DESIGN OF A CONFOCAL RESONATOR PICK-UP

T. Ekelöf, A. Ferrari, V. Ziemann
A. Rydberg, E. Öjefors, M. Johnson

UPPSALA UNIVERSITY, SWEDEN

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- *Analytical calculations*
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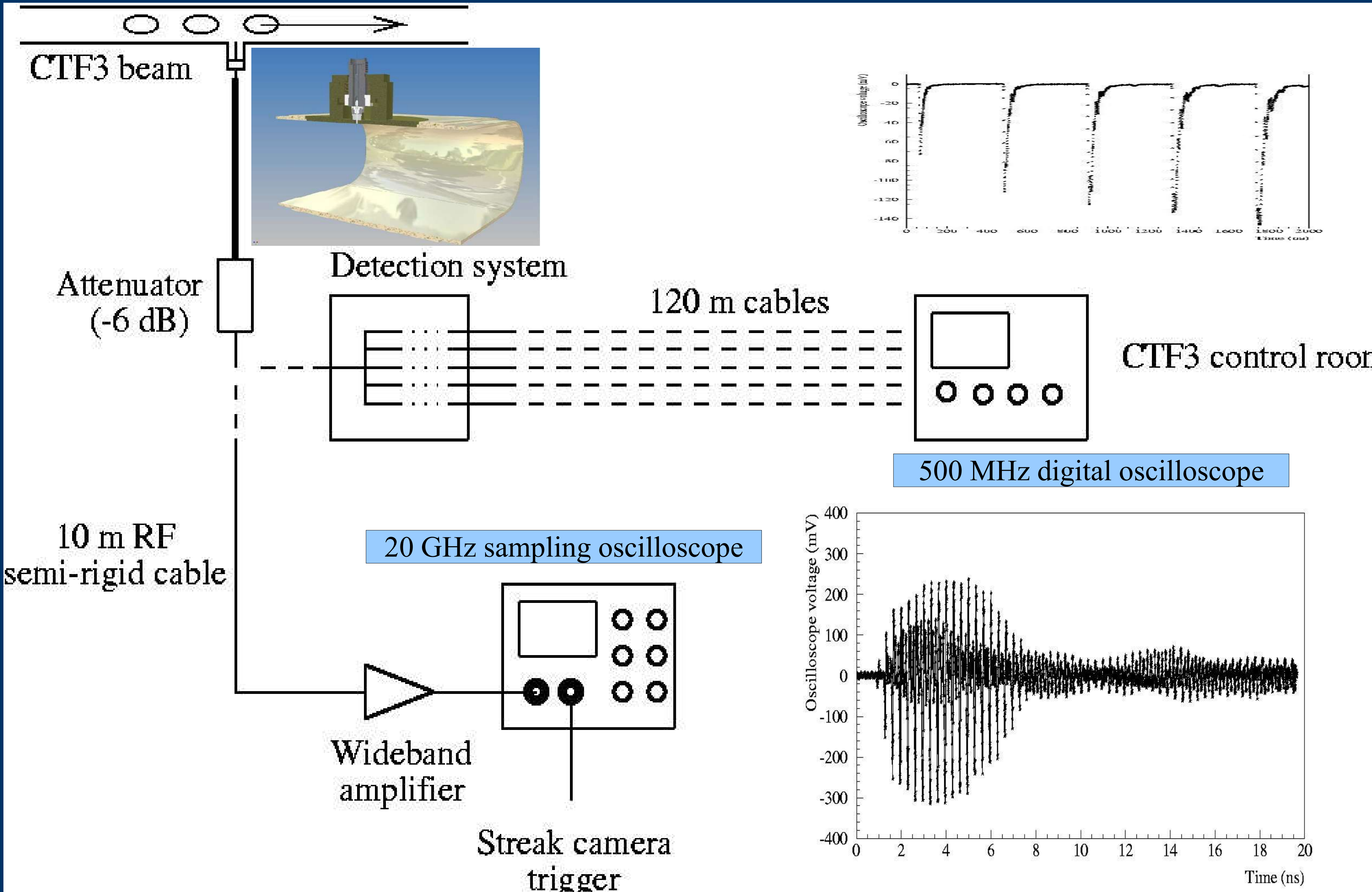
PARASITIC WAVEGUIDE MODES

- When electron bunches travel in a vacuum pipe, they can excite modes with the same frequencies as in the beam.

- For frequencies above the vacuum pipe cut-off frequency, these “waveguide” modes propagate in the wake of the bunches, at various velocities.

- Downstream in the vacuum pipe, the waveguide modes can be detected by beam monitors and they usually give a parasitic contribution.

- Such parasitic waveguide modes were clearly observed in the commissioning the Uppsala bunch frequency monitor during the CTF3 Preliminary Phase.



Uppsala bunch frequency monitor, CTF3 Preliminary Phase 2001-2002

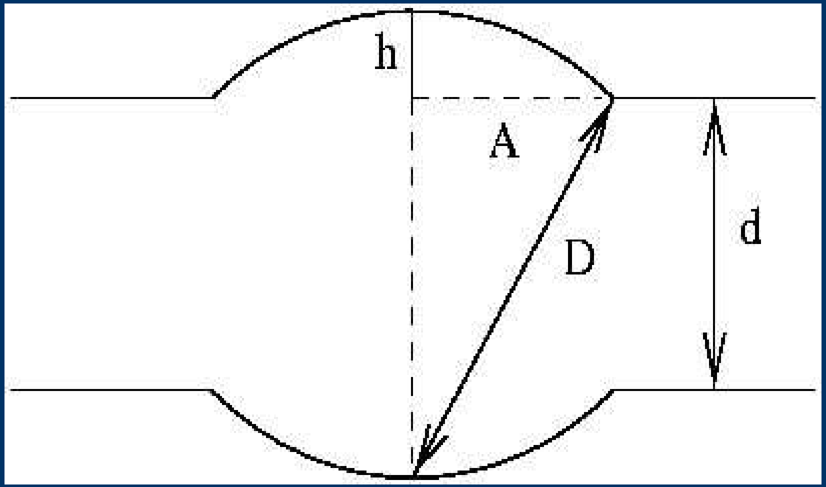
PURPOSE OF THE STUDY

- Design and test a new type of beam monitor which is mostly sensitive to the beam quasi-TEM mode and which rejects the parasitic waveguide modes.

- It was suggested that a confocal resonator pick-up could do such a job (F. Caspers, CERN). With a large Q-value for diffraction losses, the confocal resonator should not couple to external waveguide modes, by reciprocity.

- Bunch frequency monitor for the future phases of CTF3, when the combiner ring is installed (3 GHz to 15 GHz).

GEOMETRY AND RESONANT MODES



The pick-up should resonate at 15 GHz (bunch frequency monitor) and must fit into the CTF3 vacuum pipe:

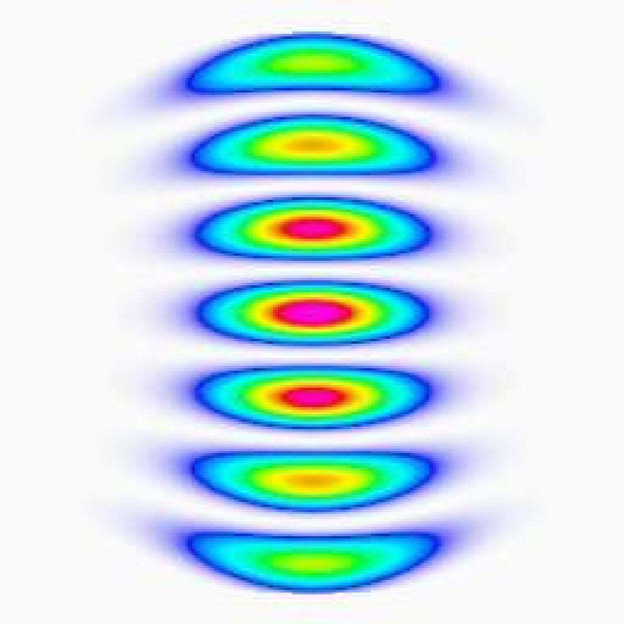
d = 3.70 cm (CTF3 combiner ring)

D = $(n+3/4)\lambda$= 7.50 cm

A= 4.99 cm and h = 1.90 cm

Here, we have chosen λ = 2 cm (i.e. a frequency of 15 GHz) and n = 3.

In these conditions, one can analytically calculate the electric field E inside the resonator.



DIFFRACTION LOSSES

They come from the oscillating "rays" that miss the half-orange mirrors and the corresponding Q-factor is:

$$Q_d = 2\pi D/\alpha_d\lambda, \text{ with } \alpha_d = 16\pi^2 N_F \exp(-4\pi N_F).$$

Here, the Fresnel number N_F is 1.66 and $Q_d = 10^8$ @ 15 GHz.

→ Almost no radiation of the confocal resonator into the free space around.

→ By reciprocity, there is almost no coupling of the incoming waveguide modes to the confocal resonator.

OTHER LOSSES

1. Resistive losses are due to the finite conductivity of Aluminium:

$$Q_r = G/R_s \text{ with } G = Z_0\, \pi D/2\lambda \text{ and } R_s = 1/\sigma\delta.$$

At 15 GHz, the bulk resistivity $1/\sigma$ is 2.65×10^{-8} Ω.m and the skin depth is 0.67 µm, so $Q_r = 5.6 \times10^{4}$.

2. A coupling hole should be drilled in one of the half-oranges to extract RF signals into a rectangular waveguide where only a TE_{10} mode can propagate at 15 GHz (a = 2b= 15.8 mm). Requiring that the impedance of the resonator with a hole (i.e. shunt inductance) matches the waveguide impedance leads to:

$$r_0^{\,3} = 3ab/16\pi^2 \times \lambda/[1-(\lambda/2a)^2] \times (\pi/2Q)^{1/2}.$$

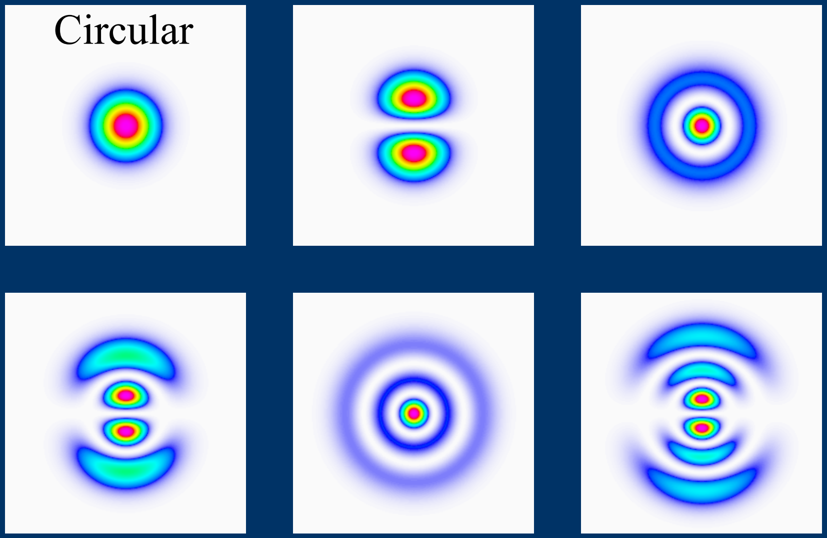
Here, this leads to an optimal coupling hole diameter of 1.5 mm (if the hole depth is negligible).

OTHER ISSUES TO CONSIDER

The confocal resonator has more than one resonant frequency:

* for circular modes in the z=0 plane, $\lambda = 7.5 / (n+3/4)$ in cm and one thus has $f_n = 3 + 4n$ GHz. The CTF3 beam (3 GHz) can thus excite other modes, and these must not stay in the confocal resonator → absorbing material!!

* some other modes must also be considered, with a non-circular shape in the z=0 plane...



All eigen-frequencies should be listed, and we must identify the dangerous ones for the operation with the CTF3 beam!!

SIMULATIONS

For simulations of the electromagnetic fields in the confocal resonator, we use FEMLAB, HFFS and CST Microwave Studio, with the following purposes:

* computation of all eigen-frequencies in the confocal resonator,

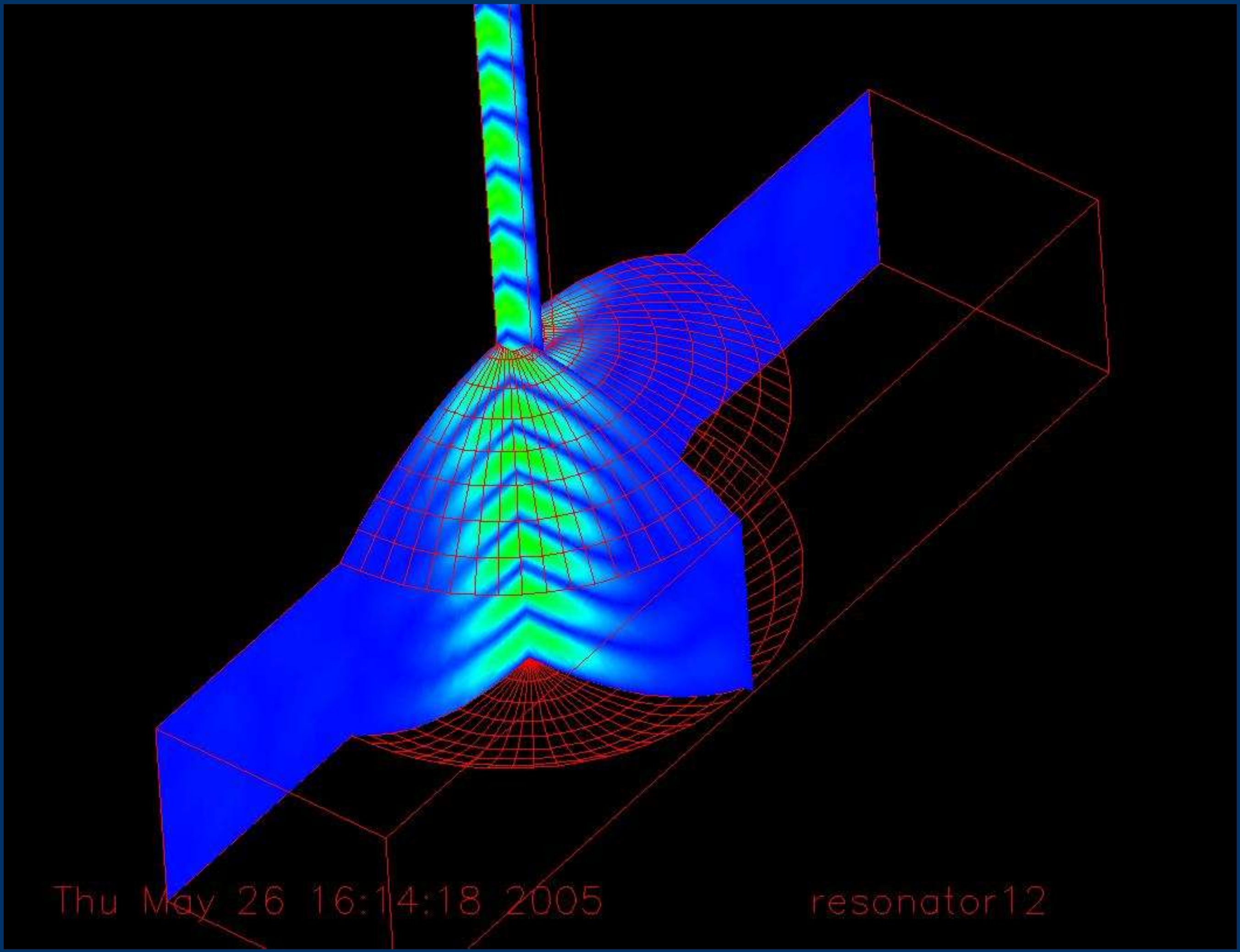
* computation of S-parameters between the incoming waveguide modes and the extracted mode at 15 GHz,

* with a TE10 mode injected in the waveguide, the computation of S11 allows to compute Q-values and to optimize the coupling between the confocal resonator and the extraction waveguide,

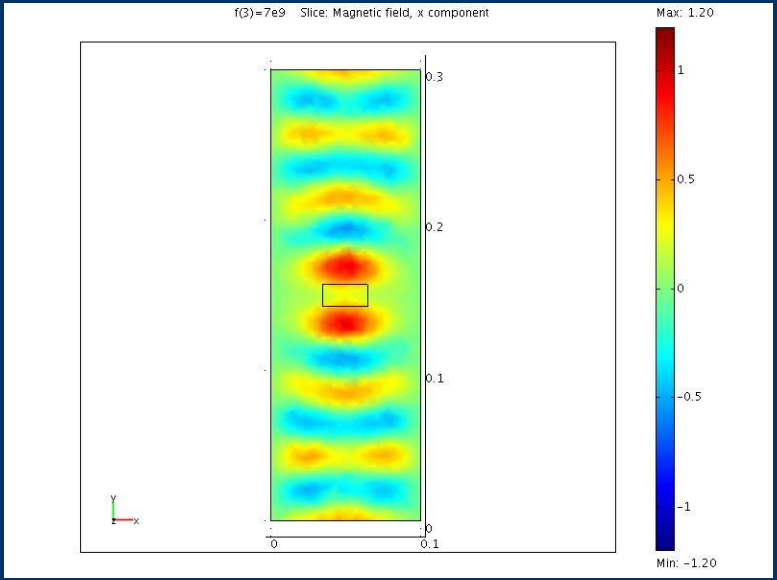
* design of the absorbing material for the damping of unwanted resonant modes.

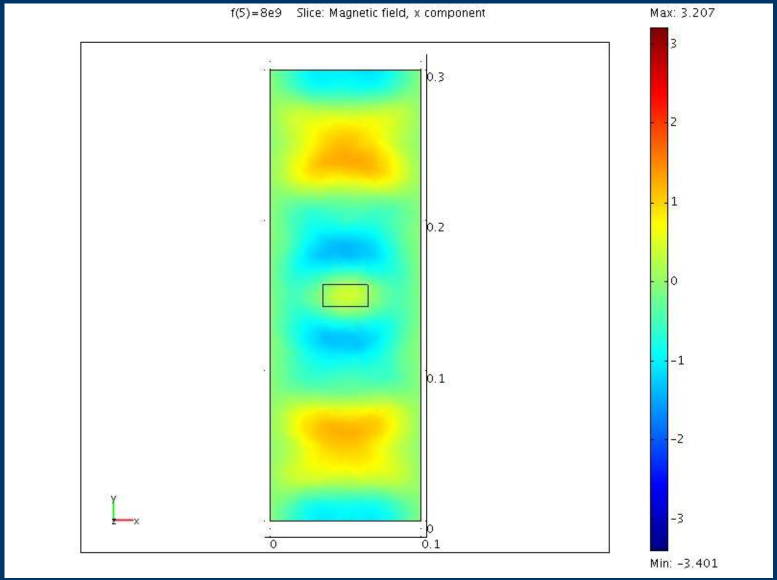
For the later simulation of the couplings between a beam and the confocal resonator, we will use GDIFDL.

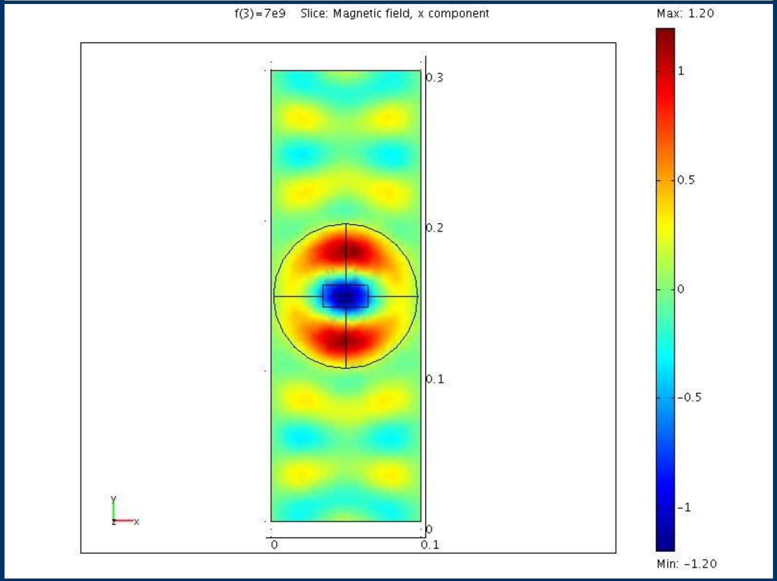
FIRST SIMULATION RESULTS/HFSS

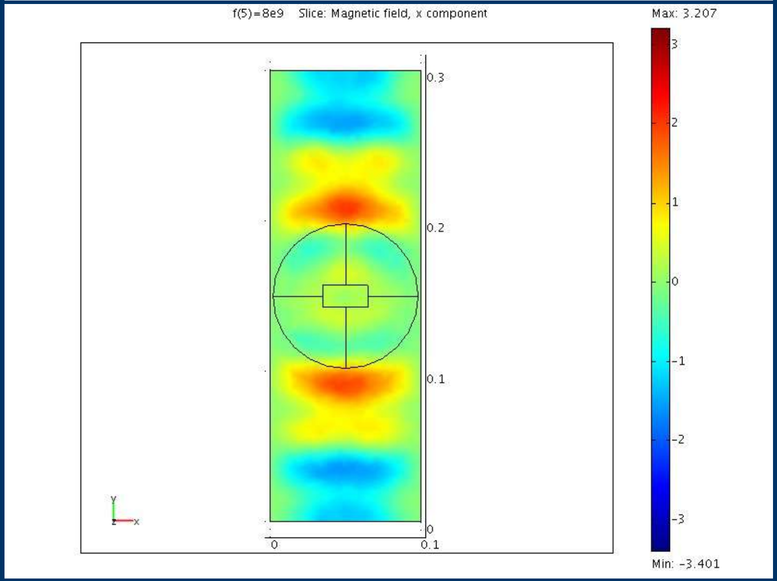


Simulation Results/FemLab

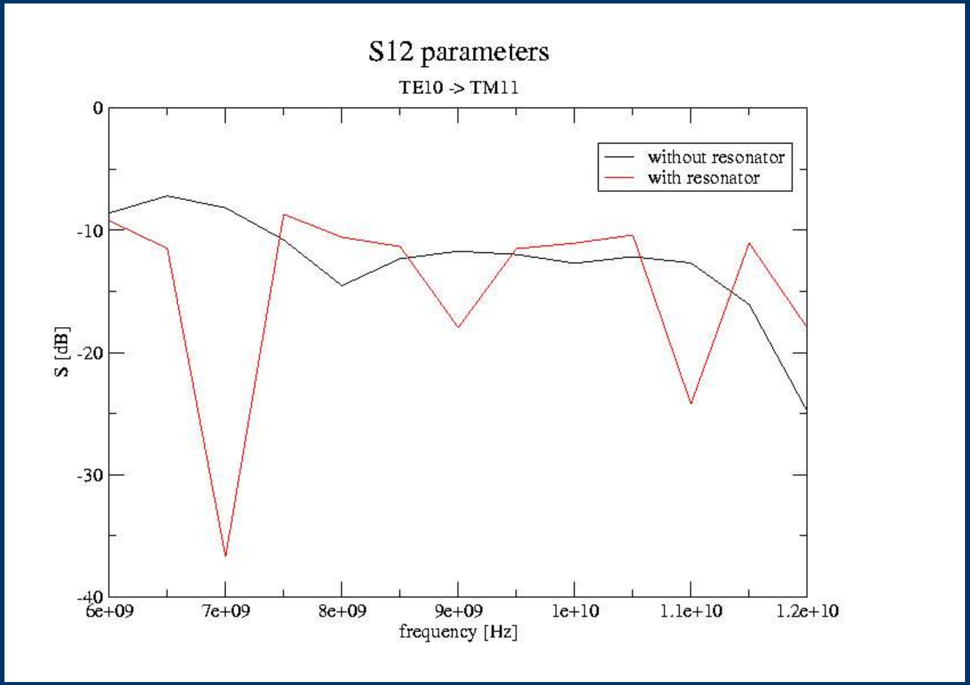


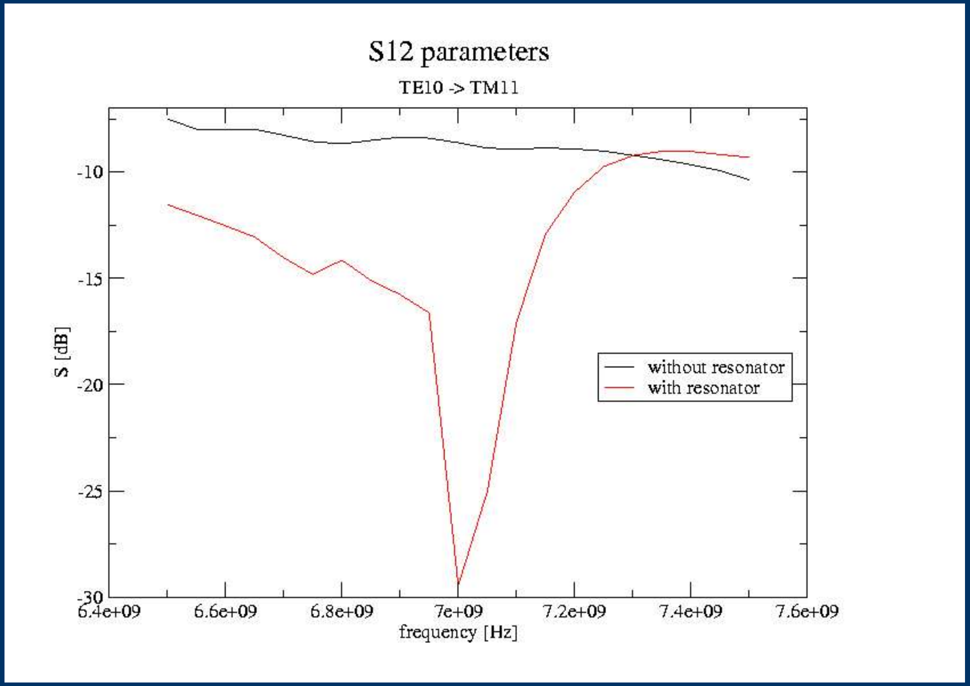




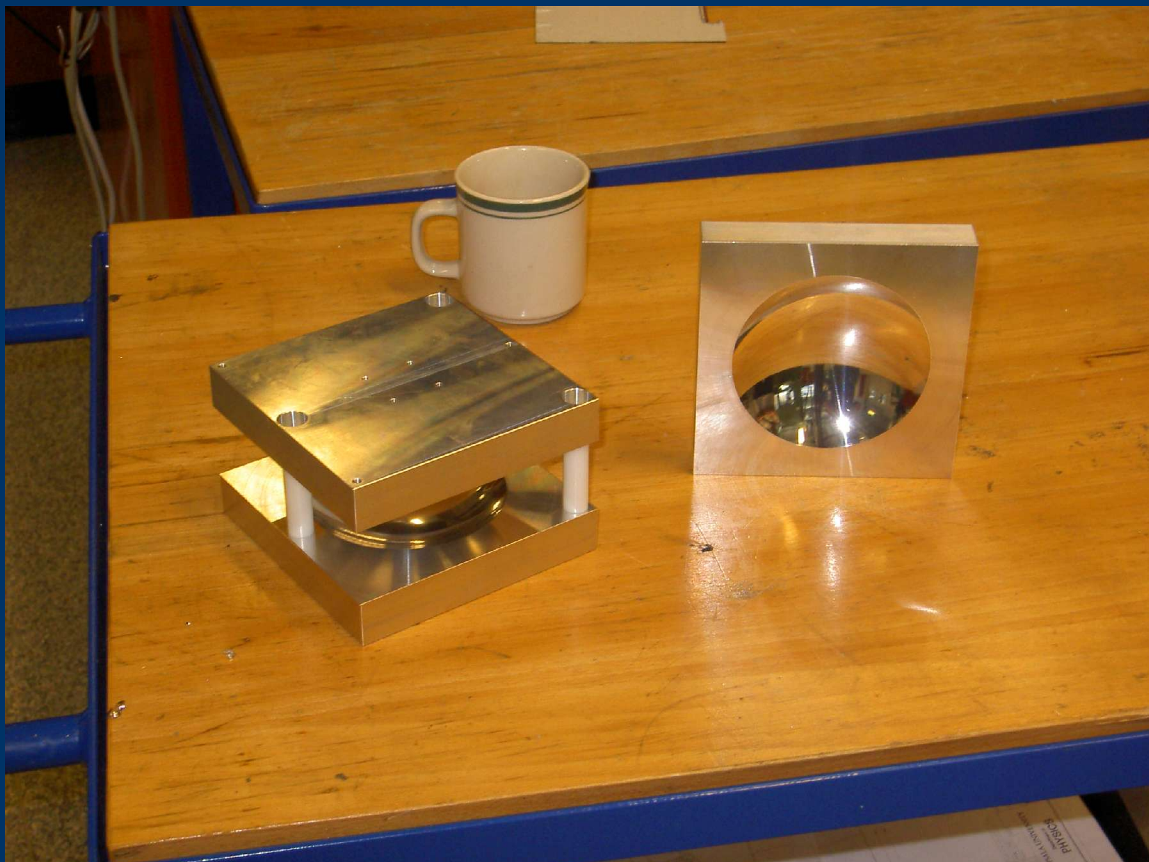


S-Parameters

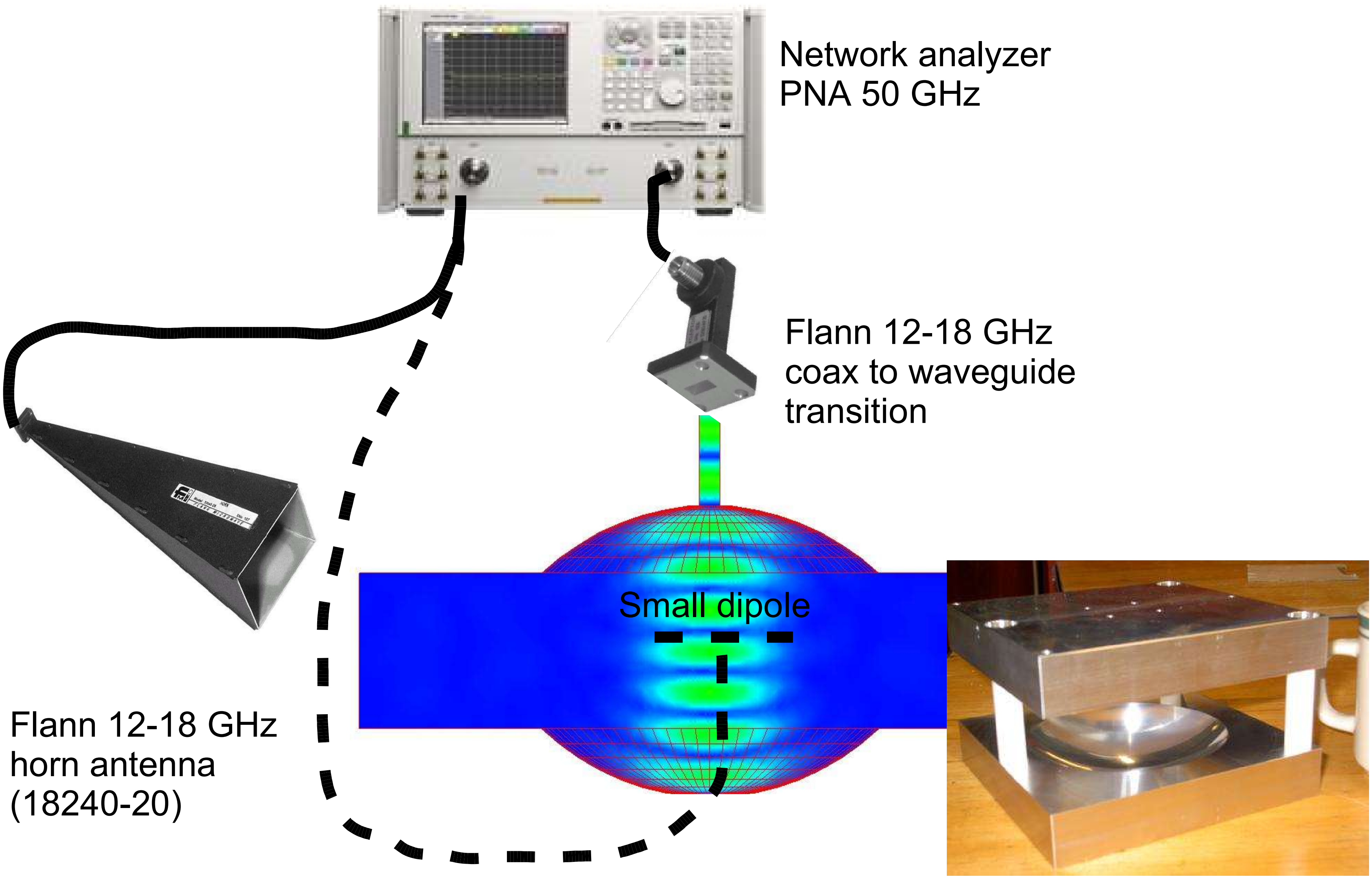




Aluminum Prototype



Measurement setup



FUTURE PLANS and Gantt Chart

WP1: CFBPM												
	2005				2006				2007			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Recruitment												
PostDoc	1.1											
Undergraduate student		1.2										
Simulation calculations												
Femlab: Resonator parameters		2.1	>>>	>>>	>>>	>>>						
Femlab: S-parameters		2.1	>>>	>>>	>>>	>>>						
uStudio: Purchasing and learning		2.3	>>>									
uStudio: Resonator parameters			2.4	>>>	>>>	>>>						
uStudio: S-parameters			2.4	>>>	>>>	>>>						
Status Reports on Simulations				2.6		2.6						
GDFIDL simulations						2.7	>>>	>>>				
Position sensitive device				3.1	>>>	>>>	>>>	>>>				
Tolerances												
Analytic estimates			4.1	>>>	>>>							
Simulations				4.2	>>>	>>>	>>>	>>>				
Prototype testing					4.3	>>>	>>>	>>>				
Simple Aluminum prototype												
Drawings		5.1										
Construction		5.2										
Bench-testing			5.3	>>>	>>>	>>>						
Full prototype												
Drawings					6.1	>>>						
Construction						6.2	>>>					
Bench testing							6.3	>>>	>>>			
Tests with beam									6.4	>>>	>>>	
Microwave test stand												
Specification		7.1										
Assembly			7.2									
Testing devices				7.3	>>>	>>>	>>>	>>>	>>>			

CONCLUSION AND OUTLOOK

- Investigate Confocal resonator pickup to improve the noise susceptibility
- Analytic estimates
- Simulations with Femlab and HFSS
- Prototype under construction
- Test bench under preparation
- Start measurements after the summer break