SLAC NATIONAL ACCELERATOR LABORATORY

Overview of High Power Vacuum Dry RF Load Designs

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Introduction

Accelerating particles more efficiently and over much shorter distances is an important core competence in the SLAC activity. SLAC has been developing next generation accelerator technologies for science, medicine, industry, and homeland security since 1962. Achievement of 100 MeV/m accelerating gradients is one major problem of "warm" type accelerator technology. SLAC scientists have contributed to this program for many years and the progress in this field is remarkable. One shall recall that high accelerating gradient is a function of the energy stored in the accelerating structure that, in turn, depends on the input RF power. Progress in both: (1) technology of RF accelerating structures and (2) high power RF sources has been substantial. However, another important component in this technology needs to be considered; RF loads which terminate significant residual powers. **For traveling wave accelerating structures, the termination problem of residual RF power is directly linked with the development of high gradient structures and multi-Megawatt peak RF sources.** The problem of inadequate high power S-Band vacuum dry loads for the SLAC linac exists today (and for the next generation of accelerator technologies) and needs to have a modern technical solution.

Accelerating Gradient in the RF Linac

High Gradient Structures

High Power RF Sources

Stable Termination of the Residual RF Power

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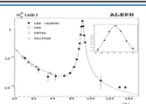
Stability of SLAC Linac vs. Program Runs

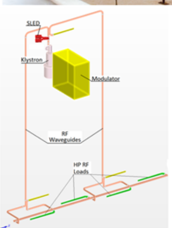
Z-Boson resonance ⟶ $\frac{dE}{E} \cong \frac{2.5}{91.2}$ i.e. ~2.7%



B-Boson resonance ⟶ Linac served as an injector. Stability of linac system did not play a major role. Stability of HER and LER systems were required.

FEL ⟶ Specification of the bunch parameters and stabilities are tight. Level of required LCLS linac stabilization is ~0.02%

The modern energy stability requirement for linac systems and subsystems is 10^{-3} to 10^{-4}



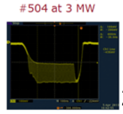
Vacuum Dry RF Loads at SLAC Linac

"Most of the high-power loads were tested only to power levels of 8 to 10 MW peak power. The maximum input power to the loads is approximately 2 MW peak, when one klystron is used to drive four 10-ft sections of disk-loaded waveguide." (cited in the "Blue Book")

There were no data concerning to:

- Stability of the high power RF termination
- RF load lifetime under a high power stress

#504 at 3 MW



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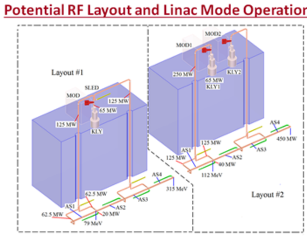
Potential RF Layout and Linac Mode Operation in the Future *(for "Warm" Part of the SLAC Linac)*



➢ **Potential Linac RF Layout**

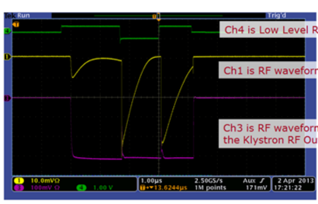
The Layout #1 represents the existing RF configuration of each SLAC klystron station.

A potential LCLS-I upgrade is shown in the Layout #2.

- The FEL X-ray energy could be increased by $\sqrt{2}$ and reach approximately 14 keV.
- The Layout #2 allows having more headroom and flexibility for the linac operation.

However the accelerating gradient in the accelerating structures will be approx. 40 MeV/m and each **RF load has to absorb approximately 40 MW peak.**

➢ **Two Bunch Mode Operation During Each Linac Pulse**



Klystron continuously feeds the SLED cavity. During this time the phase at LLRF is modulated two times. An RF energy is extracted two times from the SLED accordingly. The energy extraction delay can be as long as a filling time of the accelerating structure.

The SLED RF power extraction delay may be less than a decay of the HOM power left from the first bunch. **The broadband RF loads would be required.**

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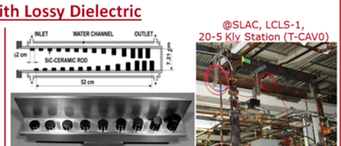
Vacuum Dry RF Loads with Lossy Dielectric

- Designed at SLAC (1995)
- TE10, AlN ceramic loaded with 7% glassy carbon

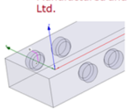
This load was design to terminate a 60 MW peak, (~ 3 kW average) with 10% bandwidth at 11.424 GHz centre frequency.

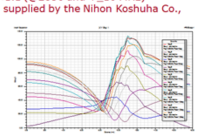
The load did not meet the spec due to surface breakdown of ceramic.

@SLAC, LCLS-1, 20-5 Kly Station (T-CAV0)

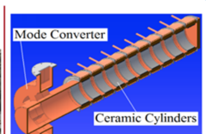


- Originally designed at KEK
- TE10, SiC, VSWR<1.1 (@2856 and +_10 MHz)
- Manufactured and supplied by the Nihon Koshuha Co., Ltd.



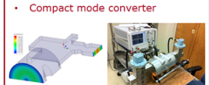


45 [kV/cm] @25 MW at SiC surface

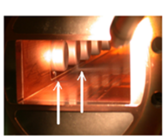


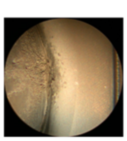
- Proposed by Muons, Inc. under DoE SBIR grant
- TE01, porcelain doped with SiC
- TE10-TE01 mode converter is needed
- Muons Inc. designs the lossy part of the load
- SLAC designs the mode converter

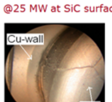
- Compact mode converter



A pilot RF load is not fabricated, there is no high power test result







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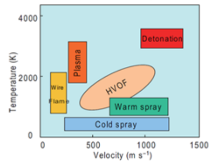
"All-metal" Vacuum Dry RF Loads

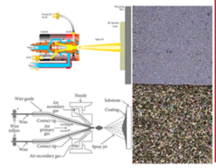
- Matrixes

Element	C	Mn	Si	P	S	Cr	Ni	Al
SS430	0	0	0	0	0	16	0	0
	0.12	1	1	0.04	0.03	18	0.5	0
Kanthal	0	0	0	0	0	20.5	0	5.8
	0.08	0.4	0.7	0	0	23.5	0	5.8
NiCr	0	1	1	0	0	30	68	0

Qs: What is a best technology for a formation of the multi-MW "all-metal" RF load? Outgassing? Matrix of material? Attenuation rate? Cost? Technological issues: gas pressure, flow rate, plasma gun distance against coating surface, powder feed rate, etc. etc. etc.

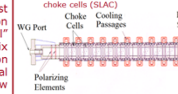
- Thermal Spray Technologies





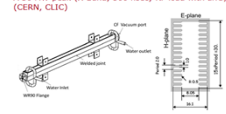
➢ High power RF loads based on the SS430 usage

- A 100 MW peak (X-Band), 8 kW average RF load with array of choke cells (SLAC)



TE11, circ. WG, choke-pair with different sizes, brazing technology

- A 50 MW peak (X-Band, 300 nsec) RF load with array of wedges (CERN, CLIC)



TE10, oversize WG, two machined parts, weldment

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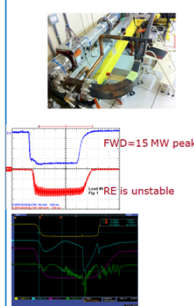
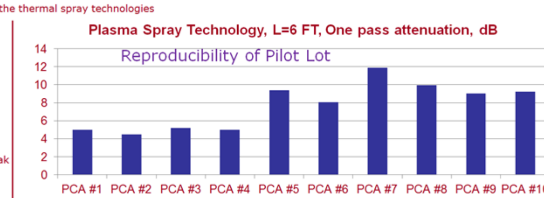
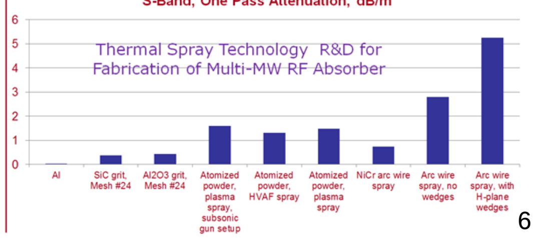
➢ High power RF loads based on the thermal spray technologies



- Original RF loads for the SLAC linac, TE10 mode, Tapering & coated RF load concept
- Kanthal wire was flame-sprayed onto a stainless steel
- Designed to terminate 2 MW peak





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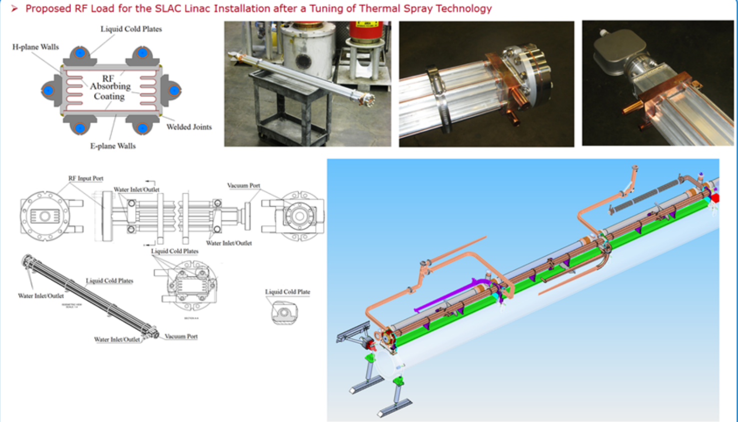
➢ Proposed RF Load for the SLAC Linac Installation after a Tuning of Thermal Spray Technology



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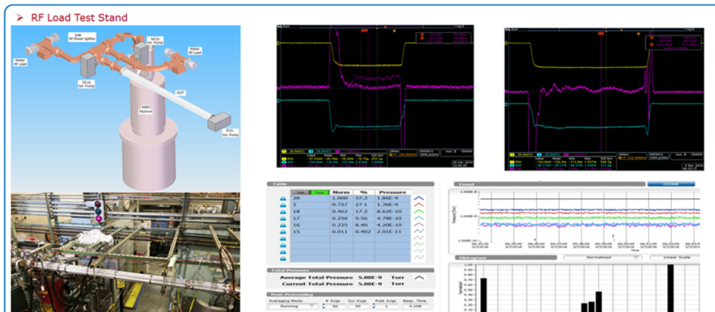
➢ RF Load Test Stand



Conclusion

A brief overview of multi MW peak vacuum dry load designs is discussed. Two concepts were considered: (1) designs based on the usage of lossy ceramic and (2) designs based on "all-metal" approach. The "all-metal" designs are a cost effective and reliable to terminate stably a residual RF lower at multi-MW peak levels in the traveling wave accelerating structures.

Acknowledgement

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