

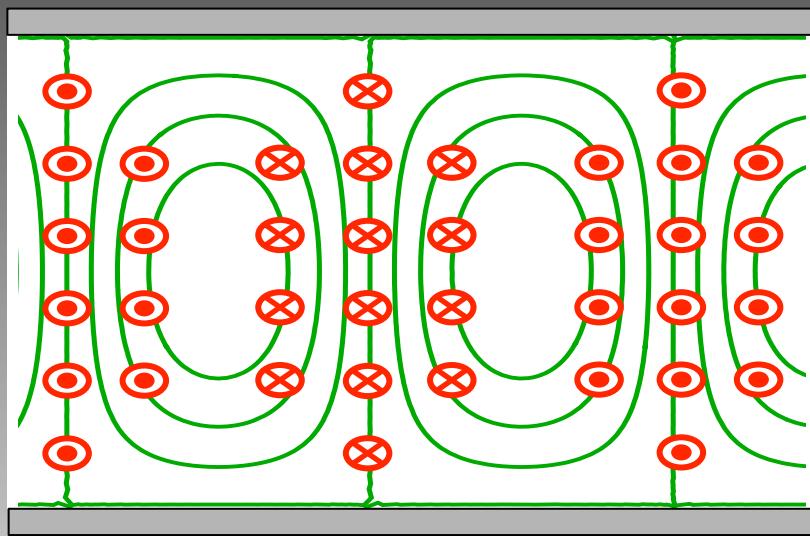
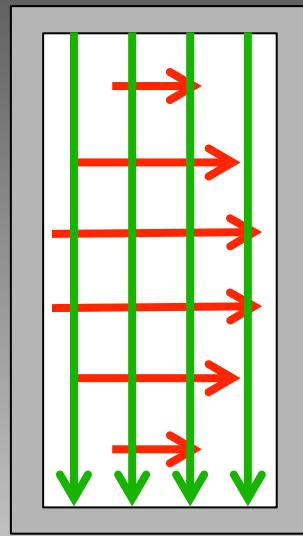
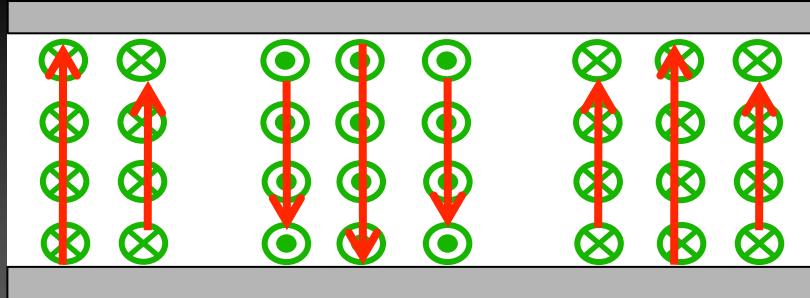
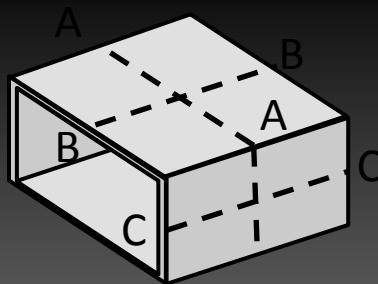
Seventh CW and High Average Power RF Workshop 2012



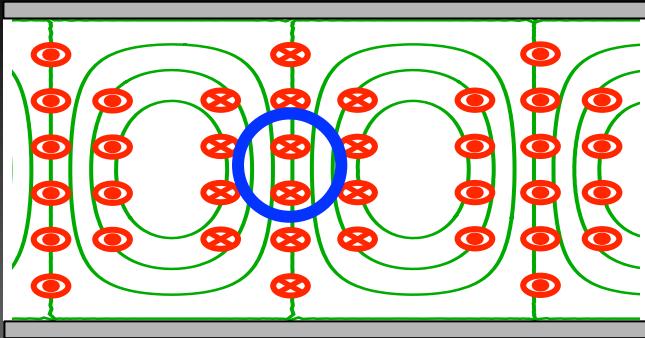
**Waveguide Directional Couplers
Standing Wave Issue**

Nikolai Schwerg - CERN BE RF KCA

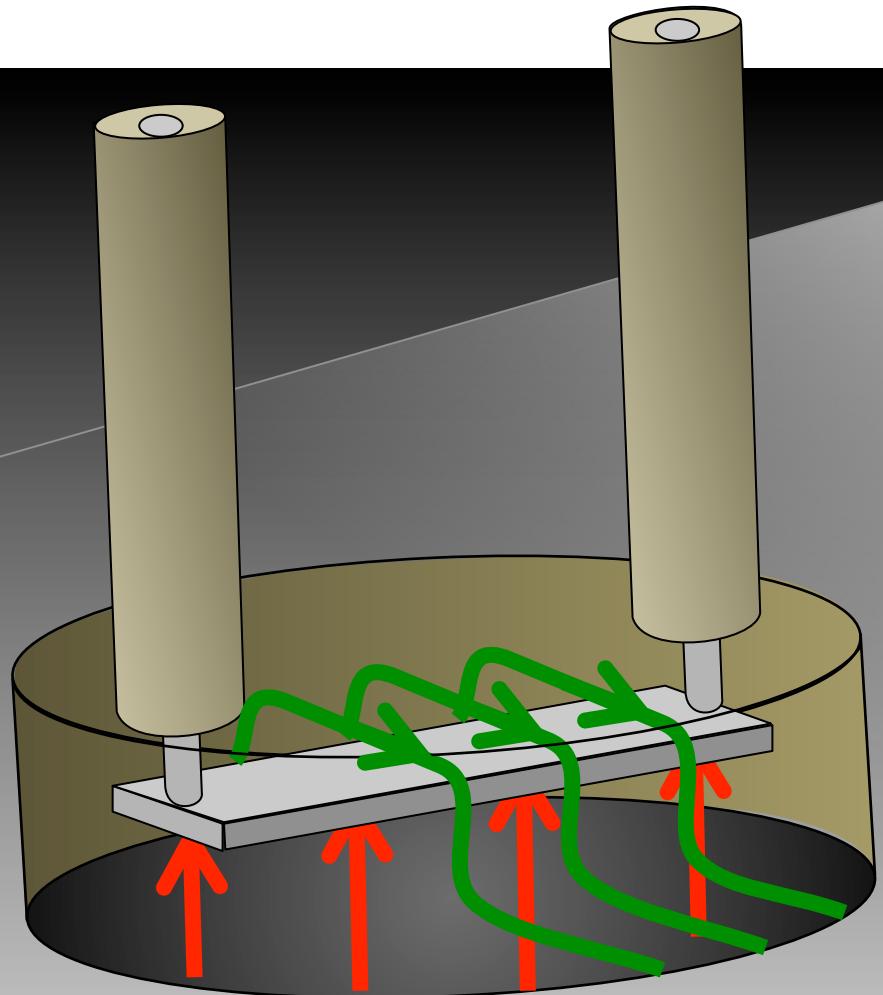
Waveguide TE₁₀-Mode



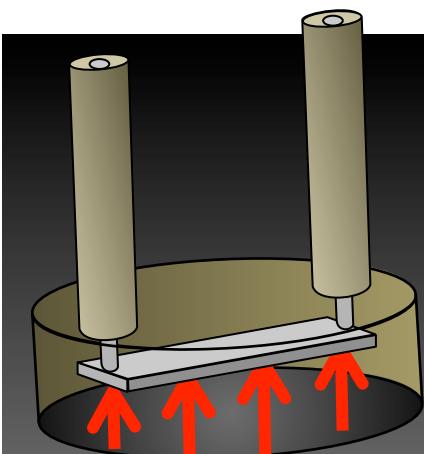
Directional Coupler



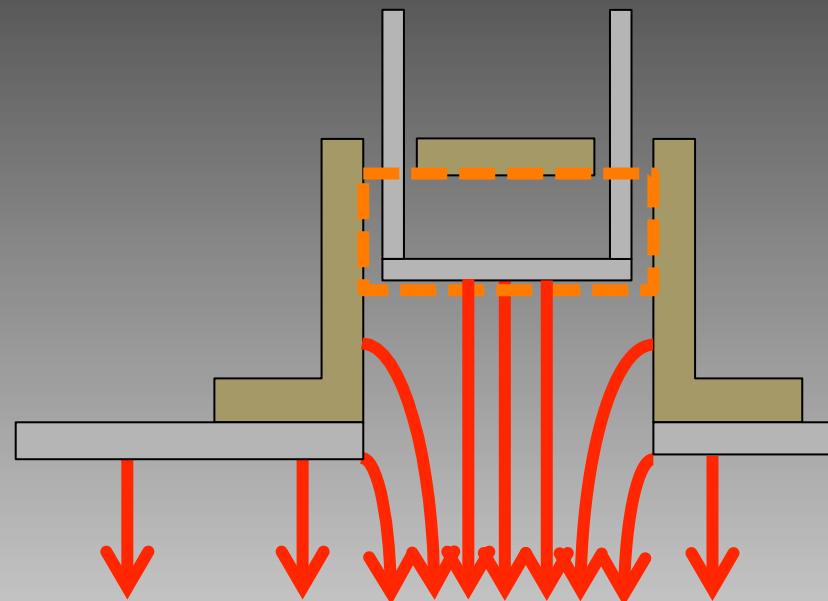
E-Field
H-Field



Electric Field Coupling

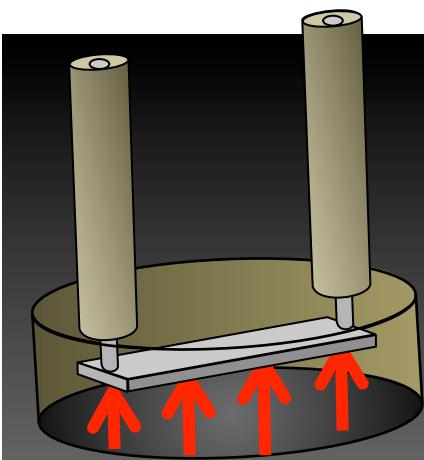


$$\epsilon_0 \oint_{\partial V} \vec{E}_{(d)} \cdot d\vec{O} = Q_{(d)}$$

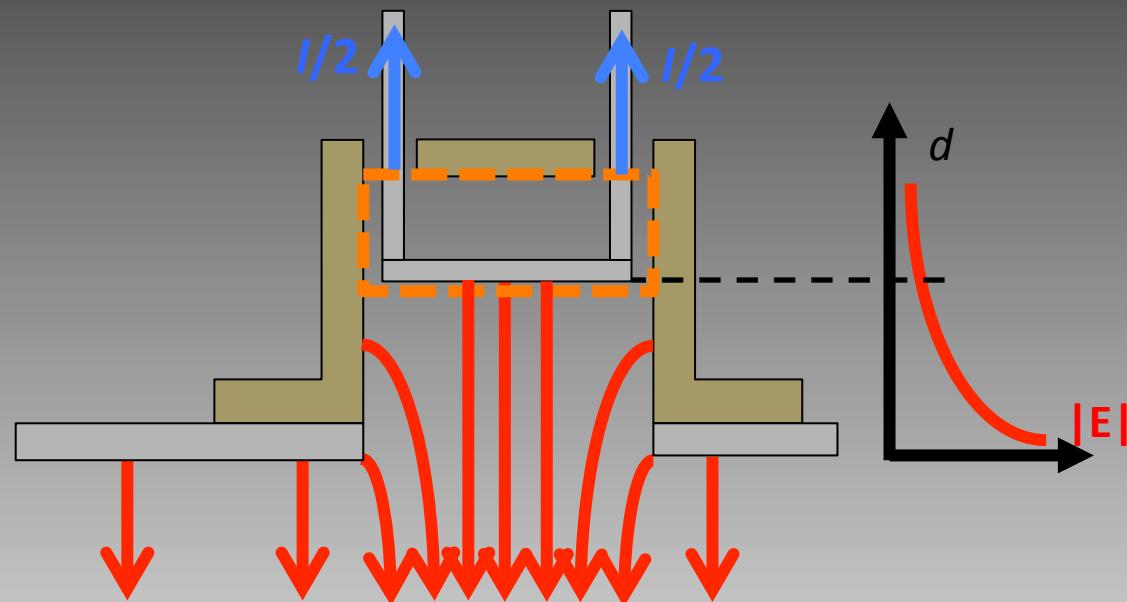


E-Field
Current

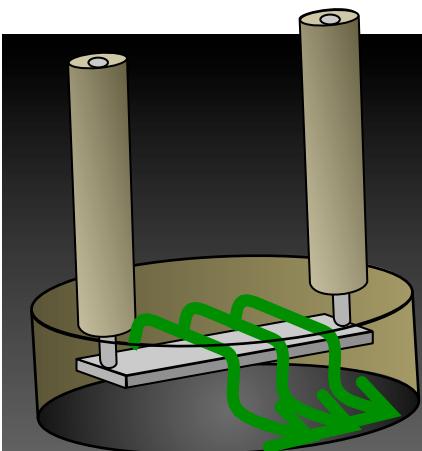
Electric Field Coupling



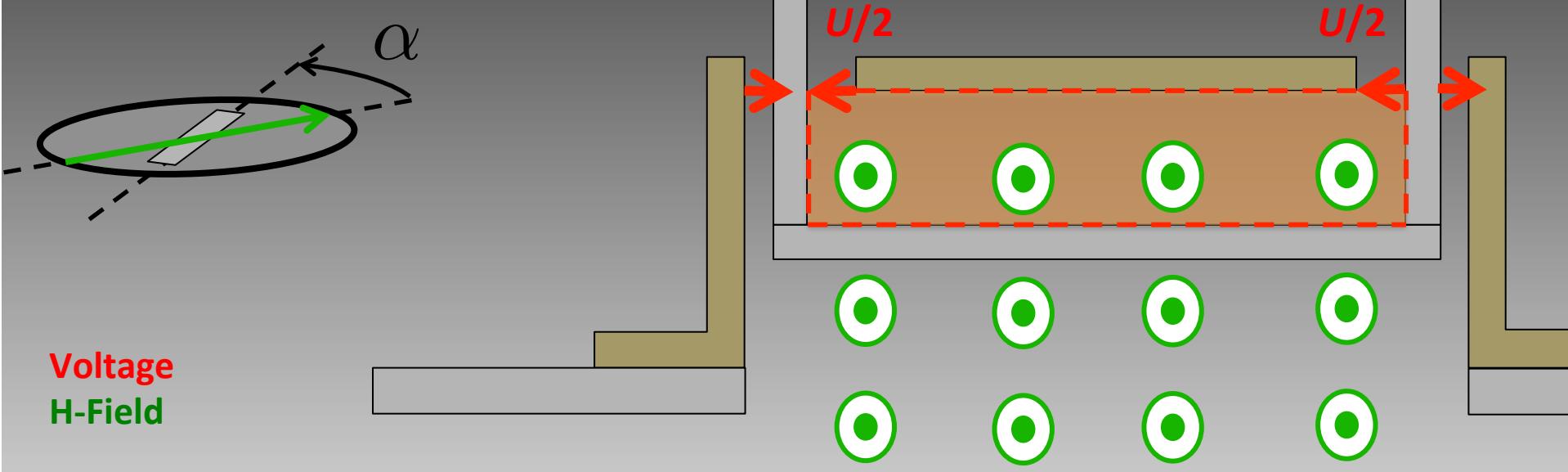
$$\frac{d}{dt} \left(\epsilon_0 \oint_{\partial V} \vec{E}_{(d)} \cdot d\vec{O} \right) = \frac{dQ_{(d)}}{dt} = -I_{(d)}$$



Magnetic Field Coupling



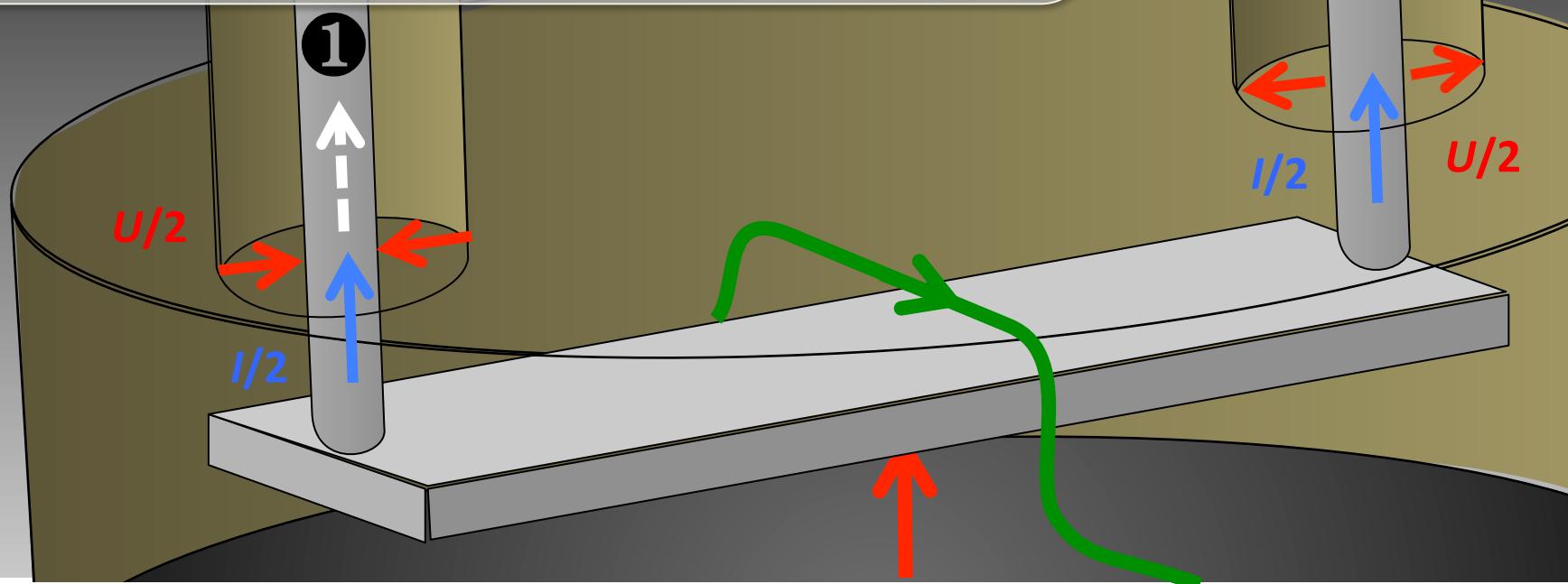
$$\frac{d}{dt} \int_A \vec{B}_{(d)} \cdot d\vec{a} = - \oint_{\partial A} \vec{E} \cdot d\vec{s} = -U_{(d,\alpha)}$$



Coupling & Directivity

$$U_1 = I/2 Z_L + U/2 = U \quad \leftarrow U(d, \alpha) = Z_L I(d)$$

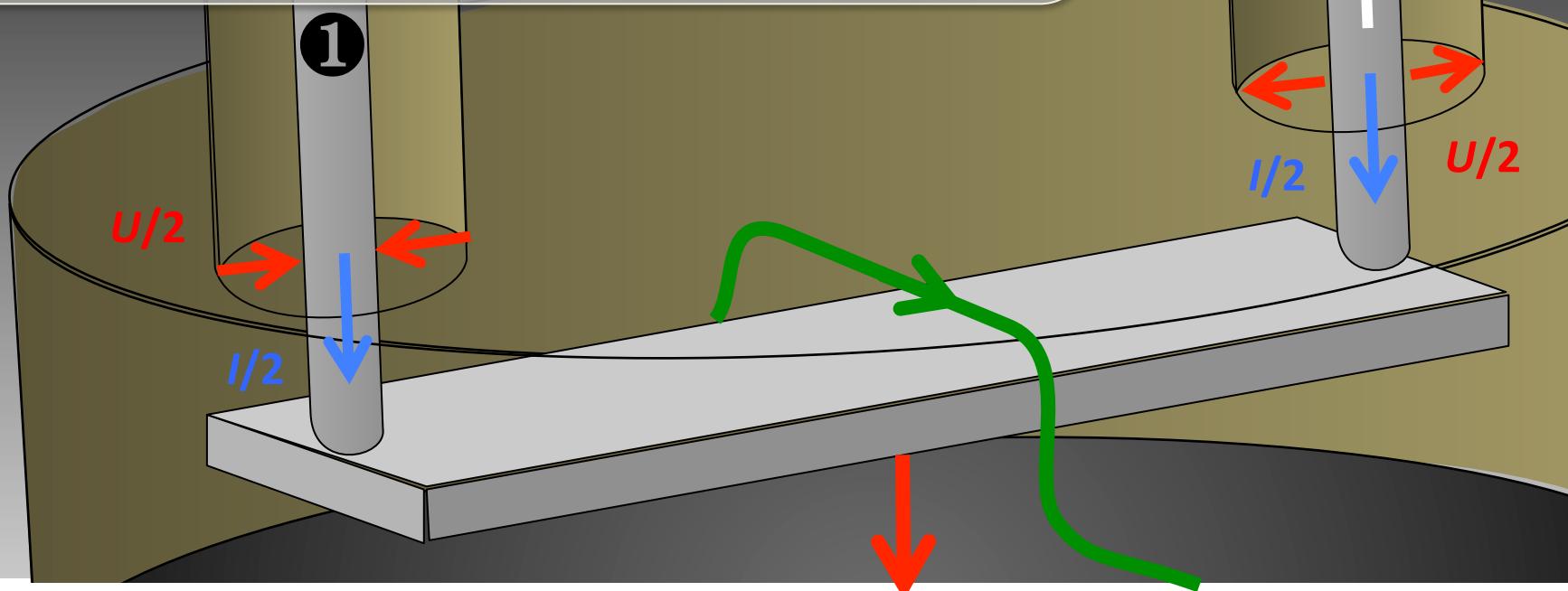
$$U_2 = I/2 Z_L - U/2 = 0$$



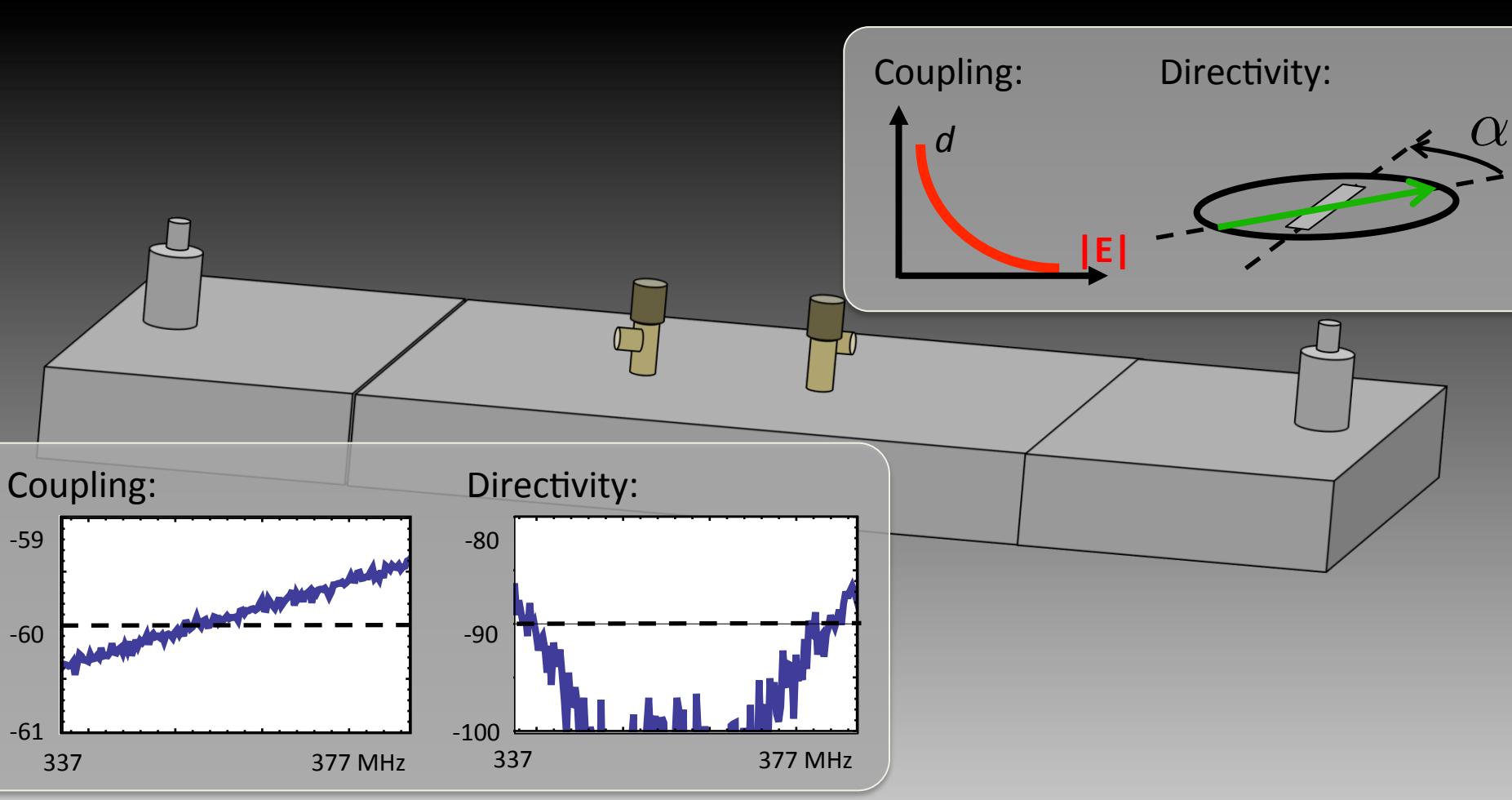
Coupling & Directivity

$$U_1 = I/2 Z_L + U/2 = 0$$

$$U_2 = I/2 Z_L - U/2 = U \quad \leftarrow U(d, \alpha) = -Z_L I(d)$$



Calibration Procedure



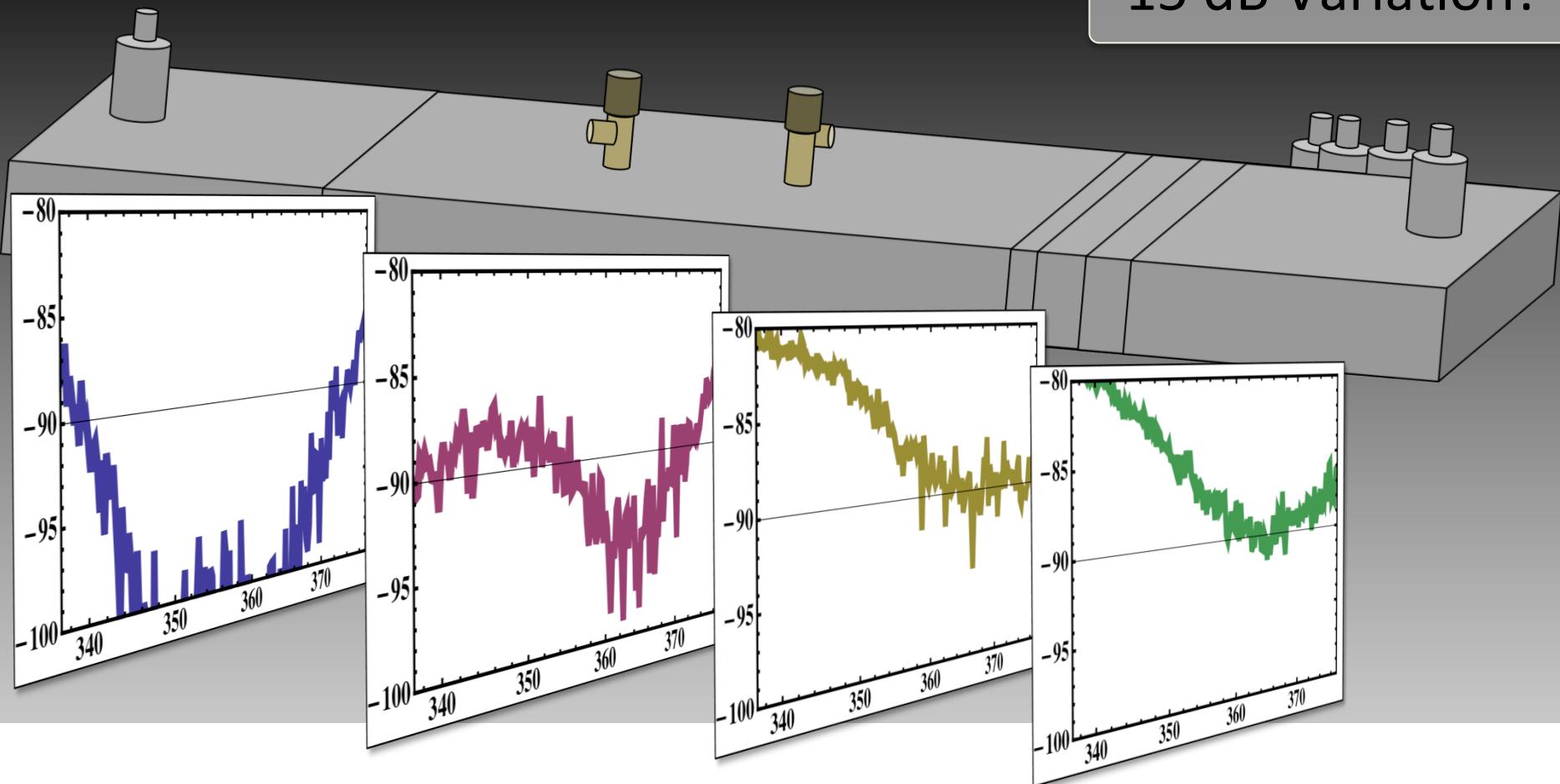
Calibration Procedure

- 90 dB Isolation close to VNA noise floor
- Aim for directivity first
- Maintaining good directivity when
 - Re-connecting loads
 - Re-attaching couplers
 - Swapping couplers



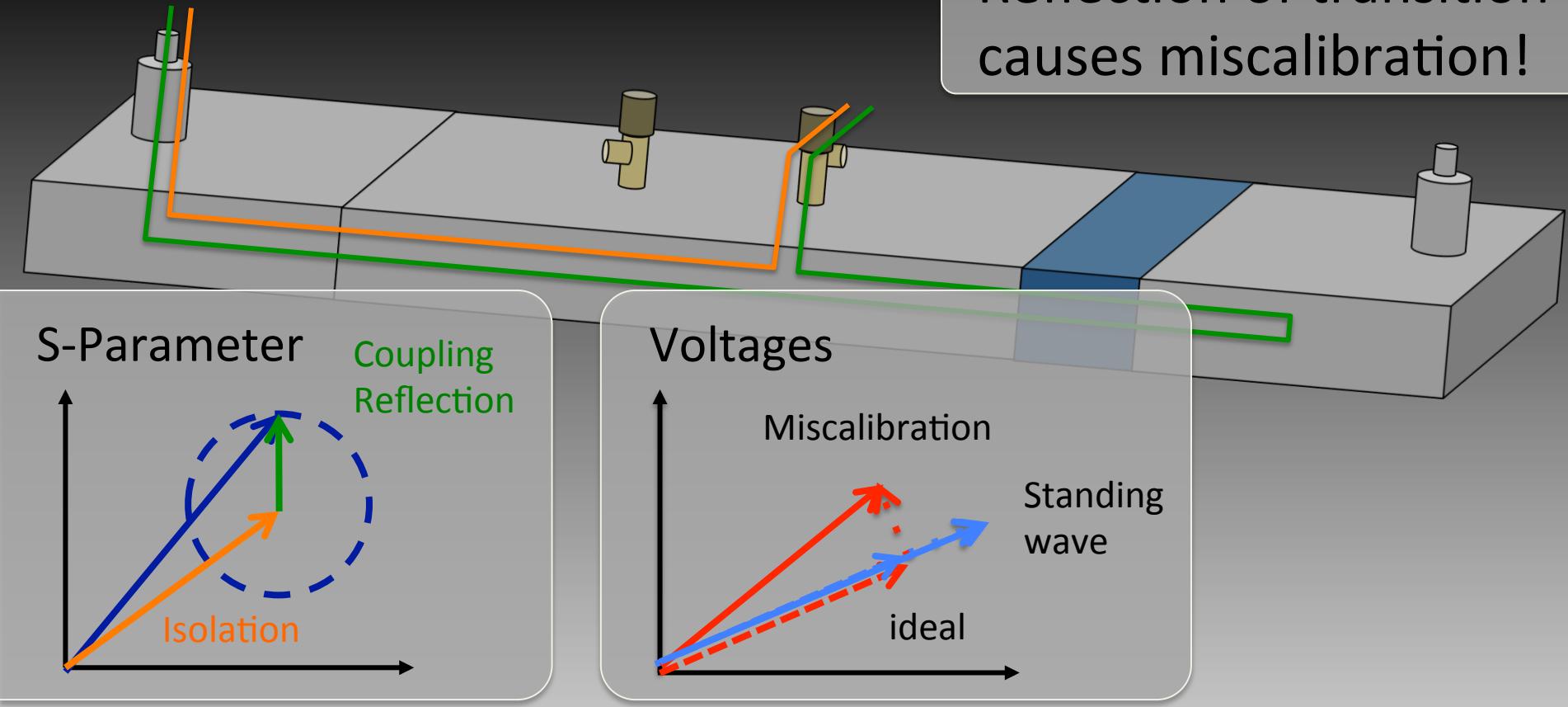
Directivity Issue

15 dB Variation!

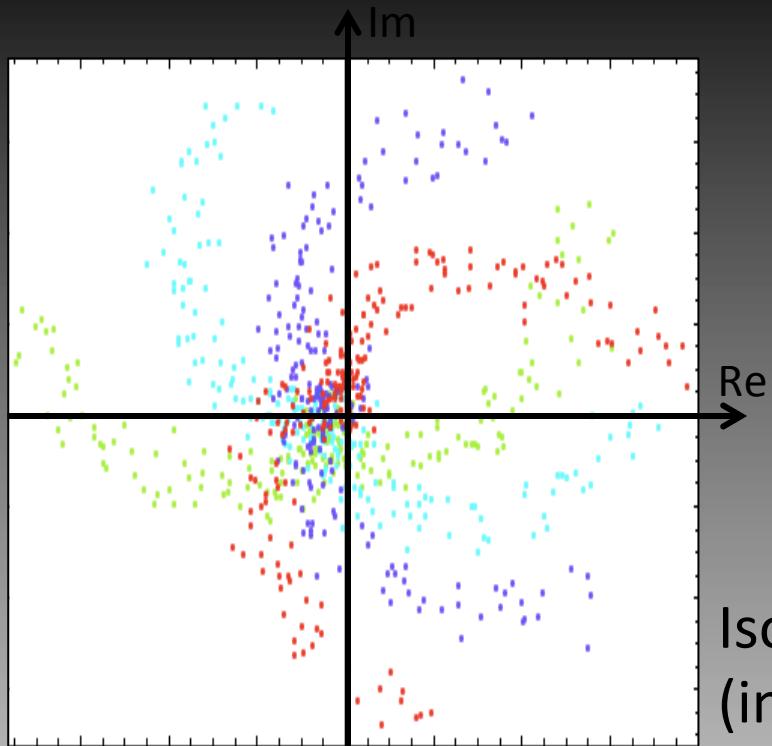


Isolation Signal

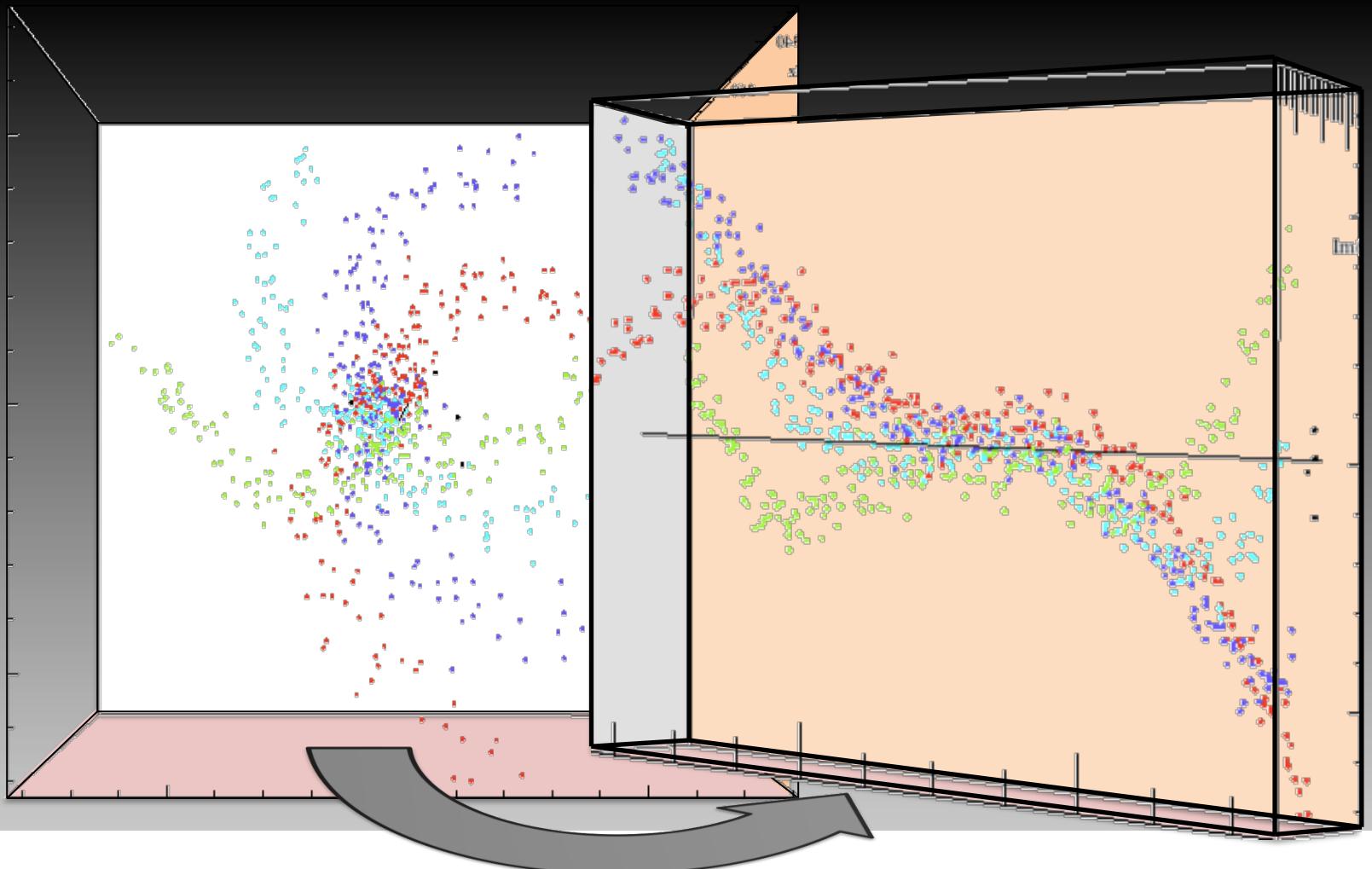
Reflection of transition causes miscalibration!



Extracting “Real” Isolation



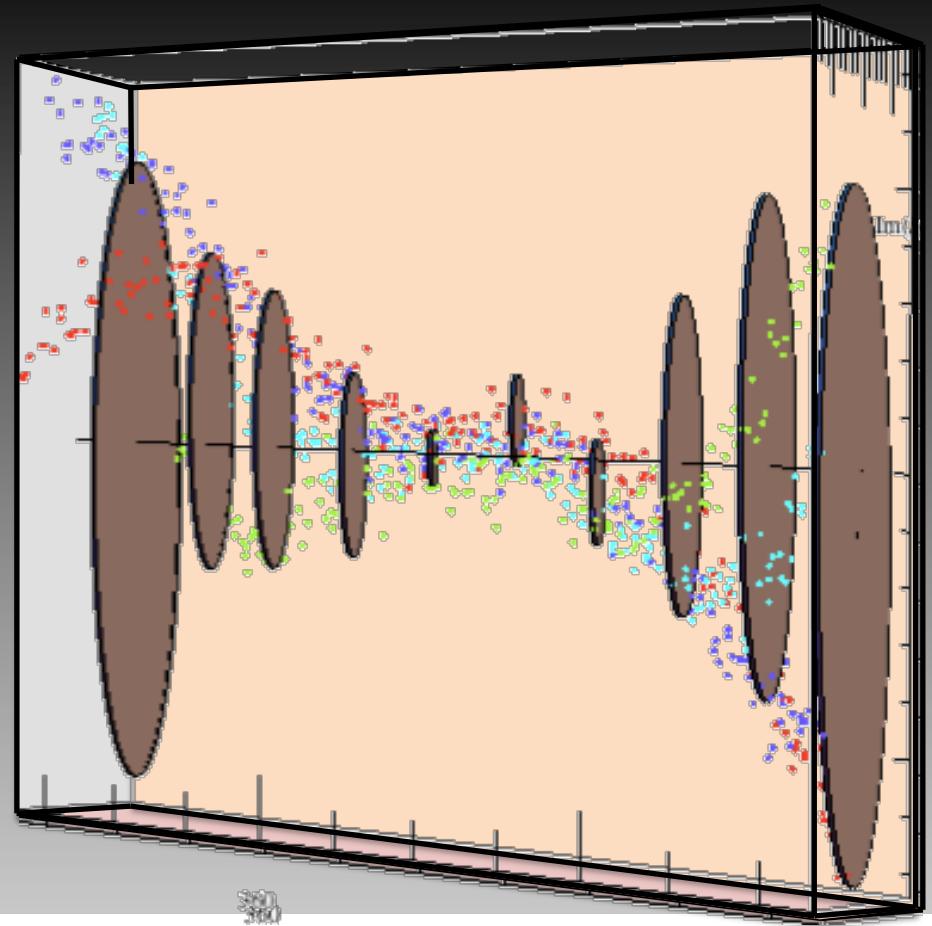
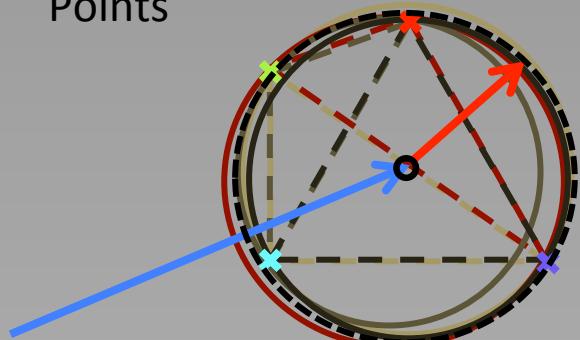
Extracting “Real” Isolation



Extracting “Real” Directivity

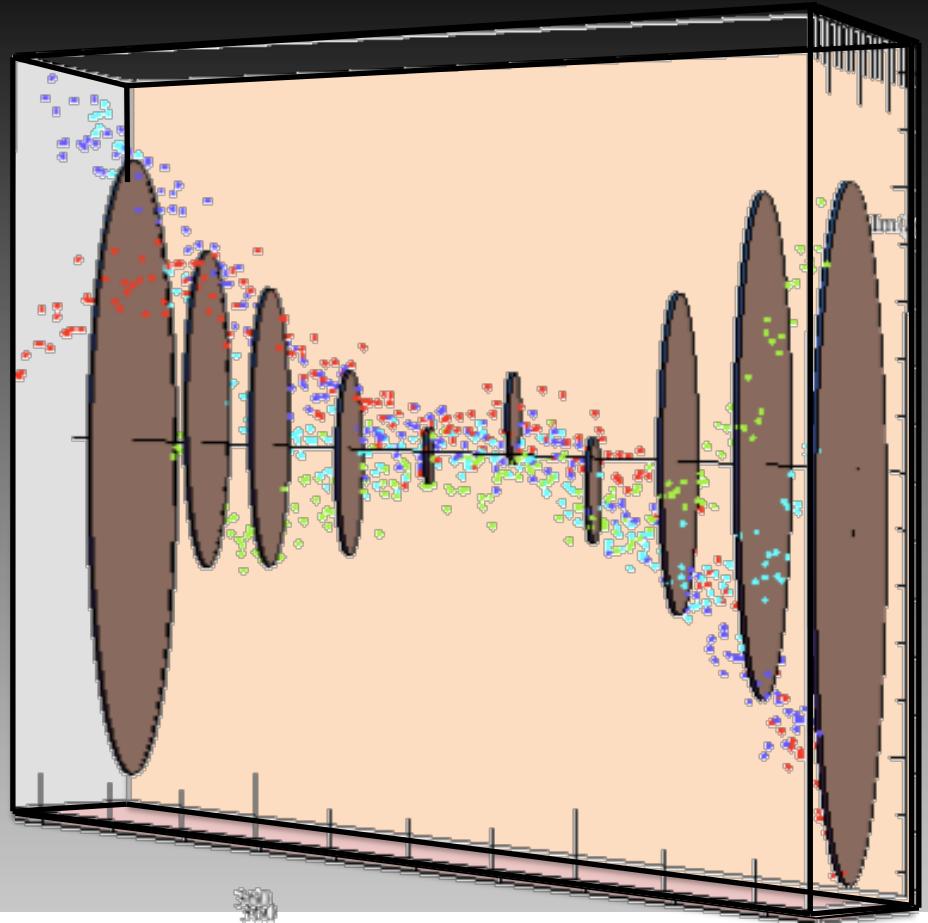
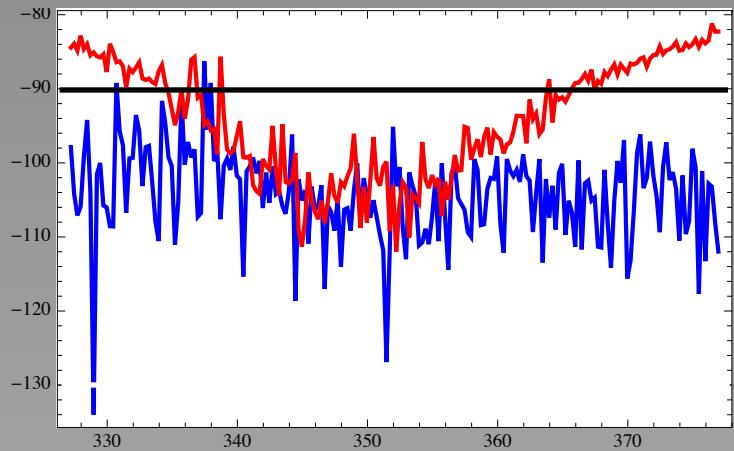
Reconstruction

Measurement
Points



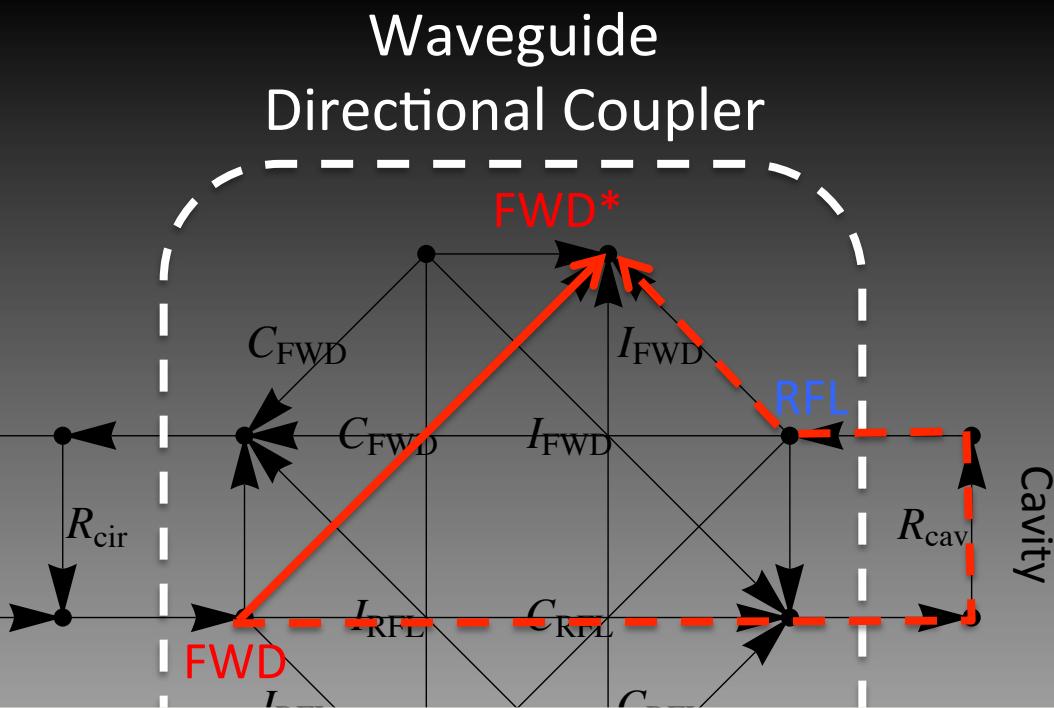
Extracting “Real” Isolation

Isolation and “variable” Fraction

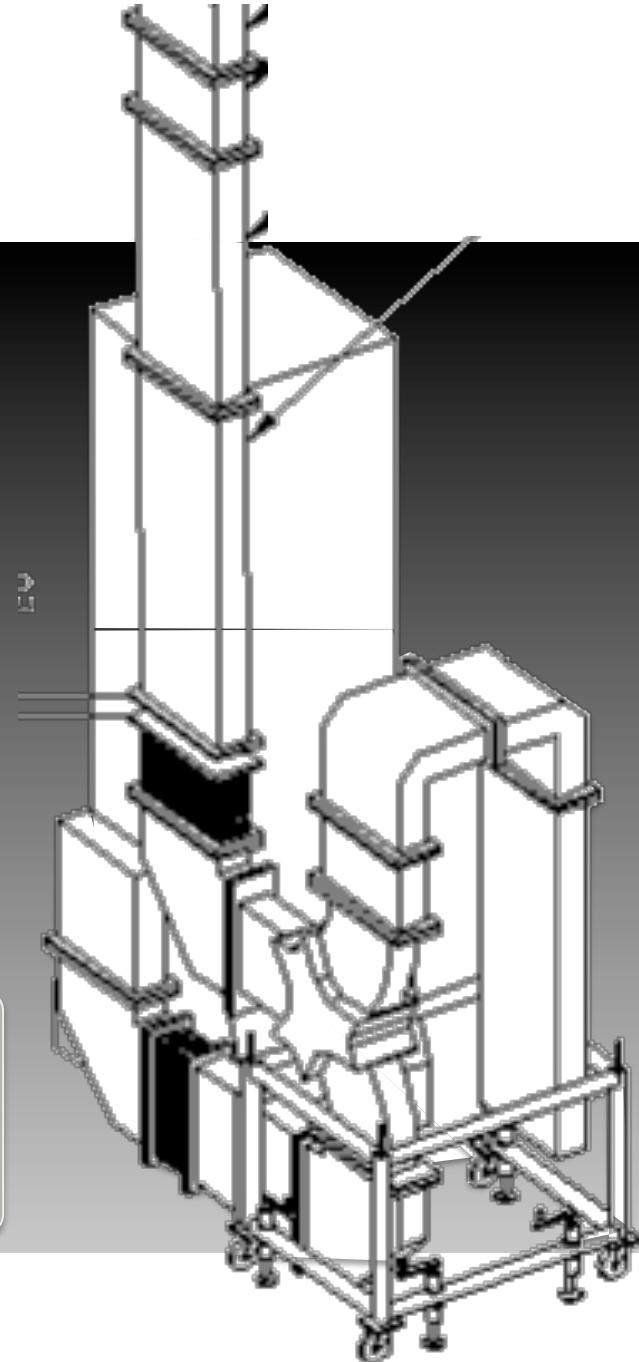


Application

from Circulator



$$FWD_* = \frac{C_{\text{FWD}} + I_{\text{FWD}} R_{\text{Cav}}}{1 - R_{\text{Cir}} R_{\text{Cav}}} FWD$$



Summary

- Loop couplers are more “resistant” than we thought
- Inevitable standing waves strongly affect directivity
- With increased effort standing waves can be compensated for



Thank you for your attention!

