

## AN IMPROVED VERSION OF TOPAZ 3D \*

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### Abstract

An improved version of the TOPAZ 3D gun code is presented as a powerful tool for beam optics simulation. In contrast to the previous version of TOPAZ 3D, the geometry of the device under test is introduced into TOPAZ 3D directly from a CAD program, such as Solid Edge or AutoCAD. In order to have this new feature, an interface was developed, using the GiD software package as a meshing code. The article describes this method with two models to illustrate the results.

### INTRODUCTION

The problem of simulating high-current electron devices can be formulated into a set of field equations, particles motion equations, and the conservation law for the total charge. The EGUN [1] 2D code has been available at SLAC for several years and is designed to simulate trajectories of charged particles in electrostatic and magnetostatic fields. The modern development of high power electron devices is bound up with the multi-beam and sheet beam microwave sources. They are attractive for the design of gigawatt range free electron masers, pumping systems of gas lasers, and quasi-optical gyrotrons. For example, multi-beam [2] and sheet beam [3] X-band klystrons may be good candidates for R&D of the Next Linear Collider program. The design of such devices is practically impossible without the development of 3D computer codes. TOPAZ 2D [4] and TOPAZ 3D [5] are computer codes, which have been orientated for the simulation of relativistic charged particle optic problems using the Boundary Element Method. This method provides more precise solutions to complex geometries. The TOPAZ codes are available at SLAC now. Both versions of TOPAZ were revised for the modern computer platform and its shells. More details about the TOPAZ code are available in [5]. The new TOPAZ 3D adds the ability to import a 3D geometry directly and to compute the trajectories of particles in the external electromagnetic fields, including space charge effects, self-magnetic fields, and relativistic effects.

### FROM SOLID EGDE INTO GID

The original version of TOPAZ 3D had an expansive set of standard geometric objects (plane, cone, sphere, cylinder, torus, triangle, quadrangle, ring, etc.). These objects could then be operated upon (shift, rotate, stretch, reflect, etc.). This was the original approach used prior to simulation. Typically, the designer had to spend an appreciable amount of time to create a working input file without any errors. However, the visualisation of objects and the ability to work with them was not as user-friendly as preferred. The above disadvantages were the major

motivation for improving TOPAZ 3D. There are several 3D CAD programs, which are available at SLAC. The most sophisticated is the Solid Edge CAD software. This software is powerful and effective to work with 3D objects. However, there is no option to mesh three-dimensional geometries.

GiD [6] is a powerful and reasonably priced software package. It was designed as a universal, adaptive and user-friendly graphical interface for geometrical modelling, data input and visualisation of results for all types of numerical simulation programs. Typical problems that can be successfully tackled with GiD include most situations in solids and mechanics. This program is used as the main interface between Solid Edge and the new version of TOPAZ.

The design of a sheet beam gun can be used to illustrate the new features of TOPAZ. The sheet beam gun consists of three electrodes: anode, focus electrode, and cathode. The results of the Solid Edge gun design and the meshing of this geometry using GiD are presented in Fig. 1 a) and b) accordingly.

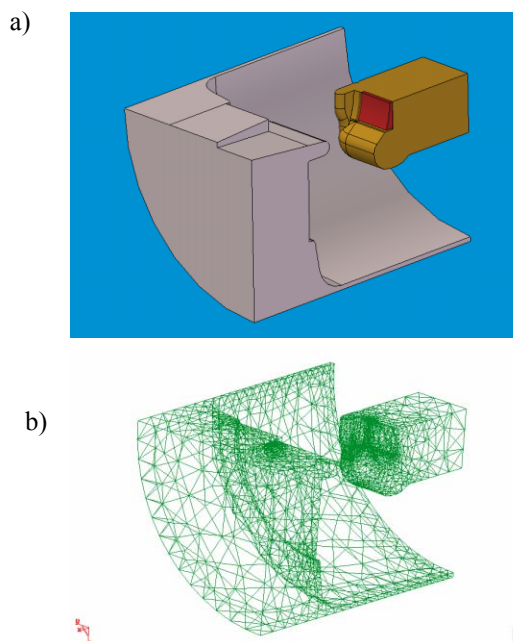
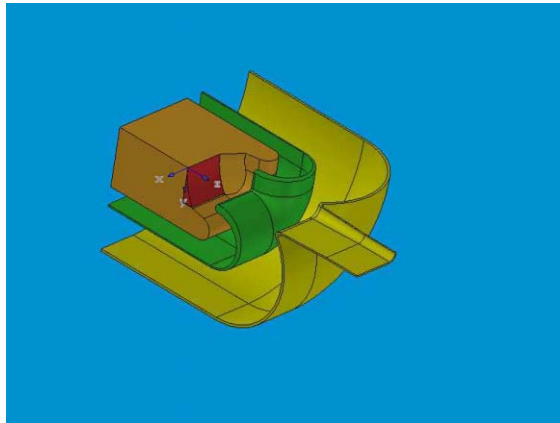


Figure 1:

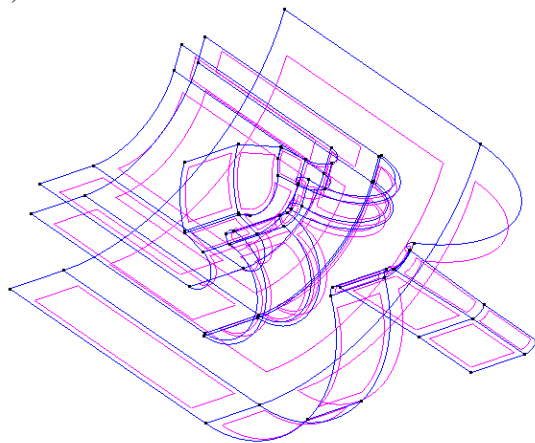
- a) Sheet beam gun design: anode in grey, cathode in red, and focus electrode in yellow
- b) Unstructured mesh of the geometry using GiD

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Here, a quarter model of the whole sheet beam gun geometry is shown. As it is seen, GiD generates a mesh for each surface of the gun. GiD also shows the volumes of the metallic elements where there is not an electric field. However, the Boundary Element Method, which is used in TOPAZ, only requires the surface representation of boundary conditions. From this point of view, the GiD output file might include extraneous information. The geometry can be easily edited before it is exported into TOPAZ. The example shown in Fig. 2 a) and b), is the result of editing the volumes of the electrodes of the three-electrode sheet beam gun (see Fig 2a).



a)



b)

Figure 2:

- a) Quarter model of three-electrode sheet beam gun;
- b) Surface representation of electrodes after editing the geometry using the GiD software package

Unnecessary surfaces, lines and nodes were removed from the gun geometry before the TOPAZ simulation. The removal of unnecessary elements will simplify the output GiD file. The assigning of surfaces for the gun electrodes is the next necessary action. After the geometry is simplified and all the electrodes are assigned, the next step is to mesh the surface. Users can choose the

size of the mesh inside the GiD program. The result of meshing the three-electrode gun geometry is shown in Fig. 3. Here the green colour is the surface of the cathode, blue is the focus electrode, pink is the modulating anode, and cyan is the anode.

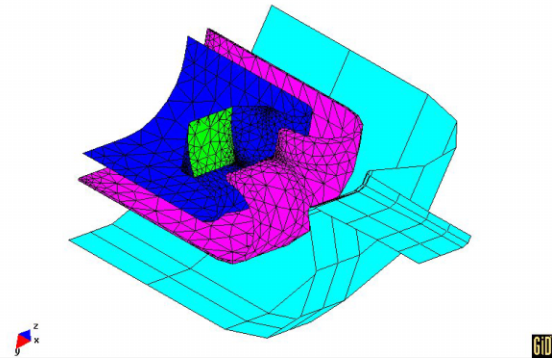


Figure 3: Result of surface meshing the three-electrode sheet beam gun in GiD

The geometry is ready to simulate.

### FROM GiD INTO TOPAZ 3D

The output file from GiD represents the numerical data for the studied geometry (the sheet beam gun in this case). The additional interface between GiD and TOPAZ is necessary to sort the output GiD data in such a way that they are separated for each element (anode, cathode, focus electrode, etc.).

#### GiD to TOPAZ

Project Title: 415-150f  
 Author: A. Krasnykh  
 Date: 03-18-2003

Number of Surface Points: 1485  
 Number of Elements: 2648

Cathode Potential: 0  
 Focus Electrode Potential: 0  
 Mod Anode Potential: 150  
 Anode Potential: 415

Created by Aaron Jensen  
 Modified by Anatoly

```

0 0 0 0
0,001
1
0 0 0 0
1 -3.9370079000 0.0000000000 7.9133858000
2 -3.9370079000 0.5181305978 7.8907637296
.....
1484 9.8425197000 0.3149606300 0.5520450636
1485 9.8425197000 0.3149606300 0.0000000000
0 0 0 0
1 445 432 421 cathode
1 459 445 440 cathode
.....
4 270 147 143 anode
4 143 259 270 anode
2 307 298 306 focus_electrode
.....
2 398 391 389 focus_electrode
3 1243 1217 1255 mod_anode
.....
3 1077 967 1039 mod_anode
0 0 0 0 null
1
0
3150
4415

```

The GiD output data is created in the text format and segregated into four sections:

- User information
- Coordinate data
- Element data
- Condition data

This file is the input file for TOPAZ 3D. Before simulation it is necessary to create a volume mesh for the beam. The next types of beam meshes are available in TOPAZ:

- Cartesian type (x,y,z)
- Cylindrical type (r,φ,z)
- Spherical type (ρ,θ,φ)
- Generalized curvature orthogonal type

Figure 4: Structure of the GiD output file

The volume, where the beam is going to be propagated, can be split into small discrete distances for each type of coordinate system. The charge and beam current are equally spread inside cells. Fig. 5 shows the result of the sheet beam simulations for the gun geometry shown in Fig. 1. The trajectories for two planes are shown here. Approximately 100 trajectories are shown.

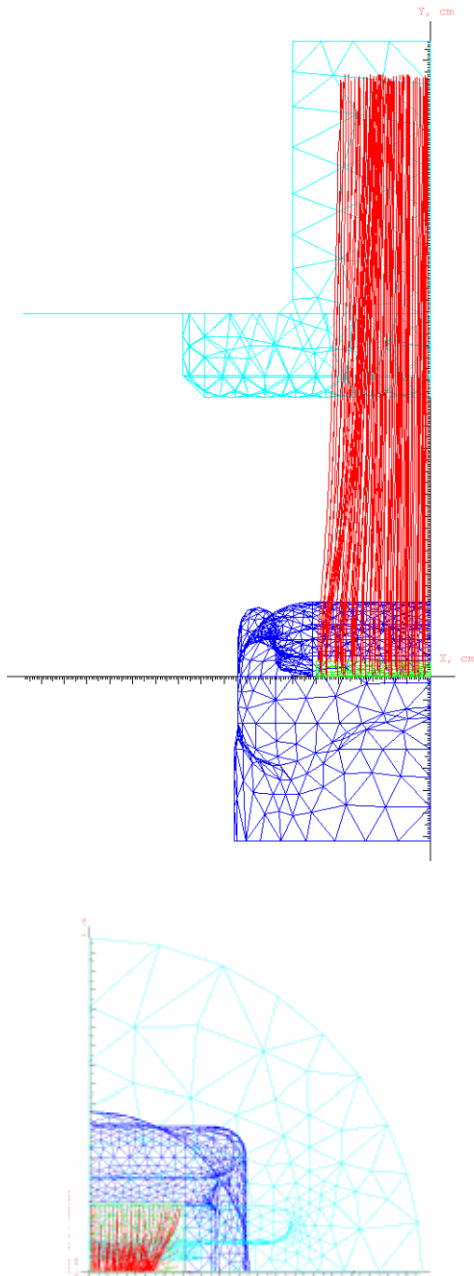


Figure 5: Result of sheet beam gun simulation

It is seen from the above simulation that the shape of the focus electrode for the gun is not optimized. The sheet beam has converged too much for the non-convergence plan. The region of the focus electrode, that is not optimized, is shown in Fig. 6. Similar beam behaviour is

seen for this shape of focus electrode when the indirect method [6] is used.

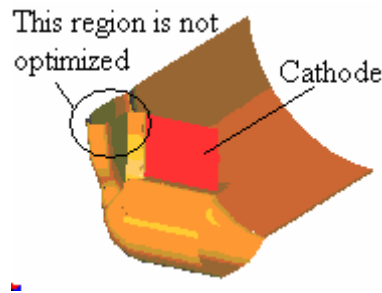


Figure 6: Focus electrode and cathode of sheet beam gun

The numerical result of the electron gun simulation shows the ability to simulate the complicated sheet beam geometries directly from Solid Edge. The pre-processor stage for preparation of the geometry for simulation is simpler and more user-friendly. In this case Solid Edge and GiD features are used. The geometry is edited and converted into the digital text format after creation of the solid model.

## CONCLUSIONS

There are several codes to simulate the behavior of a sheet beam. Some of them are focused on the analysis of the confinement characteristics of sheet beams focused by periodically permanent magnets. The TOPAZ 3D code is optimized to run fully three-dimensional stationary problems such as the design of a relativistic beam gun and following after the gun the beam optics system. Solid Edge CAD and GiD software were adopted as the TOPAZ 3D pre-processor for the preparation of the geometry for simulation and the creation of the input file.

## ACKNOWLEDGEMENTS

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