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Optimization of the T4FASC-CSS-SPVSHC and T4FASC-CSS-CPVCHC configurations

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Abstract

In this paper, numerical simulations are used to explore the peak focal impulse amplitude and the beam width as a function of the feed-arm and loft lengths, height of the cylindrical support structure and the radius of the pressure vessel for the T4FASC-CSS-SPVSHC configuration. The feed-arm and loft lengths of the T4FASC-CSS-CPVCHC structure are also explored in a similar manner. The results are used to identify practically suitable ranges which yield reasonable electric field amplification with a small compromise in the spot size.

1 Introduction

The T4FASC-CSS-SPVSHC and T4FASC-CSS-CPVCHC structures have been established as the most attractive configurations [1–3]. However, the dimensions of the components were arbitrarily chosen to gain some insight into the problem [1, 2]. Therefore, the next (and final) stage is to optimize various parameters of the designs. In this paper, the peak focal impulse amplitude, E_{max}, and the spot size are investigated as a function of the following parameters,

- feed-arm and loft lengths, l, for T4FASC-CSS-SPVSHC and T4FASC-CSS-CPVCHC,
- the height of the CSS, H_{css}, for T4FASC-CSS-SPVSHC,
- the radius of the pressure vessel, r_{pv}, in T4FASC-CSS-SPVSHC.

The primary objective is to find a range of practically suitable values for the parameters which yield a large E_{max} with a very small compromise in the spot size.

The geometry of the switch cones, and hence the hydrogen chamber, are representative of typical dimensions used in fabrication and are therefore not explored here. The radius of the oil container is not significant as long as it fully encloses the pressure vessel.

2 Setup

2.1 Structure visualization

2.1.1 T4FASC-CSS-SPVSHC configuration

The setup is identical to that in [1]. Figure 2.1 shows the side view and geometrical details of the system. Recall from [4] that the maximum E_{max} was obtained for a loft height of $h_{\text{loft}} = 8.0$ cm $\approx (4/5)l_{\text{loft}}$. The total length is $l = l_{\text{loft}} + l_{\text{FA}}$, where

$$l_{\text{loft}} \approx \begin{cases} (5/4)h_{\text{loft}}, & \text{if } h_{\text{loft}} \leq 8.0 \text{ cm}, \\ (5/4)\ 8, & \text{if } h_{\text{loft}} > 8.0 \text{ cm}, \end{cases} \tag{2.1}$$

and $(h_{\text{loft}} \leq 8.0 \text{ cm}) \Rightarrow l_{\text{FA}} = 0$ cm.

When optimizing each parameter, the remaining dimensions are kept identical to those in [1].

2.1.2 T4FASC-CSS-CPVCHC configuration

The setup is identical to that in [2]. Figure 2.2 shows the side view and geometrical details of the system. Note that for this configuration H_{css} is fixed by the formulas in [5] and therefore does not need to be optimized. The effect of the pressure vessel radius has already been examined in [2].

3 CST parameters

- CST parameters and probe placements are identical to those in [6].
- In all simulations, a discrete port, 1 V, 100 ps, ramp rising step, excitation is applied between a 2 mm gap in the switch cones.

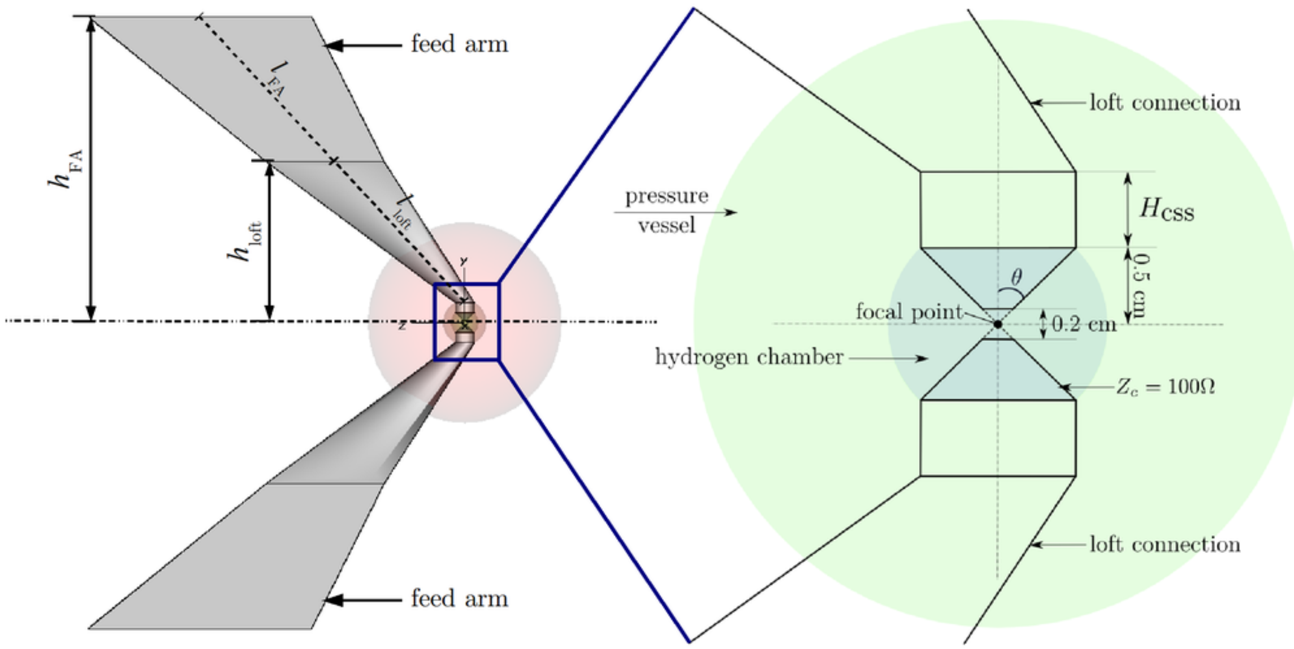

Figure 2.1: "Zoomed-in" side view and geometric details of switch system for the T4FASC-CSS-SPVSHC configuration.

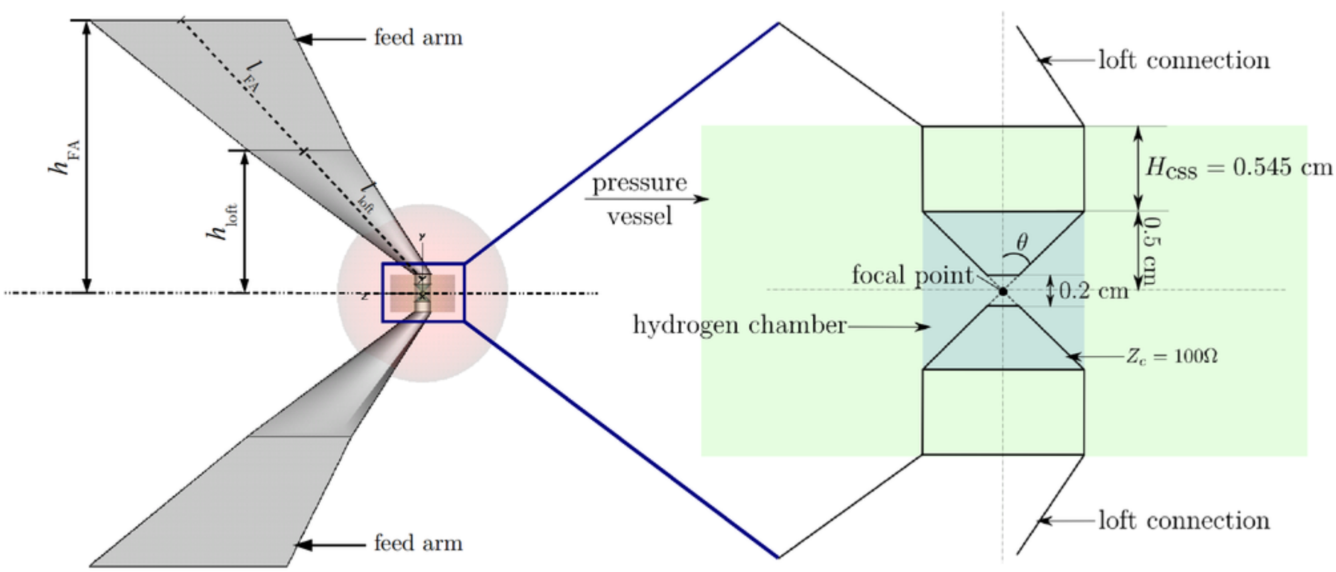

Figure 2.2: "Zoomed-in" side view and geometric details of switch system for the T4FASC-CSS-CPVCHC configuration.

4 Results

4.1 T4FASC-CSS-SPVSHC

4.1.1 Feed-arm and loft lengths, $l = l_{\mathbf{FA}} + l_{\mathbf{loft}}$

The peak focal impulse amplitude and beam width as a function of the feed-arm and loft lengths, $l = l_{\mathrm{FA}} + l_{\mathrm{loft}}$, are shown in Fig. 4.1. One observes that a range of 18 cm $\leq l \leq$ 22 cm yields the highest peak electric fields and beam widths. As in [4], $l \approx 19.0$ cm yields the maximum $E_{\max}$ and the largest spot size. There is approximately a 10.95% decrease in $E_{\max}$ from $l = 19.0$ to $l = 62.5$ cm. The corresponding decrease in spot size is only 6.15%.

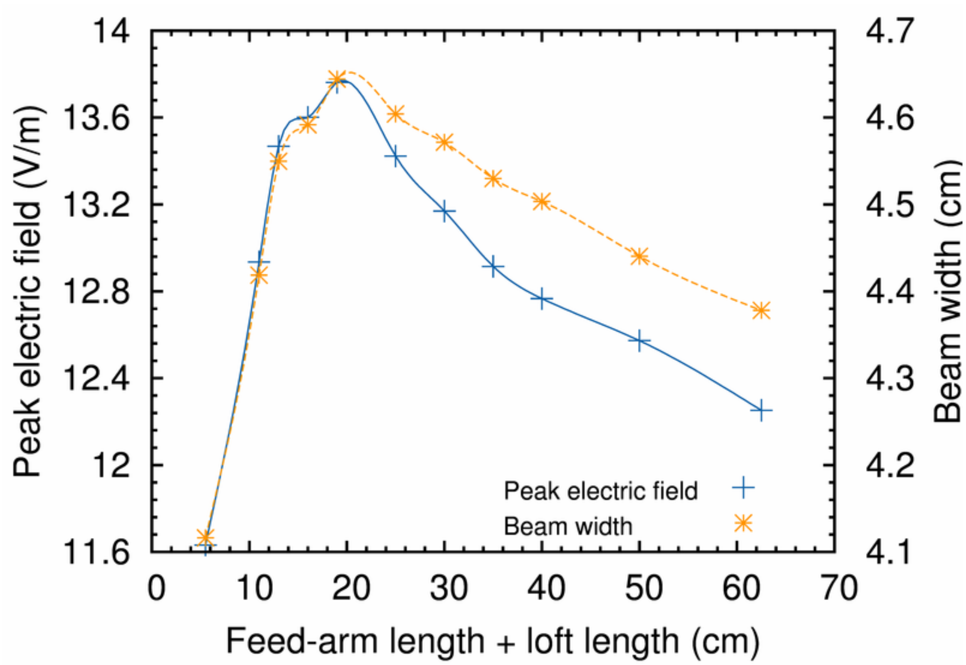

Figure 4.1: Peak focal amplitude and spot size as a function of feed-arm and loft lengths for the T4FASC-CSS-SPVSHC configuration.

4.1.2 Height of CSS, H_{css}

The peak focal impulse amplitude and beam width as a function of the height of the cylindrical support structure, H_{css}, are shown in Fig. 4.2. Clearly, a smaller H_{css} is more preferrable as it yields a large $E_{\max}$. This is because a small H_{css} minimally perturbs the guiding structures (feed arms and loft connections) in the time of interest, i.e., $H_{\mathrm{css}} \ll ct_{\delta}$. A range of 0.2 cm $\leq H_{\mathrm{css}} \leq 0.6$ cm provides a reasonable amplification in $E_{\max}$ without much compromise in the spot size.

4.1.3 Radius of pressure vessel, r_{pv}

The peak focal impulse amplitude and beam width as a function of the pressure vessel radius, r_{pv}, are shown in Fig. 4.3. Although the electrical length of the loft and feed-arms increases with increase in r_{pv}, this increase is insignificant as observed in Fig. 4.3. Experimentally however, two criteria dictate the size of the pressure vessel,

1. It is simpler to provide structural support to a large PV,
2. Too large a PV would lead to intolerable loss and dispersion in the dielectric medium.

Based on the above constraints one finds 1.50 cm $\leq r_{\mathrm{pv}} \leq 3.0$ cm to be a practically suitable range.

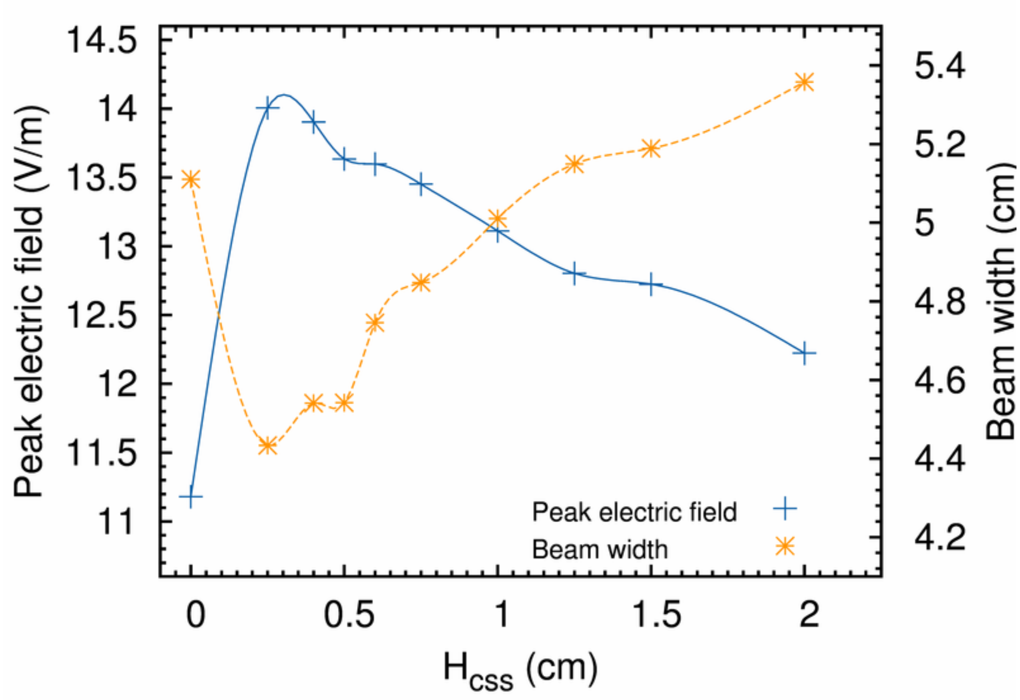

Figure 4.2: Peak focal amplitude and spot size as a function of H_{css} for the T4FASC-CSS-SPVSHC configuration.

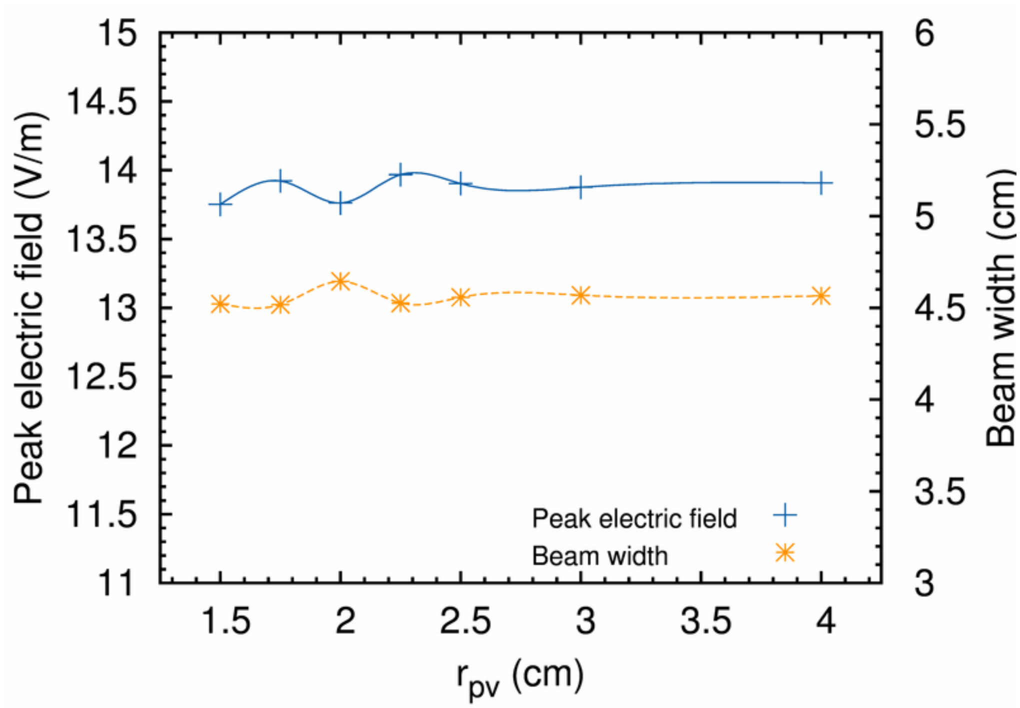

Figure 4.3: Peak focal amplitude and spot size as a function of the pressure vessel radius, r_{pv}, for the T4FASC-CSS-SPVSHC configuration.

4.2 T4FASC-CSS-CPVCHC

4.2.1 $l_{\mathbf{FA}}$ and $l_{\mathbf{loft}}$

The peak focal impulse amplitude and beam width as a function of the feed-arm and loft lengths, $l = l_{\mathrm{FA}} + l_{\mathrm{loft}}$ are shown in Fig. 4.4. The results are almost identical to the T4FASC-CSS-SPVSHC case, i.e., a range of 18 cm $\leq l \leq$ 22 cm yields the highest peak electric fields; $l \approx 19.0$ cm yields the maximum E_{max} and the largest spot size. There is approximately a 12.96% decrease in E_{max} from $l = 19.0$ to $l = 62.5$ cm. The corresponding decrease in spot size is only 4.99%.

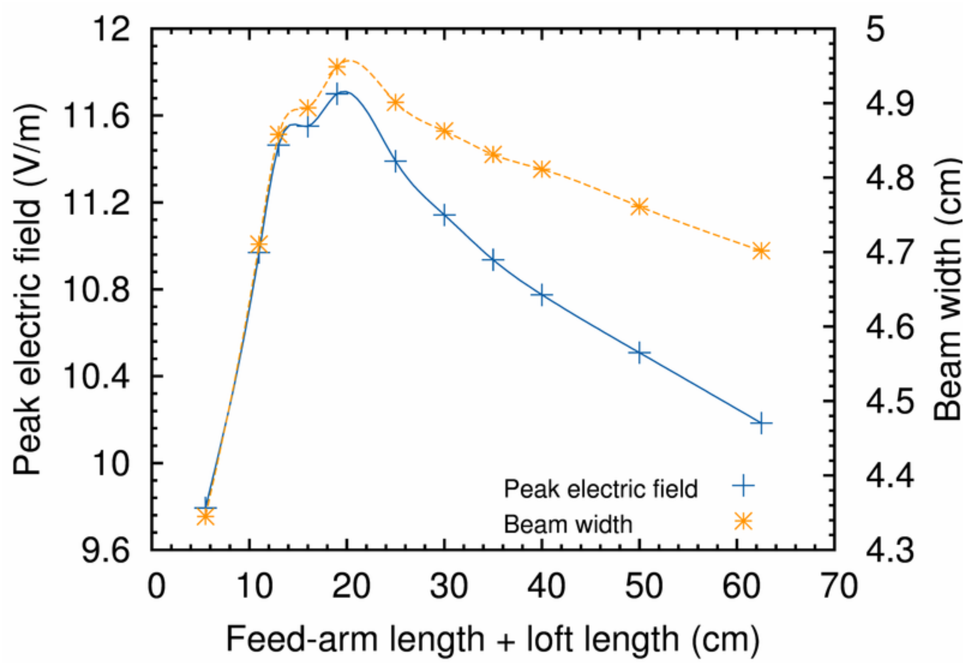

Figure 4.4: Peak focal amplitude and spot size as a function of feed-arm and loft lengths for the T4FASC-CSS-CPVCHC configuration.

5 Conclusions

For the T4FASC-CSS-SPVSHC configuration the following ranges for l, H_{css} and r_{pv} yield a reasonable electric field amplification with a small, acceptable compromise in the spot size,

- 18 cm $\leq l \leq$ 22 cm
- 0.2 cm $\leq H_{\mathrm{css}} \leq$ 0.6 cm
- 1.50 cm $\leq r_{\mathrm{pv}} \leq$ 3.0 cm

The peak electric field is obtained for $l \approx 19.0$ cm, $H_{\mathrm{css}} \approx 0.2$ cm and is independent of r_{pv}. However, experimentation may be required to more accurately determine precise dimensions. For the purposes of further discussion, henceforth, $l = 19.0$ cm, $H_{\mathrm{css}} = 0.2$ cm and $r_{\mathrm{pv}} = 2.0$ cm is assumed unless mentioned otherwise.

The range of l for the T4FASC-CSS-CPVCHC configuration is identical to the T4FASC-CSS-SPVSHC design. Again, for the purposes of further discussion, $l = 19.0$ cm is assumed.

References

[1] Prashanth Kumar, Carl E. Baum, Serhat Altunc, Christos G. Christodoulou and Edl Schamiloglu, "The truncated four feed-arm configuration with switch cones (T4FASC) and a spherical pressure vessel." EM Implosion Memo 42, May 2010.

[2] Prashanth Kumar, Carl E. Baum, Serhat Altunc, Christos G. Christodoulou and Edl Schamiloglu, "The truncated four feed-arm configuration with switch cones (T4FASC) and a cylindrical pressure vessel." EM Implosion Memo 43, May 2010.

[3] Prashanth Kumar, Carl E. Baum, Serhat Altunc, Christos G. Christodoulou and Edl Schamiloglu, "150 Ω impedance-matched bicone switch configuration with a spherical pressure vessel." EM Implosion Memo 43, May 2010.

[4] Prashanth Kumar, Carl E. Baum, Serhat Altunc, Christos G. Christodoulou and Edl Schamiloglu, "Optimization of the feed arm and loft lengths for the truncated four feed arms with switch cones (T4FASC) configuration." EM Implosion Memo 40, Feb. 2010.

[5] Prashanth Kumar, Carl E. Baum, Serhat Altunc, Christos G. Christodoulou and Edl Schamiloglu, "Design considerations for a cylindrical pressure vessel with a spherical launching lens." EM Implosion Memo 40, Mar. 2010.

[6] Prashanth Kumar, Carl E. Baum, Serhat Altunc, Christos G. Christodoulou and Edl Schamiloglu, "Effect of the impedance of a bicone switch on the focal impulse amplitude and beam width." EM Implosion Memo 38, Feb. 2010.