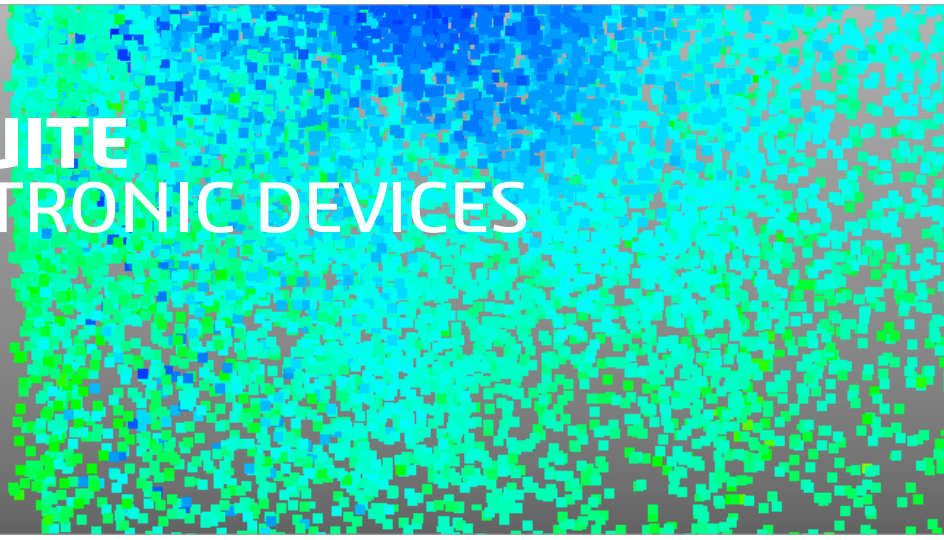
SIMULIA

3DEXPERIENCE

CST STUDIO SUITE
VACCUM ELECTRONIC DEVICES

Datasheet



CST Studio Suite® the fast and accurate 3D analysis of charged particle dynamics in 3D electromagnetic fields. The CST Studio Suite particle solvers are fully integrated in the design environment, taking advantage of the user-friendly interface as well as the technology of the high-frequency, low-frequency and multiphysics solvers.

CST STUDIO SUITE SOLVERS FOR VACUUM ELECTRONIC DEVICES

- Particle Tracking Solver (TRK Solver) – DC gun simulation including space charge
- Particle-in-Cell Solver (PIC Solver) – self-consistent transient particle simulation, with GPU support

ELECTRON GUN SIMULATION

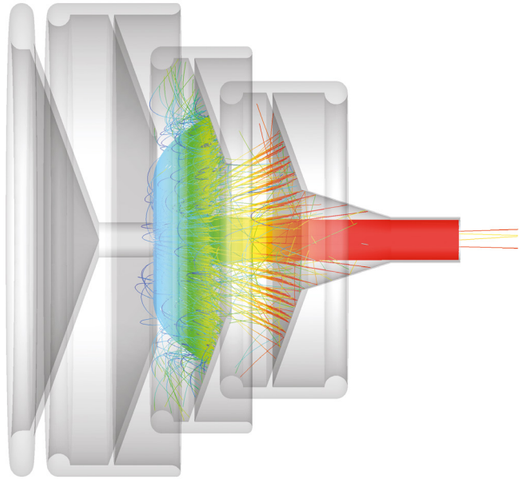
Linear electron devices such as traveling wave tubes need an electron gun to provide the beam, which later on interacts with a slow wave structure in order to generate or amplify electromagnetic waves. CST Studio Suite increases simulation efficiency by offering the best solver for each component in the same interface.

Several emission models are available for space charge/thermionically limited guns and cold cathodes (via field emission). Conformal mesh support helps to represent complicated geometries such as gridded guns and enables the simulation of small deformations very accurately.

DASSAULT SYSTEMES

Magnets and electrodes can be simulated quickly using the Magnetostatic and Electrostatic Solvers, and the integrated interface allows these fields to be imported directly into the particle simulation. This means that a typical focussing structure, such as the periodic permanent magnet (PPM) stackups as shown on the right, can be simulated and optimized quickly, beginning with an on-axis 2D magnetostatic simulation and ending with a full particle tracking simulation.

The TRK Solver uses the electro- and magnetostatic sources to evaluate the particles trajectory including their space charge. For high voltage guns also the self focussing effect of the beam can be taken into account.



Secondary emission: Depressed collector simulation under the influence of secondary electron emission.

CHARGED PARTICLE SIMULATION

ADVANCED MATERIAL MODELS

Secondary Electron Emission

Secondary electron emission is an important aspect in the understanding of vacuum electron devices. It plays a role in magnetrons, when the main current is coming from a cold cathode via secondary emission and for collector analysis, where a figure of merit is the current backstreaming into the tube, which is caused by secondary electrons. This is also critical for analyzing multipaction.

The secondary electron emission is a material property and can therefore be added individually to each material. It is expressed by the secondary electron emission yield (SEY) and is modeled statistically. CST Studio Suite supports both the Furman and Vaughan models, and includes commonly used materials in its library. Measured SEY data can also be imported.

COMPACT FOIL MODEL

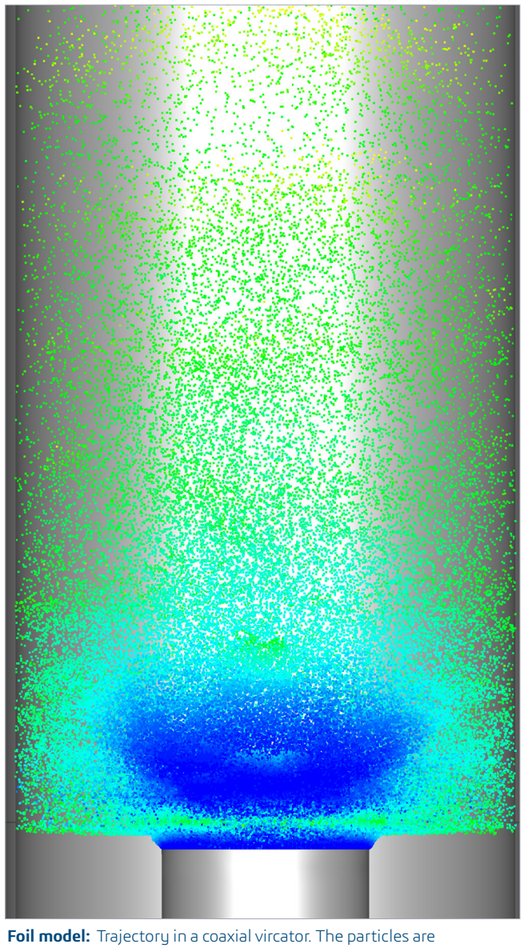
A vircator's anode is typically represented by a foil or grid, which can be efficiently modeled as infinitely thin sheet. This sheet serves as electric boundary condition for the fields, but is transparent to particles. The transparency could be either given as fixed value or as a probability depending on the energy of the penetrating particles.

VOLUME IONIZATION

Plasma assisted vacuum electron devices can be simulated either using ionization of background gas by incident particles (assigning an ionization cross section to a materia) or by loading of an existing plasma as predefined electron and ion clouds (using the particle import interface).

DISPERSIVE MATERIALS

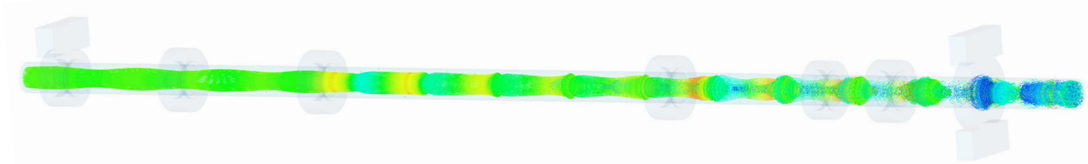
CST Studio Suite offers dispersive materials such as Drude models to simulate cold plasmas and their losses. These models can also be used in combination with particles moving through the corresponding areas in order to support particle interaction into plasma.



Foil model: Trajectory in a coaxial vircator. The particles are penetrating a foil anode and forming a virtual cathode (blue cloud).

GPU COMPUTING

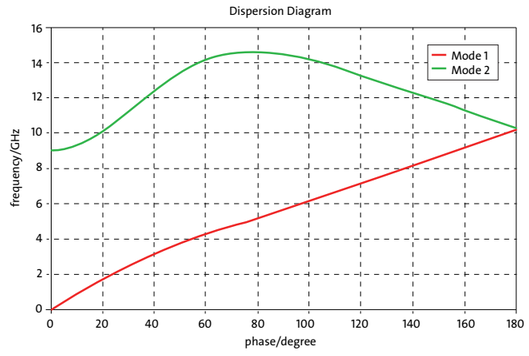
Simulation of vacuum tubes can easily be a time consuming task depending on the complexity and electrical size of the device. In addition a fine mesh for particle simulations is needed to resolve the field gradient accurately. With GPU accleration, the PIC Solver shows a significant speedup and can produce results for complex structures such as the klystron on the left within minutes. This enables the full simulation of startup processes from magnetrons as well as the simulation of electrically large devices as gyrotrons and klystrons, signficantly broadening the applications of simulation in the design flow. The solver supports single and multi-GPU usage.

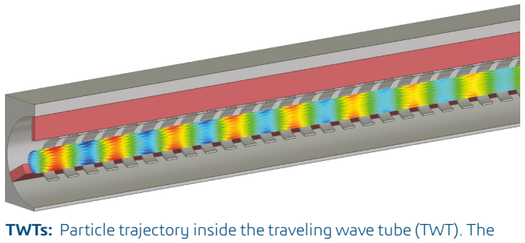


GPU accleration: Particle trajectory in a klystron. The bunching towards the output section can clearly be observed. The model shows an electrical length of 12 –13 lambda and can be accurately simulated in 3D in about 15 minutes on a GPU.

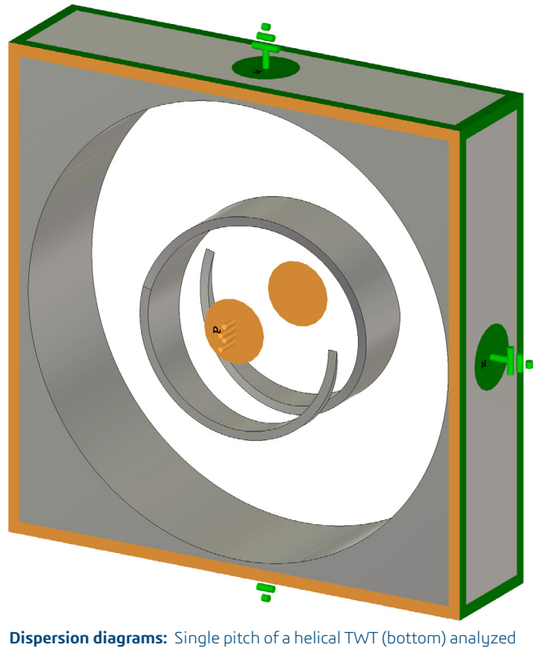
ADDITIONAL FEATURES OF CST Studio Suite

- Intuitive parametric 3D modeling
- VBA compatible macro language
- Powerful user-definable postprocessing
- Conformal mesh via Perfect Boundary Approximation (PBA)®
- Particle, field and power monitors
- TRK-PIC interface for hybrid simulation of beam input created by an electron gun
- User defined particle source via ASCII interface
- Import of external fields
- Eigenmode Solver for accurate cavity analysis
- Periodic boundaries and mode dispersion diagrams
- Heat loss transfer to Thermal Solver of volume and surface losses from fields
- Particle collision data





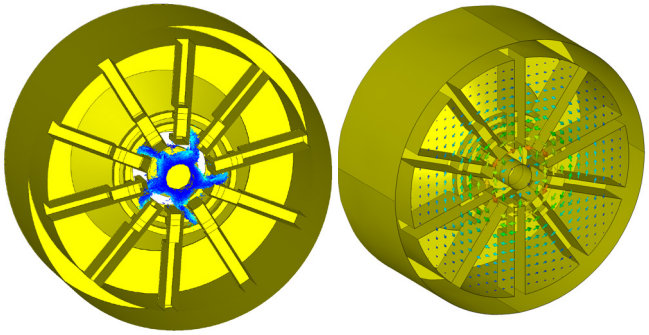
TWTs: Particle trajectory inside the traveling wave tube (TWT). The velocity modulation of the particles is shown by the different colours.



Dispersion diagrams: Single pitch of a helical TWT (bottom) analyzed in CST Studio Suite Eigenmode Solver to obtain dispersion diagram (top).

APPLICATION AREAS

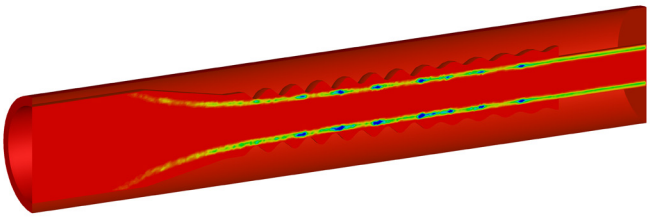
In vacuum electronics, different classes of devices are distinguished – classical devices and relativistic devices (see below) – and a variety of different emission models are available to simulate these. CST Studio Suite includes the DC beam emission model (could be also used to model thermionically limited), the explosive emission model (which can be space-charge limited) and the annular emission model. In addition, the particle interface allows arbitrary particle sources to be used and allows the results from the simulation of one component to be used as the source for the simulation of another.



Magnetron: Particle spokes formed in a cooker magnetron and corresponding pi mode obtained by a previous eigenmode simulation. Straps are used to avoid mode competition.

Classical Electron Devices

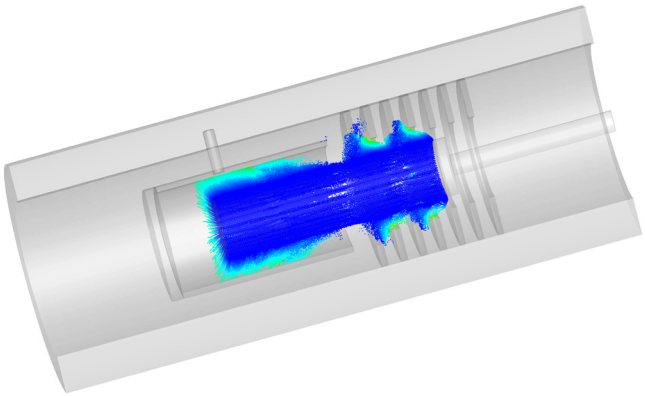
- Traveling Wave Tubes
- Klystrons
- Magnetrons
- Gyrotrons



BWO: Space charge inside a high power backward wave oscillator. Bunching can be seen by space charge accumulation in blue dots. The output power of this device is around 600MW.

Relativistic Electron Devices

- Vircators
- Magnetically Insulated Line Oscillators (MILO)
- High Power Backward Wave Oscillators (BWO)



MILO: Particle Trajectory inside the MILO. We can see the pi mode operation as spokes are in every other cavity are formed. The rest of the beam ends up in the collector (left in the picture).

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