Peking University

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Steady state multipacting in a micro-pulse electron gun

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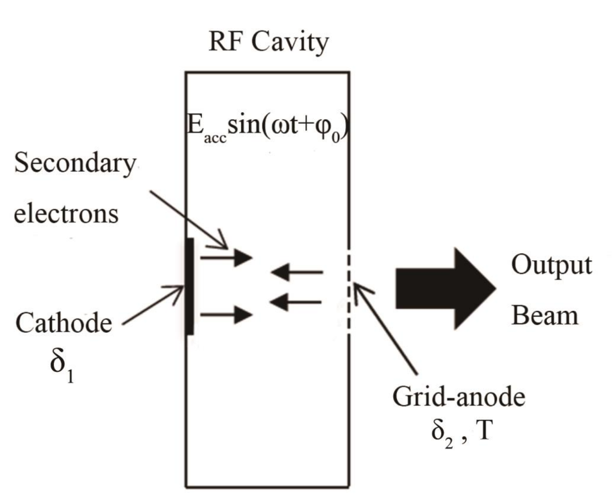
Abstract

Multipacting is a resonant electron discharge phenomenon via secondary electron emission, while micro-pulse electron gun (MPG) utilizes the multipacting current in a radio-frequency (RF) cavity to produce short pulse electron beams. The concept of MPG has been proposed for many years. However, the unstable operating state of MPG vastly obstructs its practical applications. This paper presents a study on the steady state mulitpacting in a MPG. The requirements for steady state multipacting are proposed through the analysis of the interaction between the RF cavity and the beam load. Accordingly, a MPG cavity with the frequency of 2856 MHz has been designed and constructed. Various kinds of grid-anodes are tested in our primary experiments. Both the unstable and stable multipacting current have been observed. Presently, the stable output beam current has been detected at about 12.2 mA. Further experimental study is under way now.

The MPG Model

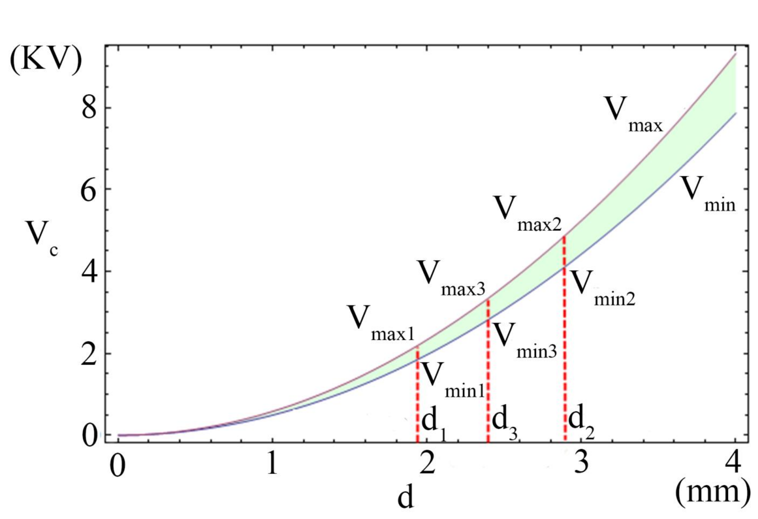


The schematic diagram of the MPG model

1. an RF cavity working in the TM_{010} mode.
2. a cathode to generate secondary electrons.
3. a grid-anode with transmission coefficient T (T<1).

- The total effective secondary electron yield: $\delta = \delta_1(E_i)\delta_2(E_i)(1-T)$

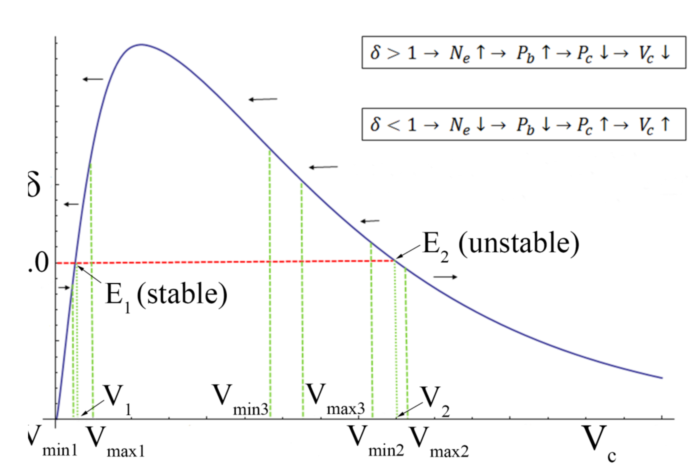
Analysis of steady state MP



The resonant gap voltage range versus the gap distance d when f_0 = 2856 MHz.

$$V_c = \frac{m}{e}\frac{\omega_0^2 d^2}{2\sin\varphi_0 + \pi\cos\varphi_0}$$

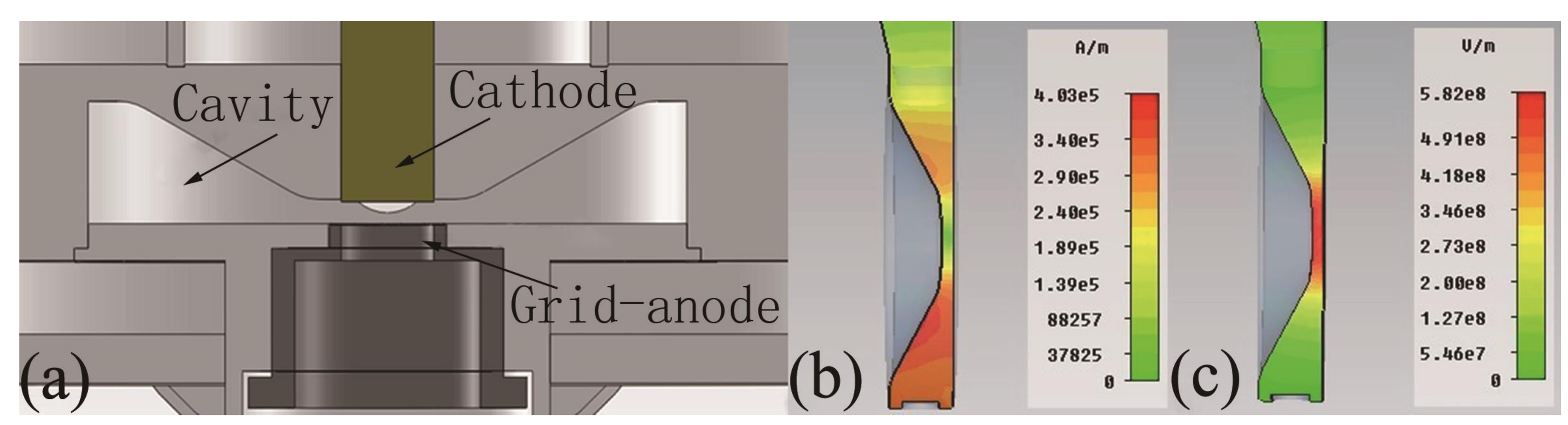
$$V_{min} = \frac{m}{e}\frac{\omega_0^2 d^2}{\sqrt{\pi^2+4}},\quad V_{max} = \frac{m}{e}\frac{\omega_0^2 d^2}{\pi}$$



The total effective SEY curve versus the gap voltage V_c.

- E1 is the steady state operating point for the MPG, not E2.
- [Vmin1, Vmax1] should be set as the resonant gap voltage range.
- V1 must be included in this resonant range.

Cavity design and test stand

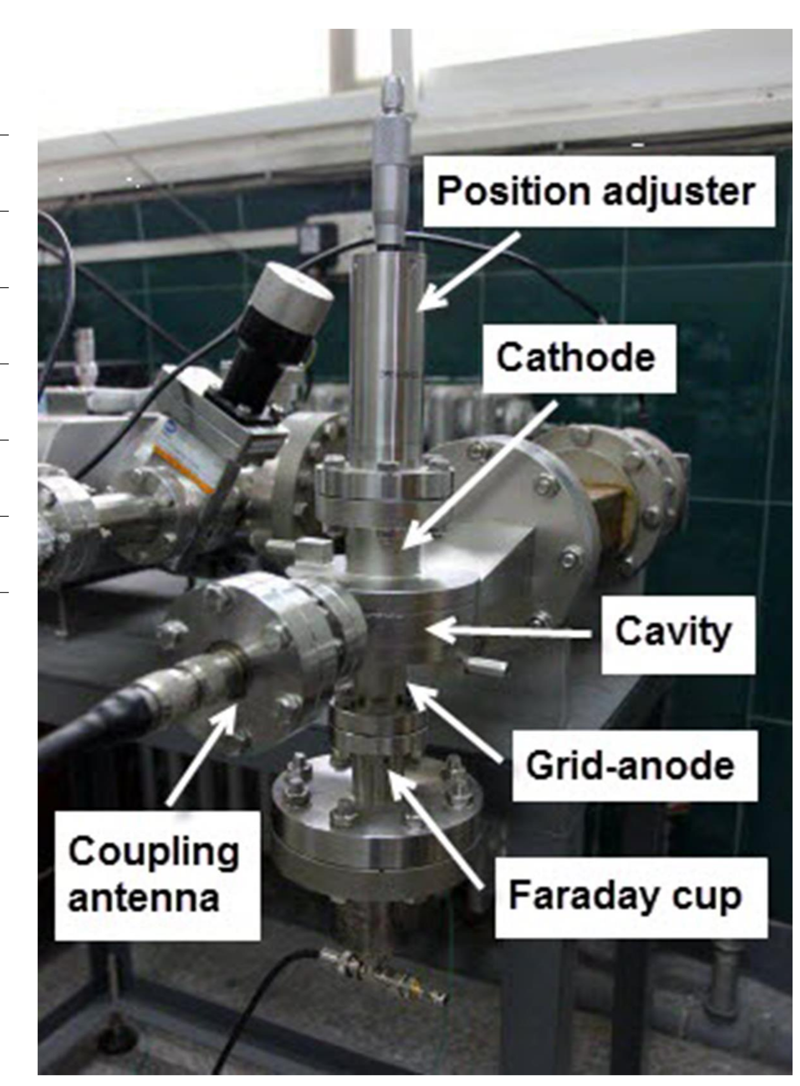


(a) the cross section of the MPG; (b) the magnetic field distribution; (c) the electric field distribution.

The designed RF parameters of the MPG cavity.

RF parameters	Designed value
f_0	2856 MHz
d	1.75 mm
Q_0	653
r_{shunt}	0.036 MΩ
β_0	1.25

- The RF cavity is made of SS*.
- The Cathode is made of Cu-Al-Mg alloy.
- The output electrons beams are collected by a faraday cup, which is connected to a 50 Ω resistance in parallel and measured by a HP 54503A oscilloscope with 1 MΩ input impedance .

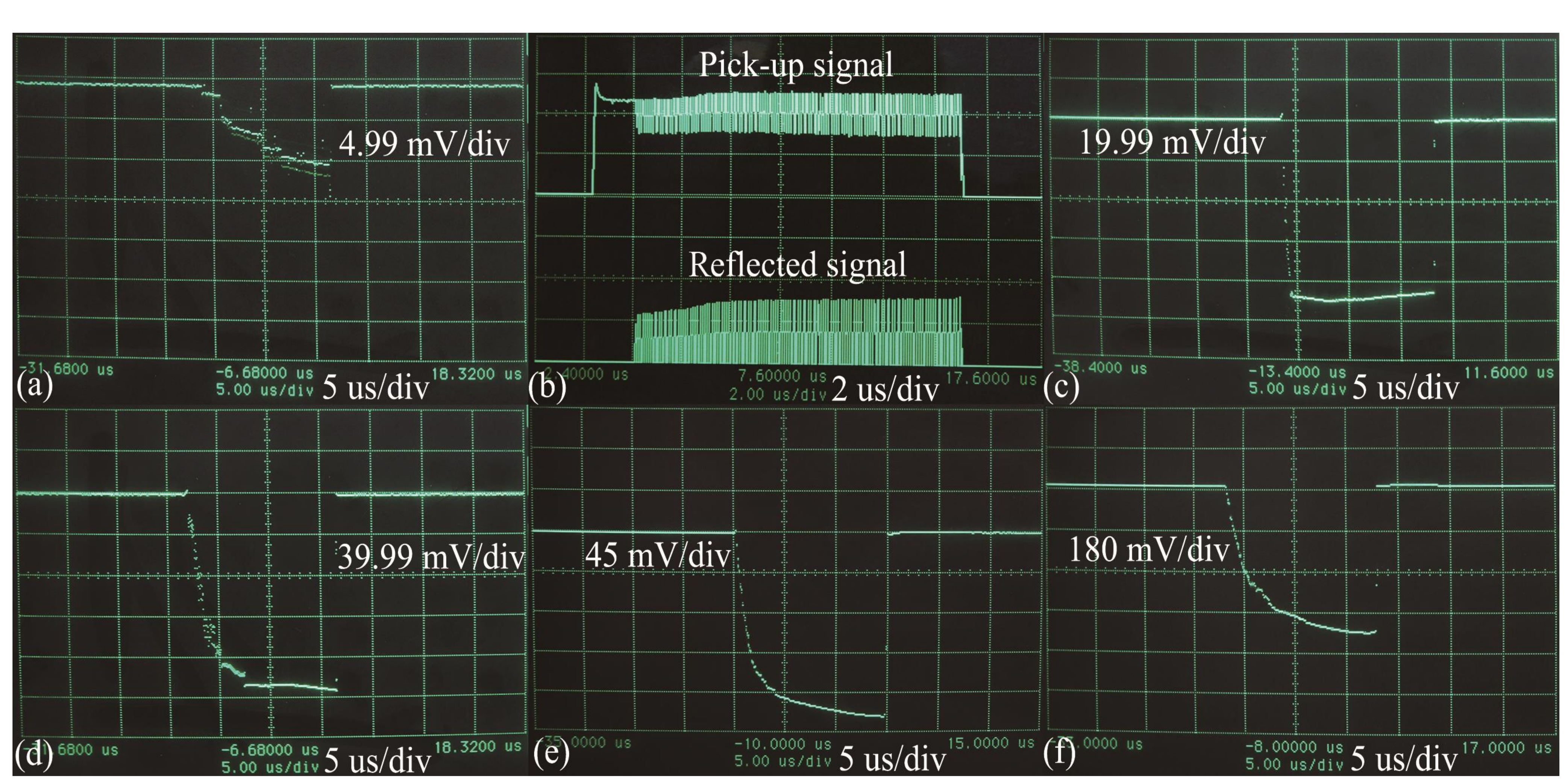


The test stand

Experimental results

The measured output beam currents (Ib) with various grid-anodes.

Grid-anode No.	1	2	3	4
Material	SS*	SS	OFC*	OFC
T	6%	18.3%	18.3%	25%
Measured Ib (mA)	≈ 0.2	3.8	4.2	12.2



(a) is the output beam current (0.2 mA) when the grid-anode is No.1; (b) is the pick-up signal and reflected signal corresponding to (a); (c) is the output beam current (1.7 mA) when the grid-anode is No.2; (d) is the maximum detected output beam current (3.8 mA) when the grid-anode is No.2; (e) is the output beam current (4.2 mA) when No.3 grid-anode is tested; (f) is the output beam current (12.2 mA) when No.4 grid-anode is tested.

* SS represents stainless steel and OFC represents oxy free copper.

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