Cornell Laboratory for Accelerator-based Sciences and Education (CLASSE)

Design of a symmetric coupler for superconducting elliptical cavities

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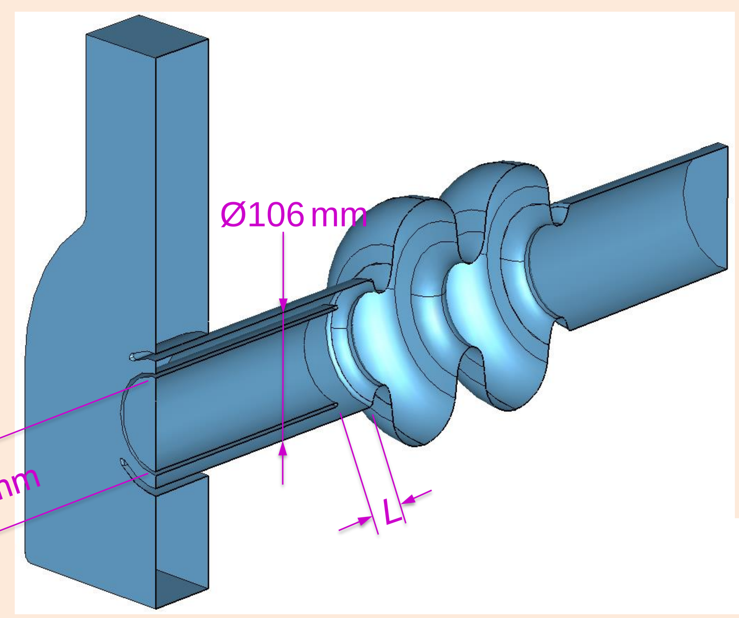
Abstract

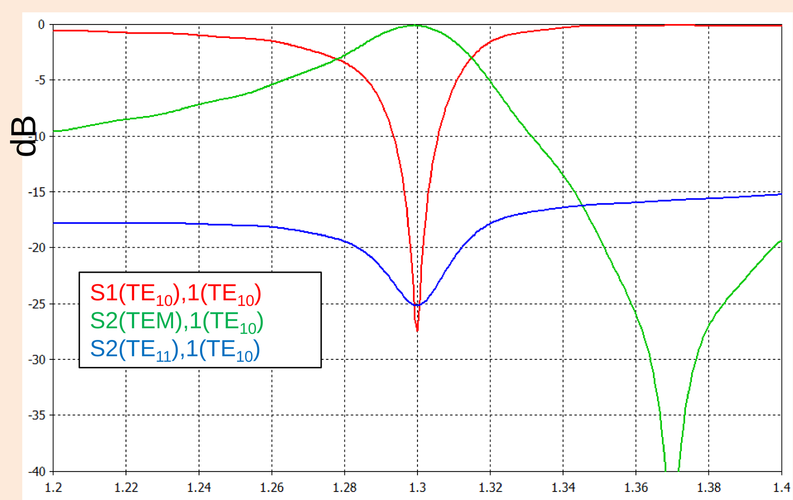
As kicks from fundamental power couplers become a concern for low emittance future accelerators, a design for a symmetric coupler for superconducting accelerating cavities has been started. In this coupler, a rectangular waveguide transforms into a coaxial line inside the beam pipe to feed the cavity. So far the RF design revealed an extremely low transversal kick on which we will elaborate. We will also adress concerns about cooling and the thermal stability of the coaxial transition line. Therefore, we will calculate the heat, heat transfer and thermal stability of this coupler and evaluate the risk of quenching due to particle losses on the coupler

RF Design and Optimization

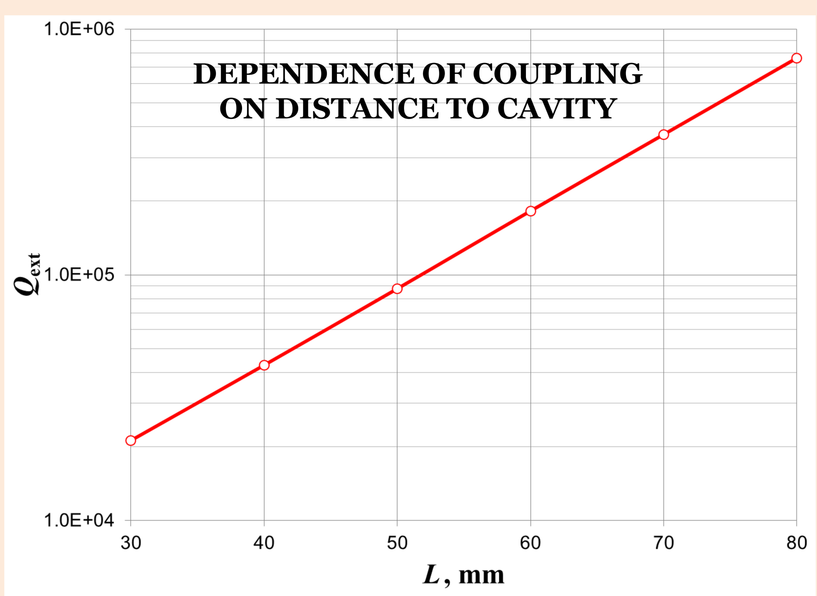
1.3 GHZ ERL INJECTOR CAVITY WITH SYMMETRIC COUPLER



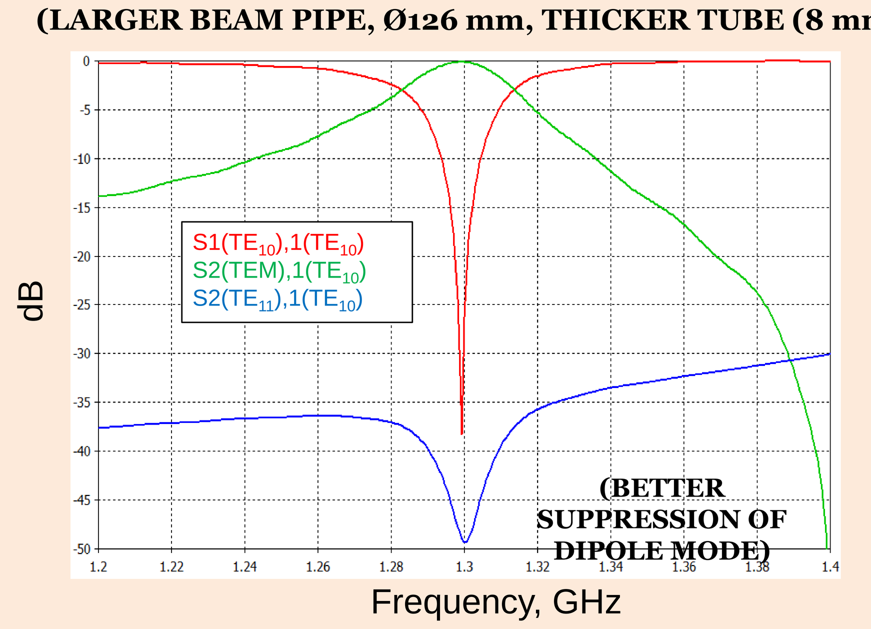
S-PARAMETERS OF THE WAVEGUIDE-TO-COAX TRANSITION

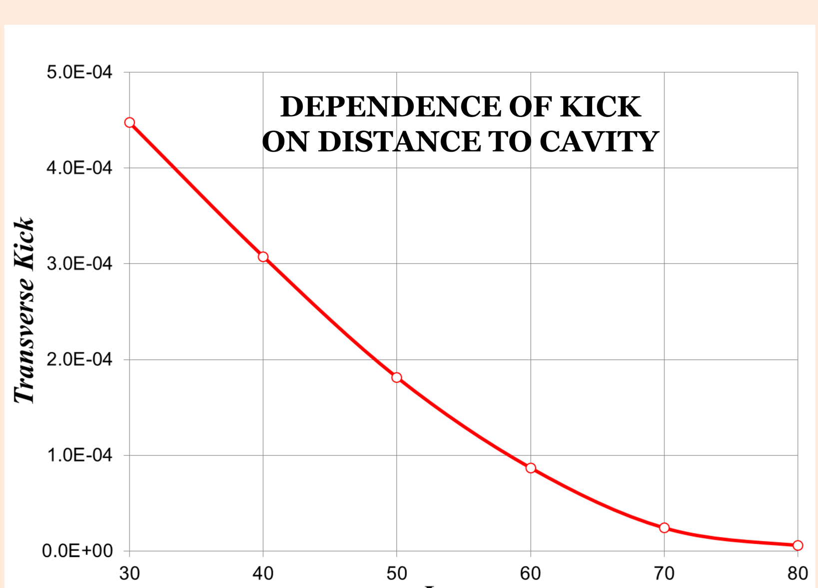


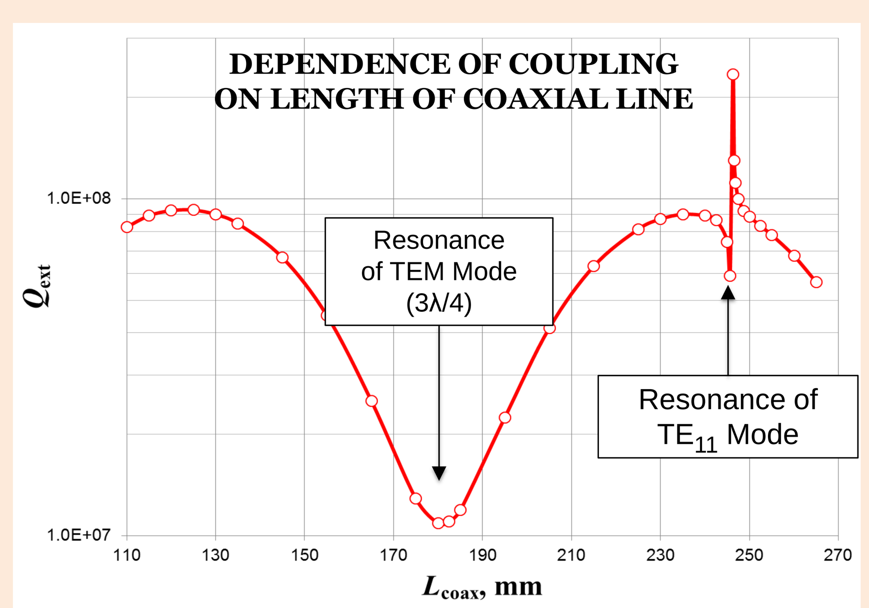
Parasitic dipole TE_{11} mode can be excited and propagate in the coaxial line inside the beam pipe and produce a transverse kick to the beam. The goal of optimization is minimizing the kick for given coupling.

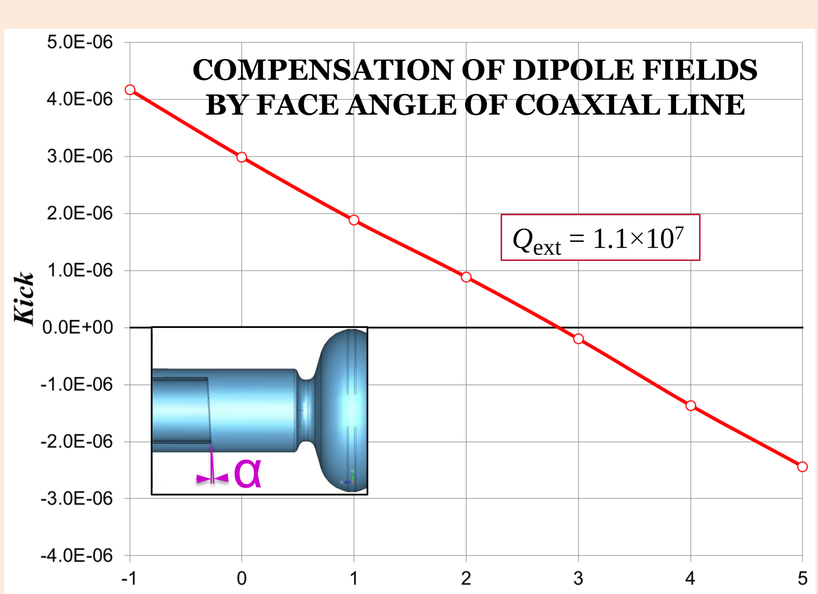


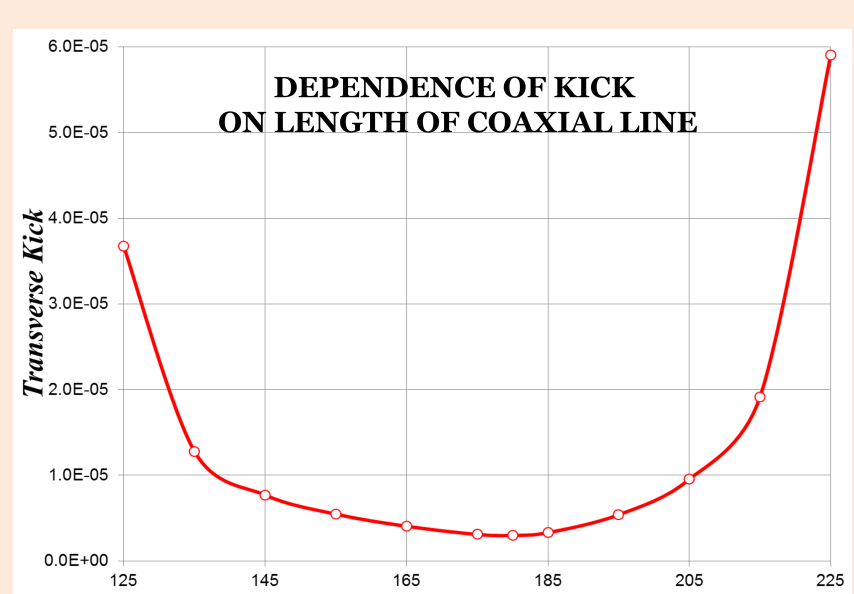
IMPROVED WAVEGUIDE-TO-COAX TRANSITION (LARGER BEAM PIPE, Ø126 mm, THICKER TUBE (8 mm))







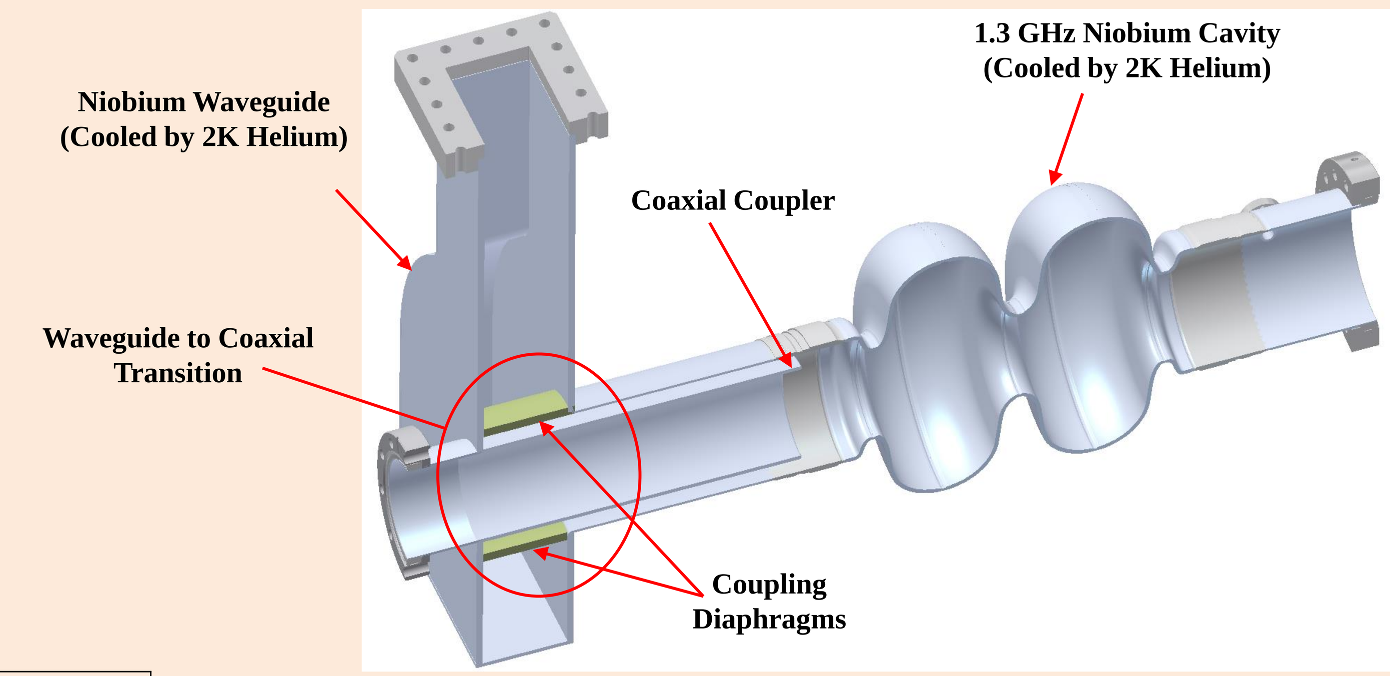




Thermal Analysis

PROBLEMS FOR THERMAL ANALYSIS

1. Will the cylinder inside the beam pipe be superconducting after heat flow in the cylinder has reached steady state?
2. If a part of the cylinder reaches a normal-conducting temperature, will the cooling mechanism be sufficient to return it to a superconducting temperature?

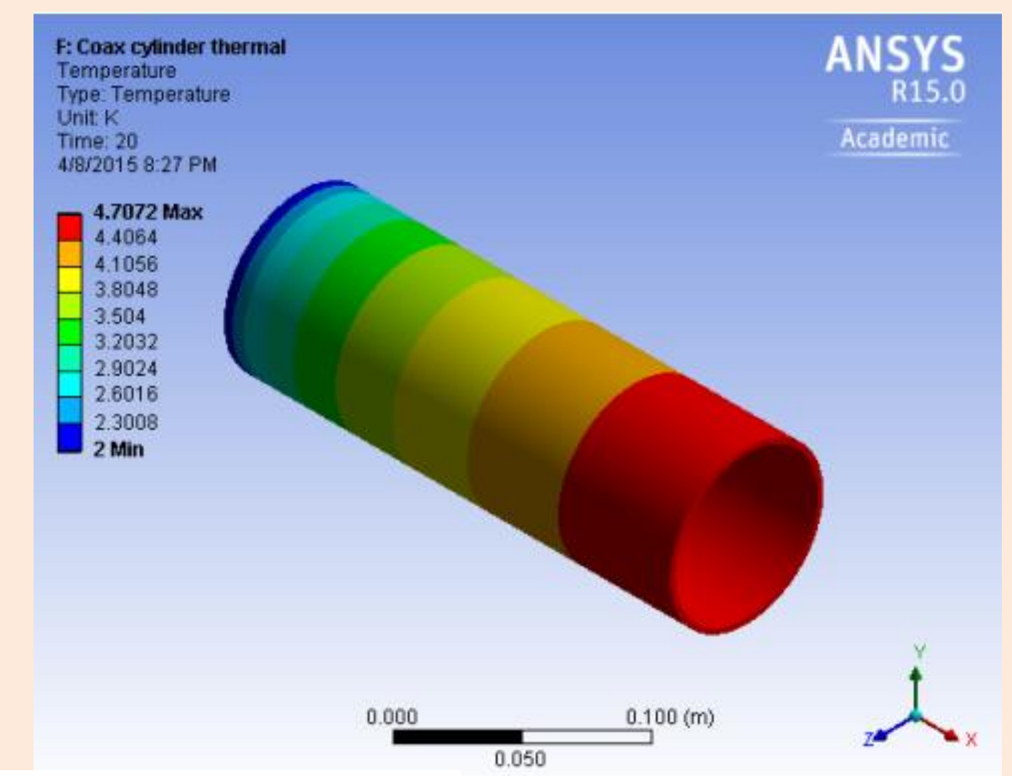


THERMAL CONDUCTIVITY FOR T < 5.8 K:

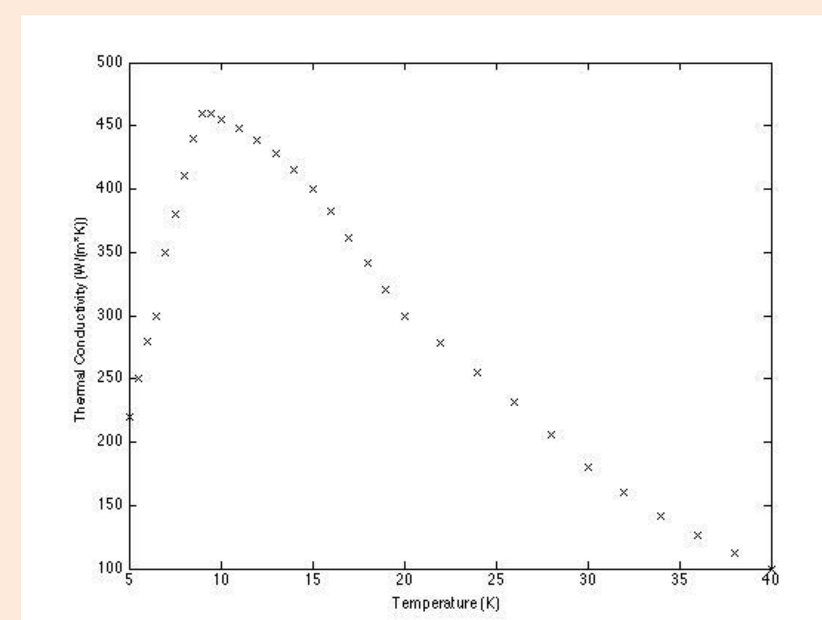
$$K_s(T) = \frac{K_{es}}{K_{en}}\left(\frac{\rho_{295K}}{L \cdot RRR \cdot T} + aT^2\right)^{-1} + \left(\frac{1}{D\, e^{\frac{\alpha T_c}{T}}\, T^2} + \frac{1}{B\, l\, T^3}\right)^{-1}$$

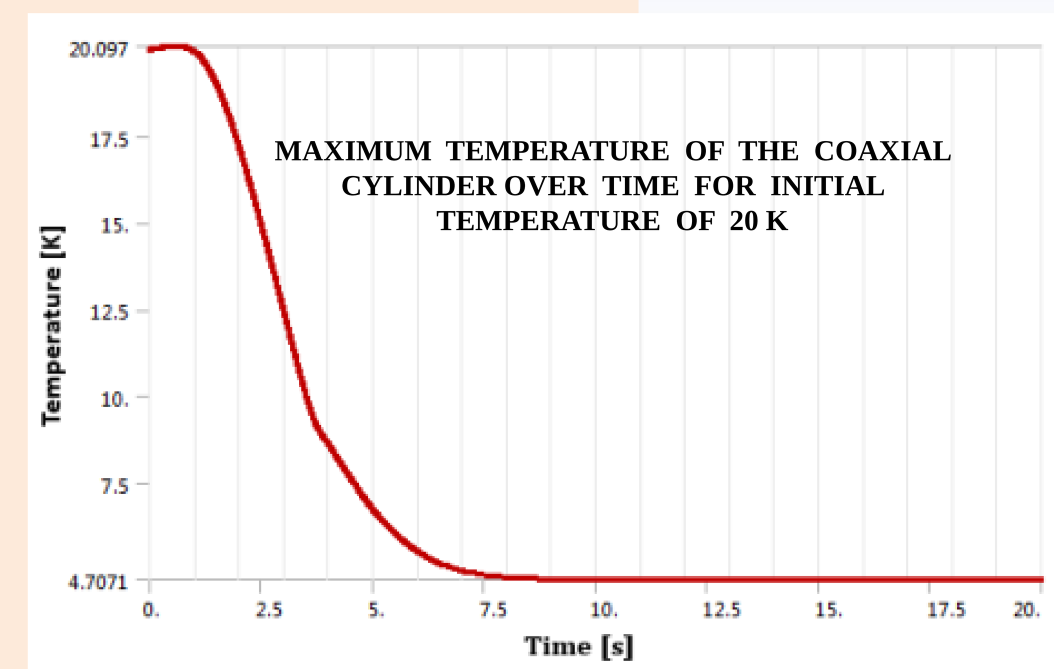
RRR	400
ρ_{295K}	14.5×10^{5} Ω·m
l	50 μm
T_c	9.2K
L	2.45×10^{-8} WK^{-2}
a	2.30×10^{-5} mW^{-1}K^{-1}
B	7.0×10^{3} Wm^{-2}K^{-4}
$1/D$	300 m K^{-3}W^{-1}
α	1.76

COAXIAL CYLINDER STEADY STATE TEMPERATURE



DATA USED FOR T > 5.8 K (EMPERICAL)





SPECIFIC HEAT (DEBEY MODEL) :

$$C_v = \gamma T + AT^3$$

γ	0.0946 J/(kg·K^2) for $T > T_c$
γ	0 for $T < T_c$
A	1.28×10^{-3} J/(kg·K^4) for $T > T_c$
A	5.01×10^{-3} J/(kg·K^4) for $T < T_c$

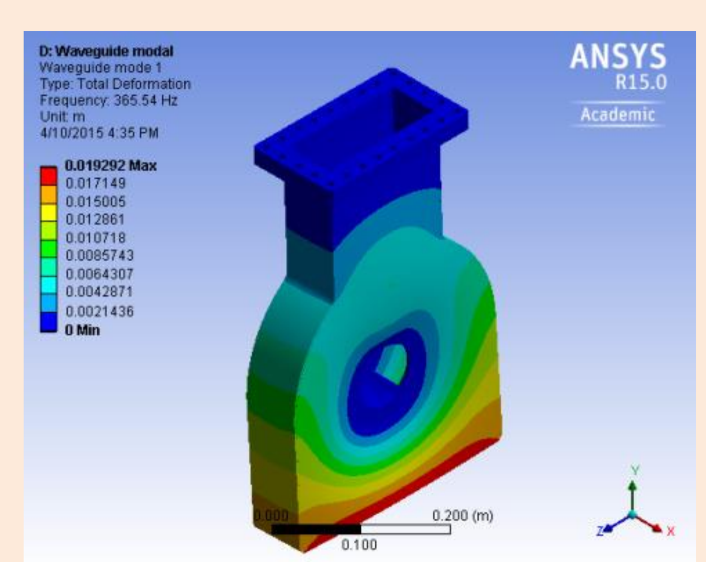
Heat sources : electron beam halo (0.5 W) + RF losses

RESULTS :

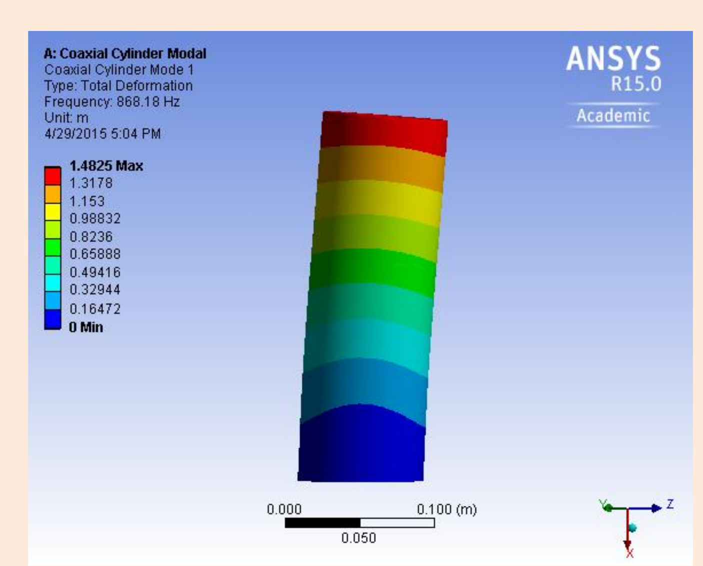
The coaxial cylinder inside the beam pipe is expected to remain in a superconducting state, even being hit by particles depositing up to 5.5 W. If the cylinder fluctuates into a normal-conducting temperature range for any reason, it should return to a superconducting temperature range within a few seconds.

Mechanical Analysis

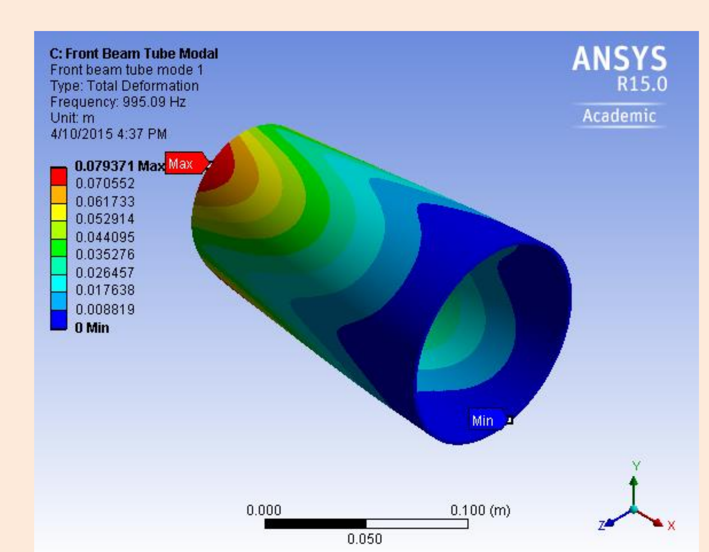
DEFORMATION OF THE WAVEGUIDE AT THE 365 Hz MODE



DEFORMATION OF THE COAXIAL CYLINDER AT THE 868 Hz MODE



DEFORMATION OF THE BEAM PIPE AT THE 995 Hz MODE



LOWEST FREQUENCIES OF MECHANICAL RESONANCES :

frequency, Hz	where
365	waveguide
515	waveguide
628	waveguide
649	waveguide
730	waveguide
868	coax cylinder
967	coax cylinder
995	beam pipe

Niobium with *RRR* > 250, Young's modulus = 125 GPa

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