GdfidL: How it works, Limitations, Pros/Cons and new current Developments

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Specialities

- Small Memory Footprint: Fieldvalues only in interesting Cells.
- The Fieldupdate and the Preprocessing is parallelised.
- Low Dispersion Higher Order FDTD-Scheme is available.
- Short Range Wakepotentials: 'Moving Mesh'
  Yee-Scheme, Strang-Splitting and low Dispersion FDTD.
- For Moving Mesh, the FD-Coefficients are computed on the Fly.

GdfidL

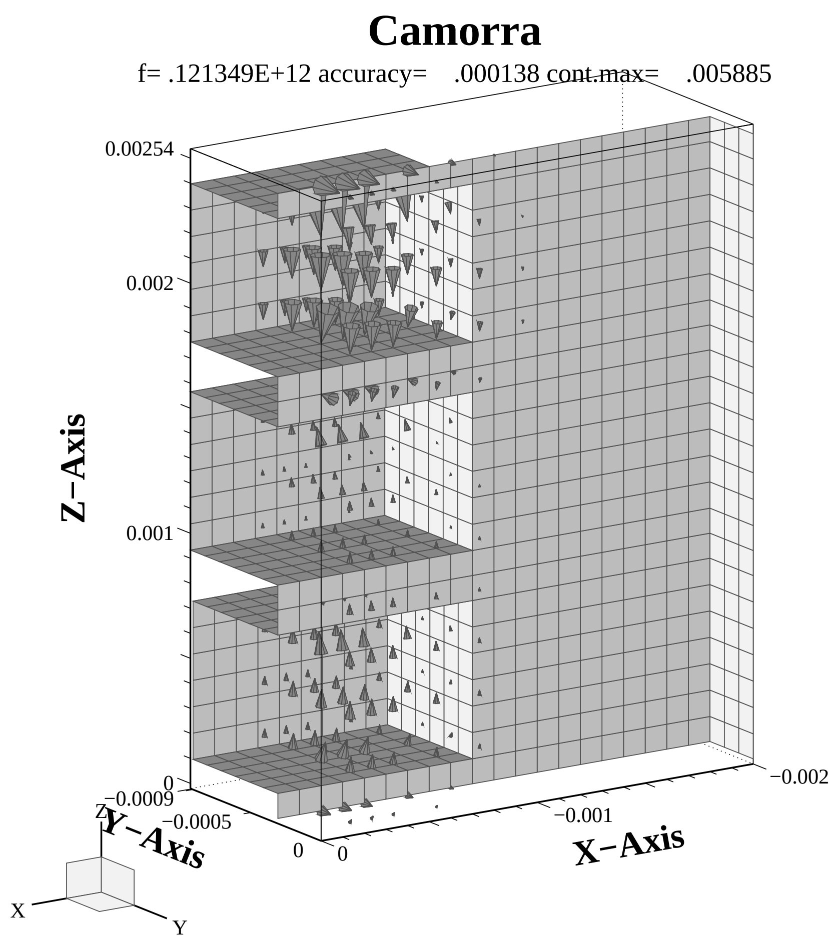
GdfidL is an Acronym for

Gitter drüber, fertig ist die Laube

which Jamie Rosenzweig translated as

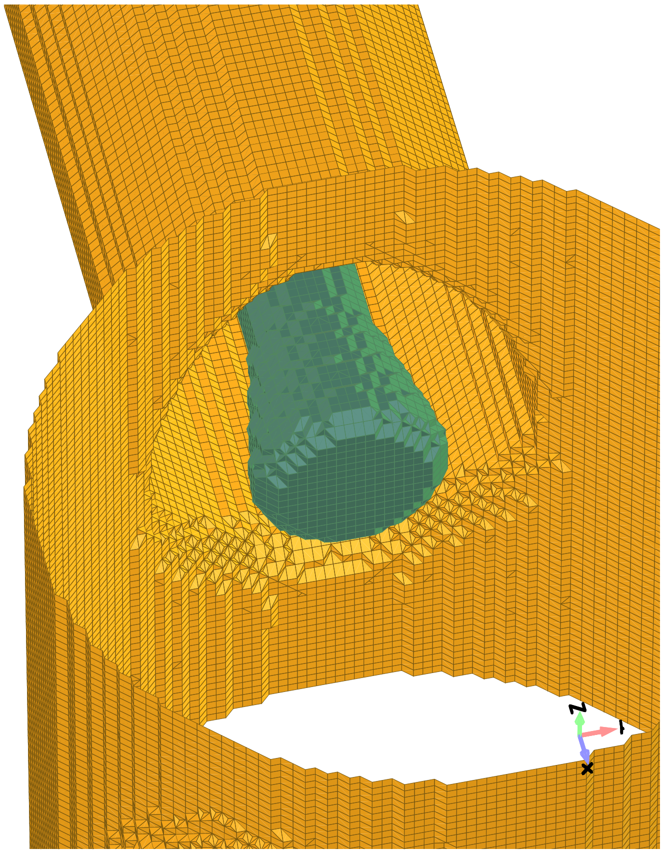
SuperImpose a Mesh, Problem Looks Easy

19 Years ago



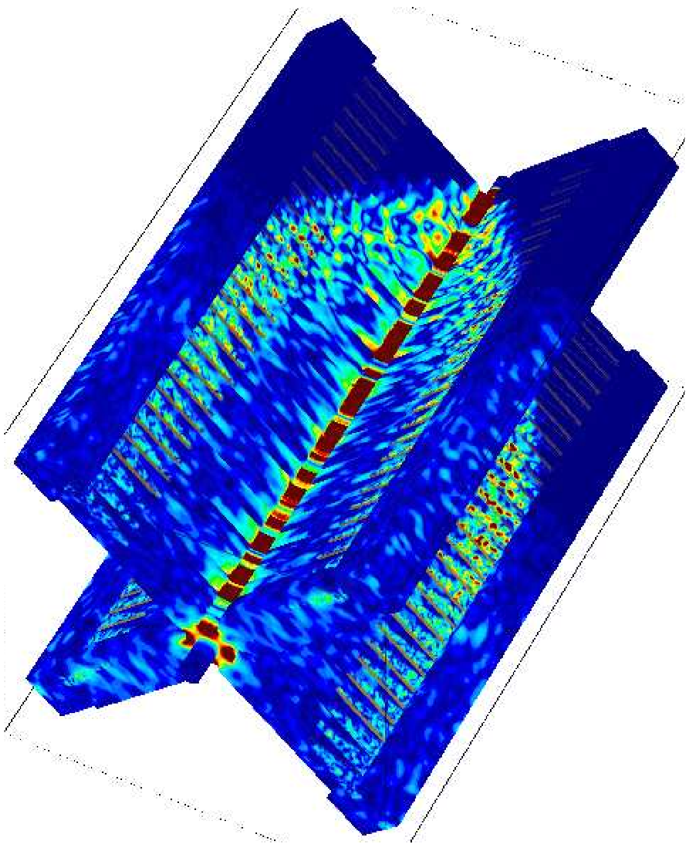
Mon Jan 2 14:28:57 1995

Generalised diagonal Fillings



Detail of the Coupler Region of an ILC Module.
Data from Andrei Lunin, ANL.

Small Memory Footprint



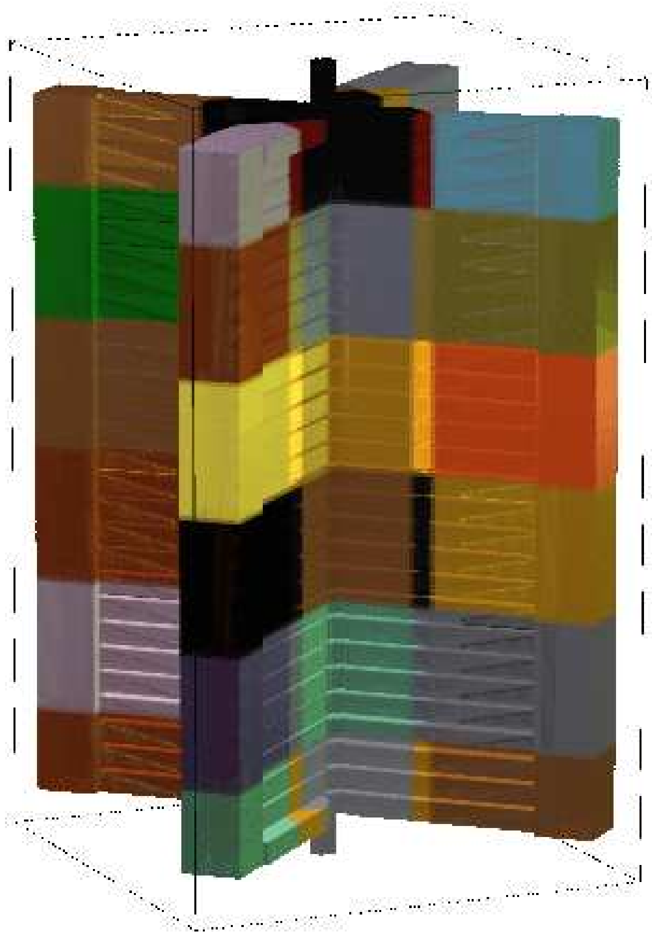
Wall Currents in a CLiC Accelerating Structure. Due to the Position of damping Materials, the Device has no Symmetry. 16 % of the computational Box is filled with interesting Cells. Discretising the Box with 996 Million Cells of 0.185 mm, GdfidL needs 8.3 GByte of Ram to compute the Wakepotential. Using 2x4 Cores of a 2010 Mac-Pro, GdfidL needs 0.72 Seconds per Timestep. This is 221 MCells/Second. The Device Description is from Giovanni De Michele, CERN

1 Integer per Cell, plus 6 Reals and 32 Bits per dielectric Cell.

Small Memory Footprint

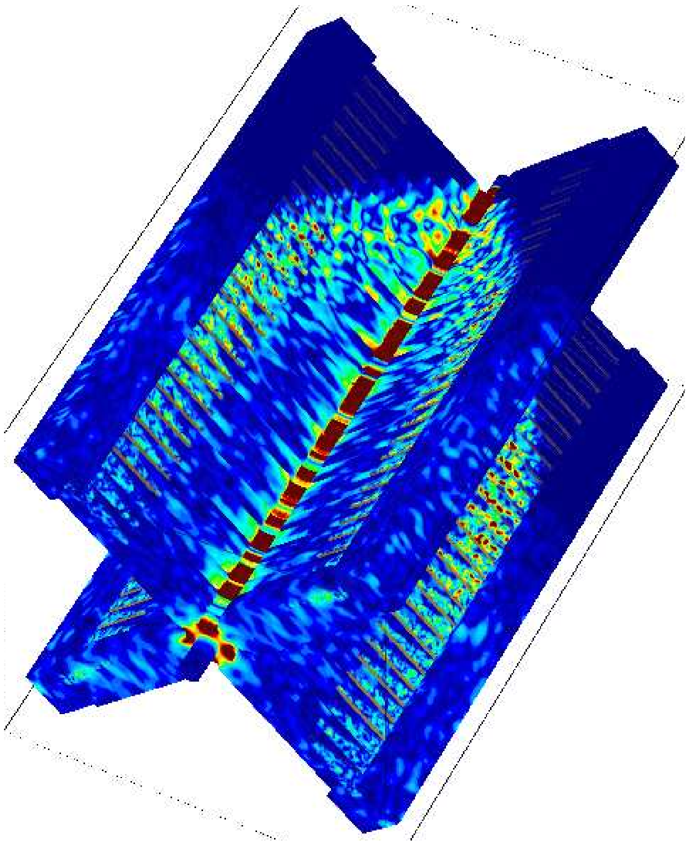
```
   FOR iz IN Block.iz1 .. Block.iz2 LOOP
      FOR iy IN Block.iy1 .. Block.iy2 LOOP
         FOR ix IN Block.ix1 .. Block.ix2 LOOP
            i:= NrofCell(ix,iy,iz);
            IF i>0 THEN
               --
               -- Dielectric Cell.
               --
               iType:= CellType(i);
               ixp1:= NrofCell(ix+1,iy  ,iz  );  -- Number of Neighbour in +x.
               iyp1:= NrofCell(ix  ,iy+1,iz  );
               izp1:= NrofCell(ix  ,iy  ,iz+1);
Hds(1,i):= Hds(1,i)*Hf1(1,iType) - Hf2(1,iType)*( Eds(3,iyp1) - Eds(3,i) - Eds(2,izp1) + Eds(2,i) );
Hds(2,i):= Hds(2,i)*Hf1(2,iType) - Hf2(2,iType)*( Eds(1,izp1) - Eds(1,i) - Eds(3,ixp1) + Eds(3,i) );
Hds(3,i):= Hds(3,i)*Hf1(3,iType) - Hf2(3,iType)*( Eds(2,ixp1) - Eds(2,i) - Eds(1,iyp1) + Eds(1,i) );
            END IF;
         END LOOP;
      END LOOP;
   END LOOP;

 NrofCell : Integer-Array with nx*ny*nz Elements.
 Eds, Hds : Real-Arrays with (3 * Number of dielectric Cells) Elements.
 Celltype : Integer-Array with (Number of dielectric Cells) Elements.
 Hf1, Hf2 : Real-Arrays with typically less than 30000 Elements.
```

NuMA-aware and Cache aware Update



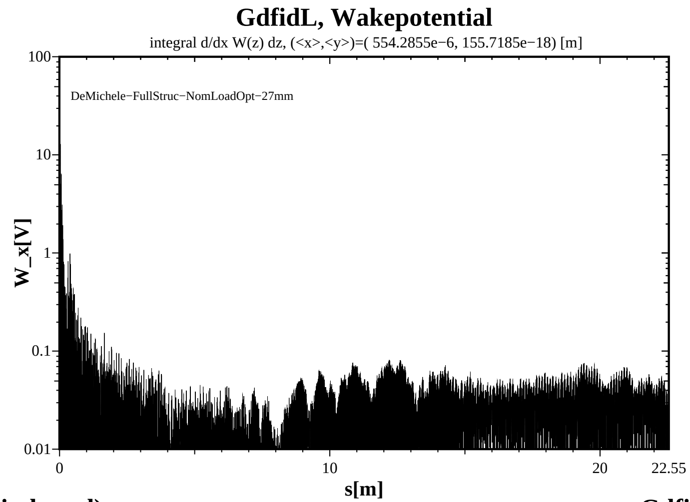
Multi-Socket Systems are Non-Uniform-Memory Access Machines.
Memory Initialisation and Accesses are done by the same Core. Factor of 2 on 4-Socket Systems.
Blocked Field Update. Blocksize such that a local Gridplane fits into the Cache. Factor of 2 for large Problems.

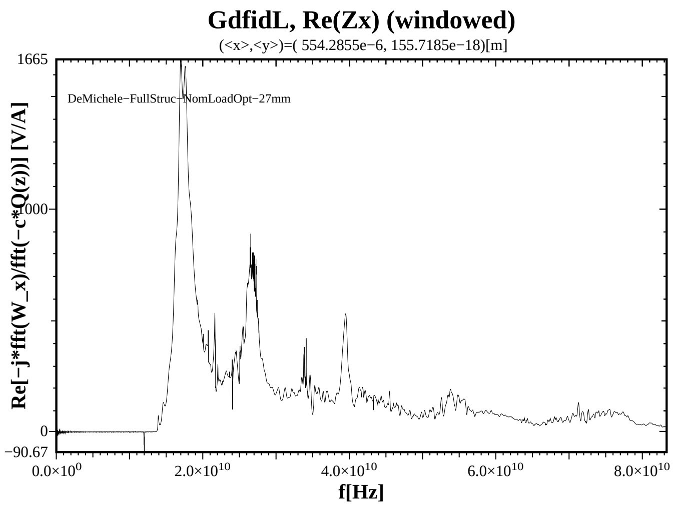
Parallelised: Grid Generation, Field Computation

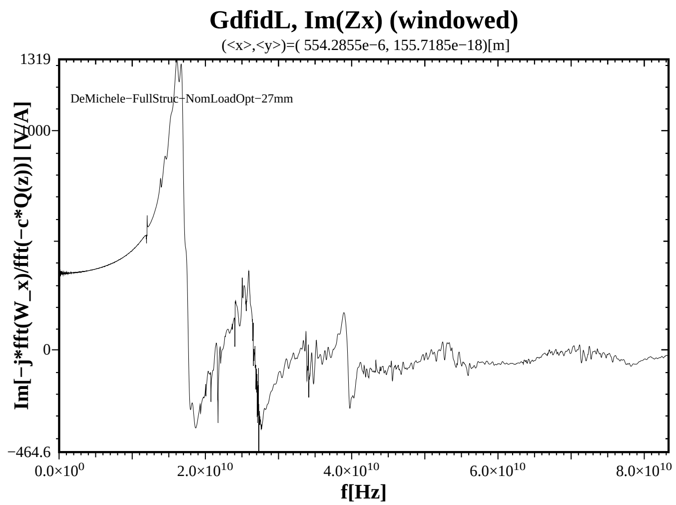


Not only the Field-Update is parallelised for Multi-Core Systems and Clusters of MultiCore Systems, but the Mesh Generation etc as well. For this 996 Million Cells Example, all the Processing needed before the Time Domain Computation itself starts takes 53 Minutes on a 2010 2x4-Core Mac-Pro. The Material is decribed via CAD-Files having 90720 Triangles in it. The Wakepotential up to s=2 Metres then is computed within 7 Hours. The Device is 0.26 Metres long, the Gridspacing is 185 um.

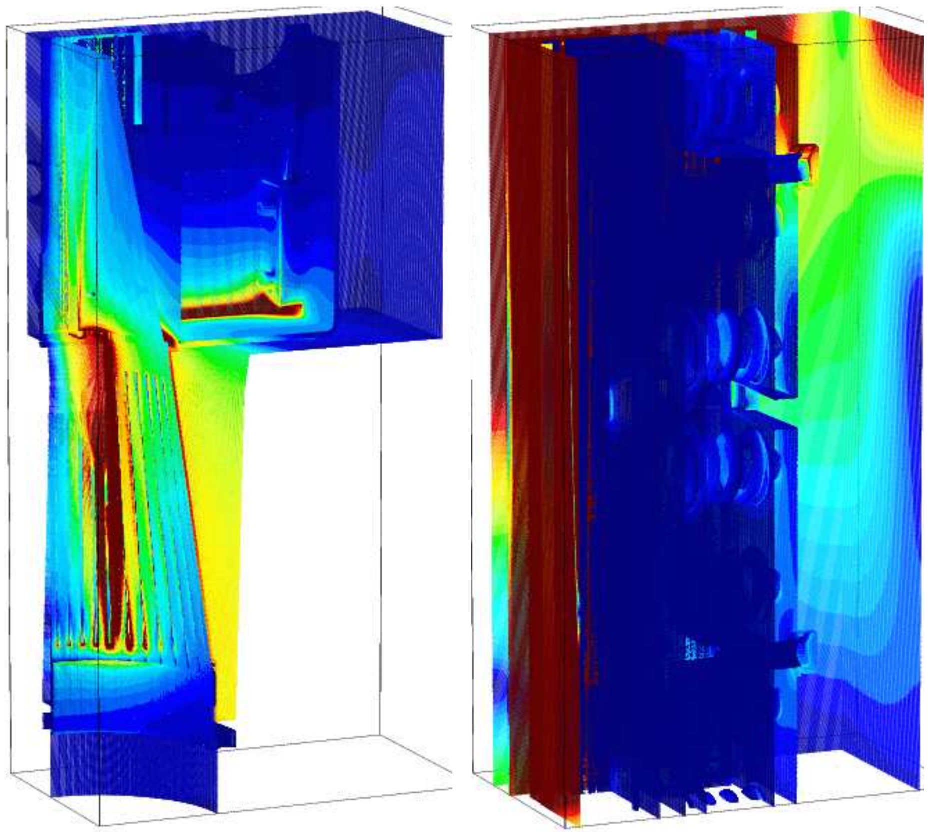
Parallelised: Grid Generation, Field Computation







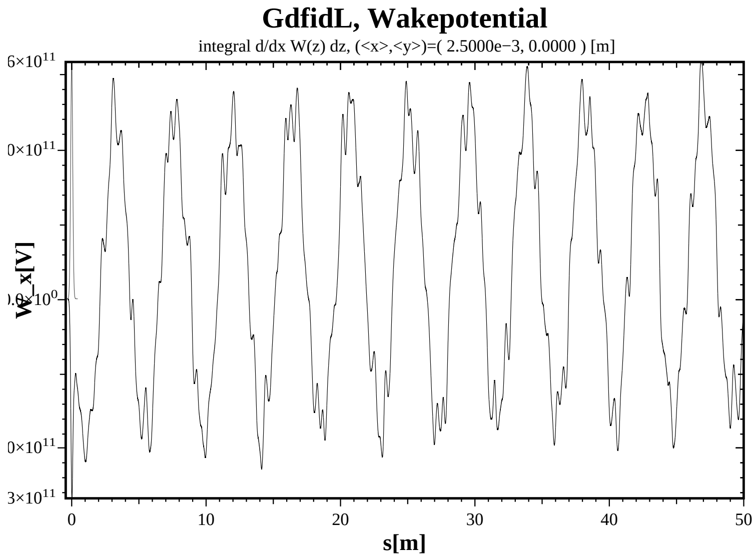
Parallelised: Grid Generation, Field Computation



Wall Currents in a LHC-Collimator. Left: Details of the Fingers. Right: Details of the Springs. The small Features of the Device are described via Lists of 0.36 Million Triangles in STL-Files. The Device Description is from Oscar Frasciello, INFN.

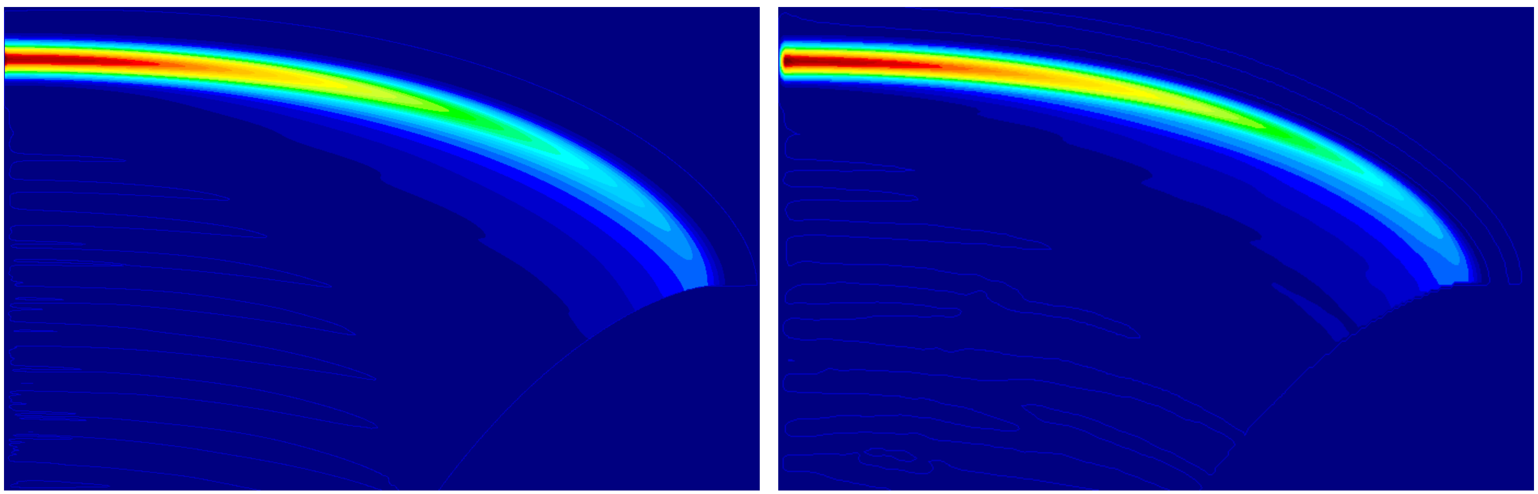
Computing the Wakepotentials of a LHC-Collimator, Length=1.5 Metres, up to s=2 Metres with the Yee Scheme in a Grid of 1100 Million Cells needs 16 GBytes and 7 Hours on a 2010 2x4-Core Mac-Pro. This includes the Grid-Generation.

Everything needed before the Field-Update itself starts takes about 1 Hour.


GdfidL, Wakepotential
integral d/dx W(z) dz, (<x>,<y>)=(2.5000e−3, 0.0000) [m]
W_x[V]
s[m]
0
10
20
30
40
50

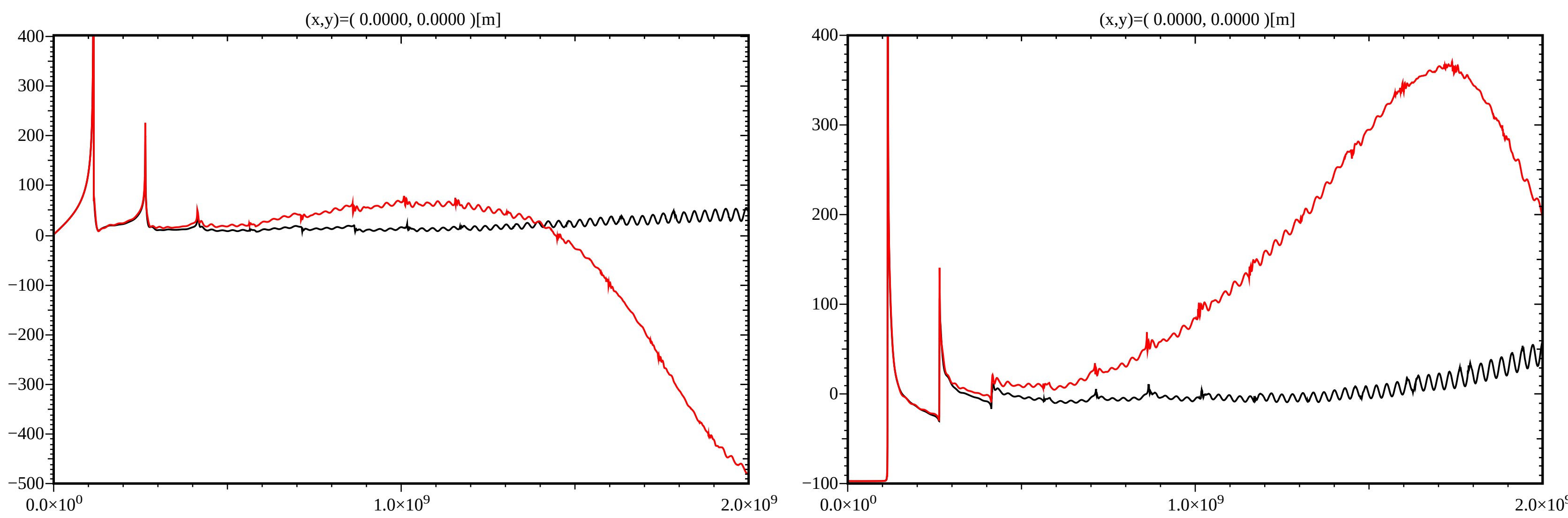
Low Dispersion FDTD-Scheme

The implemented modified FDTD-Scheme has very low Phase-Error in x-, y-, and z-Direction. It is Divergence Free. It may be applied with partly filled Cells. The implemented Scheme needs about 4 times the CPU-Time and two times the Memory as compared to the Yee-Scheme.



Fieldplots of a Linecharge exiting a Tractrix-Horn. Left: Computed with the Yee-Scheme, Sigma/dz=18. Right: Computed with the Hfdtd-Scheme, Sigma/dz=3.

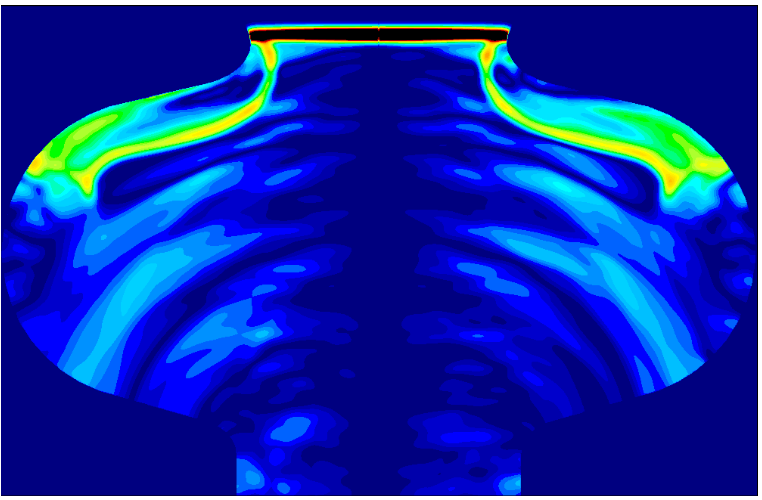
Low Dispersion FDTD-Scheme

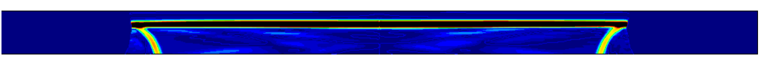


Impedance of a Step, computed with the Yee-Scheme and with the modifified FDTD-Scheme. 200 Gridplanes of dz=25mm before the Step. The Frequency where the Wavelength is sampled by 20 Gridplanes is $f = \frac{\mathrm{C}}{20\Delta z} = 600\mathrm{MHz}$.

Moving Mesh, FD-Coefficients

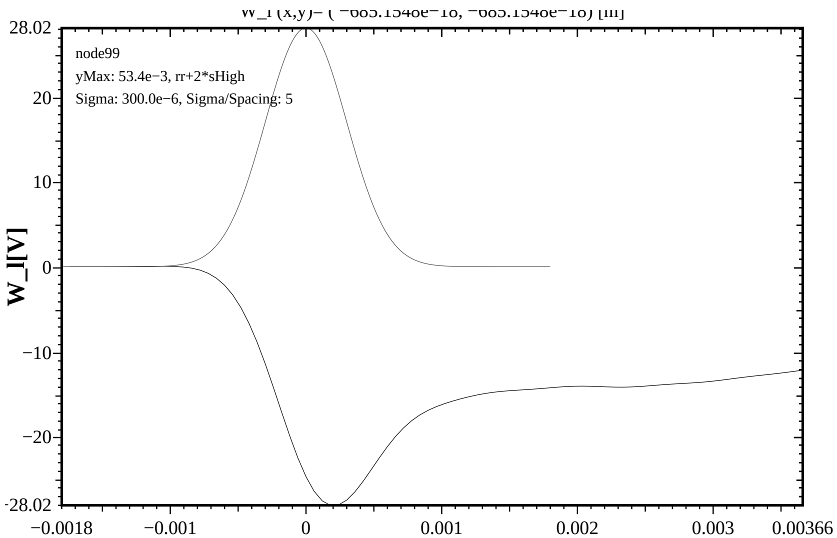
Computing in a moving window, K. Bane, T. Weiland, 1983.



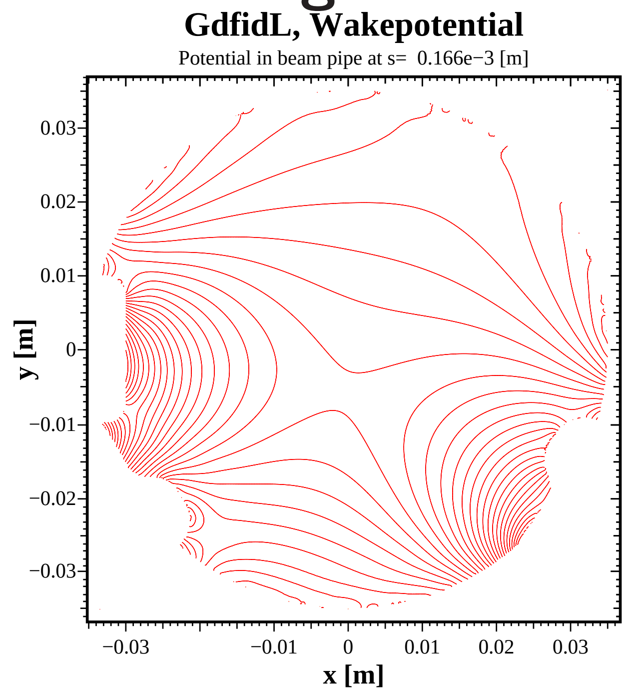


The Pictures have different Scalings. Computed with the m-FDTD-Scheme.

Fieldplots of a Linecharge in a 9-Cell ILC-Module, entering the second Cavity. Above: Sigma=1.3 mm, sHigh= 96 Sigma = 0.125 Metres. dx=dy=dz= Sigma/6 = 0.217 mm. nx=ny=958, nz=629, 577 Million Cells. 2x4 Cores of a 2010 Mac-Pro need on Average 12 Seconds to compute everything needed to advance the Volume by one Gridplane. (zMax-zMin+sHigh+6*Sigma)/dz = 6676 Gridplanes have to be traversed. The FD-Coefficients of $6676 \times (958)^2 = 6.1 \times 10^9$ Cells have to be known. Below: In a restricted Volume. Sigma=0.3mm, dz=Sigma/6 = 50 um, sHigh= 12 Sigma = 3.6 mm. nx=ny: 1782, nz= 107. 340 Million Cells. 12 GByte of RAM. 7 Seconds to advance by one Gridplane. 26000 Gridplanes have to be traversed. The FD-Coefficients of $26000 \times (1782)^2 = 83 \times 10^9$ Cells have to be known.


node99
yMax: 53.4e−3, rr+2*sHigh
Sigma: 300.0e−6, Sigma/Spacing: 5
W_l[V]
28.02
20
10
0
−10
−20
-28.02
−0.0018
−0.001
0
0.001
0.002
0.003
0.00366

Moving Mesh



Wakepotential of a 9-cell TESLA i(ILC) Structure with Couplers. Shown is the Wakepotential as a Function of (x,y) at a fixed Position s. The artificial Boundary can be placed so near to the shown Region that none of the wrong Fields can reach the Region within the Range s.

Pros and Cons

Pros:
Fast.
Low Memory Requirements.
Efficient use of MultiCore Systems and Clusters of MultiCore Systems.
Restart-Facility.

GdfidL does not have a sophisticated Solid-Volume Modeler.
STL-Files can be imported.

Cons: No Impedance Boundary Conditions yet.

Future Developments

Impedance Boundary Conditions will be implemented *next Week*.
This Decade: Local Grid-Refinement, using DISCONTIOUS GALERKIN.