# More coupler calculations + what's next

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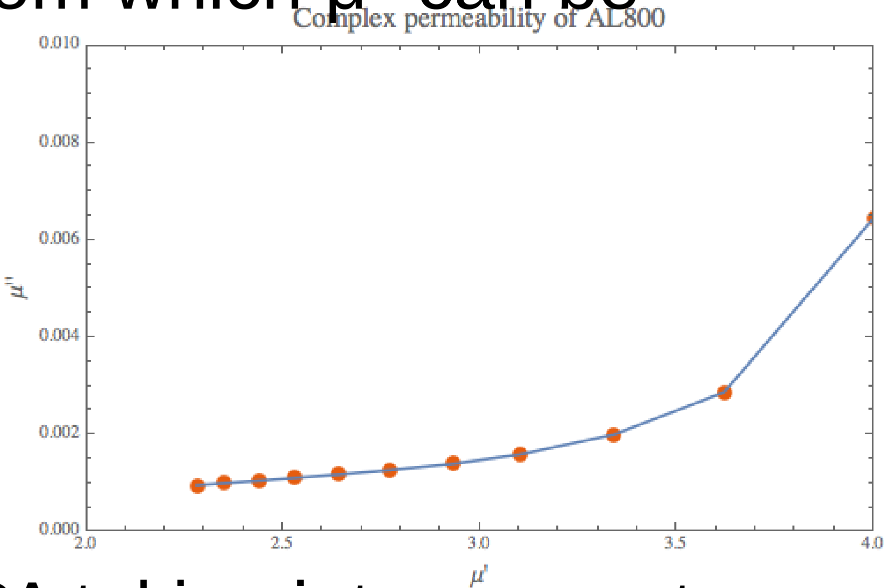
# Updates

- Robyn discovered a mistake that I made in the coupler calculations
  - Impedance seen by the tube is smaller than what I had originally found because I was calculating it at the wrong point! Oops!
  - Unfortunately, does not change the essential result that 25 – 30% of the power will be reflected due to impedance mismatch.
- Location of coupler has to moved from the middle to nearer the gap for better matching.
- More calculations were done, this time double checking with SSC published results.
  - Checked R/Q and Rs (cool trick to use $R/Q = 2(\omega_0\, dB/d\omega)^{-1}$, B is susceptance of the model)
  - They match!

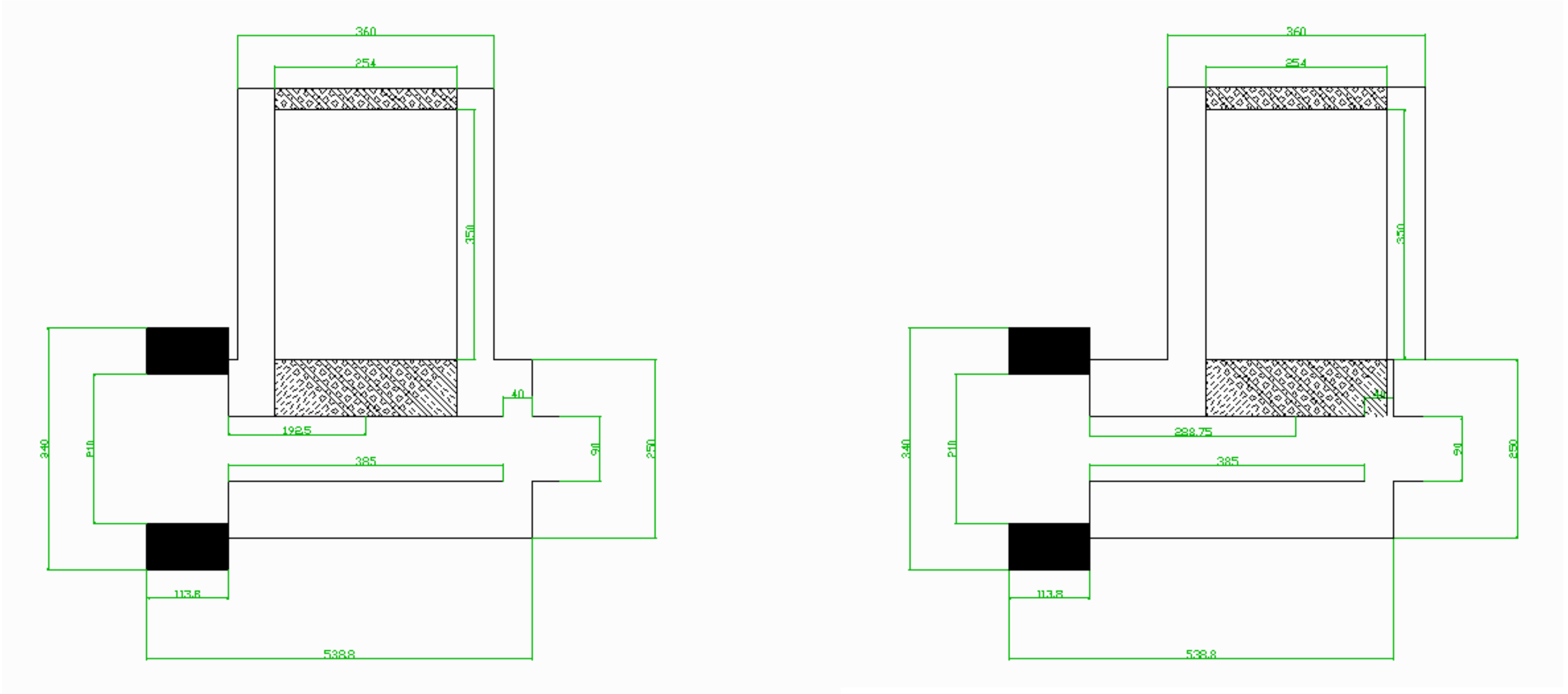
# Calculating Rs and Q of the cavity+coupler

- The calculation involved using Robyn's AL800 measurements of Q, and m' from which μ'' can be derived μ'' = μ'/Q.

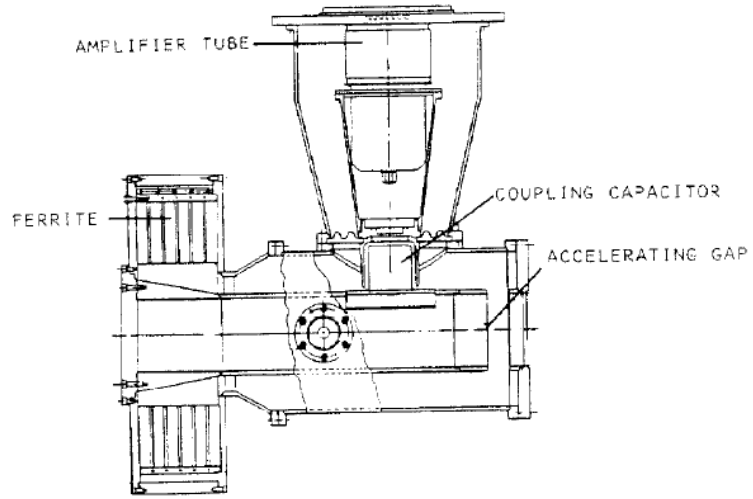



- Use transmission line model
  - Include copper losses
    - Decreases both Q and Rs
- Calculate matching to coupler
- Calculate power required for PA taking into account both PA efficiency in class B operations and reflections.

# Move coupler closer to gap



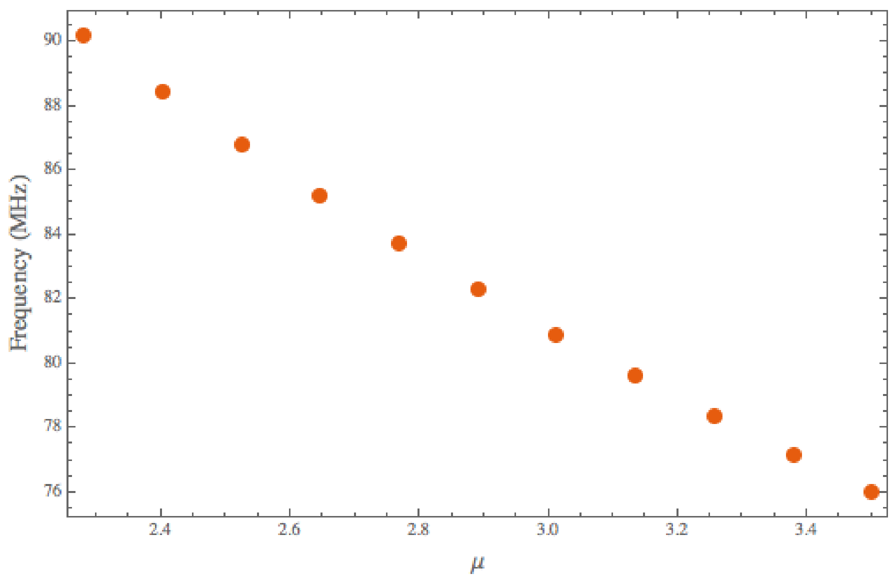

Coupler shifted so that the non-garnet part is divided into 3:1 parts.



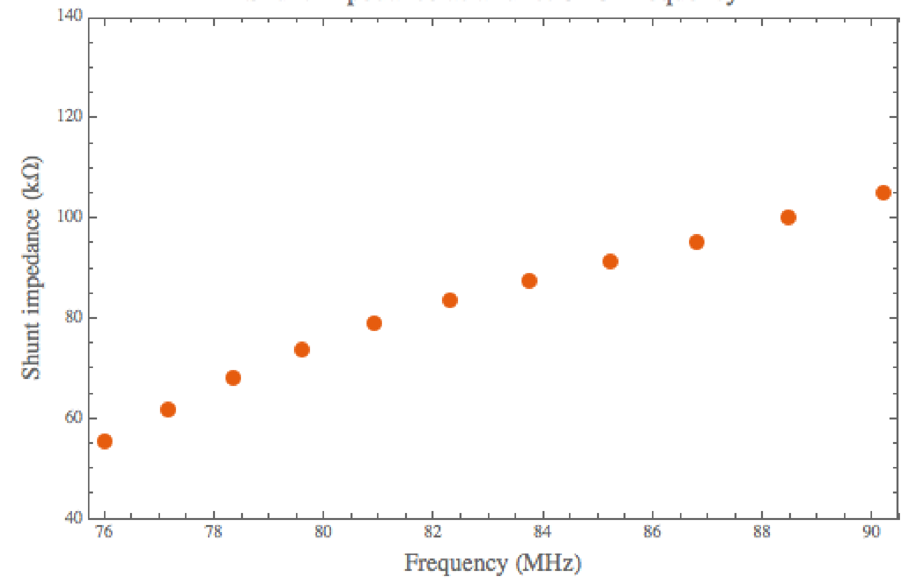

Note that coupling capacitor is a lot smaller than what I drew. See SSC cavity.

# Results for shifted coupler

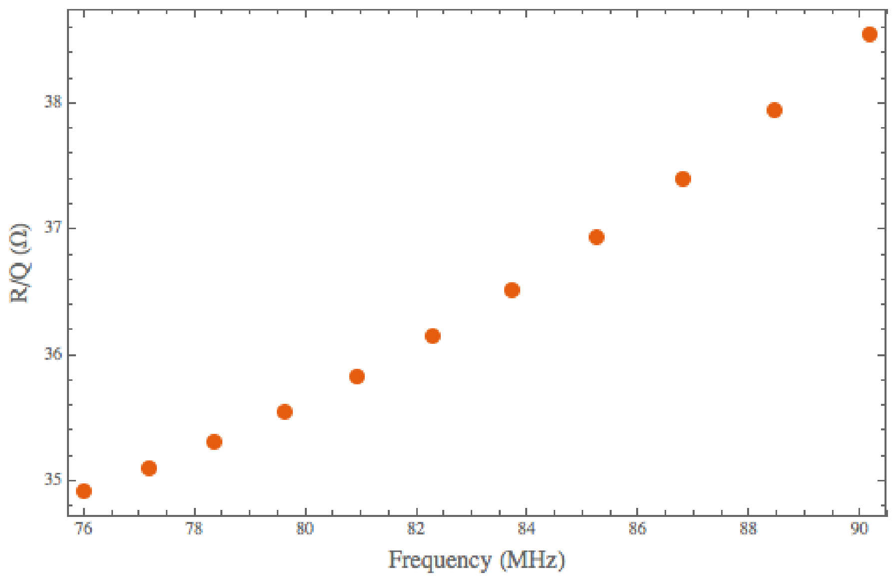
Resonant frequency as a function of permeability



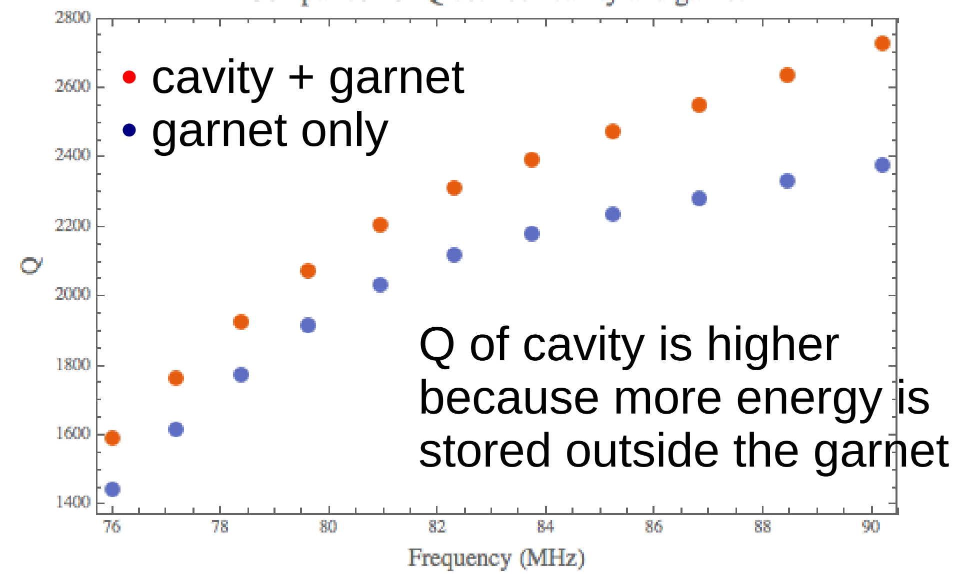

Shunt impedance as a function of frequency



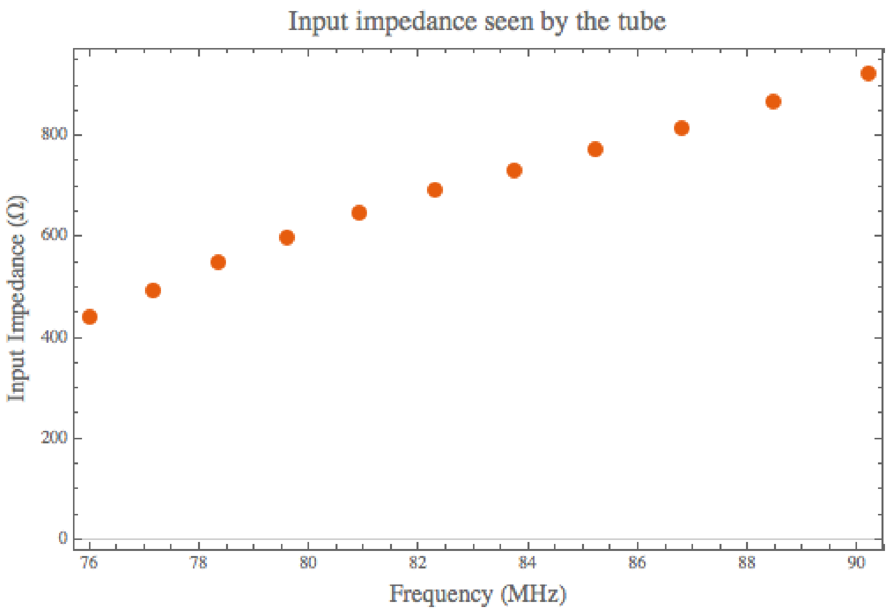

R/Q as a function of resonant frequency

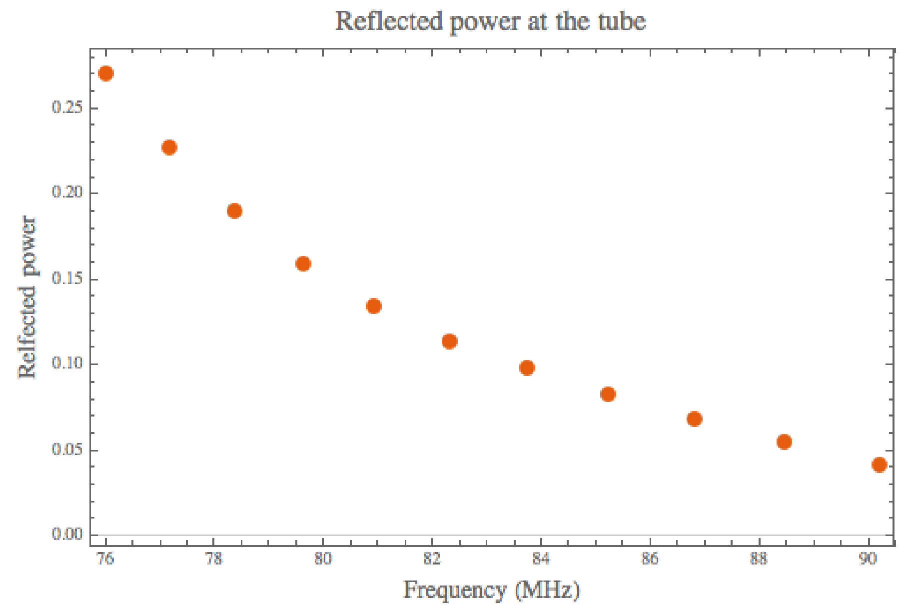


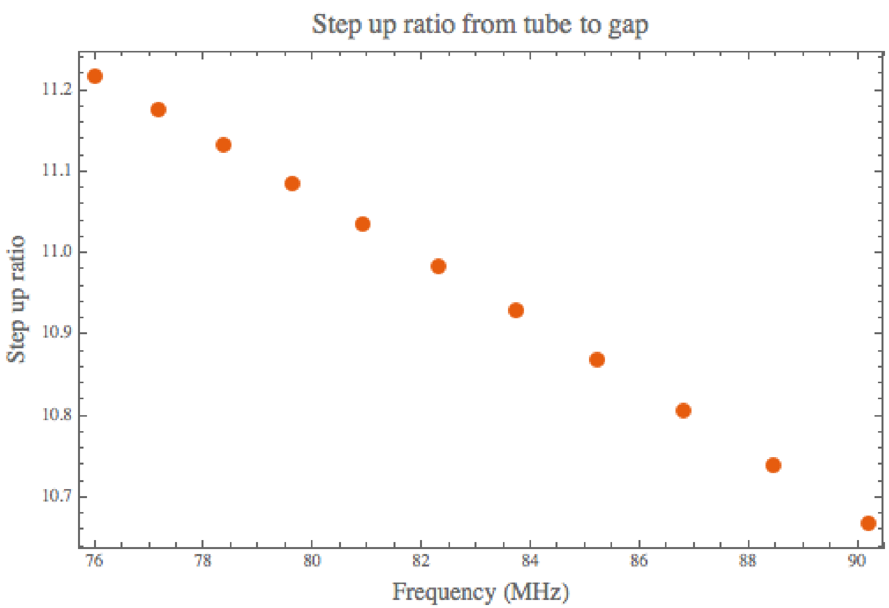

Comparison of Q between cavity and garnet



# At the tube



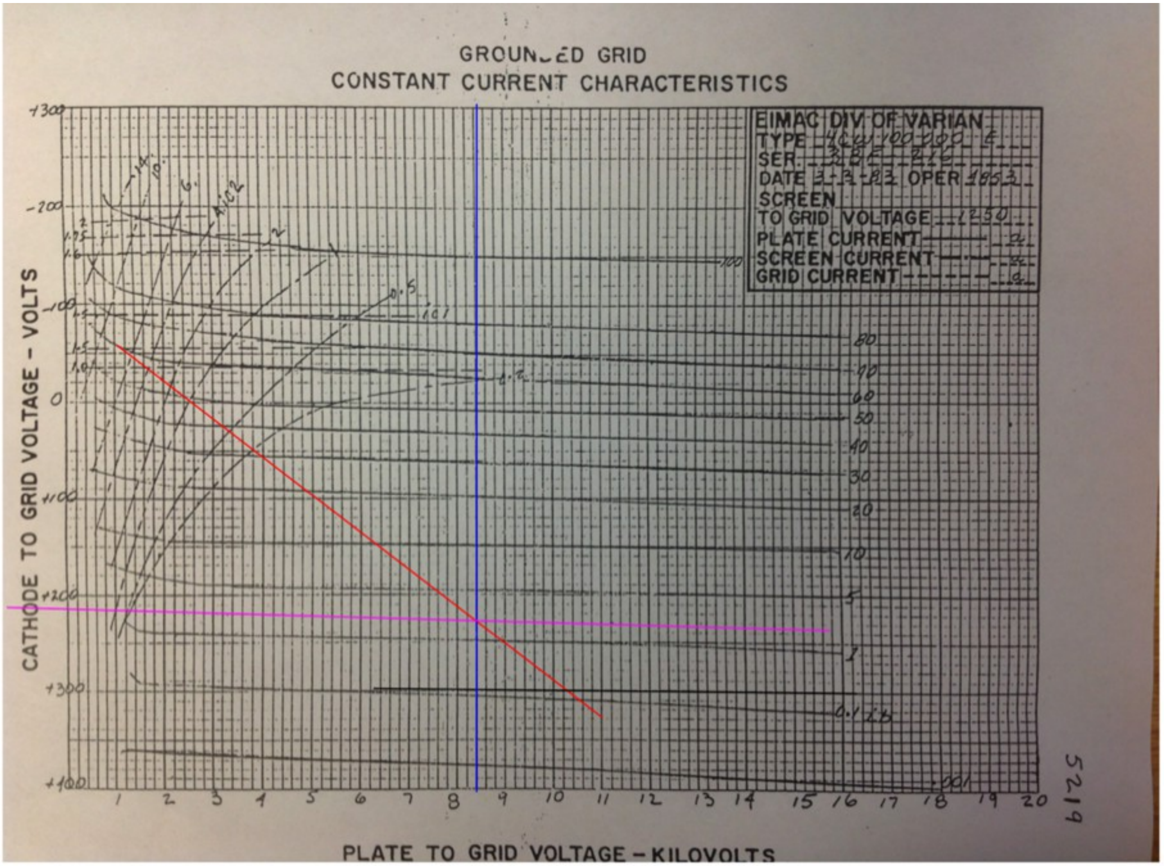

By moving the coupler closer to the gap, the reflected power goes from 35% at the centre to 27%. This assumes that the tube has 1.4 kΩ impedance (J. Dey)

Robyn checked that the step up voltage from tube anode to the gap is correct using SPICE.

# Is this 27% reflection ok? Can the tube handle it?

- Let's work at 76% where the reflection is the worst at 27%.
  - Assume class B operation, efficiency is about 75%.
    - Thus overall efficiency is $\eta = 0.75*(1 - 0.27) = 0.55$.
  - In the ideal case, if all power goes into the cavity, the required power to get 100 kV across the gap is
    - $P_{rf} = V_{gap}^2/(2\ R_s) = 100e3^2/(2*55.6\ k\Omega) = 90$ kW @76 MHz
    - Taking into account the inefficiency, I will require $P_{rf}/\eta = 164$ kW from the tube.
    - This implies that (164 – 90) kW = 74 kW will be reflected into the tube.
      - This should still be ok. Tube anodes, depending on model can dissippate between 100 kW to 150 kW.
  - Must check this with a more proper load line calculation. See next slide.

# Grounded grid, class B operation




Top left point of red line (plate to grid voltage=1 kV, anode current = 60 A), bottom right point (plate to grid voltage 11 kV, cathode to grid voltage = 320 V).

1 kV from minimum anode voltage is 1 kV.

Maximum current:

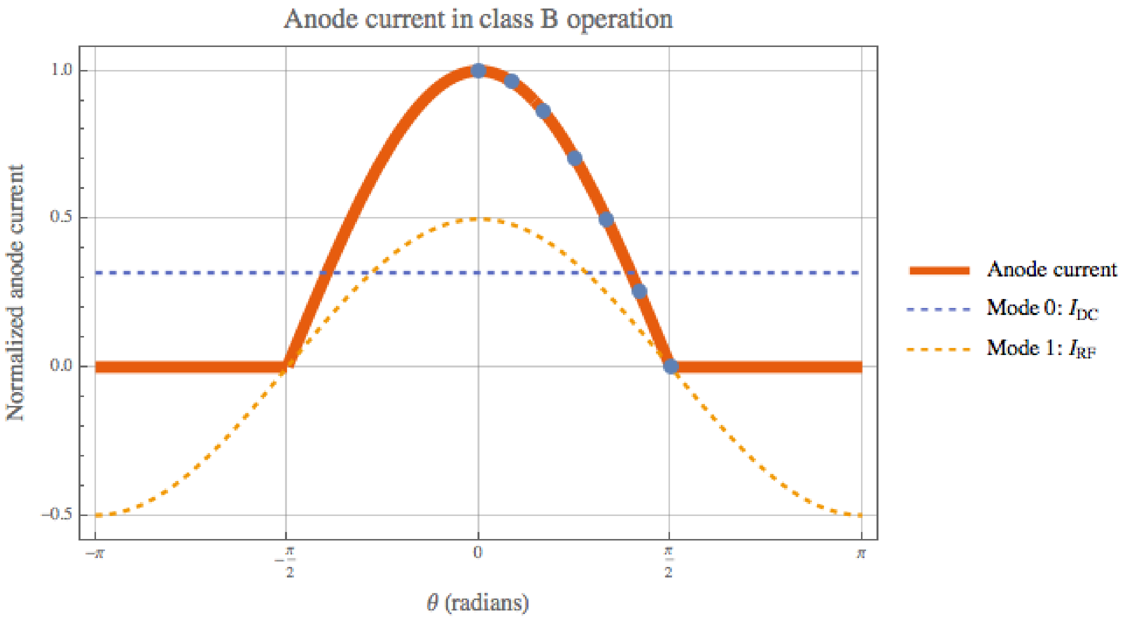
the required tube voltage 10 kV (assuming step up of 10 to get 100 kV in gap) + 1 kV for screen voltage and the required power of 164 kW.

DC anode current = 164 kW/(10+11)kV = 15 A.

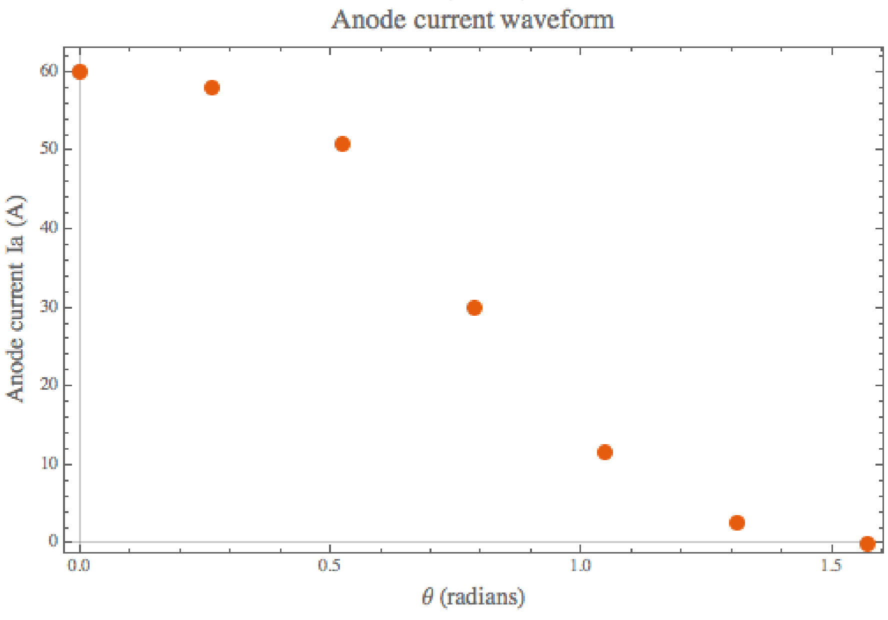
The peak current for class B operation Ipeak = 4*15 = 60 A. (Using 4 rather than π to take into account non-linearity of tube)

Min cathode to grid voltage:
320V comes from Recycler cavity requirements. Checked with J. Dey.

# Create anode current plot vs phase ($\theta = \omega_{RF}\Delta t$) curve




The shows ideal class B anode current. The Fourier components of the anode current gives the DC current and the RF current




These are the points read off from the load-line curve. This gives the points from 0 to π/2.

Reflect about θ = 0 to get curve that looks the similar to the ideal class B anode current curve.

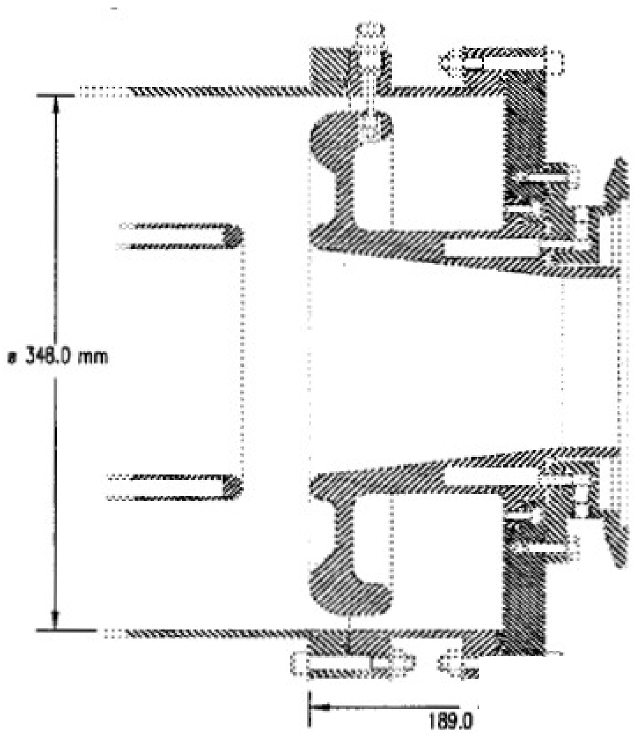
# Fourier analysis of the anode current derived from the load line plot

- $I_{DC}$ = 15 A.
  - DC input power Pdc = 15.275 A * (10+1) kV = 168 kW (think of Pdc as the average power going into the tube)
- $I_{RF}$ peak = 26.3 A
  - RF power Prf = 1/2*(26.3 A)*(10 kV) = 131 kW
- Thus efficiency Prf/Pdc = 131/168 =0.78 which is close to 0.75 assumed earlier.
- Power lost in anode from class B operation = (168 – 131) kW = 37 kW
- Power lost from reflection 0.27*131 kW = 35 kW
- Total power that is dissipated on the anode is (37+35) kW = 72 kW < 100 kW power that can be dissipated by the tube. So we are OK!
  - This is the same as what was calculated using the back of the envelope earlier!

# Summary for coupling calculations

- The coupler needs to be moved from the middle to a point that is closer to the gap. This reduces power reflection from 35% to 27% when tube is 50% closer to the gap.
- Tube cooling should be ok.
  - Within power cooling specifications of tube.
    - Depending on tube model, it is either 100 kW or 150 kW > 72 kW of expected power loss on anode.
- Required power is within the power output of tube.
  - Output power specs is 100 kW to 250 kW > 163 kW
  - Tube can be run reliably at 220 kW (source: J. Dey, c.f. MI).

# Next comes the HOM dampers




Re-entrant cavity HOM damper.

Modified cavity HOM damper with HPF.