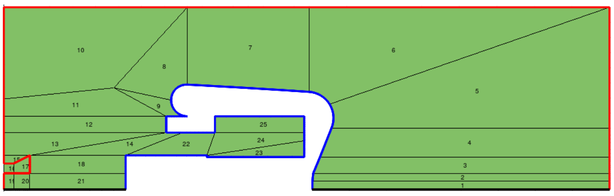
1 Shape Optimization of a Photo Gun

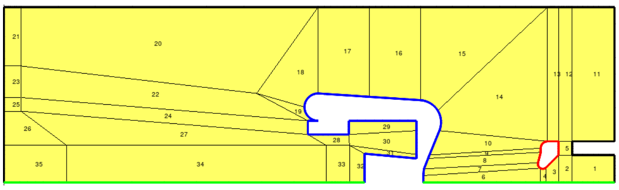
1.1 Geometry

The two latest geometries are depicted in fig. 1a and fig. 1b. The numbers refer to the individual patches in the context of IGA. The patch boundaries are indicated by grey lines.

We also observe triple points within the computational domain. These are defined by material boundaries between air/vacuum, steel and the insulator.



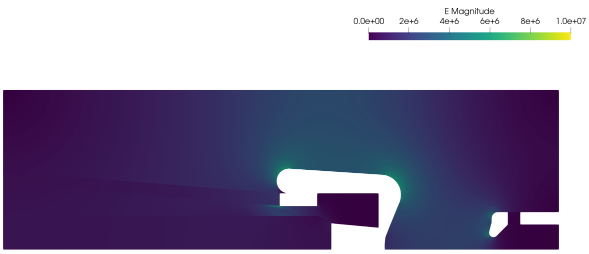
(a) Version 5.



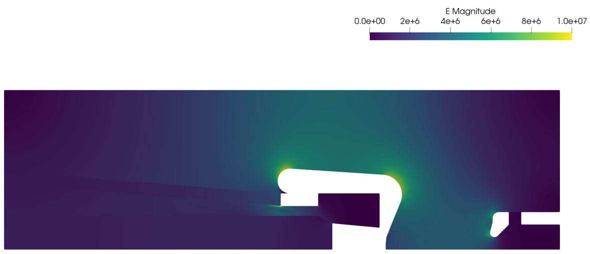
(b) Version 6.

1.2 Electric Field

The solution for the electric field are shown in fig. 2a and fig. 2b. It was computed with $p = 2$ as the degree of the basis functions and $n_{\text{sub}} = 16$ as the number of elements that each knot vector is uniformly split into. It is evident that there exist parts of the domain where the magnitude of the electric field is close to the limit of $10\frac{\text{MV}}{\text{m}}$. There are also very high gradients visible at the triple points, however these also coincide with sharp corners so numerical issues might play a role.



(a) 200kV.



(b) 300kV.

1.3 Optimization

The aim of the optimization is to minimize the maximal field amplitudes. For practicality we will only look at the critical points of the geometry, i. e. the curvatures of the upper electrode and their respective control points are the DoFs. Aside from geometrical constraints we also consider a volume constraint.

1.3.1 Cost Function

1.3.2 Volume Constraint

1.3.3 Additional Constraints

As an additional constraint we require C^1 continuity of the section that is optimized. The starting nurbs is depicted in fig. 3. Furthermore the control points, which represent the DoFs, are constrained to stay inside their respective patch boundaries and in the correct order.

Figure 3: C^1 continuous nurbs that is to be optimized including the variable control points which represent the DoFs.

1.3.4 NLopt

For the optimization we used implementations of BOBYQA and COBYLA as given by the NLopt libary.

1.3.5 Results

Figure 4: Optimization result using BOBYQA.

In order to compare the results with the original geometry and simulation the optimized geometry was also imported and simulated in CST. The results indicate a clear improvement from the optimized geometry over the original one. This is in agreement with the numerical improvement observed in the context of IGA.

Figure 5: Mesh of original and optimized geometry in CST.

Figure 6: Results of original and optimized geometry in CST.

1.4 Questions

- new maximal volume for electrode?
- volume constraint for anode ring?
- make size of patch 1/11 also a parameter? (shorter connector)
- how much is inner insulator or already PEC?

- let constraint for Lagrangian return Inf or rather make all similar magnitude? (vector for ctrl-constraint)

- fieldmap convergence (fixed $H_{\max}$, field from optimization)
- laser spot 4 mm (rms beam size)?
- how many probe particles?
- time integrator convergence (fixed fieldmap, $H_{\max} = H_{\min}$)
- 3D space charge or 2D cylindrical grid? (tracking always in 3D)
- space charge convergence (number of grid cells, number of particles)

- cost function, rms beam size (individual trajectories)

1.5 Astra

In the future we may also optimize the electrode boundary next to the puck, i. e. patches 3, 4 and 5 to obtain optimal particle trajectories. The cost function will be computed using Astra. The desired total bunch charge is 10 pC with a beam current of $(20 - 100)\ \mu$A, whereas a typical value would be 100 fC. The bunch length is around 5 ps with a normalized transversal emittance of $e_{x,y} \leq 1$ mm mrad. The desired energy resolution is $\frac{\Delta E}{E} \leq 10^{-4}$. The tracking will be performed using individual bunches from a pulsed laser. The emission model may be derived from [**wagner**].