HLRF
Summary and Work Assignment

S. FUKUDA
KEK

Content

- **Current Status of XFEL**

  HLRF status, LLRF status

- **LLRF Issues for HLRF related**

  Overhead issues, LLRF for NML, LLRF for S1 in KEK

- **R&D Status, S1 global**

  Marx Modulator, SBK, PDS in SLAC, PDS for S1,S1 global in KEK

- **Consideration for the Ql variable and P variable**

  Julian's talk, Noguhi's talk, Chris's talk

- **Discussion and work assignment**

Status of HLRF in XFEL

Presented by S. Choroba

- Historical data of 8 V. MBKs are explained.
- Three H. MBKs are under progress. Toshiba H. MBK's performance was excellent. Eff. of 65.4% was achieved.
- DESY's cooling system was introduced. Actual data and experience was useful for ILC cooling system.
- Additional commercial vendor's modulator was under progress: Bouncer type and PSM modulator.
- Current PDS, composed of asymmetric shunt tee, fixed phase shifter, shunt tee with integrated phase shifter and 500kW circulator, was explained, Latest operation status were reported.

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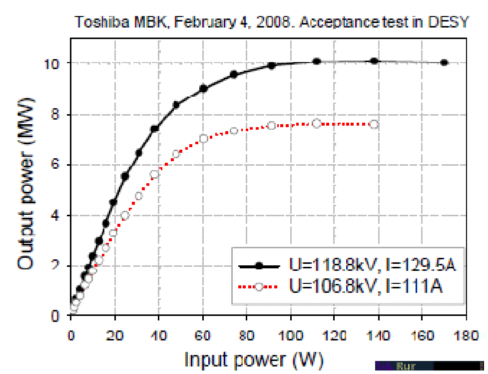
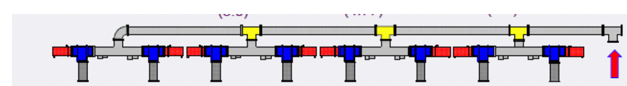




Overhead Issues for LLRF

Presented by S. Michizono

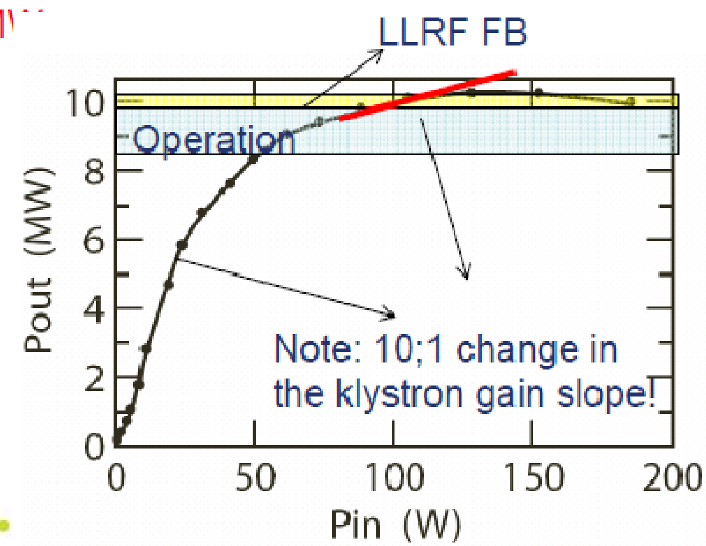
- RF power budget
  - cavity input 8.02 MW (33 MV/m * 1.038 m * 26 cav. * 9 mA)
  - cavity reflection (or tuning error) 1% (VSWR~1.2)
  - non-optimal coupling 1% (if overcoupling)

(We should also consider the rf-output reduction due to the rf reflection to klystron)

  - rf loss 8.54% (should be minimized!)
  - beam fluctuation 1% (should be compensated by fast feedforward)
  - modulator ripple 2.5%
  - cavity detuning 2% (corresponding to ***40 Hz peak*** of Lorentz force and microphonics)
- Remained rf power:

  10 MW – 8.02 MW*(1.01^3 * 1.025 * 1.02)/(1-0.0854)=0.56 M
- LLRF feedback overhead
  - 8.02* (1.01 * 1.025 * 1.02* x)/(1-0.0854)=10

    -> x=1.059 (6%) ***(3% in amplitude)***
  - The overhead is used for field regulation.
  - Performance of the field stability depends on
    - feedback gain
    - additional rf power
- Strategy for cavity quench or mistuning should be considered.



Status of LLRF in XFEL and STF

Presented by S. Michizono/S. Simrock, V. Ayvazyan

Summary

- FLASH and STF-0.5 study (without beam) indicate that 10%-15% actual llrf overhead will be necessary.
- This does not include the rf losses due to
  - reflection from waveguide system (additional ~1%)
  - performance change of klystron due to reflection (~?%)
  - coupler (over-coupled) (additional ~2%)
  - beam compensation (additional ~1%)
  - Lorentz force detuning (additional ~2%)
  - *any other items to be discovered…*
- Total overhead (llrf feedback + additional fluctuation) should be 17%~22%. (overhead after ML KO meeting is14%.)

- Increase in total overhead could be the cost-driver but this is the “trade-offs” (cost v.s. field stability, high availability).

LLRF in NML

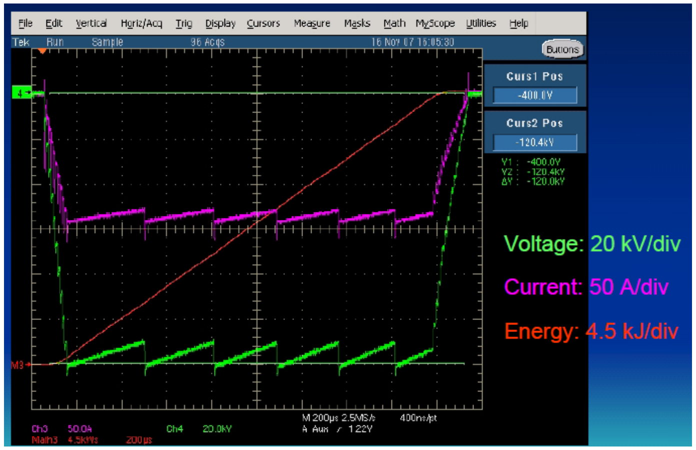
Presented by B. Chase

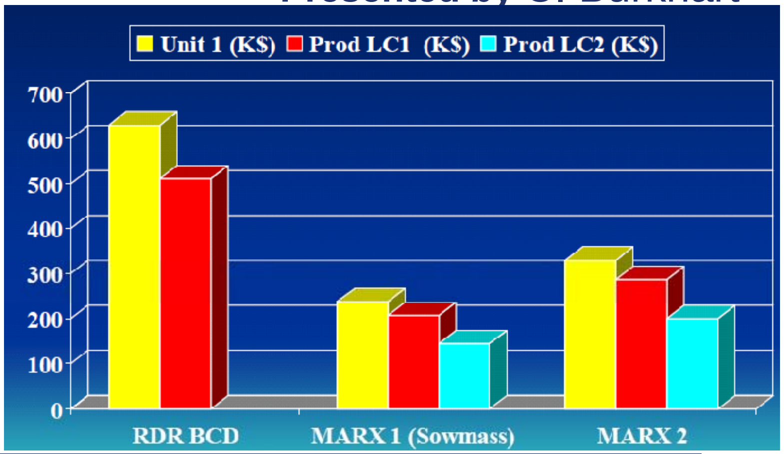
- Plan and time table of NML was reported.
- Revised NML technical plan after the budget reduction was shown.
- Basic LLRF support for cryomodule testing in the refined short term goal is highest priority.
- Important schedule:

Delivery of WG from SLAC	June/08
1st Cryomodule delivery to NML	July/08
Install LLRF	Aug/08
1st Cryomodule RF warm test	Sep/08
Begin Cold RF test	Feb/09

Marx Generator Status

Presented by C. Burkhart

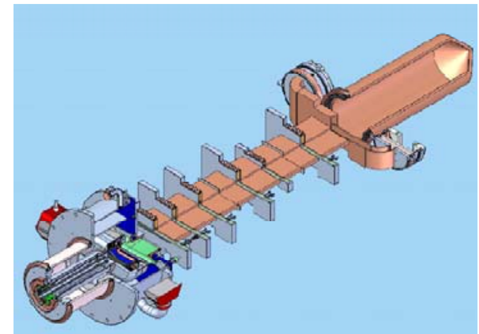


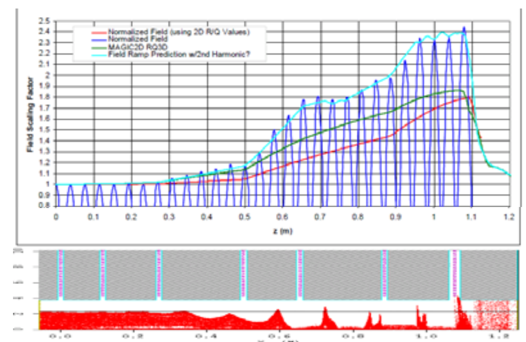


- P1-Prototype Nearing Completion (FY08-Q3)
- Integrate P1 into L-band Facility (FY08-Q4) Initiate Life Testing of Marx and MBK
- Complete Vernier Regulator and Integrate into P1 (FY08-Q3/4)
- Nth Unit Cost Re-examined: $200k - 290k, ~30% Increase from Snowmass '05 Estimate
- P2-Prototype Development FY09-10

SBK Development in SLAC

Presented by E. Jongewaard





- R&D Development of L-band SBK was presented. Design was explained. Manufactured parts were shown.
- Current status;

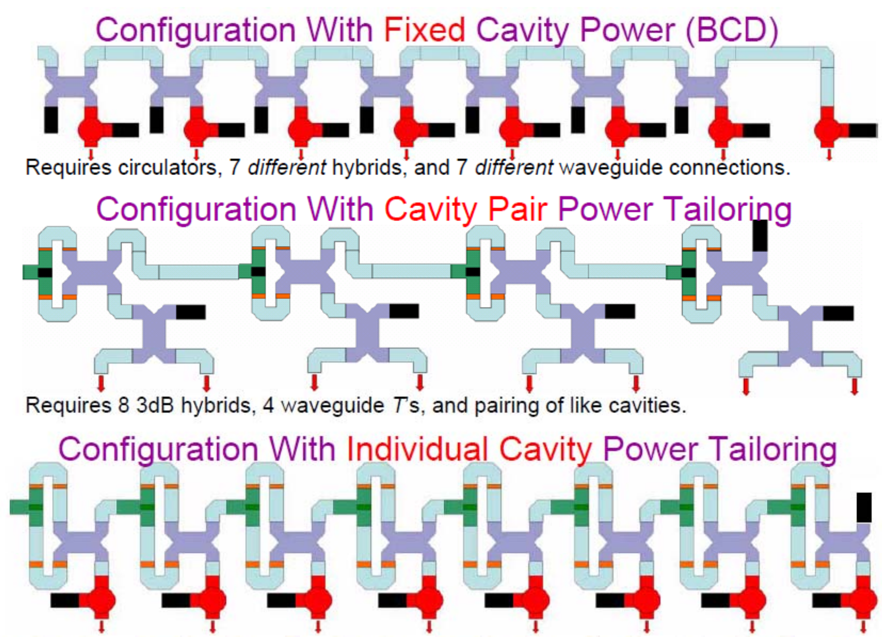
  1^{st} cathode in QC. Anode parts in QC. Beam diagnostic tester was under progress.
- Test of beam tester at 3^{rd} Q/Fy08.
- 1^{st} SBK test at 1^{st} Q/Fy09

PDS Status in SLAC

Presented by C. Nantista

- Cold measurements of PDS components and assembly was shown.
- Scheme without circulators are discussed. **Simulations suggest that with pairing of cavities to allow identical QL's, elimination of circulators should not pose a problem to field stabilization.** Experimental demonstration at NML.
- Alternative to VTO was considered and discussed.

To reduce cost, elimination phase sifter and simplifyin VTO are introduced.

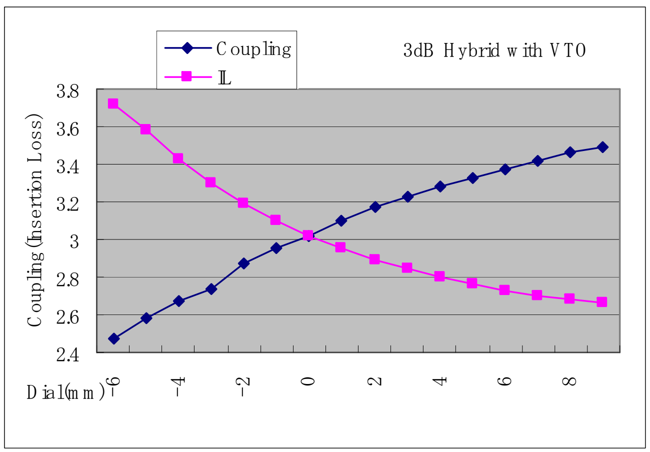


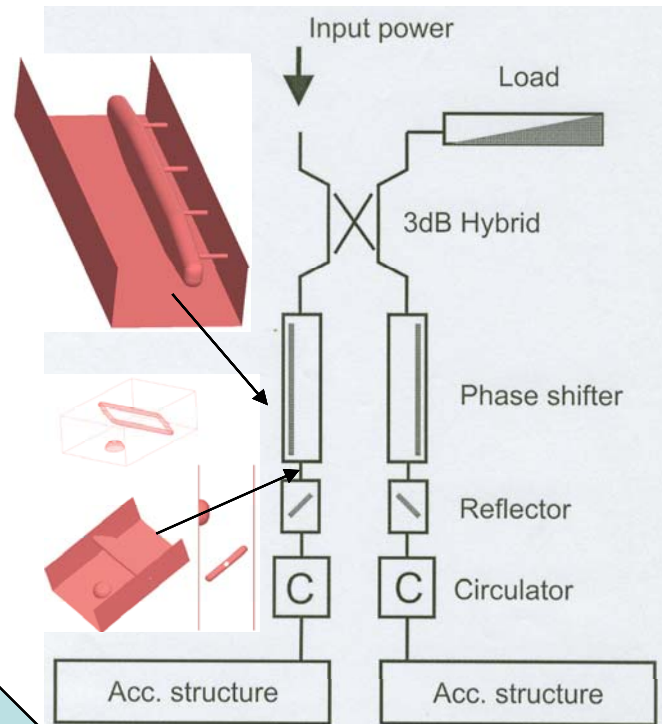
PDS for S1 and S1 Global in KEK

Presented by S. Fukuda

3dB / 4.7dB Hybrid with VTO（KEK) :cheep & Simple. Isolation of 30dB. +-10% variable

Possible scheme of impedance adjusting:





6dB with VTO is not available.

Applicable to ILC PDS such as 9-cavity?

How about the circulator elimination?

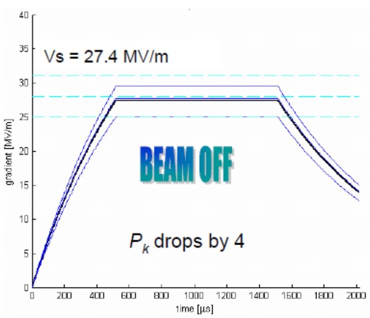
Cost comparison Between the elimination of coupler tuner and this system.

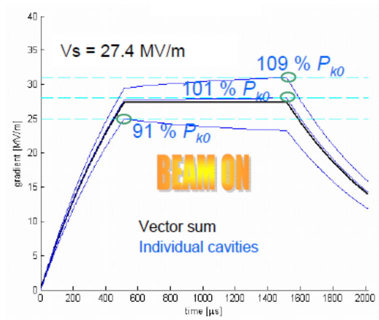
Optimal Ql &Pk Settings for all Beam Currents

Presented by J. Branlard

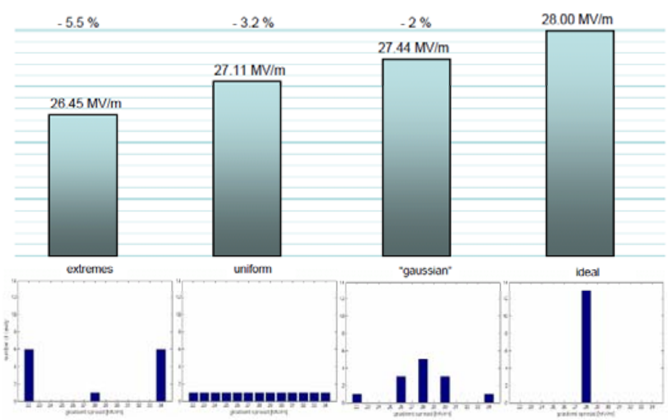
This approach: individual P_k, same Q_L (optimized for beam)

1 - choose Q_L	→ sets $\tau = 2Q_L / \omega_0$
2 - choose $t_{inj} = \tau \ln 2$	→ guaranties flat top when beam is OFF
3 - distribute power so that $\frac{1}{N}\sum_i I_{gi} = 2I_{b0}$	→ guaranties flat top when beam is ON
4 - check if cavity exceeds limit	→ new Q_L for maximum Vs (optimization)





Impact of the cavity gradient distribution for a fixed 22-34 MV/m spread



Approach comparison - summary

Approach	indiv. Q_L, indiv. P_K	same Q_L, indiv. P_K
Maximum gradient	28 MV/m	27.4 MV/m
P_{FWD} (total 26 cavities)	7.4 MW	6.6 MW
P_{REF} (total 13 cavities)	540 kW	40 kW
Operate at any beam current	No	Yes
Operate without individual coupler tuning	No	Yes

for a uniform gradient spread ranging from 22 MV/m to 34 MV/m

+ We can maintain a constant vector sum for the entire flat top duration and for 0 to full beam current
- We operate at a gradient below the maximum gradient (~ -2% depending on cavity spread and distribution)
+ The total reflected power during beam is reduced by 0.5 MW
+ All cavities operate with the same loaded Q → similar control response

Gradient for various RF dist systems and cost of Dist components

Presented by C. Adolphsen

Cost Comparisons for Single Feed Syster

(Assumes 22-34 MV/m Flat Gradient Distribution)

Adjustability	Cost of P+Q	Loss of Grad	Cost Of Grad	Net (M$)
P + Q	48 + 18	0	0	66
P, No Q Narrow G*	48	1.5%	75	123
No P, Q Baseline	18	2.7%	135	153
P+Q but Q common	48 + 18	3.0%	150	216

* Assumes Gaussian (4.5% sigma) gradient spread (no sorting), full wall plug power if run at lower currents and increased cooling water overhead.

Consideration for the Ql variable and Pk variable

Gradient for various RF dist systems and cost of Dist components

Presented by C. Adolphsen

Gradient Optimization with and Without VTOs and Circulators

Consider uniform distribution of gradient limits $(G_{lim})_i$ from 22 to 34 MV/m in a 26 cavity rf unit - adjust cavity Q's and/not cavity power (P) to maximize overall gradient while keeping gradient uniform (< 1e-3 rms) during bunch train

Optimized $1-\langle G\rangle/\langle G_{lim}\rangle$; results for 100 seeds

Case	Not Sorted [%]	Sorted [%]
Individual P's and Q's (VTO and Circ)	0.0	0.0
1 *P*, individual *Q*'s (Circ but no VTO)	2.7 ± 0.4	2.7 ± 0.4
P's in pairs, *Q*'s in pairs (VTO but no Circ)	7.2 ± 1.4	0.8 ± 0.2
1 *P*, *Q*'s in pairs (no VTO, no Circ)	8.8 ± 1.3	3.3 ± 0.5
G_i set to lowest G_{lim} (no VTO, no Circ)	19.8 ± 2.0	19.8 ± 2.0

Gradient for various RF dist systems and cost of Dist components

Presented by C. Adolphsen

Summary of RF Dist Costs

(For RDR, 560 rf units at 296 k$ per system = 166 M$)

Configuration	8-Cavity Cost (k$) (small quantities)	Cost (M$) Differences Scaled to ILC	Cost (M$) due to Gradient Loss*	Net Cost Change (M$)
Baseline	282	-	135	135
ACD Two Feed	260	-13	40	27
ACD Two Feed Economy Version	216	-39	40	1
ACD One Feed Economy Version	322	+24	0	24

* For ACD Two Feed case, assume 0.8% grad loss if 26 cavities sorted in pairs by grad

Maximum Gradient Operation

Presented by S. Noguchi

Cost Comparison

ML costs 4000 MILC, Assembly & Tuning Cost are not evaluated.

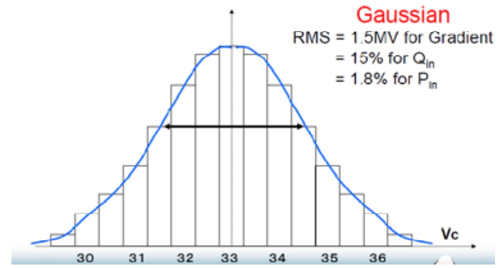
	Energy Reduction	Extra Cost	Devise Cost	Total Cost-Up
No Tuning	> 10 %	> 400	0	> 400
Full Tuning	0	0	60 + 60	120
Coupling 2.5 – 6.7 x 10^6	1.8 %	72	60	132
Power 227 – 347 kW	1.5 % 1.6 % (5mA)	60	60	120

Simple 1mA Beam Tuning

If we do not Re-tune the power Ratio, Pulse Head Gradient have to be Reduced in some Low Gradient Cavities.

Then the Gain Reduction becomes 1.8 % in 9 mA Operation.

Realistic Gradient Distribution



Summary

- Cavity Grouping Scheme is Proposed. Power Effective, Small Tuning Range & Less DLD Effect.
- If we use this scheme, and assume the following number, the coupling tune-ability may be not cost effective.
  Coupling Error : 15 % RMS
  Gradient Distribution : 1.5MV RMS
- Input Coupler must have a capacity of 400 kW.
- Precise Evaluation of cost performance is necessary.

SCRF PM Meeting @ FNAL
2008/4/22, S.Noguchi
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Discussion and work assignment

Overhead Issues

- Overhead for LLRF feedback is obviously small as long as we start from the BCD parameter of 33MV/m gradient.
- And this value is very ambitious for cavity technology nowadays.
- It is necessary to check the various overhead (such as the micro phonic effect and so on) experimentally by making use of XFEL.

  So making the action plan to list up the important items to be measured at TTF.

Overhead Issues (2)

- Possible solutions to solve the poor overhead are as follows;

(1) Increase the output power of the klystron by raising the power from the wall-plug. (cheapest)

(2) Decrease the numbers of cavity in a unit, and increase the klystron units.

(3) Lower the gradient and increase the RF unit (highest cost).

It is necessary to argue what is the most cost effective among the all technical group.

It is worth value to have an R&D for the klystron to increase the output power, for example, up to 12MW.

It is necessary for ILC to collaborate with the vendor if they need the extra cost to develop this plan.

Pk and Ql Issues

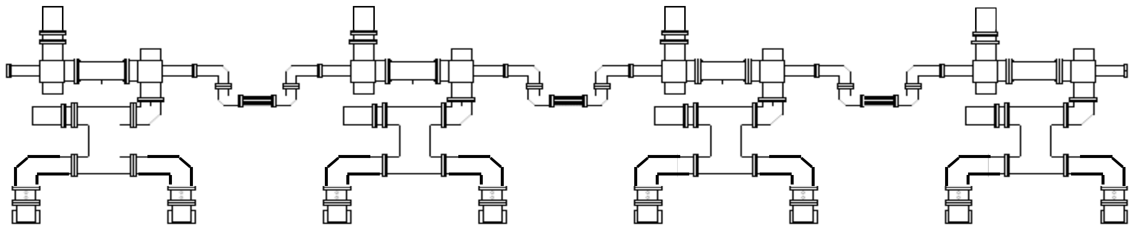
- **Three interested schemes of Julian, Noguchi and Chris are discussed. Each of them has the attractive feature.**
  - **Chris's scheme: flat field in the cavity with a beam. Most cost effective. some amounts of reflection.**
  - **Julian's scheme: flat without a beam and small refection even with a beam. Lower acceleration, so not cost effective. Some gradient distributions are introduced.**
  - **Noguchi's scheme: Similar approach as Julian, while grouping of the cavity gradient is taken into account. Spread of cavity gradient distribution after choosing the narrow bin of the gradient are taken into account.**

Pk and Ql Issues

- Three schemes are involving the P's and /or Ql's adjustment.
- Study for these scheme using STF, NML and XFEL to evaluate their characteristics is important.

Elimination of the circulator

- PDS Scheme of Pairing two cavities, with the high isolation power splitter (>40dB) may a solution of eliminating the circulator.



- Scheme of tailoring power distribution with spacers and 3dB hybrid was also introduced.

- If one cavity was deteriorated completely, effect to the next cavity is negligibly small and the reflected power is roughly 1/26**2.

- C. Nantista showed some case studies.
- C. Adolphsen showed cost comparison with/without circulator.

- Experimental result will be shown in NML in FNAL. KEK also has an experiment without circulator.

Summary

- HLRF session included many presentations covering XFEL status, LLRF, R&D status and discussion about the QI's and Pk's issues. Useful discussions were performed in this meeting.
- Understanding of overhead proposed by LLRF was obtained, and tasks are presented.
- Qi's and Pk's issues requires the experimental evaluation in each laboratory.
- Elimination of the circulator should be checked by experimental evaluation too.
- Listing HLRF Tasks for the test in XFEL is highly desirable.