$

$$\left(2^{\frac{2\,\pi\,\Gamma-\pi\,\Gamma c}{\pi\,\Gamma-\pi\,\Gamma c}}\,e^{\frac{\omega\,\mathrm{Arg}\left[\frac{\Gamma c}{\Gamma+\Gamma c}\right]}{\pi\,\Gamma-\pi\,\Gamma c}}\,\pi\,\Gamma\,\Gamma c\left(\frac{\Gamma c^2}{(\Gamma+\Gamma c)^2}\right)^{\frac{\pi\,\Gamma}{2\,(\pi\,\Gamma-\pi\,\Gamma c)}}\,\mathrm{Cos}\left[\frac{\pi\,\Gamma\,\mathrm{Arg}\left[\frac{\Gamma c}{\Gamma+\Gamma c}\right]}{\pi\,\Gamma-\pi\,\Gamma c}-\frac{\omega\,\mathrm{Log}\left[\frac{\Gamma c^2}{(\Gamma+\Gamma c)^2}\right]}{2\,(\pi\,\Gamma-\pi\,\Gamma c)}\right]\right.$$

$$\left.\mathrm{Sin}\left[\frac{\omega\,\mathrm{Log}[2]}{\pi\,\Gamma-\pi\,\Gamma c}\right]\right)\Big/\left((\Gamma-\Gamma c)\left(\pi^2\,\Gamma^2+\omega^2\right)\right)-$$

$$\left(2^{1+\frac{\pi\,\Gamma}{\pi\,\Gamma-\pi\,\Gamma c}}\,e^{\frac{\omega\,\mathrm{Arg}\left[\frac{\Gamma c}{\Gamma+\Gamma c}\right]}{\pi\,\Gamma-\pi\,\Gamma c}}\,\pi\,\Gamma c^2\left(\frac{\Gamma c^2}{(\Gamma+\Gamma c)^2}\right)^{\frac{\pi\,\Gamma c}{2\,(\pi\,\Gamma-\pi\,\Gamma c)}}\,\mathrm{Cos}\left[\frac{\pi\,\Gamma c\,\mathrm{Arg}\left[\frac{\Gamma c}{\Gamma+\Gamma c}\right]}{\pi\,\Gamma-\pi\,\Gamma c}-\frac{\omega\,\mathrm{Log}\left[\frac{\Gamma c^2}{(\Gamma+\Gamma c)^2}\right]}{2\,(\pi\,\Gamma-\pi\,\Gamma c)}\right]\right.$$

$$\left.\mathrm{Sin}\left[\frac{\omega\,\mathrm{Log}[2]}{\pi\,\Gamma-\pi\,\Gamma c}\right]\right)\Big/\left((\Gamma-\Gamma c)\left(\pi^2\,\Gamma c^2+\omega^2\right)\right)-$$

$$\left(2^{\frac{2\,\pi\,\Gamma-\pi\,\Gamma c}{\pi\,\Gamma-\pi\,\Gamma c}}\,e^{\frac{\omega\,\mathrm{Arg}\left[\frac{\Gamma c}{\Gamma+\Gamma c}\right]}{\pi\,\Gamma-\pi\,\Gamma c}}\,\pi\,\Gamma^2\left(\frac{\Gamma c^2}{(\Gamma+\Gamma c)^2}\right)^{\frac{\pi\,\Gamma}{2\,(\pi\,\Gamma-\pi\,\Gamma c)}}\,\mathrm{Cos}\left[\frac{\omega\,\mathrm{Log}[2]}{\pi\,\Gamma-\pi\,\Gamma c}\right]\right.$$

$$\left.\mathrm{Sin}\left[\frac{\pi\,\Gamma\,\mathrm{Arg}\left[\frac{\Gamma c}{\Gamma+\Gamma c}\right]}{\pi\,\Gamma-\pi\,\Gamma c}-\frac{\omega\,\mathrm{Log}\left[\frac{\Gamma c^2}{(\Gamma+\Gamma c)^2}\right]}{2\,(\pi\,\Gamma-\pi\,\Gamma c)}\right]\right)\Big/\left((\Gamma-\Gamma c)\left(\pi^2\,\Gamma^2+\omega^2\right)\right)-$$

$$\left(2^{\frac{2\,\pi\,\Gamma-\pi\,\Gamma c}{\pi\,\Gamma-\pi\,\Gamma c}}\,e^{\frac{\omega\,\mathrm{Arg}\left[\frac{\Gamma c}{\Gamma+\Gamma c}\right]}{\pi\,\Gamma-\pi\,\Gamma c}}\,\pi\,\Gamma\,\Gamma c\left(\frac{\Gamma c^2}{(\Gamma+\Gamma c)^2}\right)^{\frac{\pi\,\Gamma}{2\,(\pi\,\Gamma-\pi\,\Gamma c)}}\,\mathrm{Cos}\left[\frac{\omega\,\mathrm{Log}[2]}{\pi\,\Gamma-\pi\,\Gamma c}\right]\right.$$

$$\left.\mathrm{Sin}\left[\frac{\pi\,\Gamma\,\mathrm{Arg}\left[\frac{\Gamma c}{\Gamma+\Gamma c}\right]}{\pi\,\Gamma-\pi\,\Gamma c}-\frac{\omega\,\mathrm{Log}\left[\frac{\Gamma c^2}{(\Gamma+\Gamma c)^2}\right]}{2\,(\pi\,\Gamma-\pi\,\Gamma c)}\right]\right)\Big/\left((\Gamma-\Gamma c)\left(\pi^2\,\Gamma^2+\omega^2\right)\right)-$$

$$\left(2^{\frac{2\,\pi\,\Gamma-\pi\,\Gamma c}{\pi\,\Gamma-\pi\,\Gamma c}}\,e^{\frac{\omega\,\mathrm{Arg}\left[\frac{\Gamma c}{\Gamma+\Gamma c}\right]}{\pi\,\Gamma-\pi\,\Gamma c}}\,\Gamma\left(\frac{\Gamma c^2}{(\Gamma+\Gamma c)^2}\right)^{\frac{\pi\,\Gamma}{2\,(\pi\,\Gamma-\pi\,\Gamma c)}}\,\omega\,\mathrm{Sin}\left[\frac{\omega\,\mathrm{Log}[2]}{\pi\,\Gamma-\pi\,\Gamma c}\right]\right.$$

$$\left.\mathrm{Sin}\left[\frac{\pi\,\Gamma\,\mathrm{Arg}\left[\frac{\Gamma c}{\Gamma+\Gamma c}\right]}{\pi\,\Gamma-\pi\,\Gamma c}-\frac{\omega\,\mathrm{Log}\left[\frac{\Gamma c^2}{(\Gamma+\Gamma c)^2}\right]}{2\,(\pi\,\Gamma-\pi\,\Gamma c)}\right]\right)\Big/\left((\Gamma-\Gamma c)\left(\pi^2\,\Gamma^2+\omega^2\right)\right)-$$

$$\left(2^{\frac{2\,\pi\,\Gamma-\pi\,\Gamma c}{\pi\,\Gamma-\pi\,\Gamma c}}\,e^{\frac{\omega\,\mathrm{Arg}\left[\frac{\Gamma c}{\Gamma+\Gamma c}\right]}{\pi\,\Gamma-\pi\,\Gamma c}}\,\Gamma c\left(\frac{\Gamma c^2}{(\Gamma+\Gamma c)^2}\right)^{\frac{\pi\,\Gamma}{2\,(\pi\,\Gamma-\pi\,\Gamma c)}}\,\omega\,\mathrm{Sin}\left[\frac{\omega\,\mathrm{Log}[2]}{\pi\,\Gamma-\pi\,\Gamma c}\right]\right.$$

$$\left.\mathrm{Sin}\left[\frac{\pi\,\Gamma\,\mathrm{Arg}\left[\frac{\Gamma c}{\Gamma+\Gamma c}\right]}{\pi\,\Gamma-\pi\,\Gamma c}-\frac{\omega\,\mathrm{Log}\left[\frac{\Gamma c^2}{(\Gamma+\Gamma c)^2}\right]}{2\,(\pi\,\Gamma-\pi\,\Gamma c)}\right]\right)\Big/\left((\Gamma-\Gamma c)\left(\pi^2\,\Gamma^2+\omega^2\right)\right)+$$

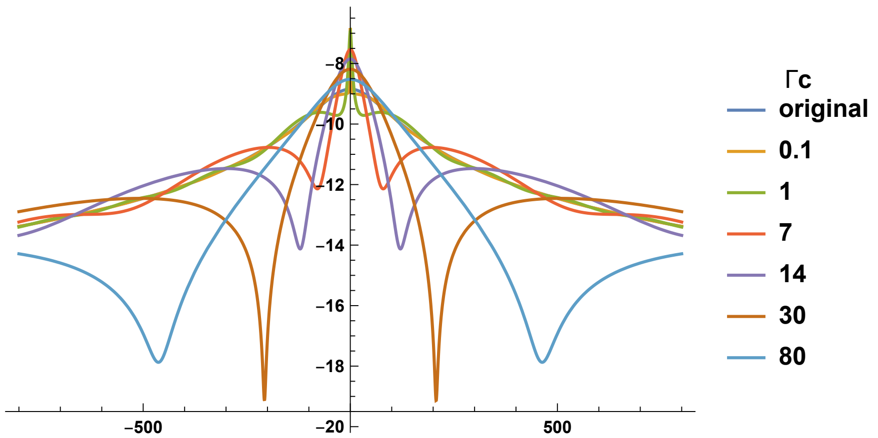
$$\left(2^{1+\frac{\pi\,\Gamma}{\pi\,\Gamma-\pi\,\Gamma c}}\,e^{\frac{\omega\,\mathrm{Arg}\left[\frac{\Gamma c}{\Gamma+\Gamma c}\right]}{\pi\,\Gamma-\pi\,\Gamma c}}\,\pi\,\Gamma c^2\left(\frac{\Gamma c^2}{(\Gamma+\Gamma c)^2}\right)^{\frac{\pi\,\Gamma c}{2\,(\pi\,\Gamma-\pi\,\Gamma c)}}\,\mathrm{Cos}\left[\frac{\omega\,\mathrm{Log}[2]}{\pi\,\Gamma-\pi\,\Gamma c}\right]\right.$$

$$\text{Sin}\left[\frac{\pi\,\Gamma c\,\text{Arg}\left[\frac{\Gamma c}{\Gamma+\Gamma c}\right]}{\pi\,\Gamma-\pi\,\Gamma c}-\frac{\omega\,\text{Log}\left[\frac{\Gamma c^2}{(\Gamma+\Gamma c)^2}\right]}{2\,(\pi\,\Gamma-\pi\,\Gamma c)}\right]\Bigg)\Big/\left((\Gamma-\Gamma c)\left(\pi^2\,\Gamma c^2+\omega^2\right)\right)+$$

$$\Bigg(2^{1+\frac{\pi\,\Gamma}{\pi\,\Gamma-\pi\,\Gamma c}}\,e^{\frac{\omega\,\text{Arg}\left[\frac{\Gamma c}{\Gamma+\Gamma c}\right]}{\pi\,\Gamma-\pi\,\Gamma c}}\,\Gamma c\left(\frac{\Gamma c^2}{(\Gamma+\Gamma c)^2}\right)^{\frac{\pi\,\Gamma c}{2\,(\pi\,\Gamma-\pi\,\Gamma c)}}\,\omega\,\text{Sin}\left[\frac{\omega\,\text{Log}[2]}{\pi\,\Gamma-\pi\,\Gamma c}\right]$$

$$\text{Sin}\left[\frac{\pi\,\Gamma c\,\text{Arg}\left[\frac{\Gamma c}{\Gamma+\Gamma c}\right]}{\pi\,\Gamma-\pi\,\Gamma c}-\frac{\omega\,\text{Log}\left[\frac{\Gamma c^2}{(\Gamma+\Gamma c)^2}\right]}{2\,(\pi\,\Gamma-\pi\,\Gamma c)}\right]\Bigg)\Big/\left((\Gamma-\Gamma c)\left(\pi^2\,\Gamma c^2+\omega^2\right)\right)\Bigg]$$

```
Plot[{Log[Abs[ψ1]^2] /. {Γ → 26.53, ω0 → 0}, Evaluate@
   Table[Log[Abs[NewPsiF]^2] /. Γ → 26.53, {Γc, { .1, 1, 7, 14, 30, 80 }}]},
 {ω, -800, 800},
 PlotLegends → LineLegend[
   Table[ Γc, {Γc, {"original", .1, 1, 7, 14, 30, 80 }}], LegendLabel → Γc],
 PlotRange →
  All]
```



Print in a python - compatible format

```
pw = PageWidth /. Options[$Output];
SetOptions[$Output, PageWidth → Infinity];
FortranForm[NewPsiF //.
  {E^x_ → exp[x], Complex[z_, y_] → 1 j , Pi → pi, Γ → Gamma, Γc → Gammac}]
SetOptions[$Output, PageWidth → pw];
```

```
(Gamma*(1 - 2**((2*Gamma*pi - Gammac*pi + j*ω)/(Gamma*pi - Gammac*pi))*(Gammac/((
```