2013/10/22 ERL検討会

ERL2013及びLLRF2013の報告

RF関係

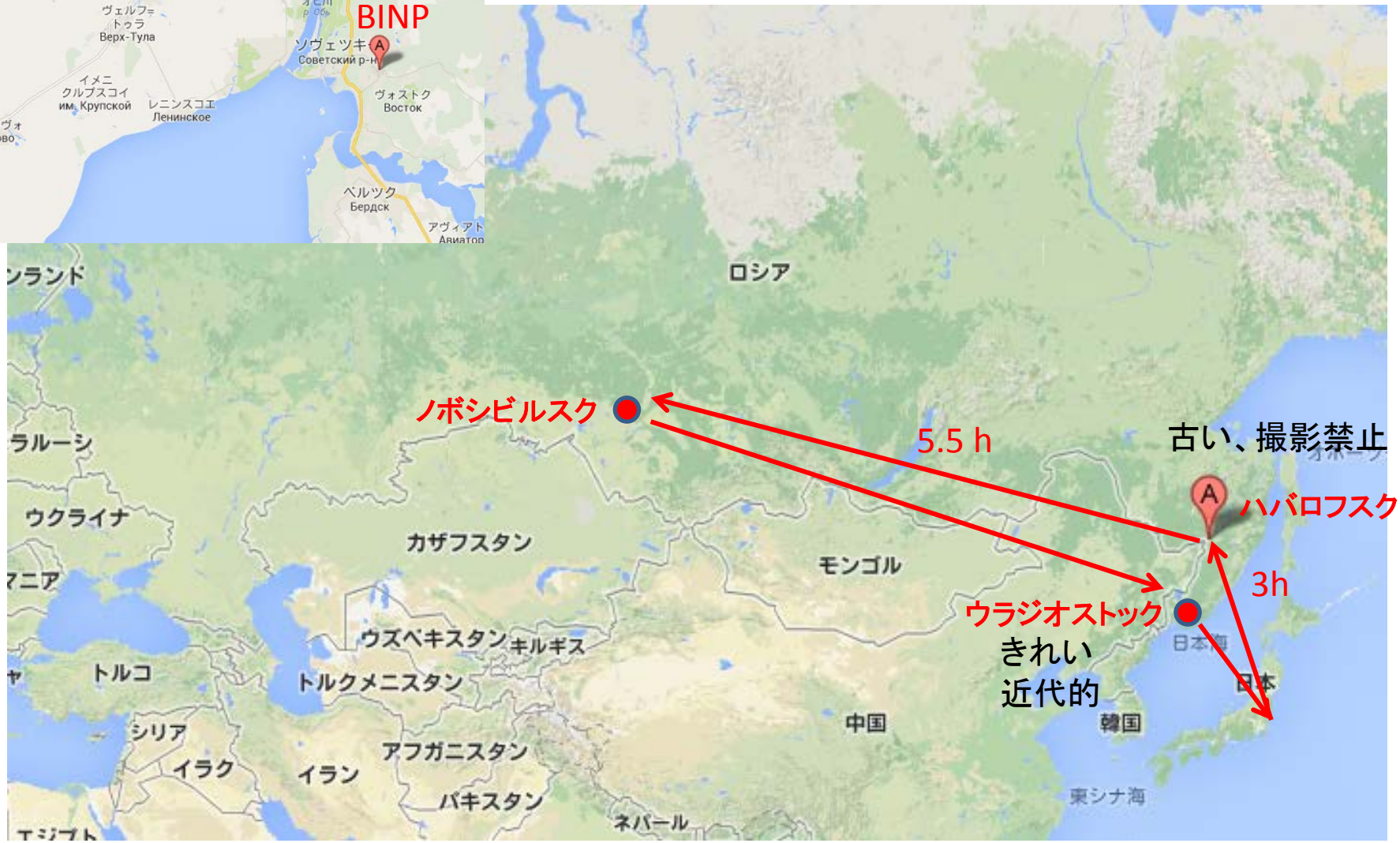
三浦　孝子

ERL 2013

9 -13 September, 2013, BINP, Novosibirsk, Russia

ノボシビルスク


マルシノ
Марусино
Дзержинский р-н
ラストリノエ
Раздольное
ノヴォシビルスク
レニンスキ
Новосибирск
Ленинский р-н
パヴィノ
Павино
オビ
Обь
レメスレシニ
Ремесленный
ビェルヴォマイスキー
Первомайский р-н
コリツォヴォ
Кольцово
エリトニ
Элитный
BINP
ヴェルフ=トゥラ
Верх-Тула
ソヴェツキ
Советский р-н
イメニクルプスコイ
им. Крупской
レニンスコエ
Ленинское
ヴォストク
Восток
ヤルコヴォ
Ярково
ベルツク
Бердск
アヴィアトル
Авиатор


ロシア
ノボシビルスク
5.5 h
古い、撮影禁止
ハバロフスク
3h
ウラジオストック
きれい
近代的
ウクライナ
カザフスタン
モンゴル
ウズベキスタン
キルギス
トルクメニスタン
トルコ
シリア
イラク
イラン
アフガニスタン
パキスタン
ネパール
中国
韓国
日本海
日本
東シナ海

とても治安が良い

Workshop Dinner (あっさりして日本人好み)

オビ川の貯水池．広い砂浜になっていた。
寒いのに泳いでいる老人発見

金曜日、ひたすら歩くツアー。(10:00 ~ 16:00).
11:00 ~ 15:00 水なし、ごはん無し、トイレ無し

Projects with ERLs

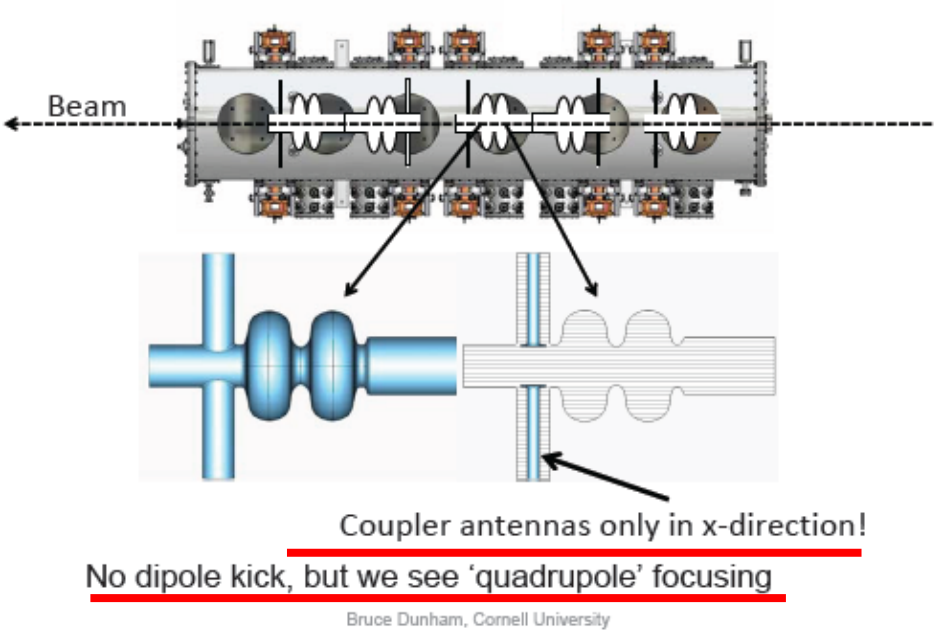
HZB Helmholtz Zentrum Berlin

ALICE@ダラスベリー

コーネル Injector

Cornell Laboratory for Accelerator-based Sciences and Education (CLASSE)

SRF Cavity Couplers



Cornell Laboratory for Accelerator-based Sciences and Education (CLASSE)

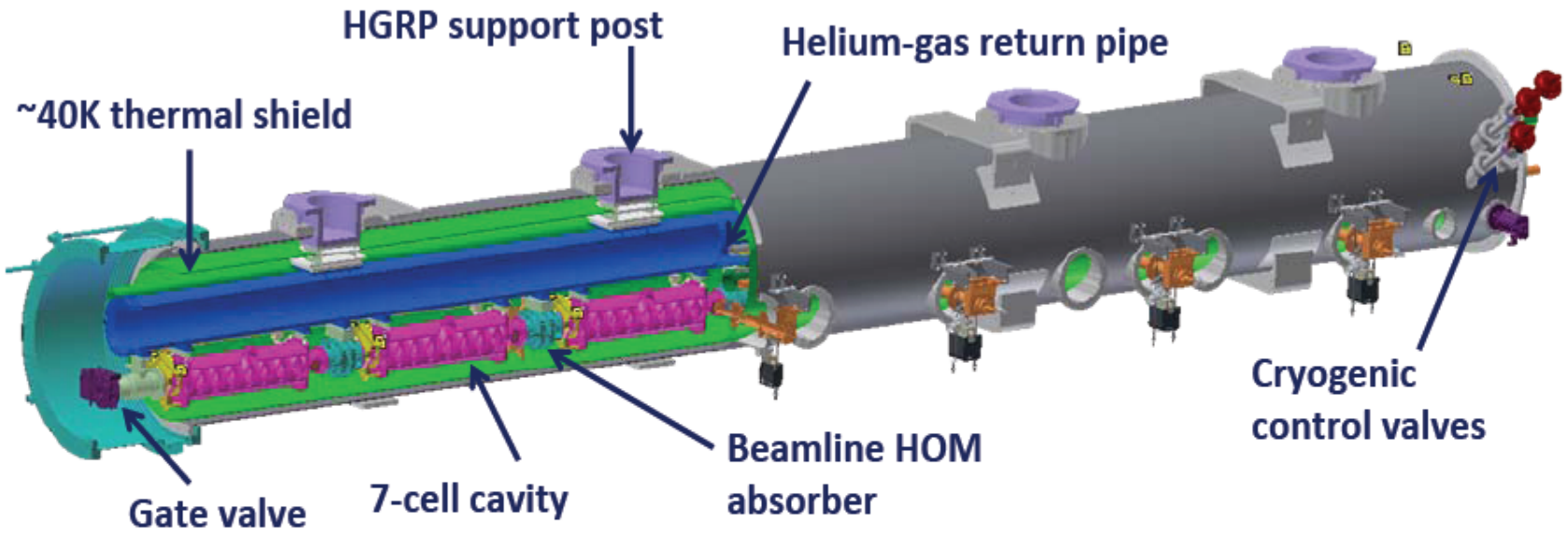
Coupler Summary

- No dipole kick as we desire, but a 'quadrupole' focusing exists, distorts beam at low energies.
- First pair of couplers must be ***after*** the first cavity in the injector
- flange problem, fixed with new seal in next design iteration
- inadequate cooling – tubing diameter mismatch
- Need to use the beam for conditioning at high average powers

最初のカップラーは、下流側に配置すべき

カップラーは左右対称に配置
→ダイポール成分は無いが、4極成分が問題となった

Cryomodule



- Acceleration gradient 16.2 MV/m
- Q_{ext} 6.5×10^{7}
- RF power per cavity 5 kW
- Amplitude stability 2×10^{-4} (rms)
- Phase stability 0.1° (rms)

STATUS

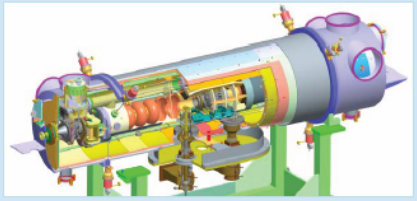
Design complete

Procuring parts

Construction starting

ALICE@ダラスベリー

Status of the CW ERL Cryomodule at Daresbury

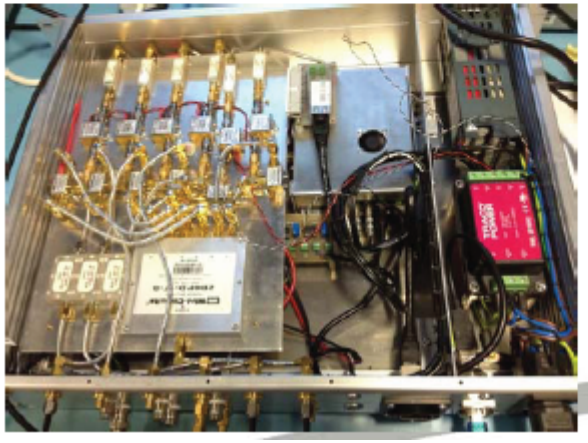


Shrikant Pattalwar
ASTeC, STFC, Daresbury Laboratory (UK)
ERL-2013, September 9-13, Novosibirsk

On behalf of
ERL Cryomodule Collaboration

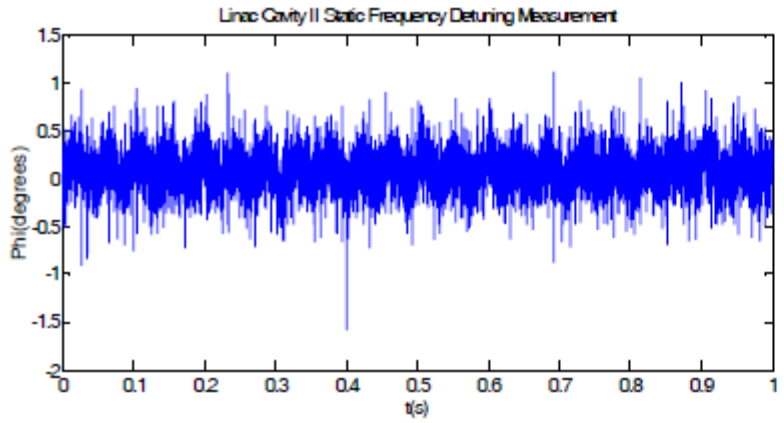
多くの研究所と共同研究

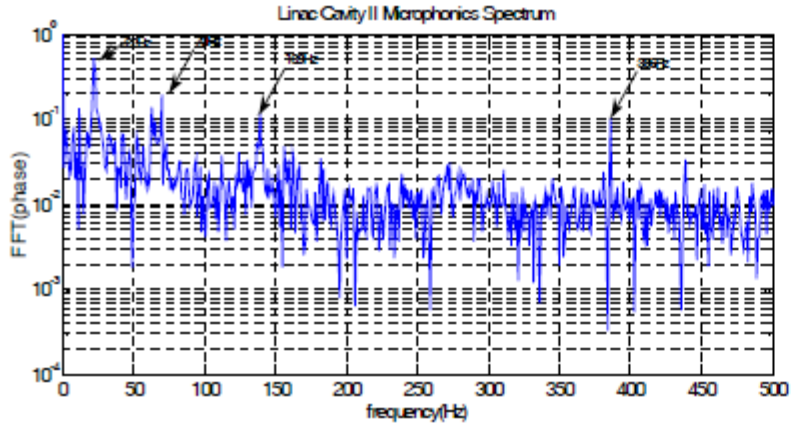
- New ERL Linac
- The new ERL cavities were driven with a CW wave from the digital LLRF system. The cavity probe signal is then mixed with the forward RF signal and filtered by a low pass filter.
- The cavities have been analysed in self excited loop and open loop operations.



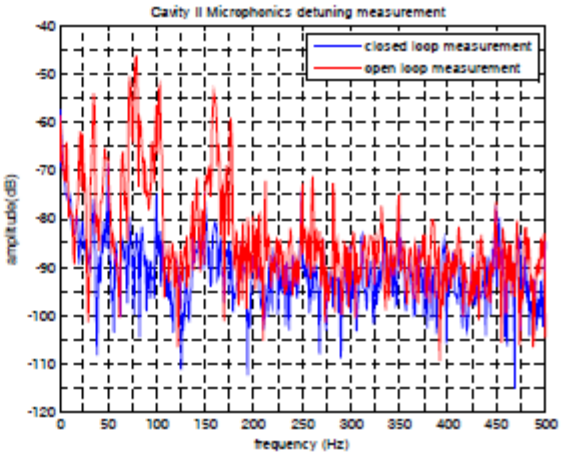
Based on the LLRF4 development board, designed by Larry Doolittle of LBNL

Integration and Commissioning – LINAC Cavity 2





Detuning peaks at 22Hz, 70Hz,63Hz,139Hz,386Hz.



- Open loop operation, strong resonances have been observed at:-

⇨ 1Hz, 7Hz , 21.5Hz, 23.5Hz, 35Hz, 48Hz, 68Hz, 71Hz, 78Hz, 82Hz, 98Hz, etc.

- Loop closed, resonances remain at 1Hz, 37.5Hz, 50Hz and its side bands.

Science & Technology Facilities Council


LLRF 2013
Low-Level Radio Frequency Workshop
Lake Tahoe, California
1 – 4 October, 2013
Photo Credit: The Tahoe Guy - Michael Marfell

気になった話題

- 高効率半導体アンプ
- ピエゾの寿命
- RFリファレンスラインの安定化
- μTCAの採用状況

Brian Chase @ Fermi

高効率半導体アンプについて

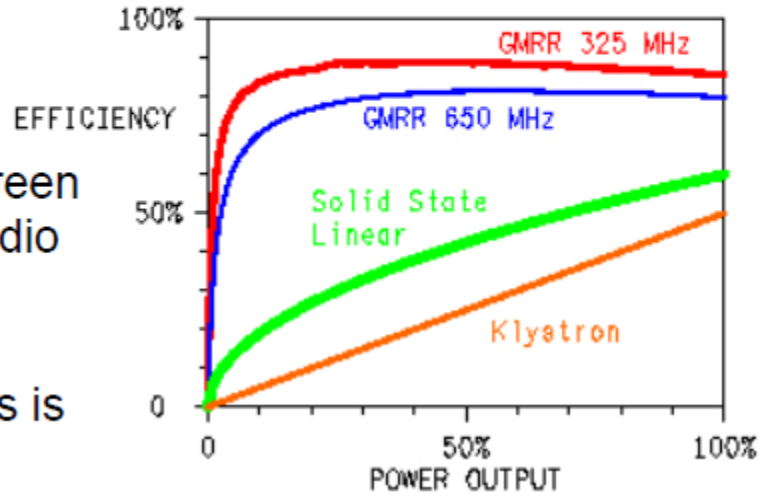
High Efficiency Solid State PA Development

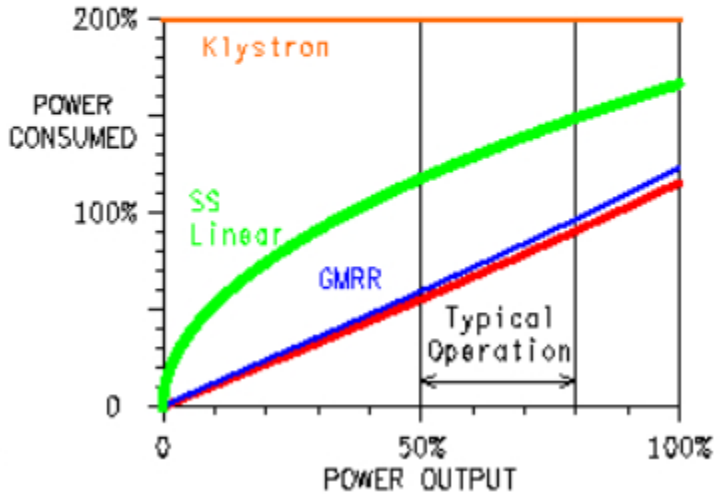
効率~80%

GMRRは企業名

SBIR with Green Mountain Radio Research

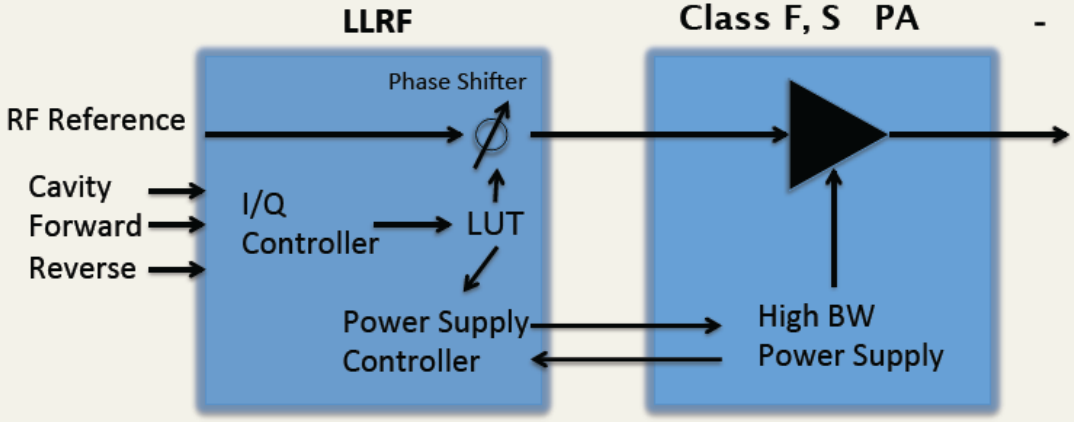
Present focus is on GaN





High-Efficiency PA

Requires tight coupling between LLRF and HLRF



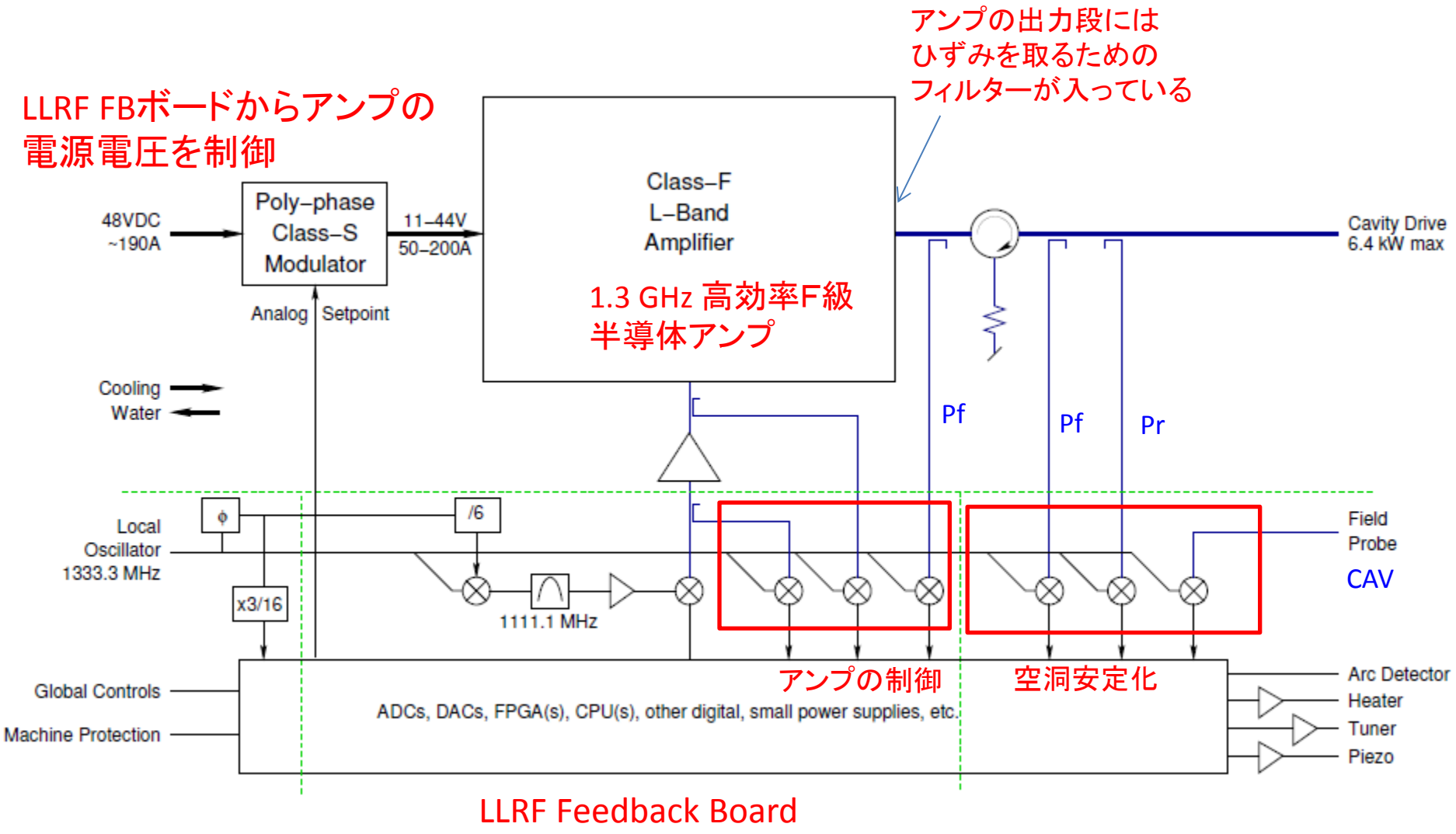
LLRF:

- controls power supply voltage
- corrects for power supply induced phase push
- optimizes for efficiency

・高効率のためF,S級アンプを使用
・LLRFでパワーアンプの電源電圧もコントロール

Larry Doolittle @ LBNL

1.3GHzの高効率パワーアンプを既に完成させた。モジュール化されている。



Larry Doolittle @ LBNL

Local Feedback Latency Account

50 ns	input analog BPF
60 ns	ADC pipe (7.5 cycles at 125 MHz)
180 ns	DSP, including PI control (22 cycles at 125 MHz)
530 ns	bandpass filter in DSP (300 kHz)
70 ns	notch filter in DSP (800 kHz for TTF $8\pi/9$ mode)
100 ns	compute amplitude with CORDIC (12 cycles at 125 MHz)
100 ns	PWM generation (dual 2.6 MHz) *pulse width modulation、PWM*
280 ns	class S modulator analog
100 ns	high-power RF cavity filter (1.6 MHz bandwidth)
50 ns	cables and waveguides
80 ns	contingency
1600 ns	total

Piezo characterization, tests and operation at FLASH

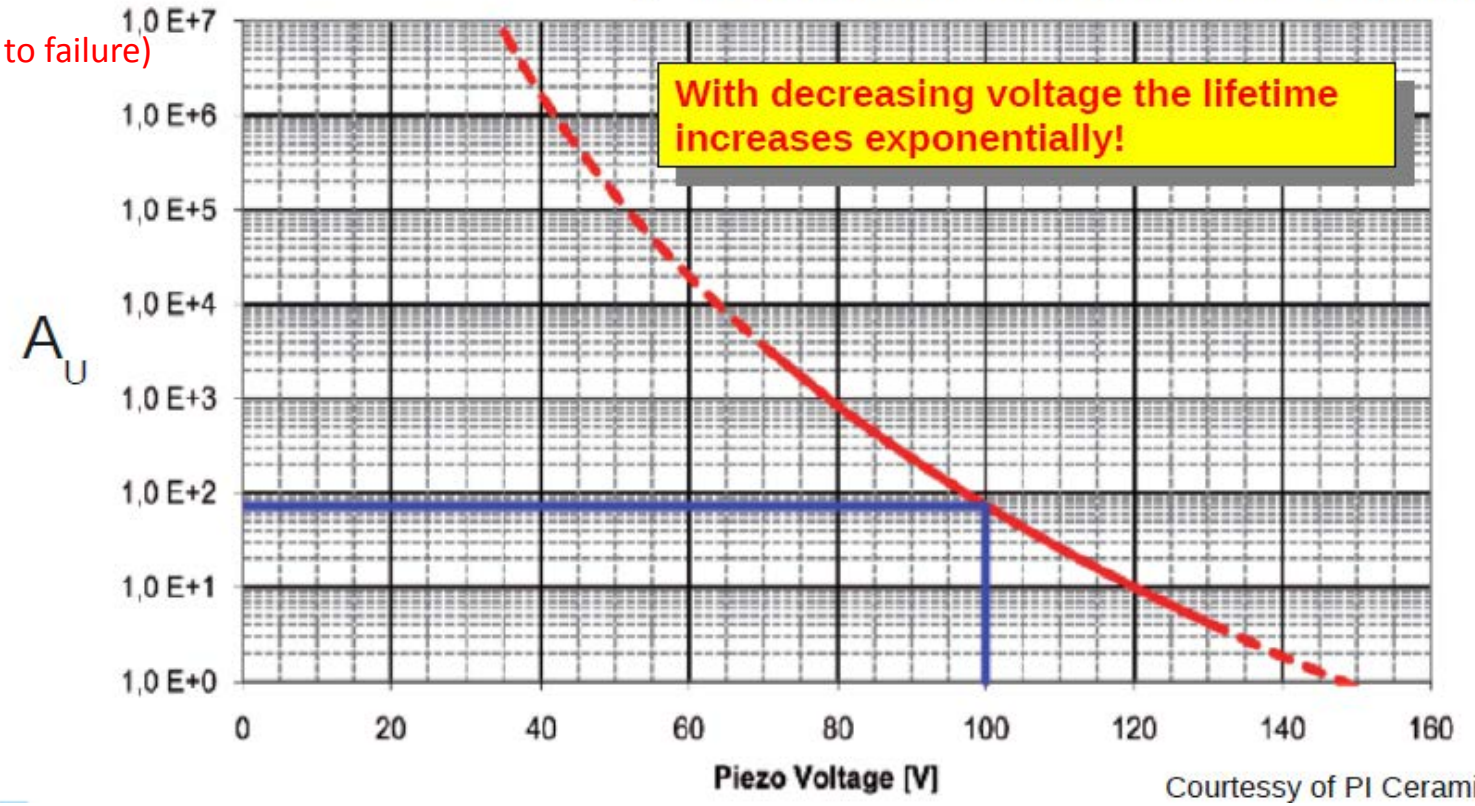
M.Grecki, DESY, Hamburg
A. Bosotti, R. Paparella, INFN Milan, Lab. LASA
T.Pozniak, K.Przygoda, DMCS, TUL

Piezo reliability

$MTTF = A_U * A_T * A_F$

A_U – voltage factor
A_T – temperature factor (constant for cryho conditions)
A_F – humidity factor (constant for cryho conditions)

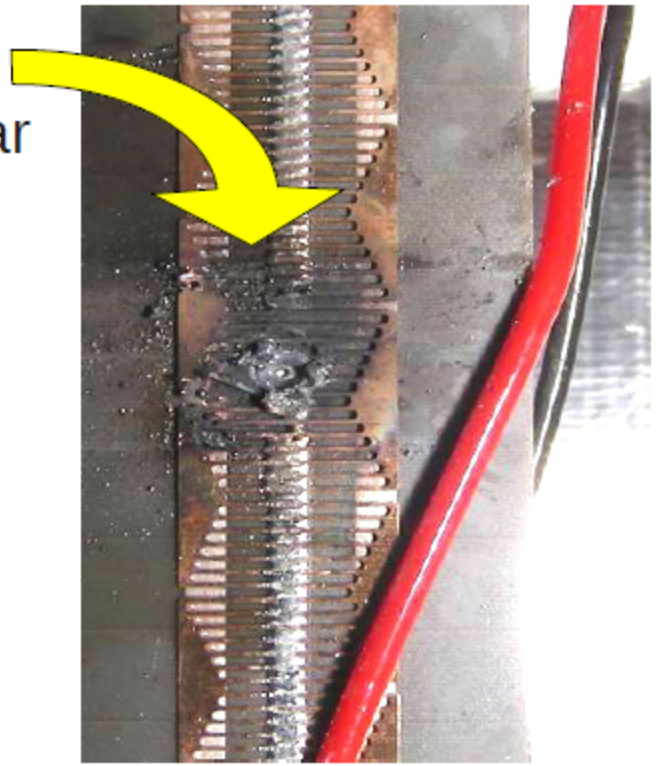
mean lifetime
(MTTF: mean time to failure)



Courtesy of PI Ceramic GmbH

Piezo driving

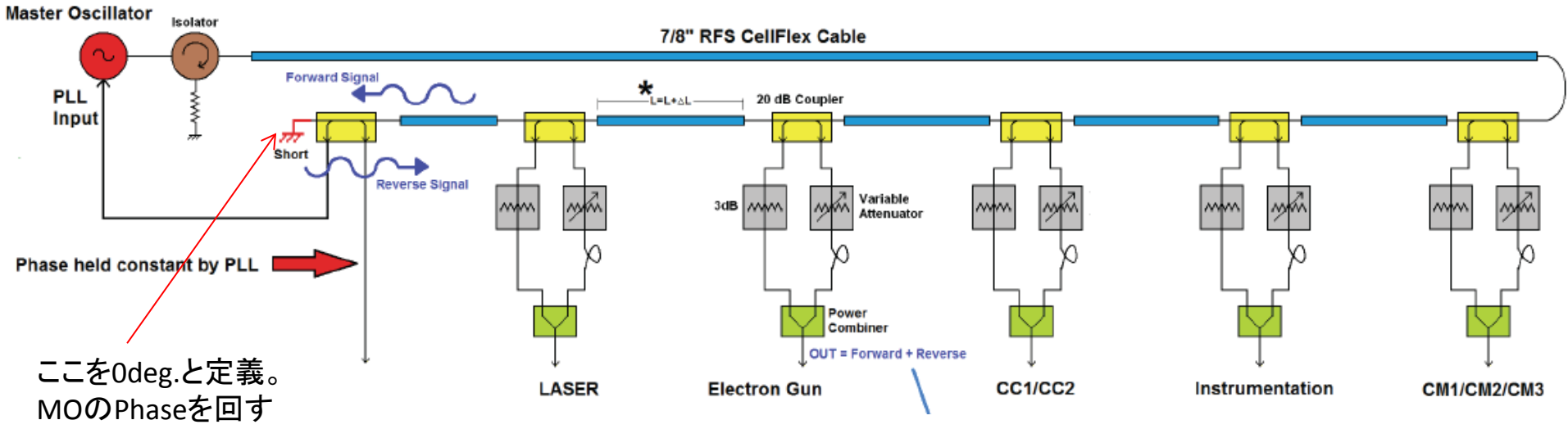
- We need for LFD compensation the peak-to-peak voltage. For unipolar operation the maximum piezo voltage is ~2x higher than for bipolar mode. That reduces reliability.
- Bipolar driving while piezo is worm is dangerous. Piezo can be broken with relatively low voltage. Therefore bipolar driving must be done together with temperature checkout



Note: limiting the voltage to ±50V may also benefit from looser safety requirements. ±50V still allows to compensate LFD up to ~40MV/m (pulse ±45V was sufficient to compensate LFD at 42MV/m)

1.3 GHz Phase Averaging Reference Line ASTA

Ed Cullerton, Brian Chase @FNAL



ここを0deg.と定義。
MOのPhaseを回す

* original design concept by J. Frisch, D. Brown, and E. Cisneros

* changes in cables lengths between tap positions due to temperature changes ($L = L + \Delta L$)

the output becomes: $OUT = A_F \cos(\omega t + \phi_F + \Delta\phi_F) + A_R \cos(\omega t + \phi_R - \Delta\phi_R)$

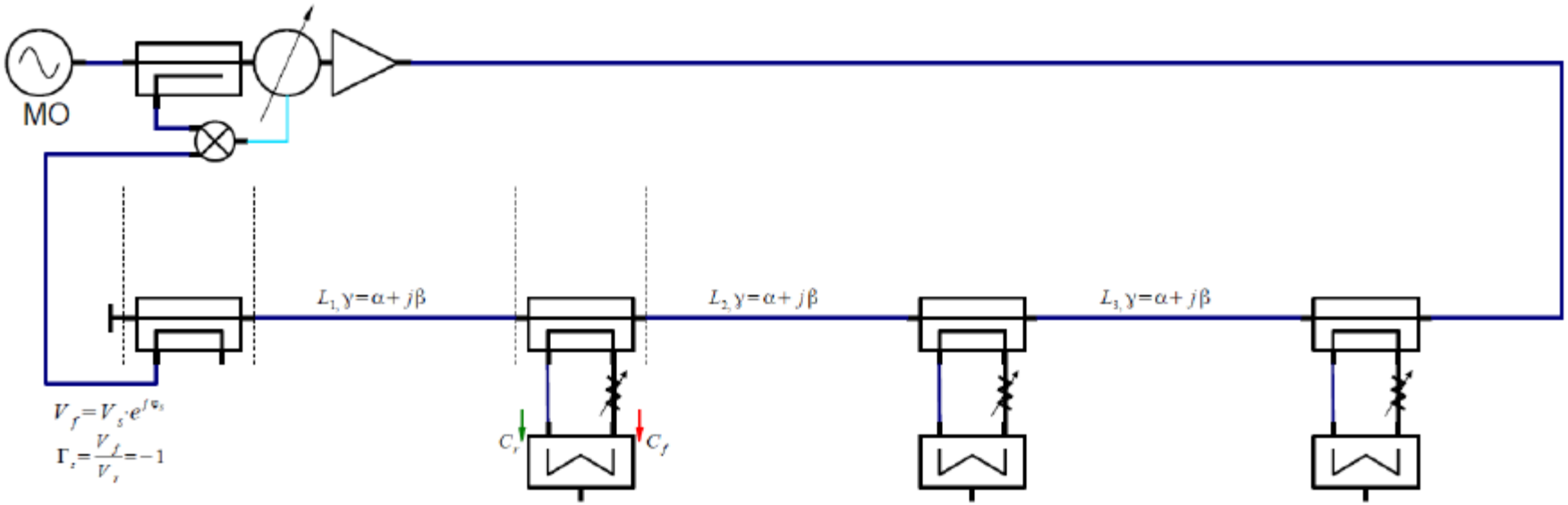
Forward Reverse

When the phase at the shorted end of the reference line is held constant, $\Delta\phi_F = -\Delta\phi_R$

When $\Delta\phi_F = -\Delta\phi_R$,

$$\arg\{A_F \cos(\omega t + \phi_F + \Delta\phi_F) + A_R \cos(\omega t + \phi_R - \Delta\phi_R)\} = \arg\{A_F \cos(\omega t + \phi_F) + A_R \cos(\omega t + \phi_R)$$

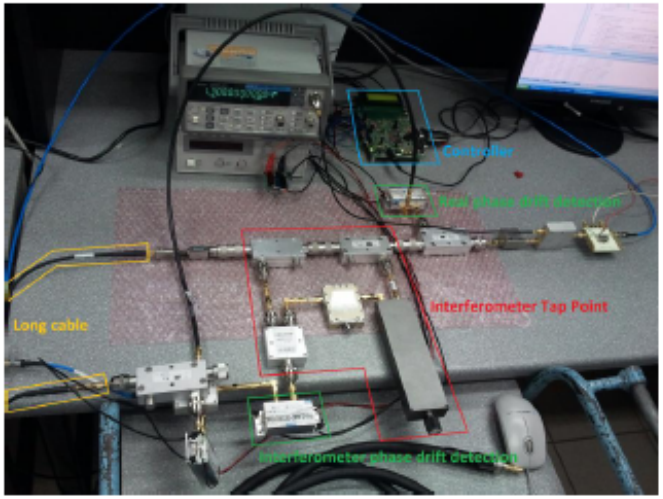
Interferometer Link

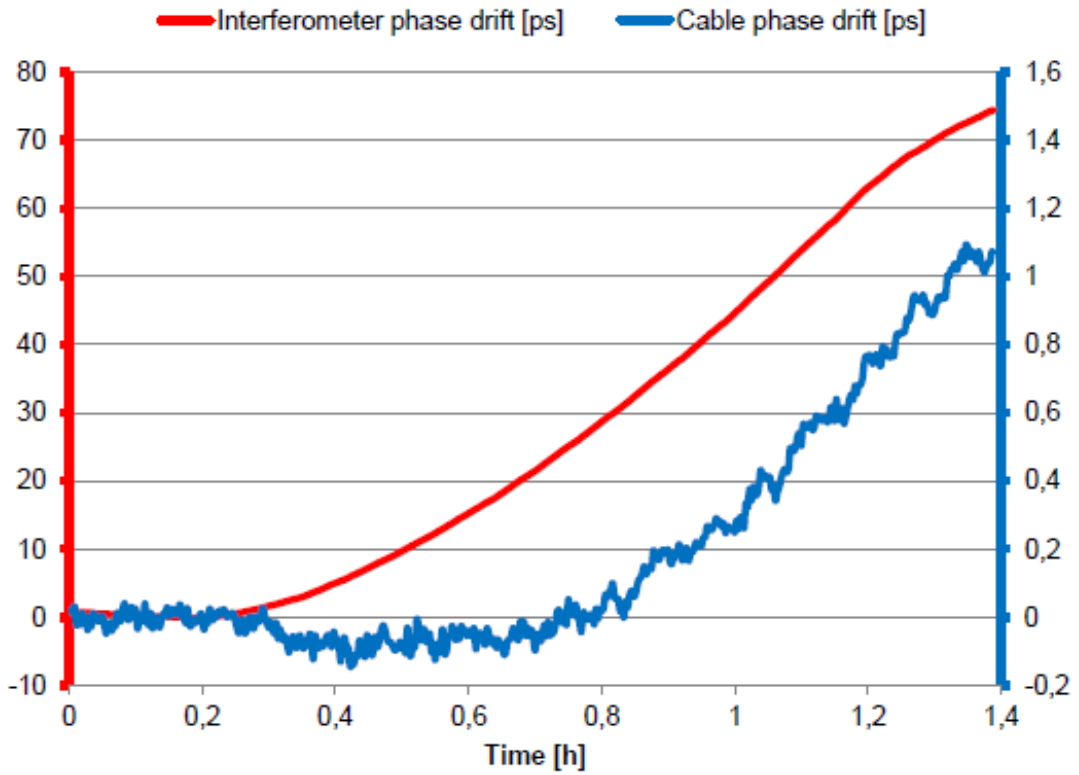


- Idea of phase averaging reference line by Brian Chase and Ed Cullerton @FNAL
- Performance limited by cable loss and coupler directivity
- Feasible distribution distances up to
  - 150m (7/8" cable, 1.3 GHz, 3 tap points)
  - 250m (7/8" cable, 1.3 GHz, 1 tap point)

Prototype Interferometer Link Tests

- Tested on the bench, no temperature stabilization
- Cable drifts up to 30 ps are compensated to 80 fs p-p over long term (suppression >300)
- This can be improved by stable mechanical design and temperature regulation
- Above 30 ps output phase drifts more (suppression 70 to 100), not well understood so far



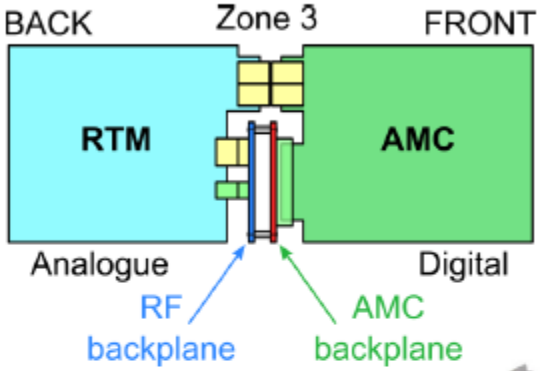


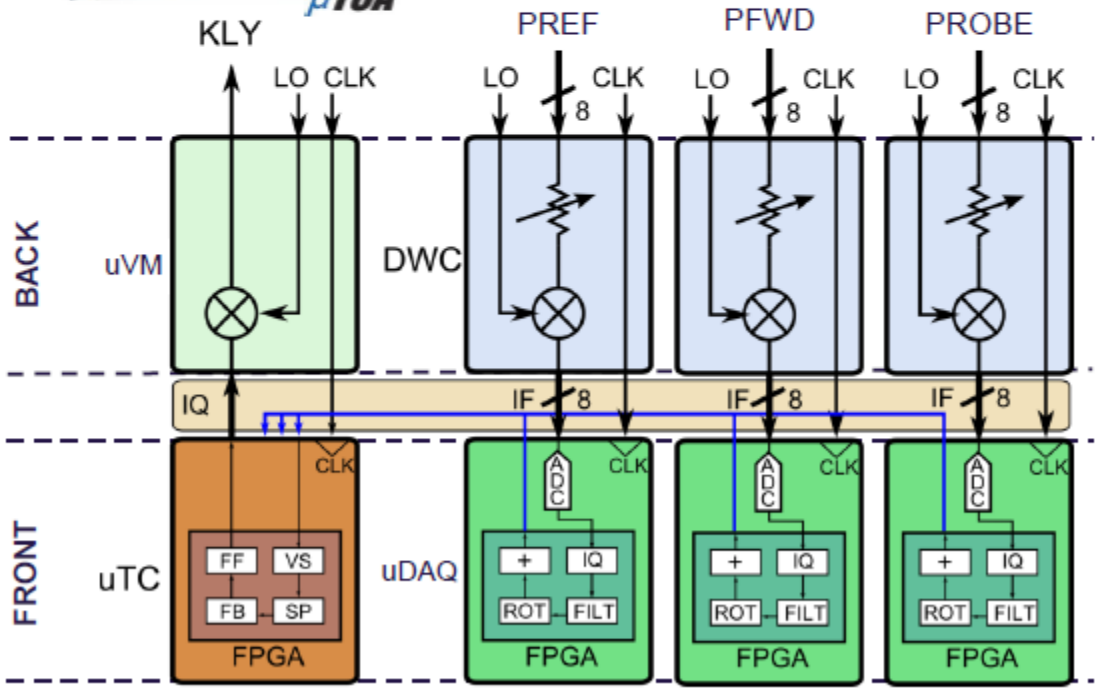
位相ドリフトの絶対値は小さくなったが、
他のポートの方向性結合器からの反射でギザギザしているようだ。
→ 補正が難しい

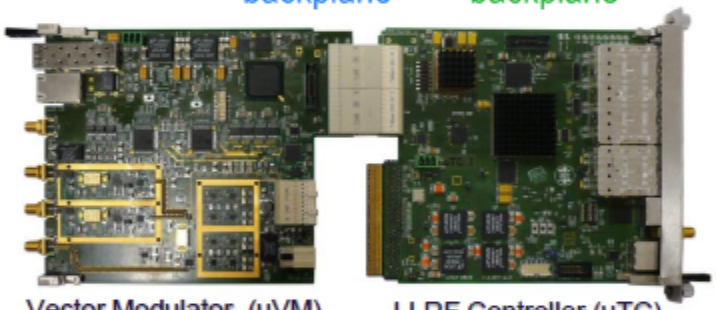
European XFEL

The MTCA.4 LLRF system

- AMC: Advanced Mezzanine Card
- RTM: Rear Transition Module
- 12 slots, hot swap
- Redundant power supply

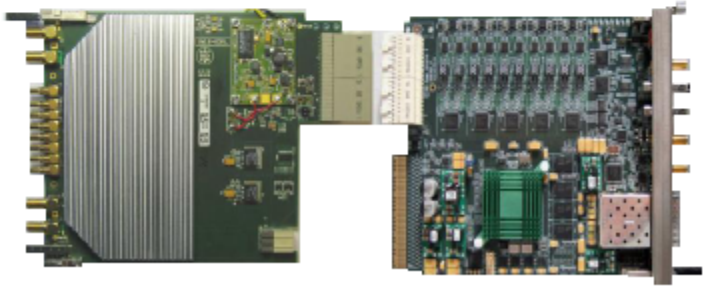






Vector Modulator (uVM)

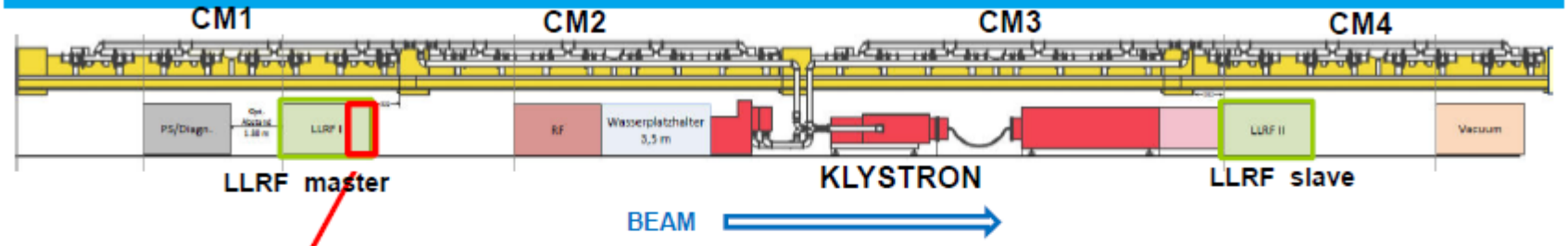
LLRF Controller (uTC)



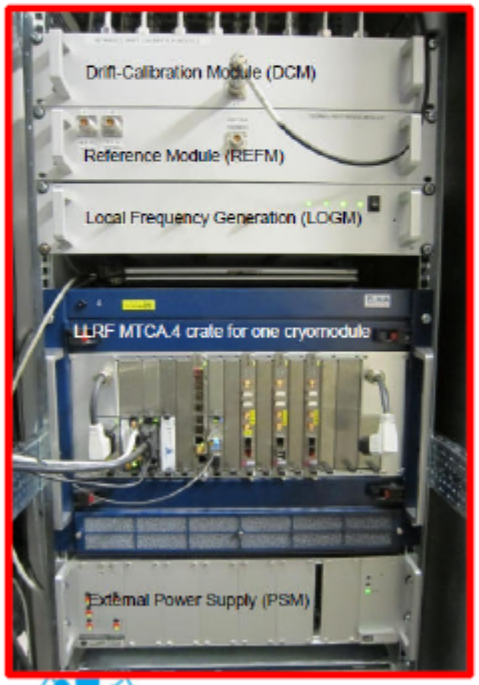
Down Converter (uDWC)

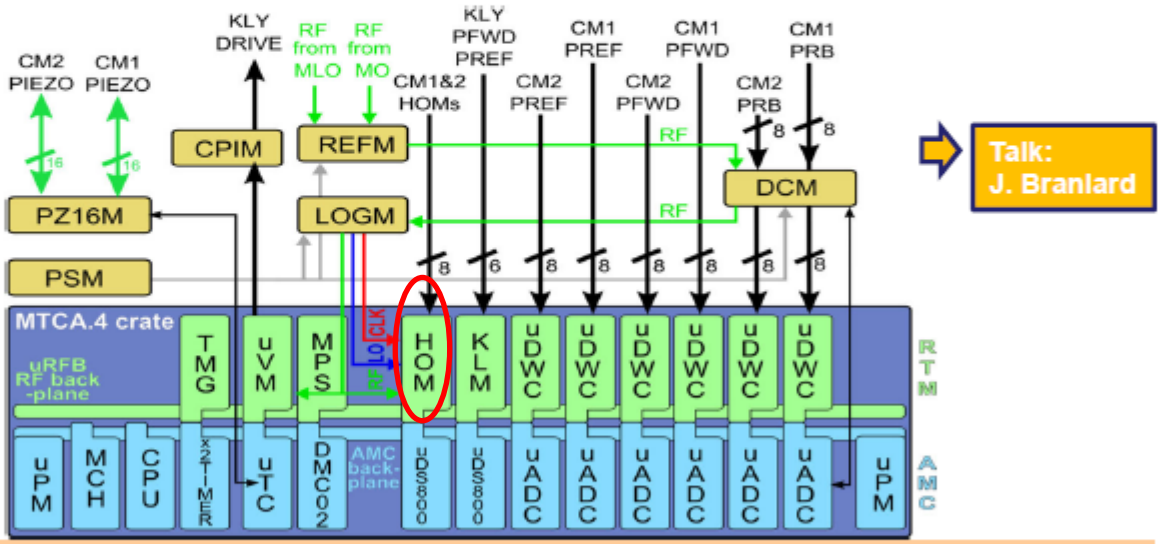
Digitizer (uADC)

Work accomplished 2011-2013: XFEL LLRF System



< 28U Rack





Talk: J. Branlard

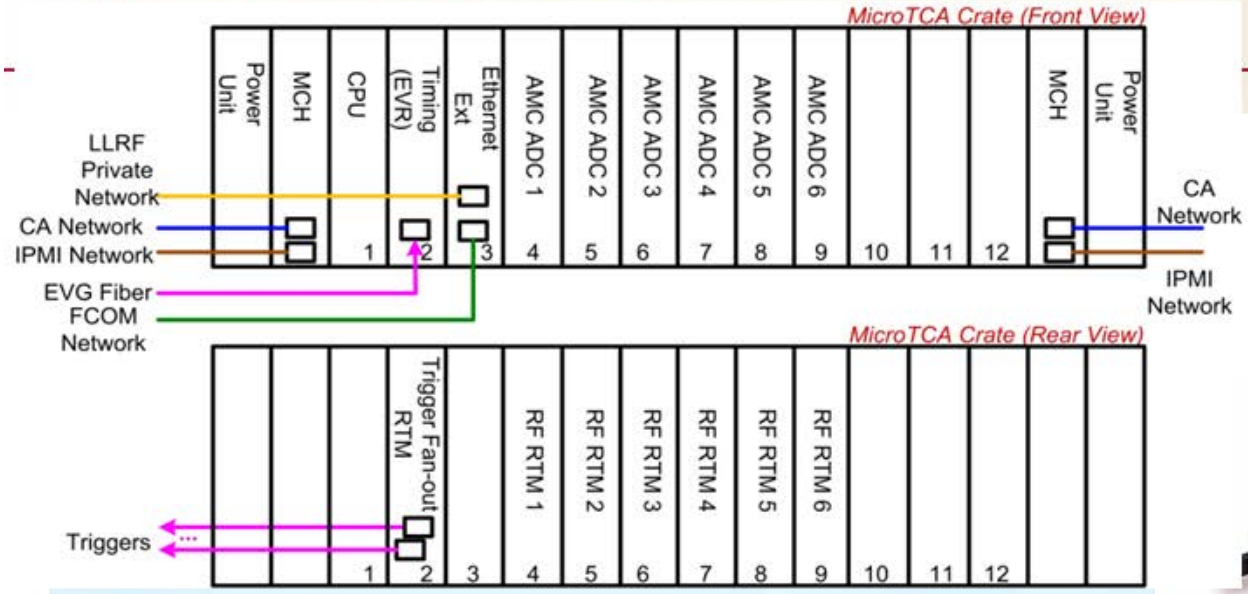
- MTCA.4 incl. complete sweet: LLRF/Diag./ Interlocks/HOM

Challenges:

- **Total: 27 RF station / 800 cavities / >3000 RF signals**
- **Stability requirements < 0.01% & 0.01deg**

SLACもMicroTCAを採用。タイミングシステム用EVRも搭載

MicroTCA Crate and FPGA AMC Board

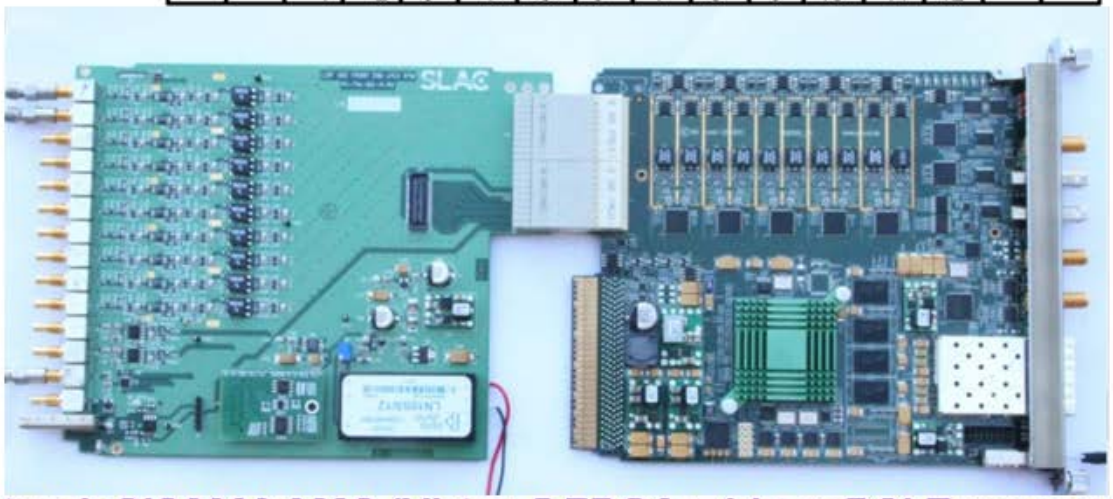


amc_adc: SIS8300 + RTM

- CH0: Reference IF
- CH1: Up Converter Output IF
- CH2: SSSB Output IF
- CH3: Klystron Output IF
- CH4: ACC Input IF
- CH5: ACC Input Reflection IF
- CH6: ACC Output IF
- CH7: ACC Output Reflection IF
- CH8: Klystron Beam Voltage

Vadatech MCH UTC002

ADLINK AMC-1000 CPU



Struck SIS8300 AMC (Virtex 5 FPGA ; 4 lane PCI Express; 10 Channels 125 MS/s 16-bit ADC; Two 250 MS/s 16-bit DACs; Twin SFP Card Cages)