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Report on High Power rf Testing of Quartz Based DLA Structure at NRL

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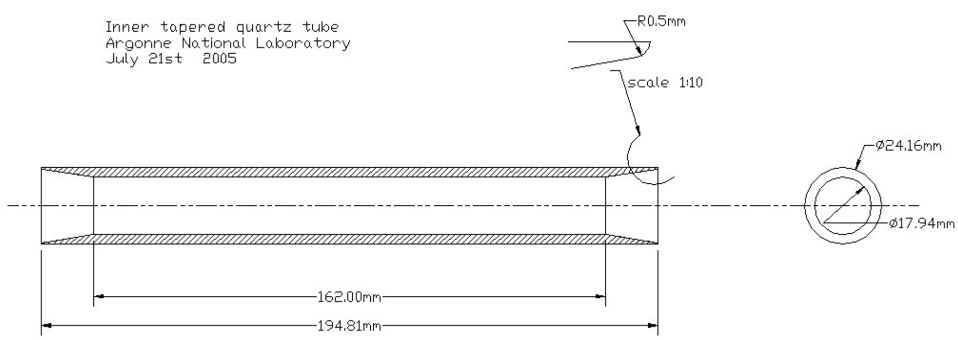
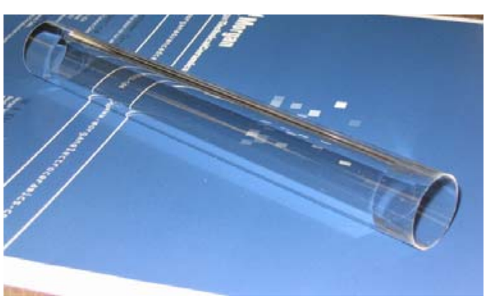
Abstract: In this article, we report the experimental results of high power rf testing on the quartz based Dielectric-Loaded Accelerating (DLA) structure carried on Feb. 2006 at Naval Research Laboratory. The motivation of this experiment is to test the multipactor effect of different material under the high power and high vacuum condition. Up to 12 MW pulsed rf went through the tube without breakdown. Multipactor appears during the experiment but with different features compared to other materials, like alumina. Photomultiplier Tube (PMT) was first time introduced into the experiment to observe the light emission time and intensity.

Structure facts: The selected material in this DLA structure is fused silicon (quartz), with dielectric constant of 3.78. In order to reuse the prior developed X-band couplers and avoid using separate taper sections as alumina or MCT based DLA structures [1, 2], we fixed the OD of the loaded quartz tube to be the same as the ID of the coupler and adjusted ID of the quartz tube to satisfy the synchronization condition. The inner tapers were machined on both ends of the quartz tube to match the impedance. Figure 1 shows its geometry and pictures of the quartz tube and assembly. Table1 is its major accelerating parameters.



(a)



(b)

(c)

Fig. 1 (a) geometry of the quartz tube; (b) picture of the quartz tube; (c) picture of quartz based DLA structure after assembling.

Table 1: accelerating parameters of the quartz based traveling wave DLA structure

IR (mm)	OR (mm)	ε	tanδ	Q	Vg	r/Q (Ω/m)	r (MΩ/m)	Attn (dB/m)	P for 1MV/m
8.971	12.079	3.78	2*10e-5	7715	0.38c	3614	27.9	0.35	439KW

Bench test: Using network analyzer, we measured the rf characteristics of the structure. The results are shown in Figure 2. The structure has a very good rf response within 1GHz bandwidth. 0.2dB transmission loss and less than -25dB reflection are measured at the operating frequency of 11.424GHz.

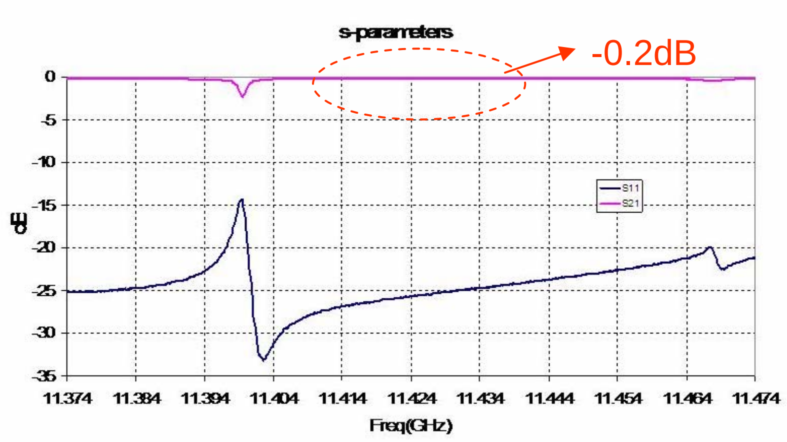
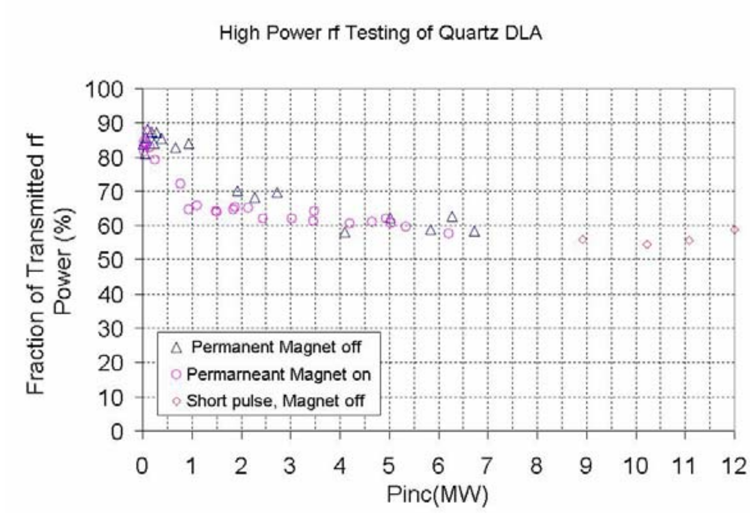


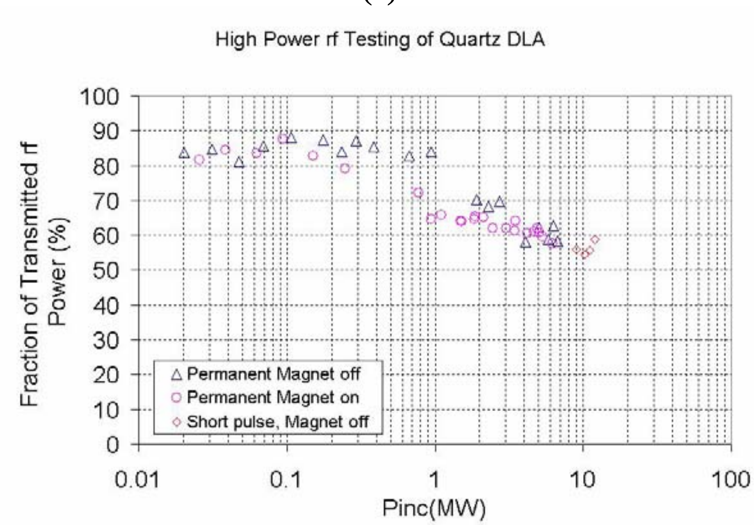
Fig. 2 Bench testing results of the quartz based DLA structure.

High rf power testing: The experiment was carried on at NRL where an X-band Magnicon is available as the external rf source. The setup is identical as our previous experiment [1, 2]. Up to 12 MW pulsed rf went through the tube without breakdown, although the corresponding accelerating gradient is low (5.2MV/m) due to the dimensions of the structure. During the experiment, we observed: 1) light emission due to the multipactoring; 2) rf power absorption due to the multipactoring; 3) fraction of the transmitted rf power saturated at certain incident power level; 4) light color is blue; 5) light turning on time and intensity by using PMT; 6) Mulitpactor advanced by applying a transverse permanent magnet field.

In this section, we will present all experimental data in series of figures. Explanation will be given in the corresponding captions.

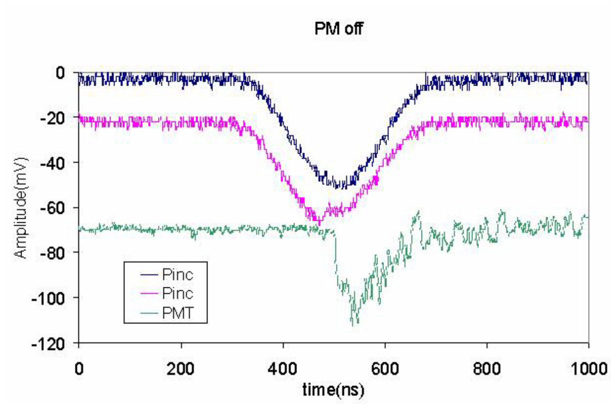


(a)

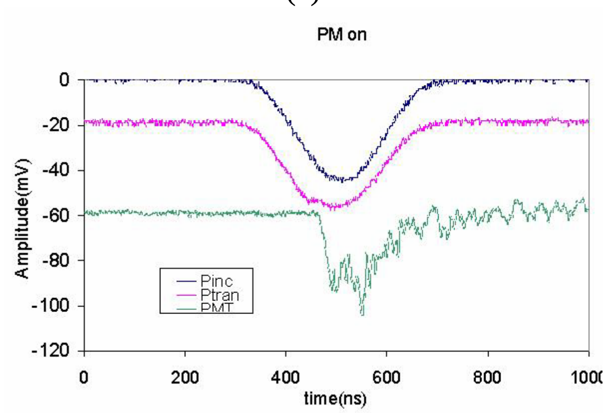


(b)

Fig. 3. Fraction of the transmitted rf power vs. incident rf power in linear scale (a) and log scale (b). The pulse length of input rf is around 200ns when peak power below 7MW, and shortened to be 100ns when peak power beyond 7MW. The highest power level reaches 12 MW and no any breakdown signature observed. A 180 Gauss permanent magnet was put on and off at the upstream end of the quartz tube in two cases, and both of them are presented in the data plot. Obviously, like our previous results of high power testing on alumina based DLA structure, the transmission coefficient starts dropping at a certain incident power level which is a proved signature for onset of the multipactoring. However, a saturation stage appears for this quartz based DLA structure when higher rf power is input. This phenomenon was only observed in the experiment on the TiN coated alumina tube. Transverse magnetic field advances 'knee' point of the curves, and consistently makes the rf transmission worse during the further dropping stage of the curve, but no significant change for the saturation stage. The last three points in the data plot shows 5% improvement of rf transmission when incident power beyond 10MW, however, we needs higher rf power to justify if the multipactor can be overcome when incident rf power higher than a certain level.



(a)



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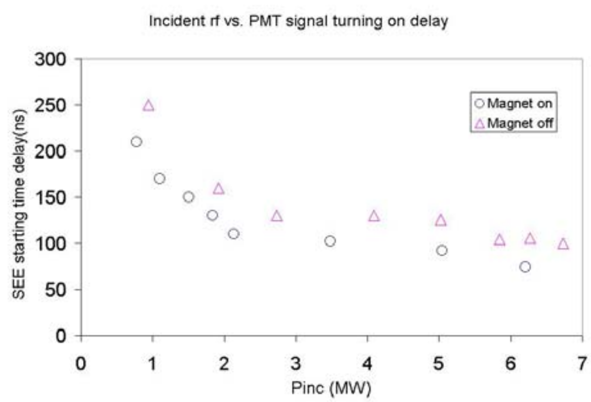
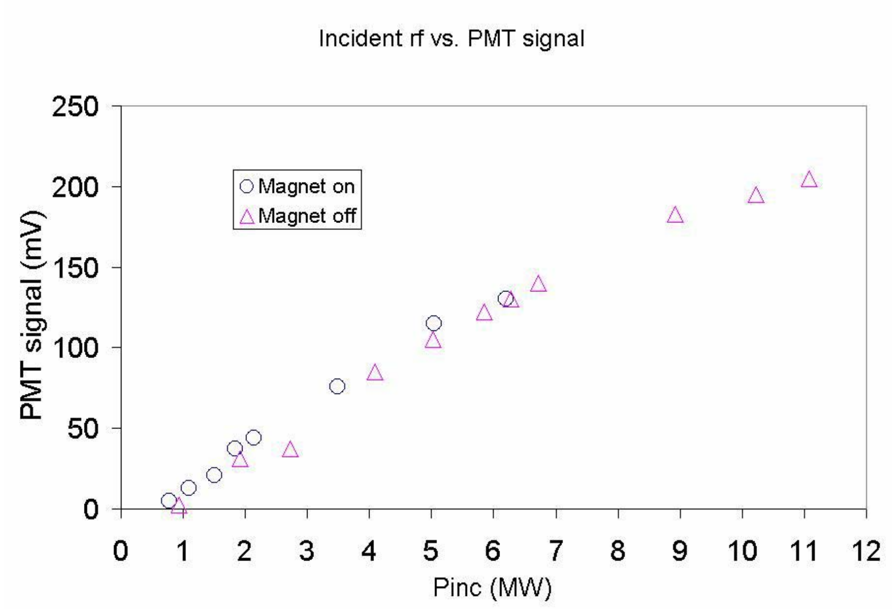
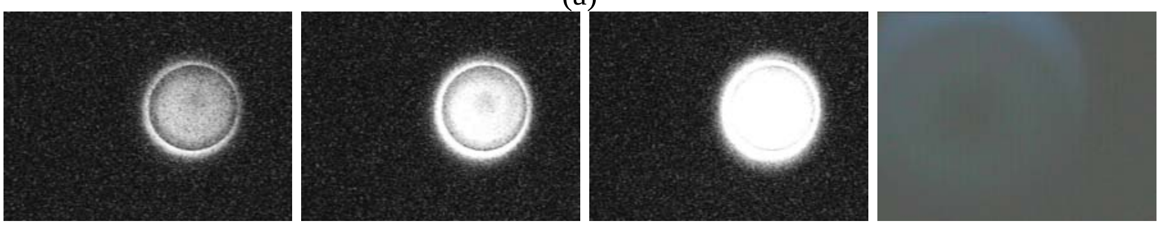


(c)

Fig. 4. The onset time of multipactor is advanced when applying a 180 Gauss permanent magnet on the upstream end of the quartz tube. (a) signals of incident, transmitted and Photomultiplier Tube (PMT) detected by diodes at the moment of around 1.9 MW rf power input with permanent magnet off; (b) signals with permanent magnet on at incident power of 1.9MW; (c) onset time delay of light emission from the incident rf leading edge varies with the peak power of incident rf. PMT was installed at the upstream end window to monitor the light emission. Figure 3(a) and 3(b) clearly show the transmitted rf signal is distorted when light by secondary electron emission turning on. Figure 4(c) shows the advancing time induced by certain transverse magnetic field is roughly a constant.

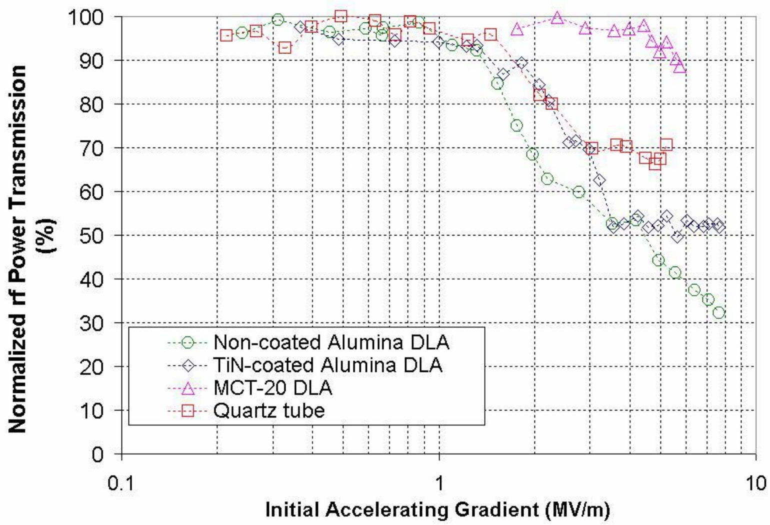


(a)

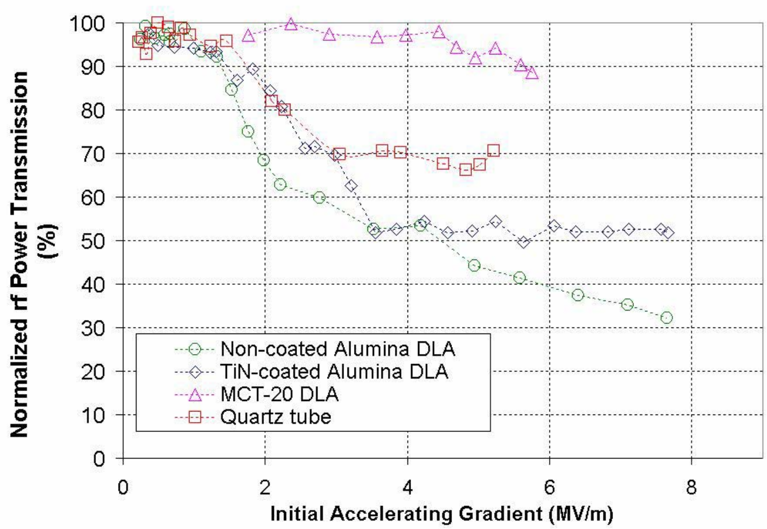


(b) (c) (d) (e)

Fig. 5. (a) light intensity is proportional to the incident power level, and it is higher when magnet applied; (b), (c), and (d) are pictures taken at three different incident power level; (e) using a color CCD video camera, the light color was identified. It is blue, and we also observed it by eye through a big reflecting mirror when experiment was carrying on.



(a)



(b)

Fig. 6. We plot experimental results of high power rf testing on four different materials for comparison (log scale in (a) and linear scale in (b)). Obviously, quartz tube has a similar behavior as the TiN coated alumina tube because both of them show a saturation stage when incident rf power beyond a certain level.

Conclusion: up to 12MW rf power was applied to the quartz based DLA structure without breakdown. We observed the multipactor starting and saturation stage. We observed transverse magnetic field influence on the multipactoring behaviors. A higher rf power testing is highly expected. A 3D multipactor physical model is highly expected.

[1] J. Power, et al. Phy. Rev. lett. 92 164801, 2004
[2] C. Jing, et al. Proc. Advanced Accelerator Concepts 2004, Stony Brook, NY