Shape Optimization of a Compact DC Photo-Electron Gun using IGA

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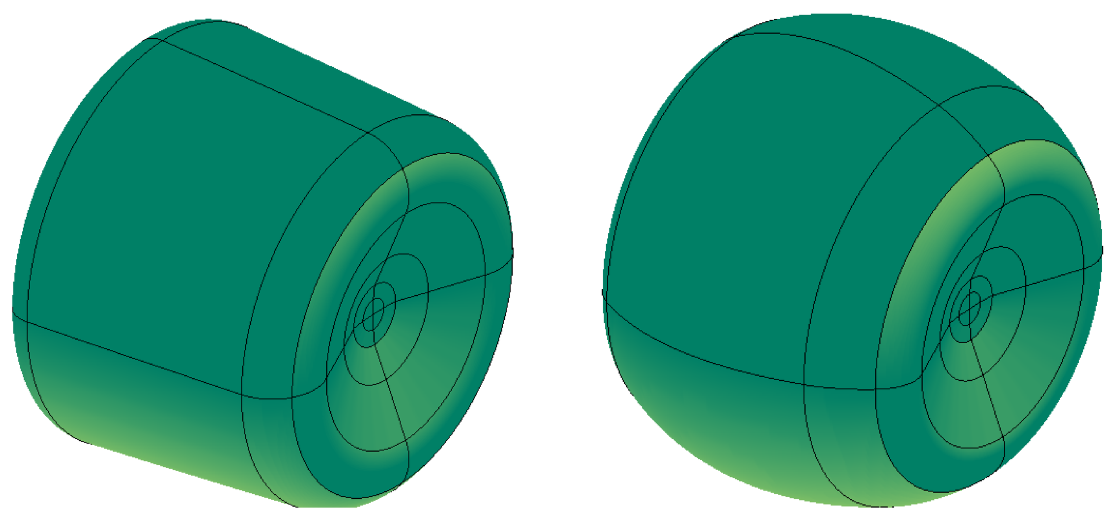
Motivation

Compact DC photo-electron guns meet the demands of high-current applications such as energy recovery linacs. A main design parameter is the electric field strength, which is limited by the field emission threshold of the electrode material. Optimizing the electrode geometry allows for higher gradients and thus increased gun perfomance.



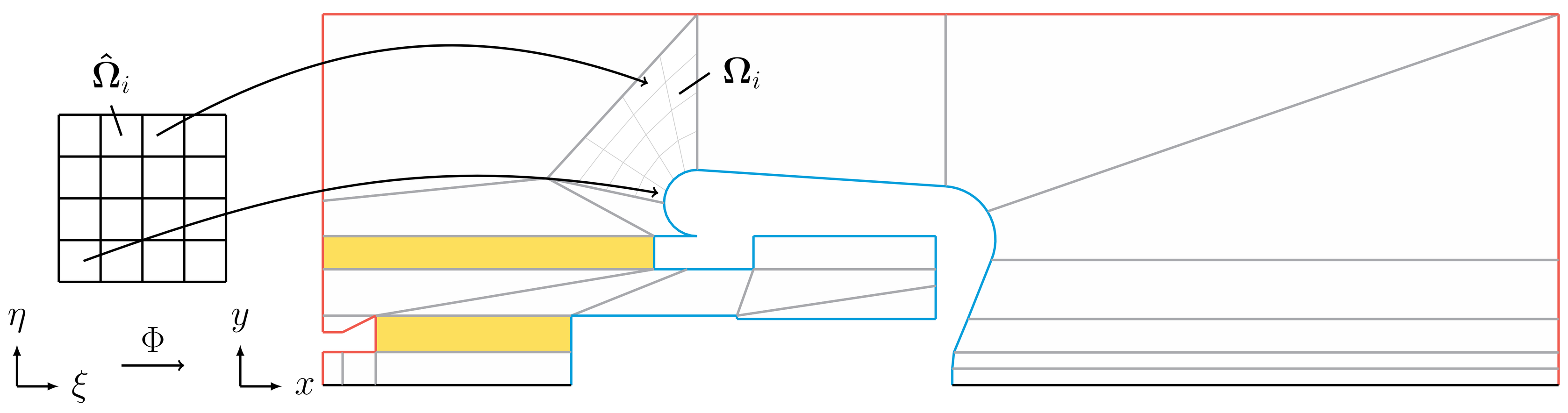
The underlying electrostatic problem is described by Maxwell's equations and the PDE reads

$$\nabla \cdot (\varepsilon \nabla \varphi) = 0 \quad \text{in } \Omega,$$

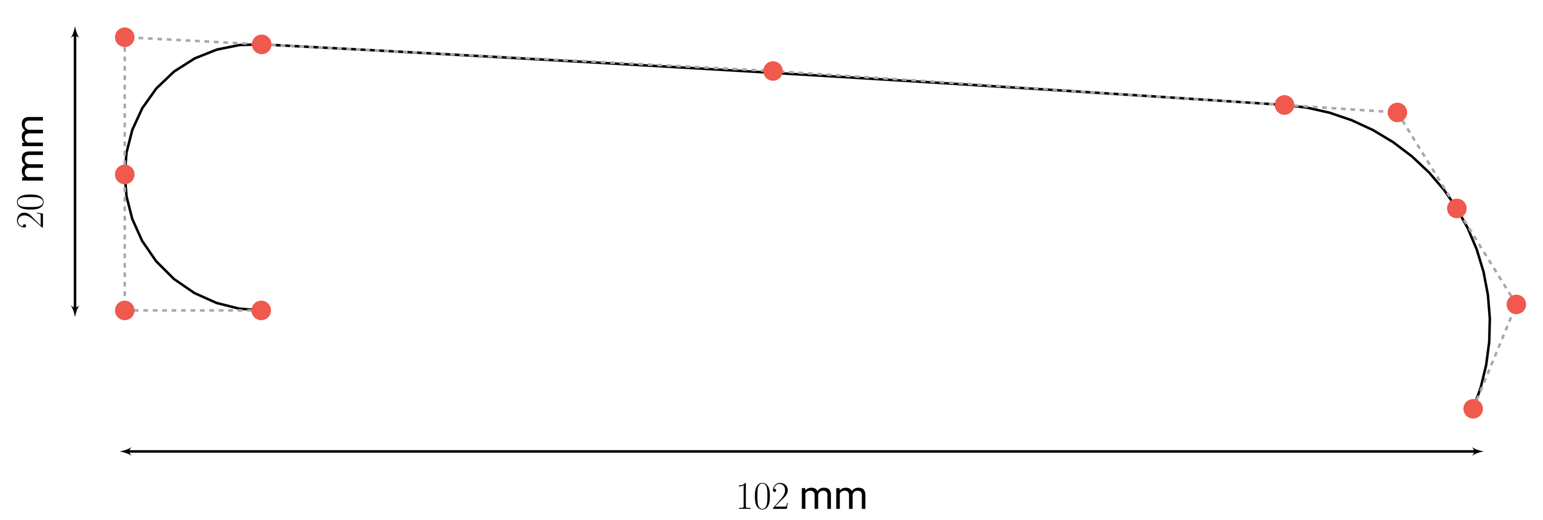
where φ is the electrostatic potential, ε the electric permittivity and Ω the problem domain.

Isogeometric Analysis

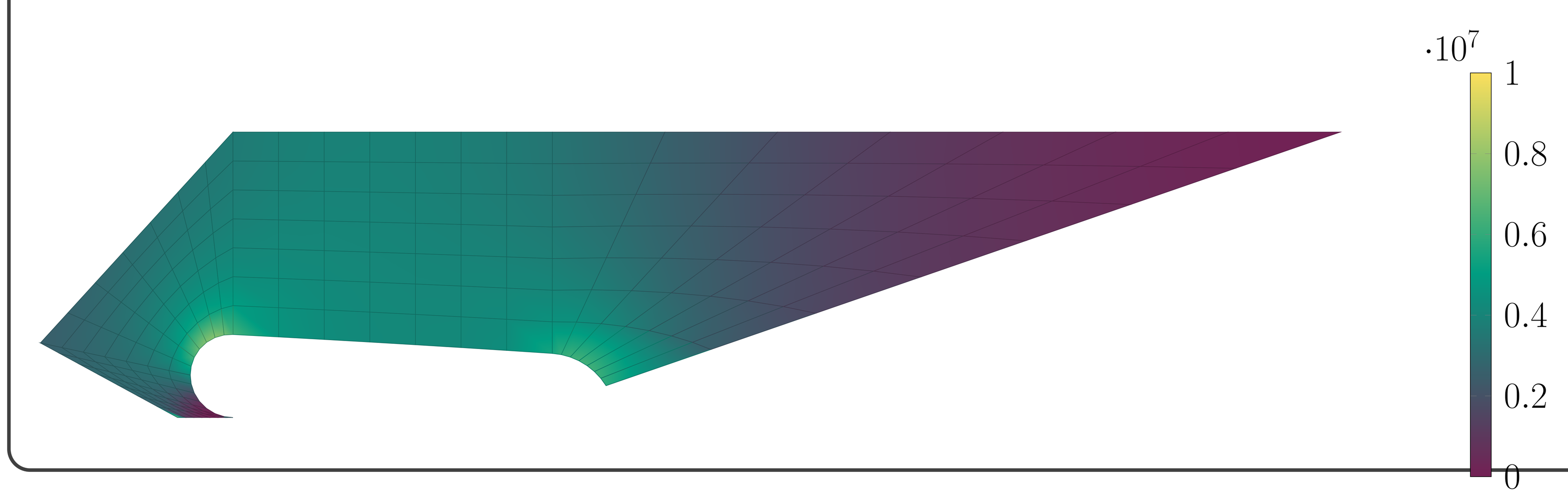
Isogeometric Analysis employs NURBS basis functions for both the geometry description and as the solution space of the numerical method. This allows to exactly represent curved geometries and at the same time leads to smooth field solutions.



The elements of a patch share a single parameter space and are mapped to the physical space via a NURBS mapping $\Phi : \hat{\Omega}_i \to \Omega_i$. Individual curves can easily be manipulated by moving their control points and multiple curves may be glued together to attain higher continuity at their boundaries.



Using the C^1 continuous curve for the optimization guarantees an optimized geometry that is manufacturable.



Geometry Optimization

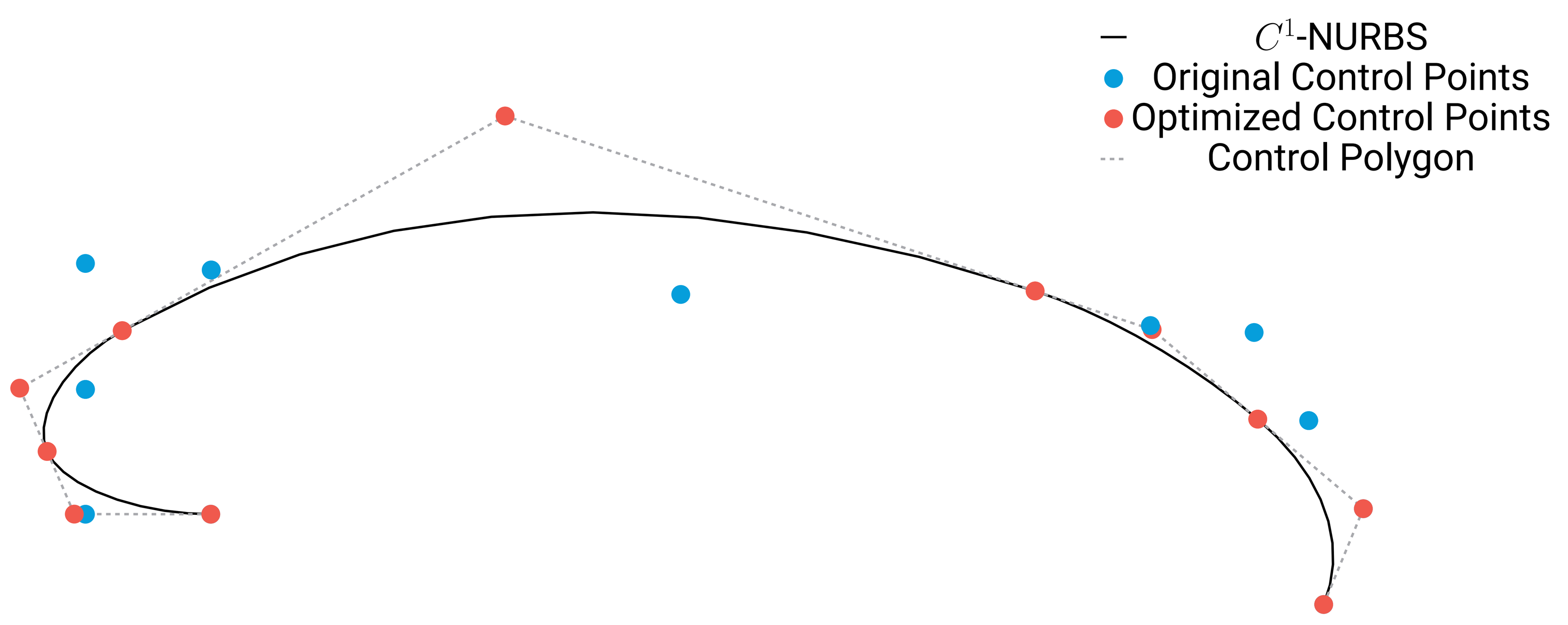
The aim of the optimization is to minimize the maximal electric field strength in the vicinity of the electrode. This is accomplished by finding an optimal configuration of the control points under the constraints that the volume of the electrode may not exceed a certain limit and the patches should not become degenerate. The cost function is given by

$$f(\mathbf{p}) = \frac{1}{|I|} \sum_{i \in I} \max_{\mathbf{x} \in \Omega_i} \|\mathbf{E}(\mathbf{x})\|_2,$$

where $\mathbf{p}$ denotes the control point coordinates, I is an index set and $\mathbf{E}$ is the electric field. The domains Ω_i are approximated by the quadrature nodes. The maxima are averaged to ensure that the field strength is simultaneously minimized on each of the patches. The full optimization formulation then reads

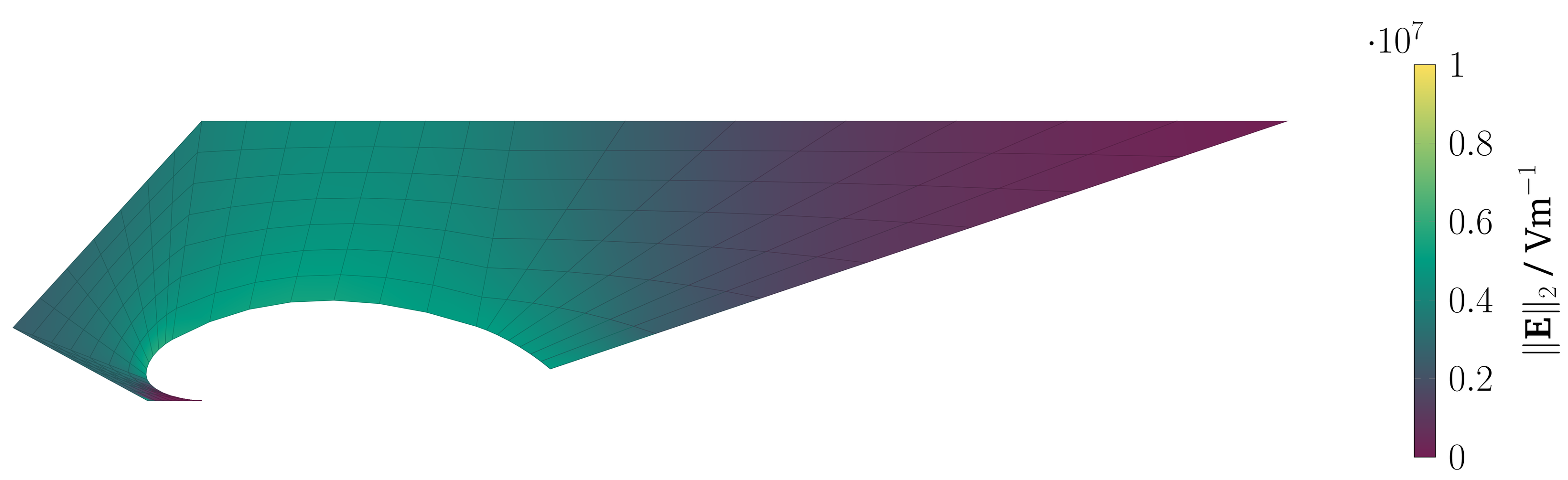
$$\begin{aligned} \min_{\mathbf{p}} \quad & f(\mathbf{p}), \\ \text{subject to} \quad & \mathbf{h}(\mathbf{p}) \leq \mathbf{0}, \end{aligned}$$

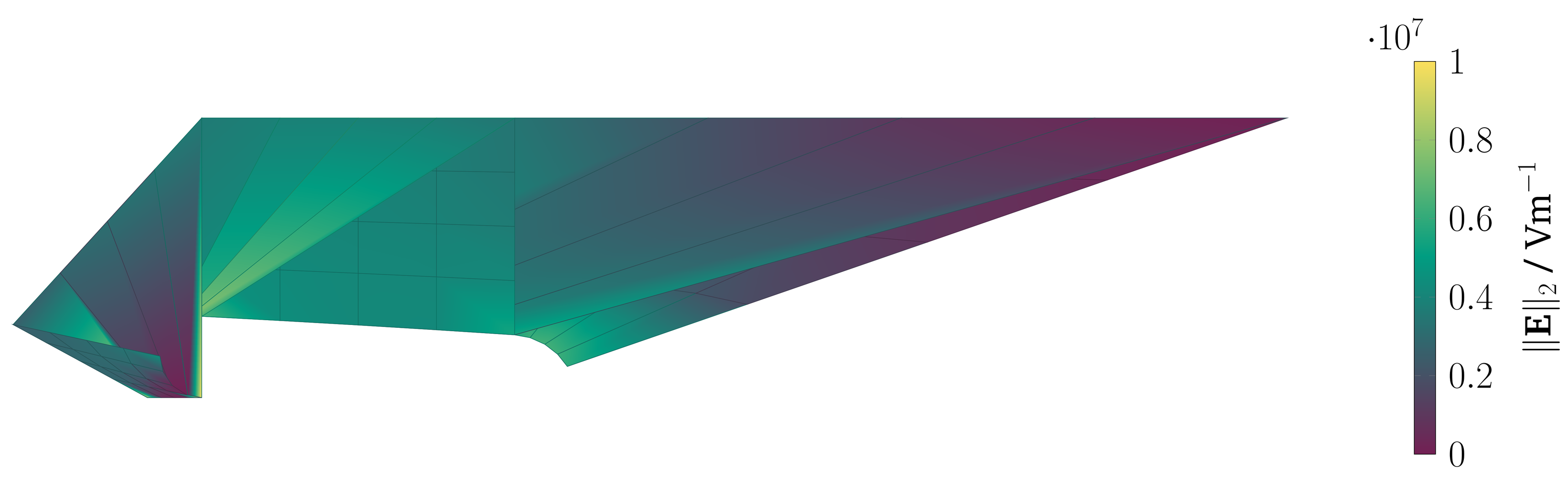
where $\mathbf{h}$ is made up of constraints on the volume of the electrode and the relative position of the conrol points.



Results

show field magnitude for starting and optimized geometry (also values?) cst as well?





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