DESIGN OF MINIATURE WAVEGUIDES AND DIAMOND WINDOW ASSEMBLY FOR RF EXTRACTION AND VACUUM ISOLATION FOR THE CWA

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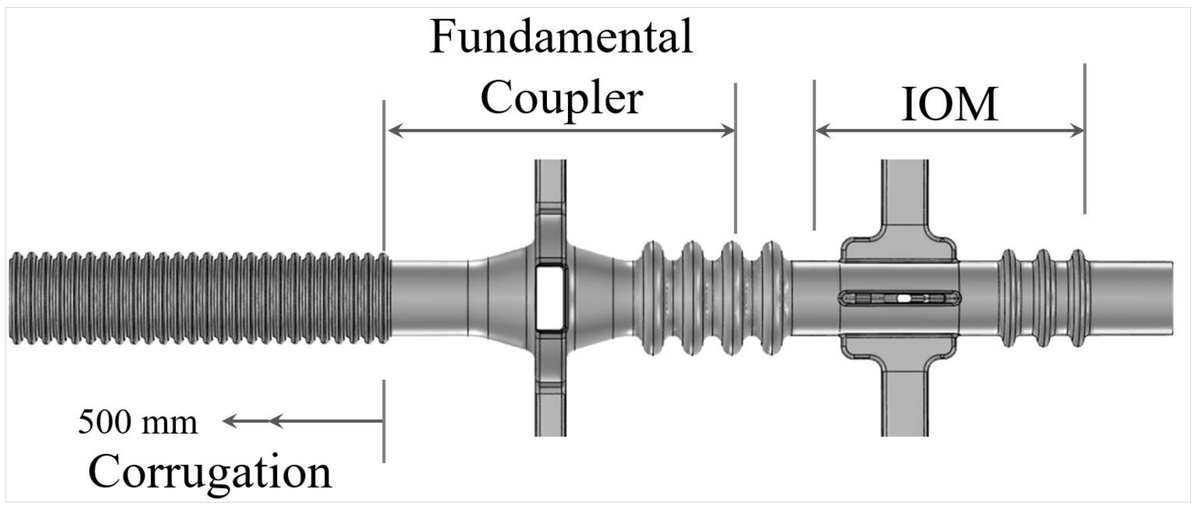
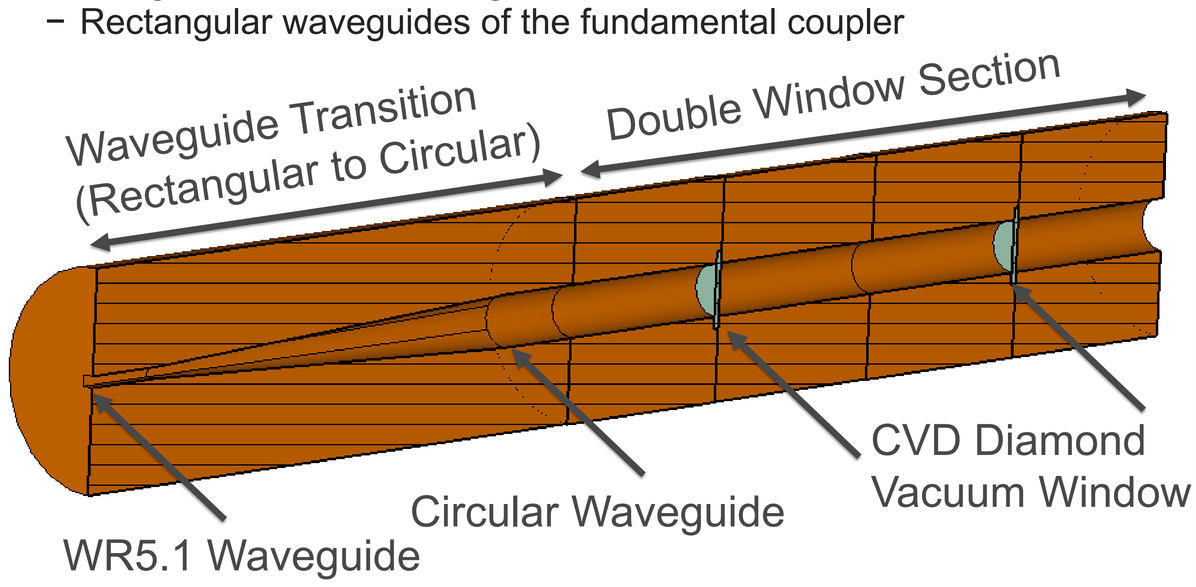
ABSTRACT

- Corrugated Wakefield Accelerator (CWA) [1]
  - Operating at millimeter wavelengths (180 GHz)
  - High power levels (up to 600 W)
  - Necessary to extract accelerating mode via fundamental coupler
- mmWave vacuum window
  - Chemical Vapor Deposition (CVD) diamond [2,3]
- Miniature waveguides and transitions
- Electromagnetic simulation study
- Fabrication challenges at mmWave frequencies



DESIGN

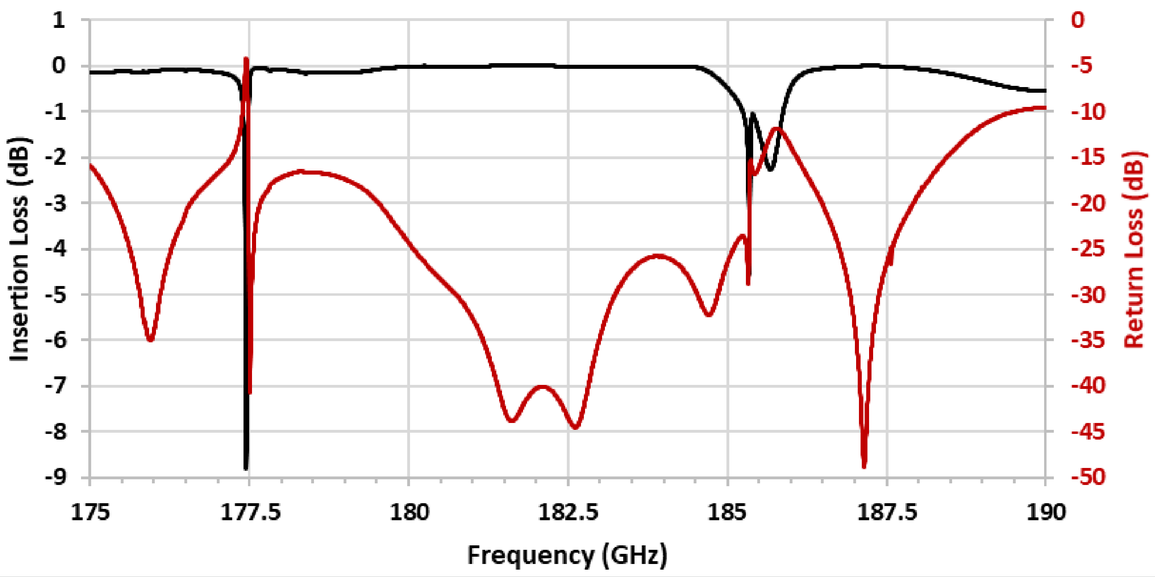
- Chemical Vapor Deposition (CVD) Diamond windows
  - Outstanding thermal conductivity (2000 W/m/k)
  - Low EM Loss (TanD = 1E-5)
- Circular CVD diamond windows
  - Structurally strong
  - Easier assembly
  - Specify half wavelength (λ) (at 180 GHz) thickness
    - Relative permittivity (ε) of 5.8
- Double window design for vacuum safety
- Rectangular to circular waveguide transition
  - Rectangular waveguides of the fundamental coupler



ELECTROMAGNETIC SIMULATION

- Minimal insertion loss (-0.17 dB) at 180 GHz
  - Mostly due to conductive losses in the structure
- Wide bandwidth (7.5 GHz) centered at 180 GHz
  - Adjusted window dimensions to avoid resonances within the window
- Very low reflection (< -15 dB)
- Adequate spacing between windows to prevent standing waves

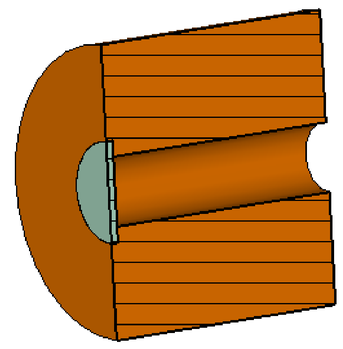
CVD Diamond Vacuum Window Assembly EM Simulation Results



FABRICATION ISSUES AT MMWAVE FREQUENCIES

- Surface finish
  - Roughness Average (R_A) value used
  - Skin depth (δ) of EM waves
  - 155 nm at 180 GHz for Copper
  - Ideally $R_A < \delta$
    - If not, seen as conductive losses [4]
- Fabrication Tolerances are vital
  - +/- 50 um equivalent to +/- 5 GHz in vacuum
  - Simulation study of a single window
    - Variance of +/- 50 μm
    - Largest effect is window thickness (0.35 mm for 180 GHz)
      - Equivalent to window's λ/2 at 207 GHz and 177 GHz
  - CVD Diamond window is EM qualified before use in the assembly

Insertion Loss (dB) at 180 GHz		Window Thickness		
		-50 μm	0.35 mm	+50 μm
Window Radius	-50 μm	- 0.70	- 0.09	- 0.64
	2.2 mm	- 0.90	**- 0.015**	- 0.66
	+50 μm	- 0.815	- 0.014	- 0.77



CONCLUSIONS

- CVD diamond window material
  - Excellent EM & thermal performance
- Simple double window design
  - Transition from rectangular to circular waveguide
- Adequate performance at 180 GHz
  - Low insertion loss, minimal reflections
- Fabrication tolerances explored
  - Design is achievable with EM qualification of CVD Windows

NEXT STEPS

- Vacuum and mechanical design
- Sourcing of parts
- Electromagnetic testing & qualification at ANL's new mmWave Test Lab
  - Individual windows qualification
  - Entire assembly
- Assembly and vacuum qualification
- Deployment on ANL's corrugated wakefield accelerator

REFERENCES

- [1]A. Zholents et al., "A compact wakefield accelerator for a high repetition rate multi user X-ray free-electron laser facility," in Proc. 9th International Particle Accelerator Conference(IPAC'18), Vancouver, BC, Canada, 29 April-04 May 2018, pp. 1266–1268.
- [2]G. Gantenbein et al., "First operation of a step-frequency tun-able 1-mw gyrotron with a diamond brewster angle output window,"IEEE Transactions on Electron Devices, vol. 61, no. 6,pp. 1806–1811, 2014
- [3]Y. Gorelov, et. Al., "Characteristics of diamond windows on the 1 mw, 110 GHz gyrotron systems on the diii-d tokamak," in Twenty Seventh International Conference on Infrared and Millimeter Waves, 2002, pp. 161–162
- [4]D. Gamzina et al., "Nanoscale surface roughness effects on THz vacuum electron device performance, "IEEE Transactions on Nanotechnology, vol. 15, no. 1, pp. 85–93,

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