The CLIC Experience

- A little bit of history,
- present experimental and theoretical efforts,
- some results,
- no conclusions.

The central challenge so far for our high gradient work has been finding 30 GHz power.

Walter Wuensch
Structure Breakdown Workshop
SLAC, 28 August 2000

Paper on pulsed surface heating, 1987.

First constant impedance prototype accelerating structure completed, 8.2 % v_g, 86 cells, no power source available, 1991.

Test at KEK, X-band, 22 cells, 1.1 % v_g, 100-200 ns, peak accelerating gradient 138 MV/m (126 MeV/m average) power source limited, KEK structure, same cell geometry, 68 MV/m average, 1993.

Test at MIT, 33 GHz, 26 cells, scaled CLIC constant impedance structure, 20 ns, Pulse shortening at 65 MeV/m, FEL, difficult experimental conditions, 1 shot per 2-3 minutes, now suspect poor vacuum, 1993-4.

Test at SLAC, X-band, 26 cells, 1.1 v_g, 100-200 ns, peak accelerating gradient 154 MV/m (125 MeV/m average) limit unclear, visual inspection in 1998, test done in 1994.

Tests at CTFI, 95 MV/m acceleration, 125 MV/m deceleration, few ns pulses, no activity observed on RF signals, conditioning defined by performance of CTF, 1994-5.

All these structures were made using optical quality diamond machined parts, assembled under normal laboratory conditions, and joined in a vacuum furnace using our standard hybrid diffusion bonding/brazing technique (silver alloy).

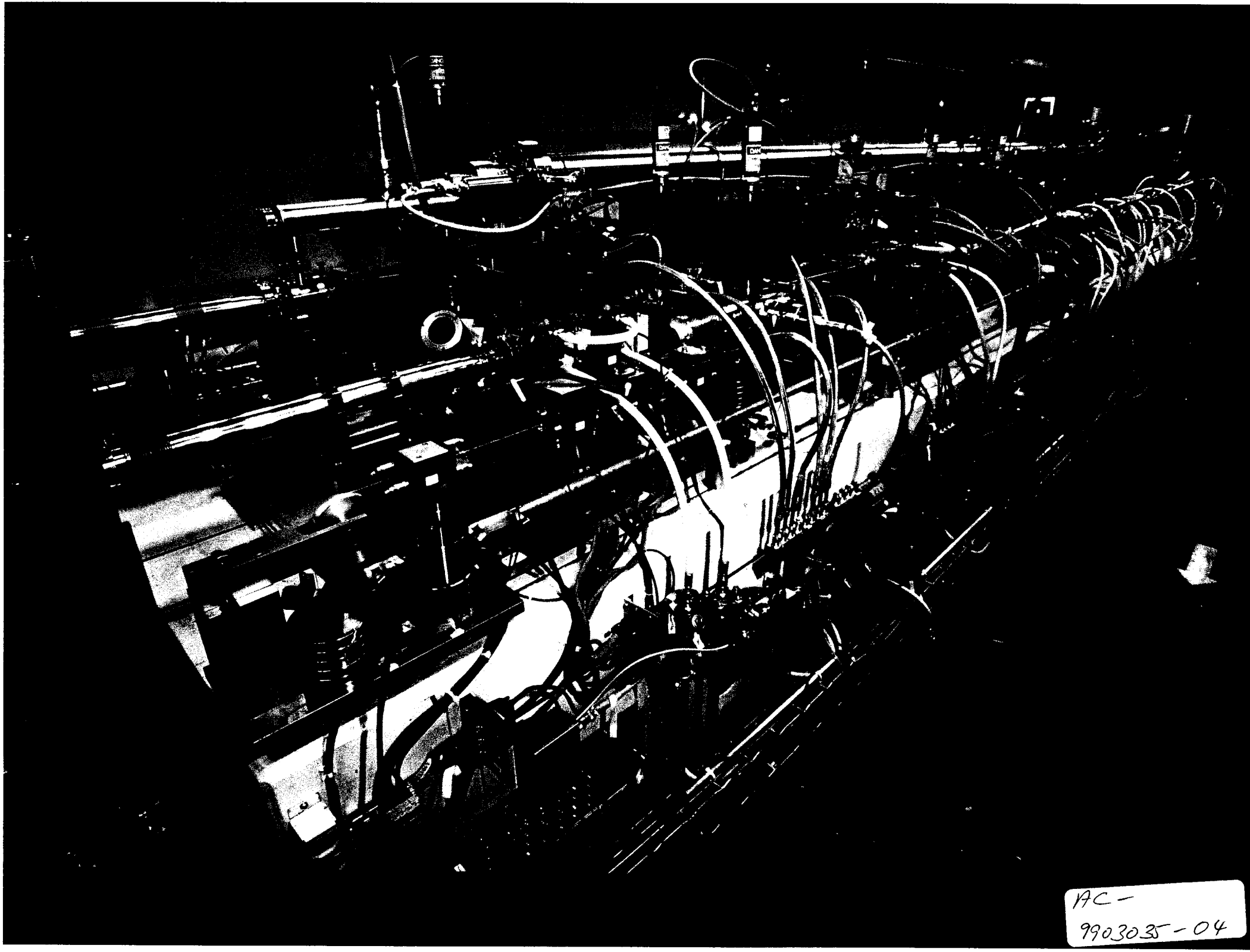
What we are trying to do now - experimentally,

All testing is done in CTFII. About 100 MW are available, 16 ns pulse length.

Develop appropriate on-line diagnostics: RF, wall current monitors, vacuum readouts, X-rays, light, etc. **Improve vacuum.** (This is not trivial at 30 GHz.) + existing modules. More pumping + Develop bake-out capability, glow discharge, etc.
Test existing prototypes, which are all single feed constant impedance sections, single cell cavities and eventually a series of short structures with special characteristics (symmetrical couplers, low v_g, include damping features, etc.).

Try to establish a conditioning procedure/strategy. Monitor appearance of damage. Find ultimate performance. Relate performances with short pulses in test structures to realistic gradients in CLIC. Etc.

Search for better power sources - 150 ns! Develop 'Test Stand' for CTF3.



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What we are trying to do now theoretically,

We are also fighting against excessive pulsed surface heating, a low Q in the TDS (poor estimation of Q from MAFIA), a high peak surface electric field and a high average power dissipation.

All of these difficulties are eased, and waveguide damping is improved, for lower v_g's. We now hear this may also improve damage from breakdown…

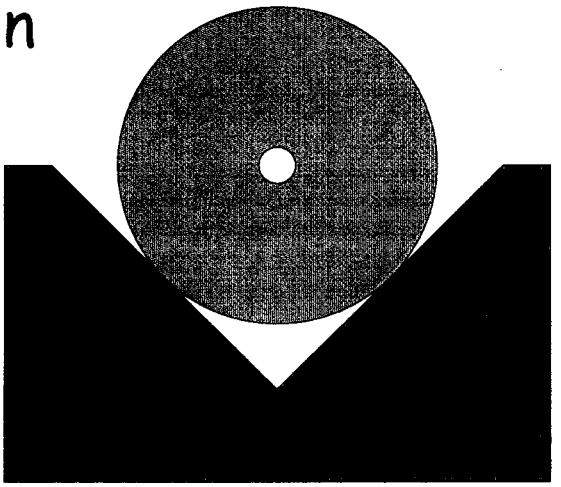
Re-optimize TDS.

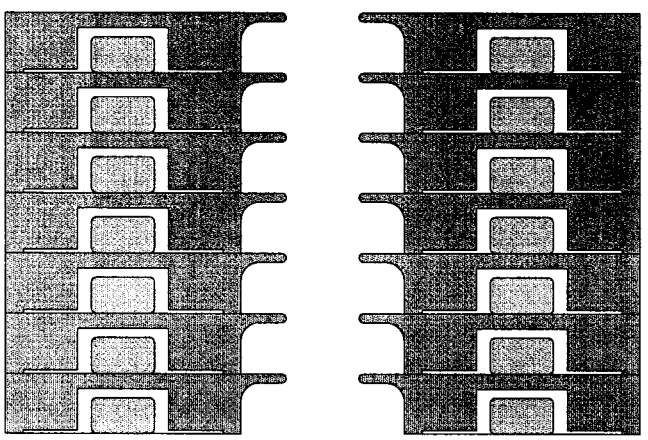
Reactivate study of slotted iris structures. We feel we have resolved a number basic problems. Much better for pulsed surface heating. 3 GHz version is now under study for the drive beam accelerator.

Investigate how to obtain lower vg, without exaggerating on the short-range transverse wake.

The CLIC braze/diffusion bond joint

Assembly in precision granite V-block

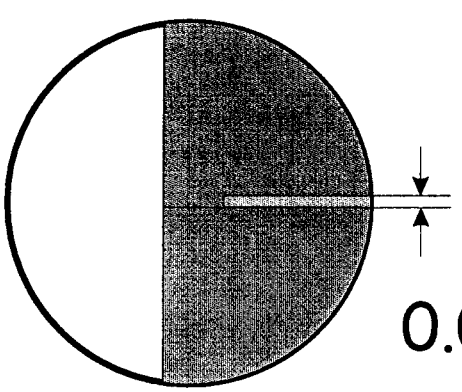




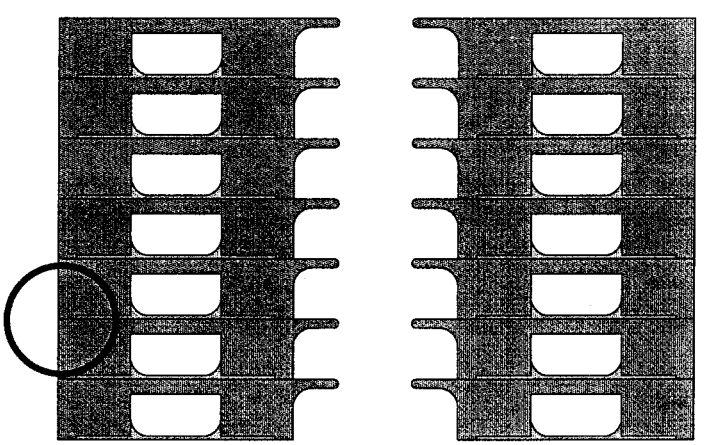
Vertical in brazing oven

Diamond machined on Diamond machined surface

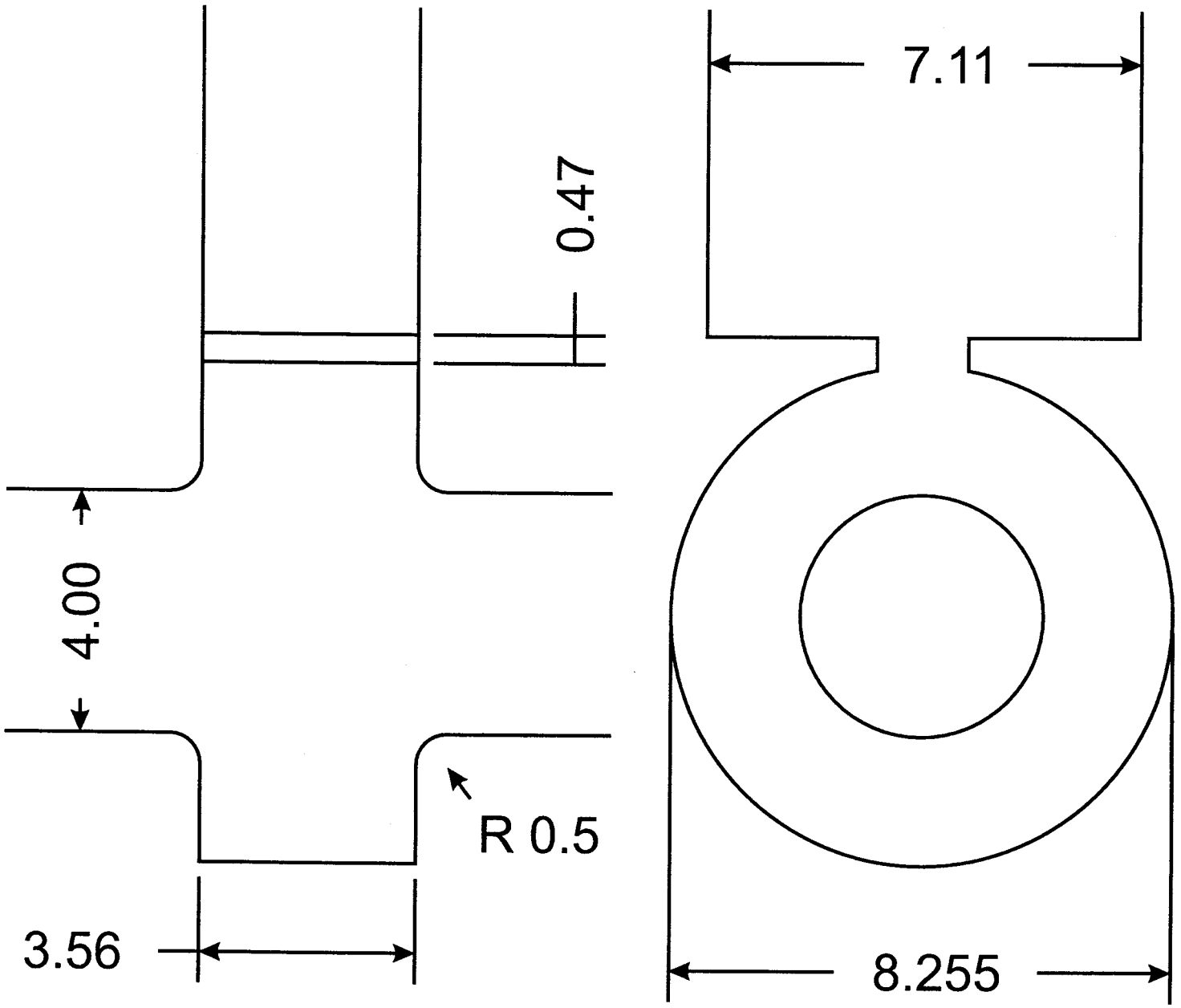
Braze/diffusion bond

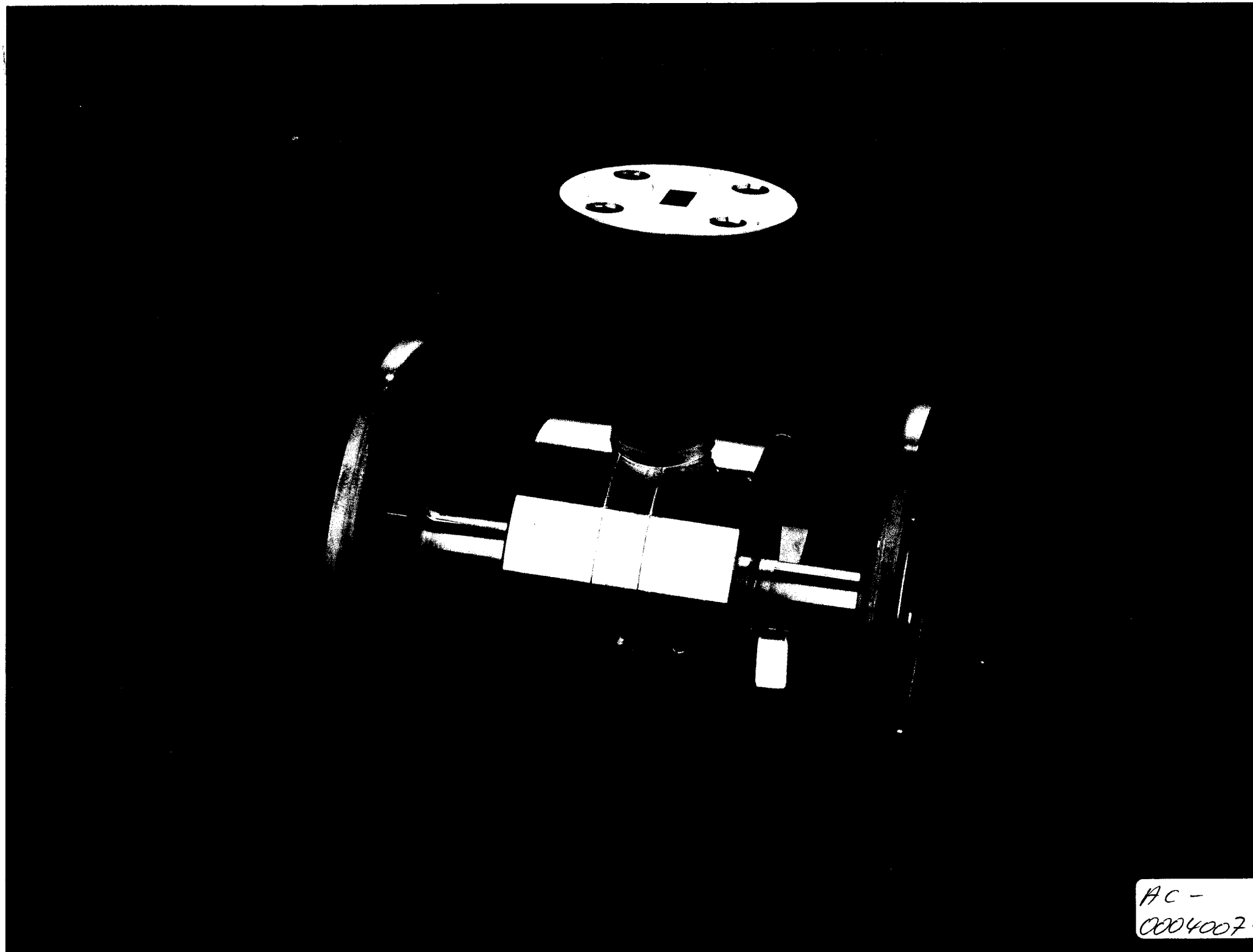


0.03 mm

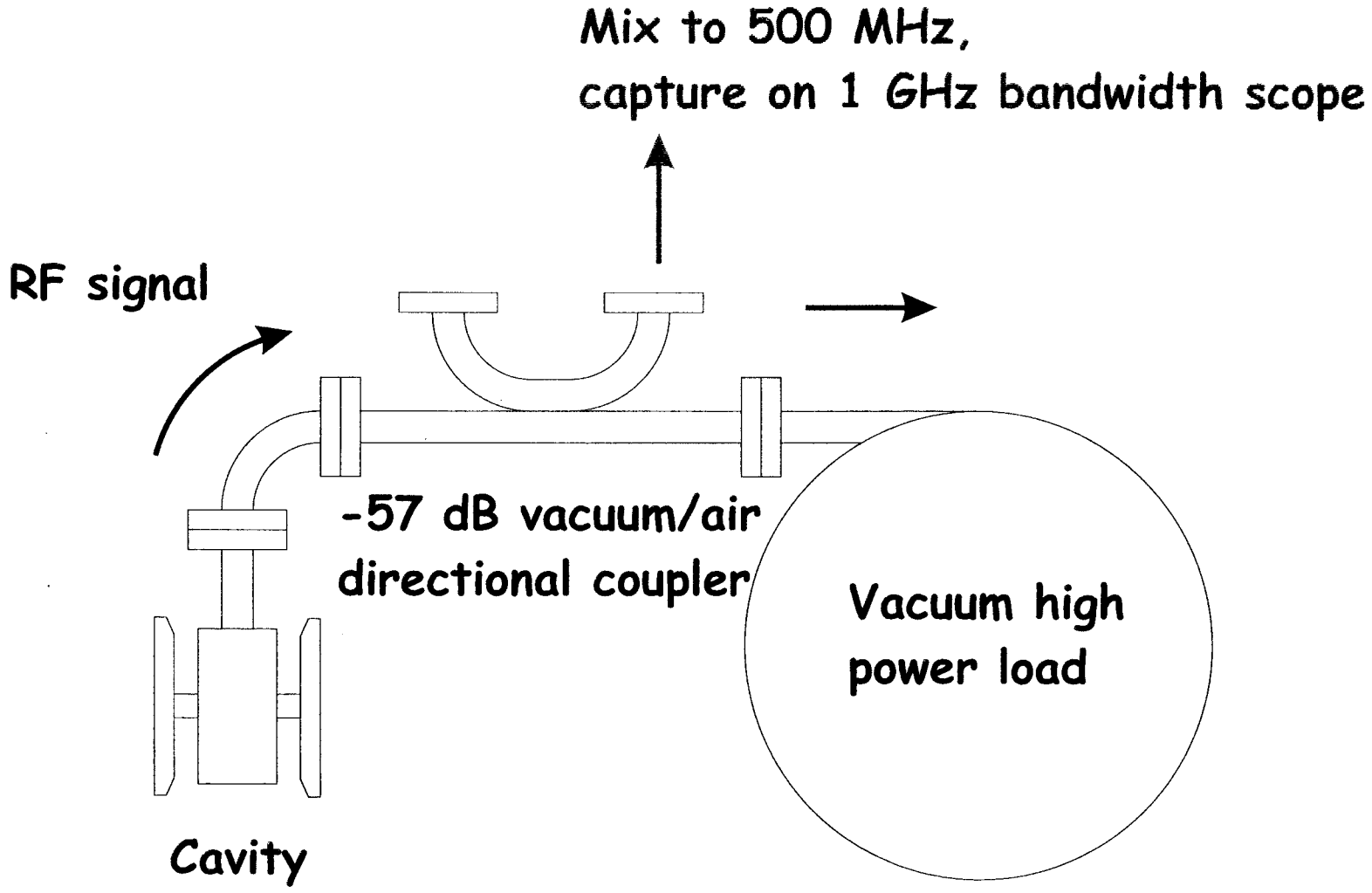


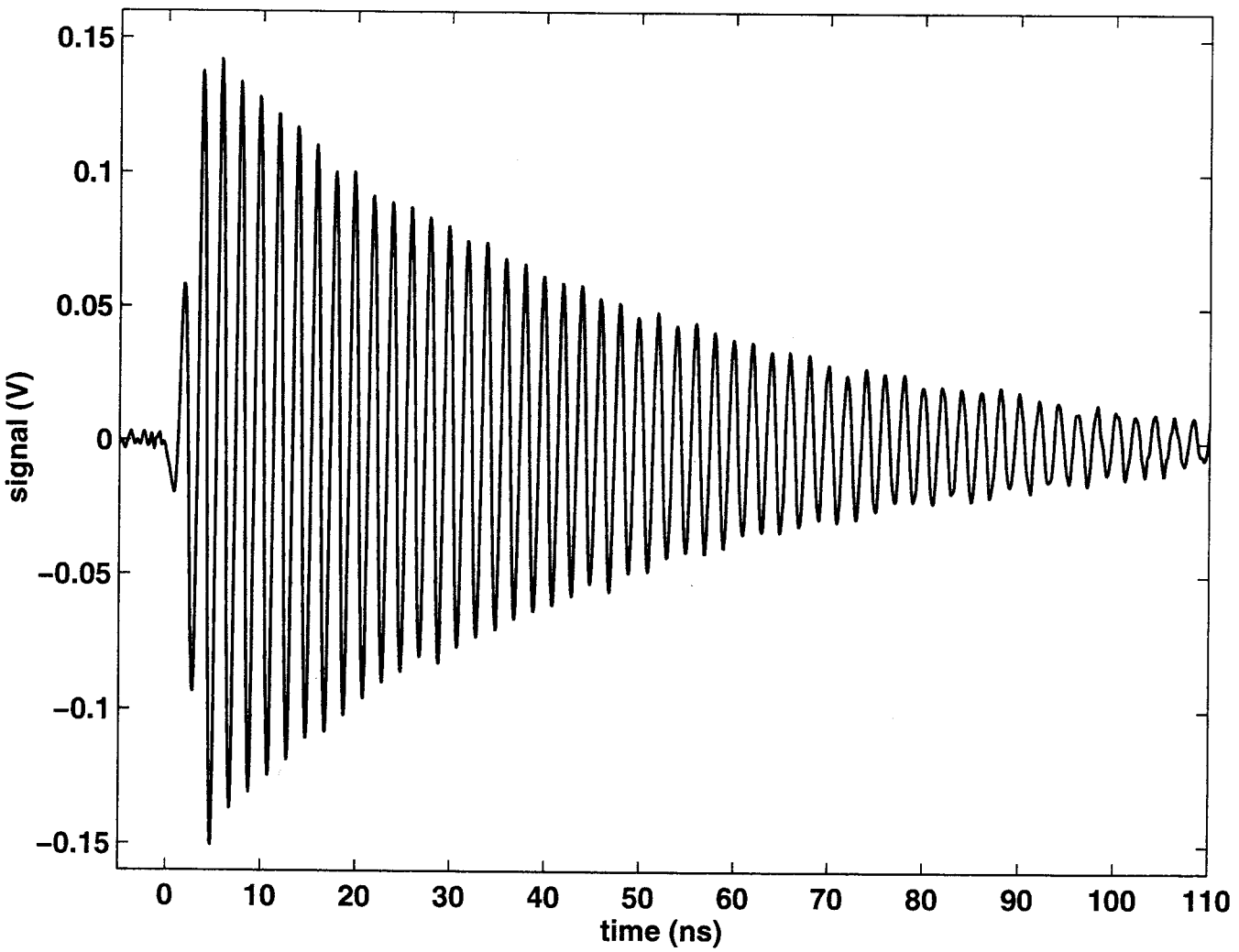
High-gradient cell geometry





RF plumbing


Mix to 500 MHz,
capture on 1 GHz bandwidth scope
RF signal
-57 dB vacuum/air
directional coupler
Vacuum high
power load
Cavity


0.15
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0
−0.05
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−0.15
signal (V)
0
10
20
30
40
50
60
70
80
90
100
110
time (ns)

Summary of behavior

Onset of breakdown: 290 MV/m accelerating gradient (530 MV/m surface field).

Breakdown on every pulse: 320 MV/m accelerating gradient (575 MV/m surface field).

Breakdown immediately after maximum field level: 480 MV/m accelerating gradient (750 MV/m surface field).

Breakdowns occur at field levels well ***below*** the pulse maximum.

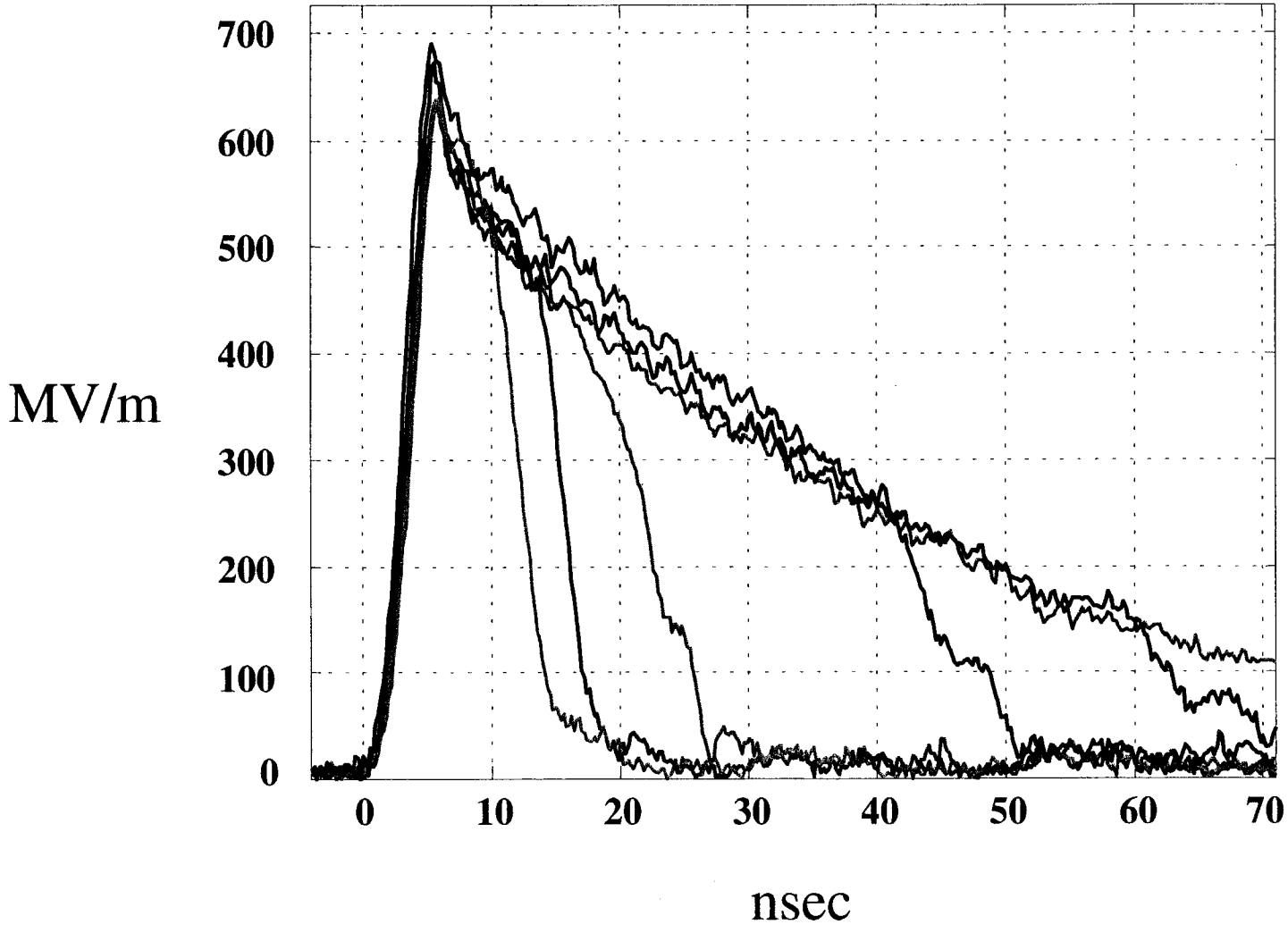
Resonant frequency goes ***up*** during breakdown.

No **conditioning** observed *.

No **damage** observed *.

* very little run time was available, corresponding to only about 10^4 shots. Still we pushed the structure **very** hard…

Peak surface field

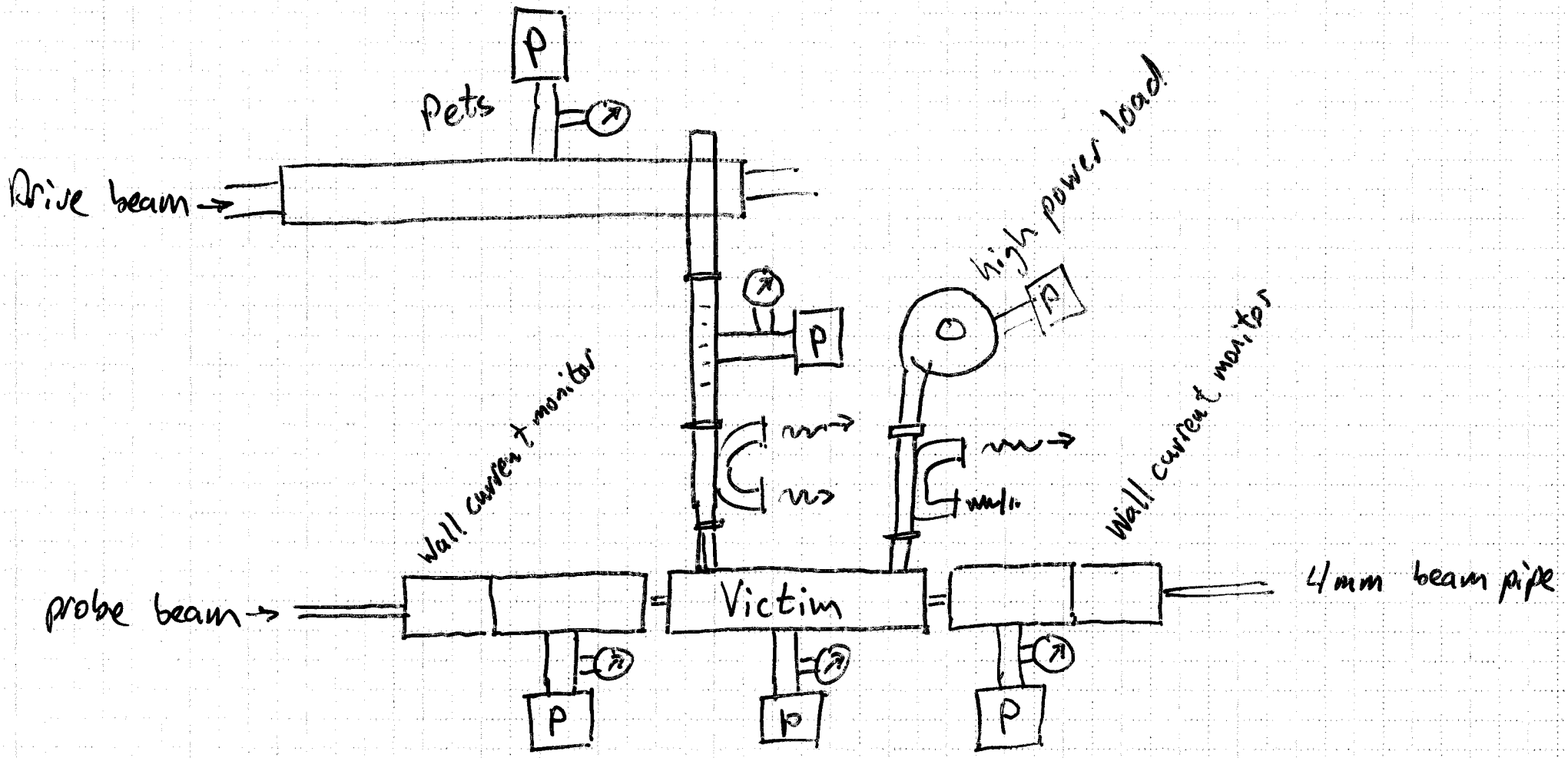


Interpretation

Very high field levels can be achieved and held for many tens of ns.

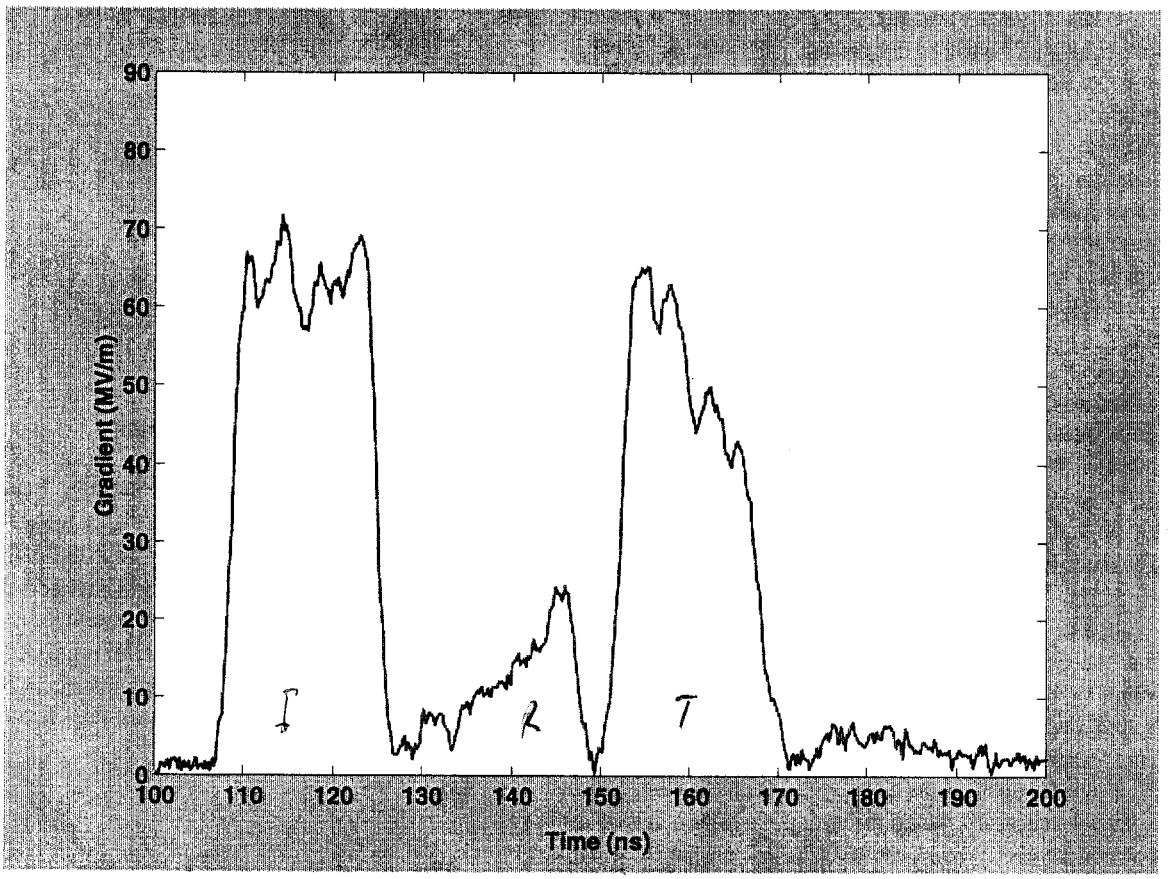
Breakdown well after pulse maximum $\Rightarrow$ is breakdown due to heating?

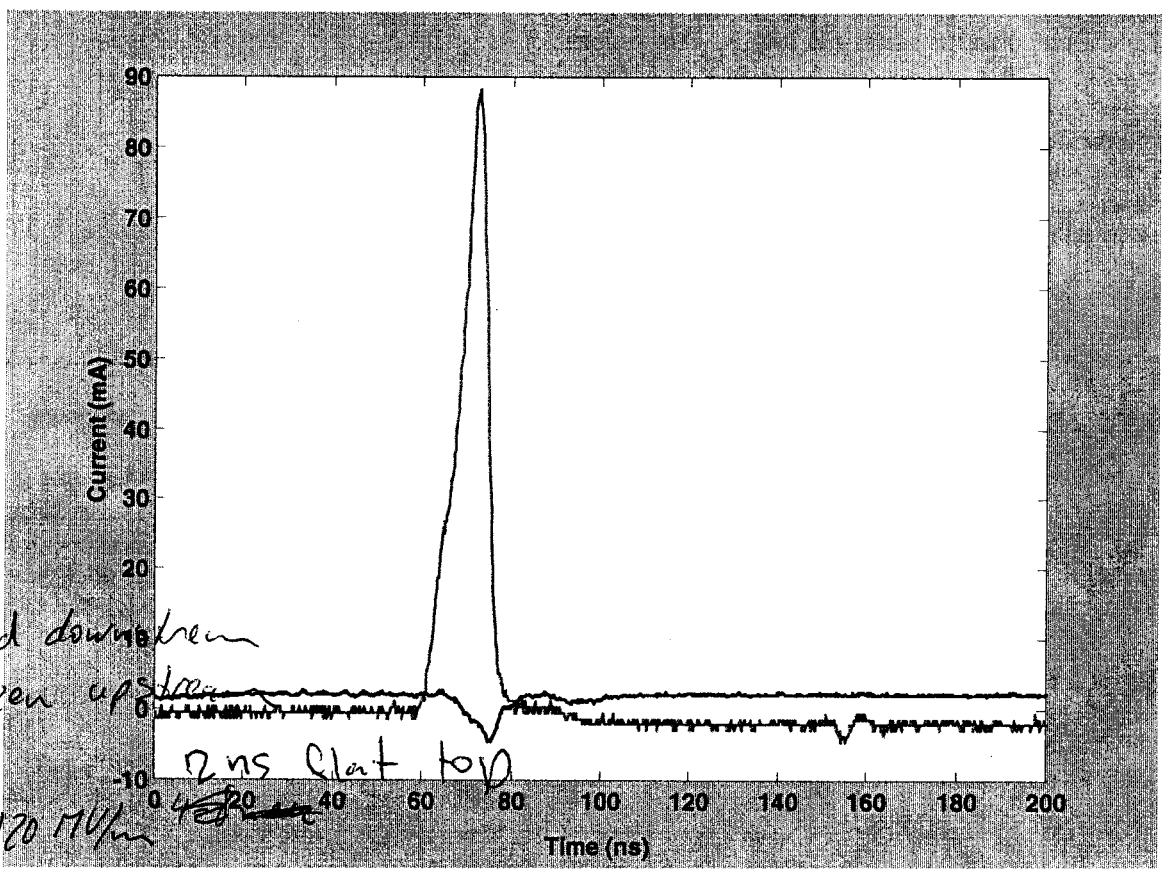
Neither conditioning nor damage $\Leftarrow$ stored energy in the cavity is very small (10^{-3} J for 100 MV/m) and there is no power flow $\Rightarrow$ test very far from real accelerator conditions.



Existing CTF II set-up

Typical signals





Onset 120 MV/m

This is a replacement for the missing transparency.)

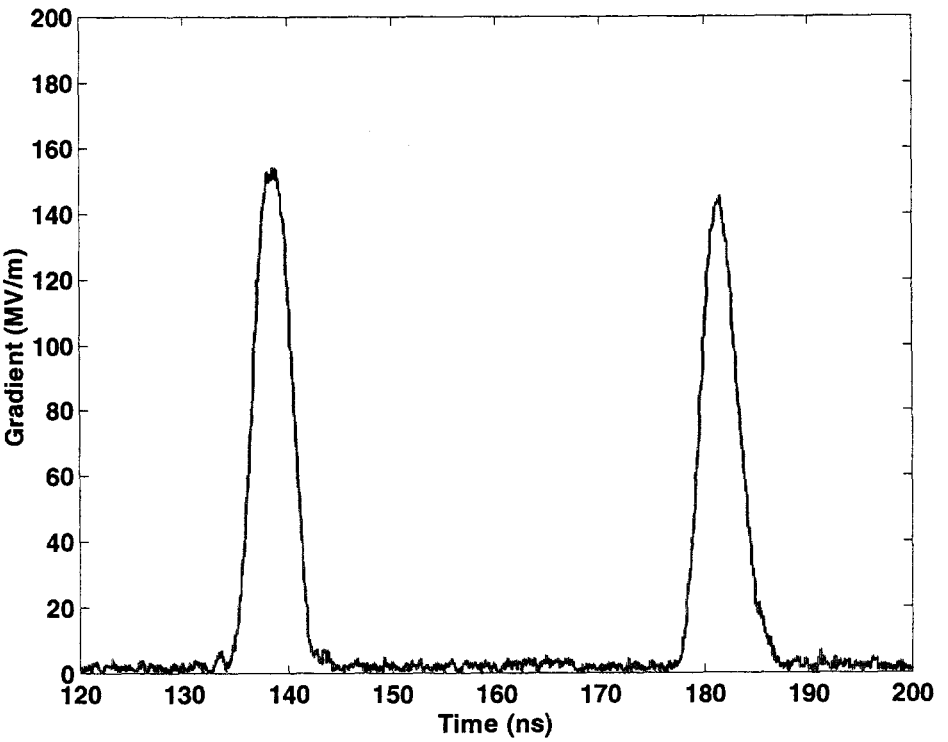
"Breakdown currents

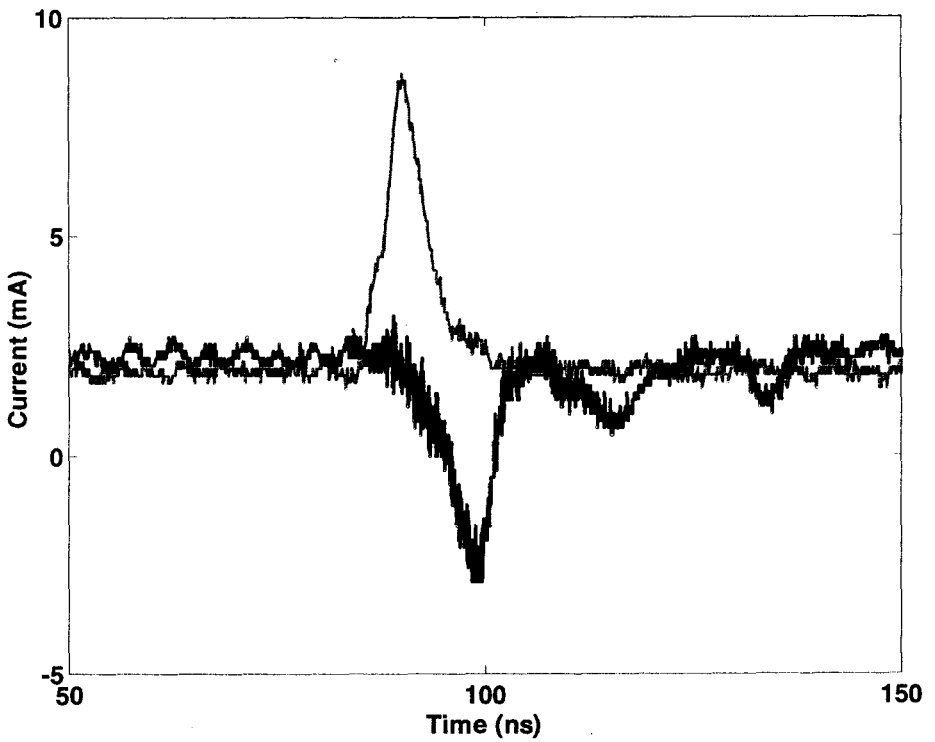
- but -

nothing on the RF signal."

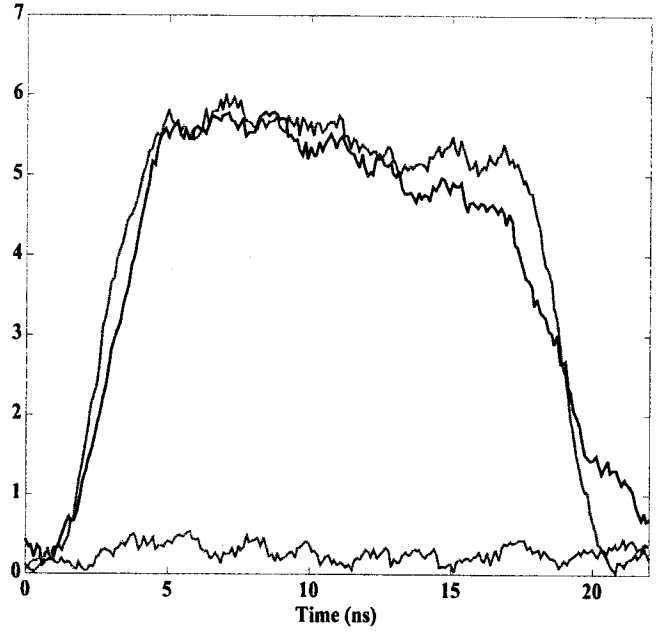
Breakdown currents are now used as the signal that controls the conditioning process.

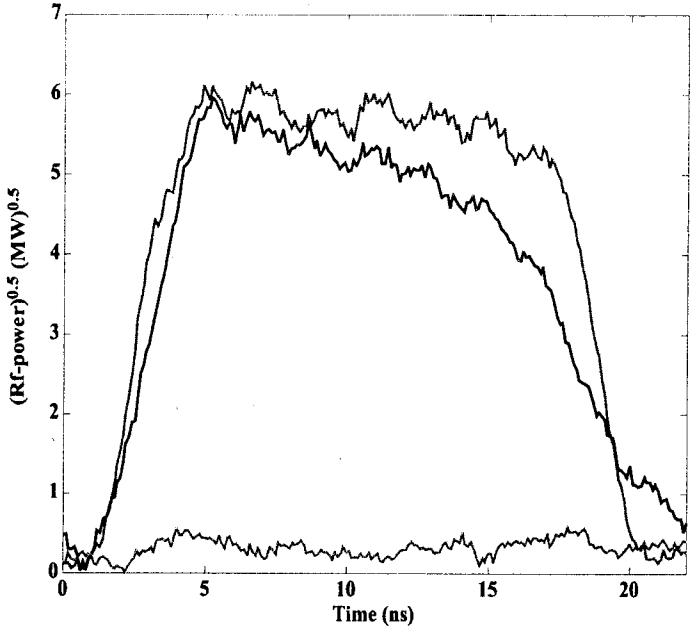
Observation of dark currents in the CTF II 30 GHz accelerating structure

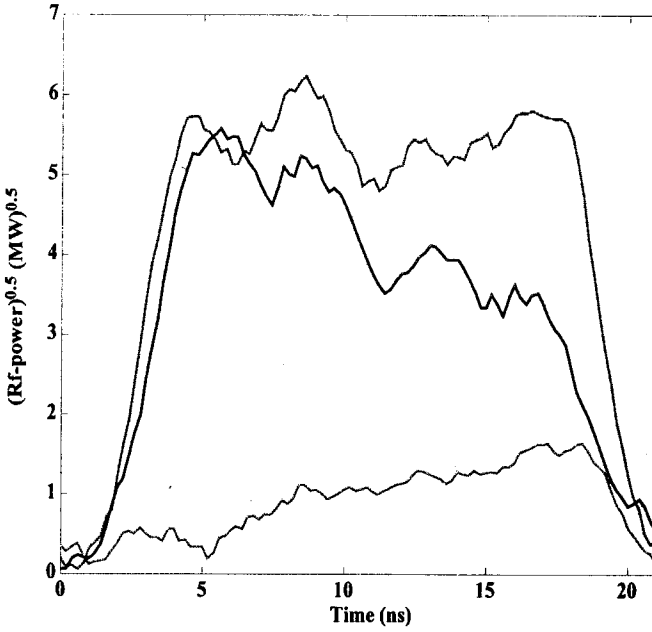




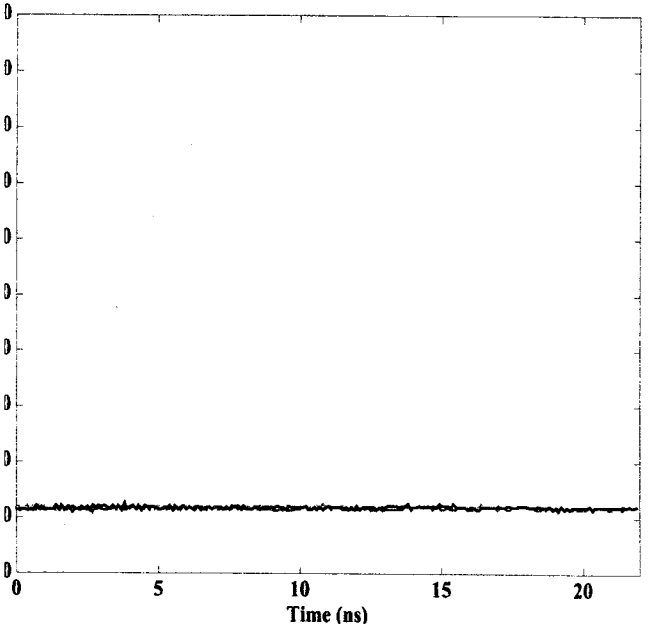
RF power (incident, transmitted, reflected)

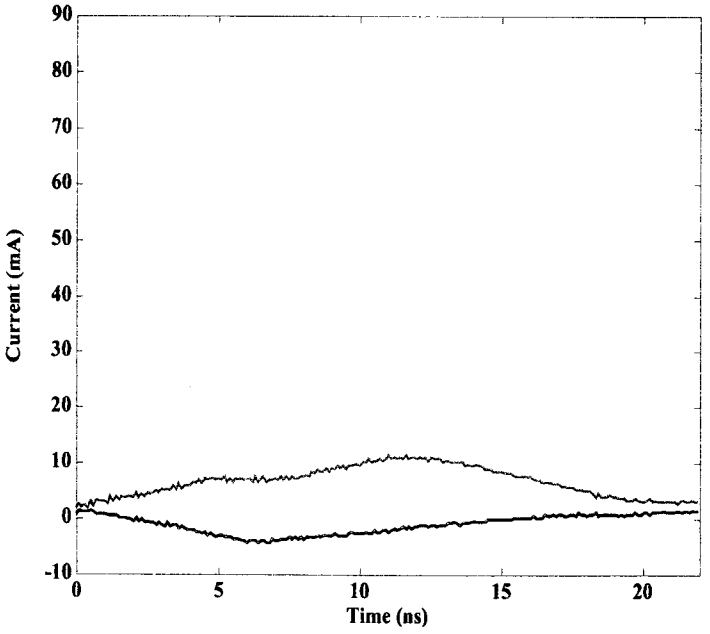


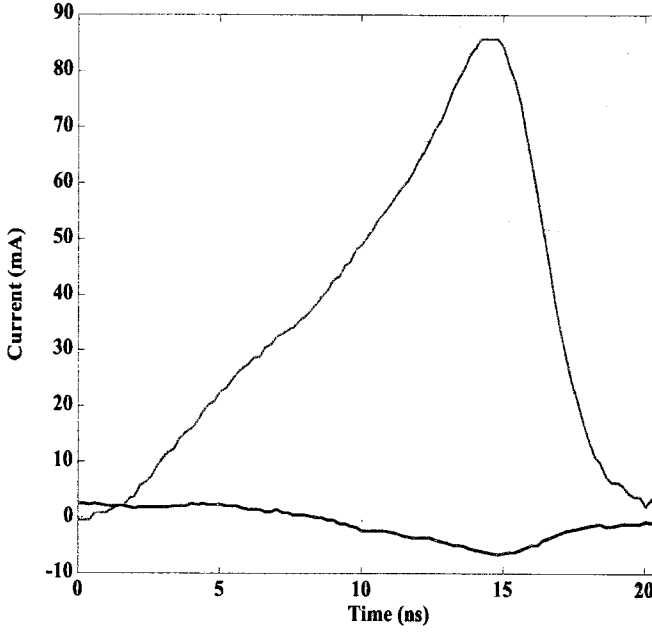




current emission (downstream of structure, upstream of structure)

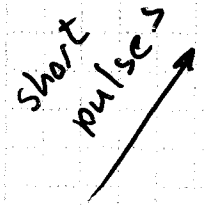






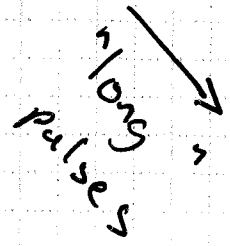
Breakdown behaviour

dark currents



nothing

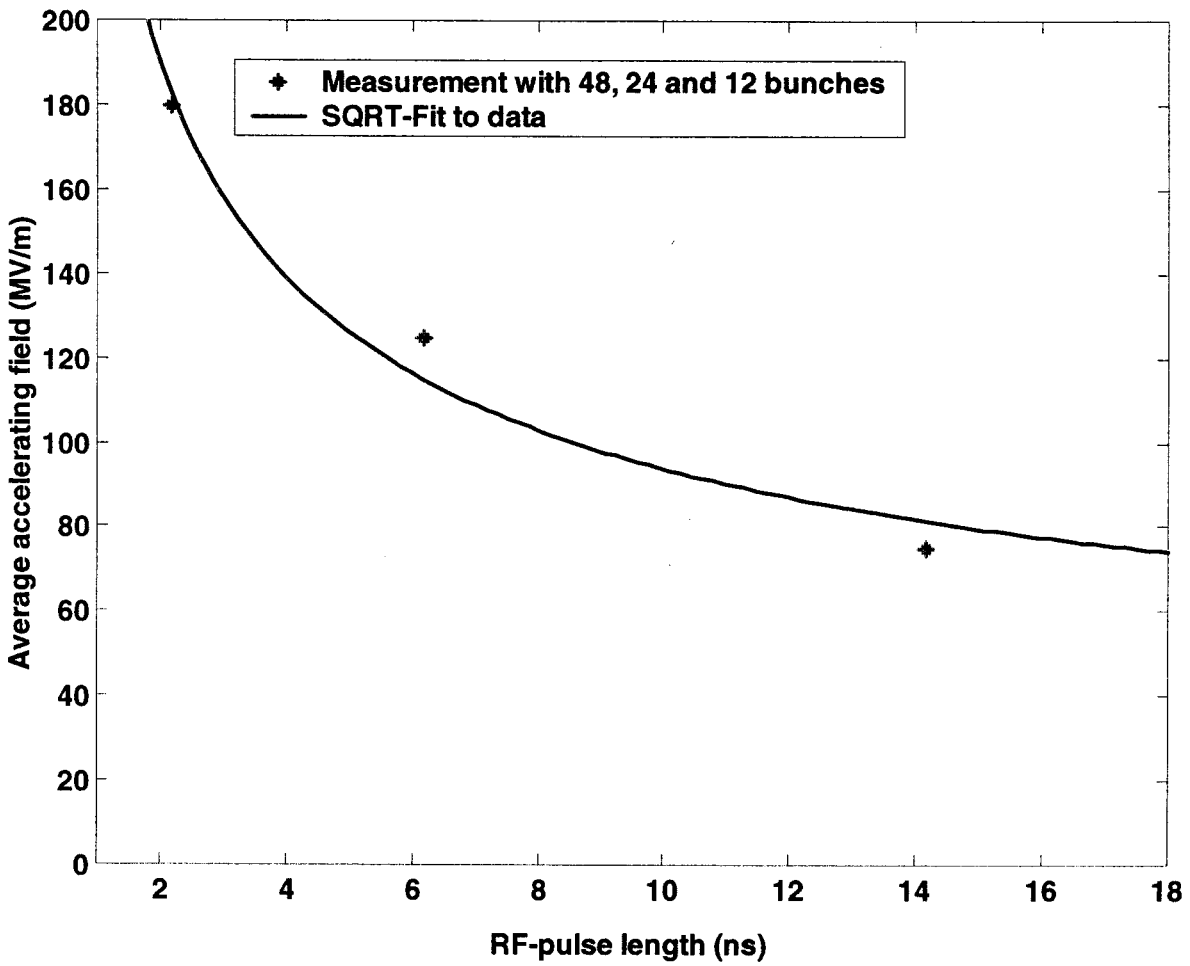
breakdown
currents

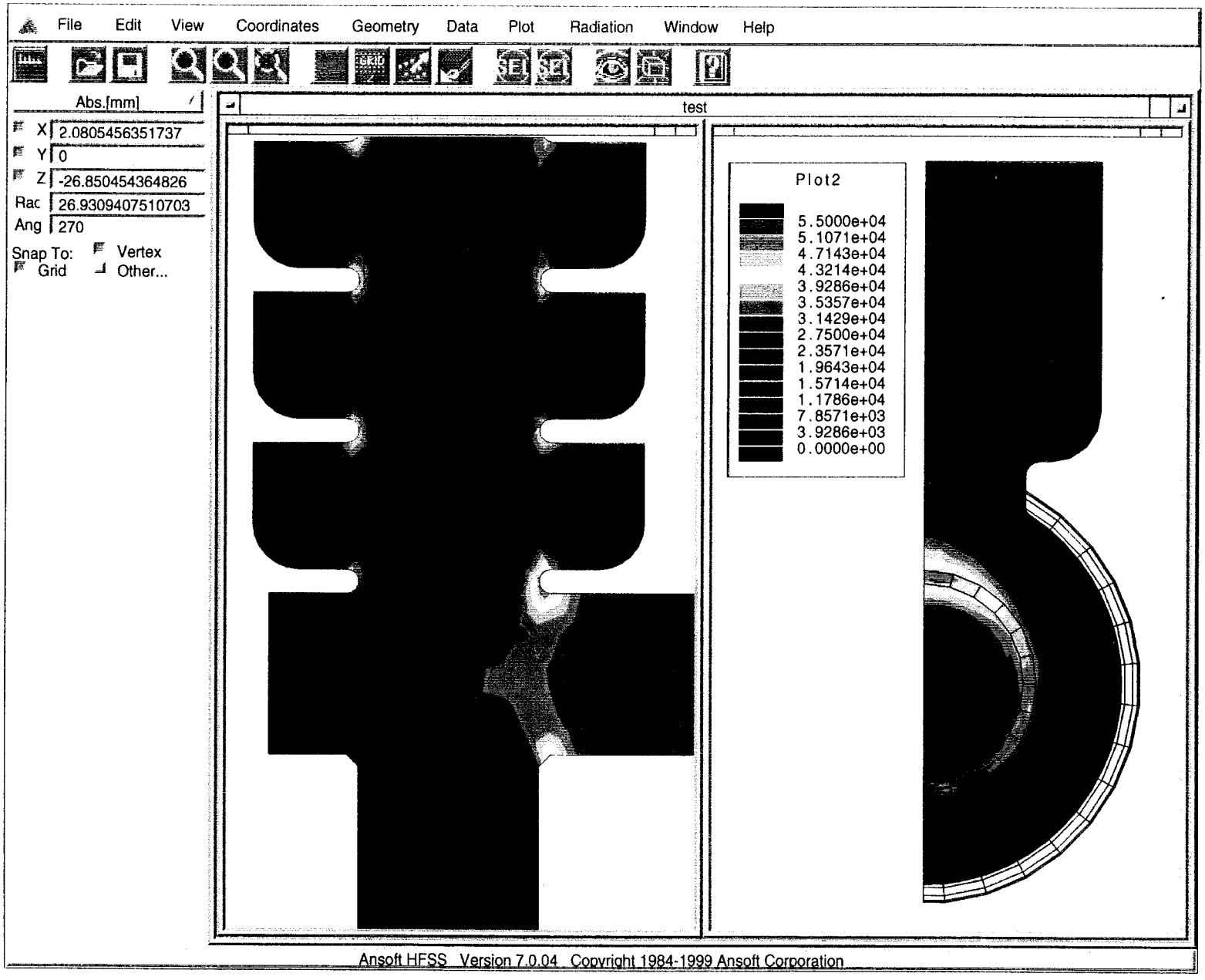


RF breakdown
signals

dark currents

Pulse length dependence of rf-break-down fields in a 30 GHz accelerating structure at CTF II

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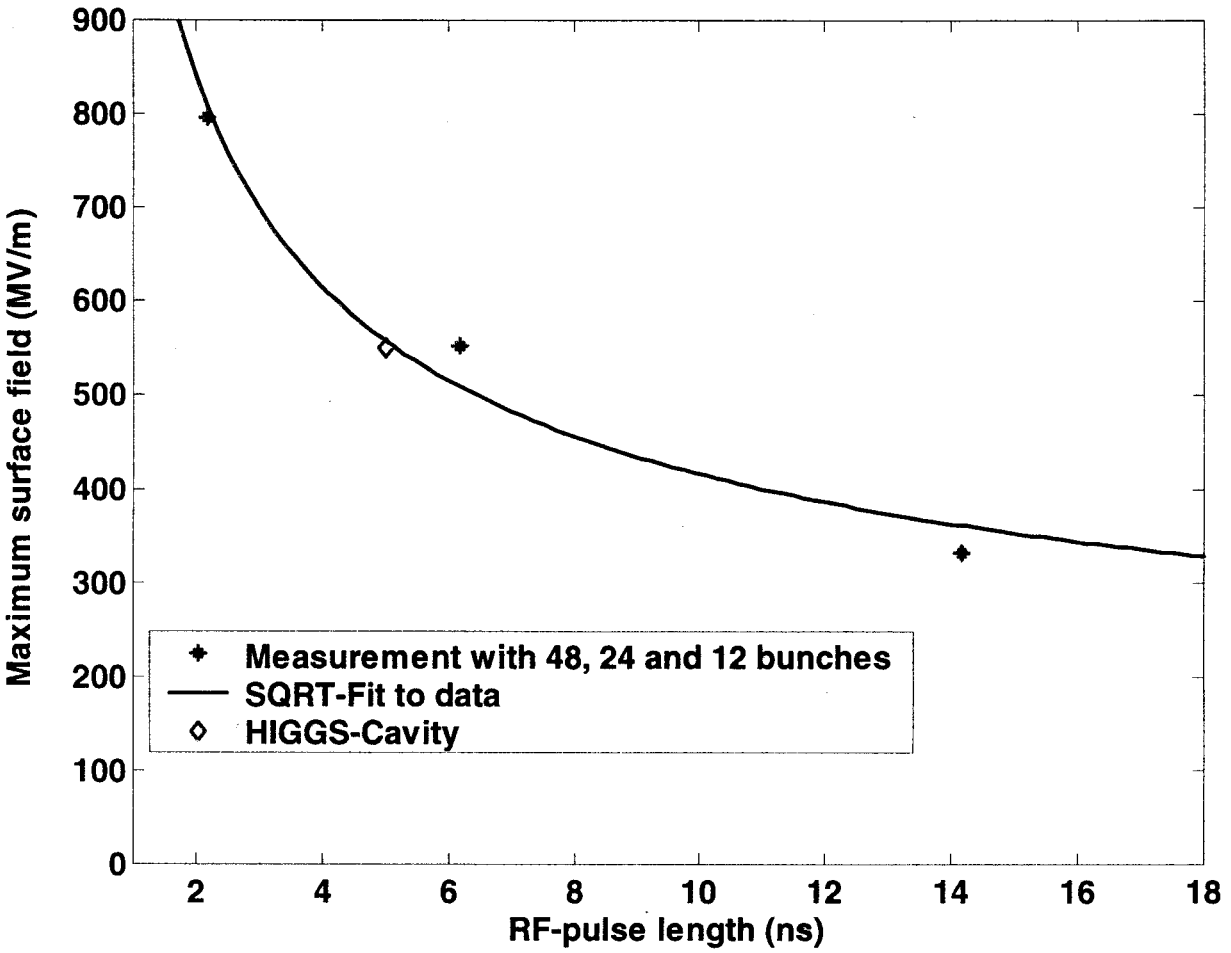
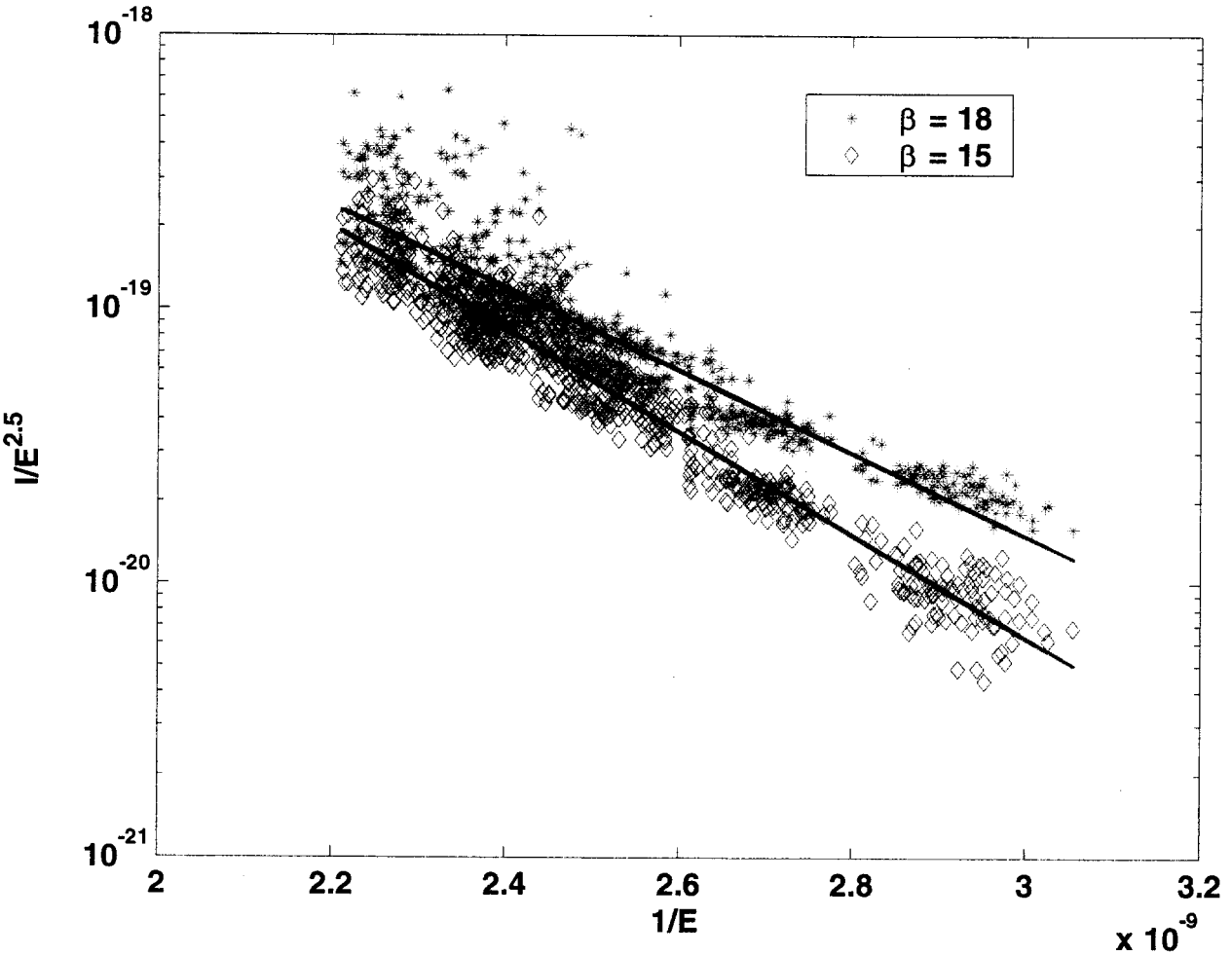
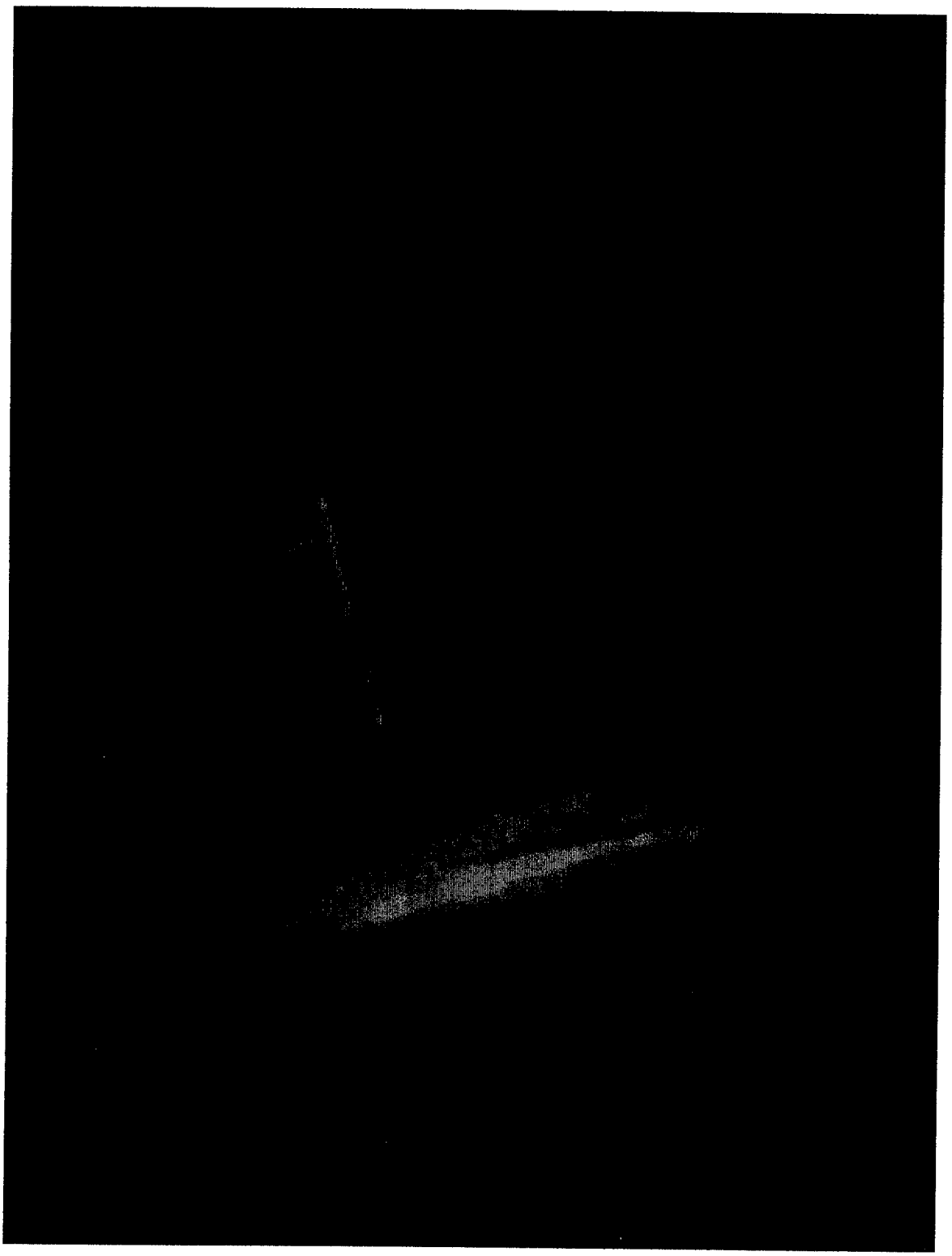
Pulse length dependence of the maximum surface fields in a 30 GHz accelerating structure at CTF II

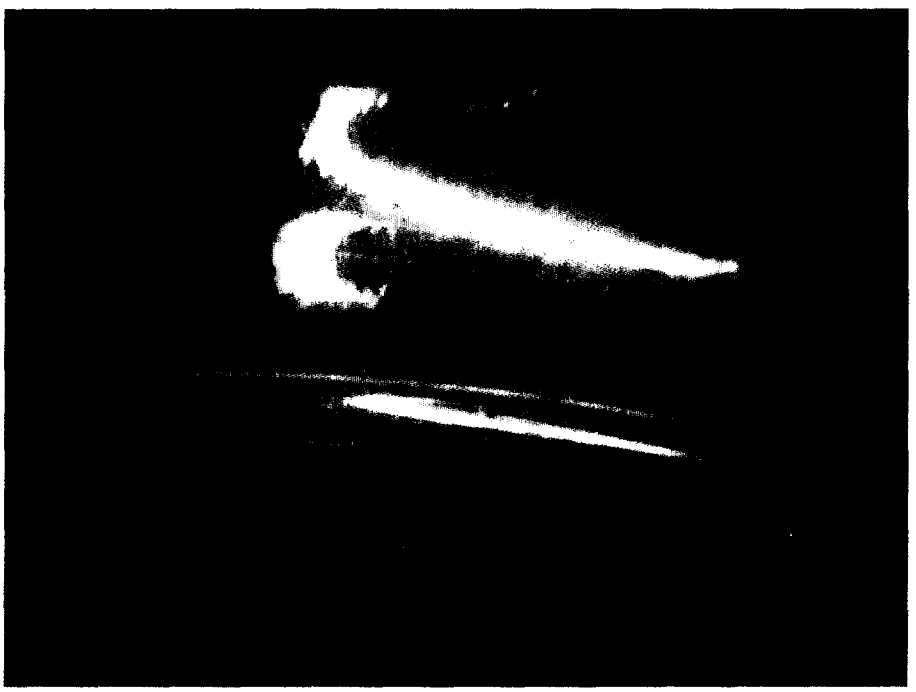


Fowler-Nordheim-Plot
of 30 GHz accelerating structure





Input coupler,



three cells downstream.

Damage summary

So far only inspected with endoscope and simple RF measurements.

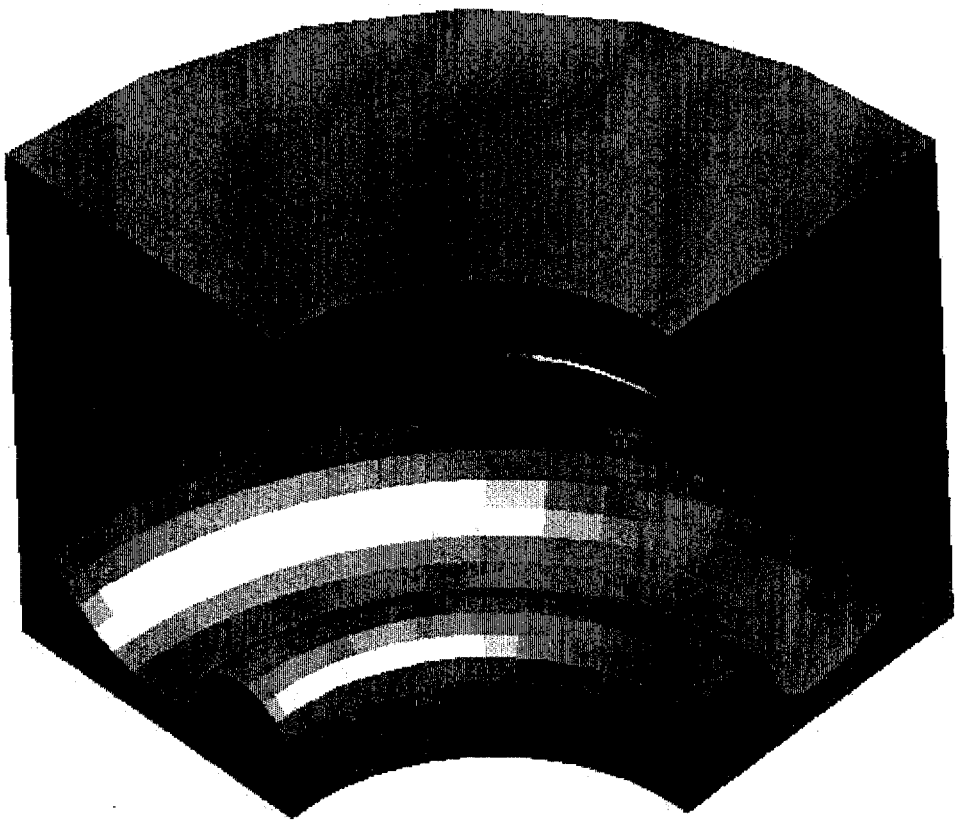
Damage to externally powered structures entirely (mostly?) confined to over-voltage region in the input coupler.

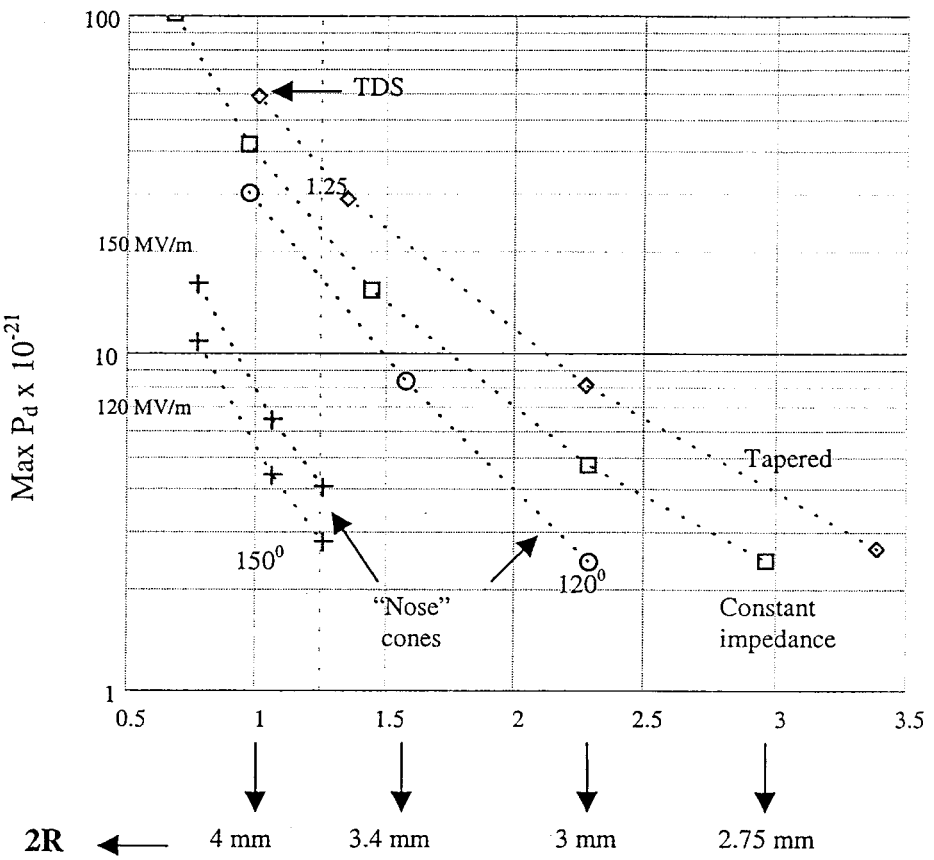
Evidence of damage from 4-16 ns long pulses, typical surface fields of 275 MV/m. No clear signals from RF, but we have since discovered substantial vacuum and emitted currents.

Vacuum conditions have been **poor**.

No conditioning strategy was used.

The view of the "nose" cone cell, optimized for the lowest surface ~~filed~~ field





"Averaged" short-range transverse kick.