RFQ coupler

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Requirements:

Coupler requirements

Parameter	Value
Frequency	162.5 MHz
Operating power (SWR: $1 \div \infty$)	75 kW, CW
Coupling type	Loop
Output port diameter	~3''
Input impedance	50 Ohm

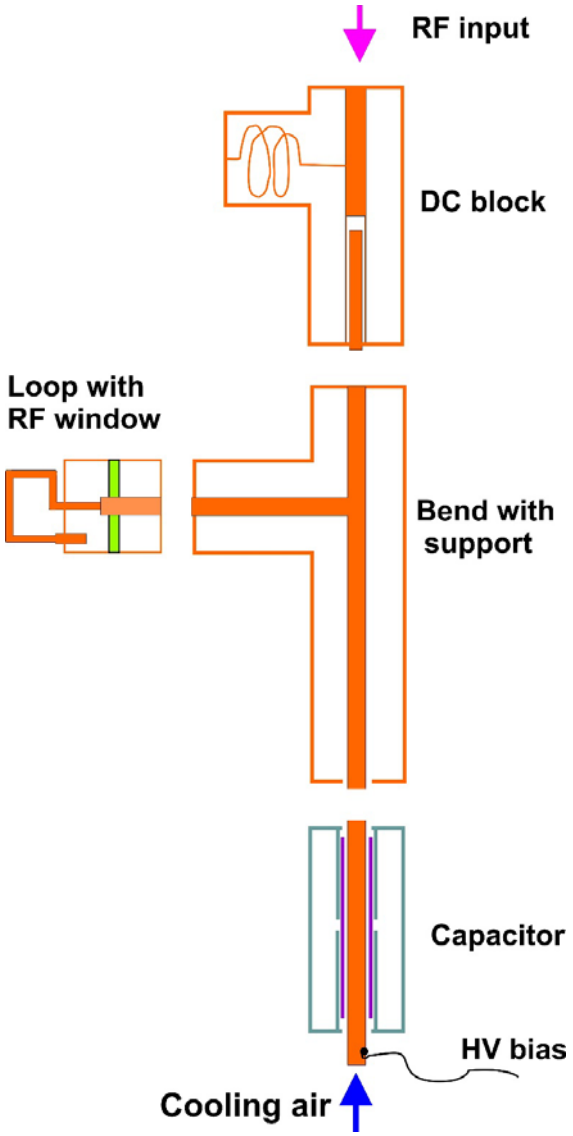
Expected problems:

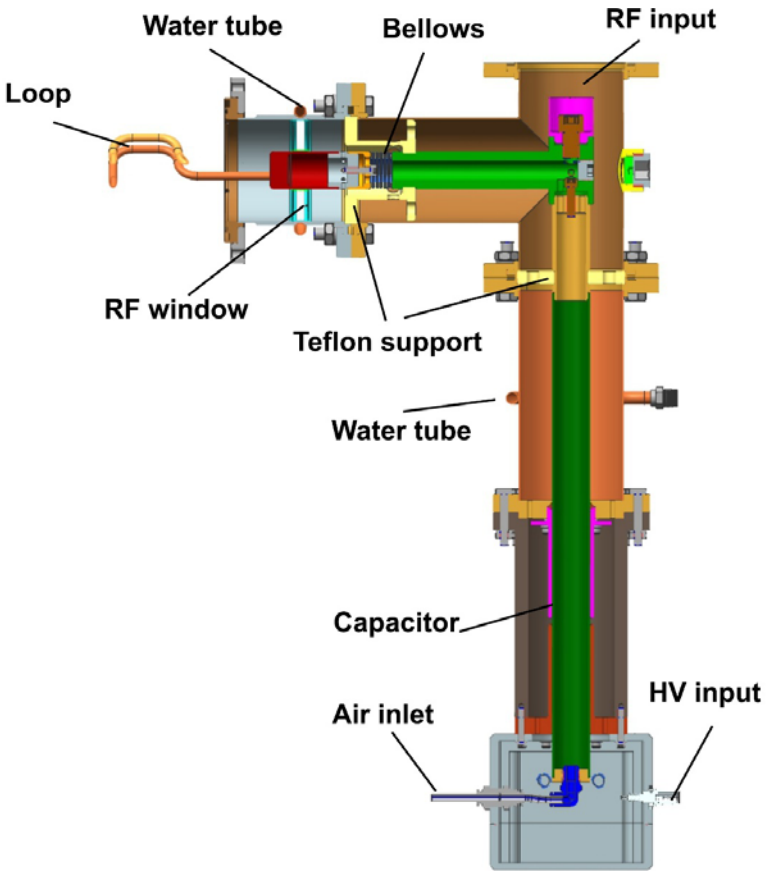
- Heating (loop, ceramic window, etc.)
- Multipactor

Solutions:

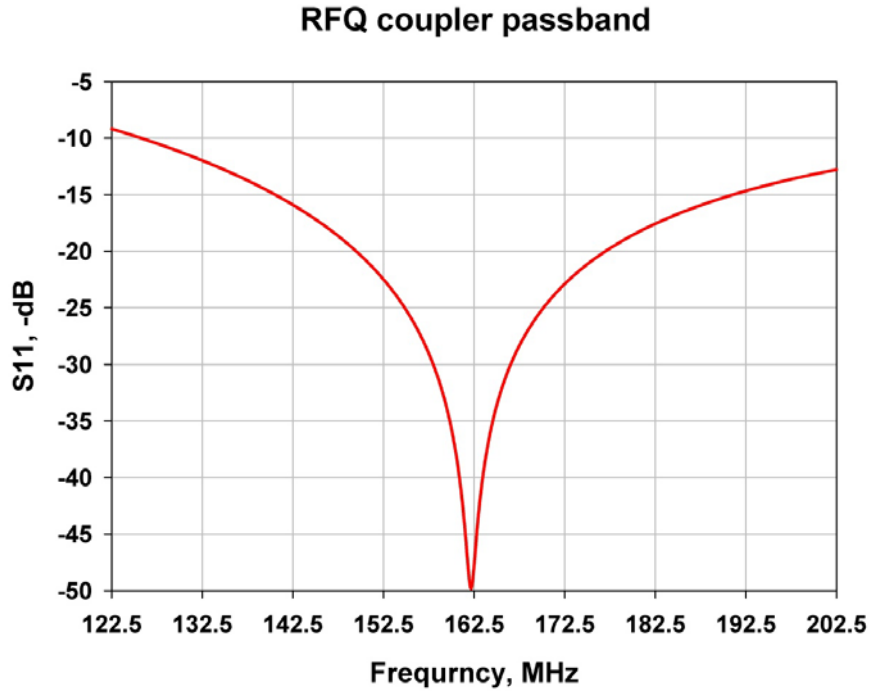
- Appropriate cooling
- HV biac

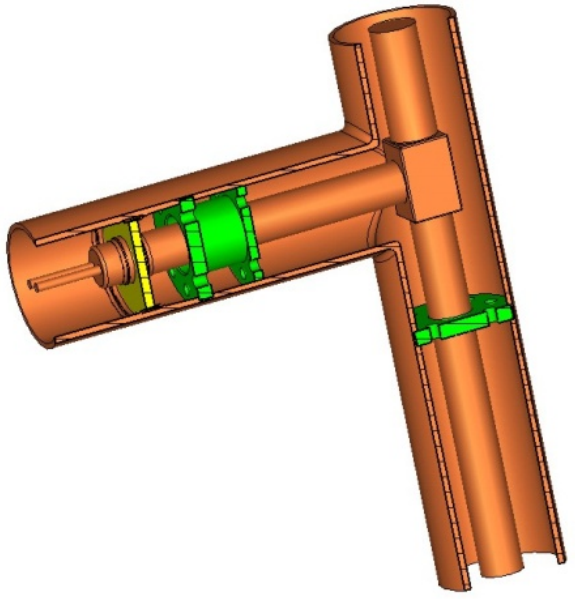
Logic of configuration





RF structure, frequency pass-band

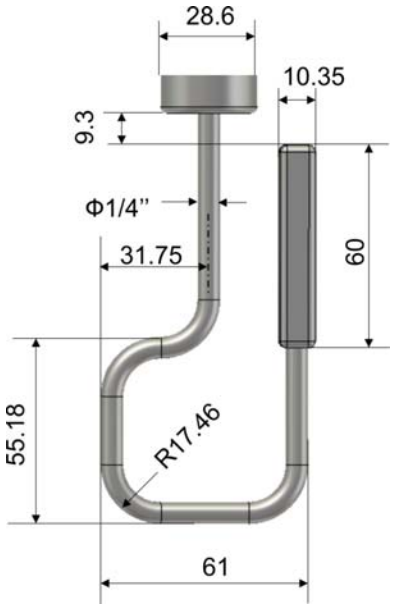


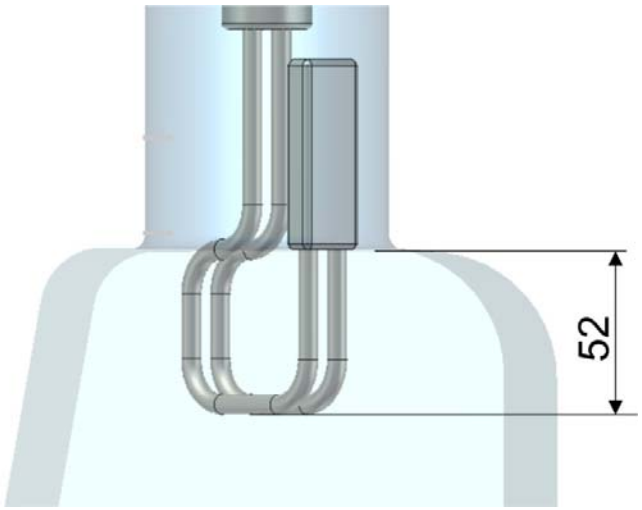


Coupler has a wide passband of ~25MHz, ~15%, (S11 < 0.1). This indicates that high precision is not required during manufacture of the coupler components.

Loop dimensions and penetration.

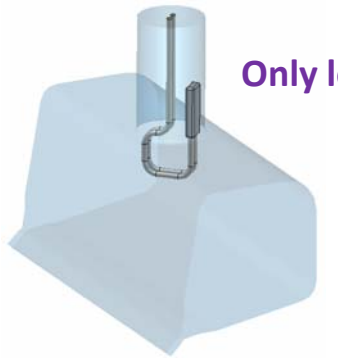
Coupling can be adjusted by loop rotation. Dimensions of the loop and it penetrations were chosen to provide optimal coupling with 45^{o} loop orientation relative to the position of max/min coupling. This allows the coupler to be tuned to compensate for both simulation and manufacturing inaccuracies.



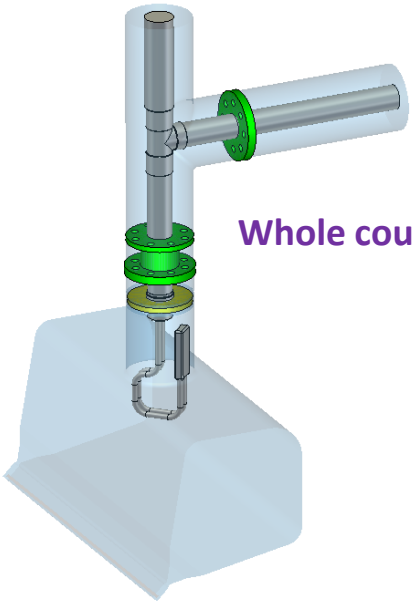


Coupling vs. orientations

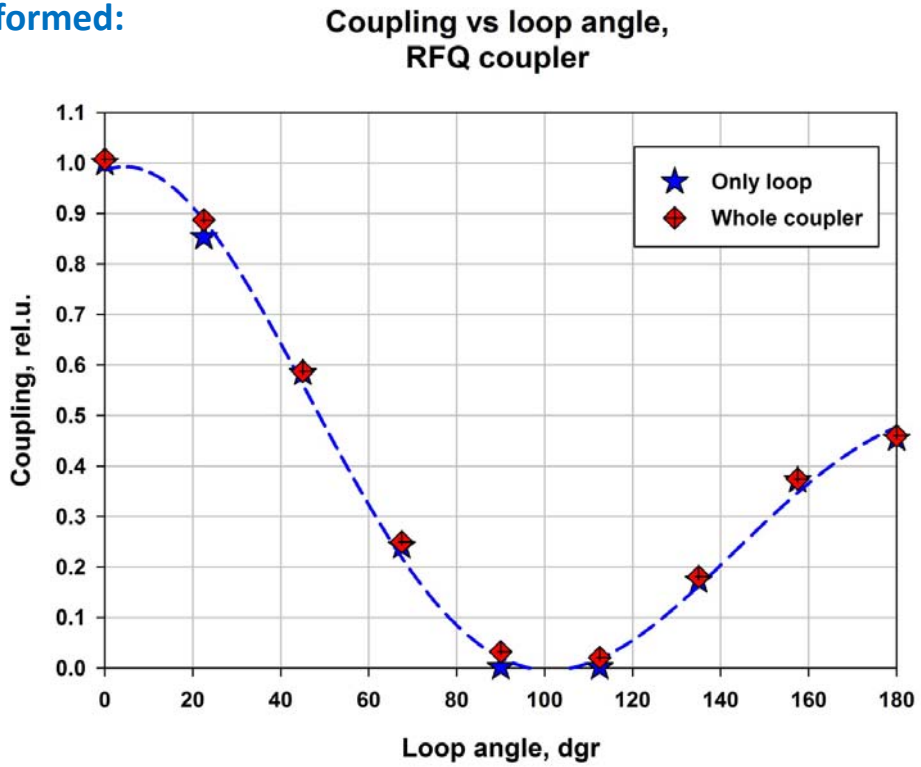
Two type of simulation were performed:



Only loop

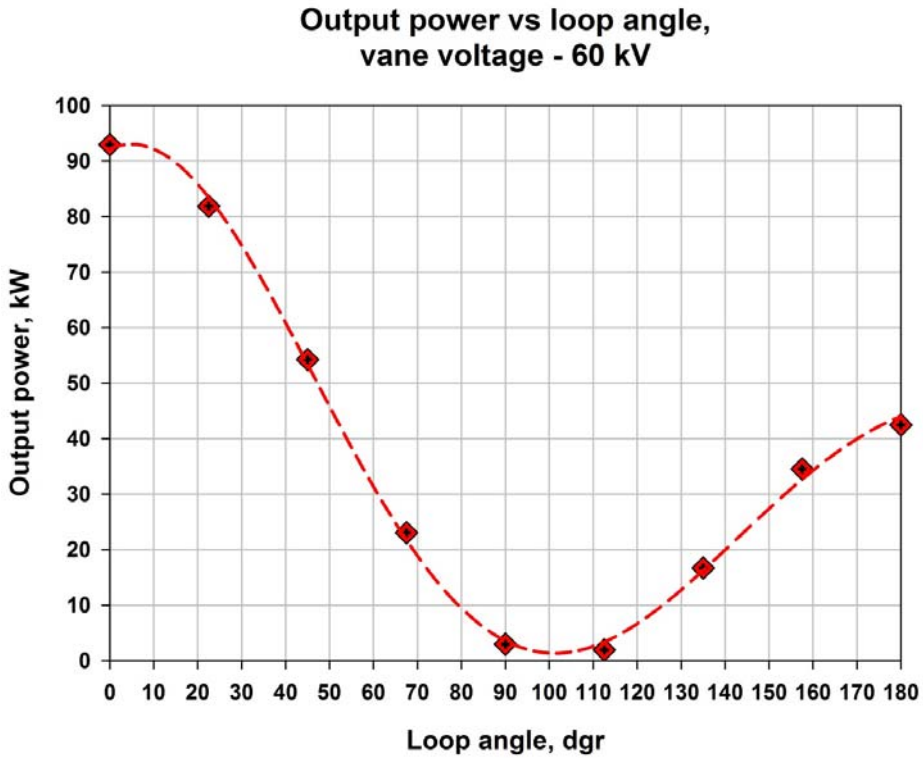


Whole coupler



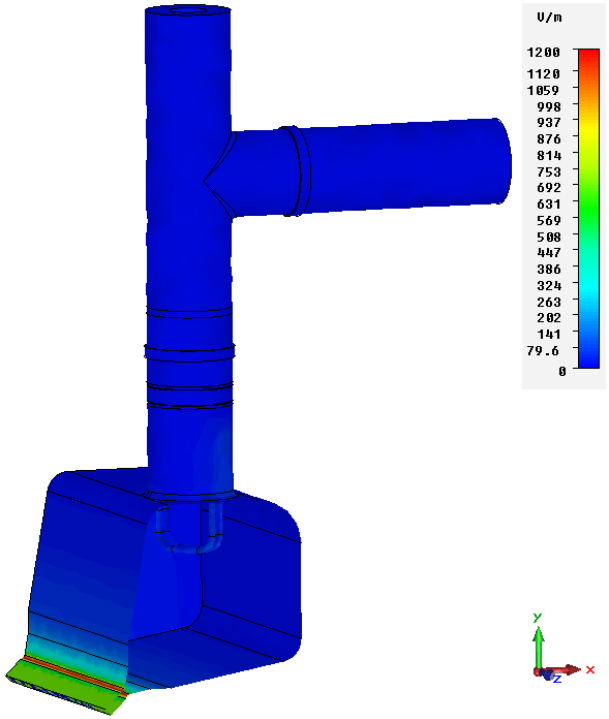
- **Both type of simulations give the same results. It means that coupler is good matched.**
- **Orientation matters. 180^{o} loop rotation gives different coupling. The reason is asymmetrical location of the coupler relative to the cavity.**

Absolute value of power vs. loop angle

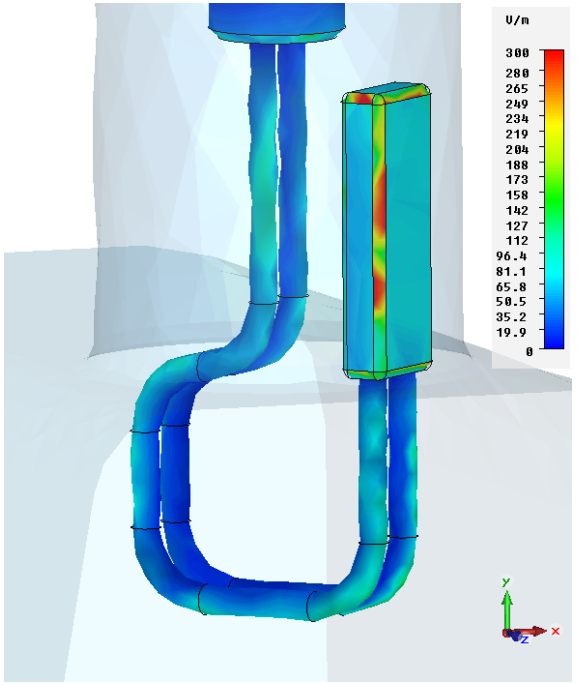


Operating angle ~ 45°

Maximum electric field at coupler surfaces



Max. E-field at vane surface
(60 kV at vane): 12.6 MV/m



Max. E-field at loop surface
(60 kV at vane): 3.2 MV/m

TKx16

Filed at loop 4 times less then field at vane,
Should be no breakdown in the coupler.

TKx16 Electric field

Timergali Khabiboulline x4693 13342N, 5/20/2013

Thermal analyses

Thermal analyses was made for input power level 80 kW, CW.

Total loss in coupler ~ 185 W (ceramic loss tang. 1e-4)
Total loss in coupler ~ 212 W (ceramic loss tang. 1e-3)

Loss in ceramic ~ 3.3 W (loss tang. 1e-4)
Loss in ceramic ~ 33 W (loss tang. 1e-3)

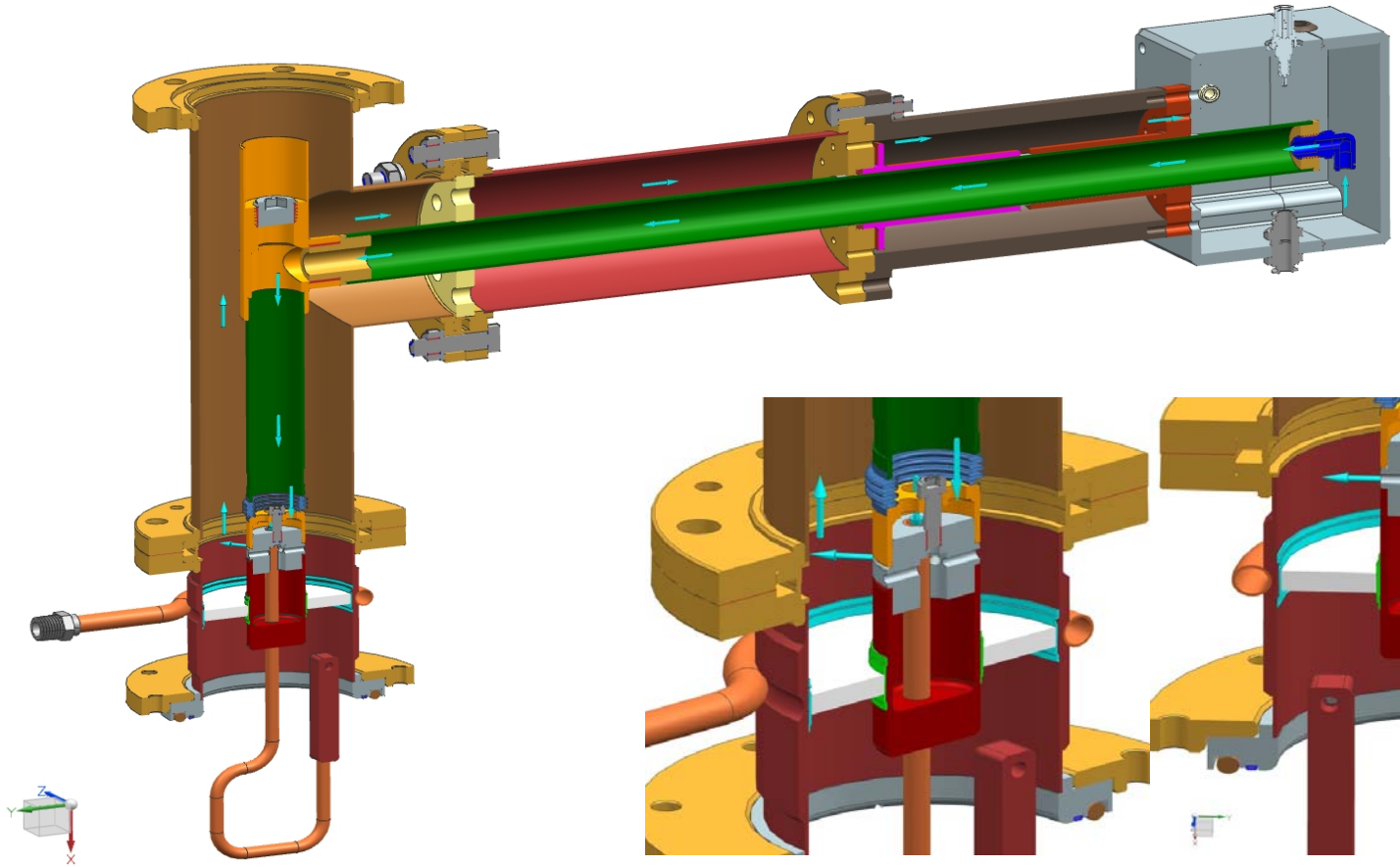
Loss in loop ~ 132 W

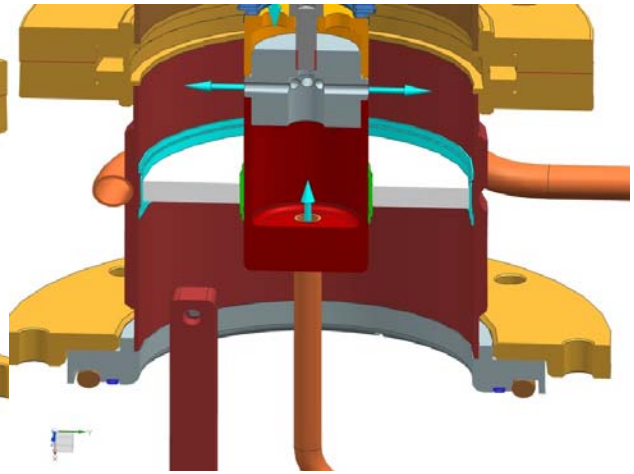
Air cooling:

Flow rate: ~3g/s
Pressure drop ~0.6 bar
Max. air velocity ~140 m/s
Input air temperature ~20 C
Output are temperature ~80 C

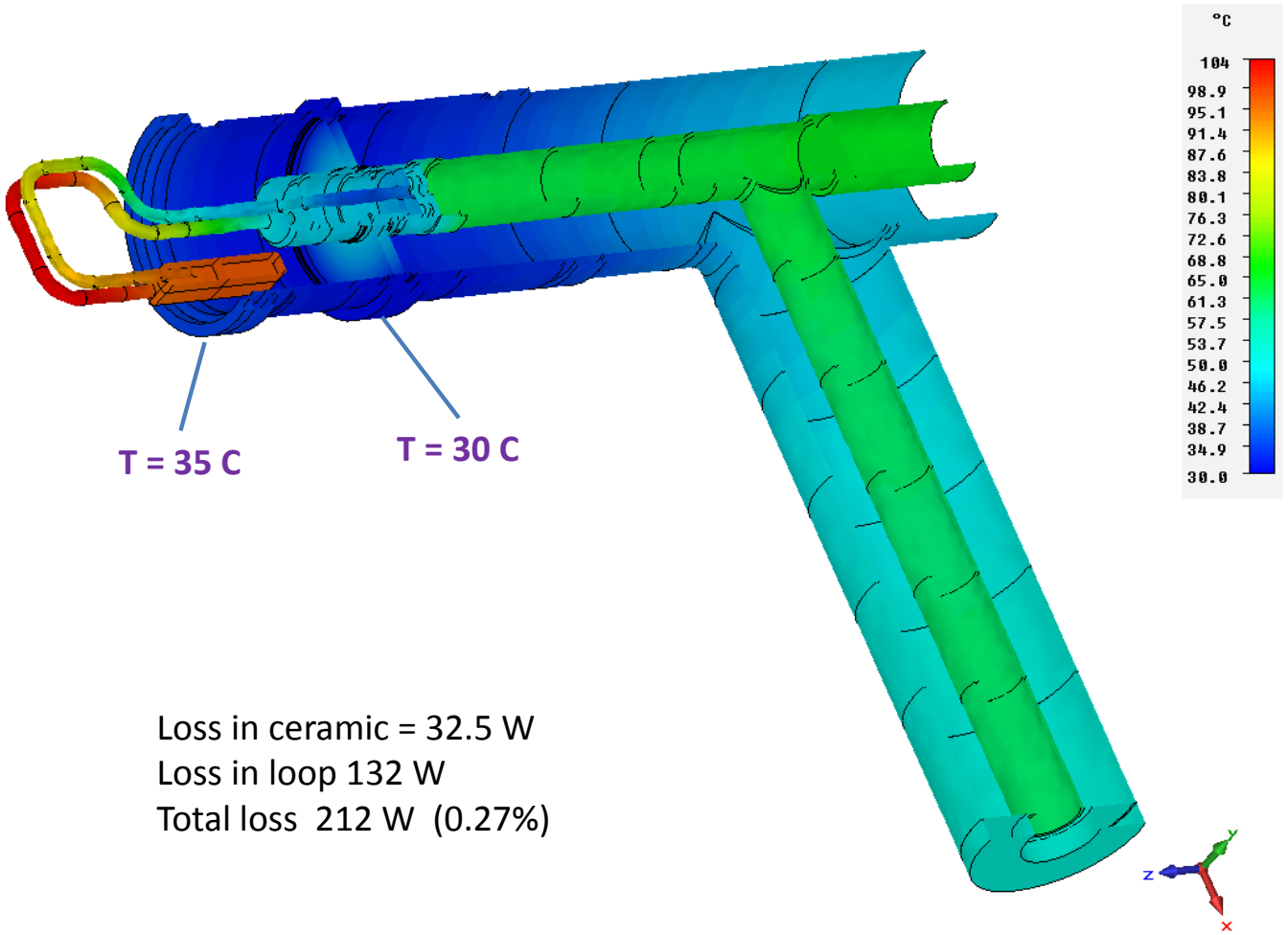
162.5 MHz coupler for RFQ

Cooling air flow

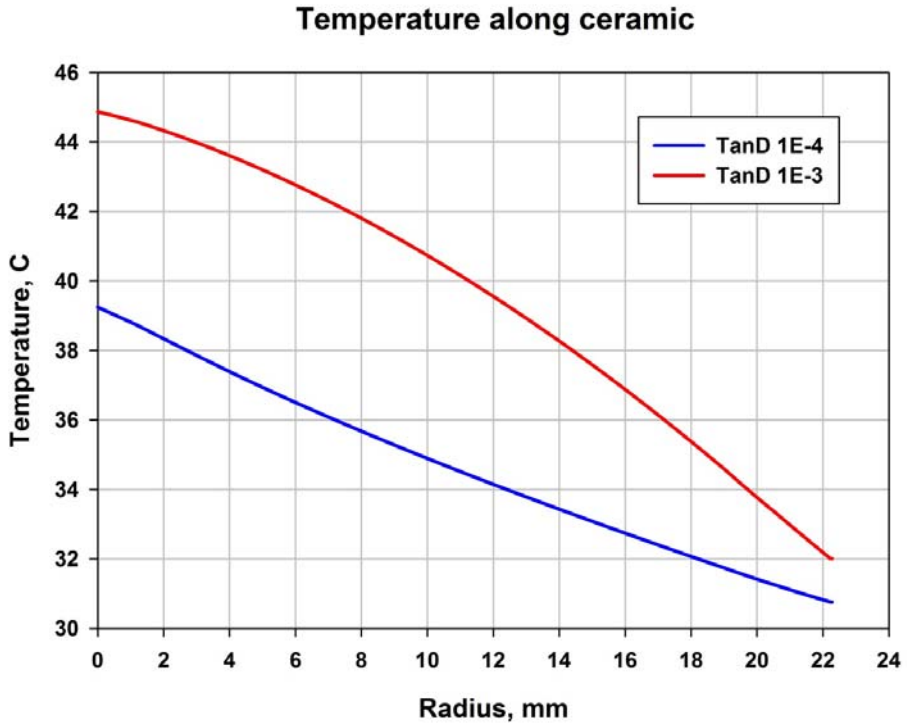




Case of P = 80 kW, TW, Tng δ = 1E-3



Loss in ceramic = 32.5 W
Loss in loop 132 W
Total loss 212 W (0.27%)



Max grad = 0.5 C/mm

Max grad = 0.8 C/mm

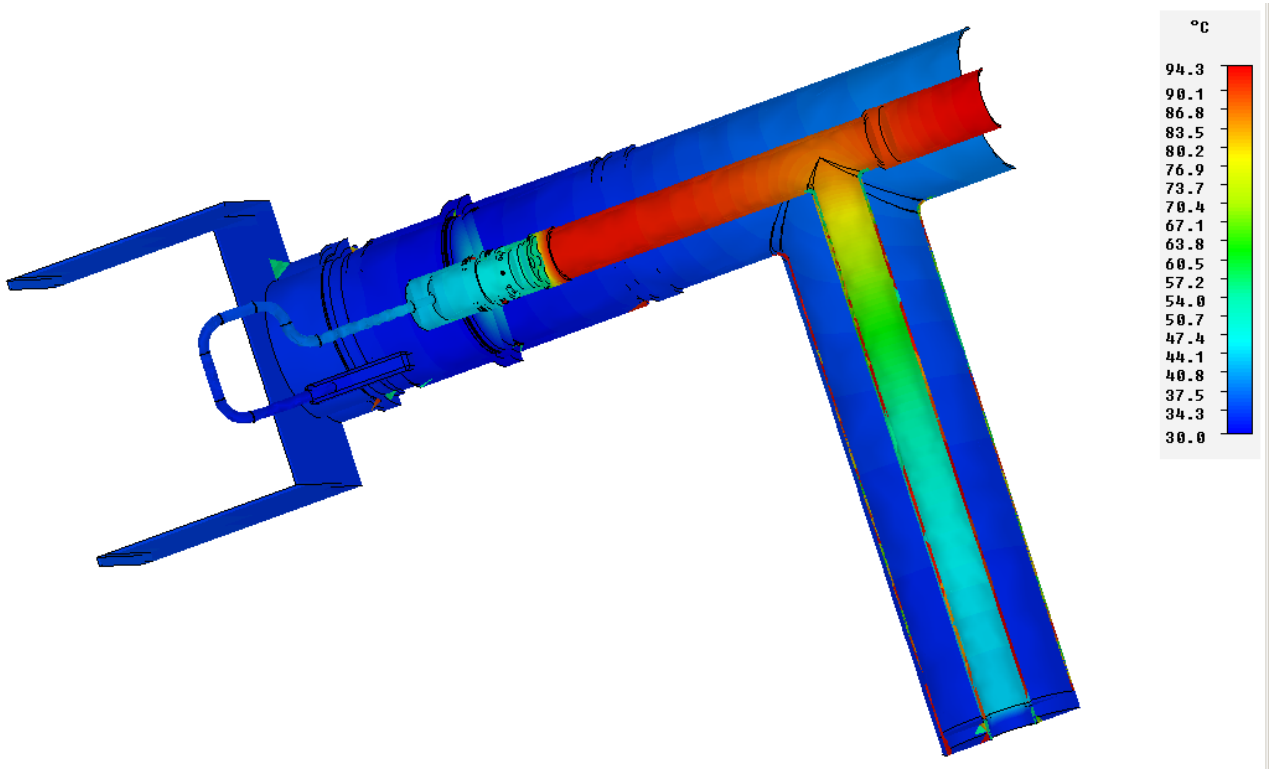
TKx114

Slide 12

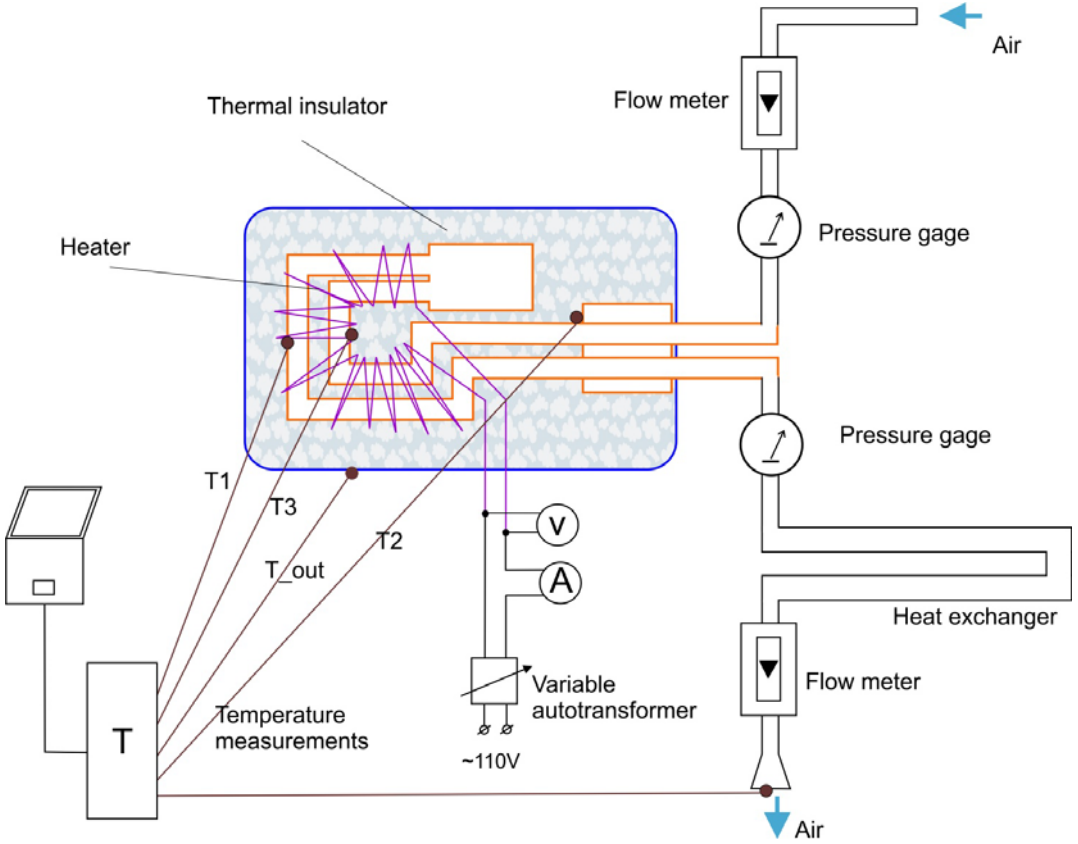
TKx114 Show exaples of safe operation with higher gradients from existing couplers

Timergali Khabiboulline x4693 13342N, 5/20/2013

Temperature distribution in case of full non-resonance reflection, P = 80 kW, Tng δ = 1e-3. Air flow rate ~ 3g/s.



Configuration of loop cooling measurements



A purpose to use a heat exchange is to cool air before flow meter. Flow meter max. temperature is 39C.

P1 = 20 psi, P2 = 10psi, dP = 10psi, Flow1 = 158 SCFH, Flow2 = 4.6 SCFM ~ **2.4 g/s**

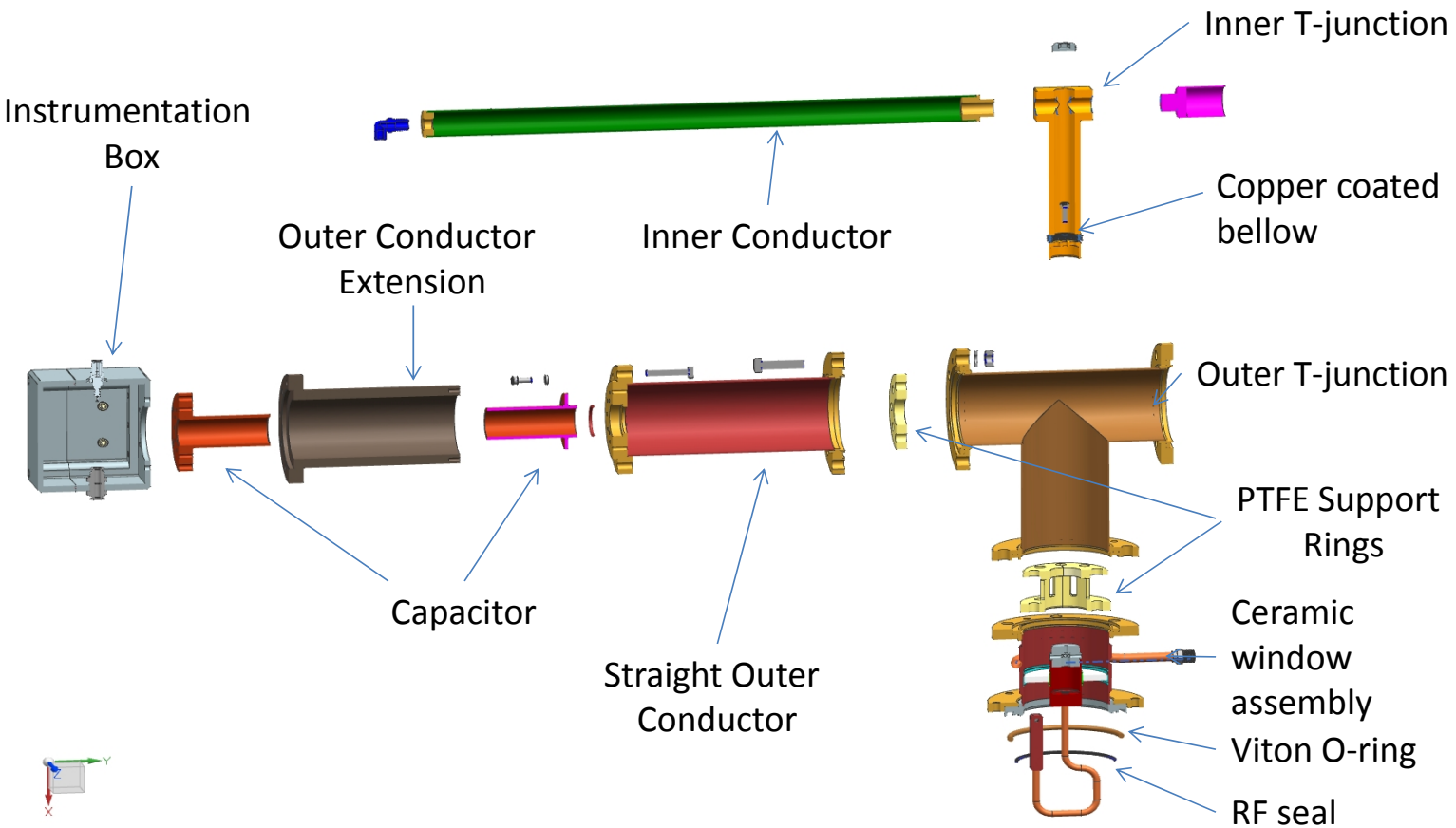
Voltage, V	Current, A	Heater power, W	T_out, C	dT, C	Convect. power, W	Power to cooling air, W	T1, C	T2, C	T3, C
114.3	1.000	114.3	59.2	37	24	90.3	90.5	39.1	74.7
126.7	1.10	139.5	66.4	44.2	28.7	111	105	43	86.2
138.8	1.203	167	71.6	49.4	32.1	135	124	48.2	101

P1 = 28 psi, P2 = 14.5psi, dP = 13.5psi, Flow1 = 130 SCFH, Flow2 = 5.6 SCFM ~ **2.9 g/s**

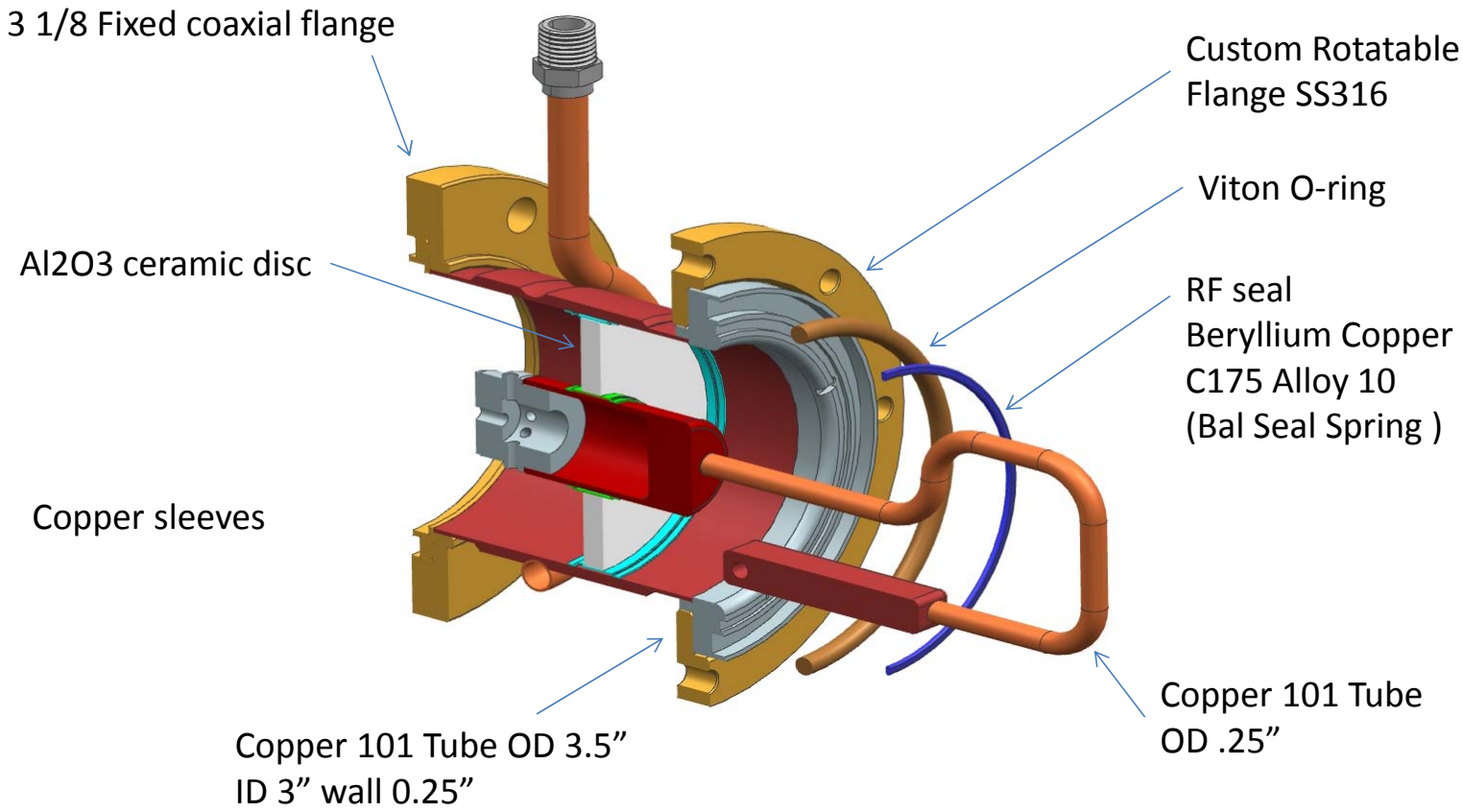
Voltage, V	Current, A	Heater power, W	T_out, C	dT, C	Convect. power, W	Power to cooling air, W	T1, C	T2, C	T3, C
145.8	1.276	180	66.4 (?)	44	28.7	151.3	122	44.7	99

Remark: proper operating condition of flow meter is atmospheric pressure at output. So only flow meter 2 shows right flow rate.

162.5 MHz Coupler for RFQ Variant 3
Main components

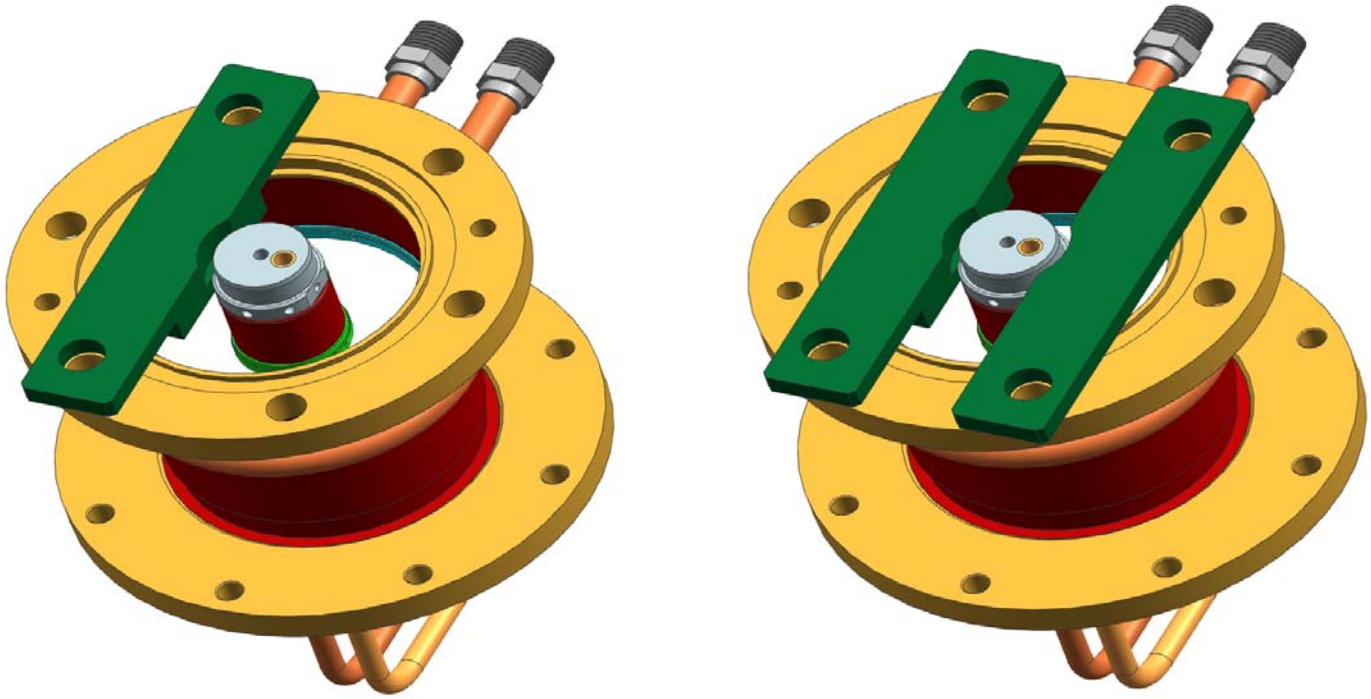


Ceramic window assembly

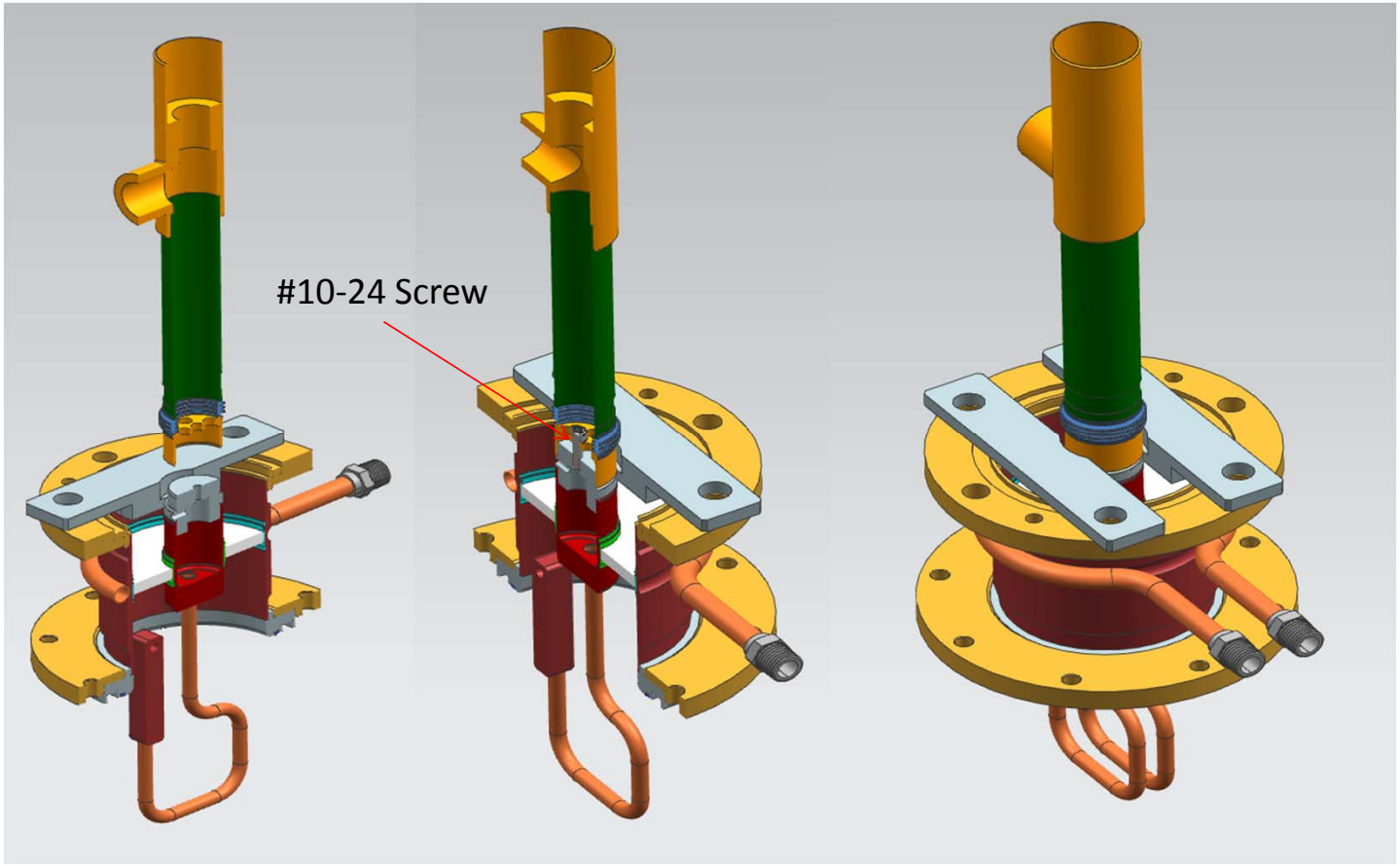


Fermilab

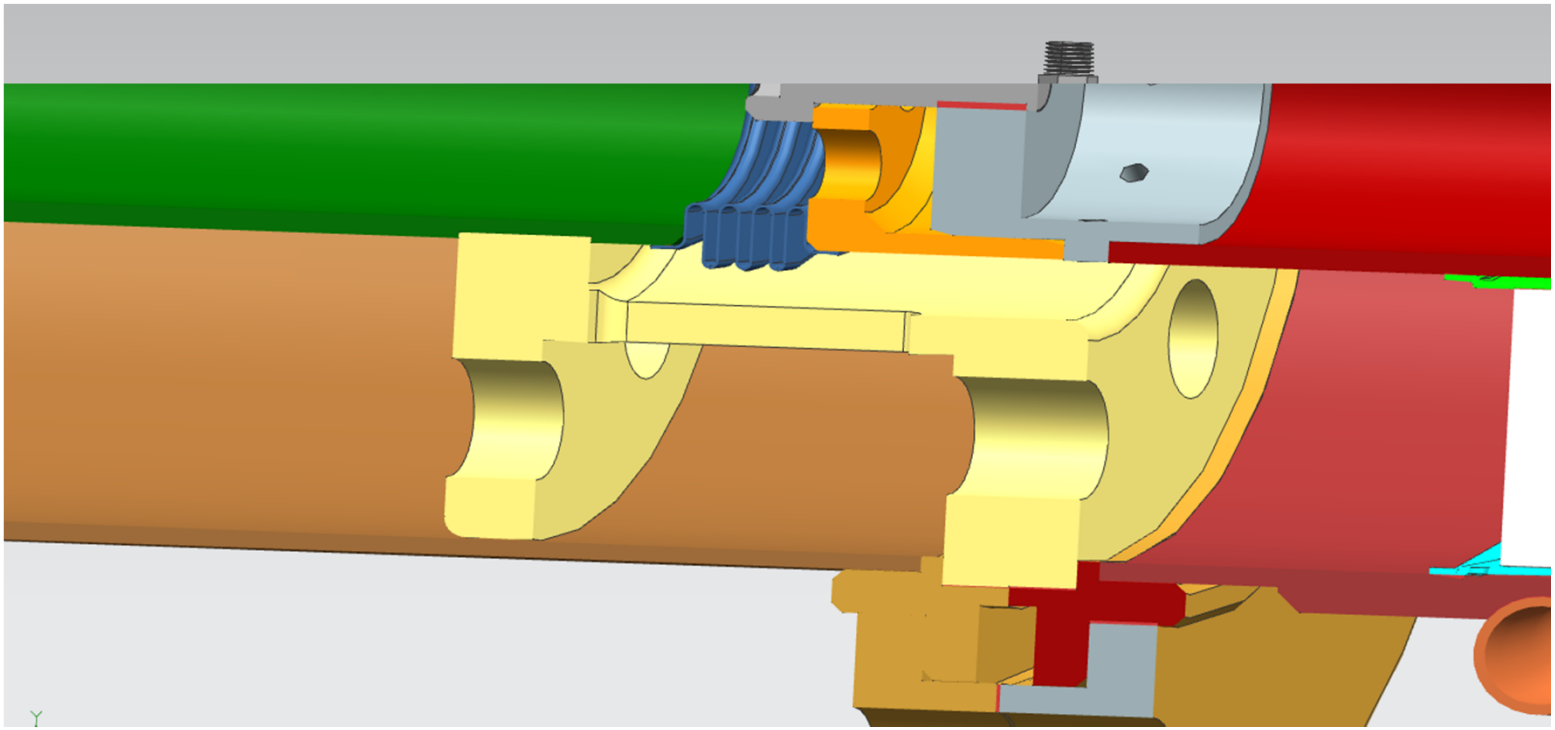
162.5 MHz Coupler for RFQ
Ceramic joint protection



162.5 MHz Coupler for RFQ
Inner T-junction installation

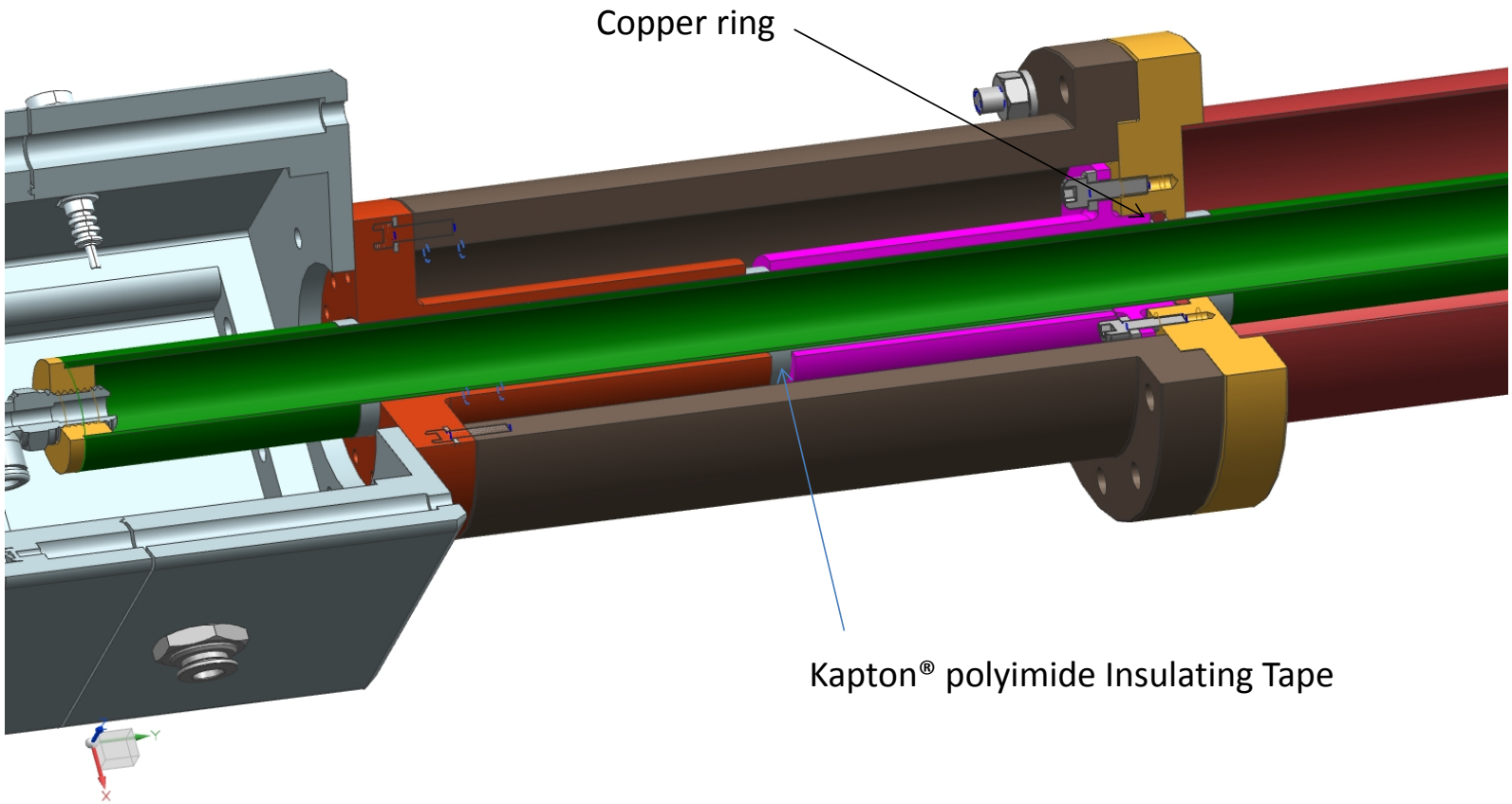


162.5 MHz Coupler for RFQ, Variant 2
Inner T-junction installation

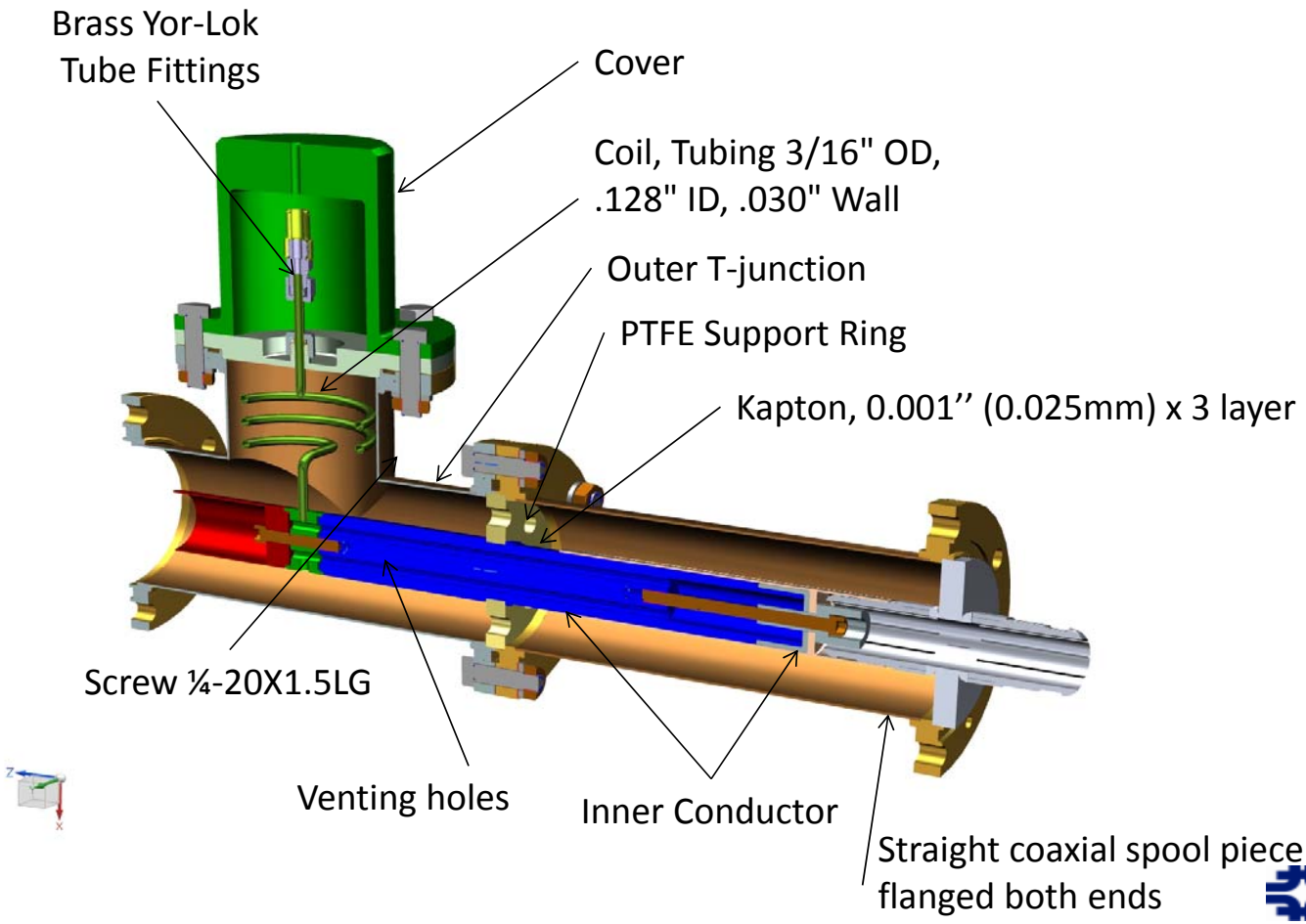


•Copper coated bellow will protect ceramic window
•Notch on inner conductor and special PTFE support will isolate bellow during coaxial line installation

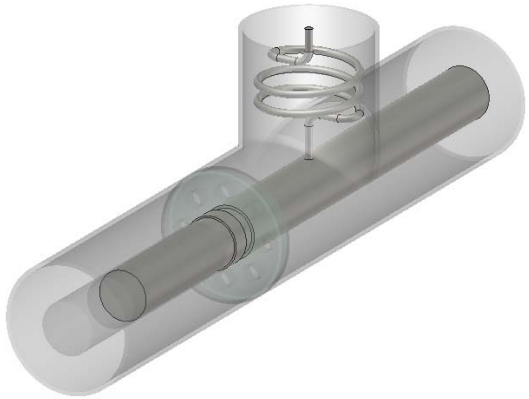
162.5 MHz coupler for RFQ
Capacitor



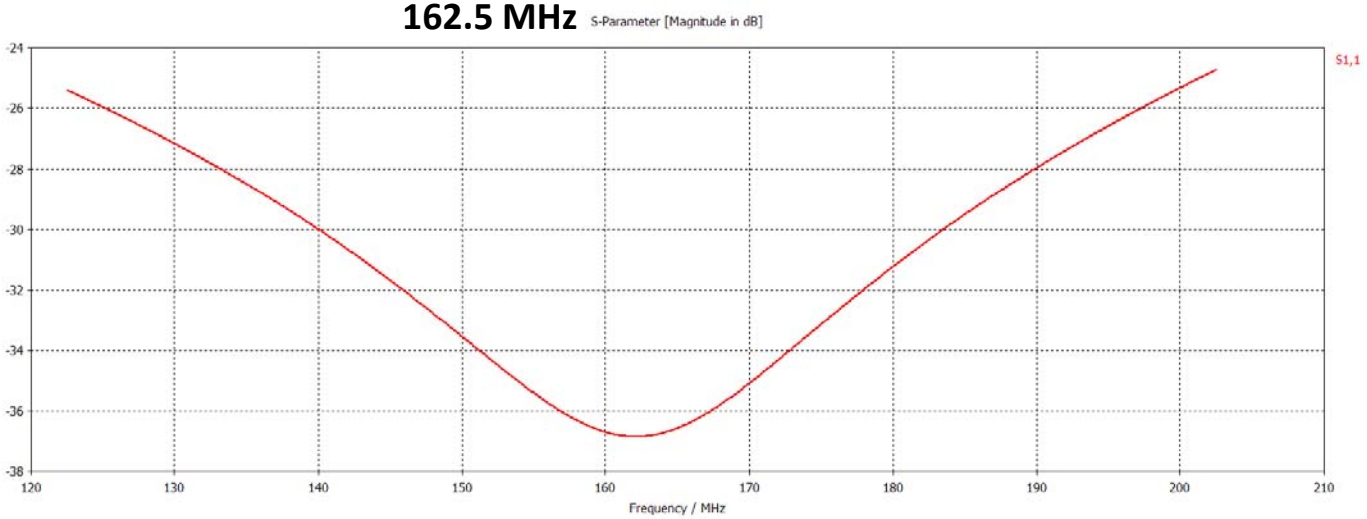
DC Block for 162.5 MHz Power Coupler

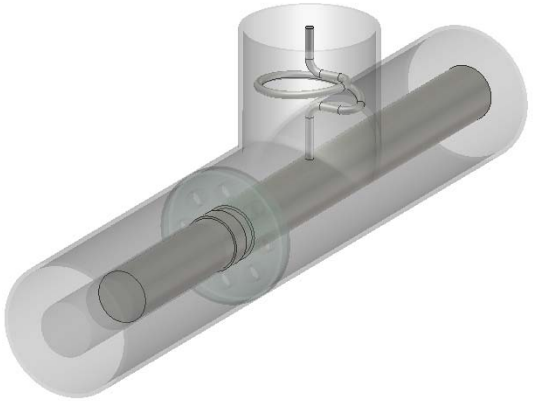


Fermilab

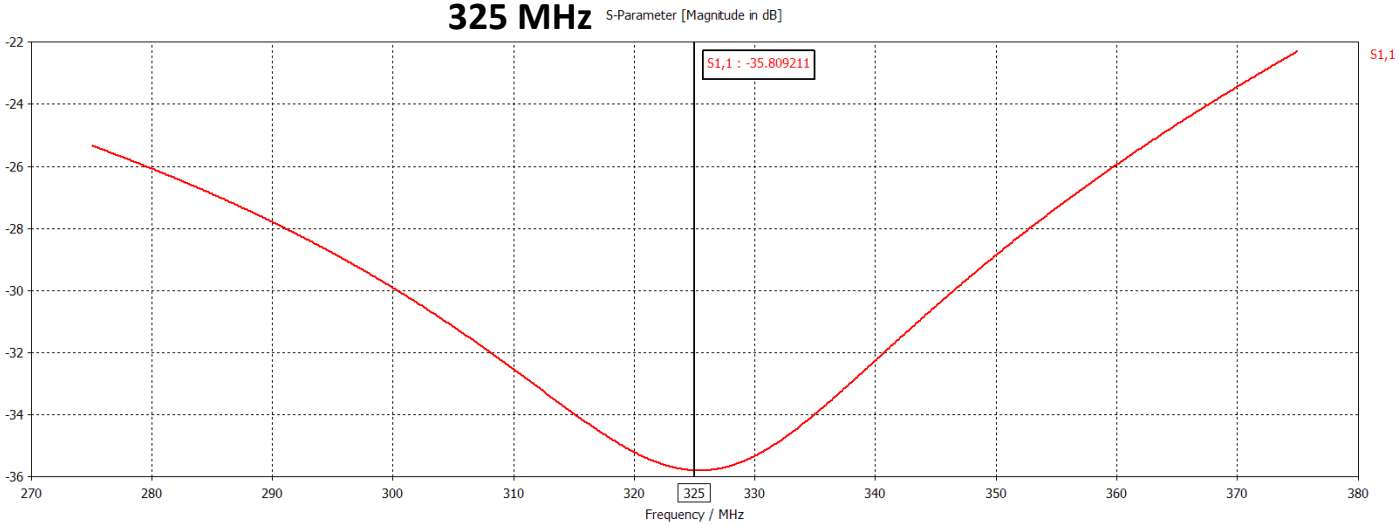


162.5 MHz

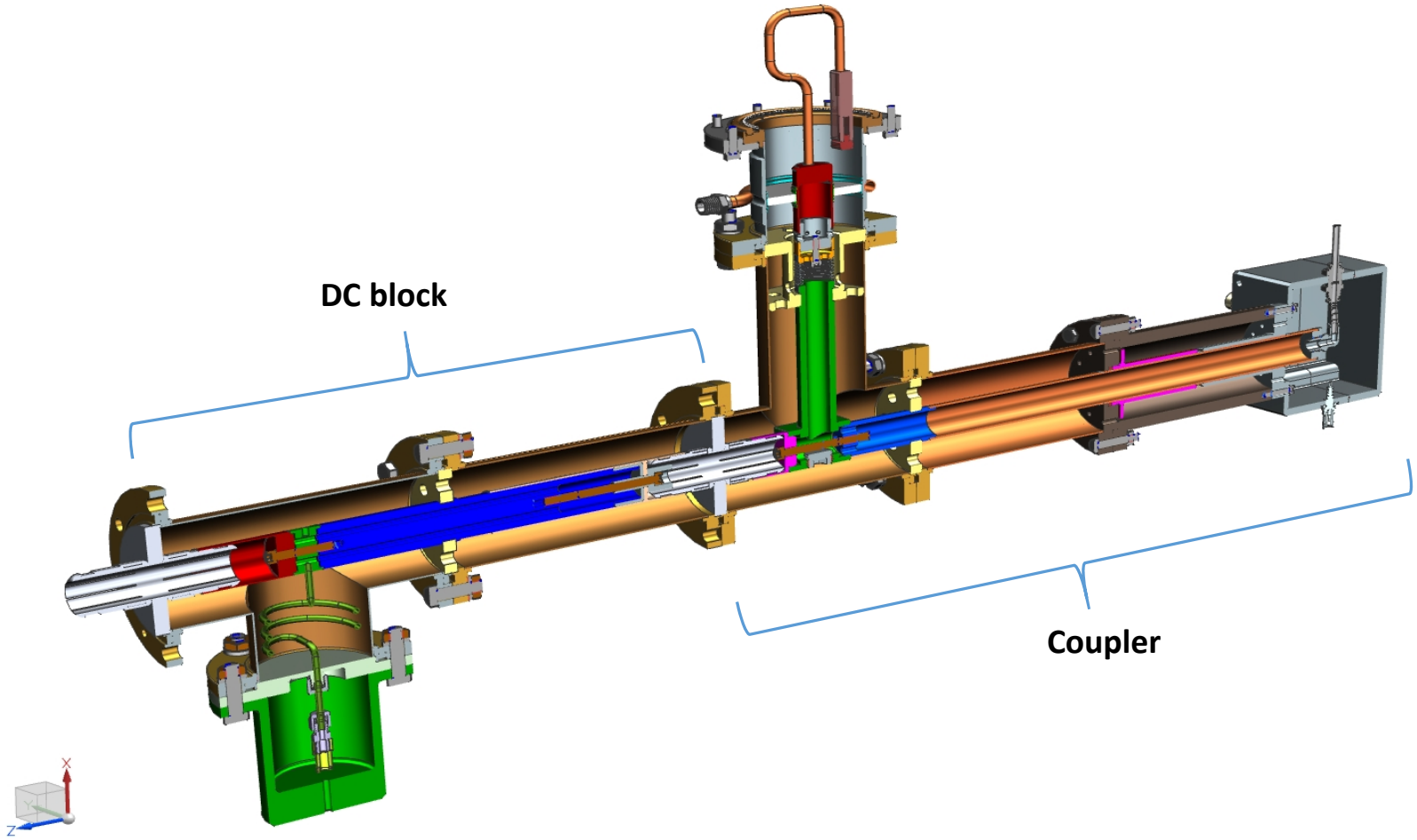




325 MHz



DC Block with 162.5 MHz Power Coupler



Couplers tuning:

Couplers tuning is finding right orientation to provide optimal coupling,
SWR ~ 1 at nominal power and nominal current (10 mA).

Total power loss in all metal walls at 60 kV of inter-vane voltage - 74.6 kW ⇔ Q0

Beam power (10 mA) - 20.7 kW ⇔ Qb = 3.6 Q0

$2/Qc = 1/Q0 + 1/Qb \Leftrightarrow Qc = 1.57\ Q0 \Leftrightarrow Qc*Q0/(Qc+Q0) = 0.61\ Q0$

Tuning procedure:

1) Both couplers orientations 90 dgr. - measurements of Q0 (or measurements without couplers).
2) Rotating one coupler to get 0.61 Q0 (orientation of other coupler is 90 dgr) – finding operating angle of orientation.
3) Do step 2) for second coupler.

Testing results of 325 MHz coupler and projection to 162.5 MHz coupler.

325 MHz coupler is tested at power level 30 kW CW, full reelection. Power is limited by RF source .
It corresponds ~ 60 kW TW. Coupler sustains this power (2 hours run without trips).

RFQ coupler and 325 MHz coupler utilize the same RF window ceramics.
Ceramic losses at 162.5 MHz will be 2 times less.

Ohmic losses at 162.5MHz will be √2.

As results, we can expect that RFQ coupler will sustain 85 kW TW or 42 kW SW.

There are problems with DC block. DC block works well for ~ 10 kW, full reflection. At power level 30 KW, full reflection we got breakdown of kapton insulator. The number of kapton layers will be increased from 3 to 5.
The test will be done at nearest days.

Current situation.

RFQ couplers are under fabrication in Mega Industries.

All mechanical parts are ready:

Waiting for vacuum brazing of ceramic windows in the bodies.

New vacuum furnace in Mega Industries:

Clean room of Mega:

Next visit to Mega :
08/11/2015