THE PLANAR DEFLECTRON

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A micro-engineered amplifier and logic device.

Introduction

- This presentation is intended to describe the function, evolution, and applications of the Planar Deflectron
- I was the instigator of the idea, but it is of course a team effort, with particular thanks to Bob Stevens, Zheng Cui and Ejaz Huq.

What it is -

- A *vacuum device* (like a sub-miniature tube/valve) which acts as an amplifier or logic element
- It uses *field emission* instead of a *heated cathode*
- It *deflects the electron path* rather than trying to modulate the current (like a television tube)= **Deflectron**
- It is *constructed in one plane* for simplicity and connectivity= **Planar**

How it evolved

- For at least 20 years people have been trying to realise a field-effect amplifier
- They have not worked because the potential of electrons produced by a field emitter is typically x100 that of a thermionic emitter, reducing gain by that amount. Hence typical valve stage gain 30 becomes 0.3!
- Also the variation in emission current (= noise!) is typically 10%. This is superposed on the signal.

How the Deflectron wins

- A cathode resistor produces 100% negative feedback, removing noise
- Having fixed the current, deflect the electrons rather than gate (amplitude modulate) them
- The lever arm and hence the amplification has in principle no limit!

Gain of the Deflectron

The Gain of the Deflectron depends on:

- ~ 1/ extractor voltage ("stiffness")
- ~ integrated deflecting E-field:
  - ~ Length of deflector plates
  - ~ 1/ Spacing of deflector plates
- ~ drift length ("lever arm")
- ~ spot size (adjustable by focus)

(In principle, there is no limit to the drift length.)

The Deflectron idea is not new

- It looks like an electrostatic CRT
- Deflection - modulated electronic tubes (valves) were made by RCA in the 1960s
- Its use as a vacuum micro-electronics device for generating microwaves has been suggested
- This particular application and the planar construction are novel

What use is it?

Niche product mainly for science:

- It will work at very high temperature - eg Venus lander ?
- It will work at very low temperature - eg quantum microdot readout ?

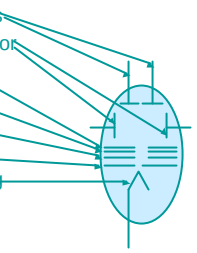
  (This could be important commercially)
- It is extremely radiation resistant - particle physics experiments, unclear industry
- It has high noise rejection

Other Advantages

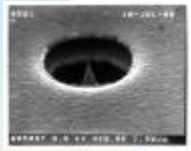
- Can work as amplifier or logic element
- Amplifier has gain/dynamic range trade-off, set by voltage parameters
- Small size means very fast
- Complementary signals in/out with high common mode rejection
- Coupling can be DC as only reacts to voltage difference
- Power consumption very low and independent of speed or state
- Simple few-step fabrication

Symbolic drawing

- A1, A2: anodes
- D1, D2: deflector
- F1: focus H
- F2: focus V
- F3:focus H
- E: extractor
- K: field emitting cathode



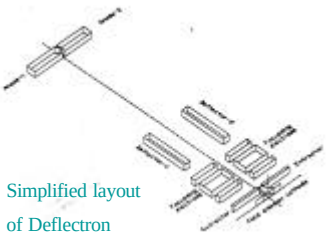
Why not conventional construction?



A scanning electron microscope picture of a conventional 2-gate field emitter. This represents "state of the art".

- To build up a device as complicated as the deflectron would require many steps = low yield.
- This gets even more difficult when the focus and deflection electrodes are added, breaking cylindrical symmetry.
- When anodes added on top, closed volume is difficult to evacuate.

Planar Construction.



Simplified layout of Deflectron

- To see how the planar device evolved, imagine a slice taken through the middle of the cylindrical device.
- Construction is then simple lithograply of metal, plus the tip fabrication.

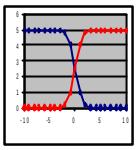
Modelling the Deflectron

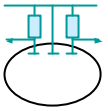
- Extractor produces high electric field on cathode
- Focus electrodes alter final spot size
- Deflection plates move beam
- Split anode collects electrons

Results of model by Z. Cui showing electron tracks for one set of parameters.

The Deflectron as Logic Element

- Focussed to a spot, the current rapidly changes from one anode to another, producing the ideal binary switch
- A tri-state device may be produced by introducing a third central anode which is connected straight to +V. Thus devices can be multiplexed to the same bus.





Tri-state device

The Deflectron as Amplifier

- By defocussing the beam to a disc, the current changes slowly (and approx. linearly over a certain amplitude).
- The size of the spot can be used to trade off gain against Dynamic Range Small disc = high gain, small DR; large disc = low gain, high DR).