ASDEX Upgrade

Max-Planck-Institut für Plasmaphysik

IPP

# MULTI-MODE GENERATOR FOR THE COLD TEST OF BROADBAND QUASI-OPTICAL GYROTRON MODE CONVERTERS


D. Wagner[1], M. Thumm[2], G. Gantenbein[2], J. Flamm[2], J. Neilson[3], R. Vernon[4]

*[1]MPI für Plasmaphysik, Association EURATOM-IPP , D-85748 Garching, Germany*
*[2]Forschungszentrum Karlsruhe, Association EURATOM-FZK, IHM, D-76021 Karlsruhe,* Germany
*[3]Calabazas Creek Research, 690 Port Drive, San Mateo, CA 94404-1010, USA*
*[4]University of Wisconsin, Madison, Wisconsin, 53706-1691, USA*


Outline:
- Introduction
- Broadband beam excitation
- Cavity design
- Measurements

# INTRODUCTION (1)

- Testing of quasi-optical mode converters requires the excitation of high-order volume modes at low power levels.

- Mode converters for advanced multi-frequency gyrotrons need to be efficient for different modes over a wide frequency range

- Mode generator required for cold tests to excite several modes with high mode purity in this frequency range

- In our case main modes of interest are:

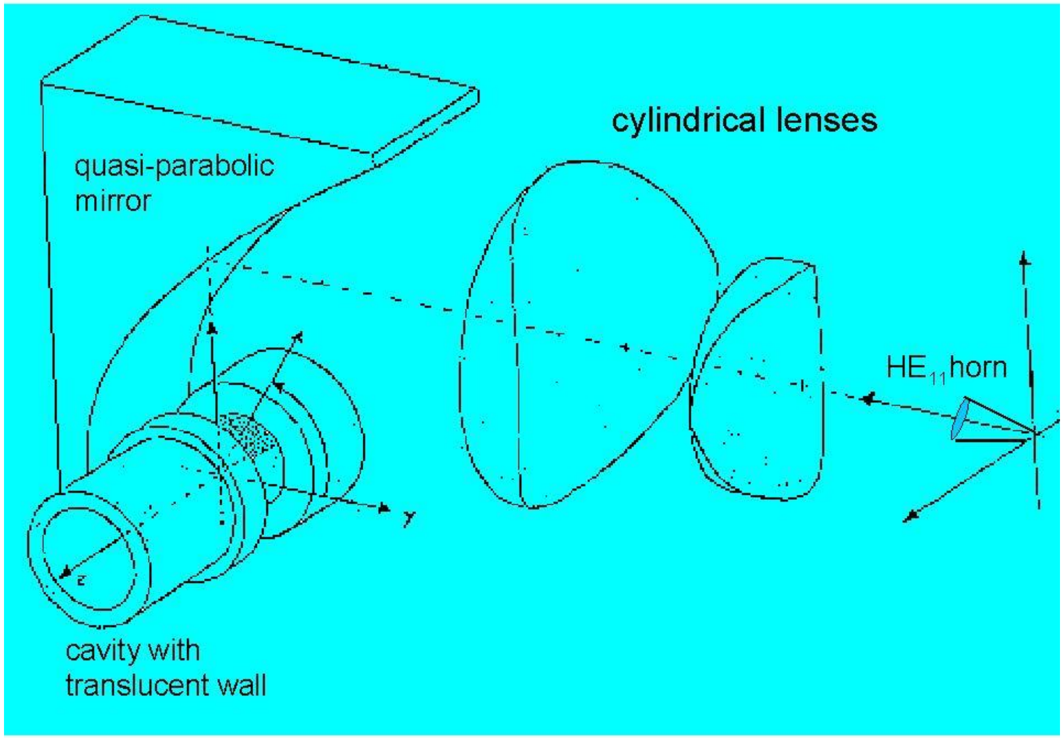
$TE_{22,6}$ @ 110.0 GHz

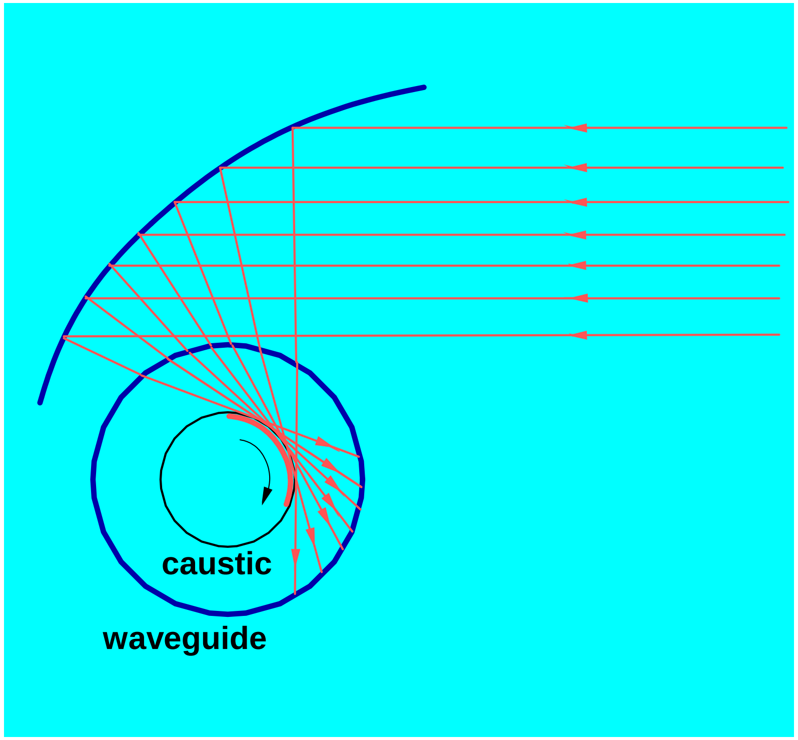
$TE_{24,7}$ @ 124.7 GHz

# INTRODUCTION (2)

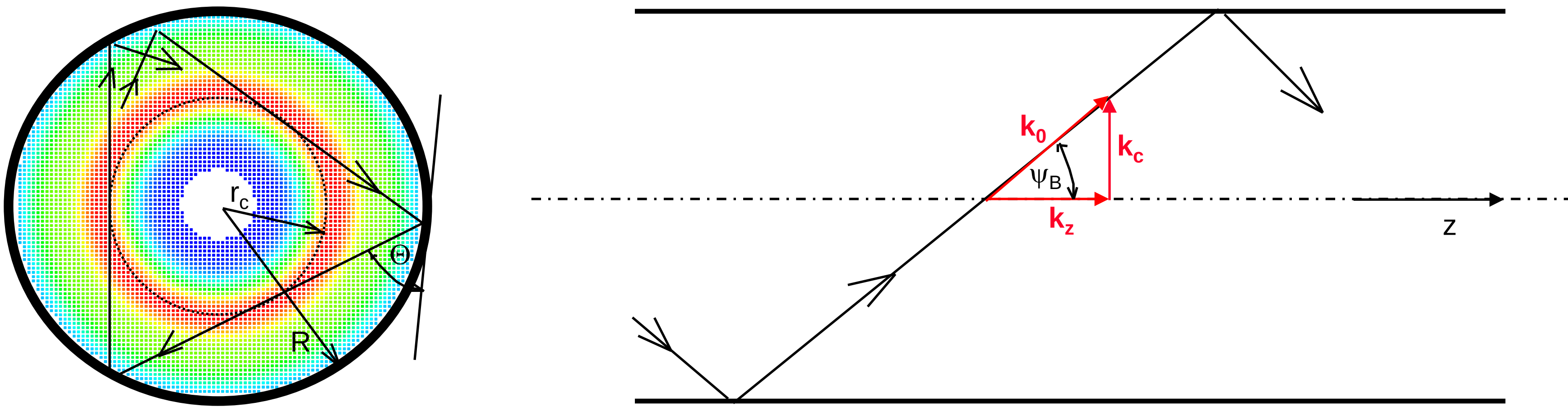
## Principle:

(Alexandrov et al., Int. J. Infrared and Millimeter Waves, 13 (1992), pp.1369)



# INTRODUCTION (3)




– Field distribution of high-order modes can be decomposed into a spectrum of plane waves

– All rays ( $\vec{S} = \vec{E} \times \vec{H}^*$ ) are tangential to the caustic with radius: $$r_c = \frac{m \cdot R}{x_{mn}}$$

– The reflection angles of the rays at the waveguide wall are given by:

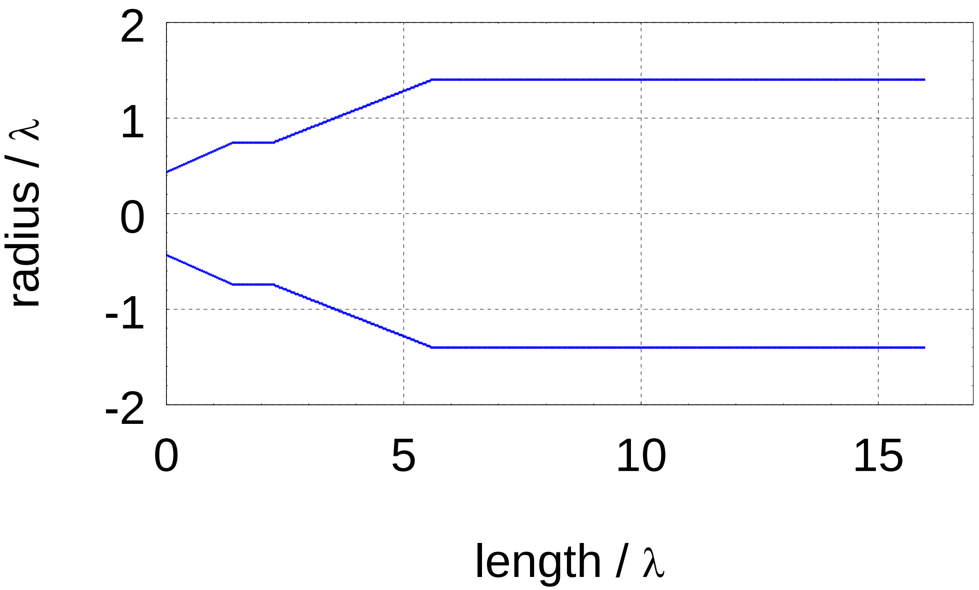
$$\cos(\Theta) = \frac{m}{x_{mn}} \qquad \sin(\psi_B) = \frac{k_c}{k_0} = \frac{x_{mn} \cdot c_0}{2\pi \cdot R \cdot f}$$

# BROADBAND BEAM EXCITATION (1)

- Gaussian beam excitation using a smooth Gauss horn

  (output mode mixture app. 86% $TE_{11}$ + 1% $TE_{11}$(180°) + 12.6% $TM_{11}$(180°) + 0.4% $TM_{12}$ (180°) )

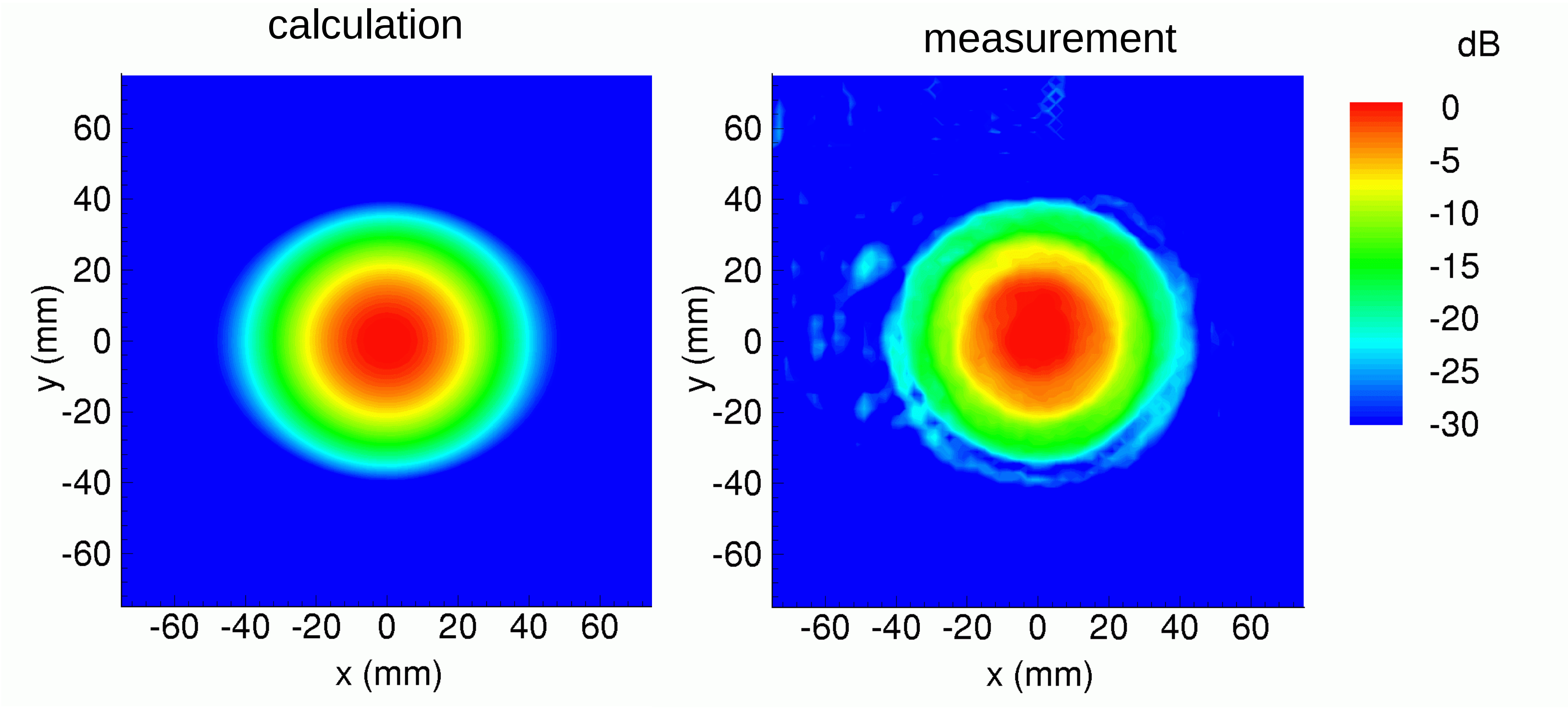
- Linear horn (2 phasing sections)




- calculated bandwidth ≈ ± 7%
- center frequency: 122.5 GHz

# BROADBAND BEAM EXCITATION (2)

- Ex.: horn pattern at center frequency (122.5 GHz, at z = 59 mm)

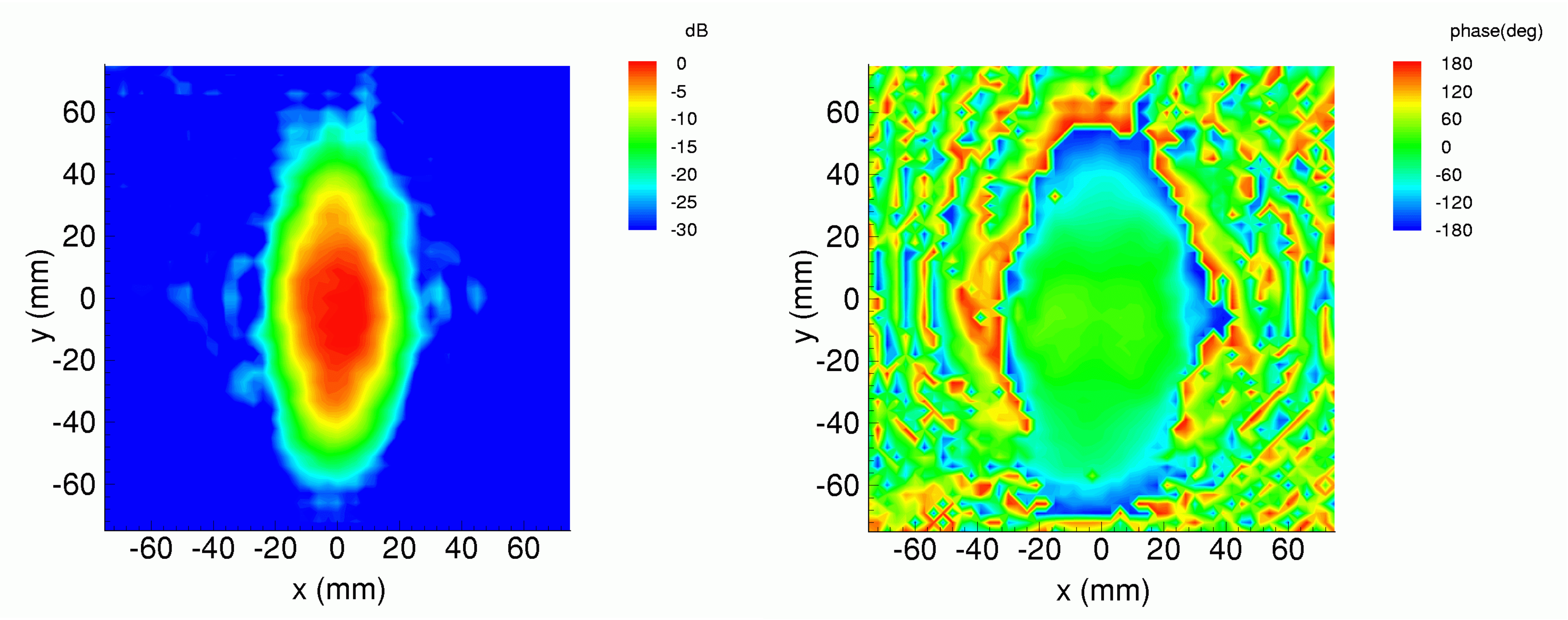


# BROADBAND BEAM EXCITATION (3)

- Lens horn contains 2 cylindrical teflon lenses

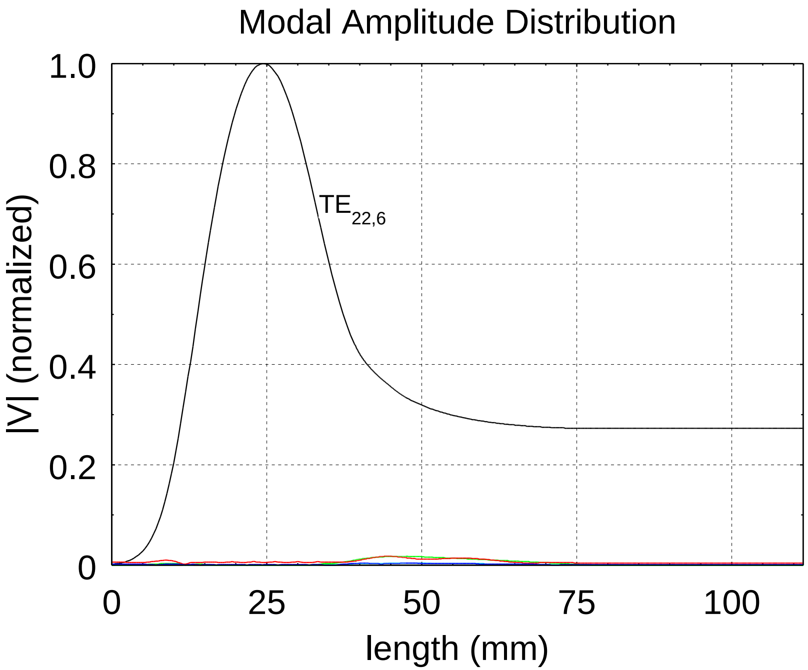
- Designed to generate astigmatic beam at f = 122.5 GHz with $w_{01}$ = 10 mm, $w_{02}$ = 33 mm at $d_2$ = 353 mm

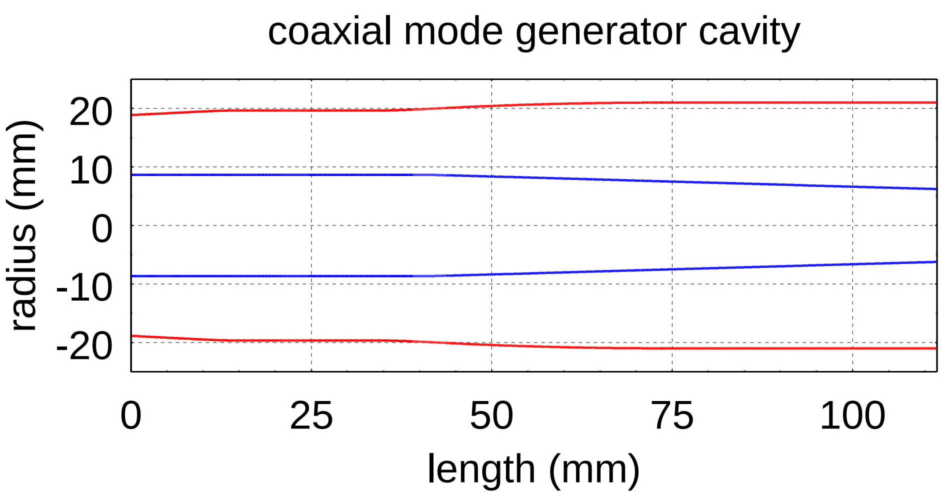
- Measured lens horn beam at the position of the quasi-parabolic mirror:

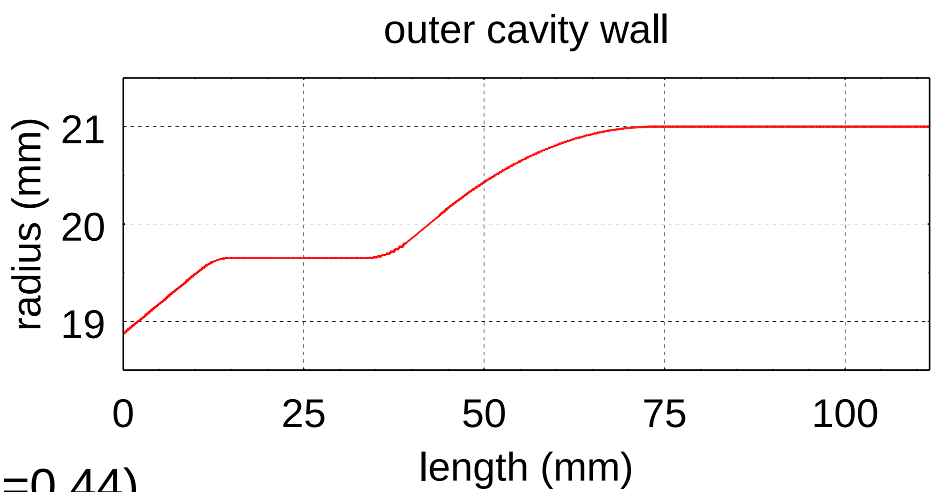


# CAVITY DESIGN (1)

- Cavity profile optimized for
  - high output mode purity
  - high Q



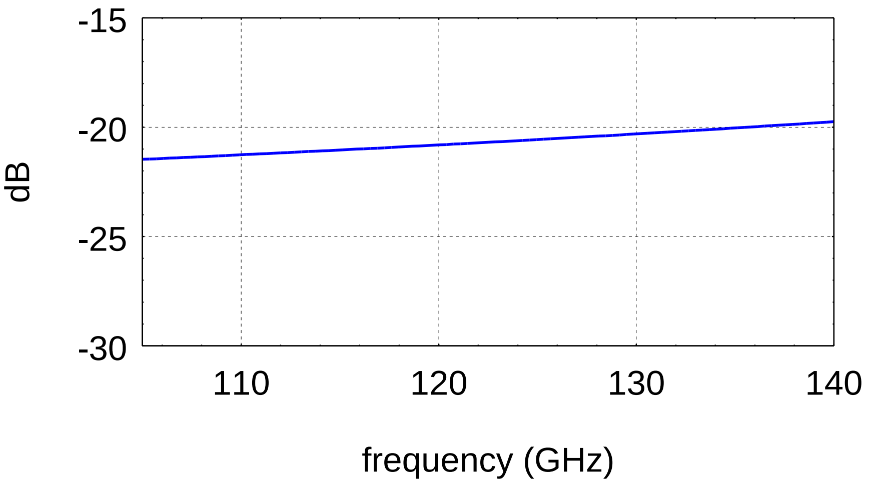

| mode | f (GHz) | $Q_D$ | η (%) |
|---|---|---|---|
| $TE_{22,6}$ | 110.00 | 1658 | 99.91 |
| $TE_{24,7}$ | 124.25 | 2095 | 99.77 |

($R_i/R_o$=0.44)

# CAVITY DESIGN (2)

- Coupling holes over whole circumference
  - → reduces counter rotation
  - → minimizes re-radiation

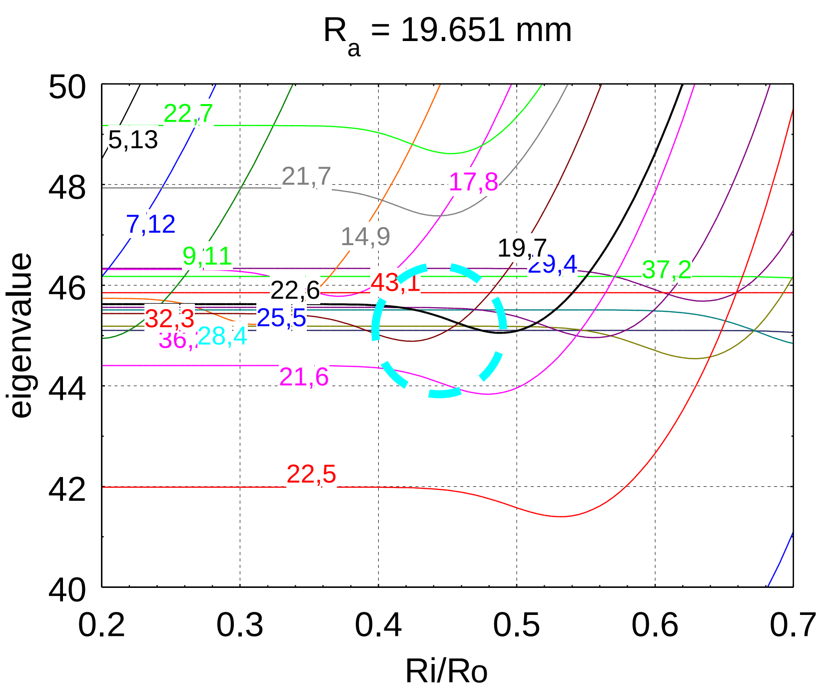
- Calculated frequency dependence of the coupling factor:



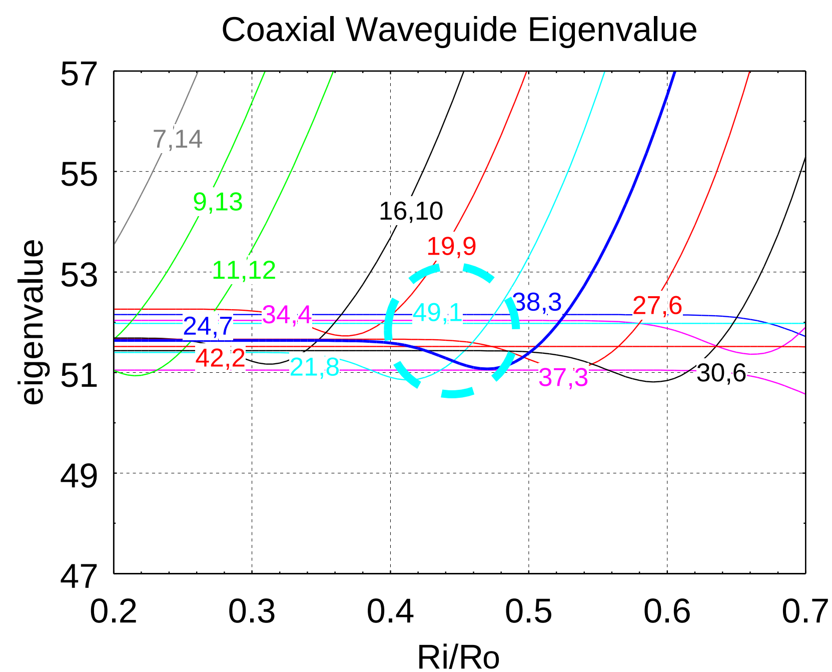

# CAVITY DESIGN (3)

- Optimum mode separation by appropriate choice of inner conductor radii
- Calculated eigenvalue spectra ($R_o$=19.65mm)

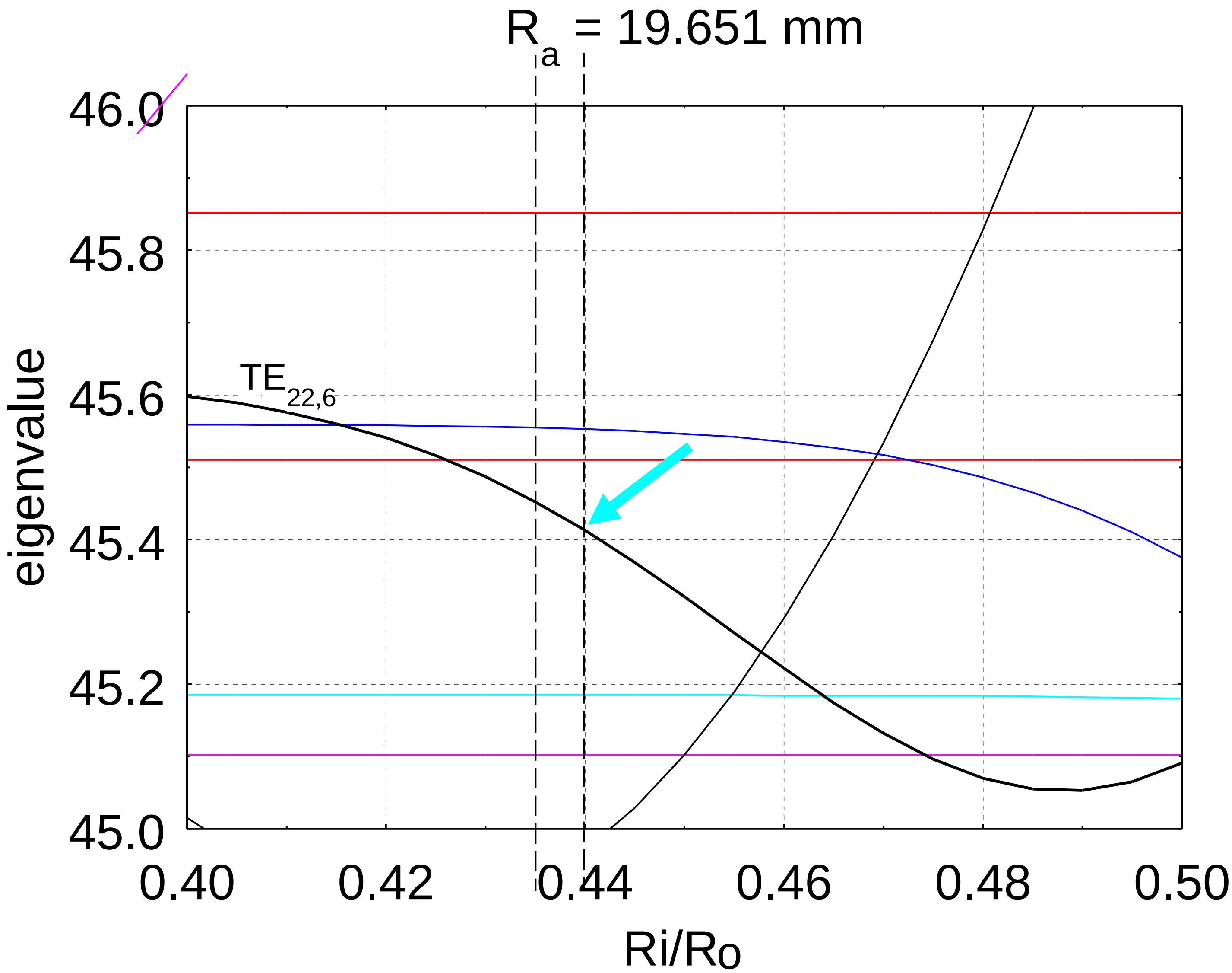
## $TE_{22,6}$ resonance




## $TE_{24,7}$ resonance



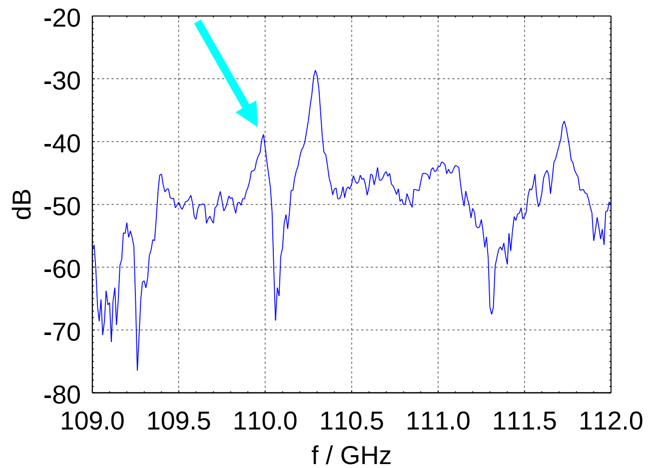
# CAVITY DESIGN (4)



# MEASUREMENTS (1)

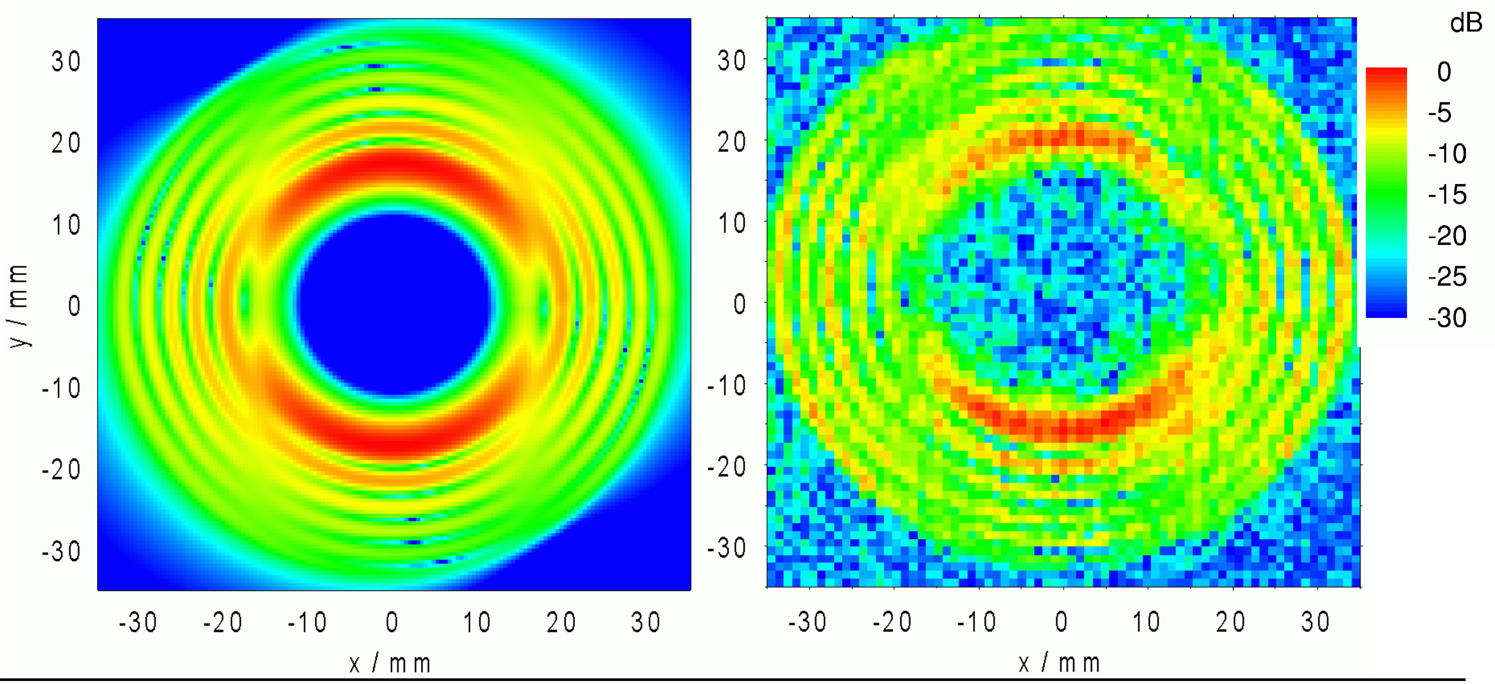
## $TE_{22,6}$

- Measured frequency response ($R_i/R_o$=0.44)

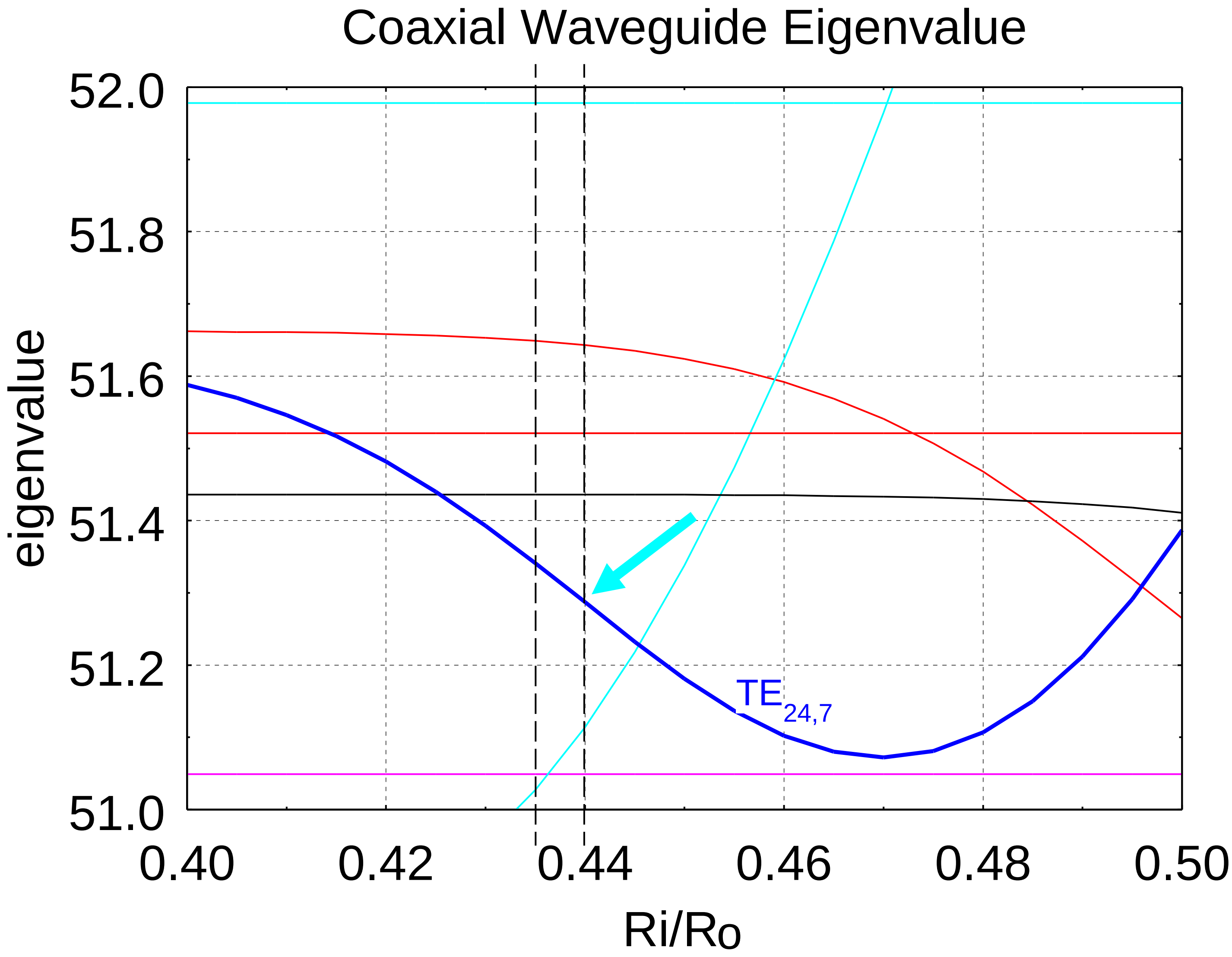



| mode | f (GHz) | $Q_D$ | η (%) |
|---|---|---|---|
| $TE_{22,6}$ | 110.00 | 1658 | 99.91 |

- Calculated and measured mode pattern (vertical polarization) @ 110.0 GHz)



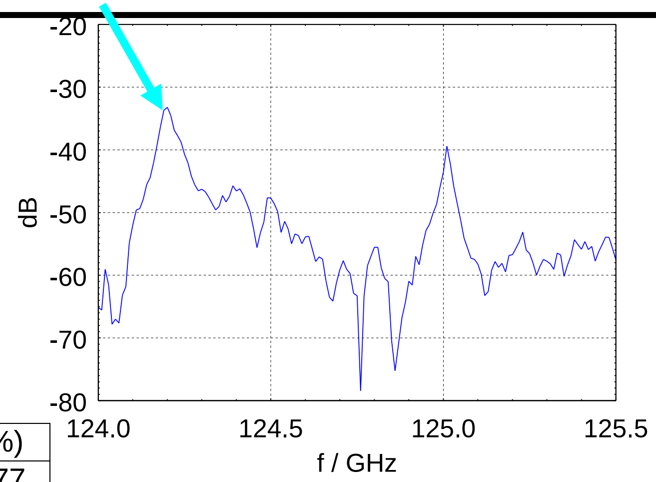
# CAVITY DESIGN (5)



# MEASUREMENTS (2)

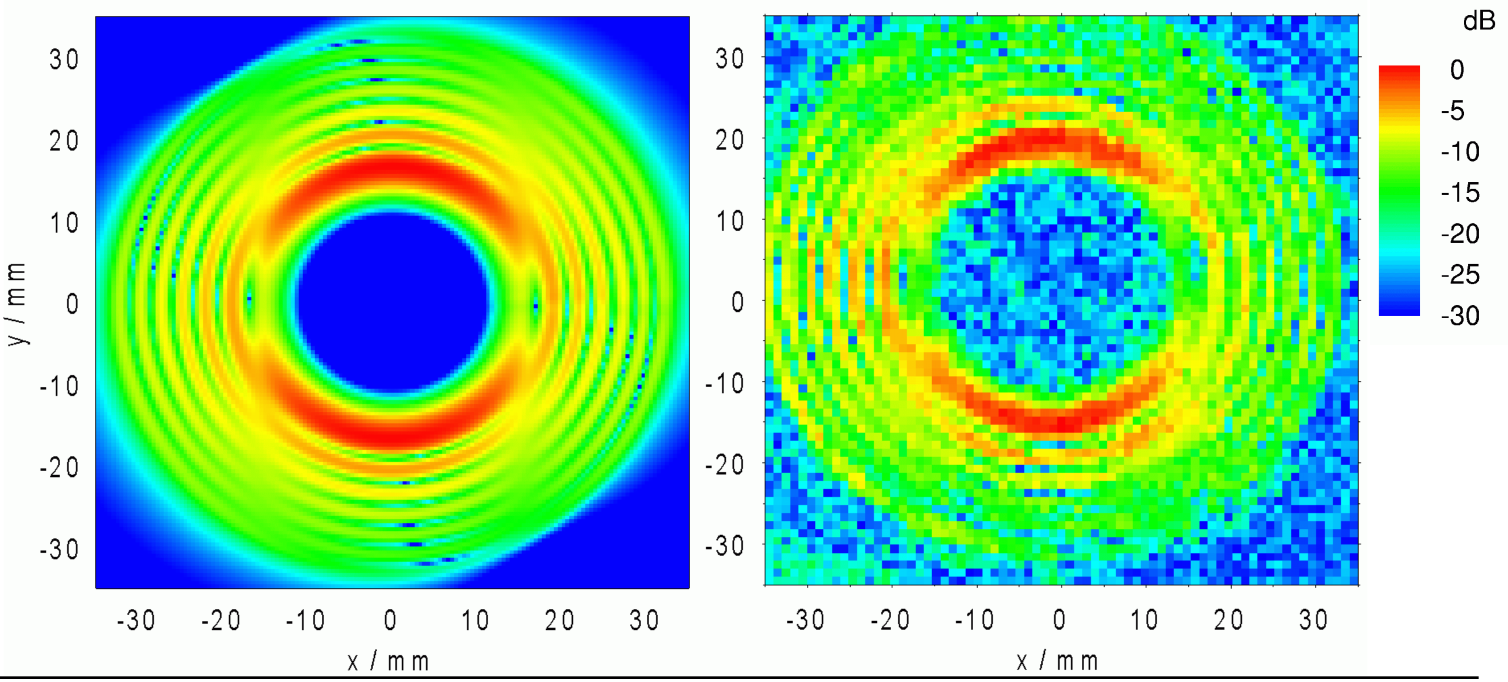
## $TE_{24,7}$

- Measured frequency response ($R_i/R_o$=0.44)




| mode | f (GHz) | $Q_D$ | η (%) |
|---|---|---|---|
| $TE_{24,7}$ | 124.25 | 2095 | 99.77 |

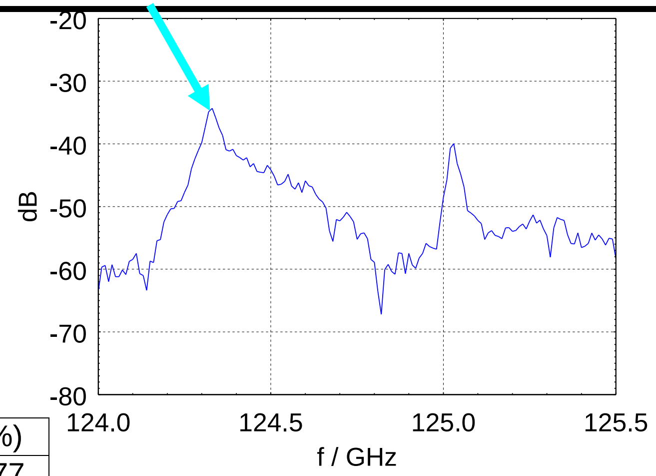
- Calculated and measured mode pattern (vertical polarization) @ 124.2 GHz



# MEASUREMENTS (3)

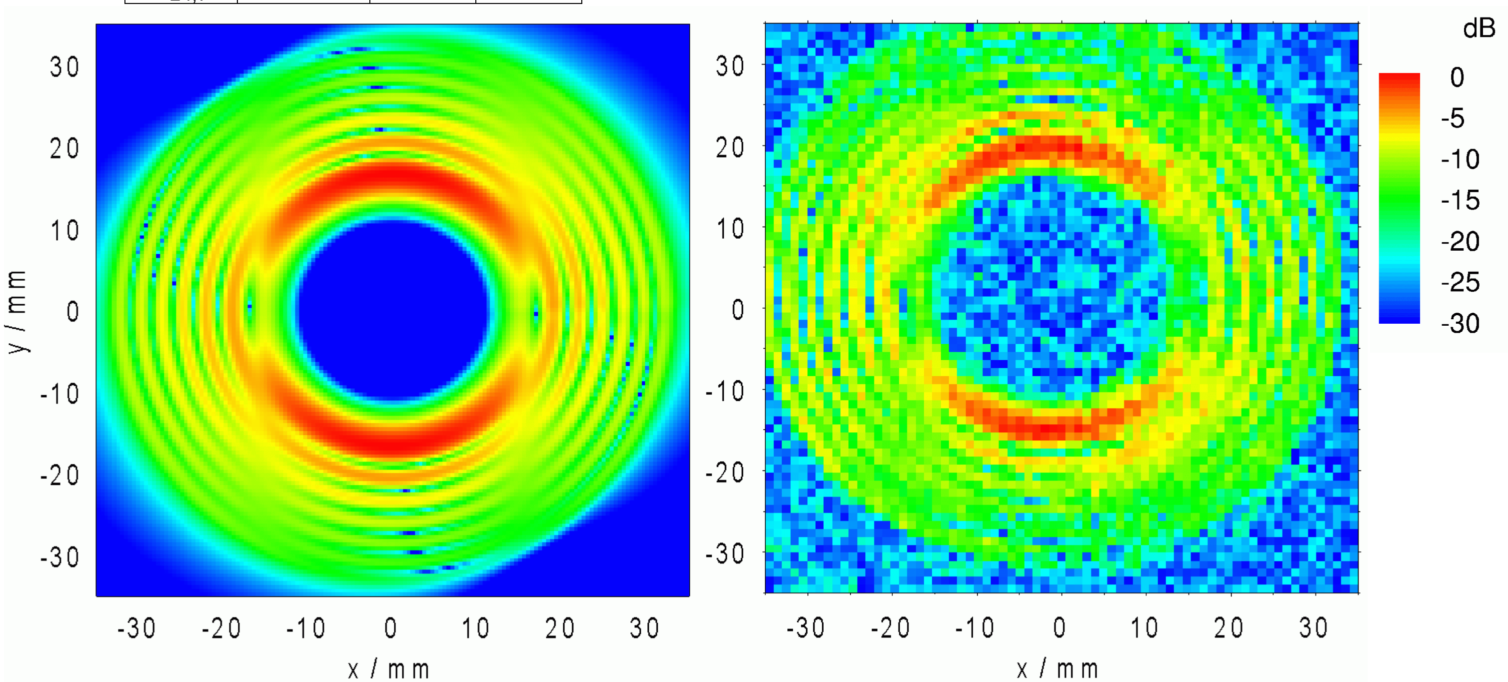
## $TE_{24,7}$

- Measured frequency response ($R_i/R_o$=0.435)

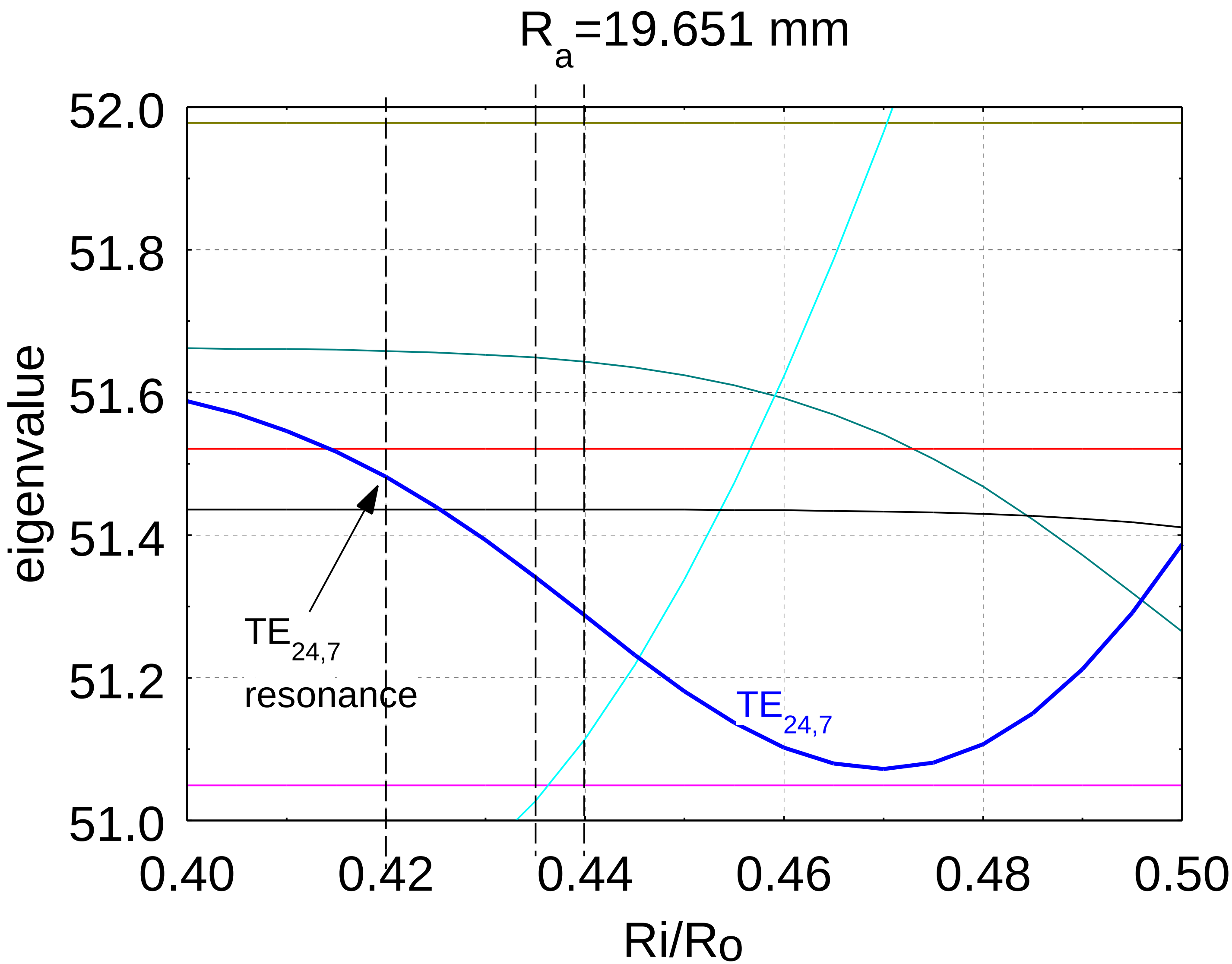



| mode | f (GHz) | $Q_D$ | η (%) |
|---|---|---|---|
| $TE_{24,7}$ | 124.38 | 2093 | 99.77 |

- Calculated and measured mode pattern (vertical polarization) @ 124.33 GHz



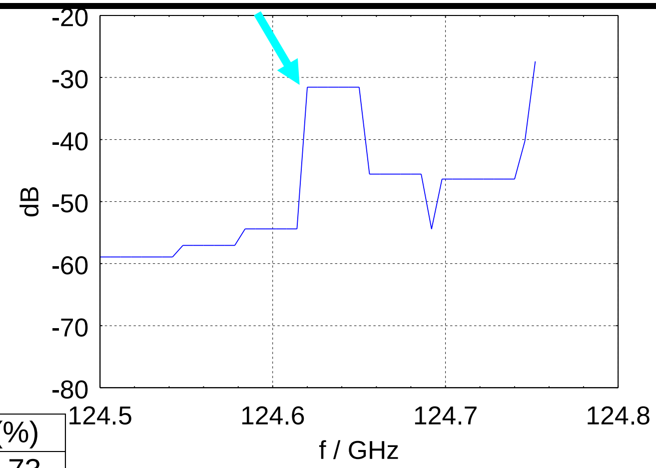
# CAVITY DESIGN (6)



# MEASUREMENTS (4)

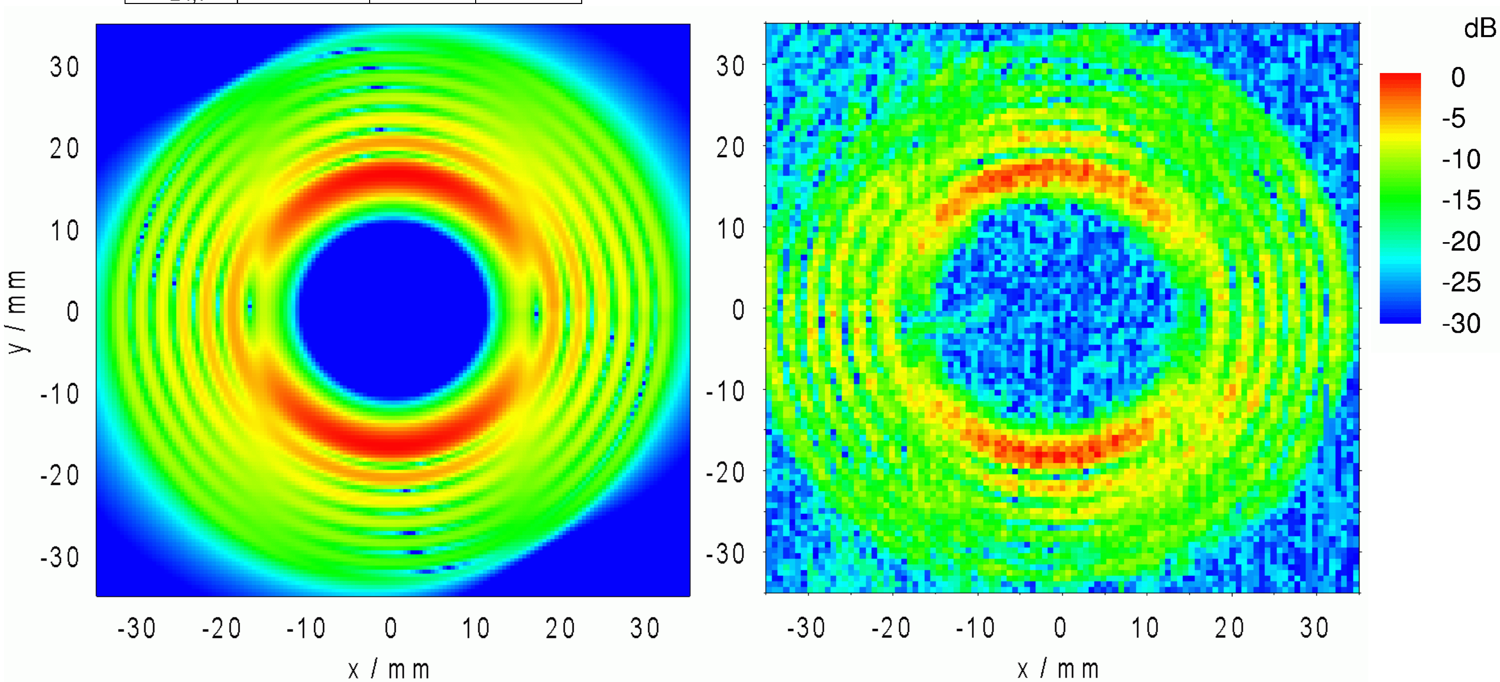
## $TE_{24,7}$

- Measured frequency response ($R_i/R_o$=0.42)



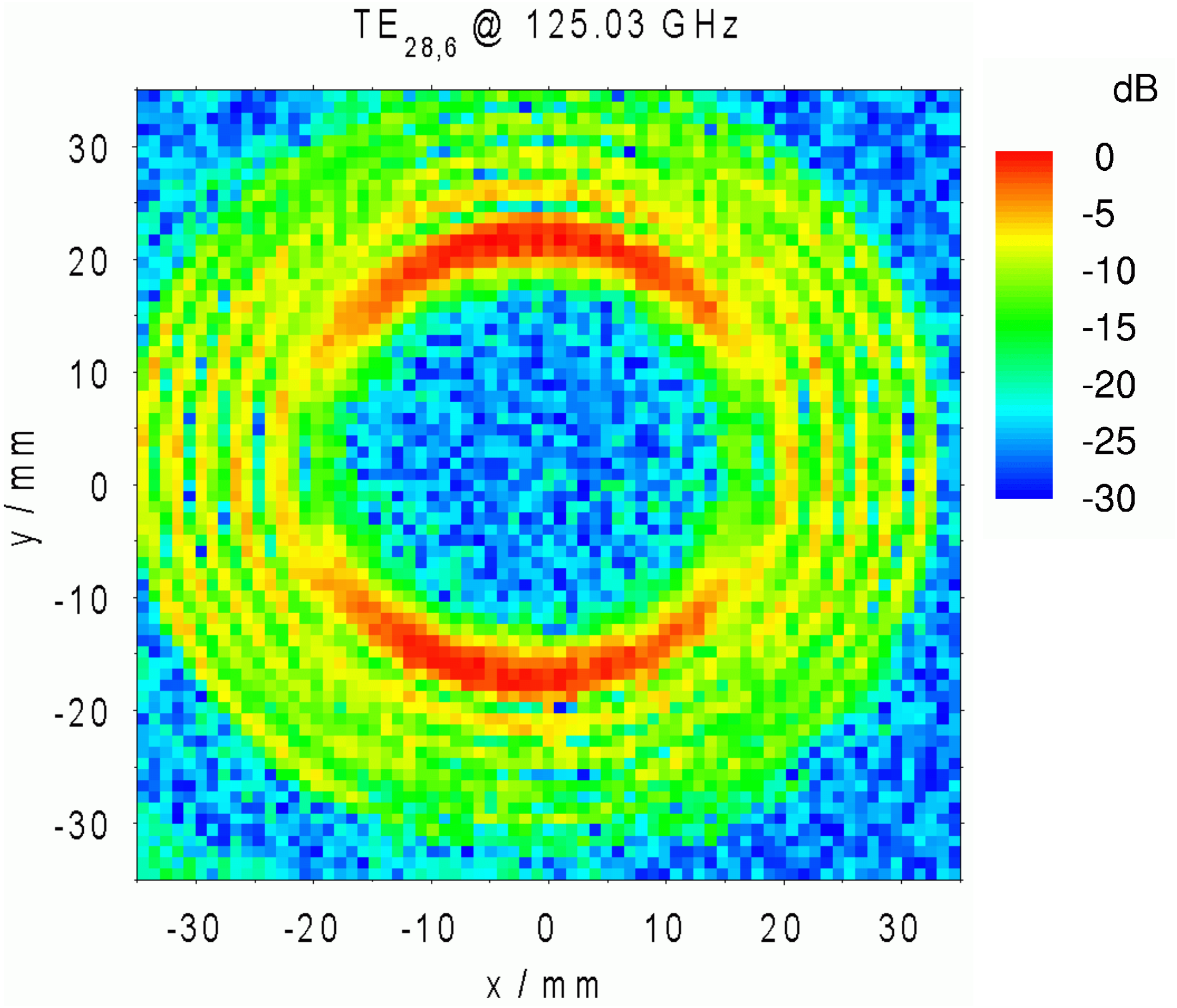

| mode | f (GHz) | $Q_D$ | η (%) |
|---|---|---|---|
| $TE_{24,7}$ | 124.67 | 2079 | 99.73 |

- Calculated and measured mode pattern (vertical polarization) @ 124.65 GHz



# MODE GENERATOR SETUP

# MEASUREMENTS (5)



# CONCLUSIONS

- Mode generator for $TE_{22,6}$ @ 110 GHz and $TE_{24,7}$ @ 124.7 GHz built and tested.
- First results show clear mode patterns with low counter rotation. Frequency matches design values within 20 MHz.
- Mode generator shipped to University of Wisconsin.