Dark Current Analysis at CERN's X-band Facility

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INTRODUCTION

The operation of high-gradient (HG) linacs is limited by RF breakdowns (BD). These are vacuum arcs produced due to high surface electric fields present on the inner cavity walls. HG structures are also affected by the so-called dark current (DC), which is formed by field emitted electrons that are accelerated through the structure [1, 2]. The magnitude of the field emitted current follows the Fowler-Nordheim law [3]

$$J = a\beta^2 E^2 e^{\frac{-b}{\beta E}}$$

The RF conditioning is a procedure that aims at progressively adapting the HG accelerating structures to the high fields they need to sustain in normal operation. During conditioning, both accelerating gradient and pulse length are gradually increased keeping the breakdown rate low.

In this work we present the dark current analysis of the conditioning data taken at CERN's X-band facility [4, 5] for several CLIC prototypes [6, 7]. First we introduce the data available and the analysis procedure. Later on we explain the main characteristics observed in the dark current behaviour during long term operation: the reduction of the emission during conditioning and the fitting to the Fowler-Nordheim law.

DARK CURRENT ANALYSIS

During the analysis we process traces like the example presented in Fig. 1. From the power signal, two relevant quantities can be obtained: peak power and pulse length. From the dark current signals, the peak value of the current registered in both downstream (DS) and upstream (US) Faraday cups is obtained.

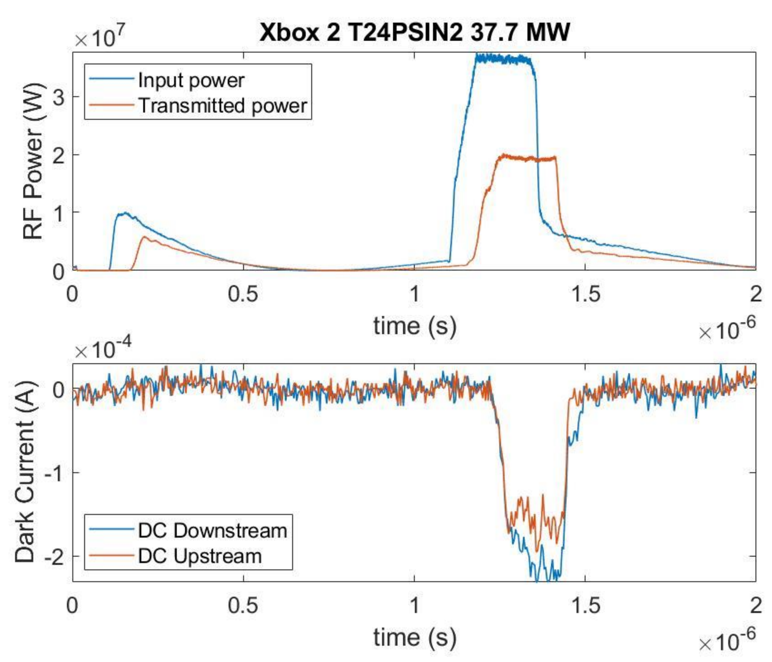

Figure 1: Example of traces measured at Xbox 2.

The RF power conditioning plot of the T24PSIN2, recorded at Xbox 2, is presented in Fig. 2a. The peak dark current as a function of the input RF power is in Fig. 2b, where the conditioning ramps for different pulse lengths are overlapped.

It can be seen how the pulses of later stages of conditioning (red) present lower dark currents at same power levels compared with the early stages (blue). The dependence on the RF power is visibly linear instead of exponential, as it would be expected from the Fowler-Nordheim law. This happens because in long term operation the exponential growth as a function of power is compensated by a decay as a function of the number of pulses, where breakdown occurrences during conditioning change the emitters' location and intensity. In consequence, for analysing the pure field emission behaviour, power scans must be made in a short period of time with no breakdowns, so that the effects of the conditioning are avoided.

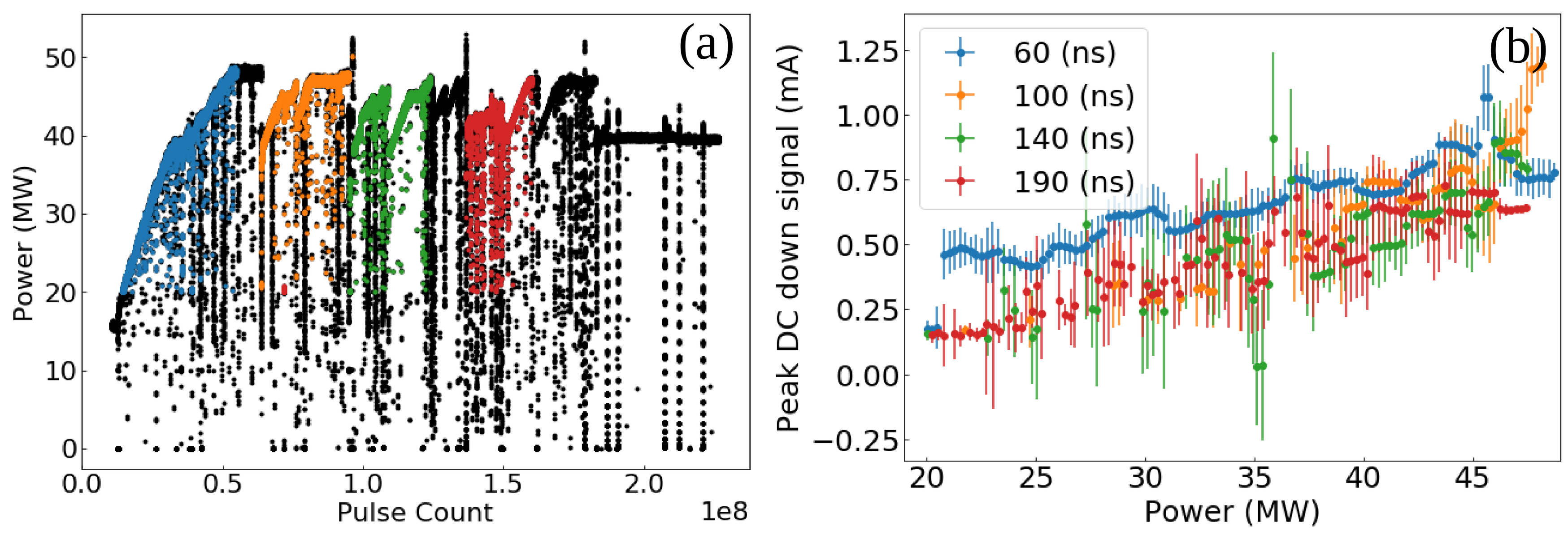

Figure 2: (a) RF power conditioning plot of the T24PSIN2 at Xbox 2, marking the different pulse length sectors. (b) Dark current versus RF power for different pulse lengths.

Figure 3 shows the conditioning plot of a TD24 tested in Xbox 3. The plot at the bottom shows the RF power and the pulse length. The plot at the top presents both US and DS dark currents, and the BD positioning. In some regions the field level is constant and the dark current decreases. The current spikes that suddenly appear are related with breakdown occurrences, as the blue dots are aligned with the jumps.

One can see how the US is smaller than the DS at the beginning of the plot, but it converges to a similar value at the end. It is also visible how the BDs are homogeneously distributed at the beginning and go closer to the first cells at the end. An homogeneous distribution of emitters leads to a higher DS current as the capture is better in that direction [2], but emission concentrated in the first cells leads to a higher reading in the US monitor, the one closer. Correlation between BD location and emitting zones has also been observed in [8].

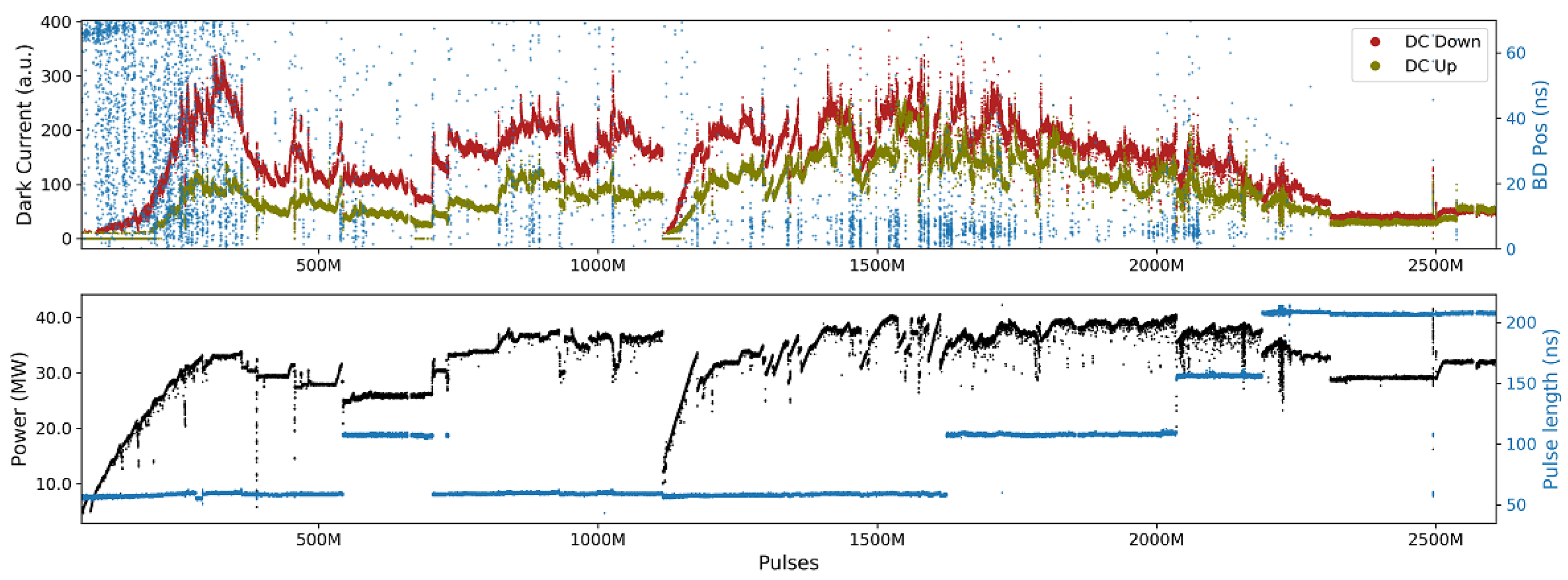

Figure 3: Full conditioning of a TD24 tested in Xbox 3. The graph in the top shows the upstream and downstream dark currents measured, together with the breakdown positioning. The one in the bottom shows the power and pulse length.

For analysing the Fowler-Nordheim dependence short time power scans are presented in Fig. 4. Dark current data for two TD24 is shown in Fig.4a and Fig. 4b, the not baked-out structure (UBO) emits more and the emission went down after conditioning in both of them. Figures 4c and 4d present radiation data of a TD26CC showing the same behaviour, as the conditioning progress it needs more power to give the same level.

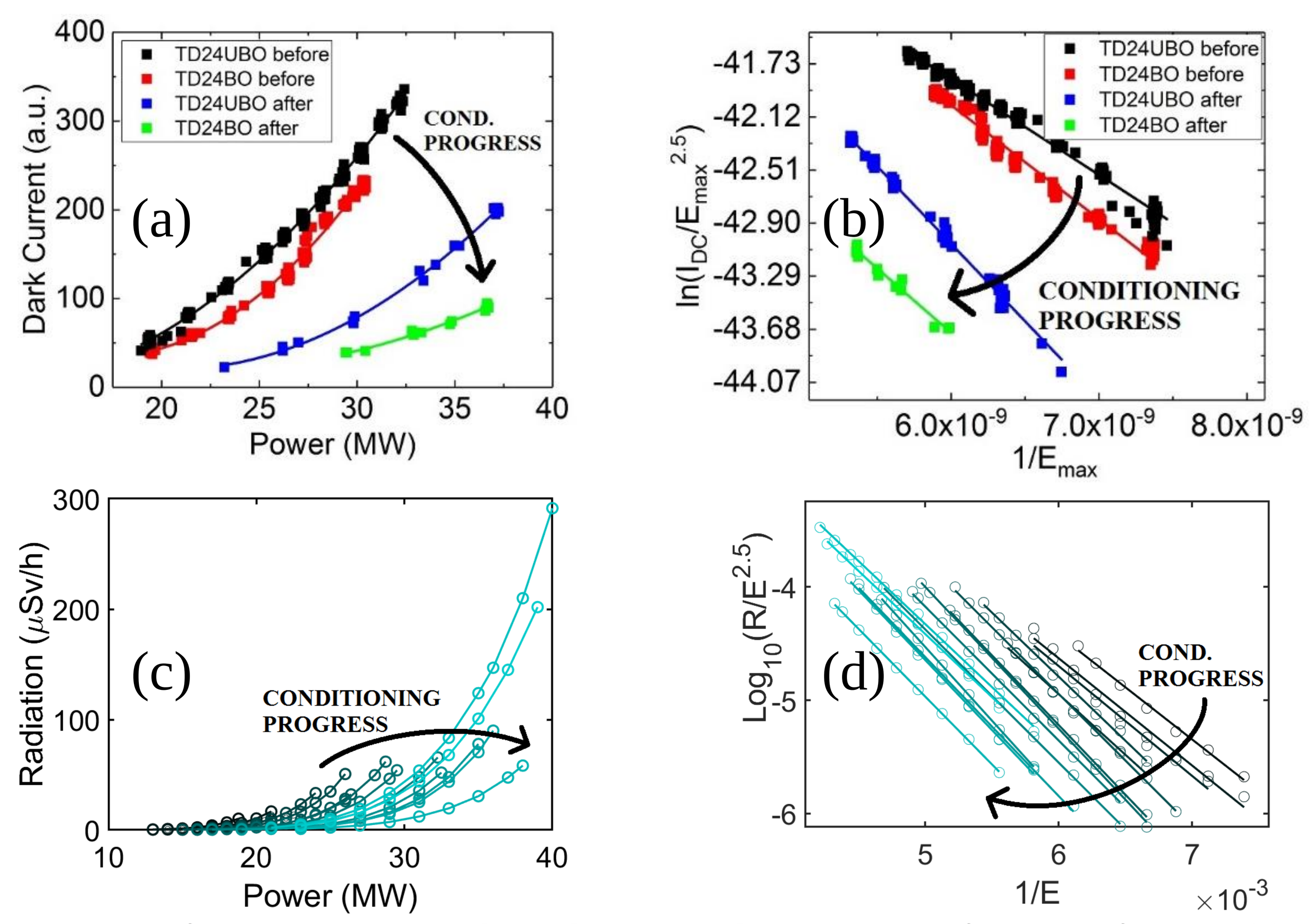

Figure 4: Power scans for two TD24 tested in Xbox 3: Dark current as a function of power (a), and Fowler-Nordheim plot for the same data (b). Power scans for a TD26CC tested in Xbox 2: Radiation as a function of power (c), and Fowler-Nordheim plot for the same data (d).

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