GDT ECH with linear Slab Profiles

Open Additional files:

Get dispersion routines by evaluating Disper.nb
Get plotting and printing routines by evaluating PlotPack.nb
Set Parameters by opening a Parameter Window

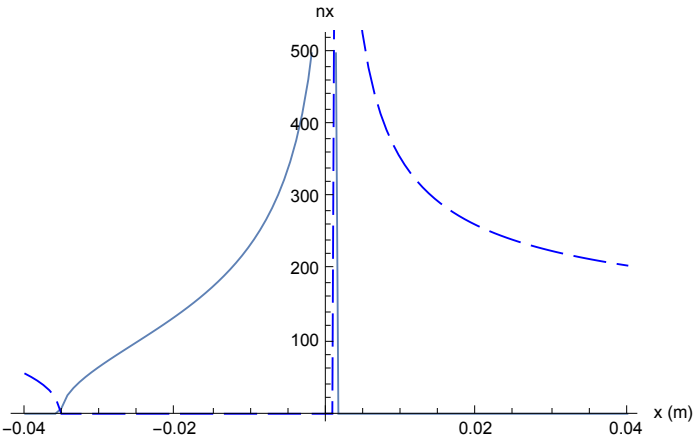
Note: Slab profile models defined in initialization cells at the bottom of this notebook.

First Do Cold Plasma

Plot Real and Imaginary parts of nx from 2nd order warm plasma dispersion relation (i.e. $E_{\|} \equiv 0$)

In[2231]:=
```
nPerpCold[x_] := Module[{ne, b, x0}, x0 = x;
   ne = nprof[x0];
   b = bprof[x0];
   ColdDis0[freq, ne, b, nz, etaList]]
nt = Table[{x, nPerpCold[x]}, {x, xmin, xmax, (xmax - xmin)/(nPoints - 1)}];
ComplexListPlot[nt, "x (m)", "nx"]
paramPrint[{dataSet, xProfileMin, xProfileMax,
    nXmin, nXmax, BXmin, BXmax, freq, nz, etaList, xmin, xmax}];
```

Out[2233]=



dataSet=Proto MPEX IC Kinetic Alfven

xProfileMin=−0.04

xProfileMax=0.04

nXmin=$1. \times 10^{19}$

nXmax=$3. \times 10^{19}$

BXmin=1.2

BXmax=1.2

freq=7.5

nz=127.324

etaList={0., 1., 0., 0., 0.}

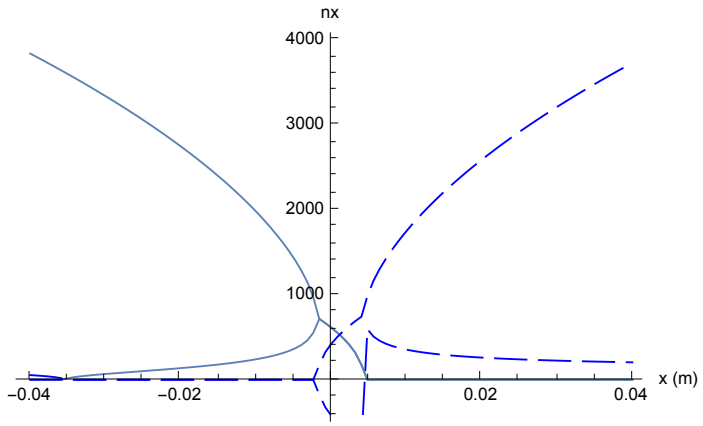
xmin=−0.04

xmax=0.04

Plot Real and Imaginary parts of nx from 4nd order cold plasma dispersion relation (i.e. fast and slow)

In[2235]:=
```
nPerp2FS[x_] := Module[{ne, b, x0}, x0 = x;
  ne = nprof[x0];
  b = bprof[x0];
      ColdDis2FS[freq, ne, b, nz, etaList]]
nt2FS = Table[Flatten[{x, nPerp2FS[x]}], {x, xmin, xmax, (xmax - xmin)/(nPoints - 1)}];
nF = Transpose[{Transpose[nt2FS][[1]], Transpose[nt2FS][[2]]}];
nS = Transpose[{Transpose[nt2FS][[1]], Transpose[nt2FS][[3]]}];
g1 = ComplexListPlot[nF, "x (m)", "nx"];
g2 = ComplexListPlot[nS, "x (m)", "nx"];
Show[{g1, g2}, PlotRange → All]
paramPrint[{dataSet, xProfileMin, xProfileMax,
   nXmin, nXmax, BXmin, BXmax, freq, nz, etaList, xmin, xmin}];
```

Out[2241]=



dataSet=Proto MPEX IC Kinetic Alfven

xProfileMin=−0.04

xProfileMax=0.04

nXmin=$1. \times 10^{19}$

nXmax=$3. \times 10^{19}$

BXmin=1.2

BXmax=1.2

freq=7.5

nz=127.324

etaList={0., 1., 0., 0., 0.}

xmin=−0.04

xmin=−0.04

Now Warm Plasma Stuff

Plot Real and Imaginary parts of nx from 6th order warm plasma dispersion relation (expanded to 2nd order in $k_\perp \rho$)

In[2263]:=
```
nPerpWarm6[x_] := Module[{ne, te, b, x0, TL},
        x0 = x;
  ne = nprof[x0];
  b = bprof[x0];
     TL = tprof[x0] * TList;
     WarmDis6[freq, ne, b, nz, etaList, TL]]
```

Compare to cold plasma roots

In[2264]:=
```
nPerp2FS[xmin]
nPerpWarm6[xmin]
```

Out[2264]=
```
{0. + 54.7543 i, 3838.1}
```

Out[2265]=
```
{0.00511243 - 55.1514 i, 5188.77 - 1418.54 i, 23 954.2 + 560.117 i,
 -0.00511243 + 55.1514 i, -5188.77 + 1418.54 i, -23 954.2 - 560.117 i}
```

Gets a root near the cutoff fast wave branch, but nothing near the slow wave branch. Should check how big Γ is. Try closer to resonance.

In[2266]:=
```
nPerp2FS[xmin / 4.]
nPerpWarm6[xmin / 4.]
```

Out[2266]=
```
{240.623, 1979.57}
```

Out[2267]=
```
{237.343 + 0.523345 i, 2700.42 - 740.17 i, 23 972.5 + 525.642 i,
 -237.343 - 0.523345 i, -2700.42 + 740.17 i, -23 972.5 - 525.642 i}
```

In[2268]:=
```
nPerp2FS[0.]
nPerpWarm6[0.]
```

Out[2268]=
```
{612.814 - 423.427 i, 612.814 + 423.427 i}
```

Out[2269]=
```
{778.068 - 568.391 i, 750.314 + 287.617 i, 23 978.8 + 514.789 i,
 -778.068 + 568.391 i, -750.314 - 287.617 i, -23 978.8 - 514.789 i}
```

Plot kx profile for 6 th order system

In[2270]:=
```
nxwarm = Table[Flatten[{x, nPerpWarm6[x]}], {x, xmin, xmax, (xmax - xmin)/(nPoints - 1)}];
roots = rootSort[nxwarm];
rootsRe = Table[Flatten[{roots[[i]][[1]],
      Table[Re[roots[[i]][[j]]], {j, 2, Length[roots[[i]]]}]}], {i, Length[roots]}];

rootsIm = Table[Flatten[{roots[[i]][[1]],
      Table[Im[roots[[i]][[j]]], {j, 2, Length[roots[[i]]]}]}], {i, Length[roots]}];

g6 = ComplexVectorListPlot[roots, "x (m)", "nx"];
paramPrint[{dataSet, xProfileMin, xProfileMax, nXmin, nXmax, BXmin,
   BXmax, freq, nz, etaList, TeXmin, TeXmax, TList, modelList, xmin, xmax}];
Show[g6, PlotRange → All]
Show[g6, PlotRange → {-2000., 2000.}]
ComplexVectorListPlot[rootsRe, "x", "Re[kx]", PlotRange → {-2000., 2000.}]
ComplexVectorListPlot[rootsIm, "x", "Im[kx]", PlotRange → {-2000., 2000.}]
```

dataSet=Proto MPEX IC Kinetic Alfven

xProfileMin=-0.04

xProfileMax=0.04

nXmin=$1. \times 10^{19}$

nXmax=$3. \times 10^{19}$

BXmin=1.2

BXmax=1.2

freq=7.5

nz=127.324

etaList={0., 1., 0., 0., 0.}

TeXmin=0.005

TeXmax=0.005

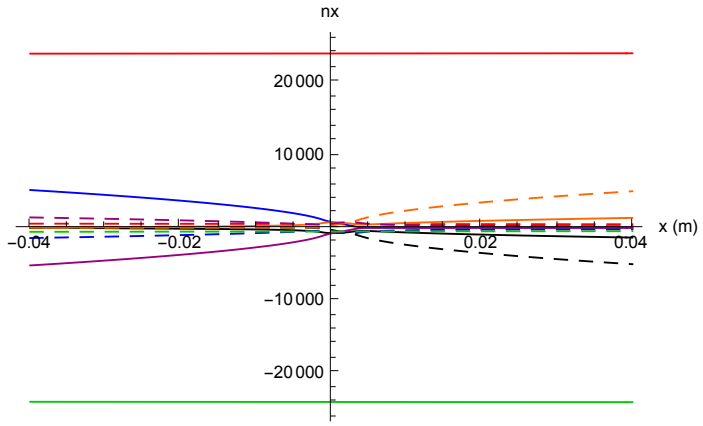
TList={1., 0., 1., 0., 0., 0.}

modelList={0, 2, 0, 0, 0, 0}

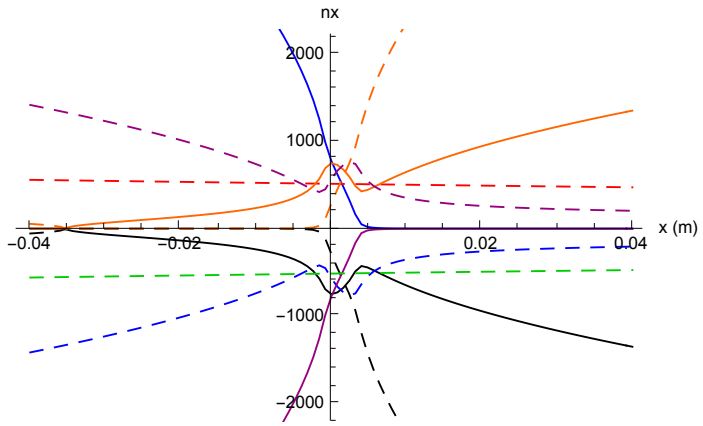
xmin=-0.04

xmax=0.04

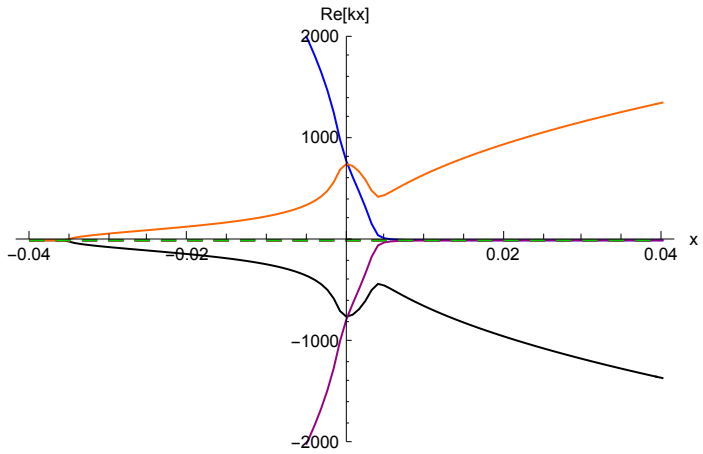
Out[2276]=



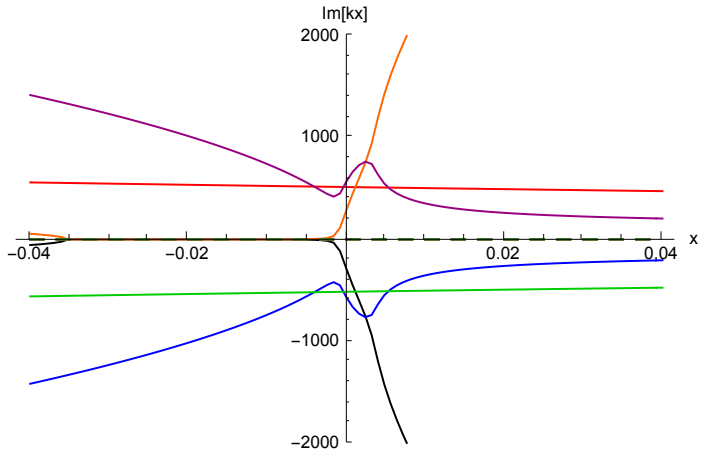
Out[2277]=



Out[2278]=



Out[2279]=



Looks plausible but the numbers aren' t close to cold plasma even at 5 ev.

Now Try with Hot Plasma Dispersion using root finder

In[2280]:=
```
nPerpHot[x_, nxGuess_] := Module[{ne, b, x0, TL, nx0},
        x0 = x;
  nx0 = nxGuess;
  ne = nprof[x0];
  b = bprof[x0];
  TL = tprof[x0] * TList;
rootRule = FindRoot[DisFuncGeneral[freq, ne, b, nz, nx, etaList, TL,
     nminList, nmaxList, modelList], {nx, nx0}, MaxIterations -> 30];
  nx /. rootRule]
```

First try root finding on warm plasma dispersion rel (model = 1)

In[2281]:=
```
modelList = Table[1, {i, 1, 6}];
```

Compare to cold plasma and 6th order system roots

In[2282]:=
```
nPerp2FS[xmin]
nPerpWarm6[xmin]
nPerpHot[xmin, nPerp2FS[xmin][[1]]]
nPerpHot[xmin, nPerp2FS[xmin][[2]]]
nPerpHot[xmin, nPerpWarm6[xmin][[1]]]
nPerpHot[xmin, nPerpWarm6[xmin][[2]]]
nPerpHot[xmin, nPerpWarm6[xmin][[3]]]
```

Out[2282]= {0. + 54.7543 i, 3838.1}

Out[2283]= {0.00511243 - 55.1514 i, 5188.77 - 1418.54 i, 23 954.2 + 560.117 i,
 -0.00511243 + 55.1514 i, -5188.77 + 1418.54 i, -23 954.2 - 560.117 i}

Out[2284]= -0.00511243 + 55.1514 i

Out[2285]= 0.00511243 - 55.1514 i

Out[2286]= 0.00511243 - 55.1514 i

Out[2287]= 5188.77 - 1418.54 i

Out[2288]= 23 954.2 + 560.117 i

Again gets a root near the cutoff fast wave branch, but nothing near the slow wave branch when initialized with cold plasma roots. Solutions from FindRoot (nPerpHot) agree with solutions from NSolve (nPerpWarm)

Look closer to resonance

In[2289]:=
```
nPerp2FS[xmin / 4.]
nPerpWarm6[xmin / 4.]
nPerpHot[xmin / 4., nPerpWarm6[xmin / 4.][[1]]]
nPerpHot[xmin / 4., nPerpWarm6[xmin / 4.][[2]]]
nPerpHot[xmin / 4., nPerpWarm6[xmin / 4.][[3]]]
```

Out[2289]= {240.623, 1979.57}

Out[2290]= {237.343 + 0.523345 i, 2700.42 - 740.17 i, 23 972.5 + 525.642 i,
 -237.343 - 0.523345 i, -2700.42 + 740.17 i, -23 972.5 - 525.642 i}

Out[2291]= 237.343 + 0.523345 i

Out[2292]= 2700.42 - 740.17 i

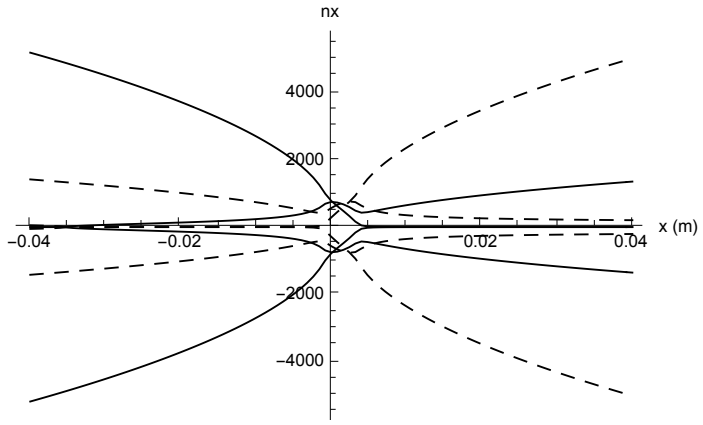
Out[2293]= 23 972.5 + 525.642 i

Plot nx profile from root finder but still with 6th order system (model = 1)

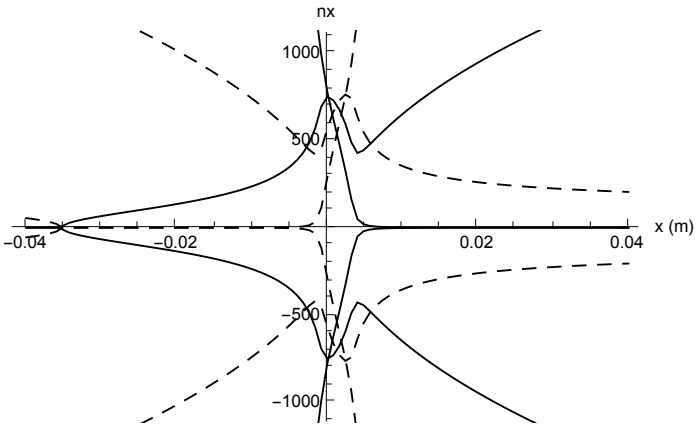
```
modelList = Table[1, {i, 1, 6}];(* Set model *)
```

In[2294]:=
```
nxhot[iRoot_] := Module[{iRoot0, nxWarm, rootsWarm, nxH, x0, ne, b, t, TL},
    nxWarm = Table[Flatten[{x, nPerpWarm6[x]}], {x, xmin, xmax, (xmax - xmin)/(nPoints - 1)}];
    iRoot0 = iRoot;
    rootsWarm = rootSort[nxWarm];
    nxH = Table[0., {i, 1, nPoints}];
    Do[
      (x0 = xmin + (i - 1) (xmax - xmin)/(nPoints - 1);
       nxGuess = rootsWarm[[i]][[iRoot0 + 1]];
       (*Print["x0 = ", x0,"  nxGuess= ",nxGuess];*)
       nxH[[i]] = {x0, nPerpHot[x0, nxGuess]};), {i, 1, nPoints}];
    nxH];
g7 = ComplexVectorListPlot[nxhot[1], "x (m)", "nx"];
g8 = ComplexVectorListPlot[nxhot[2], "x (m)", "nx"];
g9 = ComplexVectorListPlot[nxhot[3], "x (m)", "nx"];
g10 = ComplexVectorListPlot[nxhot[4], "x (m)", "nx"];
g11 = ComplexVectorListPlot[nxhot[5], "x (m)", "nx"];
g12 = ComplexVectorListPlot[nxhot[6], "x (m)", "nx"];
Show[{g7, g8, g10, g11}, PlotRange → All]
Show[{g7, g8, g10, g11}, PlotRange → {-1000., 1000.}]
paramPrint[{dataSet, xProfileMin, xProfileMax, nXmin, nXmax, BXmin,
    BXmax, freq, nz, etaList, TeXmin, TeXmax, TList, modelList, xmin, xmax}];
```

Out[2298]=



Out[2299]=



dataSet=Proto MPEX IC Kinetic Alfven

xProfileMin=-0.04

xProfileMax=0.04

nXmin=$1. \times 10^{19}$

nXmax=$3. \times 10^{19}$

BXmin=1.2

BXmax=1.2

freq=7.5

nz=127.324

etaList={0., 1., 0., 0., 0.}

TeXmin=0.005

TeXmax=0.005

TList={1., 0., 1., 0., 0., 0.}

modelList={1, 1, 1, 1, 1, 1}

xmin=-0.04

xmax=0.04

Now try with hot plasma (model = 2) for all species. Can I find the warm plasma roots with the full dispersion relation?

- Change model to 2

In[2301]:=
```
modelList = Table[2, {i, 1, 6}];
```

In[2302]:=
```
xPoint = 0.;
nPerp2FS[xPoint]
guesses = nPerpWarm6[xPoint] (* Warm plasma roots at x=0  *)
```

Out[2303]= {612.814 − 423.427 i, 612.814 + 423.427 i}

Out[2304]= {778.068 − 568.391 i, 750.314 + 287.617 i, 23 978.8 + 514.789 i,
 −778.068 + 568.391 i, −750.314 − 287.617 i, −23 978.8 − 514.789 i}

In[2305]:=
```
{nPerpHot[xPoint, guesses[[1]]],
 nPerpHot[xPoint, guesses[[2]]],
 nPerpHot[xPoint, guesses[[3]]],
 nPerpHot[xPoint, guesses[[4]]],
 nPerpHot[xPoint, guesses[[5]]],
 nPerpHot[xPoint, guesses[[6]]]}
paramPrint[{dataSet, xProfileMin, xProfileMax, nXmin, nXmax, BXmin, BXmax, freq,
   nz, etaList, TeXmin, TeXmax, TList, modelList, nminList, nmaxList, xmin, xmax}];
```

Out[2305]= {778.077 − 568.361 i, 750.301 + 287.62 i, 750.301 + 287.62 i,
 −778.077 + 568.361 i, −750.301 − 287.62 i, −750.301 − 287.62 i}

dataSet=Proto MPEX IC Kinetic Alfven

xProfileMin=−0.04

xProfileMax=0.04

nXmin=$1. \times 10^{19}$

nXmax=$3. \times 10^{19}$

BXmin=1.2

BXmax=1.2

freq=7.5

nz=127.324

etaList={0., 1., 0., 0., 0.}

TeXmin=0.005

TeXmax=0.005

TList={1., 0., 1., 0., 0., 0.}

modelList={2, 2, 2, 2, 2, 2}

nminList={−1, −2, −2, −2, −2, −2}

nmaxList={1, 2, 2, 2, 2, 2}

xmin=−0.04

xmax=0.04

- Hot plasma root finder gets 2 of the roots. Not the 6th order root at 23,000 What about at xmin?

In[2307]:=
```
xPoint = xmin;
nPerp2FS[xPoint]
guesses = nPerpWarm6[xPoint] (* Warm plasma roots at x=0  *)
```

Out[2308]= {0. + 54.7543 i, 3838.1}

Out[2309]= {0.00511243 - 55.1514 i, 5188.77 - 1418.54 i, 23 954.2 + 560.117 i,
 -0.00511243 + 55.1514 i, -5188.77 + 1418.54 i, -23 954.2 - 560.117 i}

In[2310]:=
```
{nPerpHot[xPoint, guesses[[1]]],
 nPerpHot[xPoint, guesses[[2]]],
 nPerpHot[xPoint, guesses[[3]]],
 nPerpHot[xPoint, guesses[[4]]],
 nPerpHot[xPoint, guesses[[5]]],
 nPerpHot[xPoint, guesses[[6]]]}
paramPrint[{dataSet, xProfileMin, xProfileMax, nXmin, nXmax, BXmin, BXmax, freq,
   nz, etaList, TeXmin, TeXmax, TList, modelList, nminList, nmaxList, xmin, xmax}];
```

Out[2310]= {0.00511243 - 55.1514 i, 5187.15 - 1410.74 i, 5187.15 - 1410.74 i,
 -0.00511243 + 55.1514 i, -5187.15 + 1410.74 i, -5187.15 + 1410.74 i}

dataSet=Proto MPEX IC Kinetic Alfven

xProfileMin=-0.04

xProfileMax=0.04

nXmin=$1. \times 10^{19}$

nXmax=$3. \times 10^{19}$

BXmin=1.2

BXmax=1.2

freq=7.5

nz=127.324

etaList={0., 1., 0., 0., 0.}

TeXmin=0.005

TeXmax=0.005

TList={1., 0., 1., 0., 0., 0.}

modelList={2, 2, 2, 2, 2, 2}

nminList={-1, -2, -2, -2, -2, -2}

nmaxList={1, 2, 2, 2, 2, 2}

xmin=-0.04

xmax=0.04

- Hot plasma root finder gets 2 of the 6th order roots. Try initializing with cold plasma roots

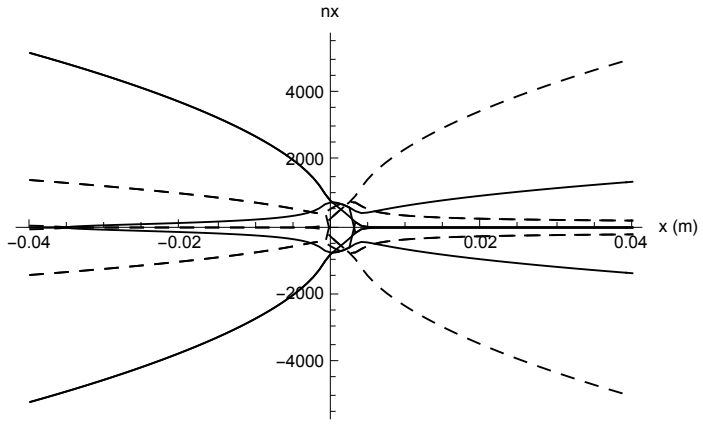
In[2312]:=
```
{nPerpHot[xPoint, nPerp2FS[xPoint][[1]]], nPerpHot[xPoint, nPerp2FS[xPoint][[2]]]}
```

Out[2312]=
```
{-0.00511243 + 55.1514 i, 0.00511243 - 55.1514 i}
```

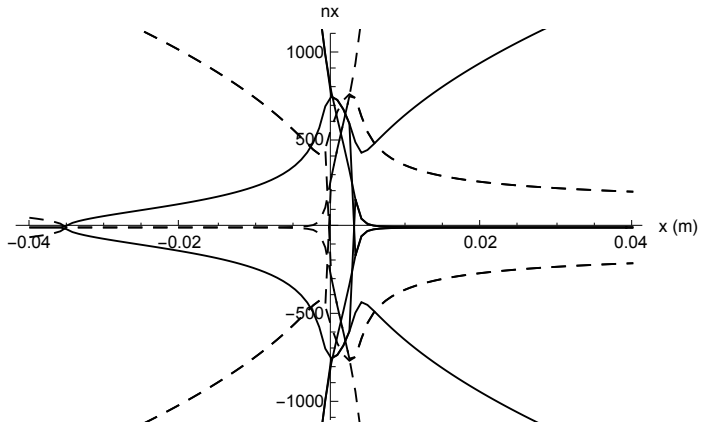
Plot hot plasma vs x

In[2313]:=
```
g7 = ComplexVectorListPlot[nxhot[1], "x (m)", "nx"];
g8 = ComplexVectorListPlot[nxhot[2], "x (m)", "nx"];
g9 = ComplexVectorListPlot[nxhot[3], "x (m)", "nx"];
g10 = ComplexVectorListPlot[nxhot[4], "x (m)", "nx"];
g11 = ComplexVectorListPlot[nxhot[5], "x (m)", "nx"];
g12 = ComplexVectorListPlot[nxhot[6], "x (m)", "nx"];
Show[{g7, g8, g9, g10, g11, g12}, PlotRange → All, AxesOrigin → {0., 0.}]
Show[{g7, g8, g9, g10, g11, g12}, PlotRange → {-1000., 1000.}, AxesOrigin → {0., 0.}]
paramPrint[{dataSet, xProfileMin, xProfileMax, nXmin, nXmax, BXmin, BXmax, freq, nz,
   etaList, TeXmin, TeXmax, TList, modelList, nminList, nmaxList, xmin, xmax}];
```

Out[2316]=



Out[2317]=



dataSet=Proto MPEX IC Kinetic Alfven

xProfileMin=-0.04

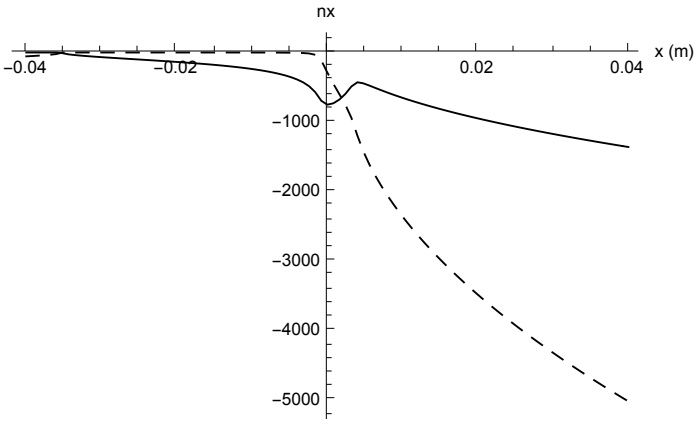
xProfileMax=0.04

nXmin=$1. \times 10^{19}$

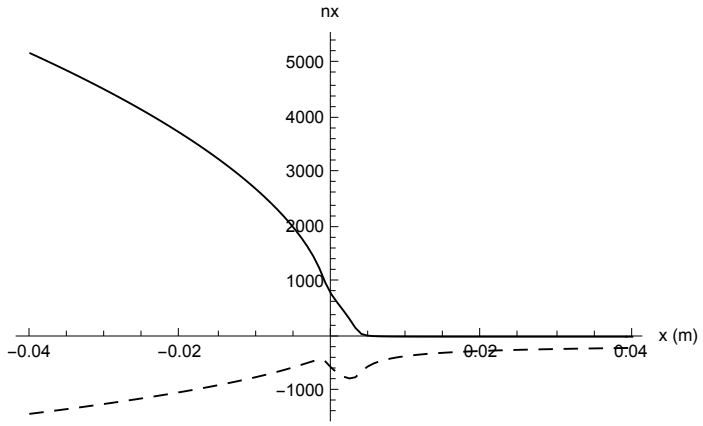
```
nXmax=3. × 10^19
BXmin=1.2
BXmax=1.2
freq=7.5
nz=127.324
etaList={0., 1., 0., 0., 0.}
TeXmin=0.005
TeXmax=0.005
TList={1., 0., 1., 0., 0., 0.}
modelList={2, 2, 2, 2, 2, 2}
nminList={-1, -2, -2, -2, -2, -2}
nmaxList={1, 2, 2, 2, 2, 2}
xmin=-0.04
xmax=0.04
```

In[2319]:=
```
Show[g7, PlotRange → All, AxesOrigin → {0., 0.}]
Show[g8, PlotRange → All, AxesOrigin → {0., 0.}]
Show[g9, PlotRange → All, AxesOrigin → {0., 0.}]
Show[g10, PlotRange → All, AxesOrigin → {0., 0.}]
Show[g11, PlotRange → All, AxesOrigin → {0., 0.}]
Show[g12, PlotRange → All, AxesOrigin → {0., 0.}]
```

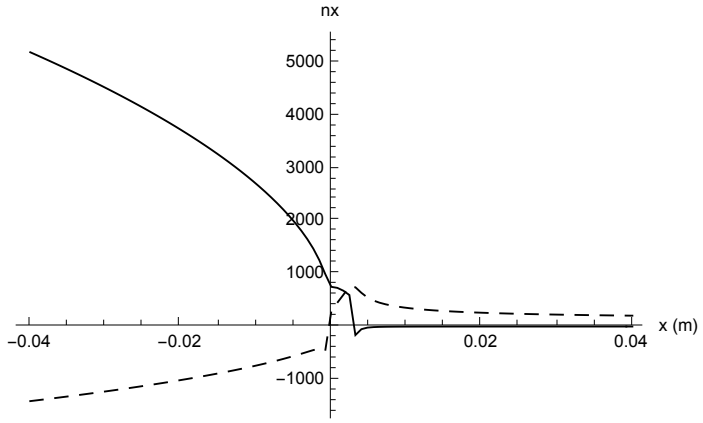
Out[2319]=



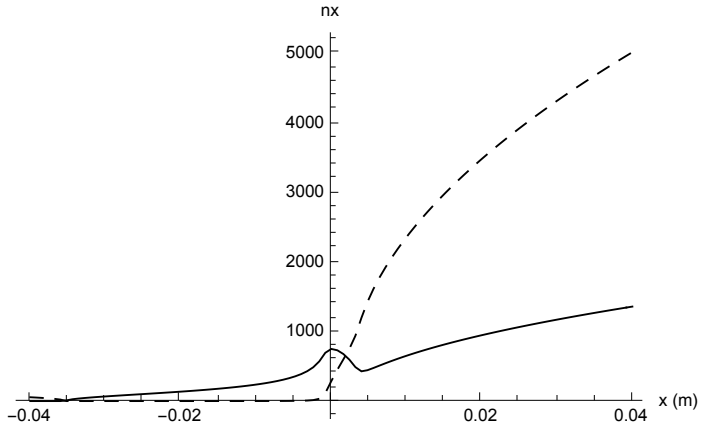
Out[2320]=



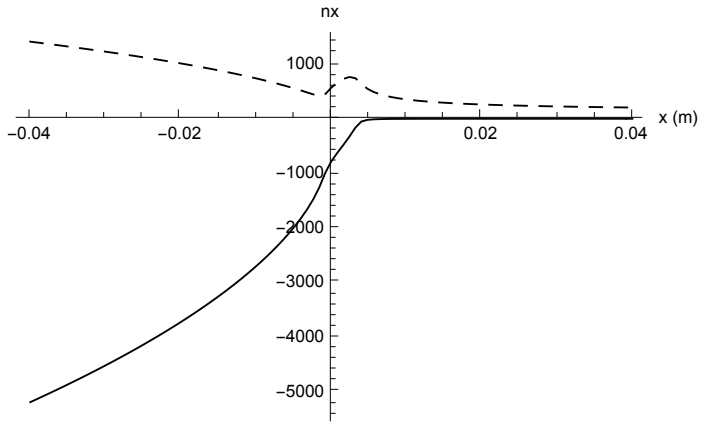
Out[2321]=



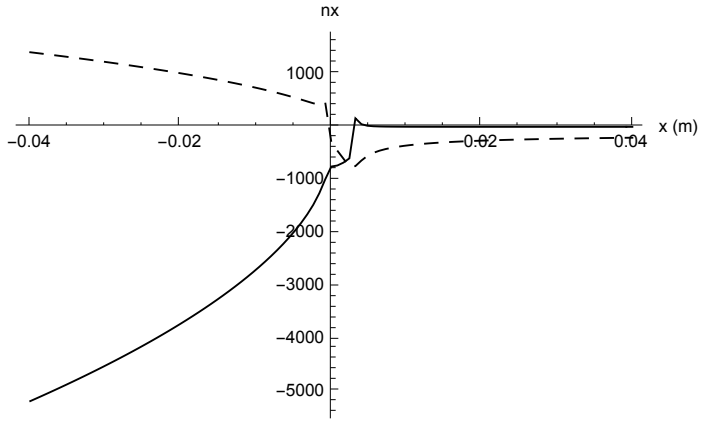
Out[2322]=



Out[2323]=

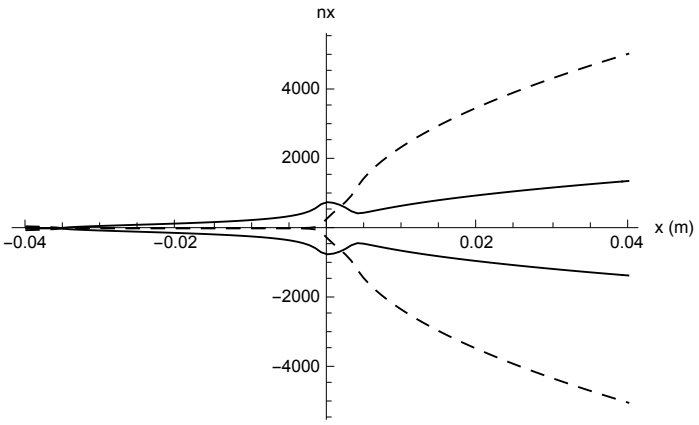


Out[2324]=

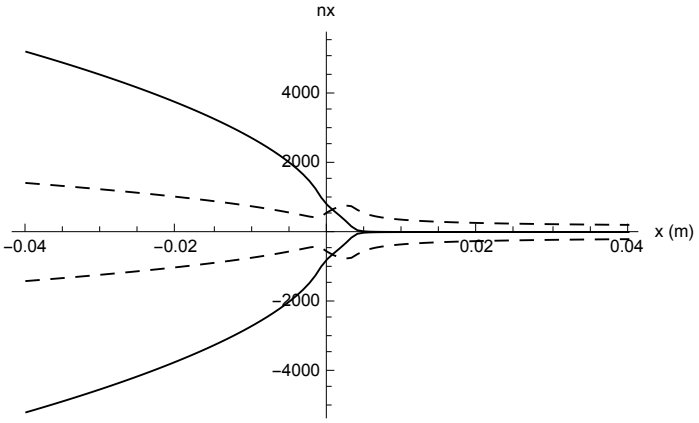


In[2325]:=
```
Show[{g7, g10}, PlotRange → All, AxesOrigin → {0., 0.}]
Show[{g8, g11}, PlotRange → All, AxesOrigin → {0., 0.}]
Show[{g9, g12}, PlotRange → All, AxesOrigin → {0., 0.}]
```

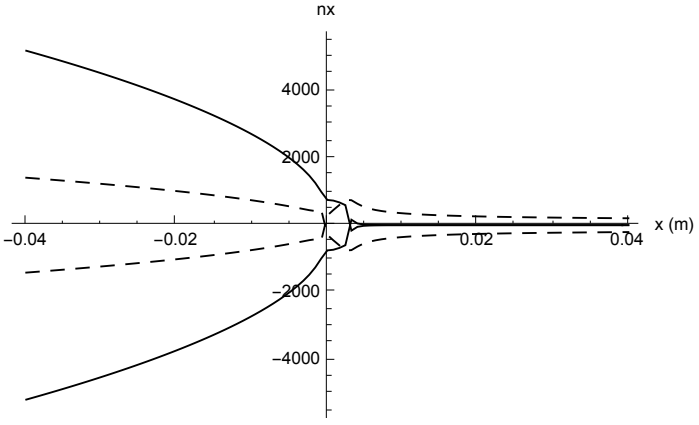
Out[2325]=



Out[2326]=

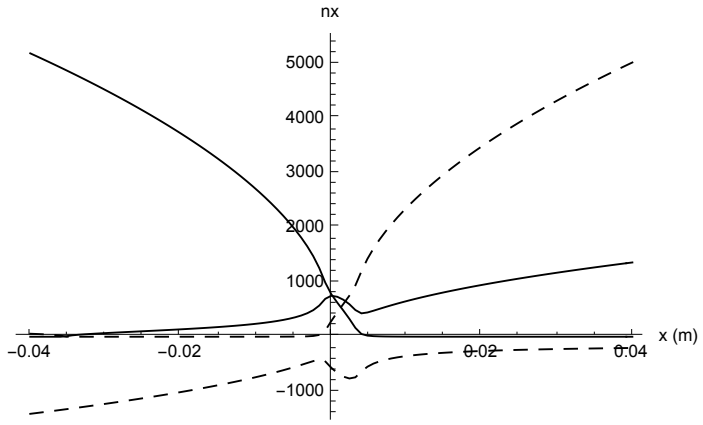


Out[2327]=



In[2328]:=
```
Show[{g8, g10}, PlotRange → All, AxesOrigin → {0., 0.}]
```

Out[2328]=



- This is very disturbing. Both the 6th order and full Bessel solutions show the slow wave branch with a large imaginary part, and negative imaginary to boot. i.e. a growing wave.

Try lowering the temperature

In[2337]:=
```
xPoint = xmin;
nPerp2FS[xPoint]
guesses = Chop[nPerpWarm6[xPoint]] (* Warm plasma roots at x=0  *)
```

Out[2338]=
```
{0. + 54.7543 i, 3838.1}
```

Out[2339]=
```
{0. + 55.3904 i, 3868.93, 176 202., 0. - 55.3904 i, -3868.93, -176 202.}
```

In[2340]:=
```
Chop[{nPerpHot[xPoint, guesses[[1]]],
  nPerpHot[xPoint, guesses[[2]]],
  nPerpHot[xPoint, guesses[[3]]],
  nPerpHot[xPoint, guesses[[4]]],
  nPerpHot[xPoint, guesses[[5]]],
  nPerpHot[xPoint, guesses[[6]]]}]
paramPrint[{dataSet, xProfileMin, xProfileMax, nXmin, nXmax, BXmin, BXmax, freq,
   nz, etaList, TeXmin, TeXmax, TList, modelList, nminList, nmaxList, xmin, xmax}];
```

Out[2340]= {0. + 55.3904 i, 3868.93, 3868.93, 0. − 55.3904 i, −3868.93, −3868.93}

dataSet=Proto MPEX IC Kinetic Alfven

xProfileMin=−0.04

xProfileMax=0.04

nXmin=$1. \times 10^{19}$

nXmax=$3. \times 10^{19}$

BXmin=1.2

BXmax=1.2

freq=7.5

nz=127.324

etaList={0., 1., 0., 0., 0.}

TeXmin=0.0001

TeXmax=0.0001

TList={1., 0., 1., 0., 0., 0.}

modelList={2, 2, 2, 2, 2, 2}

nminList={−1, −2, −2, −2, −2, −2}

nmaxList={1, 2, 2, 2, 2, 2}

xmin=−0.04

xmax=0.04

- Surprising that you have to go to 0.1ev to get close to the cold plasma roots isn't it.

The issue is that with this large nz, the argument of Z function for zero harmonic for electrons is relatively small. Gives a significant antiHermitian part to eps for electrons. Try using cold electrons. (model 1 = 0). Raise Te back to 5ev

In[2406]:=
```
xPoint = xmin;
nPerp2FS[xPoint]
guesses = nPerpWarm6[xPoint] (* Warm plasma roots at x=0  *)
```

Out[2407]= {0. + 54.7543 i, 3838.1}

Out[2408]= {0. + 55.1635 i, 3941.68, 24 318.9, 0. − 55.1635 i, −3941.68, −24 318.9}

In[2409]:=
```
Print["Initialize with cold roots"];
{nPerpHot[xPoint, nPerp2FS[xPoint][[1]]],
 nPerpHot[xPoint, nPerp2FS[xPoint][[2]]]}
Print["Initialize with warm roots"];
{nPerpHot[xPoint, guesses[[1]]],
 nPerpHot[xPoint, guesses[[2]]],
 nPerpHot[xPoint, guesses[[3]]],
 nPerpHot[xPoint, guesses[[4]]],
 nPerpHot[xPoint, guesses[[5]]],
 nPerpHot[xPoint, guesses[[6]]]}
paramPrint[{dataSet, xProfileMin, xProfileMax, nXmin, nXmax, BXmin, BXmax, freq,
   nz, etaList, TeXmin, TeXmax, TList, modelList, nminList, nmaxList, xmin, xmax}];
```

```
Initialize with cold roots
```

Out[2410]= $\{0. + 55.3952\, i, 3848.61 + 0.\, i\}$

```
Initialize with warm roots
```

Out[2412]= $\{0. + 55.3952\, i, 3848.61 + 0.\, i, 3848.61 + 0.\, i,$
$0. - 55.3952\, i, -3848.61 + 0.\, i, -3848.61 + 0.\, i\}$

dataSet=Proto MPEX IC Kinetic Alfven

xProfileMin=-0.04

xProfileMax=0.04

nXmin=$1. \times 10^{19}$

nXmax=$3. \times 10^{19}$

BXmin=1.2

BXmax=1.2

freq=7.5

nz=127.324

etaList={0., 1., 0., 0., 0.}

TeXmin=0.005

TeXmax=0.005

TList={0., 0., 1., 0., 0., 0.}

modelList={0, 2, 0, 0, 0, 0}

nminList={−1, −2, −2, −2, −2, −2}

nmaxList={1, 2, 2, 2, 2, 2}

xmin=-0.04

xmax=0.04

Look closer to resonance

In[2414]:=
```
xPoint = xmin / 2;
nPerp2FS[xPoint]
guesses = nPerpWarm6[xPoint] (* Warm plasma roots at x=0  *)
```

Out[2415]= {136.848, 2746.24}

Out[2416]= {135.96, 2824.67, 24 326.2, -135.96, -2824.67, -24 326.2}

In[2417]:=
```
Print["Initialize with cold roots"];
{nPerpHot[xPoint, nPerp2FS[xPoint][[1]]],
 nPerpHot[xPoint, nPerp2FS[xPoint][[2]]]}
Print["Initialize with warm roots"];
{nPerpHot[xPoint, guesses[[1]]],
 nPerpHot[xPoint, guesses[[2]]],
 nPerpHot[xPoint, guesses[[3]]],
 nPerpHot[xPoint, guesses[[4]]],
 nPerpHot[xPoint, guesses[[5]]],
 nPerpHot[xPoint, guesses[[6]]]}
paramPrint[{dataSet, xProfileMin, xProfileMax, nXmin, nXmax, BXmin, BXmax, freq,
   nz, etaList, TeXmin, TeXmax, TList, modelList, nminList, nmaxList, xmin, xmax}];
```

```
Initialize with cold roots
```

Out[2418]= $\{135.509 + 0.\,i, 2760.96 + 0.\,i\}$

```
Initialize with warm roots
```

Out[2420]= $\{135.509 + 0.\,i, 2760.96 + 0.\,i, 2760.96 + 0.\,i,$
$-135.509 + 0.\,i, -2760.96 + 0.\,i, -2760.96 + 0.\,i\}$

dataSet=Proto MPEX IC Kinetic Alfven

xProfileMin=-0.04

xProfileMax=0.04

nXmin=$1. \times 10^{19}$

nXmax=$3. \times 10^{19}$

BXmin=1.2

BXmax=1.2

freq=7.5

nz=127.324

etaList={0., 1., 0., 0., 0.}

TeXmin=0.005

TeXmax=0.005

TList={0., 0., 1., 0., 0., 0.}

modelList={0, 2, 0, 0, 0, 0}

nminList={−1, −2, −2, −2, −2, −2}

nmaxList={1, 2, 2, 2, 2, 2}

xmin=-0.04

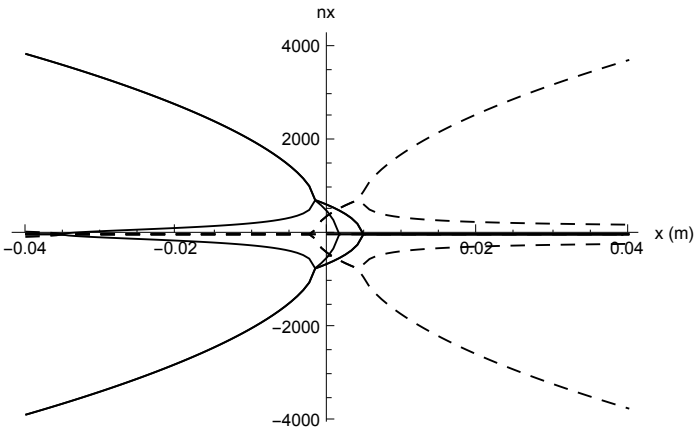
xmax=0.04

Plot nx profile from root finder ,hot ions (model = 2), cold electrons (model =0)

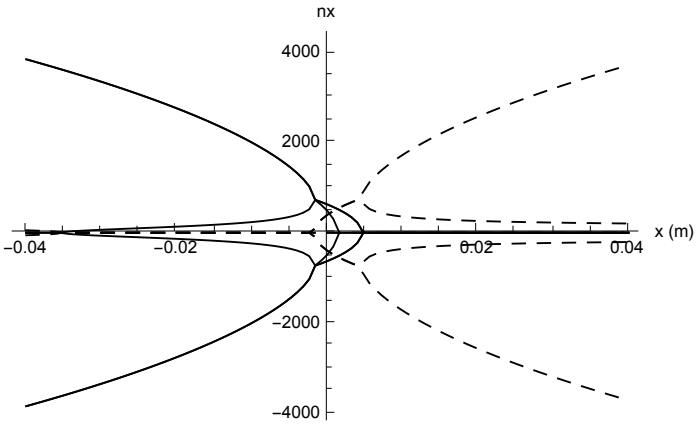
In[1429]:=
```
modelList = Table[1, {i, 1, 6}];(* Set model *)
modelList[[1]] = 0;
```

In[2422]:=
```
g7 = ComplexVectorListPlot[nxhot[1], "x (m)", "nx"];
g8 = ComplexVectorListPlot[nxhot[2], "x (m)", "nx"];
g9 = ComplexVectorListPlot[nxhot[3], "x (m)", "nx"];
g10 = ComplexVectorListPlot[nxhot[4], "x (m)", "nx"];
g11 = ComplexVectorListPlot[nxhot[5], "x (m)", "nx"];
g12 = ComplexVectorListPlot[nxhot[6], "x (m)", "nx"];
Show[{g7, g8, g9, g10, g11, g12}, PlotRange → All, AxesOrigin → {0., 0.}]
Show[{g7, g8, g9, g10, g11, g12}, PlotRange → {-4000., 4000.}, AxesOrigin → {0., 0.}]
paramPrint[{dataSet, xProfileMin, xProfileMax, nXmin, nXmax, BXmin, BXmax, freq, nz,
   etaList, TeXmin, TeXmax, TList, modelList, nminList, nmaxList, xmin, xmax}];
```

Out[2425]=



Out[2426]=



dataSet=Proto MPEX IC Kinetic Alfven

xProfileMin=−0.04

xProfileMax=0.04

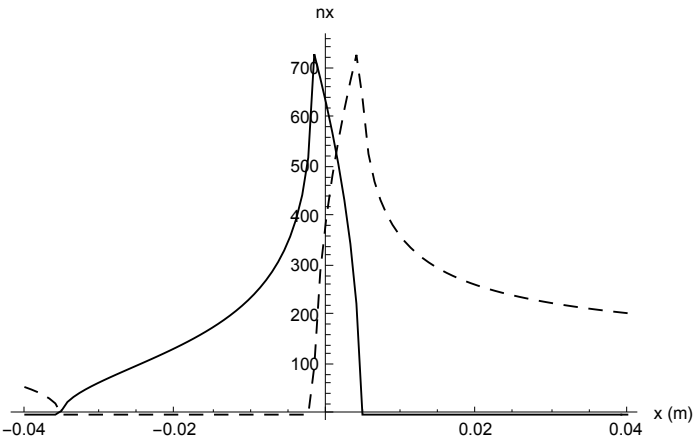
nXmin=$1. \times 10^{19}$

nXmax=$3. \times 10^{19}$

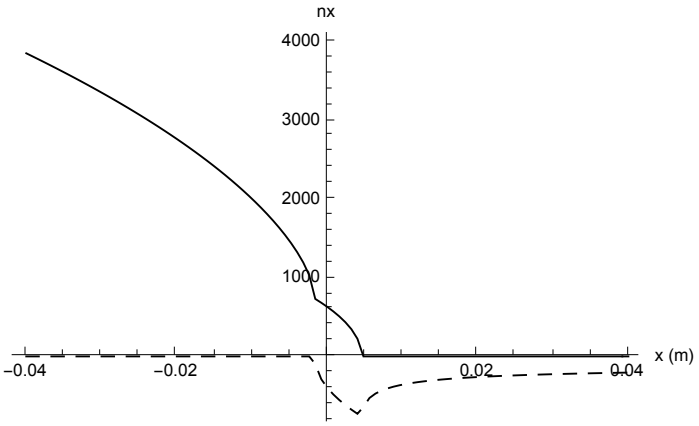
```
BXmin=1.2
BXmax=1.2
freq=7.5
nz=127.324
etaList={0., 1., 0., 0., 0.}
TeXmin=0.005
TeXmax=0.005
TList={0., 0., 1., 0., 0., 0.}
modelList={0, 2, 0, 0, 0, 0}
nminList={-1, -2, -2, -2, -2, -2}
nmaxList={1, 2, 2, 2, 2, 2}
xmin=-0.04
xmax=0.04
```

In[2428]:=
```
Show[g7, PlotRange → All, AxesOrigin → {0., 0.}]
Show[g8, PlotRange → All, AxesOrigin → {0., 0.}]
Show[g9, PlotRange → All, AxesOrigin → {0., 0.}]
Show[g10, PlotRange → All, AxesOrigin → {0., 0.}]
Show[g11, PlotRange → All, AxesOrigin → {0., 0.}]
Show[g12, PlotRange → All, AxesOrigin → {0., 0.}]
```

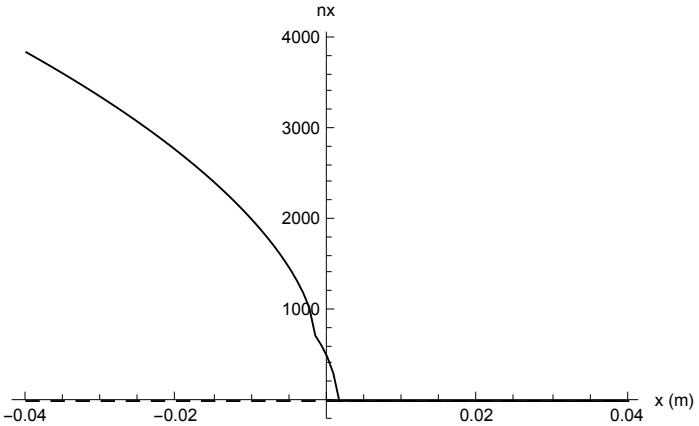
Out[2428]=



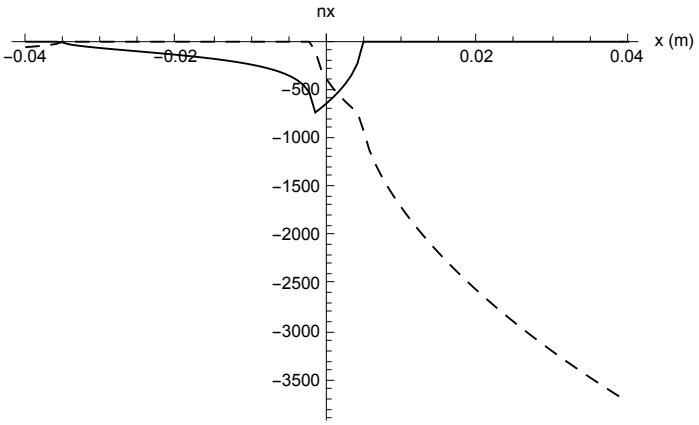
Out[2429]=



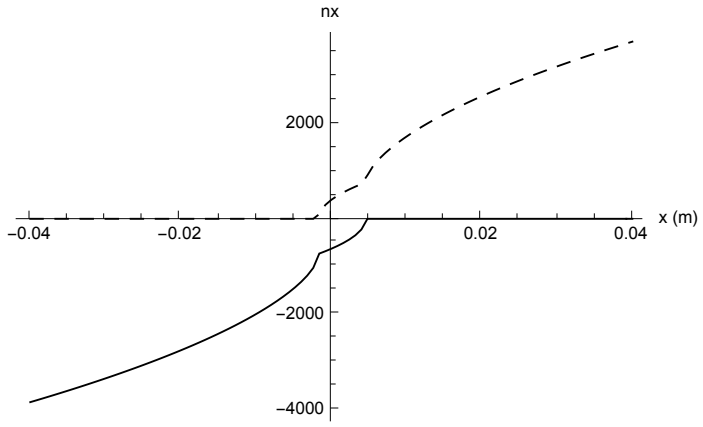
Out[2430]=



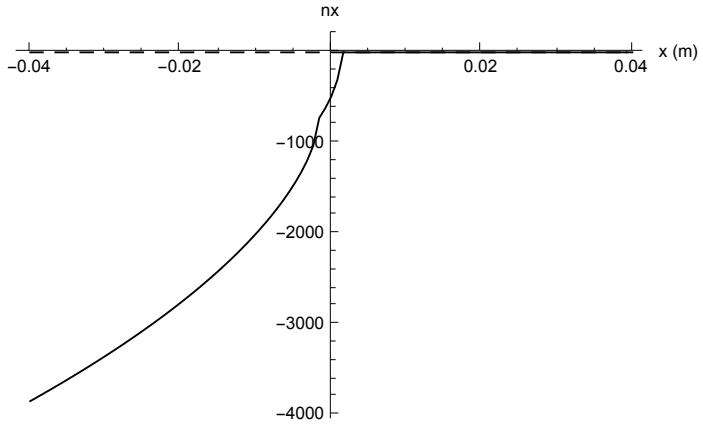
Out[2431]=



Out[2432]=

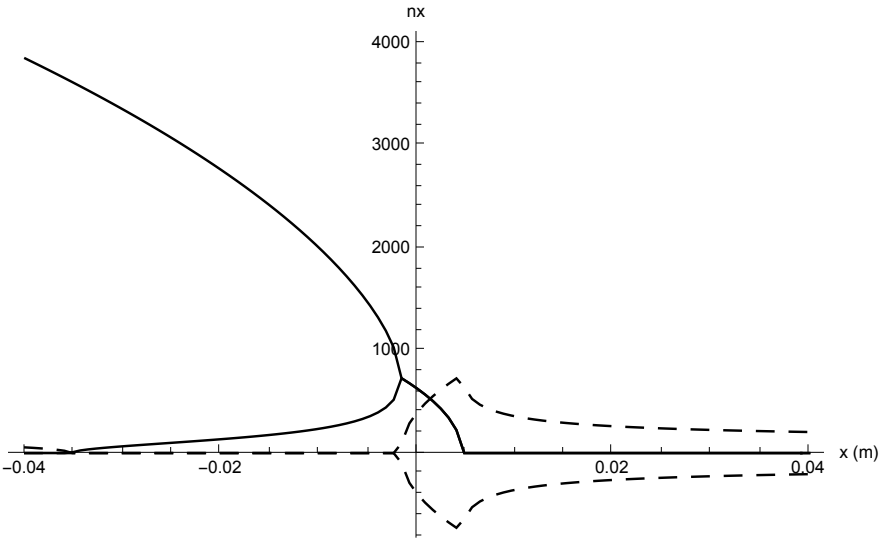


Out[2433]=

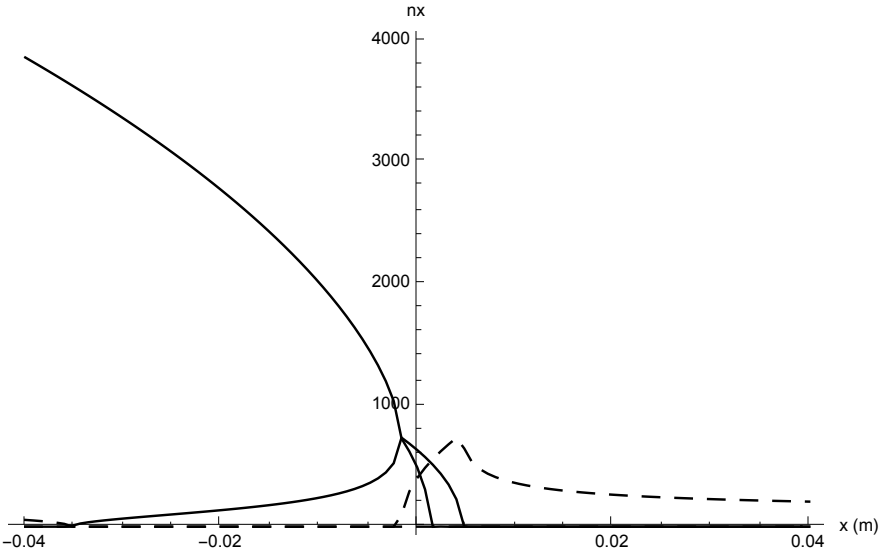


In[2438]:=
```
Show[{g7, g8}, PlotRange → All, AxesOrigin → {0., 0.}]
Show[{g7, g9}, PlotRange → All, AxesOrigin → {0., 0.}]
```

Out[2438]=



Out[2439]=



- I haven' t completely figured this out yet but it looks like all the roots are there with some jumping around. More could be done on trying to maintain continuity in x of the solutions. And the slow wave is weakly damped, not growing.

Increase temperature and look for kinetic Alfven

In[2545]:=
```
xPoint = xmin;
nPerp2FS[xPoint]
guesses = nPerpWarm6[xPoint] (* Warm plasma roots at x=0  *)
```

Out[2546]=
```
{0. + 54.7543 i, 3838.1}
```

Out[2547]=
```
{0. + 54.4523 i, 4325.34, 11049.2, 0. - 54.4523 i, -4325.34, -11049.2}
```

In[2548]:=
```
Print["Initialize with cold roots"];
{nPerpHot[xPoint, nPerp2FS[xPoint][[1]]],
 nPerpHot[xPoint, nPerp2FS[xPoint][[2]]]}
Print["Initialize with warm roots"];
{nPerpHot[xPoint, guesses[[1]]],
 nPerpHot[xPoint, guesses[[2]]],
 nPerpHot[xPoint, guesses[[3]]],
 nPerpHot[xPoint, guesses[[4]]],
 nPerpHot[xPoint, guesses[[5]]],
 nPerpHot[xPoint, guesses[[6]]]}
paramPrint[{dataSet, xProfileMin, xProfileMax, nXmin, nXmax, BXmin, BXmax, freq,
   nz, etaList, TeXmin, TeXmax, TList, modelList, nminList, nmaxList, xmin, xmax}];
```

```
Initialize with cold roots
```

Out[2549]= $\{0. + 55.3952\, i, 3848.61 + 0.\, i\}$

```
Initialize with warm roots
```

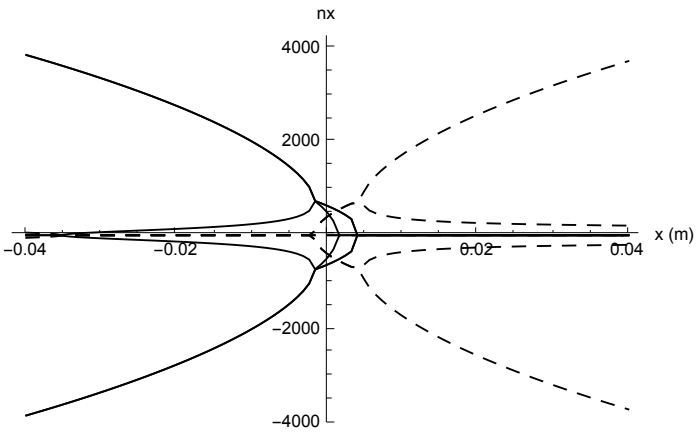
Out[2551]= $\{0. + 55.3952\, i, 3848.61 + 0.\, i, 3848.61 + 0.\, i,$
$0. - 55.3952\, i, -3848.61 + 0.\, i, -3848.61 + 0.\, i\}$

```
dataSet=Proto MPEX IC Kinetic Alfven
xProfileMin=-0.04
xProfileMax=0.04
nXmin=1.×10^19
nXmax=3.×10^19
BXmin=1.2
BXmax=1.2
freq=7.5
nz=127.324
etaList={0., 1., 0., 0., 0.}
TeXmin=0.02
TeXmax=0.02
TList={0., 0., 1., 0., 0., 0.}
modelList={0, 2, 0, 0, 0, 0}
nminList={-1, -2, -2, -2, -2, -2}
nmaxList={1, 2, 2, 2, 2, 2}
xmin=-0.04
xmax=0.04
```

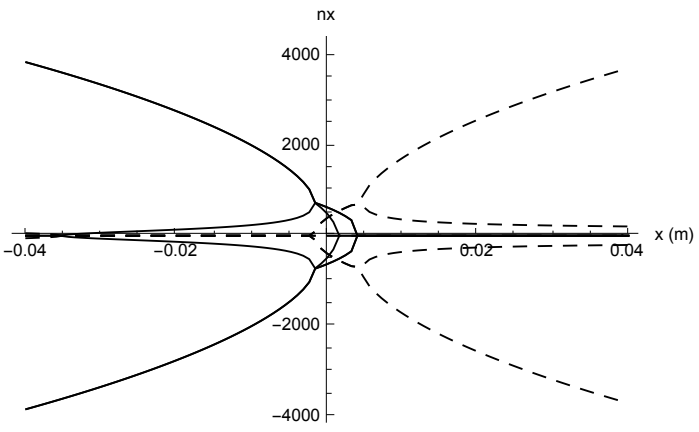
Plot nx profile from root finder , hot ions (model = 2), cold electrons (model = 0)

In[2553]:=
```
g7 = ComplexVectorListPlot[nxhot[1], "x (m)", "nx"];
g8 = ComplexVectorListPlot[nxhot[2], "x (m)", "nx"];
g9 = ComplexVectorListPlot[nxhot[3], "x (m)", "nx"];
g10 = ComplexVectorListPlot[nxhot[4], "x (m)", "nx"];
g11 = ComplexVectorListPlot[nxhot[5], "x (m)", "nx"];
g12 = ComplexVectorListPlot[nxhot[6], "x (m)", "nx"];
Show[{g7, g8, g9, g10, g11, g12}, PlotRange → All, AxesOrigin → {0., 0.}]
Show[{g7, g8, g9, g10, g11, g12}, PlotRange → {-4000., 4000.}, AxesOrigin → {0., 0.}]
paramPrint[{dataSet, xProfileMin, xProfileMax, nXmin, nXmax, BXmin, BXmax, freq, nz,
   etaList, TeXmin, TeXmax, TList, modelList, nminList, nmaxList, xmin, xmax}];
```

Out[2556]=



Out[2557]=



dataSet=Proto MPEX IC Kinetic Alfven

xProfileMin=−0.04

xProfileMax=0.04

nXmin=$1. \times 10^{19}$

nXmax=$3. \times 10^{19}$

BXmin=1.2

BXmax=1.2

```
freq=7.5
nz=127.324
etaList={0., 1., 0., 0., 0.}
TeXmin=0.02
TeXmax=0.02
TList={0., 0., 1., 0., 0., 0.}
modelList={0, 2, 0, 0, 0, 0}
nminList={-1, -2, -2, -2, -2, -2}
nmaxList={1, 2, 2, 2, 2, 2}
xmin=-0.04
xmax=0.04
```

Initialization

Magnetic field,Density and Temperature Profiles

```
bprof[x_] := If[Abs[(BXmax - BXmin) / BXmax] > 10^-6,
   BXmin + (x - xProfileMin) / (xProfileMax - xProfileMin) (BXmax - BXmin), BXmin];
```

```
nprof[x_] := If[Abs[(nXmax - nXmin) / nXmax] > 10^-6,
   nXmin + (x - xProfileMin) / (xProfileMax - xProfileMin) (nXmax - nXmin), nXmin];
```

```
tprof[x_] := If[Abs[(TeXmax - TeXmin) / TeXmax] > 10^-6,
   TeXmin + (x - xProfileMin) / (xProfileMax - xProfileMin) (TeXmax - TeXmin), TeXmin];
```