Abstract

Experimental study of DC vacuum breakdown and application to high-gradient accelerating structures for CLIC

The compact linear collider (CLIC) is a leading candidate for the next generation high energy linear collider. As any breakdown would result in a partial or full loss of luminosity for the pulse in which it occurs, obtaining a low breakdown rate in CLIC accelerating structures is a critical requirement for the successful operation of the proposed collider. This thesis presents investigations into the breakdown phenomenon primarily in the low breakdown rate regime of interest to CLIC, performed using the CERN DC spark systems between 2011 and 2014.

The design, construction and commissioning of several new pieces of hardware, as well as the development of improved techniques to measuring the inter-electrode gap distance are detailed. These hardware improvements were fundamental in enabling the exciting new experiments mentioned below, which in turn have provided significant additional insight into the phenomenon of breakdown.

Experiments were performed o measure fundamental parameters of individual breakdowns, including, the turn-on time and the delay before breakdown in order to gain an improved understanding of how breakdowns are triggered and the underlying process behind them. The turn-on time measurements are the highest bandwidth measurements made to date with the CERN DC systems and are closer than ever before to the value which is expected from the present understanding of breakdown simulations.

Another key measurement was that of the breakdown rate scaling with electric field. Previous investigations of this relationship in the DC systems were unable to investigate breakdown rates below 10^{-3} breakdowns per pulse. These new results are able to investigate this relationship down to a breakdown rate of 10^{-8} and are hence a considerable improvement. Thanks to these improved results a remarkable similarity to the scaling of the breakdown rate with electric field in RF cavities was discovered. The conditioning, or change in breakdown rate over time was also studied for the first time in the CERN DC spark systems as well as the newly built fixed gap system. The qualitative conditioning behaviour of the Fixed Gap System again showed interesting similarities to that observed in RF structures.

Preliminary studies into the effect of pulse length and magnetic field on the breakdown rate were conducted as well. This is the first time the effect of a DC magnetic field was studied in a DC spark system and in contrast to experiments in RF cavities no statistically significant effect was observed. The dependence of the breakdown rate on pulse length, again the first measurement of its kind in a DC system also revealed a similar scaling law to that observed in RF accelerating structures. Both of these preliminary measurements would need to be repeated to confirm the results.

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