SCALA

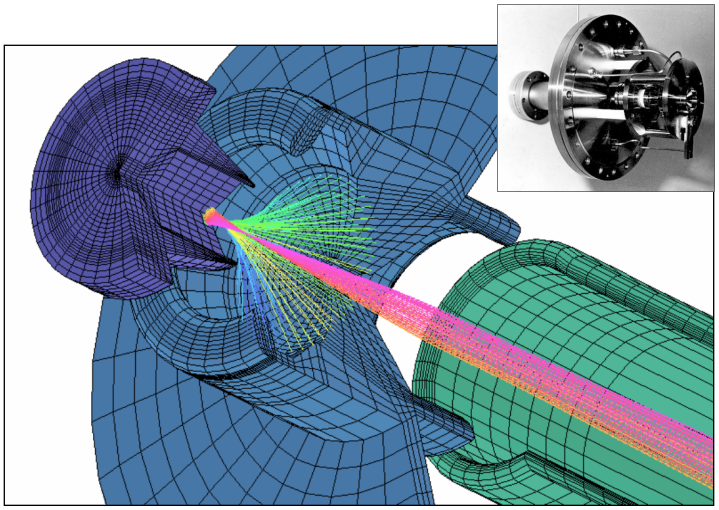
3D SPACE CHARGE ANALYSIS

The SCALA analysis package is a module of the OPERA-3d integrated suite of finite element software for 3D electromagnetic design analysis and simulation. SCALA computes the effects of space charge on beams of charged particles in electrostatic fields in three dimensions, and is based on well proven advanced numerical methods to provide high accuracy.

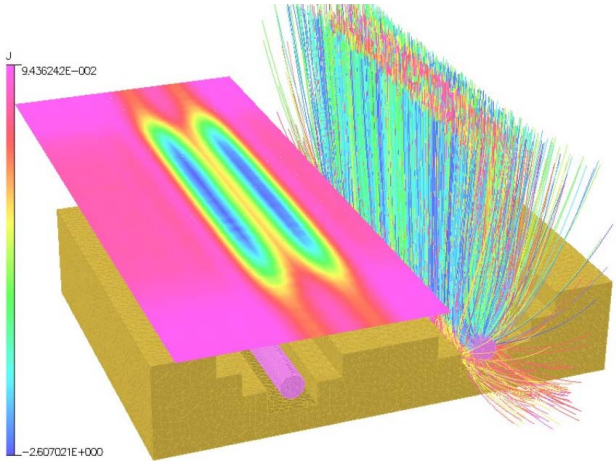
Concepts

As specialists in electromagnetic design and analysis, the team at VECTOR FIELDS has built up an enviable reputation, receiving many international awards as suppliers of easy to use, sophisticated software together with expert support for engineering and scientific applications. With the latest developments in SCALA, the analysis of space charge effects has been brought from the realms of a specialist analyst into the main stream design environment.

By incorporating SCALA into the OPERA-3d suite of programs, VECTOR FIELDS provides a software service that allows engineers and scientists to rapidly optimize the design of devices and systems. This results in prototype and testing periods being greatly reduced and provides a shorter preproduction lead time. Interfaces to major CAD packages also enables the software to be integrated into an overall computer aided engineering system.



AMS negative ion source (inset is photograph of physical device)



Simplified X-ray tube showing particle beam on right, and map of current density where beam intersects a surface on left

Applications

SCALA is designed to extend the range of 3D analysis modules provided by VECTOR FIELDS. The module addresses applications where high current charged particle beams pass through electromagnetic fields. The combined extensive experience of the application engineers and development team at VECTOR FIELDS has resulted in a versatile and easy to use package. Visualization of the electromagnetic effects in the particle beam trajectories, space charge distribution, and electrostatic fields provide detailed information on which design improvements may be based. Typical design and simulation applications include:

- Electron guns and beams
- Ion guns and beams
- Field emission microscopes
- Beam analysis in
  - CRT display tubes
  - X-ray tubes
  - Electron Lithography
  - Electron Microscopes
  - Mass Spectrometers
  - Heavy ion accelerators

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Method

SCALA uses specialist finite element analysis techniques for the analysis of electrostatic fields coupled with the space charge effects on high current (charged particle) beams. The analysis module calculates the current emitted by electrodes using a range of emission laws which may be used in combination. These include:

- **Thermal saturation limit** assuming that the current emitted is dependent on temperature (T), work function (ϕ_w) and emission constant (A)

$$j_e = AT^2 \exp(-\frac{q_e \phi_w}{kT})$$

- **Child's law** giving the maximum current density that can be carried by the beam of charged particles across an accelerating gap. The equation requires equilibrium between the charged particles and a self consistent space charge field

$$j_e = \frac{4\varepsilon_0}{9}\sqrt{\frac{2Zq}{m_0}}\frac{V_0^{3/2}}{d^2}$$

  where ε_0 is the permittivity of free space, Zq is the charge on the particle, m_0 is the particle rest mass and V_0 is the accelerating voltage applied to the accelerating gap d.
- **Langmuir-Fry current limit** is similar to Child's law method but uses a more realistic algorithm by taking into account the velocity distribution of particles in a thermionic emitter.
- **Field emission** for modeling the electron current extracted by very high fields.
- **Maxwellian velocity distribution sampling** for tracking a large number of particles whose initial conditions sample the distribution space.
- **Specified current density** allows a current density and initial particle energy to be specified.

The number of macro particles used to approximate the emission from thermionic emitters may be defined for each surface patch used to specify the emitter. The emitter models usually assume smooth, continuous variation of current over the emitter surface. The full Maxwellian velocity sampling option is provided to enable the solution of extreme cases where these approximations are not valid.

The following features are included in SCALA:

- Full 3D modeling
- Electrostatic field analysis
- Space charge distribution analysis
- Relativistic particle and beam trajectory analysis
- Complex emitter geometry
- Choice of emission characteristics and laws
- Choice of particle characteristics
- Interfaces to CAD/CAM
- Extendible post processing

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Modeler and Post Processing

As a module of the OPERA-3d suite of software, SCALA interfaces to the OPERA-3d Modeler and post processor. This gives the user access to powerful pre and post processing features specifically tailored for space charge design.

The Modeler is specifically designed for electromagnetic applications by VECTOR FIELDS using the ACIS™ kernel. The Modeler has an easy to use 'windows' interface with clear icons. This enables complex 3D models to be constructed swiftly from primitive solids using Boolean operations and automatically meshed with tetrahedra. Transfer of geometric data between CAD systems and the Modeler is through the industry standard SAT and IGES file interfaces.

The post processor is renowned for its versatility in displaying computation results. It has very comprehensive and flexible facilities enabling the user to display the results in a variety of ways controlled by an easy to use 'windows' interface. The features include:

- 3D model views from any angle with mouse driven pan, zoom and rotation
- Graphs, histograms and contour maps of the solution
- Contours of the results on any surface or beam intersection plane
- Calculation of fields and space charge distributions
- Particle beam trajectories
- User defined functions

Hardware

All Vector Fields software runs on PCs and Workstations. It is Vector Fields policy to always support the latest operating system on each hardware. A list of supported hardware, and suggested minimum configurations, are available on request.

Customer Support

Applications advice and "hot-line" support is an integral part of the Vector Fields service. Professional engineers with extensive electrical design experience are available to help users in their application of SCALA. Your main Vector Fields office or local distributor will be pleased to be of assistance at all times.

Comprehensive user documentation is provided with SCALA enabling new users to quickly apply the software to their application. In addition, training courses are held regularly to give "hands-on" training in the use of SCALA.

User group meetings are held annually giving users the opportunity to discuss their applications with Vector Fields experts and other users in a relaxed atmosphere.

Whatever your application and wherever you are located, you can be sure of Vector Fields interest and support.

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