High gradient performance of RF gun and S-band accelerator structure for dark current reduction

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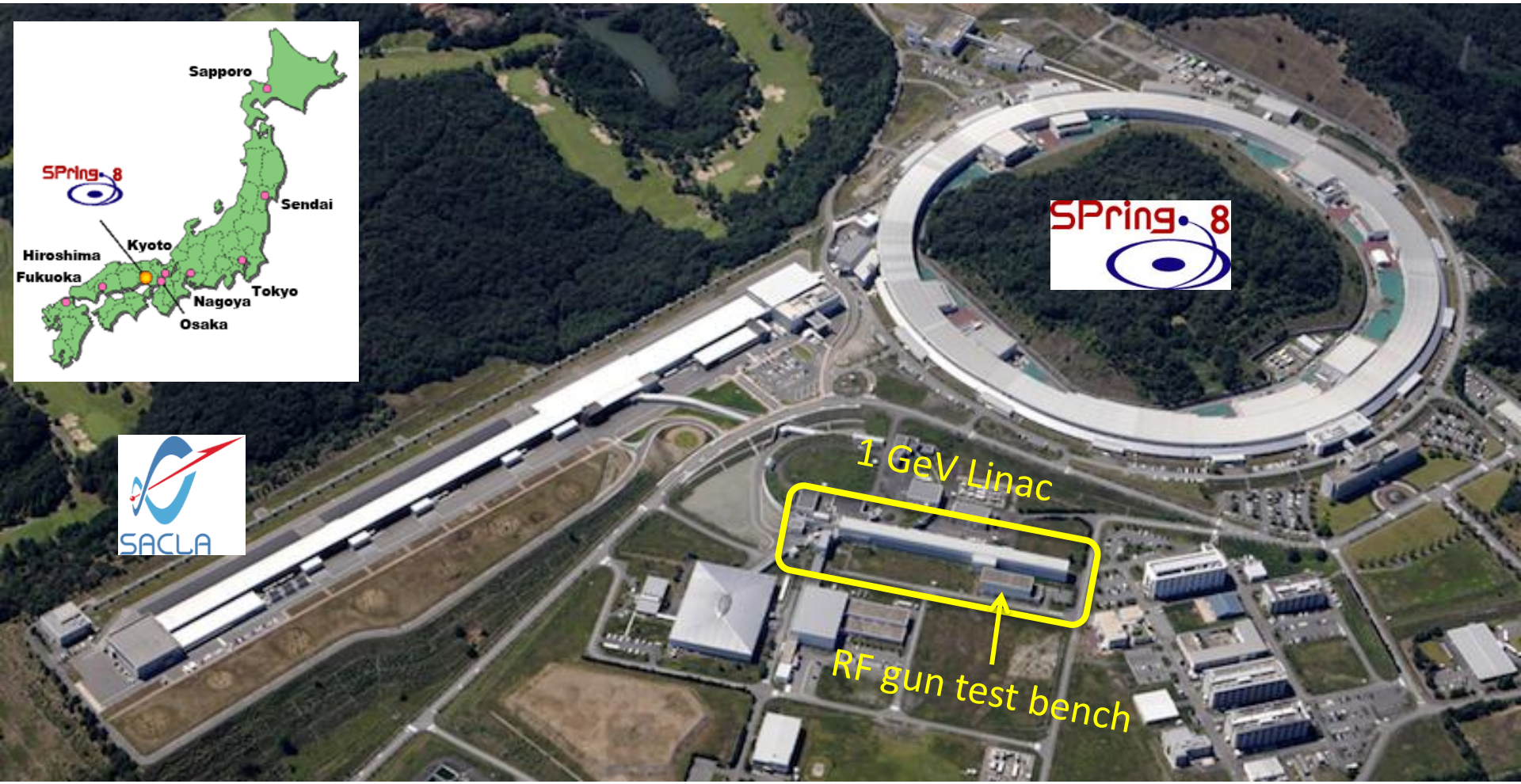
SPring-8 (Super Photon ring-8 GeV) opened for users in 1997

Injector system

8 GeV Booster synchrotron

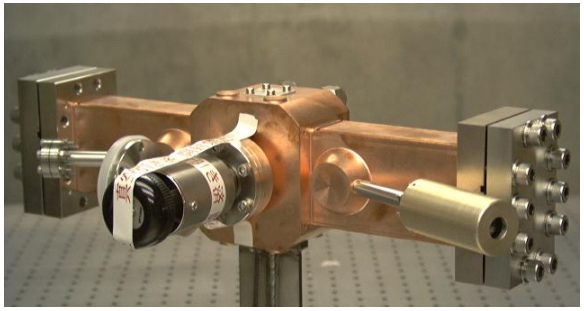
1 GeV linac (3 m x 22 structures → E_{acc} ~15 MV/m)



High gradient related topics around 1GeV linac

All S-band

- Photocathode RF Gun (max. 190 MV/m at cathode)



High power operation since 1999

- Dark current reduction of accelerating structure (E_{acc}~27 MV/m)

High power test since 2010

Photocathode RF gun at SPring-8

Brief History

1997	Photcathode RF Gun R&D started.
1999	First beam.
	Field gradient on cathode 127 MV/m with 35 MW Klystron.
2002	175 MV/m with 80 MW Klystron.
	Cartridge cathode RF gun (Gun2) installed.
2003	3m structure installed. (30 MeV)
2004	190 MV/m achieved after chemical etching adopted.
2012	SLED and bunch compressor will be installed.
	-> Test bench for femtosecond bunch monitor based on EO-sampling

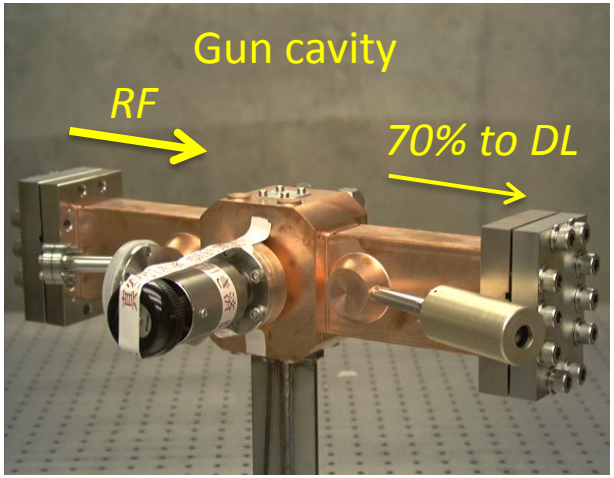
Gun cavity

Single cell with output RF port

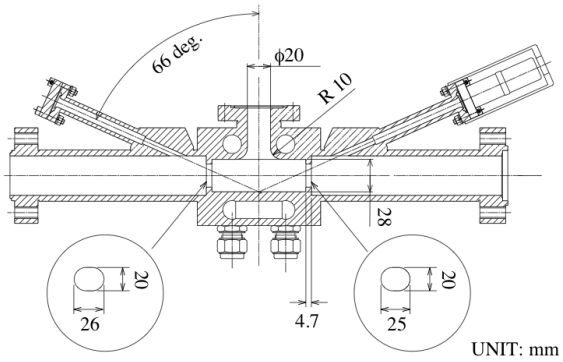
⬇

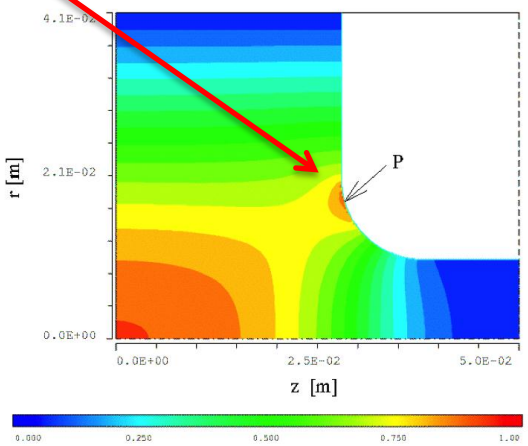
Low Q

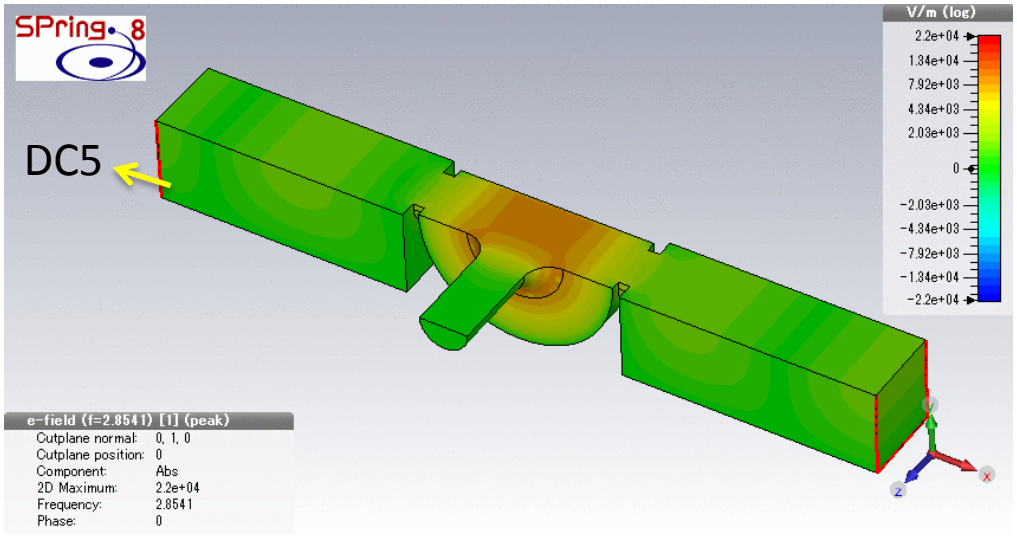
enables short RF pulse operation ➡ stability in high gradient operation



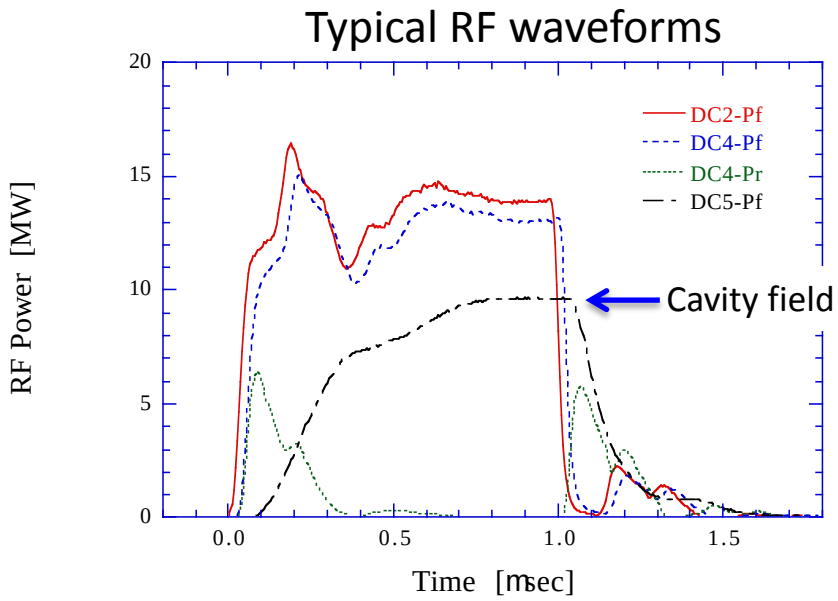
Frequency	2856 [MHz]
Loaded Q value	1414
Coupling	1.02
Filling time	0.31 [sec]
E_{max} / $E_{cathode}$	1.09







E-field in gun cavity (log scaled)

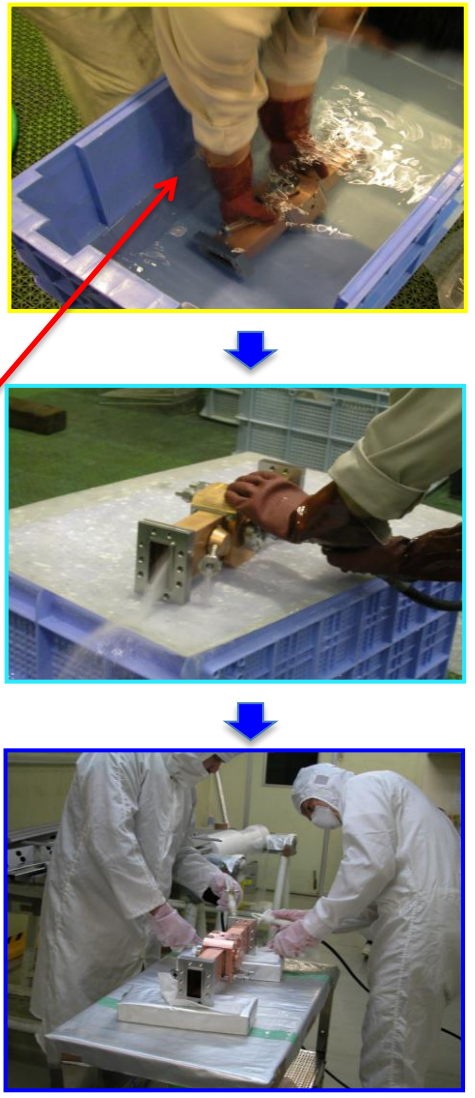


Improvement of high gradient performance

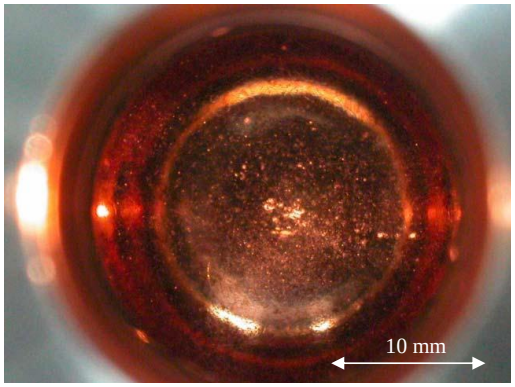
In 2002, we achieved the highest gradient of 171 MV/m (4.0MeV) , but it took 2 months for RF conditioning.

To increase the gradient and improve the quantum efficiency of the cathode (Cu), we adopted a cleaning by chemical etching.

Etching solution: H_2SO_4, H_2O_2 each at 2 wt%
This was determined from etching rate of OFC,
that is <1 μm / a few min. (controllable time by human work)



As a result, 190* MV/m (4.5 MeV) and Q.E. of 1×10^{-4} achieved after 23 days conditioning. *the maximum surface gradient : 207 MV/m



Cathode surface viewed from beam exit.
Some damage can be observed.

It may suggest that a surface treatment such a chemical etching after some RF conditioning is effective.

Waveguide system

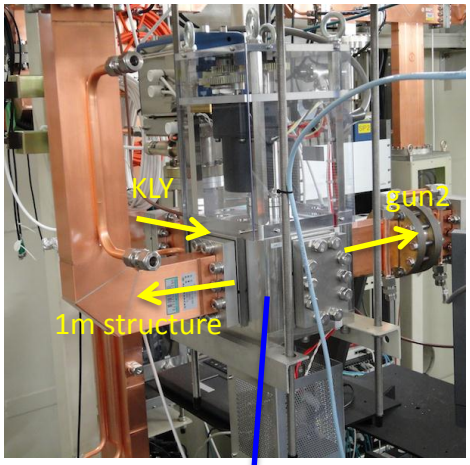
KLY

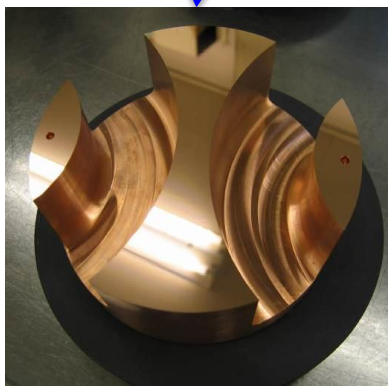
Toshiba E3712
80 MW

phase shifter

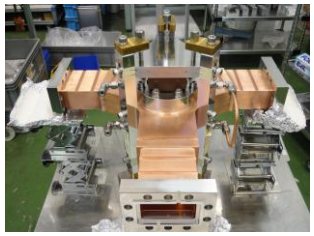
3dB coupler

Vacuum waveguide switch
developed at SPring-8
confirmed up to 60 MW, 2μs, 60pps





rotor



high power test
1m structure
vacuum circulator, isolator

RFGun2

cartridge cathode

RFGun1

157MV/m
3.7MeV

Accelerator structure (3m)

9MV/m
26MeV

30 MeV Linac

Several R&D are ongoing in parallel.

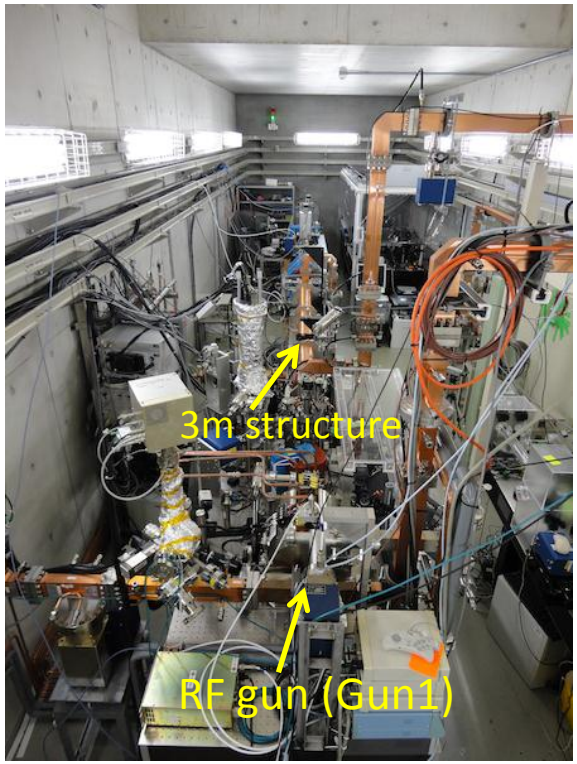
Present status

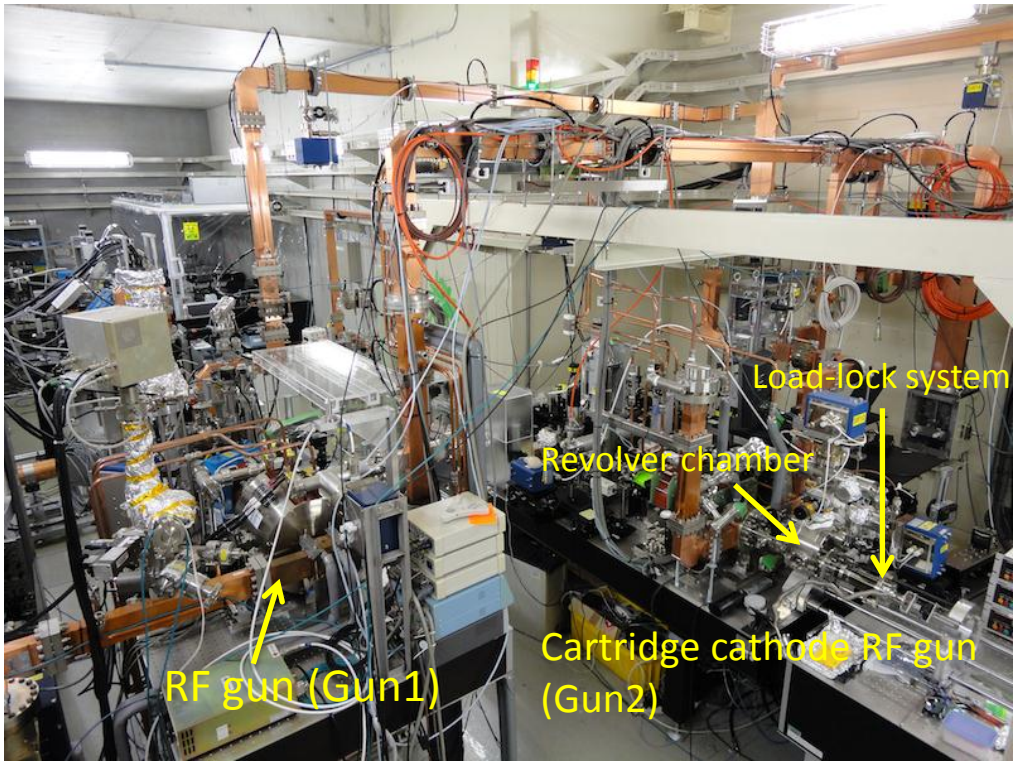
Operation parameters

Max. $E_{cathode}$	157 MV/m
RF Pulse width	700 ns
Dark current	60 pC/pulse

(vacuum pressure ~5×10^{-7} Pa @RF On)

- Low emittance study (1.4pmmmrad@0.38nC)
- Z-pol laser injection (Gun2)
- Bunch monitor R&D based on EO-sampling





Reduction of dark currents from accelerator structure

SPring-8 operation mode

Single (several) bunch operation requires a bunch impurity of 10^{-10}

a few electrons!

RF knock out system in the booster synchrotron

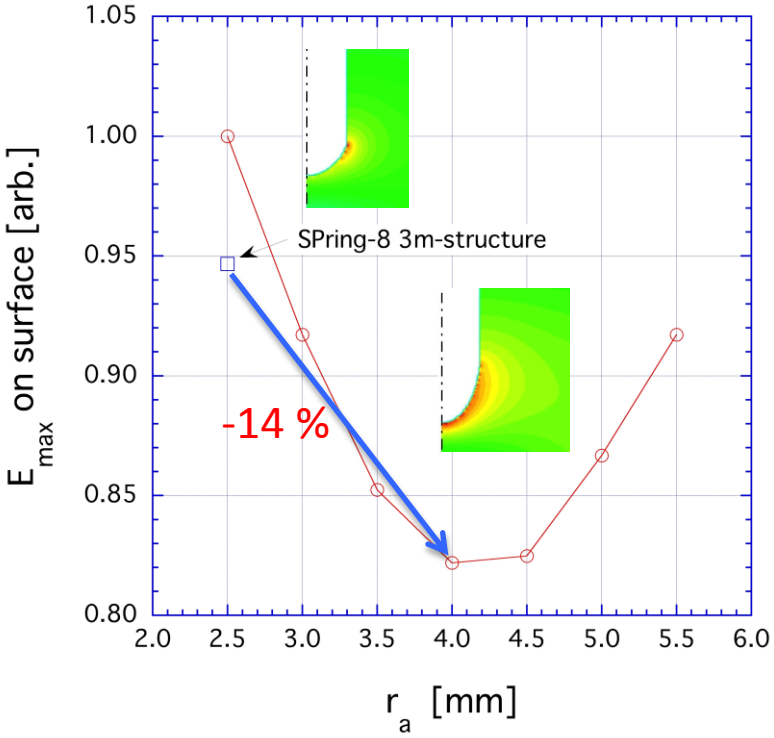
Reduction of dark current from linac is preferable

Accelerator structure R&D

Test structure (energy modulator for bunch compressor)

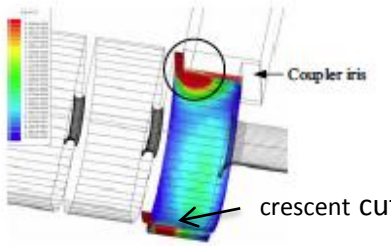
Test structure

Elliptical iris

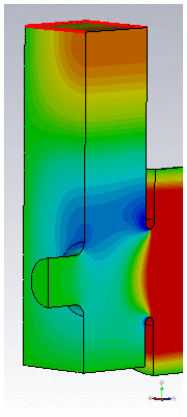


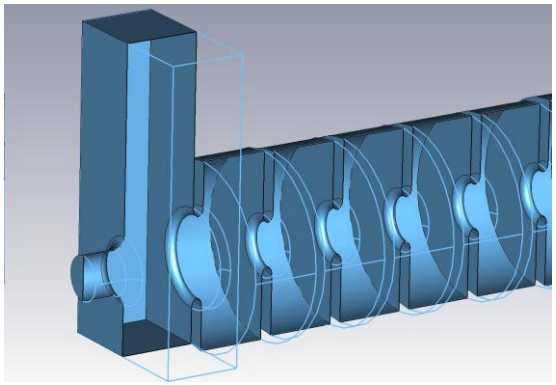
We expect a dark current reduction of one order of magnitude

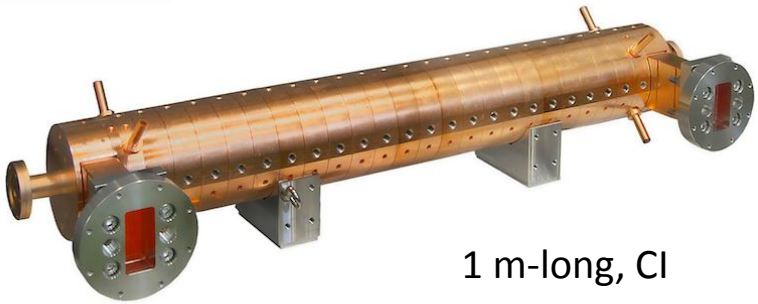
Waveguide coupler (single feed)



Avoiding pulse heating around coupler hole

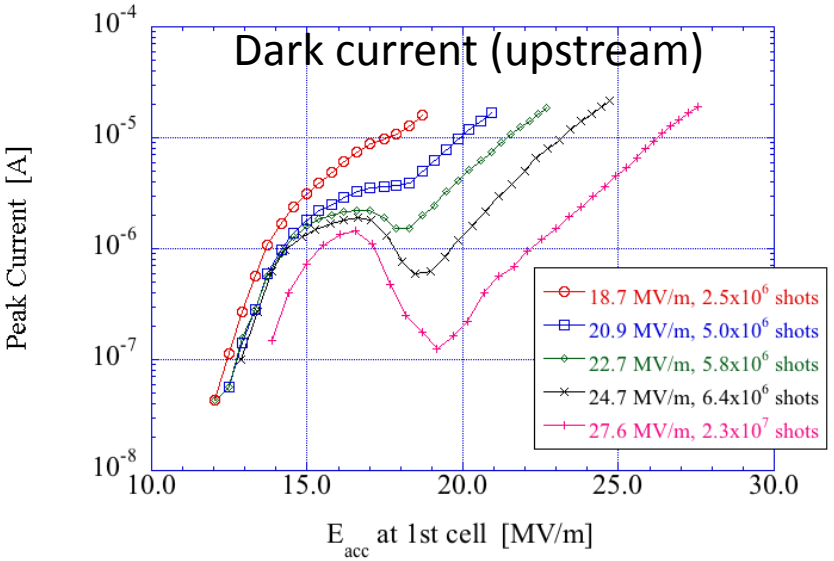


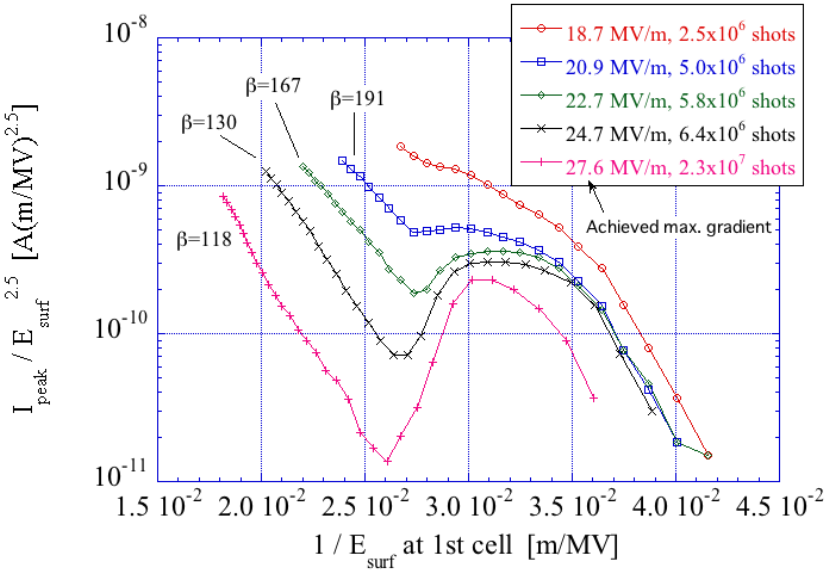




1 m-long, CI

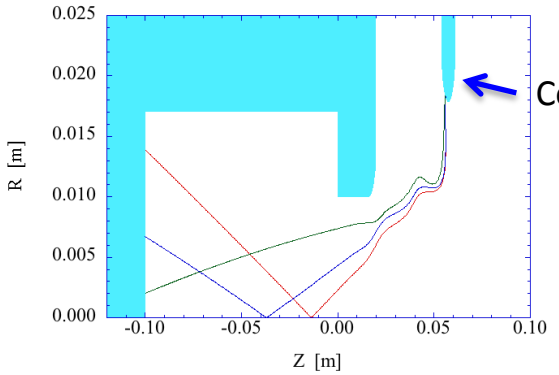
RF Conditioning (ongoing)





- Max. 27.6 MV/m (max. Klystron output)
- Bump around 16 MV/m

  Electrons emitted from upstream side of coupler iris, focused on Faraday cup by waveguide field. It's not transported to downstream because energy is low.



Summary

- RF gun cavity (single cell, low Q) has been operated in high gradient field (nominal 157 MV/m, max. 190 MV/m) more than 10 years at SPring-8.

- A high power test of a 1m-long structure designed to decrease the dark currents emitted from the structure surface, is ongoing. A chemical etching will adopt for this structure. (maybe next year)

- In 2012, upgrades of RF power (SLED) and beam energy (30 to 50 MeV) are planned as a test bench of femtosecond bunch monitor for XFEL. 3m-long accelerator structure will also be replaced by a shorter structure adopted a waveguide coupler (double feed) and ellipse cross-section of iris.