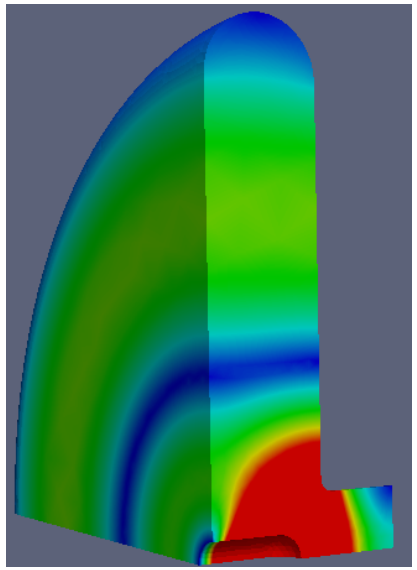
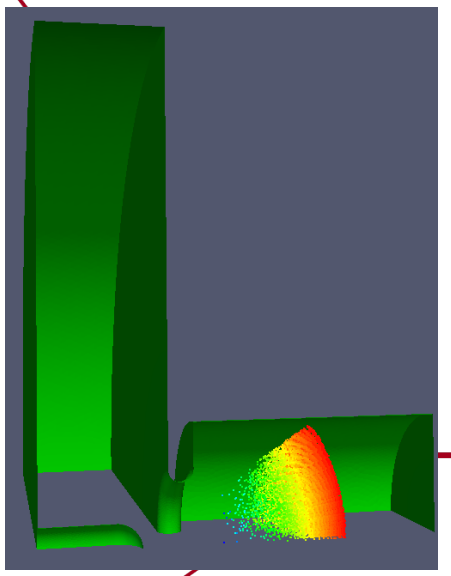
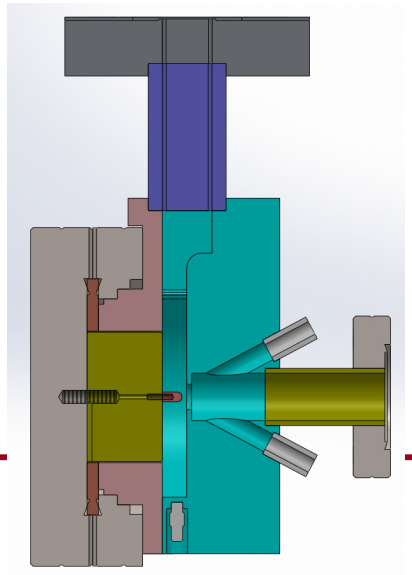
RF Design of an X-band TM02 Mode Cavity for Field Emitter Testing

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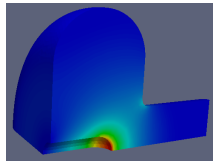
Introduction

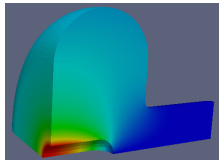
To understand the performance metrics of N-UNCD emitter in high frequency RF fields

- Nitrogen-incorporated ultrananocrystalline diamond (N-UNCD) films
  - excellent field emitter with low turn-on field and stable emission current
  - generating a high charge beam, ~1-10 pC per RF cycle
  - perform in both NCRF and SRF environments
  - handling moderate vacuum conditions
  - can grow directly on metal surface, flexible in shape and size
- N-UNCD field emitter could be a compact electron source
  - could significantly benefit system design of a wide range of accelerator applications
- A field emitter test setup using a at the X-band frequency is investigated
  - TM02 mode cavity
  - demountable emitter back-plate

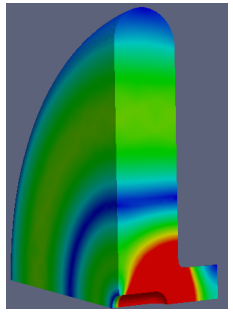
Choice of Cavity Mode – TM01 vs TM02

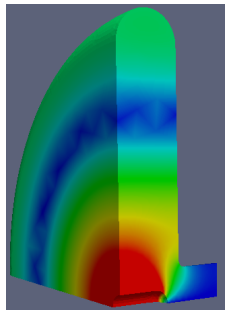
TM01



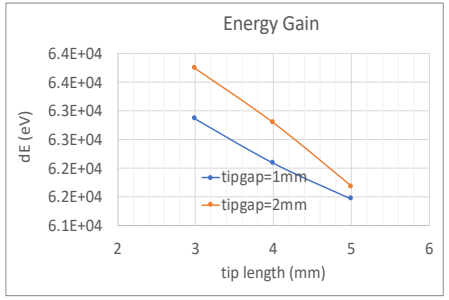


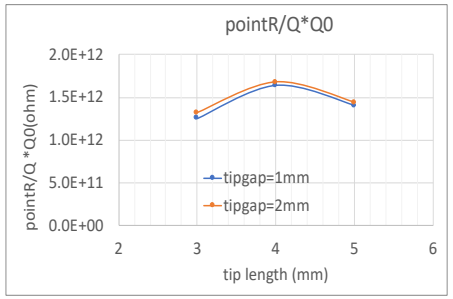
TM02

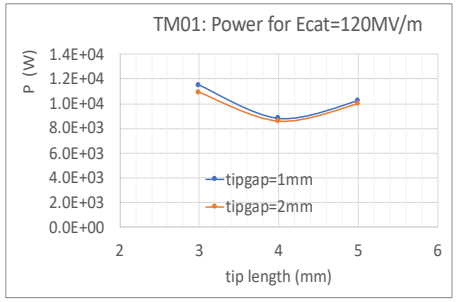


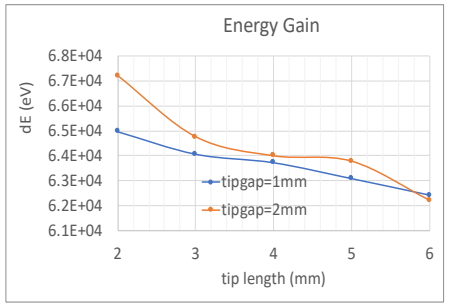


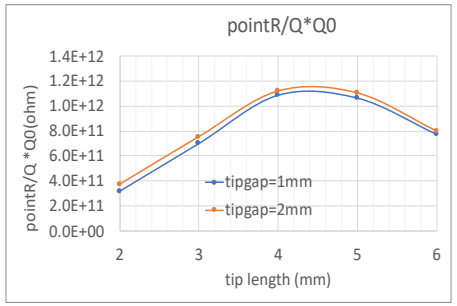
E B

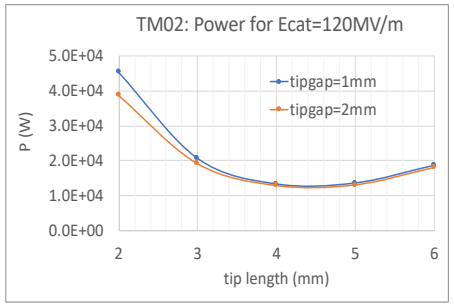










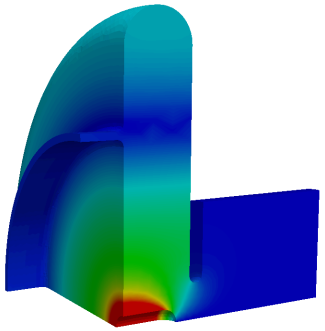


$$\left(\frac{pointR}{Q}\right) = \frac{E_{cat}^2}{\omega U}$$

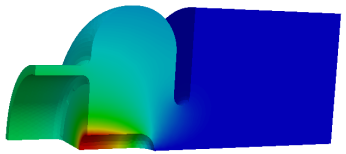
$$\text{Power} = \frac{E_{cat}^2}{\left(\frac{pointR}{Q}\right) Q_0 \frac{4\beta}{(1+\beta)^2}}$$

Using pointR to estimate power requirement

- TM01 mode incurs significant Q0 reduction due to the gap of back-plate plug
- TM02 mode design a preferred choice for the test stand
  - Emitter length: 4 mm
  - Emitter gap: 1 mm



TM02: gap position chosen to reject coupling

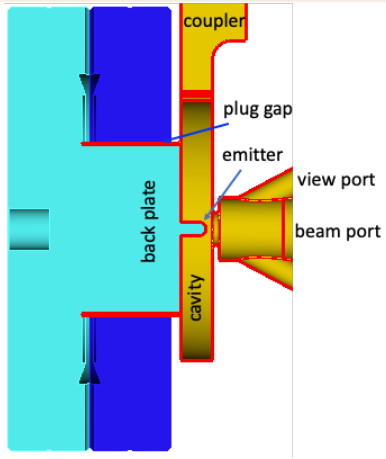


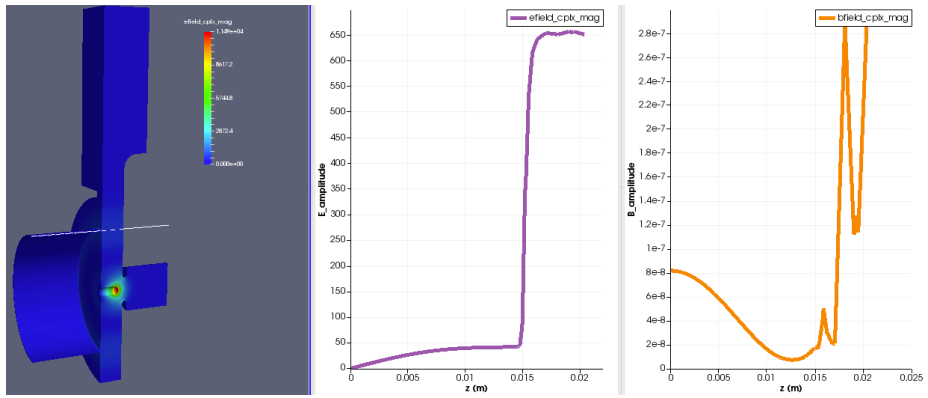
TM01: strong field in g causing Q0 reduction

TM02 Mode Cavity with the Removable Back-plate

Removable back-plate

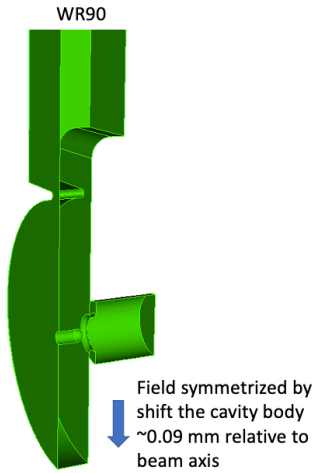
- Plug insertion gap at the radius of ~zero B field
- Small E field in gap, mpltipacting suppressed due to low electron energy gain across the gap.

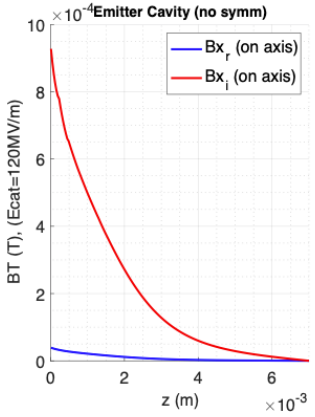




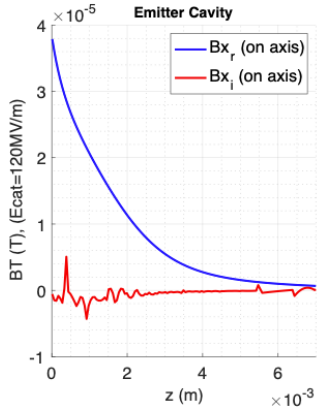
Input coupler

- Symmetrized to Minimize 3D Effect
- Cavity volume shifted off center to eliminate on axis deflecting field



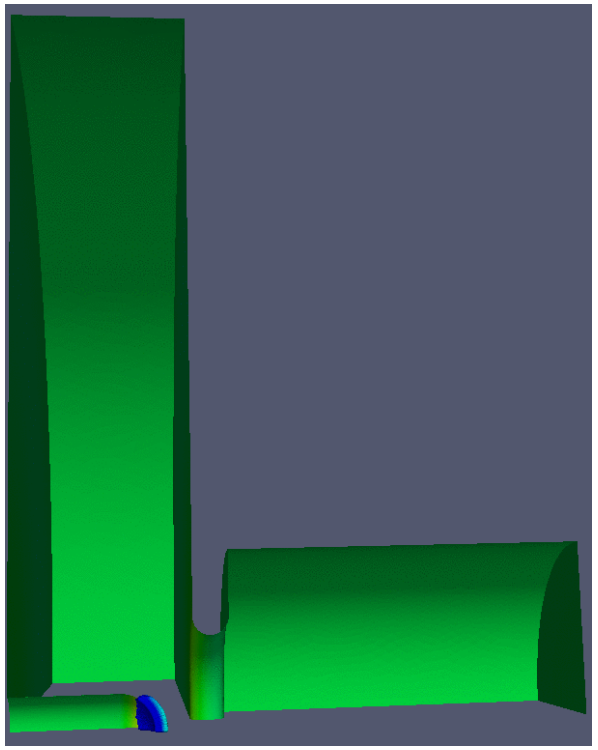


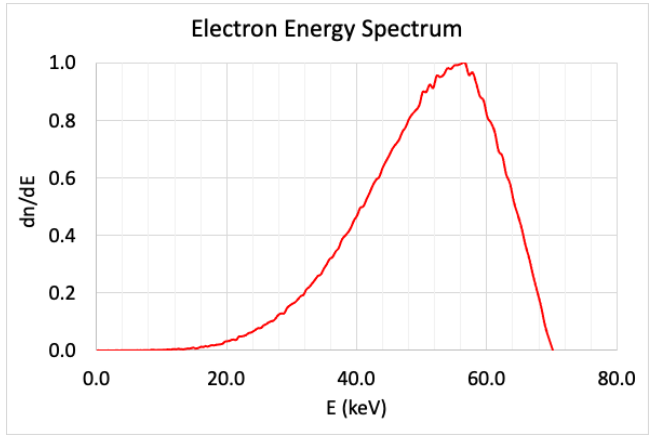
On axis B field
without symmetrization



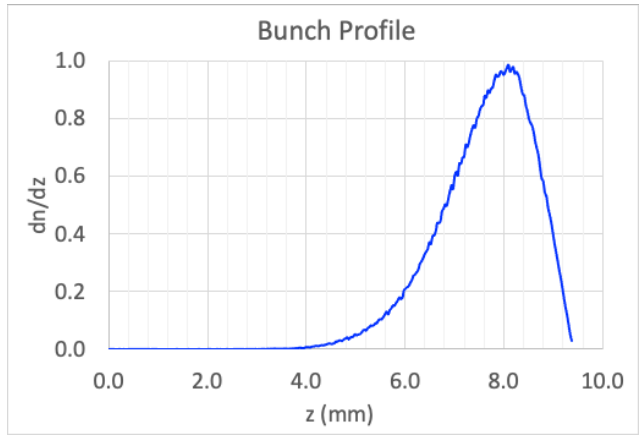
On axis B field
with symmetrization.
A factor of 20 reducti

Field Emitted Electrons – PIC Simulation (ACE3P-T3P)





Electron energy spectrum

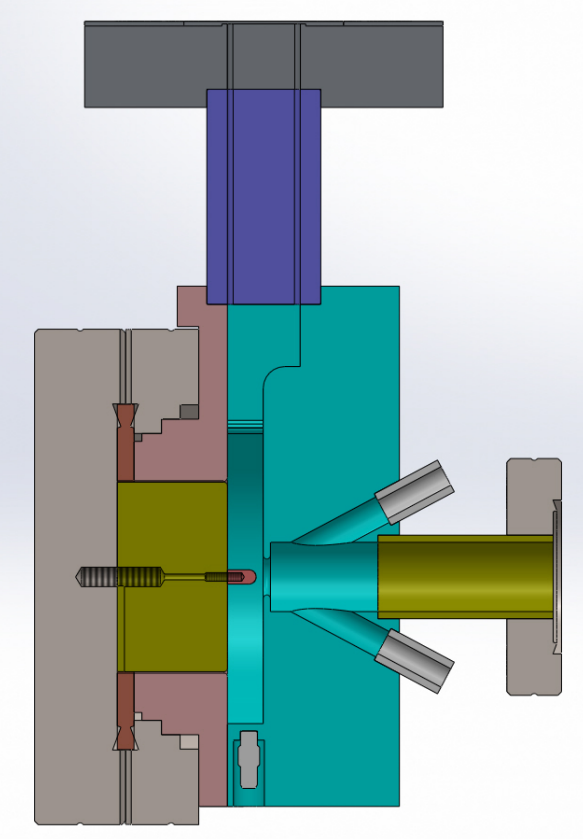


Bunched electron longitudinal distribution

- Electric field on emitter surface: 120 MV/m
- Electrons emitted on full half-sphere surface
- No external focusing

Cavity Parameters and Mechanical Design

Parameter	Value	Unit
Mode type	TM02	
Frequency	11.424	GHz
Quality factor Q0	5300	
(point Shunt impedance) pointR/Q	195	MΩ
Emitter tip electric field	120	MV/m
RF coupling beta	1.05	
RF power required	13.3	kW
Beam energy	63	kV
Bunch charge	1	pC
Cavity length	5	mm
Beam iris aperture	4	mm
Beam port radius	4.875	mm
Emitter tip radius	1	mm
Emitter tip length	4	mm
Emitter gap	1	mm
Back plug gap	0.2	mm
Back plug length	13.7	mm



- TM02 mode cavity mechanical design completed
- Parts being machined