THE CLIC PETS ON/OFF OPERATION: PRINCIPLES, STUDY AND DESIGN

A. Cappelletti, CERN - CLIC Workshop 14 Oct 2009

INTRODUCTION

- A fundamental element of the CLIC concept is two-beam acceleration, where RF power is extracted from a high-current and low-energy beam in order to accelerate the low-current main beam to high energy.

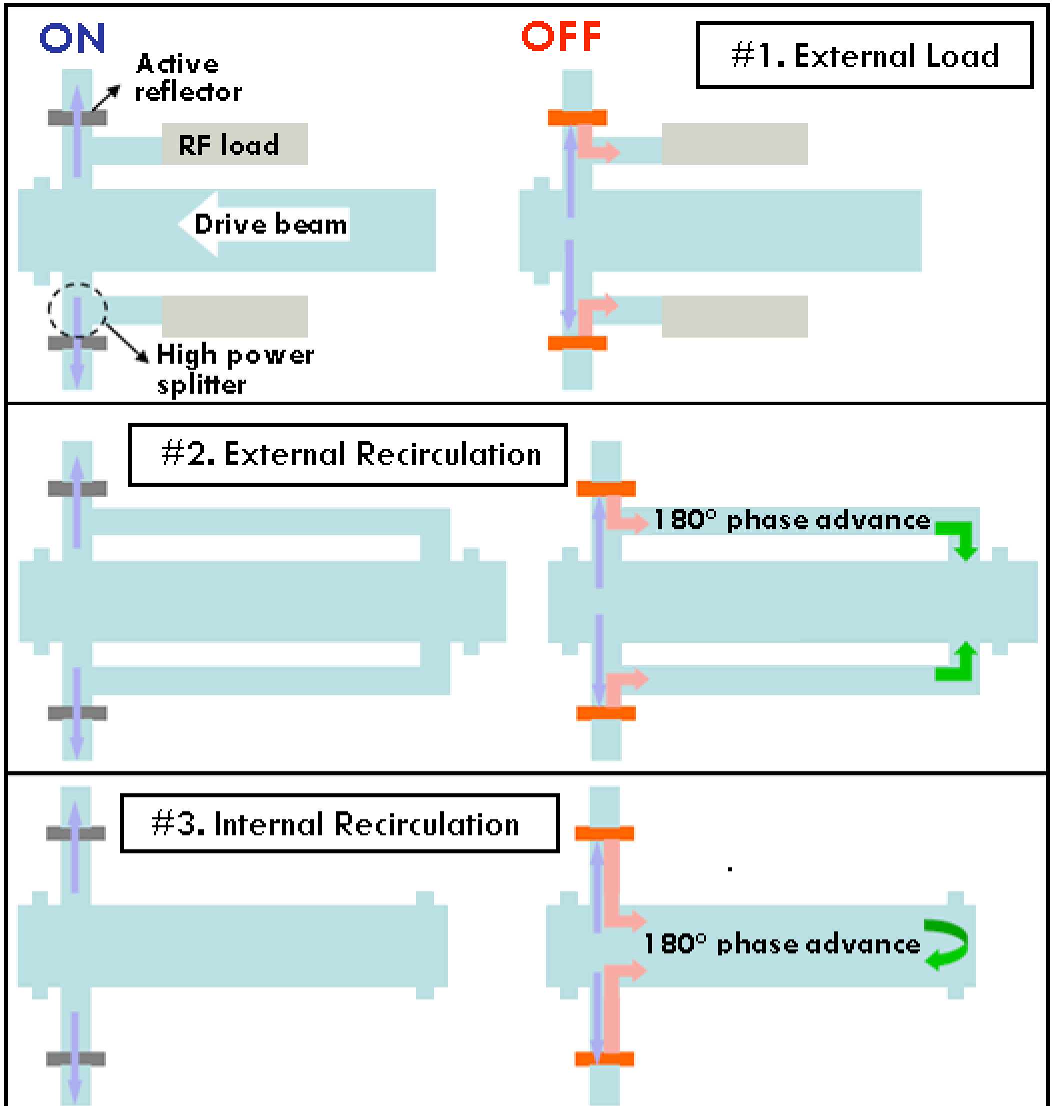
- The PETS power production principle, based on field reflection and power recirculation, is outlined.

- The data provided by HFSS and GDFIDL simulations are shown and commented, together with their post-processing and the validity of the used mathematical model.

- An important operational PETS specification is the capability of reducing the output power in the case of local breakdown in the accelerating structure, or the PETS itself.

- The possibility to use the external and compact RF waveguide devices is explored. The special RF devices necessary to implement this have been developed and are presented.

POWER RECIRCULATION

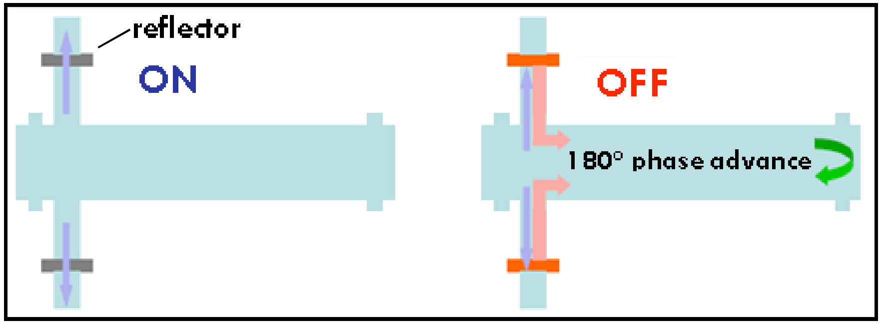


In order to keep the operation efficiency, the OFF switching has to be performed very rapidly (20 msec).

By coupling the output field back into the PETS with a 180 deg phase advance, the fields are temporarily canceled out (*coupling back the field may also be used for producing higher power*).

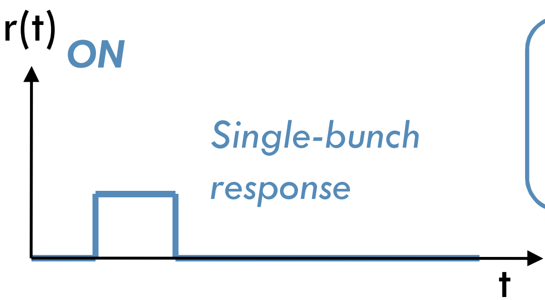
This is the solution which is going to be analyzed and delved into.

INTERNAL RECIRCULATION

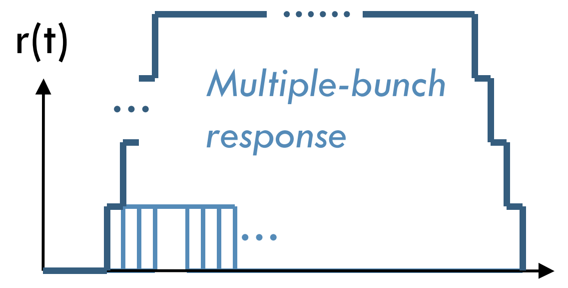


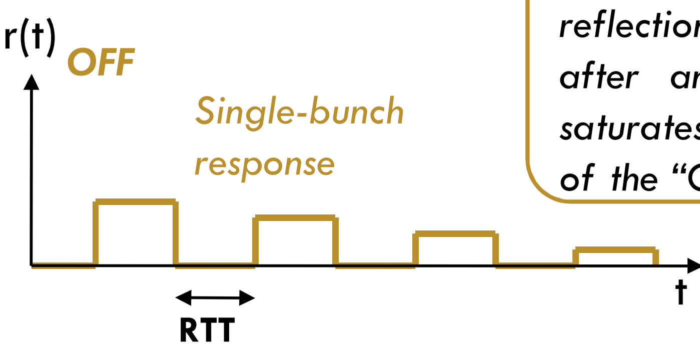
Solutions #1 and #2 require extra couplers and waveguides; also, #1 does not switch off the PETS.

We consider the signals envelopes at the reflector section, in a **dispersion-free approximation.**

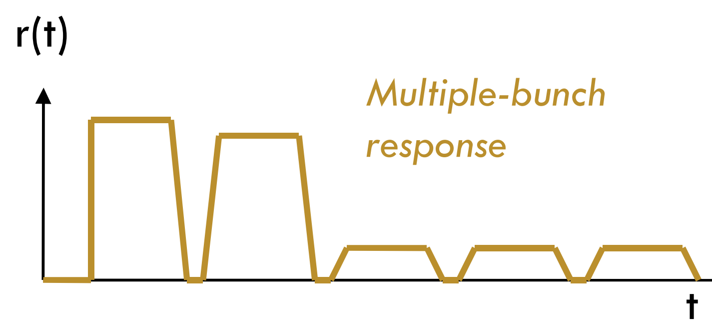


Every $t_0=\Delta_b/c$, a new signal reaches the output section and adds up to the previous ones.



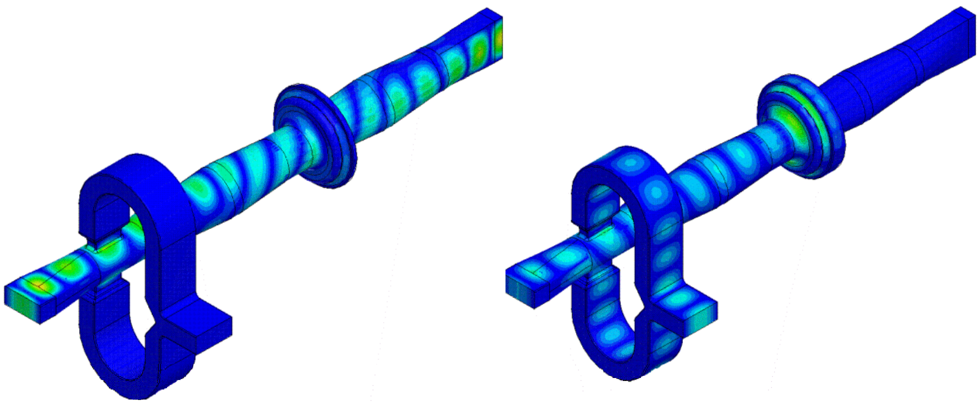


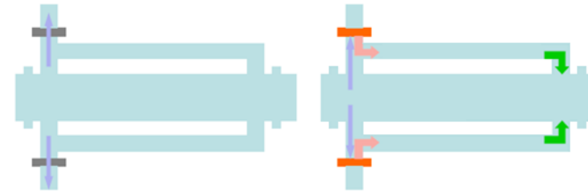
The s.b. response is made of signal reflections. The m.b. response, after an initial power build-up, saturates to not more than 25% of the "ON" power.

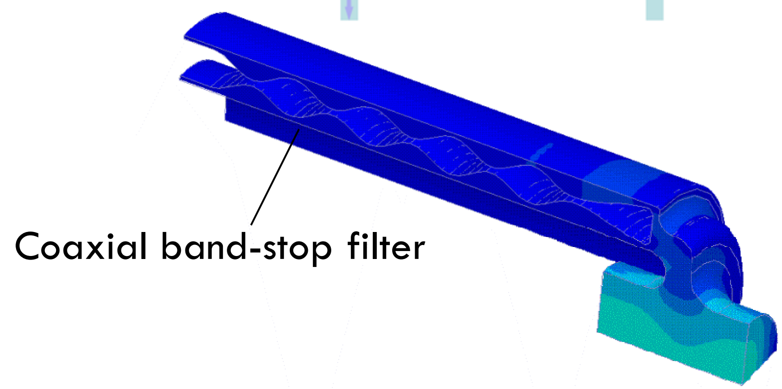


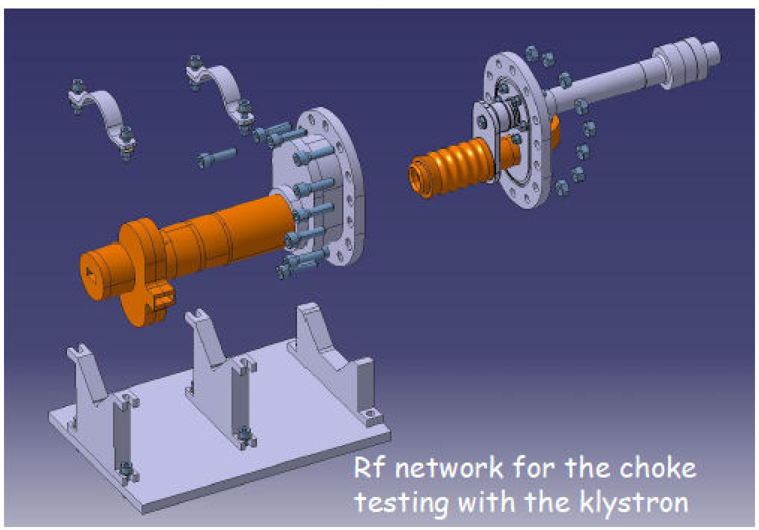
REFLECTOR: DESIGN #1

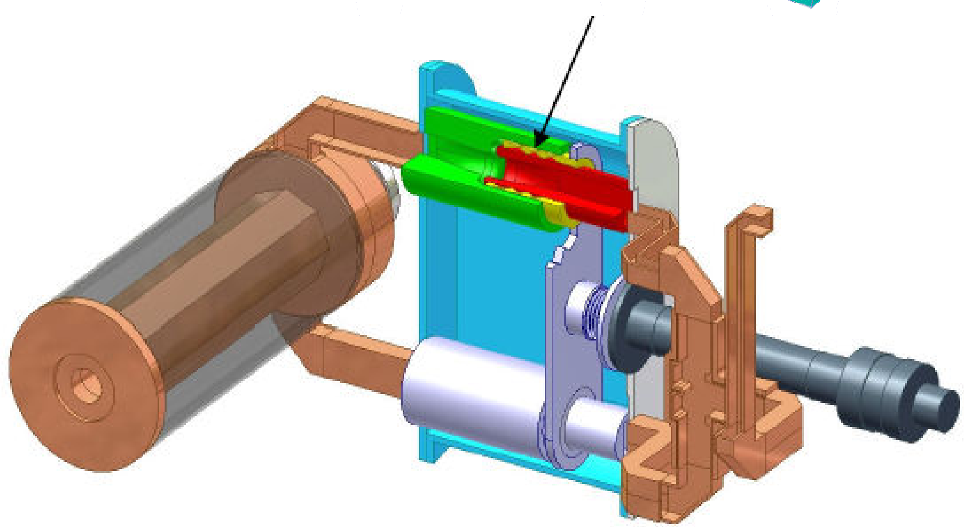
Choke-based tunable reflector





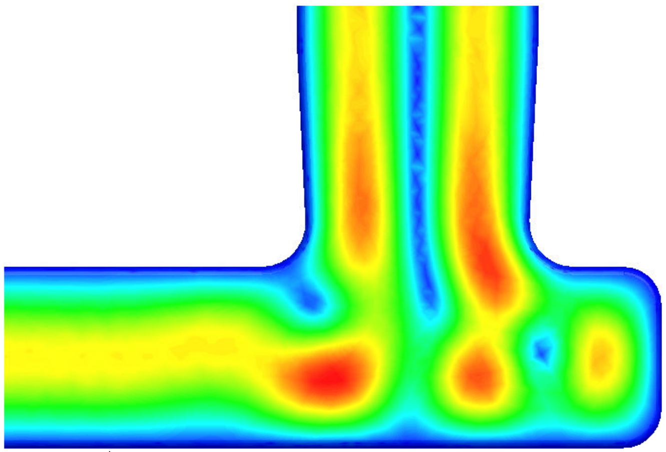






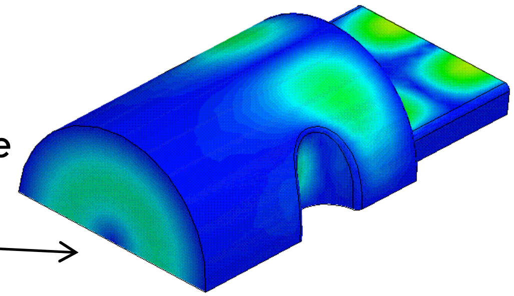
Bulky, expensive; high field concentration; testing needed, success not guaranteed.

REFLECTOR: DESIGN #2



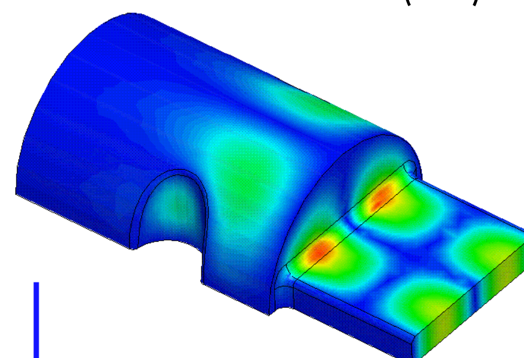
WR90 waveguide

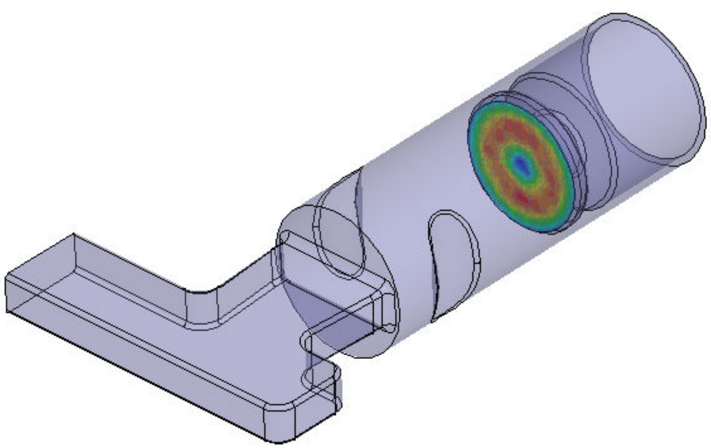
The field intensity will be uniformly distributed on the piston's surface

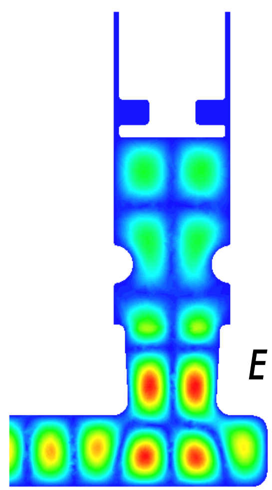


$TE_{10} \rightarrow TE_{20} \rightarrow TH_{01}$

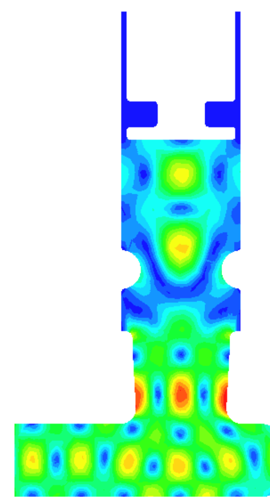
Original idea by S. Kazakov (KEK)





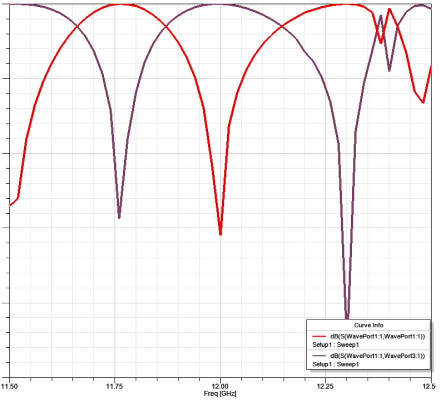


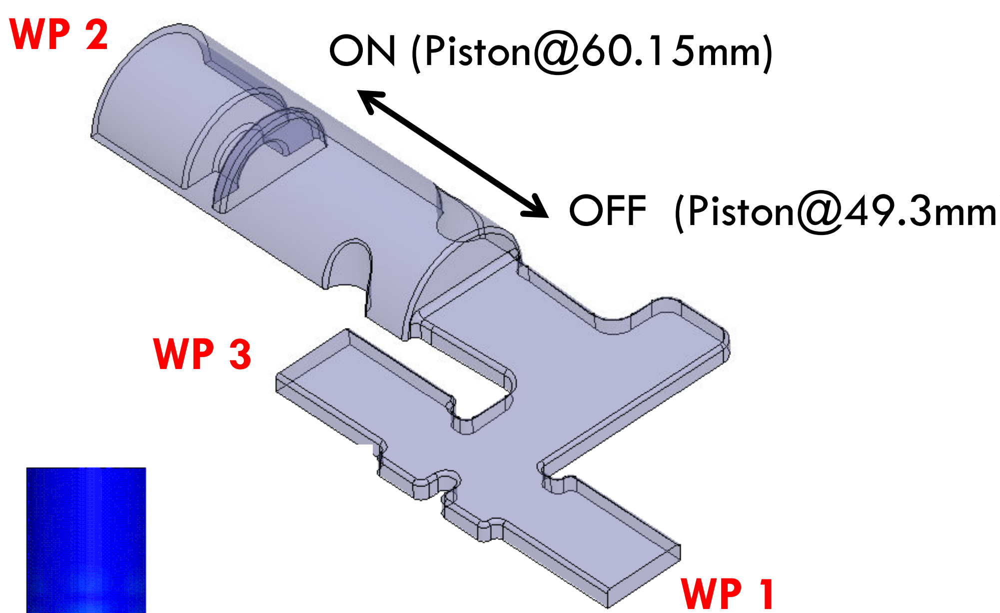
E field

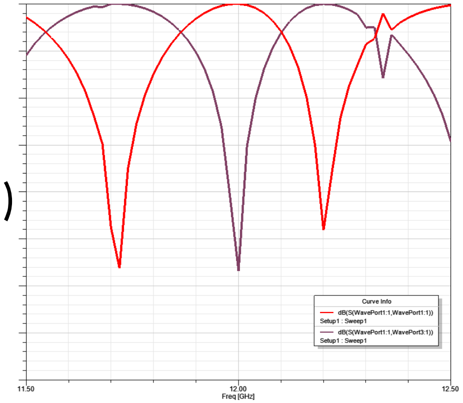


H field

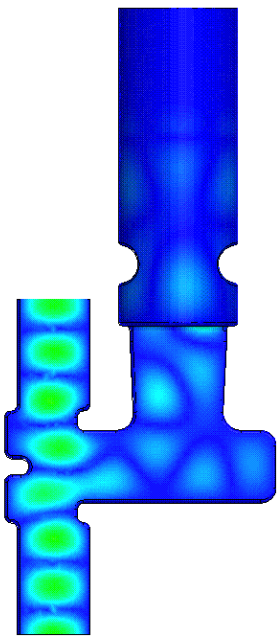
REFLECTOR: DESIGN #2





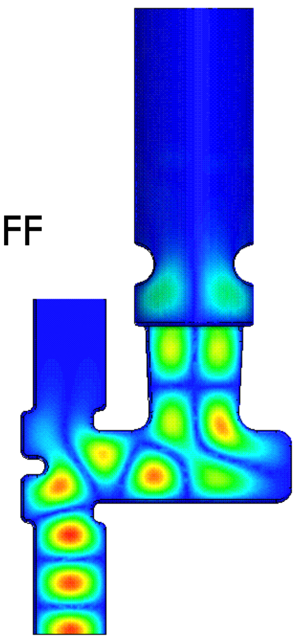


ON



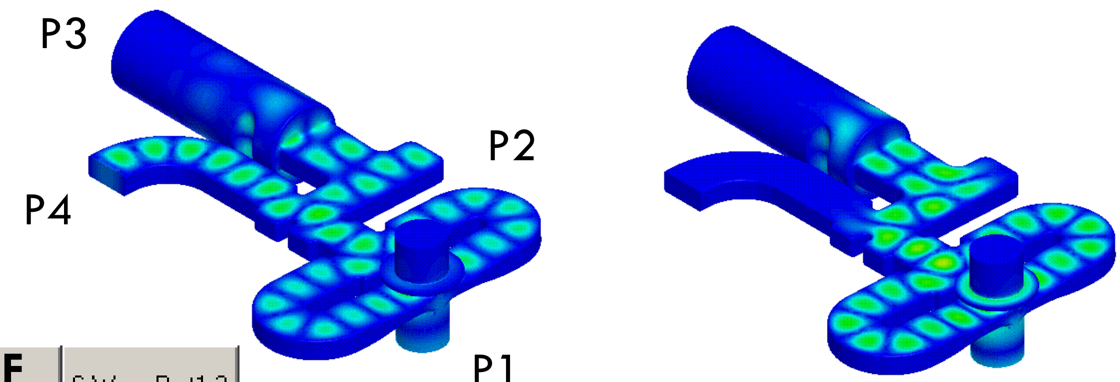
11.9942 [GHz]	WavePort1:1 -46.1
	WavePort2:1 -48.8
	WavePort2:2 -85.2
	WavePort2:3 -39.1
	WavePort2:4 -55.5
	WavePort3:1 -0.000712

OFF



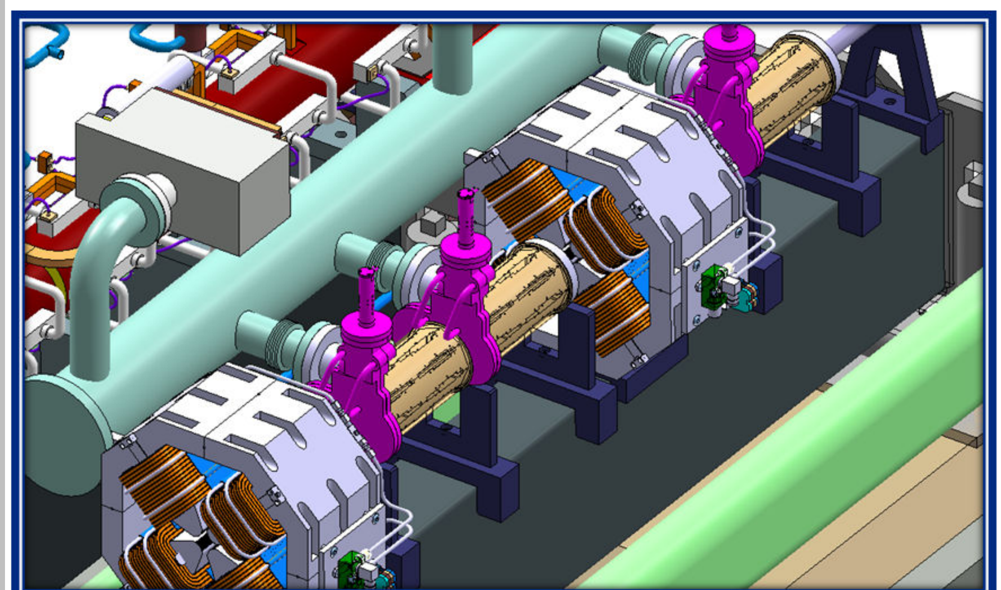
11.9942 [GHz]	WavePort1:1 -0.000528
	WavePort2:1 -43.1
	WavePort2:2 -74.7
	WavePort2:3 -58.6
	WavePort2:4 -41.6
	WavePort3:1 -60.6

THE INTEGRATED ON-OFF SYSTEM

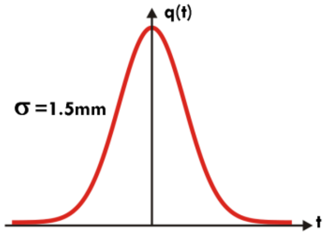


Freq	ON	S:WavePort1:3
11.9942 (GHz)	WavePort1:1	-35.2
	WavePort1:2	-65.9
	WavePort1:3	-41.3
	WavePort1:4	-39.8
	WavePort1:5	-55.7
	WavePort2:1	-58.6
	WavePort2:2	-35.7
	WavePort2:3	-39.2
	WavePort2:4	-31.9
	WavePort2:5	-47
	WavePort3:1	-70.9
	WavePort3:2	-85.6
	WavePort3:3	-48
	WavePort3:4	-85.2
	WavePort3:5	-91.5
	WavePort4:1	-0.00338

Freq	OFF	S:WavePort1:3
11.9942 (GHz)	WavePort1:1	-45.5
	WavePort1:2	-54.8
	WavePort1:3	-0.000898
	WavePort1:4	-37.7
	WavePort1:5	-54.4
	WavePort2:1	-61.5
	WavePort2:2	-48.3
	WavePort2:3	-44.9
	WavePort2:4	-46.6
	WavePort2:5	-41.6
	WavePort3:1	-108
	WavePort3:2	-56.1
	WavePort3:3	-42.5
	WavePort3:4	-72.3
	WavePort3:5	-102
	WavePort4:1	-41.6



THE PROCESSES MODELING



$$q(t) \longrightarrow \boxed{\text{System impulse response}} \longrightarrow A(t)$$

(Resulting from GDFIDL computations)

If A(t) is the single-bunch response, the multi-bunch response x(t) will simply be the sum of the N single responses, each being delayed by $t_0=\Delta_b/c$, where Δ_b is the bunch spacing [m]:

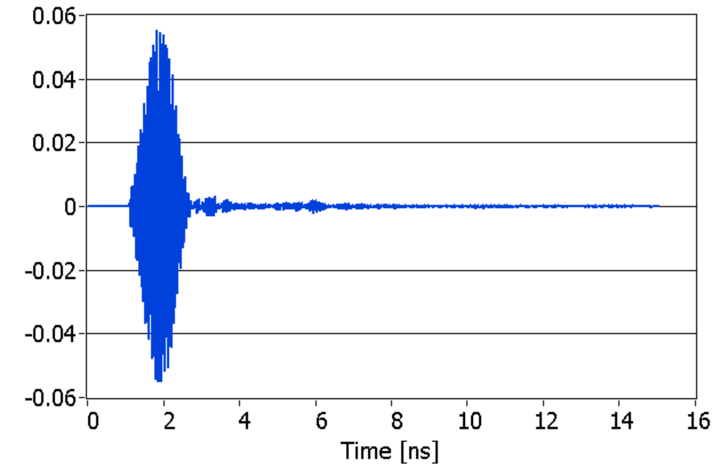
$$x(t) = A(t) + A(t-t_0) + \ldots + A(t-(N-1)t_0) = \sum_{k=0}^{N-1} A(t-kt_0)$$

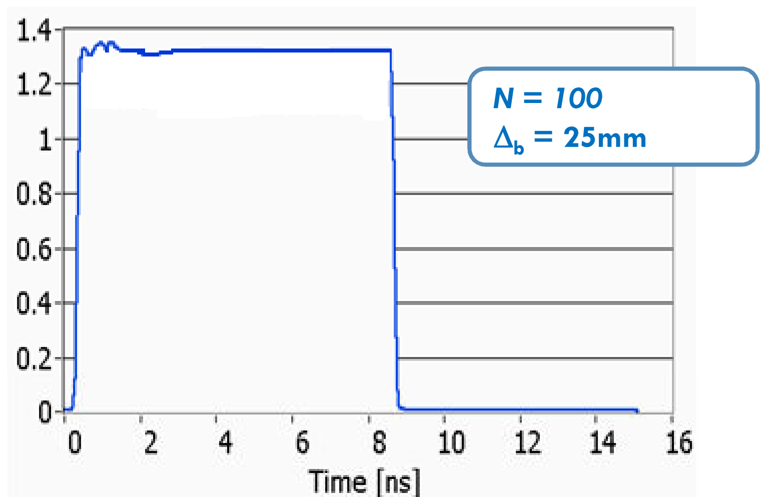
$$x(t) \xrightarrow{\Im} X(f) = A(f)\sum_{k=0}^{N-1} e^{-j2\pi fkt_0} = A(f)\frac{1-e^{-j2\pi fNt_0}}{1-e^{-j2\pi ft_0}}$$

$\Delta_b = c\, t_0$ *will be a tuning parameter.*

POST-PROCESSING RESULTS

"ON" case



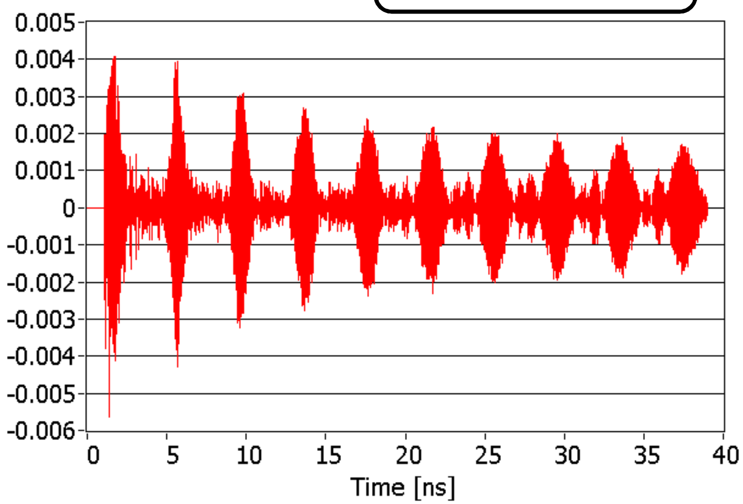


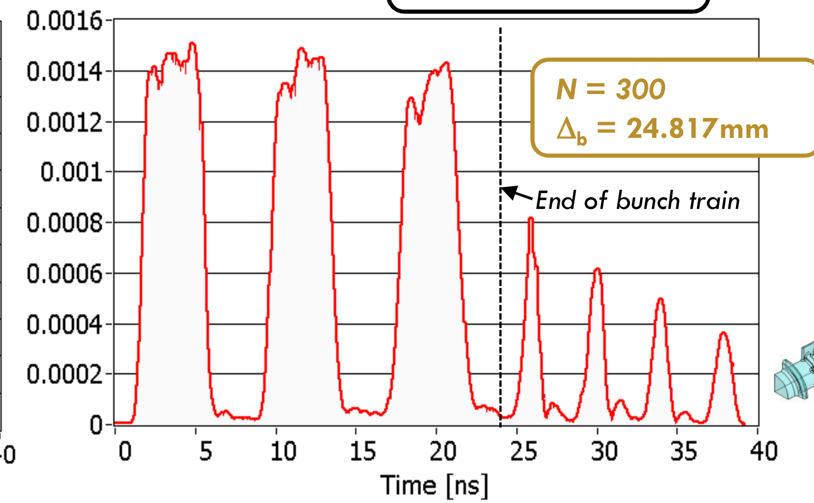
Power delivered to the structure

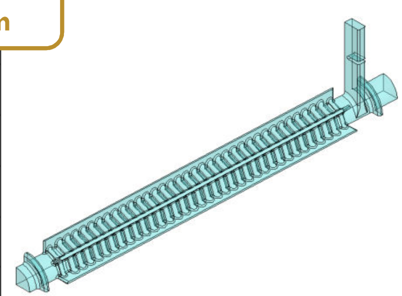
"OFF" case

Single-bunch responses (GDFIDL)

Multiple-bunch responses (post-proc.)

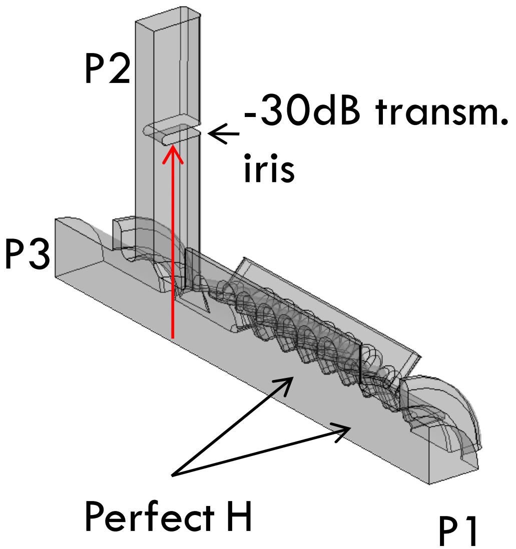


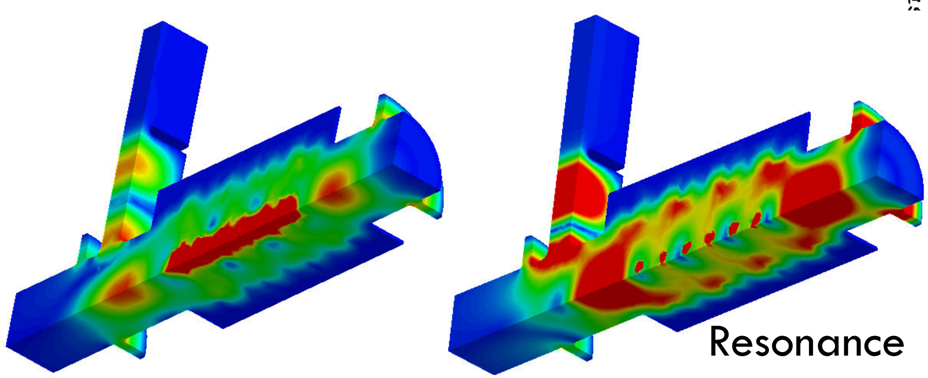


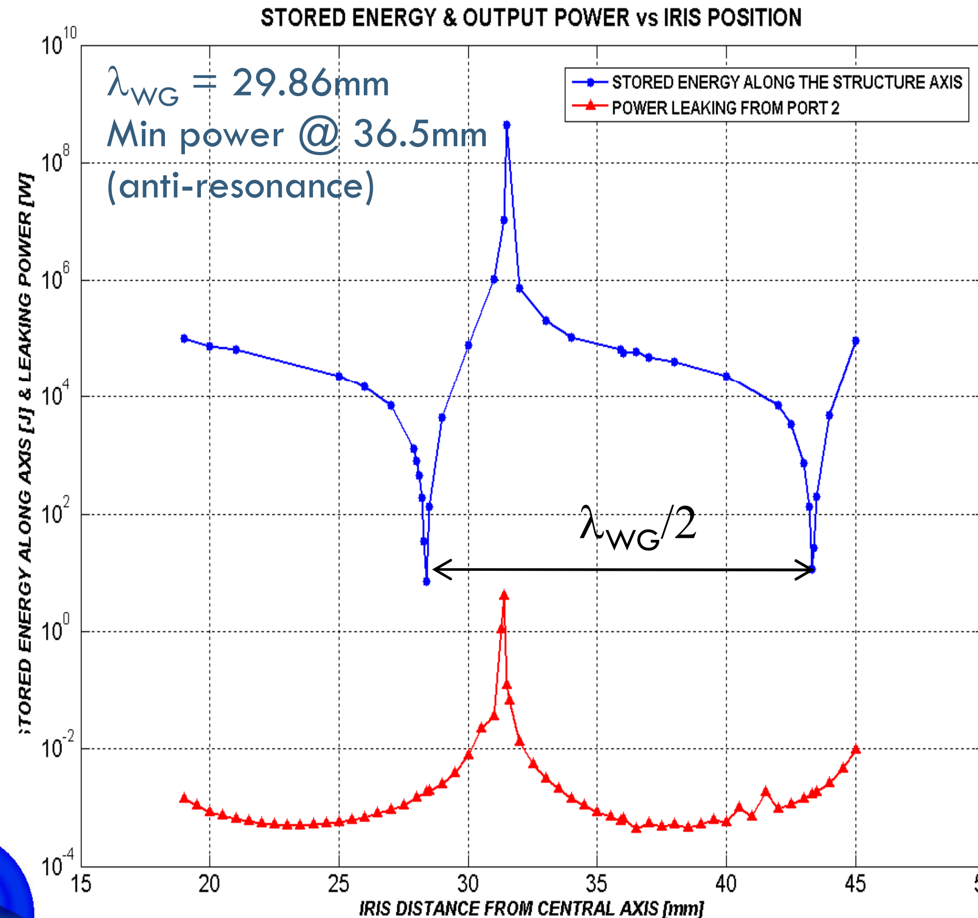


FOR TUNING PURPOSES…

The full geometry is too heavy for tuning the waveguide length to the 180° phase advance:



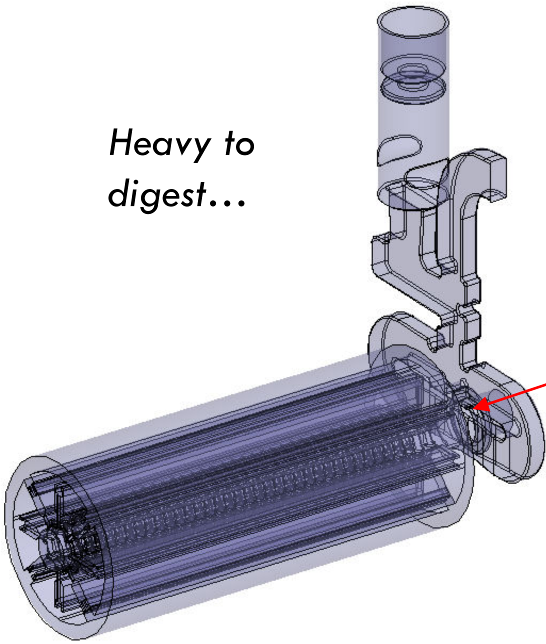




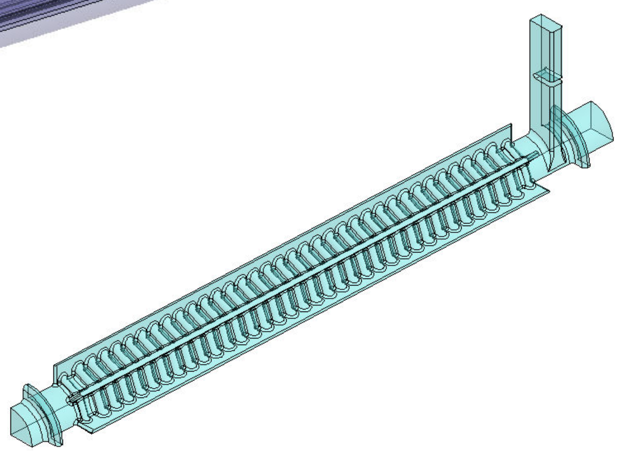
The min. output power is in correspondence with the point where d(Energy)/dt~0 ($P \propto dE/dt$).

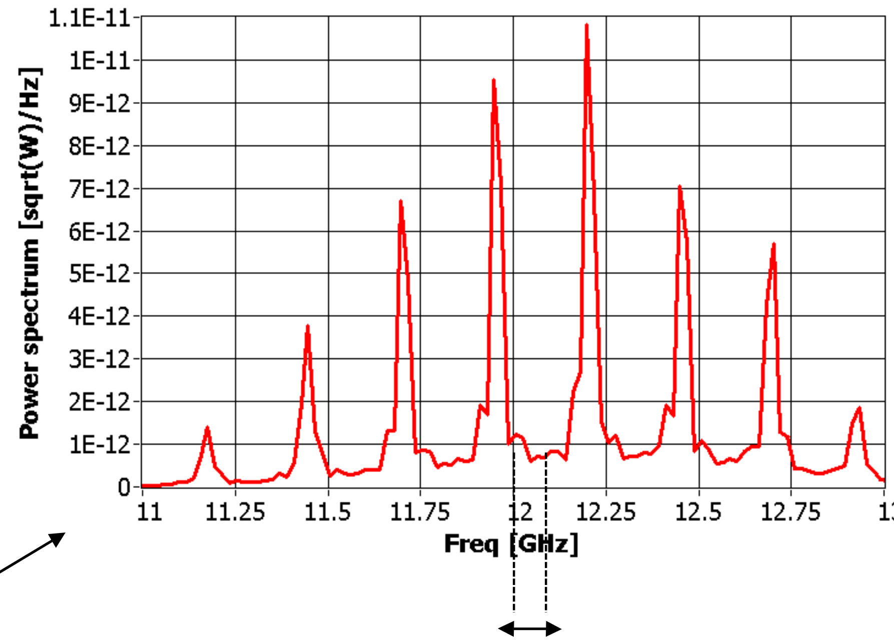
FULL GEOMETRY

Heavy to digest…



… tuning the waveguide for the OFF case is highly time/memory consuming





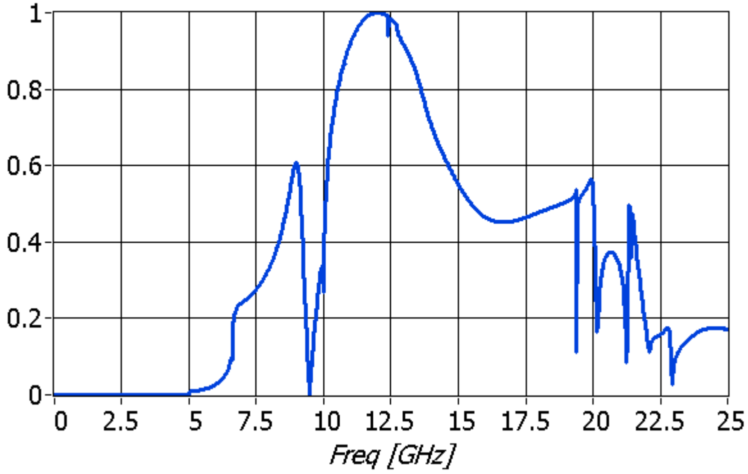
Computation error *(the tuning was done to be halfway between the peaks).*

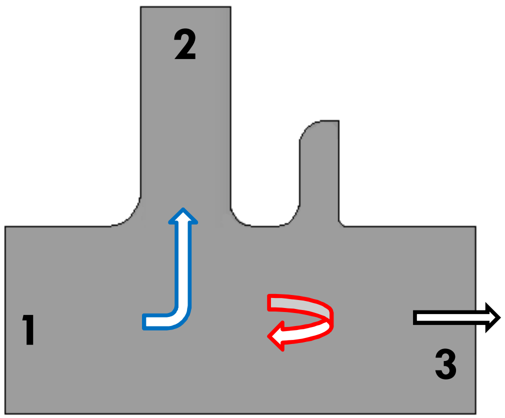
Tuning: a mathematical approach is advisable.

Intermediate piston position issues will have to be assessed.

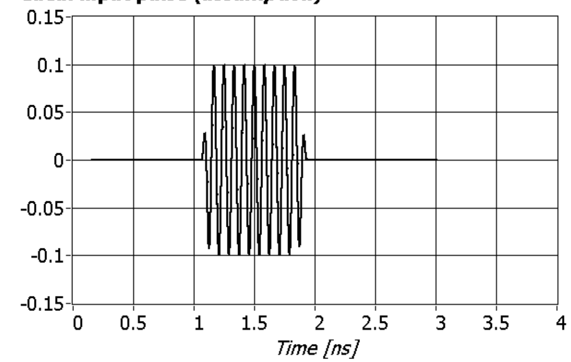
COUPLER: TRANSFER FUNCTIONS

Coupler: |S21|

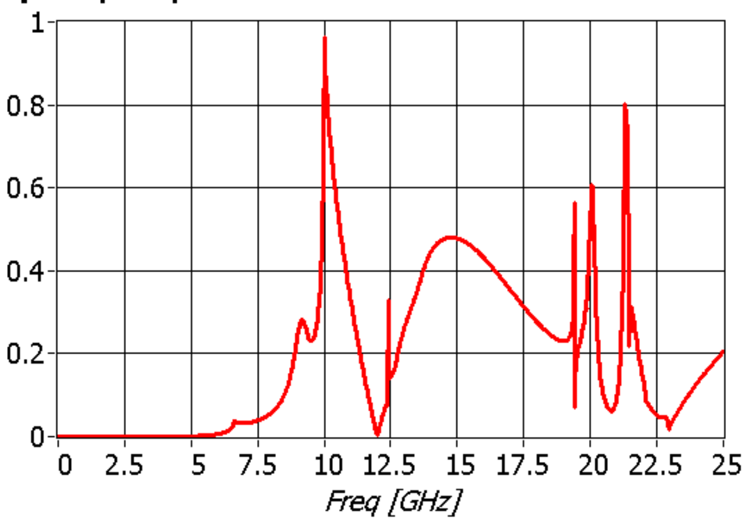




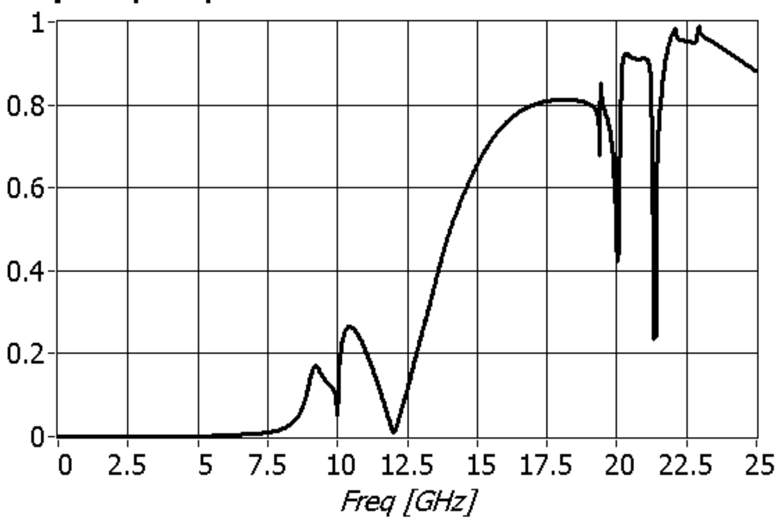
Ideal input pulse *(assumption)*



Coupler: |S11|

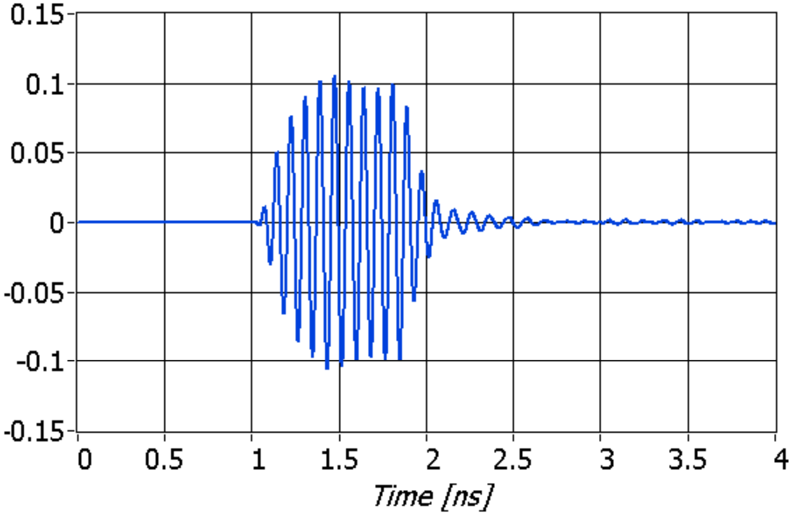


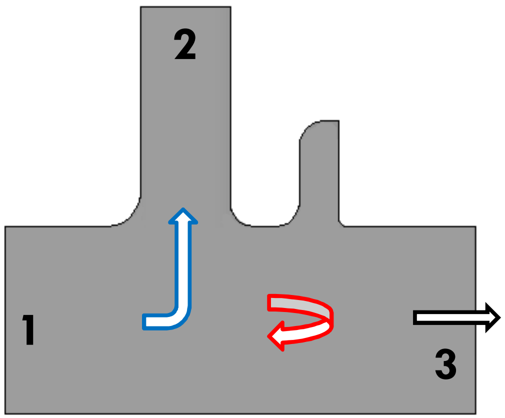
Coupler: |S31|



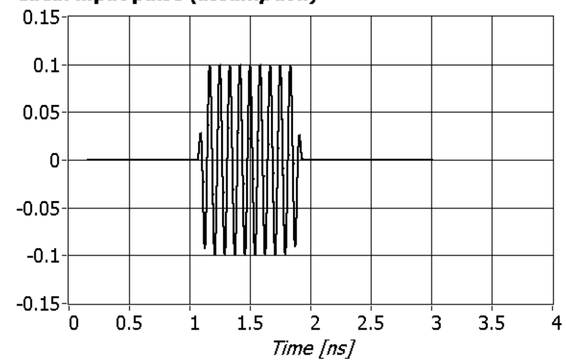
COUPLER: SIGNALS MODELING

Output at port 2

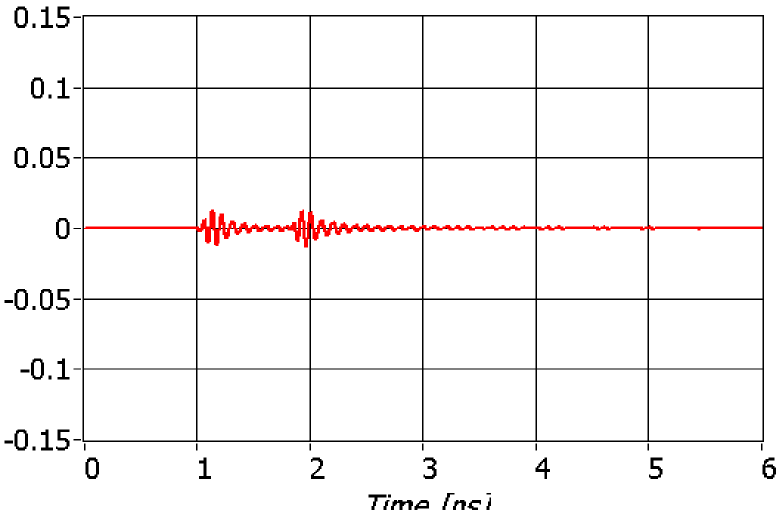




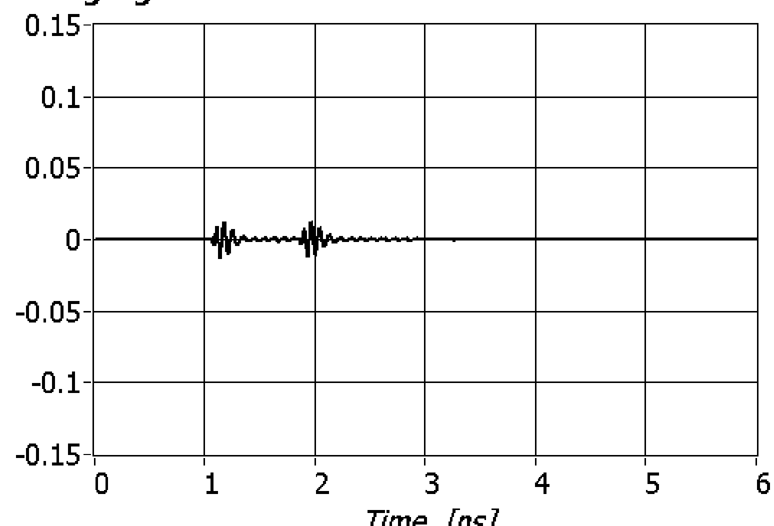
Ideal input pulse *(assumption)*



Reflected signal

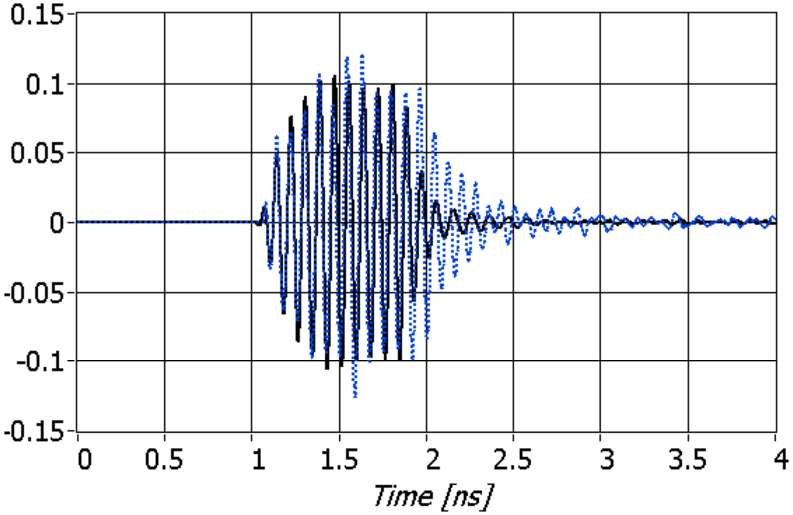


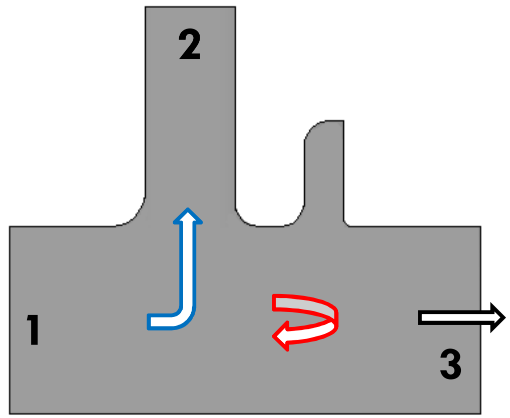
Leaking signal



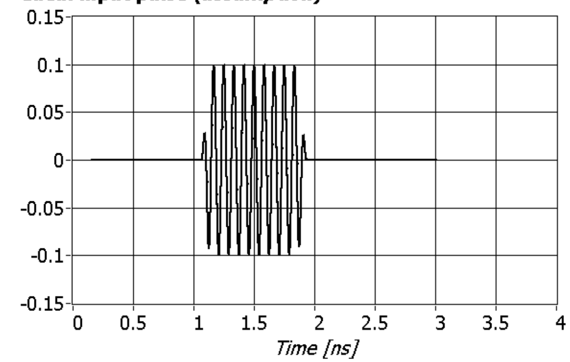
COUPLER: SIGNALS MODELING

Output comparison

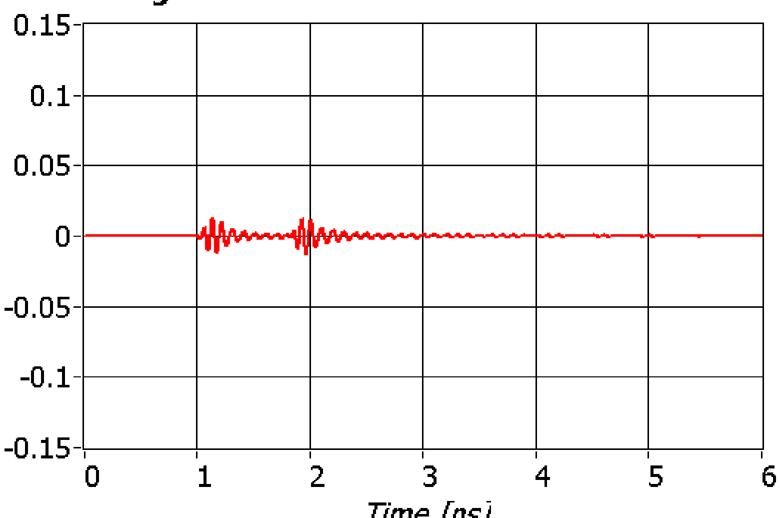




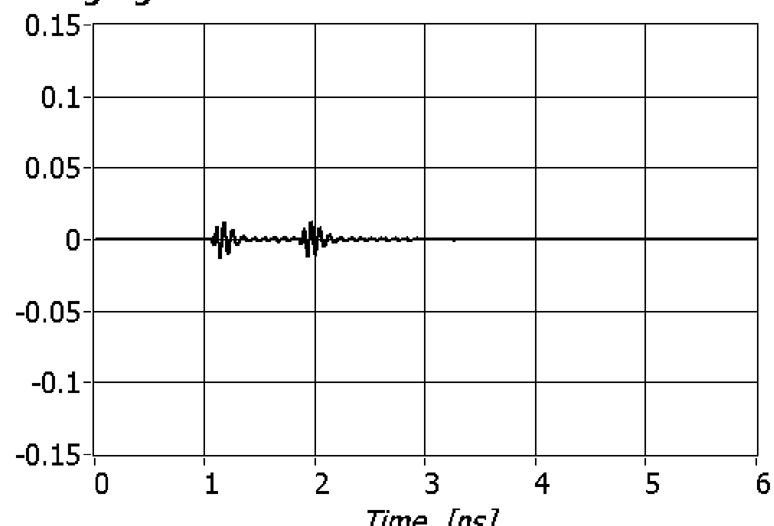
Ideal input pulse *(assumption)*



Reflected signal



Leaking signal

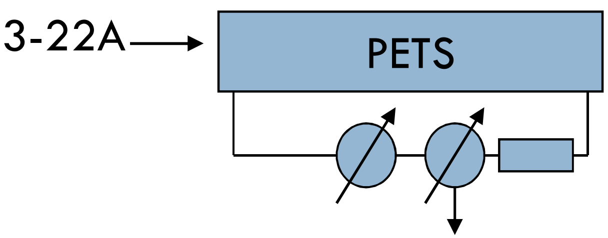


WHAT'S NEXT?

The ON/OFF feasibility demonstration (2009?-2010)

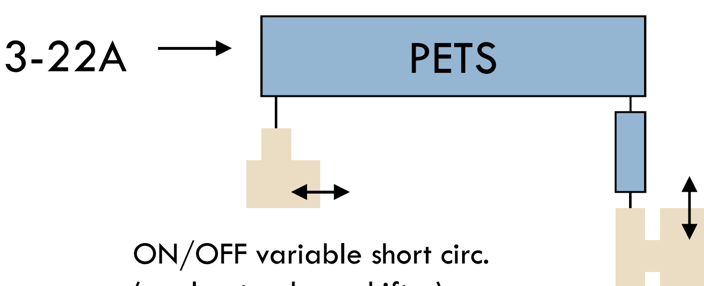
TBTS:

- PETS current configuration (recirculation)



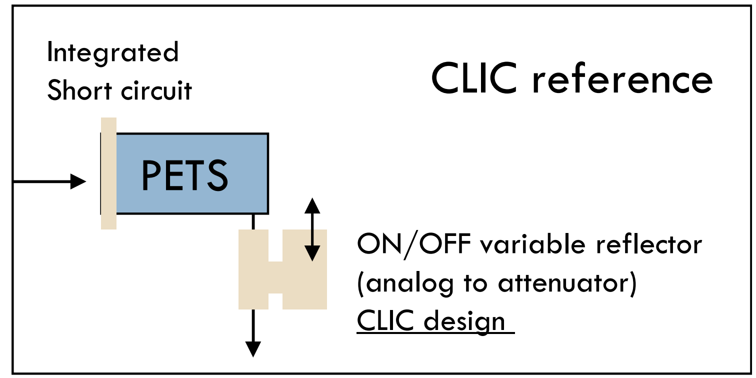
End 2009

- PETS RF network modification (internal recirculation – ON/OFF option)



ON/OFF variable short circ.
(analog to phase shifter)
CLIC design

ON/OFF variable reflector
(analog to attenuator)
CLIC design



- The PETS program with external recirculation will be completed in 2 month (or so). By then, the external recirculation can be replaced with the internal as shown. This configuration is practically identical to the ON/OFF configuration in the CLIC PETS.
-The full ON/OFF feasibility demonstration will require full (22.8 A) current.
- The standard (slow) linear actuators will be used at this stage because the hardware is already developed.
- Short circuit and reflector were sent on for the mechanical drawings.

This program will completely cover ON/OFF feasibility demonstration in the shortest possible time.