Simulation of Multipaction in LB650 Cavity with Weld Profile

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Motivation

SRF cavities are used primarily for the purposes of accelerating particles but have found its use in other fields such as exploration of dark photons, quantum computing and other dark matter searches due to its capability to store and harness electromagnetic energy with high efficiency . Hence an extensive understanding of the various properties of SRF cavities such as multipaction, cavity geometry, material property etc. is of great importance to aid in the progress of understanding the mysteries of the universe.

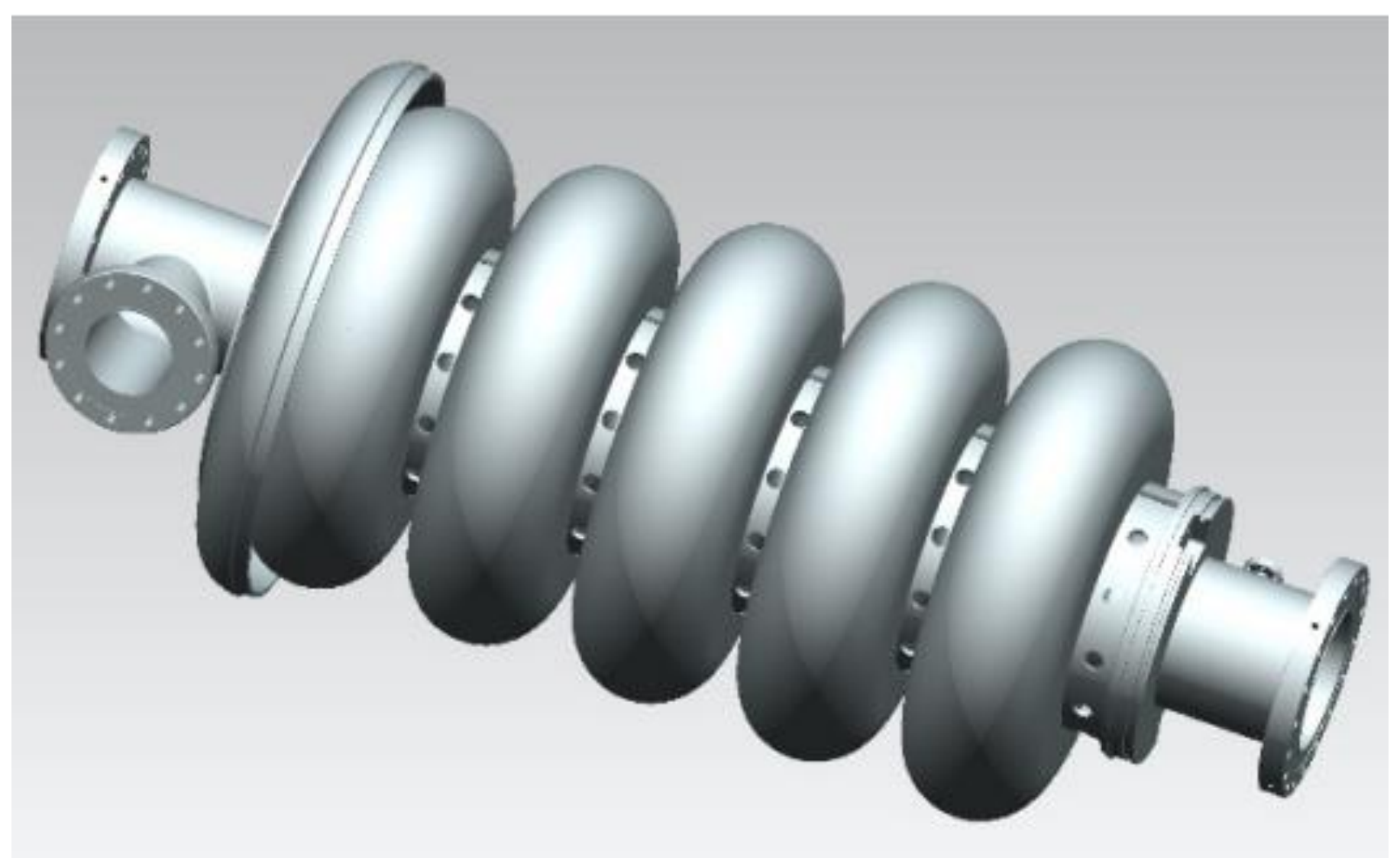

Figure 1: 3D rendering of LB650 Cavity proposed for PIP-II

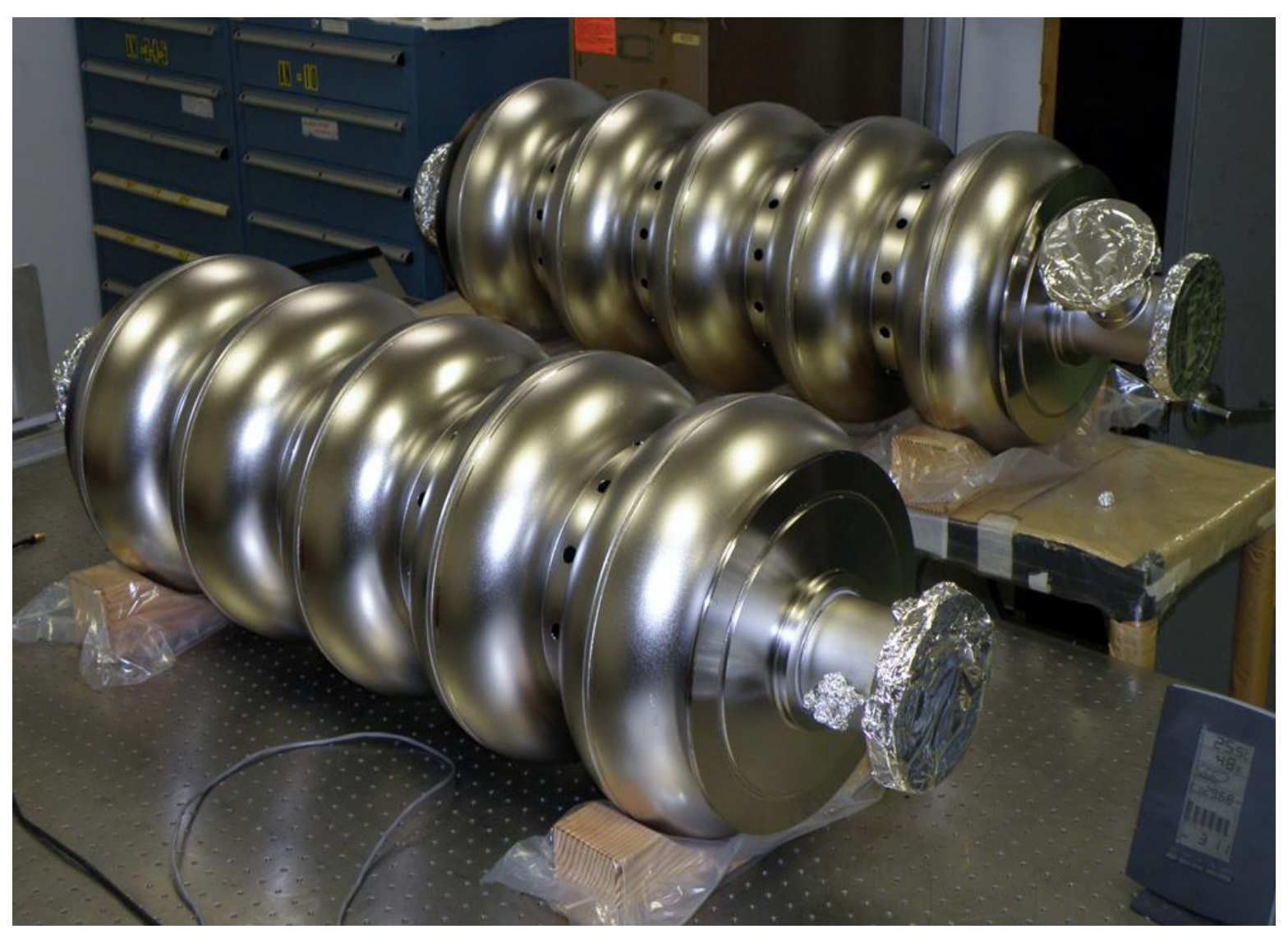

Figure 2: LB650 Cavity used in PIP-II

Introduction

Multipaction is a performance limiting phenomenon of SRF cavities, in which electrons get caught in the resonant process and releases an avalanche of electrons. This resonant discharge is observed when there is presence of clean surfaces with high SEY (such as Niobium) in combination with RF power. The conditions for multipaction are that electrons synchronize with RF fields and secondary emission coefficient is greater than unity leading to multiplication of electrons. This results in absorption of RF power for secondary emission of electrons and the generated heat at specific locations within the cavities lead to quenching of the superconducting cavity.

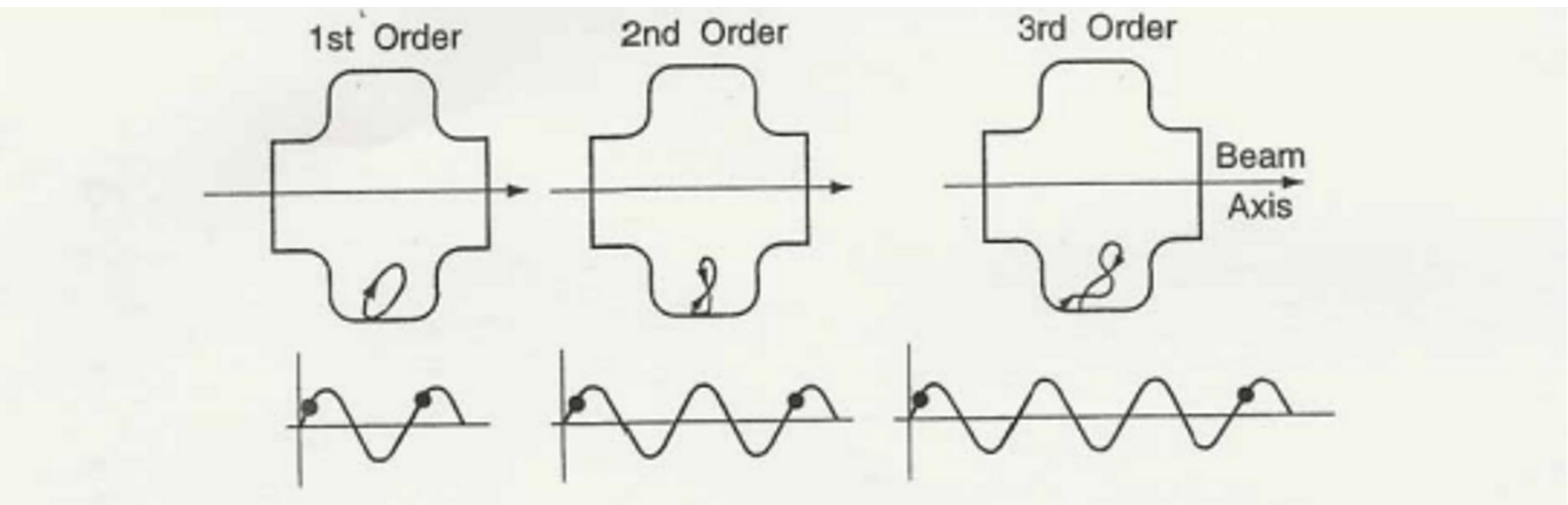

Figure 3: Multipaction in cavity equator of different orders

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Purpose

This study aims to simulate multipaction in LB650 cavity with weld profile, a first step to replicating an actual cavity, whereas past studies have ignored the same. We attempt to align the simulation data with the experimental data and report the subsequent findings.

Experiment

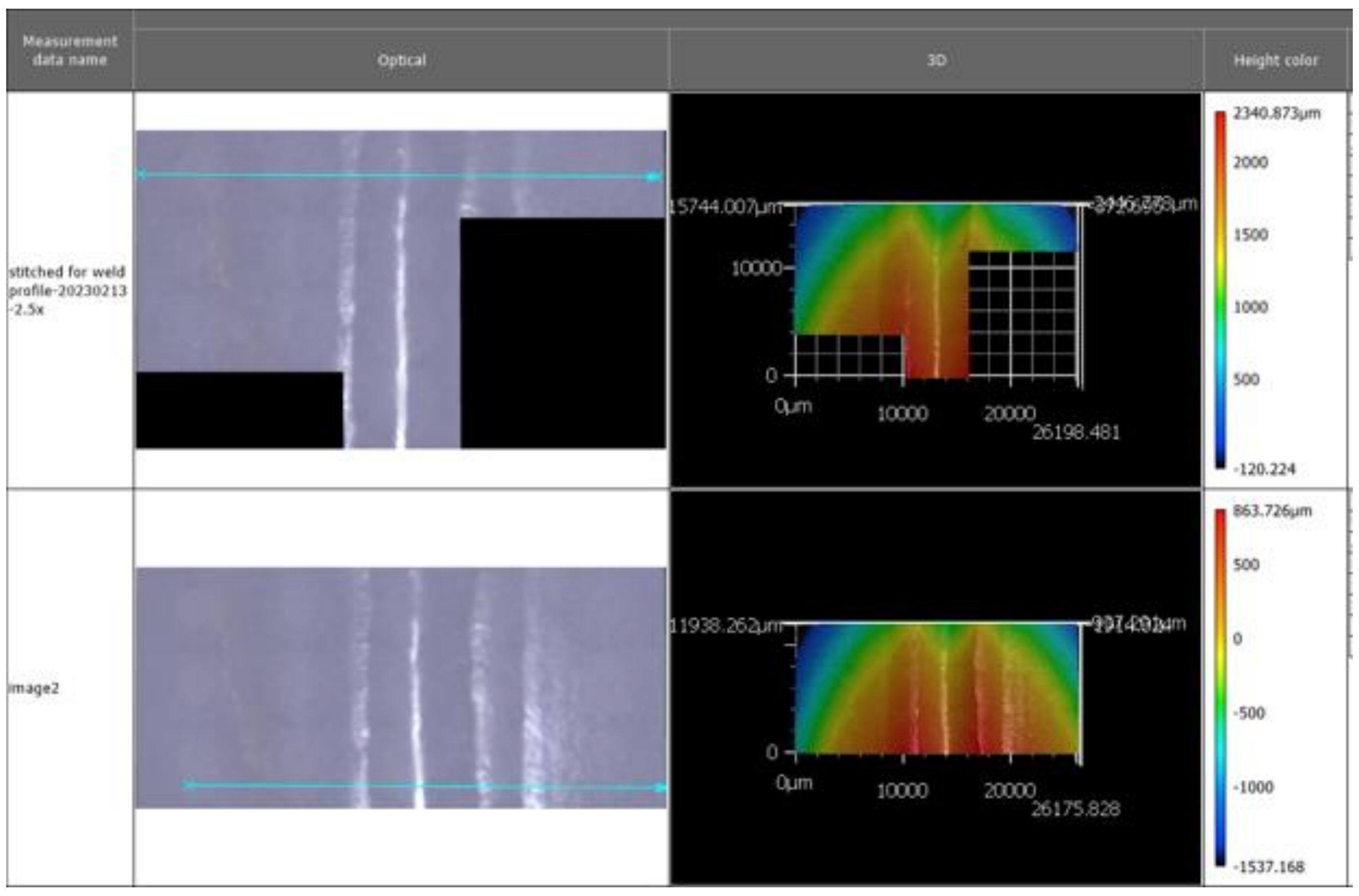

Figure 4: Microscopic analysis of LB650 Welds

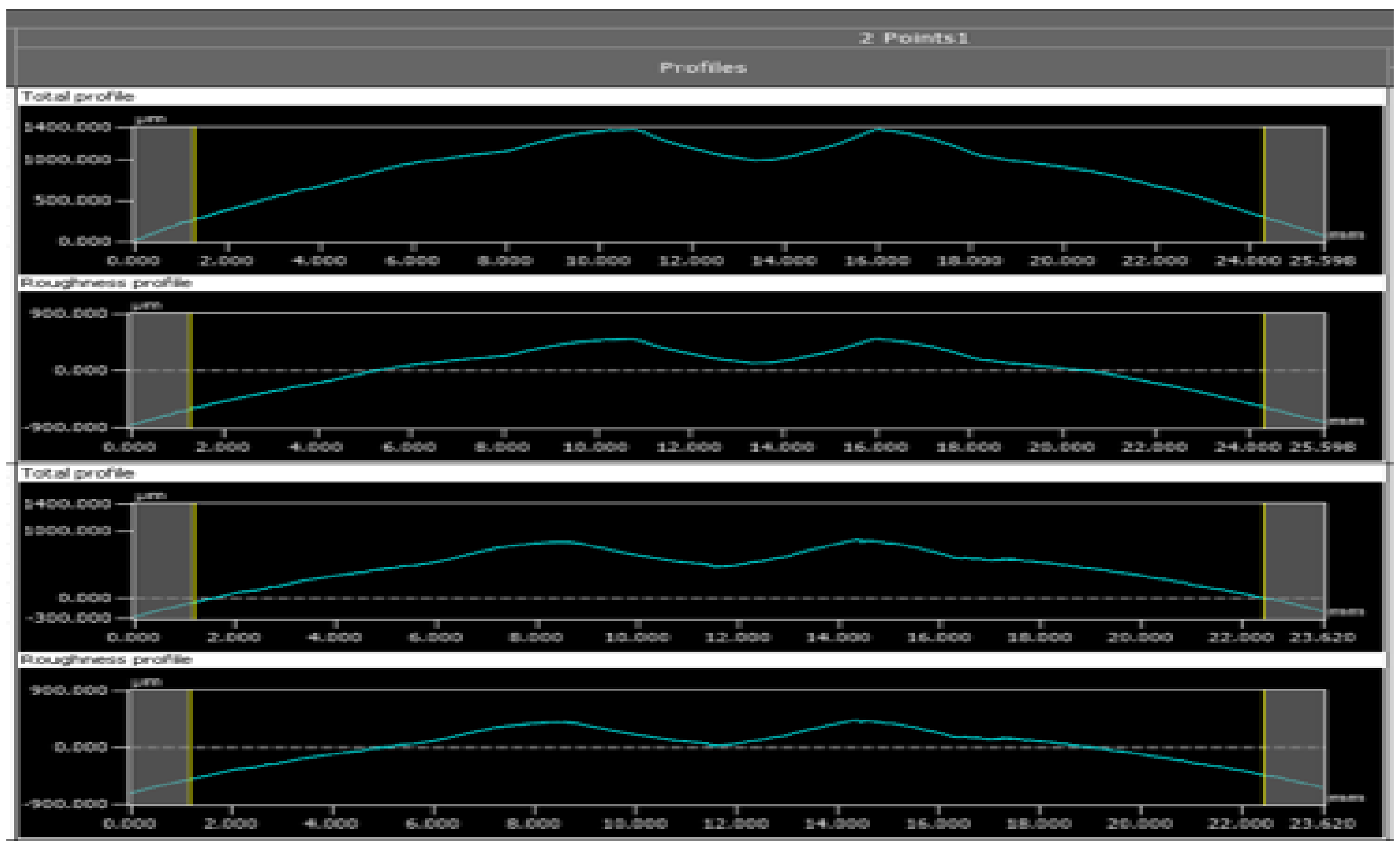

Figure 5: Weld profiles extracted from LB650 cavities

In order to carry out MP simulations for LB650 cavities, an experiment was carried out to capture the weld profile of the cavity. The procedure involves making an epoxy mold of the weld, the mold is imaged under an optical microscope, and then analyzed to make measurements. In our experiment, multiple LB650 cavities were analyzed and yielded an average radius of 10.6304 mm.

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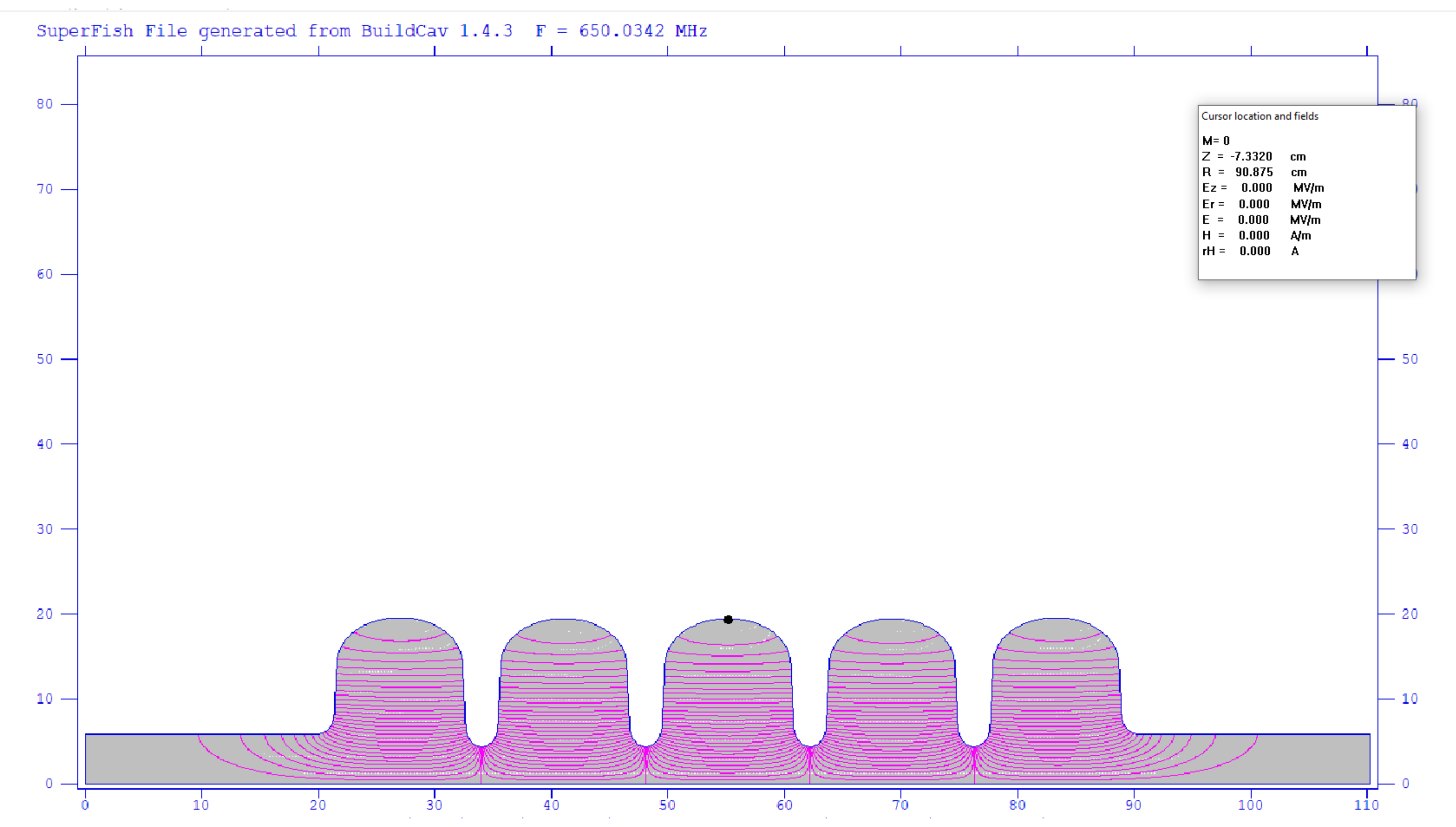
Simulation Methodology

In order to aid our understanding of multipaction in LB650 cavities, numerical tools have been built to evaluate RF structures. Since LB650 cavities are axisymmetric in nature, for the purposes of this project, we resorted to use of 2D modelers. Our first step was to generate a geometric and electromagnetic field description of the cavity, with special emphasis on quality of RF fields on RF surfaces, this is achieved with Superfish code. The generated solutions are then imported into a particle tracking software, in our case Fishpact code. The input parameters include a range of phases, changing accelerating gradient, initial energy of the primary electron and the SEY coefficient of the material, in this case Wet Niobium.



```
M= 0
Z  =  -7.3320    cm
R  =   90.875    cm
Ez =    0.000     MV/m
Er =    0.000     MV/m
E  =    0.000     MV/m
H  =    0.000     A/m
rH =    0.000     A
```

Figure 6: Superfish generated EM field for LB650 cavity

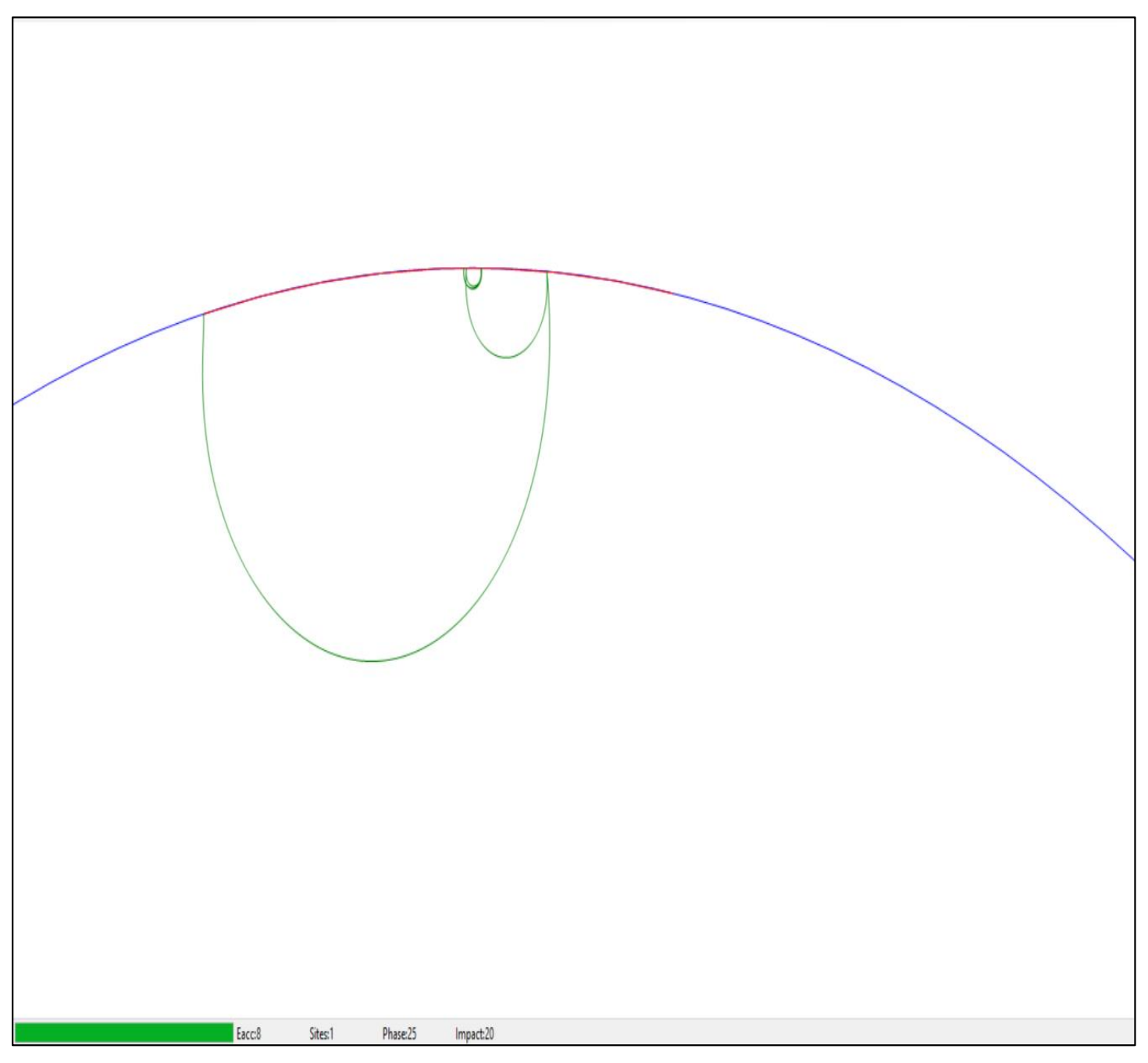


Figure 7: Multipaction of LB650 Cavity w/o Weld Bead

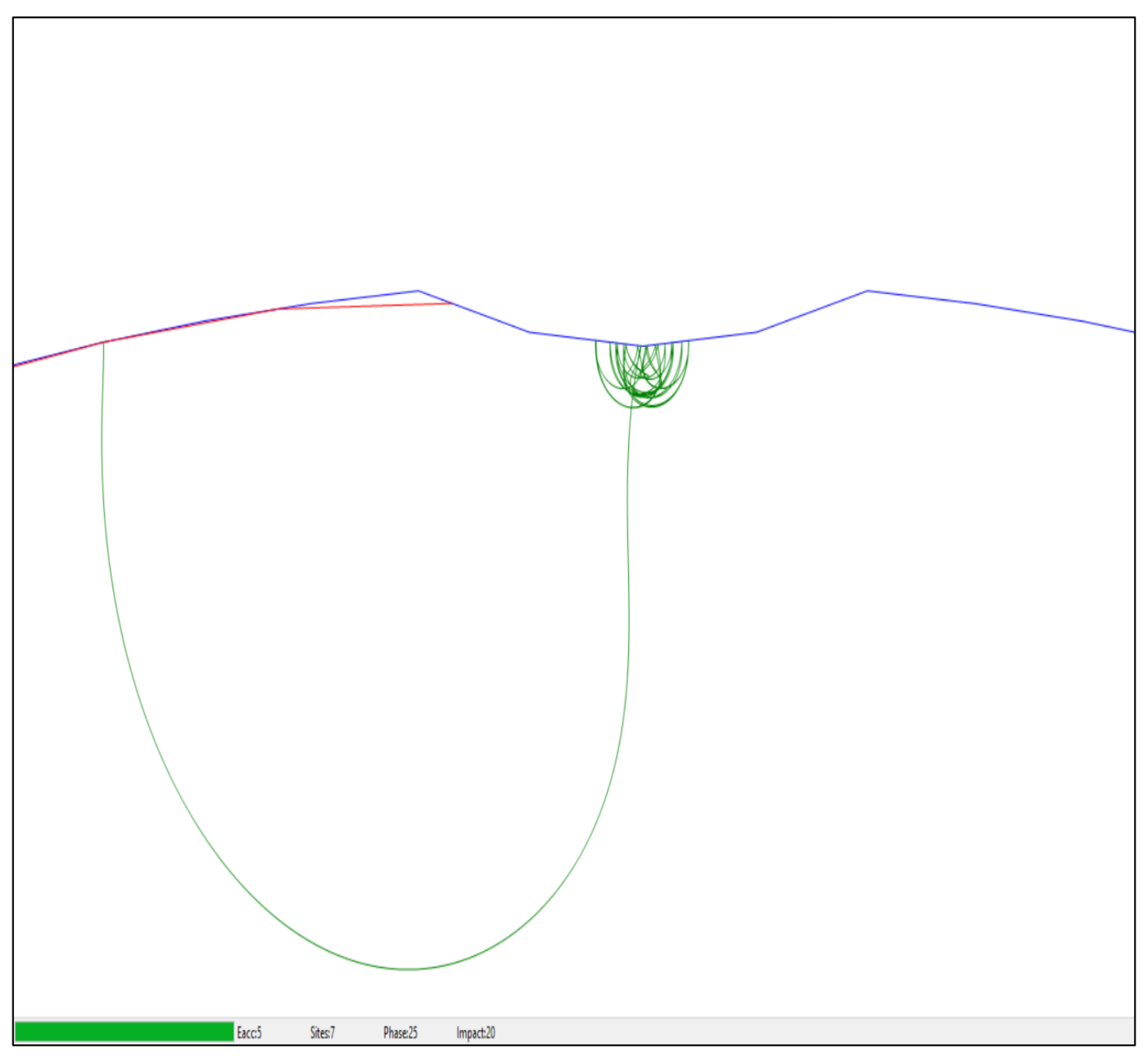
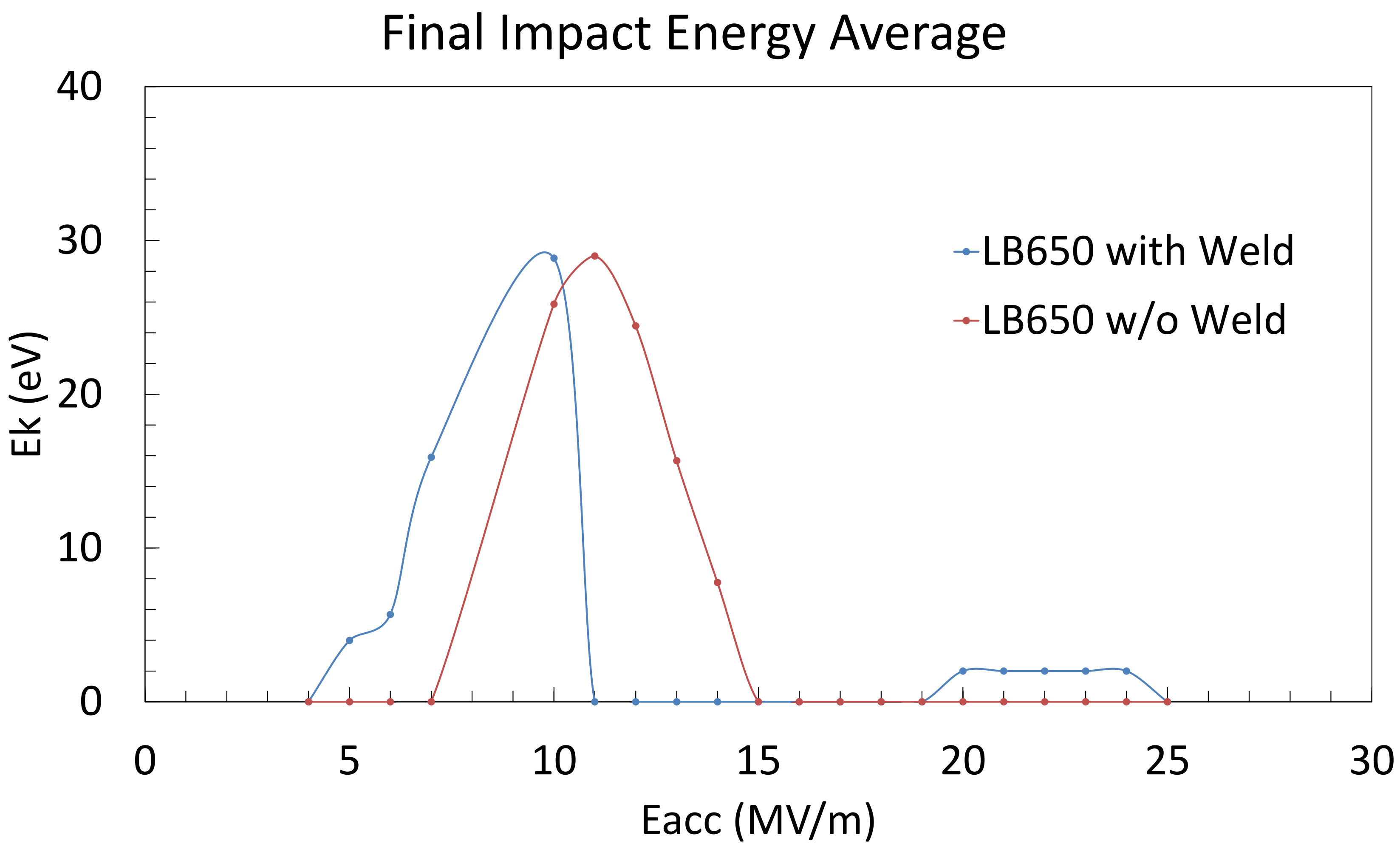


Figure 8: Multipaction of LB650 Cavity with Weld Bead

Results and Discussion

The inclusion of the weld profile in the simulation, have yielded different MP trajectories from the typically observed trajectories of similar cavities (Figure 7 and Figure 8). From the graph, a leftward shift in the peak is observed when the weld bead is taken into account in the cavity. The implication being that electrons achieves peak kinetic energy at lower accelerating gradient for such cavities. Further studies need to be done in order to understand the underlying theory behind this shift.



Conclusion

The analysis of multipaction for LB650 cavity with weld profile is first of its kind. These results are only a preliminary indication of multipaction, and further analysis is required, wherein more realistic form of electron simulation is accounted for. Such statistical methods include the Monte Carlo method, and Furman and Pivi's secondary emission model. Another avenue for further exploration of MP of cavities with weld profile, is 3D simulation of multipaction with CST Particle Studio, which can take into consideration space charge effects (usually ignored by most multipaction simulation codes) and help develop quantitative parameters of multipaction process such as discharge current, power, energy spectrum etc.

References

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