Tau3P: A Parallel Time-Domain Solver for the DOE Grand Challenge*

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Abstract: Tau3P, a parallel effort to the Omega3P project in the DOE Grand Challenge [1], is a new 3D parallel time-domain solver for simulating LARGE RF structures with an accuracy beyond what existing codes can provide. It is based on the modified Yee algorithm formulated on an unstructured grid, and uses hexahedral and pentahedral cells to obtain a more realistic geometry description. Mesh generation is performed by SIMAIL/CUBIT while the distribution of mesh data onto multi-processors is handled by the DistMesh class library as in Omega3P with the partitioning done by ParMETIS. Since the execution of Tau3P is predominantly matrix-vector operations during time advancement, the program can be readily implemented on distributed memory machines using MPI or on shared memory systems running threads. We will present results from the SGI/CRAY T3E at NERSC and from a 4-node Xeon server. The simulations include S-parameter calculations for the NLC power input coupler and an RF choke for pulse heating experiments. Parallel performance issues of the code on distributed versus shared memory architectures will be discussed.

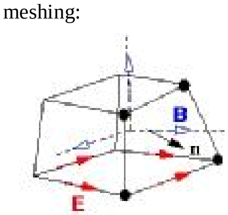
Introduction

Tau3P is developed under the ***DOE Grand Challenge*** as part of a suite of advanced electromagnetic simulators that utilize High Performance Computers to model RF components for next-generation accelerators such as the NLC.

An **essential** feature of the new tool set is the use of **unstructured grids** for conformal meshing:

Tau3P

- Non-orthogonal dual grid
- Electric field on primary grid
- Magnetic field on dual grid



Time-Domain Method on Unstructured Grid

Integral representation of Maxwell equations

$$\oint E \bullet ds = -\iint \frac{\partial B}{\partial t} \bullet dA$$

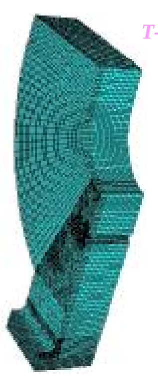
$$\oint H \bullet ds^* = \iint \frac{\partial D}{\partial t} \bullet dA^*$$

Discrete Surface Integral Method

- Leapfrog time advancement scheme with filtering
- Same as FDTD when grids are orthogonal
- Fields on grid averaged over neighboring cells

Ref: N. K. Madsen, J. Comp. Phys., **119**, 34 (1995)

Mesh Generation



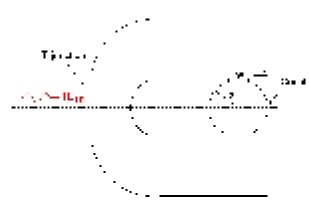
T-junction a X-Band

- ***Tau3P*** interfaces to any mesh generator such as ***SIMAIL*** & ***CUBIT***
- Presently supports hexahedral and pentahedral elements
- Maintaining reasonable element aspect ratio is key to time step and stability issue
- Predominantly uniform elements preferred for parallel efficiency

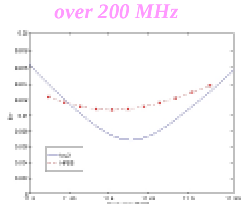
S-Parameter - Broad Band

Tau3P implements the broadband matched-impedance boundary condition at the waveguide ports to allow for pulse transmission so that S-parameter calculation can be determined over a frequency range in a single simulation.

X-Band Input Coupler



T-junction Match over 200 MHz



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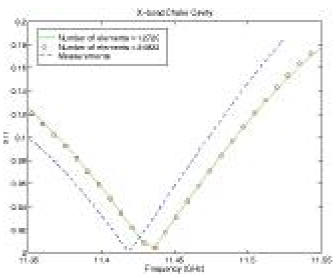
S-Parameter Broad-Band

X-Band RF choke-cavity for pulse heating experiments

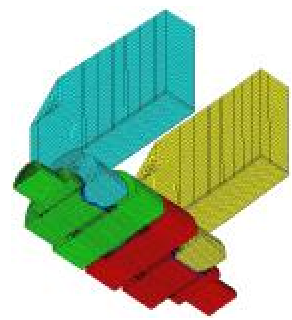
Long taper not modeled effectively on structured grid

Measured data - D. Pritzkau



S-Parameter Single-Frequency

output



input

X-Band Input Coupler for NLC accelerator section

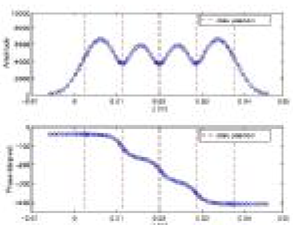
Match:

S_{11} ~ 0.005 @ 11.424 GHz

Coupler Fields at Matched Frequency

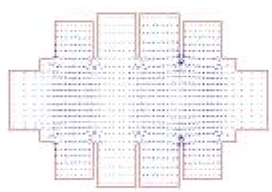
Longitudinal electric field on axis

- *Amplitude: coupler field ~15% higher than structure cell field*
- *Phase: 60^o in coupler cell, 120^o in structure cell*



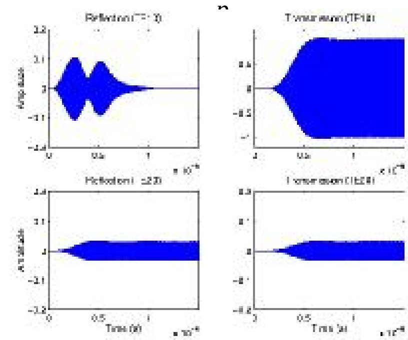
Snapshot of electric field vector at structure x-section

- 2 /3 accelerating mode



Signals in Input/Output Ports

Input Port Reflections ***Output Port Transmissions***



Parallel Efficiency

Tau3P parallelization is predominantly on the matrix-vector operations during time advancement. Due to the mixture of orthogonal and non-orthogonalelements on the mesh, the matrix bandwidth (# of non-zeros in a row) varies so that straightforward partitioning on distributed or shared memory machines would result in significant load imbalance.

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matrix.fig
Creator:
fig2dev Version 3.1 Patchlevel 2
Preview:
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Comment:
This EPS picture will print to a
PostScript printer, but not to
other types of printers.

An improved partitioning scheme is in progress

Load Balancing

RF choke example on SGI/CRAY-T3E at NERSC
- load imbalance for this mesh approaches 3 to 1 as # of processors increases