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New Design of Water Load for KSTAR 5.0 GHz LHCD Coupler*

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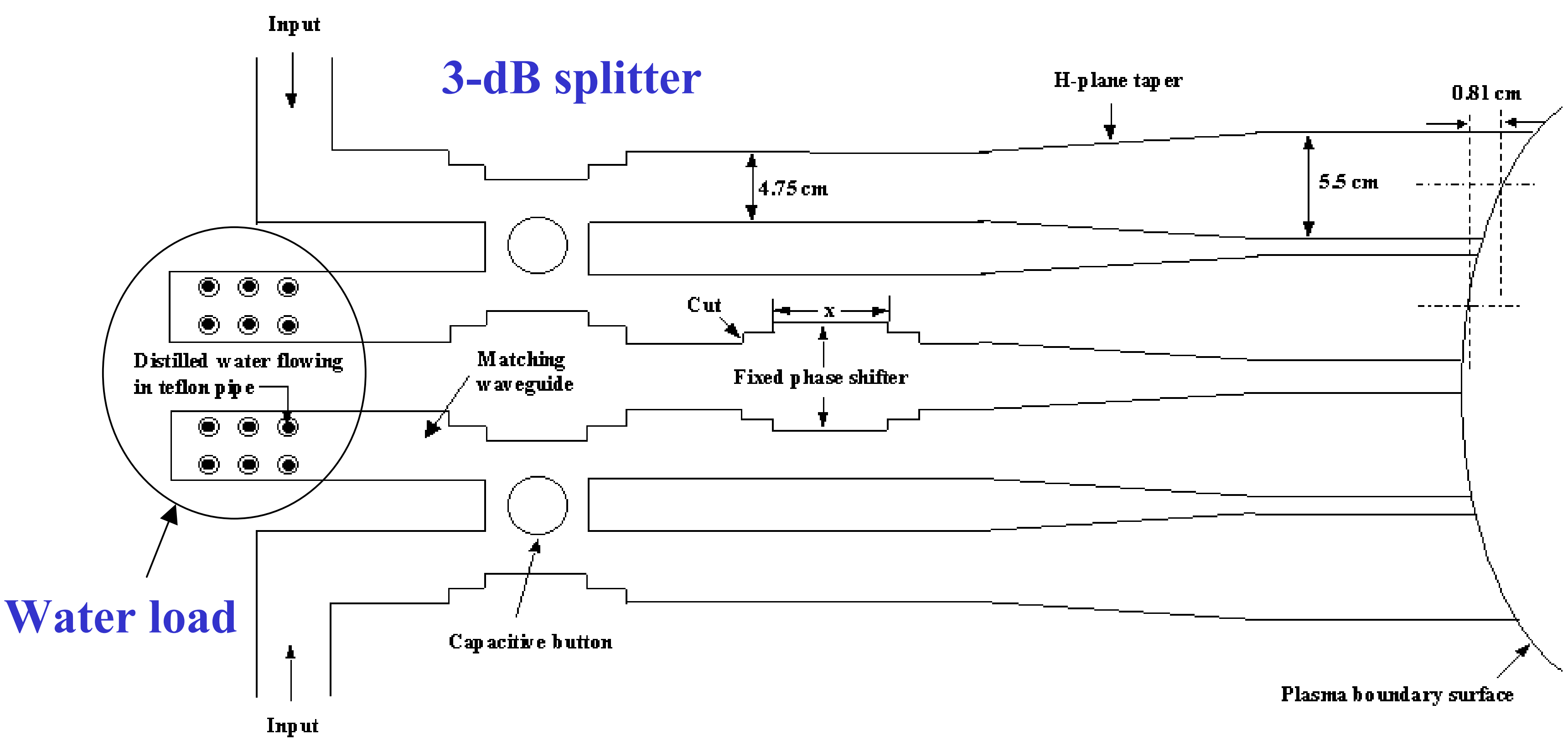
Abstract

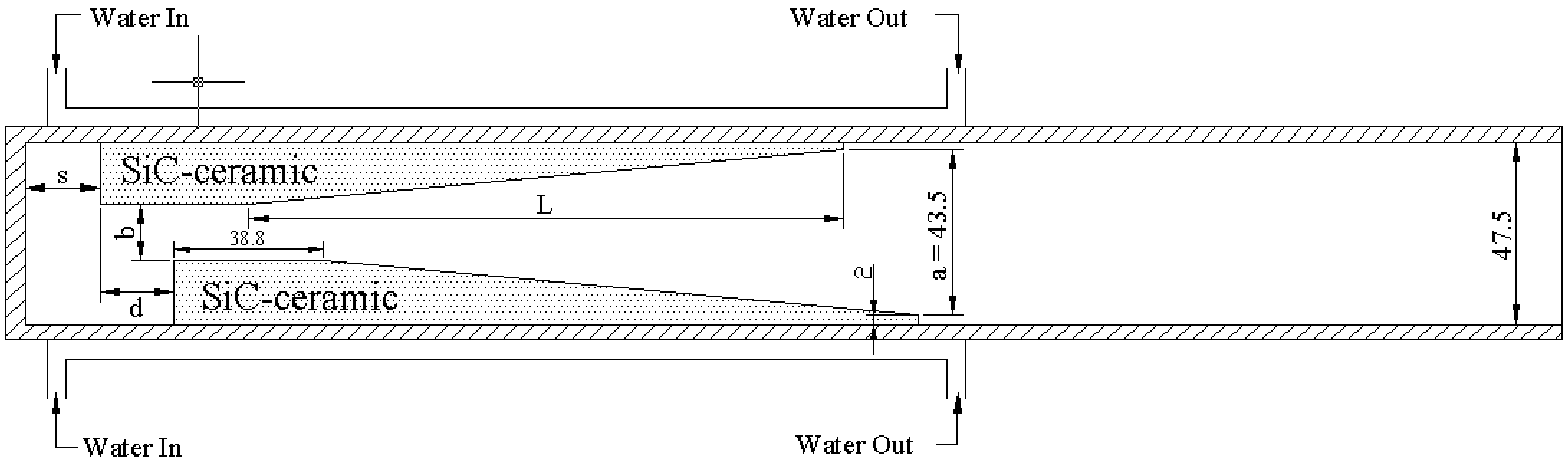
- The KSTAR 5.0 GHz Lower-Hybrid (LH) coupler design was performed and reported earlier. The coupler design was based on the Alcator C-MOD LH design running at 4.6 GHz. In the water load design of the C-MOD LH coupler, four Teflon pipes penetrate into the isolated waveguide of the 3-dB power splitter, and water flows through the Teflon pipes. However, it was reported that the power coupling between neighboring isolated waveguides is more than 10 % through the Teflon pipes. As an alternative, we designed a new solid load using Sic-ceramic placed in the waveguide. The cooling pipes are brazed on both surfaces of the H-plane walls of the isolated waveguide. In this paper, the electrical detail design as well as thermal analysis of the SiC-ceramic load are presented.

Early design of the water load



10 % coupling to next waveguide through the teflon tube !

Schematic of the water load structure



- **Design goals:**
  - **VSWR ≤ 1.001**
  - **ΔT of cooling water < 40 °C**

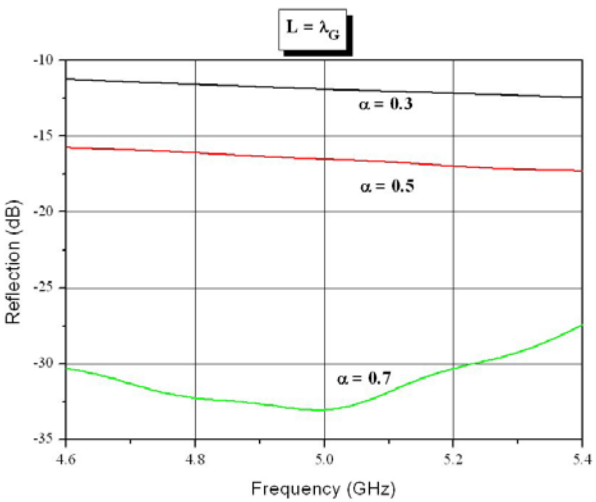
- **b = a × α = 43.5 α (mm)**
- **s = offset from the short ≈ λ_G /4**
- **d = displacement between two SiC-ceramics ≈ λ_G /4**
- **L = taper length ≈n λ_G**
- **Maximum allowed average reflected RF power = ε x 2.0 MW / (32 x 4) x 20 % = 2300 W**

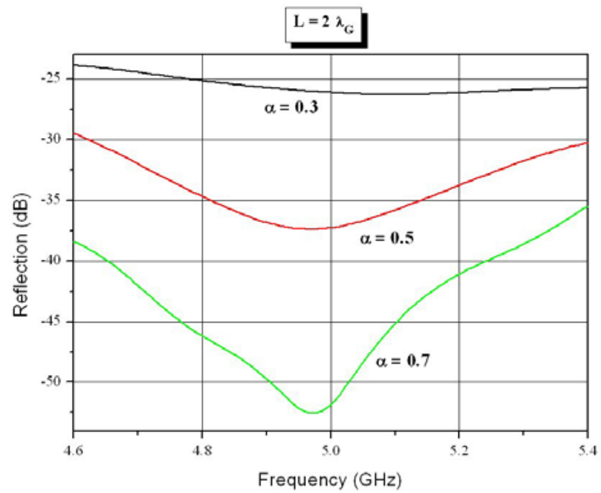
  Where, n is integer, ε = 75 % (RF power transmission loss), and λ_G = 77.4 mm

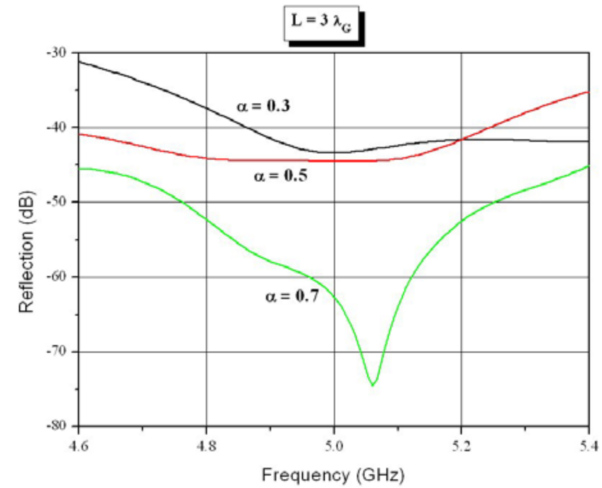
Basic characteristics of the SiC-ceramic

Density (g/cm^3)	3.14	
Hardness (Knoop, kgf/mm^2)	2900	at RT
Thermal conductivity (cal/cm·sec °C)	0.19 0.14	at RT at 600 °C
Thermal expansion coefficient ($°C^{-1}$)	4.6×10^{-6}	RT to 1200 °C
Oxidation weight gain (mg/cm^2)	0.015	at 1200 °C for 24 hours
DC resistivity (Ohm·cm)	5×10^5 7×10^{-1}	at RT at 800 °C
Dielectric constant	30 ~ 35	0.5 to 20 GHz
Loss tangent	0.3 ~ 0.5	0.5 to 20 GHz

Reflections (HFSS simulation)





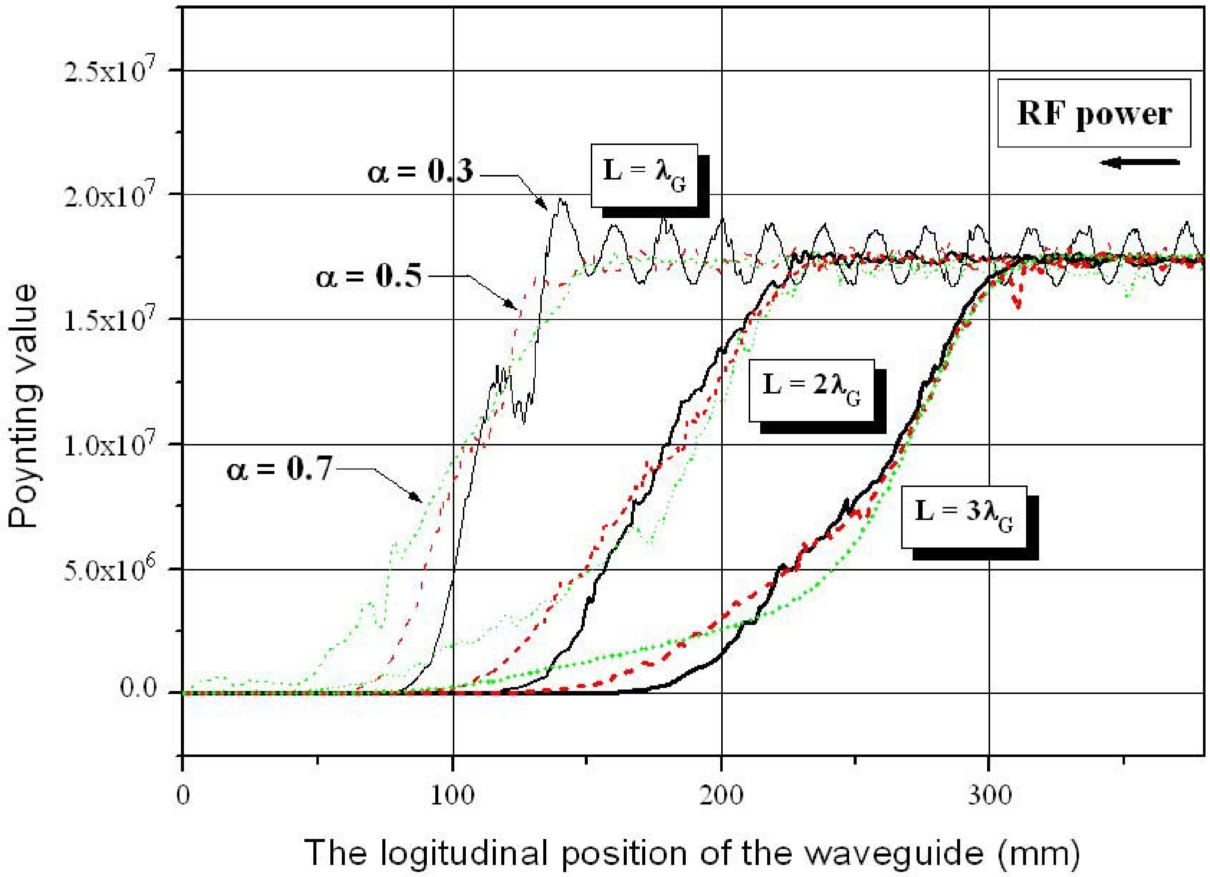


- $\alpha = 0.3$
  - s = d = 19.4 mm ($\lambda_G/4$)
- $\alpha = 0.5$
  - s = d = 19.4 mm ($\lambda_G/4$)
- $\alpha = 0.7$
  - s = 19.4 mm ($\lambda_G/4$)
  - d = 19.7 mm

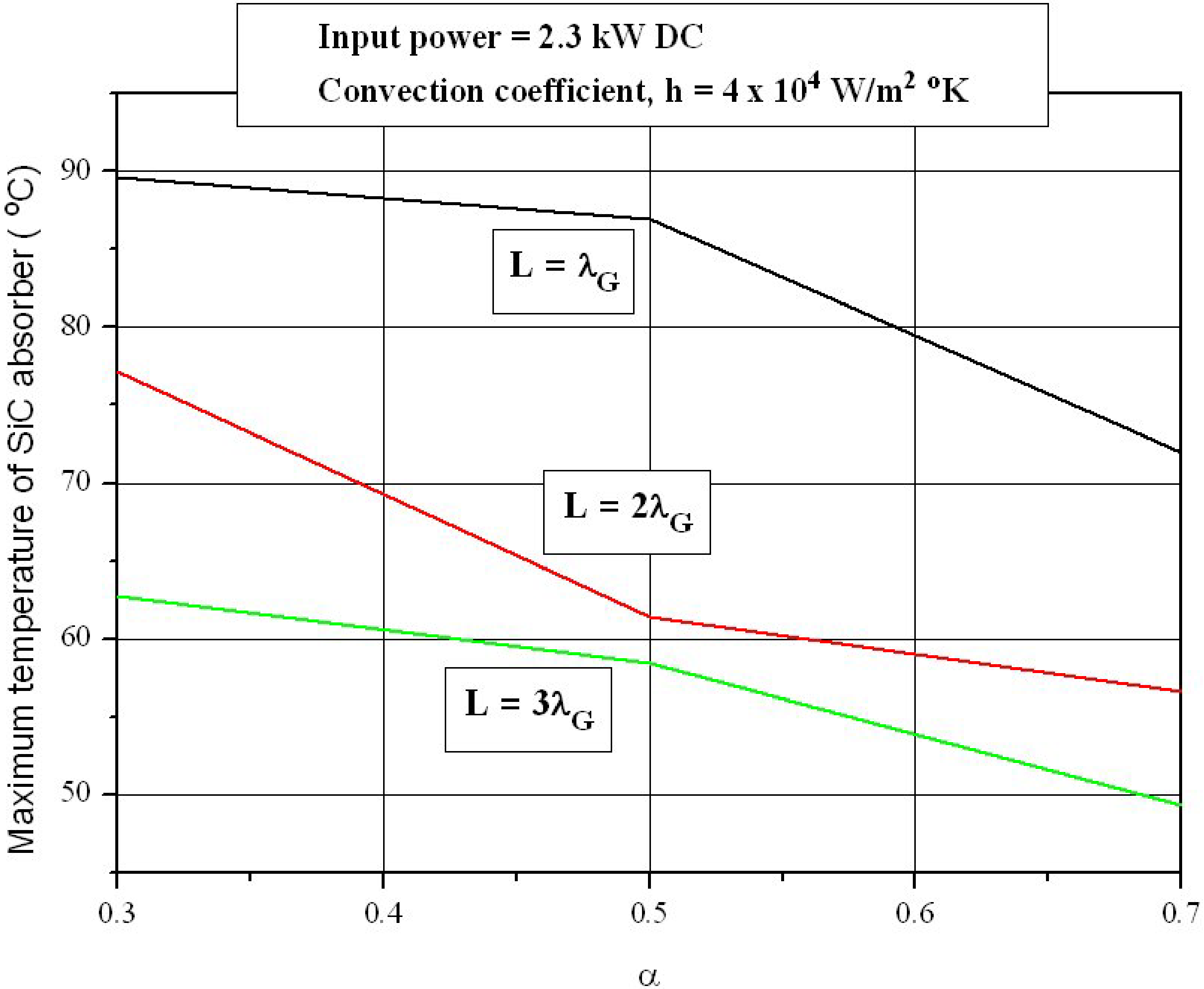
- $\alpha = 0.3$
  - s = 20.0 mm
  - d = 18.4 mm
- $\alpha = 0.5$
  - s = 19.6 mm
  - d = 19.8 mm
- $\alpha = 0.7$
  - s = 19.4 mm ($\lambda_G/4$)
  - d = 19.0 mm

- $\alpha = 0.3$
  - s = 20.2 mm
  - d = 18.4 mm
- $\alpha = 0.5$
  - s = 19.4 mm ($\lambda_G/4$)
  - d = 18.6 mm
- $\alpha = 0.7$
  - s = 20.3 mm
  - d = 20.0 mm

Power absorptions (HFSS simulation)

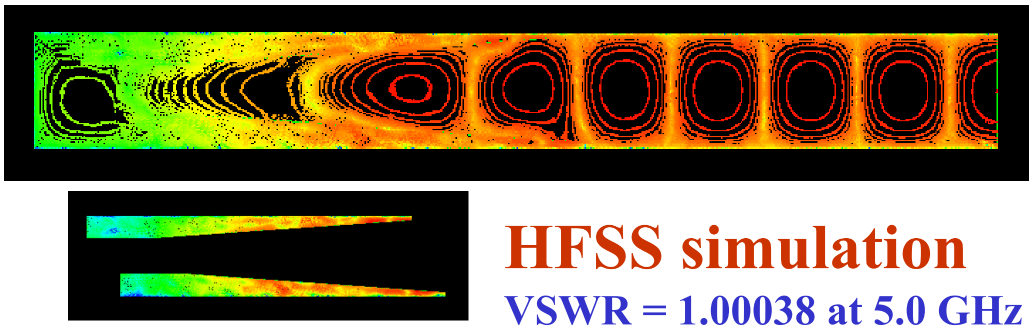


Temperature difference of cooling water (ANSYS analysis)



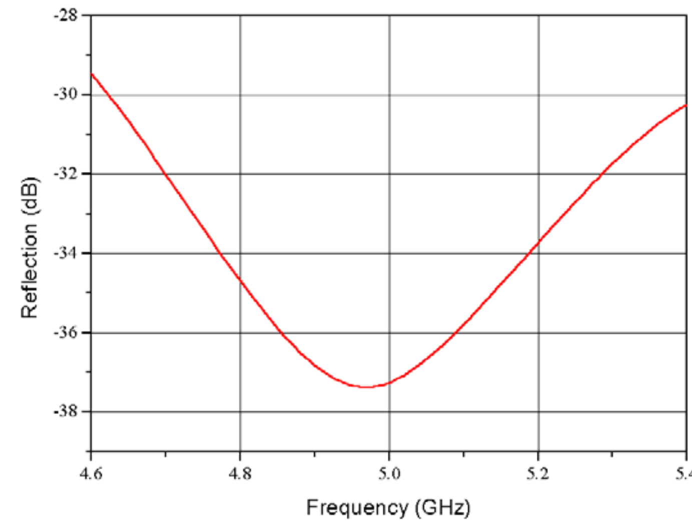
Design summary
(VSWR < 1.001 and maximum temperature < 70 ^{o}C)

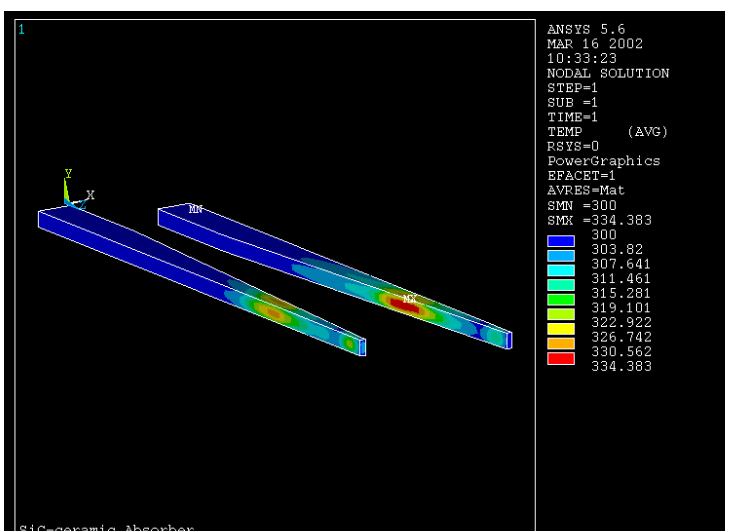
$L = 2\ \lambda_G$, $\alpha = 0.5$, s = 19.6 mm, d = 19.8 mm



HFSS simulation

VSWR = 1.00038 at 5.0 GHz
(Reflection = -37 dB)





Ansys analysis for temperature distribution

- **Maximum temperature : 334 ^{o}K = 61 ^{o}C**
- **Constraints for water cooling**
  - ✓ **film coefficient = 4 W/cm^2 ^{o}K**
  - ✓ **bulk temperature of 300 ^{o}K**

Conclusion

- In this design, the SiC absorber is located in each isolated waveguide of the 3-dB power splitter. Therefore, there is no possibility of coupling into the next waveguide. From this point of view, considered is the absorber as a good water load for KSTAR 5.0 GHz LHCD coupler unless we concern the cost of brazing it.