中国科学院近代物理研究所 Institute of Modern Physics, Chinese Academy of Sciences

中國科學院 CHINESE ACADEMY OF SCIENCES

IPAC 2017, Copenhagen, Denmark, May 15th ~19th, 2017

High intensity RFQs:

Review on Recent Development, Common Problems, Solutions

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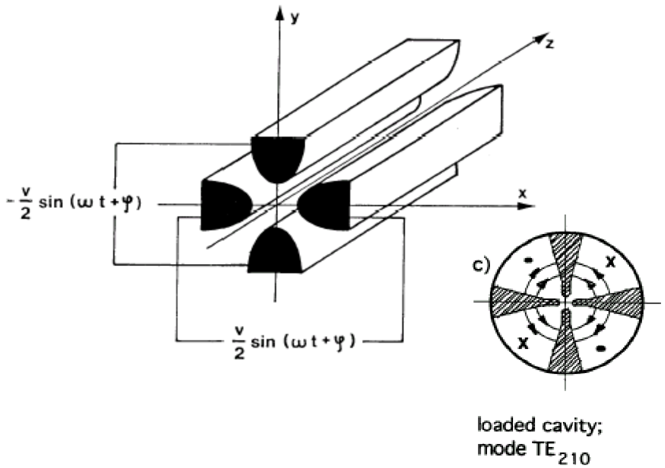
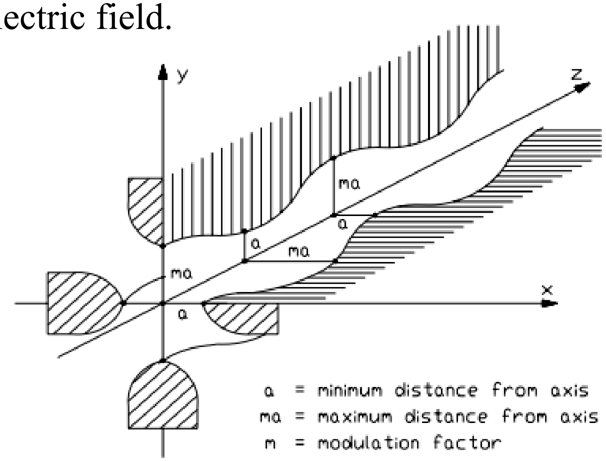
Outline

- Introduction of RFQ accelerator
- Recent progress of high intensity RFQs
- Common problems and solutions
- Summary

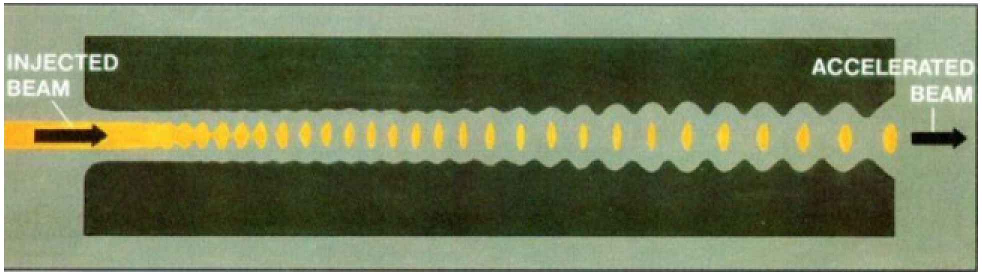
Introduction of RFQ accelerator



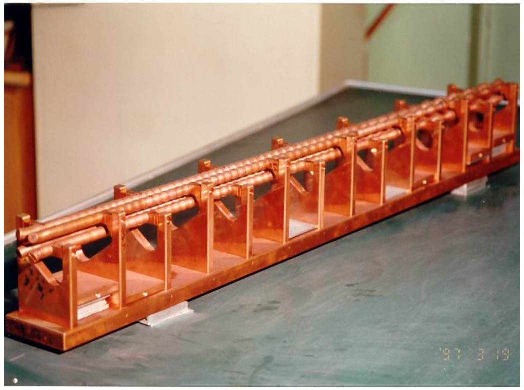
Four electrodes forms quadropole focusing electric field.



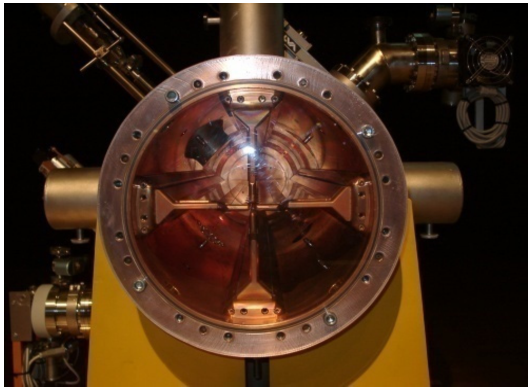
Modulation on the electrodes forms the acceleration electric field.



- The mostly first element for hadron accelerator
- To focus, bunch and accelerate beam in a several meters channel
- Beam energy ranges from several keV to MeV.
- 4-vane and 4-rod are most popular geometric structures.



Frankfurt, 4-rod, 202 MHz



1980, LANL, 4-vane, 425 MHz

Application of High Intensity RFQ

1 **Injector of Accelerator Driven System (Proton, 10s mA, MWs, CW)**

C-ADS, MYRRHA, ……

2 **Injector of Material Irradiation Facility (Deuteron, 10s mA, MWs, CW)**

IFMIF, SARAF, CMIF, ……

3 **Injector of High Flux Neutrino Production (Proton, mAs, MWs, CW/Pulse)**

PIP-II (PXIE), HP-SPL, ……

4 **Injector of Radioactive Beam (heavy ions, ~1mA, hundreds kWs, CW)**

EURO-ISO, RIBF, FRIB, Spiral2, HIAF, ROAN, BISO, ……

5 **Injector of High Flux Neutron Source (Proton, mAs, MWs, pulse)**

ISIS, SNS, J-PARC, CSNS, ESS, ……

6 **Injector of High Energy facility (Proton, mAs, MWs, pulse)**

LHC, HPPC, ……

7 **Stand alone for applications** and so on …

Progress in RFQ family (incomplete)

Project	Lab	Ion	Frequency (MHz)	Voltage (kV)	Vane length (m)	Current (emA)	Duty factor (%)	Inj. E (keV)	Exit E (MeV)	Type	*State*
SNS	ORNL	H-	402.5	83	3.72	38	6.2	65	2.5	4-vane	Upgrade
J-PARC	JAEA/KEK	H-	324	82.9/82.9/81.0	3.11/3.17/3.62	50	3	50	3	4-vane	Upgrade
LINAC4	CERN	H-	352.2	78	3.06	80	7.5	45	3	4-vane	Operation
CPHS	THU	P	325	60-132	3	50	2.5	50	3	4-vane	Operation
CSNS	IHEP	P	324	80	3.62	40	1.24	50	3	4-vane	Operation
IPHI	CEA	P	352.2	80-120	6	100	CW		3	4-vane	Commission
C-ADS inj-I	IHEP	P	325	55	4.69	10	CW	35	3.2	4-vane	Upgrade
C-ADS inj-II	IMP	P	162.5	65	4.21	10	CW	35	2.1	4-vane	Operation
PXIE(PIP II)	FNAL	P	162.5	60	4.21	5	CW	35	2.1	4-vane	Commission
FRANZ	IAP	P	175	75	1.75	200	CW	120	0.7	4-rod	Commission
SARAF	SNRC	D	176	65	3.8	5	CW	20	3	4-rod	Upgrade
IFMIF	*INFN*	*D*	*175*	*79-132*	*9.8*	*130*	*CW*	*50*	*5*	*4-vane*	*Assembly*
CIMF	*IMP*	*D*	*162.5*	*65*	*5.27*	*10*	*CW*	*20*	*3*	*4-vane*	*Construction*
SSC-Linac	IMP	A/q=7	53.667	70	2.51	0.5	CW	25	1	4-rod	Operation
Spiral2	GANIL	A/q=3	88	100-113	5	5	CW	60	2.25	4-vane	Commission
FRIB	*MSU*	*A/q=7*	*80.5*	*60-112*	*5.04*	*0.45*	*CW*	*84*	*3.5*	*4-vane*	*Assembly*
LEAF(HIAF)	*IMP*	*A/q=7*	*81.25*	*70*	*5.98*	*2*	*CW*	*98*	*3.5*	*4-vane*	*Construction*

- The high intensity RFQs include proton, deuteron and high ions machines.
- Most efforts and problems are on the CW high power RF and high power beam.

Outline

- Introduction of RFQ accelerator
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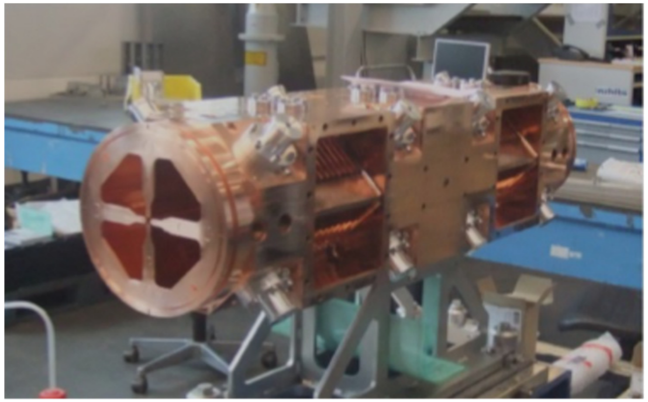
SNS RFQ at ORNL

2.5 meV, 38 mA

Original RFQ (one segment shown):
Designed and fabricated by LBL
Made from GlidCop and Copper

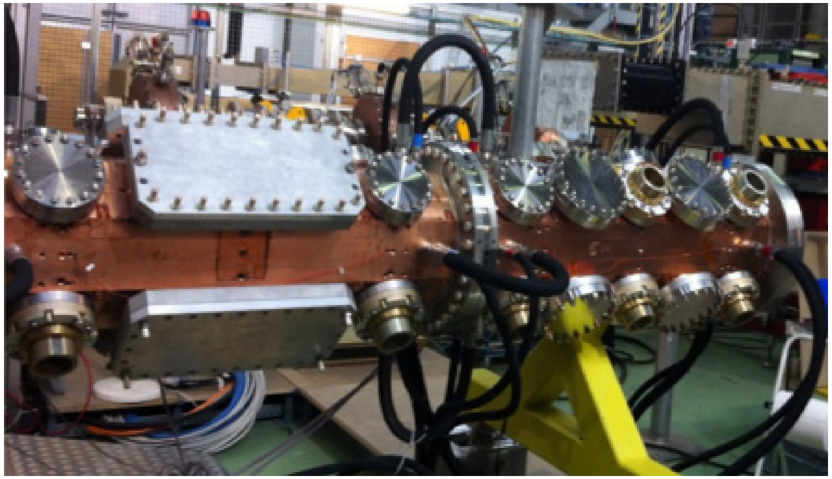


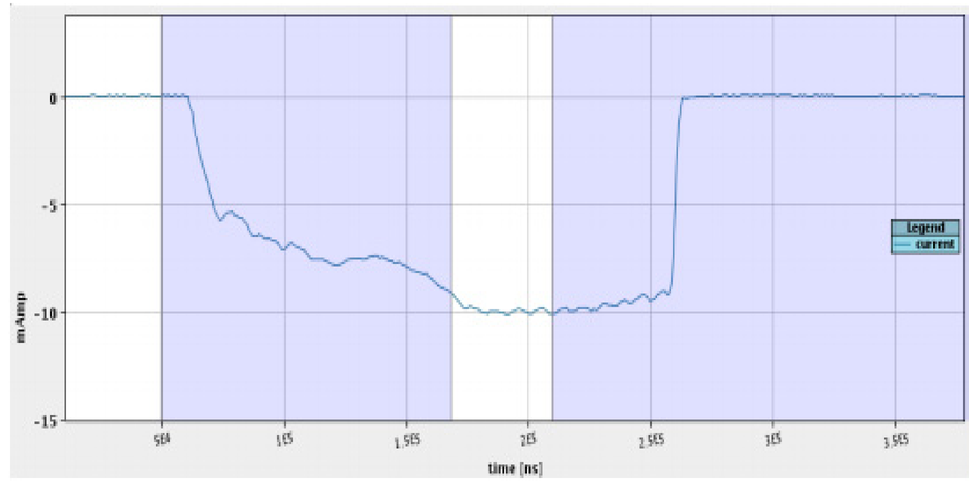
New RFQ (one segment shown):
Designed and fabricated by RI
Made from Copper (no GlidCop)
Better vacuum pumping Better water cooling More robust

- Original RFQ has a troubled history
  - First beam at SNS in 2002
  - Since then, 3 distinct detuning events – mostly corrected by re-tuning
  - Over 20% decrease in transmission
- New RFQ
  - Ordered in 2010, received in 2014
  - First beam on September 8, 2016 (on test stand)
  - Demonstrated correct energy and transmission and emittance
  - Demonstrated full duty factor (60 Hz, 1 ms, 38 mA) operation
  - Plan to install January 2018

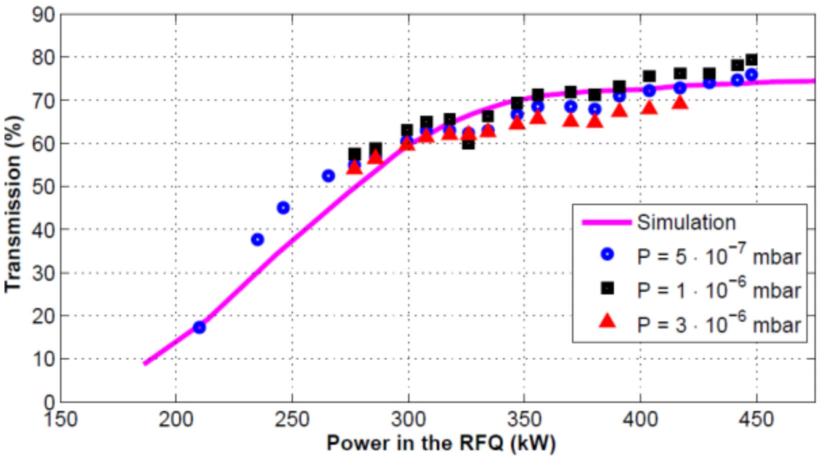
LINAC4 RFQ at CERN

3 meV, 80 mA

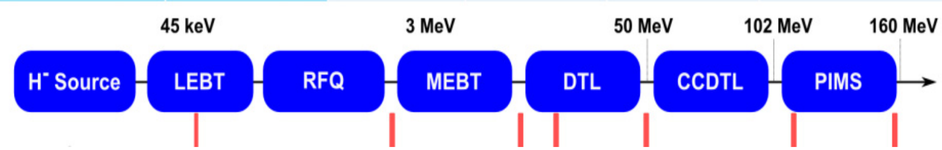




March 2013, first beam, 10 mA, 250 us / 1 Hz



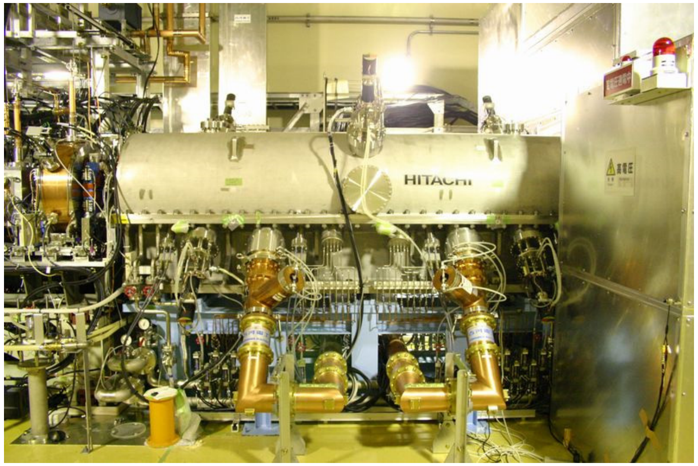
45 keV	3 MeV	12 MeV	50 MeV	105 MeV	160 MeV
Not yet the final source – details later (50mA standalone) (30mA-Nov15)*****	Octobre 2013 (10mA- Aug 14) (30mA-oct 15) (20mA-Nov15)	August 2014 (10mA- Aug 14) (20mA – Nov15)	November 2015 (20mA – Nov 15)	June 2016 (20mA – June16)	Octobre 2016 Ongoing! (20mA – Dec16)



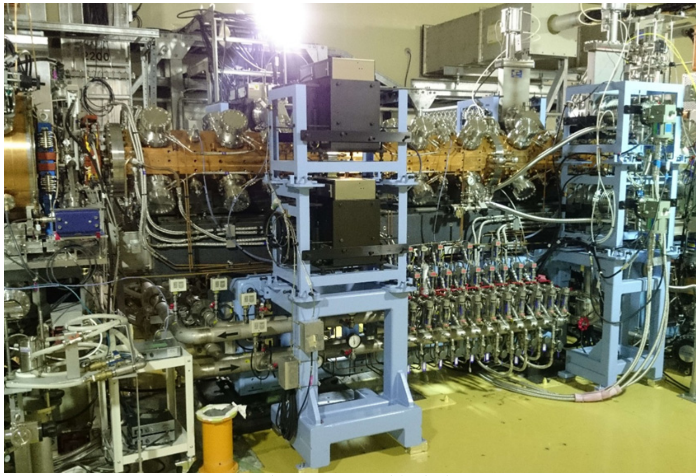
- The measured emittance in LEBT was bigger than the RFQ acceptance.
- The LEBT H_2 pressure was changed to study the effect of space charge at low energy matching. for each pressure a different setting of the LEBT solenoid had to be applied to rematch the beam and to recover the transmission.

J-PARC RFQs at JAEA/KEK

3 MeV, 50 mA



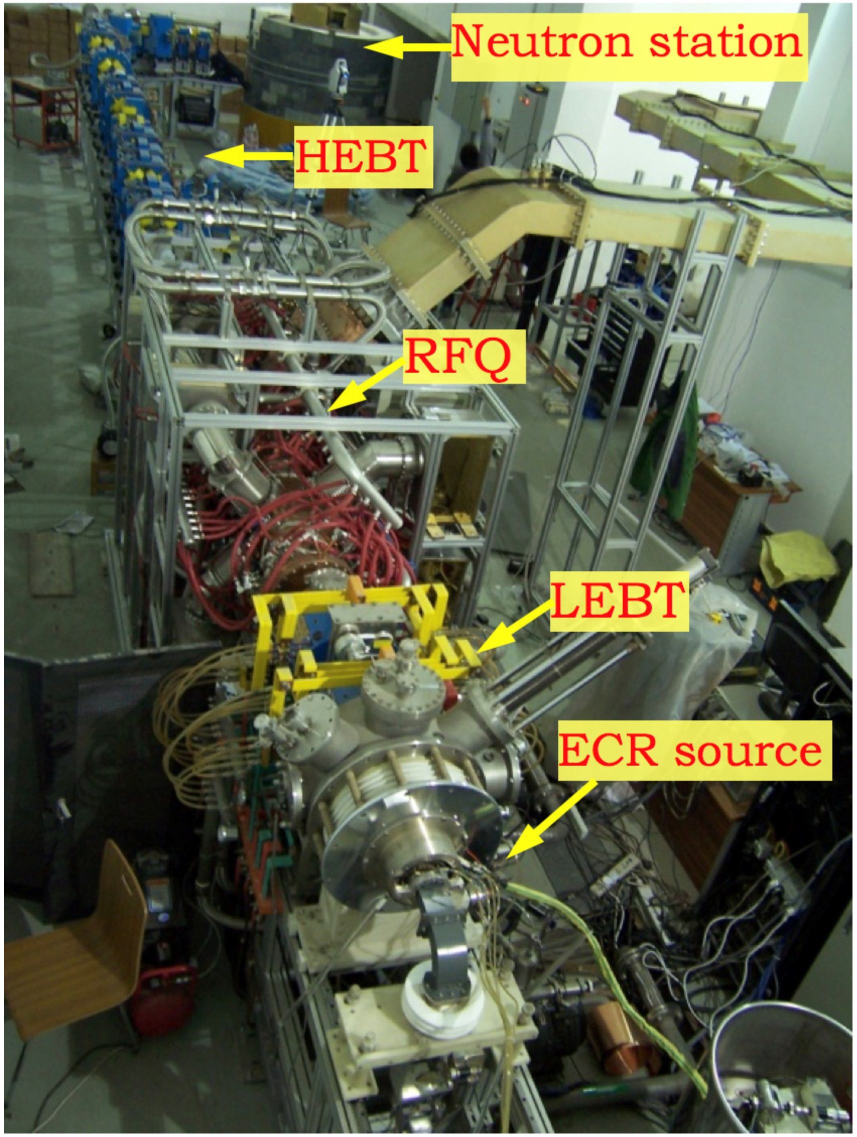
RFQ I: Separated cavity and vacuum vessel, with PI-mode Satirizing Loops

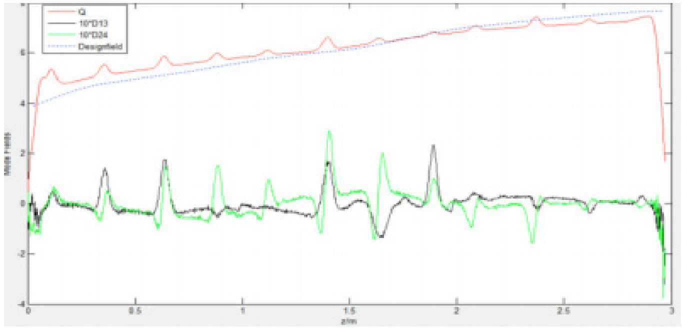


RFQ III: Brazed monolithic structure, with Dipole Stabilizing Rods

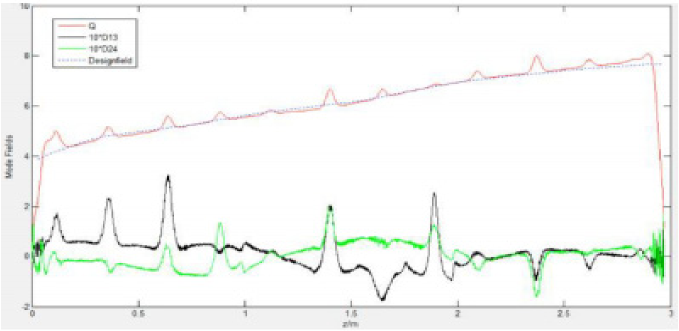
- Original 30-mA RFQ (RFQ I)
  - Frequent sparking problem in 2008.
  - Overcame by improving vacuum in 2009.
  - After that, stably operated in ~3-year user run, and still used as a test accelerator.
- Newly designed 50-mA RFQ (RFQ III)
  - Learning from the RFQ I, the structure was improved. Installed in 2014
  - 50-mA transmission, emittance agree the design
  - No serious sparking. Only < 10 /day short (recover time < 1s) trips
  - No degradation of the performance, even after 3-year user operation.

CPHS RFQ at Tsing Hua University





(a) Before re-tuning

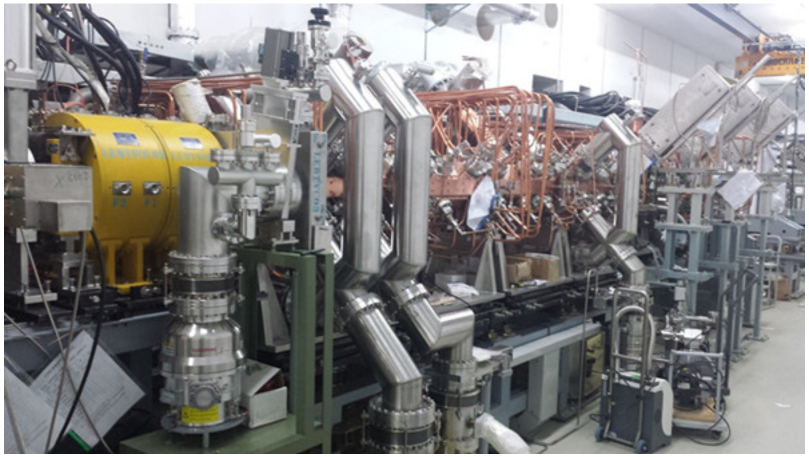


(b) After re-tuning

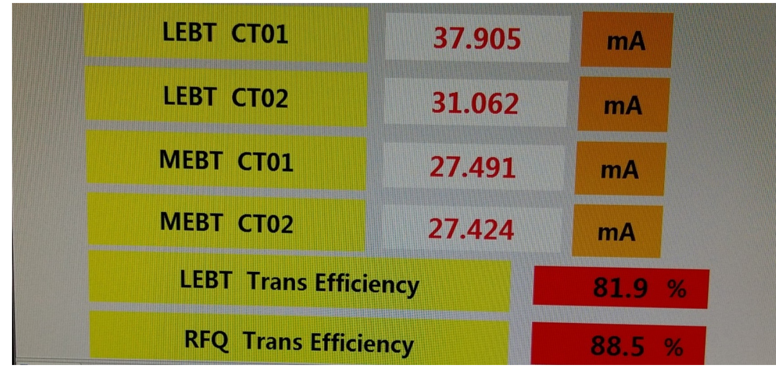
- Transmission degraded due to deformation of resonator. Field distribution deformed too.
- In order to deal with the transmission rate degradation, the field distribution was tuned and the relative error of quadrupole filed was reduced from 7.3% to 2.6%. The transmission rate raised to 91%
- CPHS operates for various applications in 2016（Total operation time ~800 hrs）

CSNS RFQ at IHEP

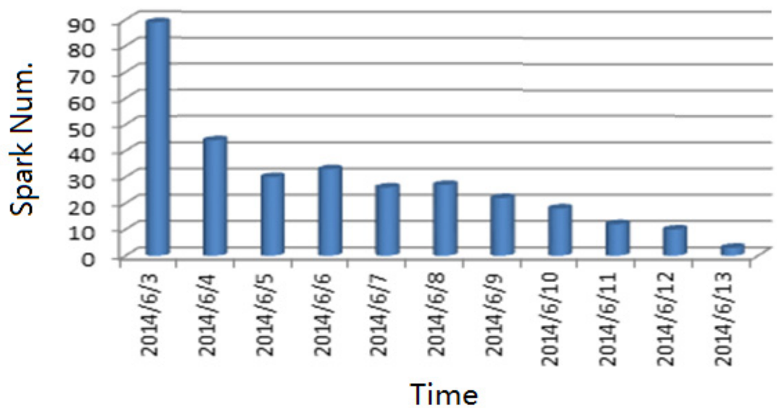
3 MeV, 40 mA



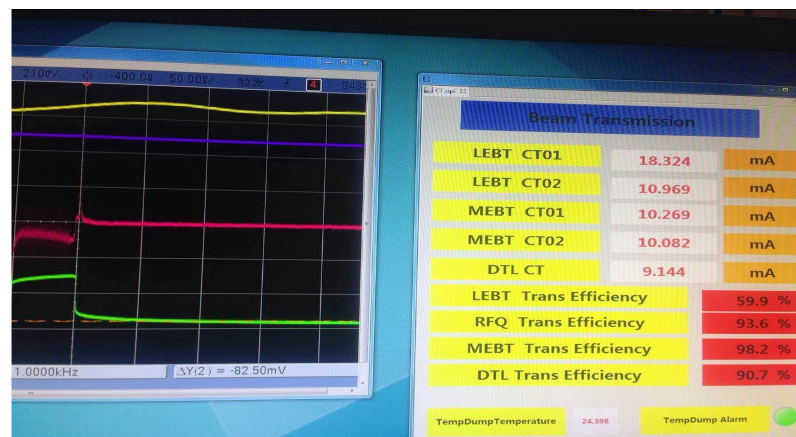
RFQ (including the RF power source) installation started on Dec. 15, 2014 and finished on Feb. 5, 2015.



- April 21, 2015, first beam with 700 us / 1 Hz
- Realize 500 us / 25 Hz with beam chopping
- Beam transmission ranges 75-88.5% due to a larger input beam emittance as to RFQ acceptance.



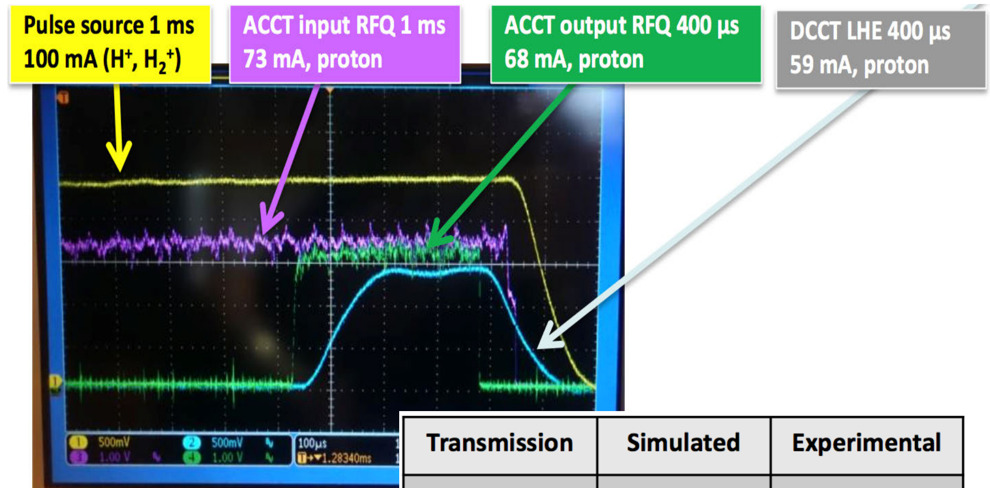
- Conditioning with duty of 700us at 25Hz
- RF power 450kW > 350kW (nominal)
- Reflection power is about 16kW
- 10 days, 24 hours per day, Spark 1~2 per day at last



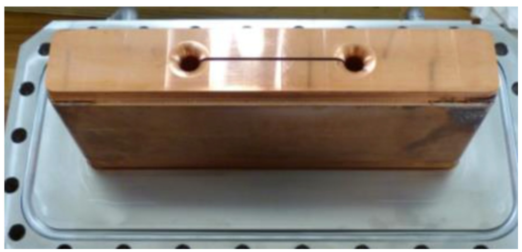
With the beam collimator installed at entrance of RFQ , RFQ beam trans : 93-96% at I =10-11mA

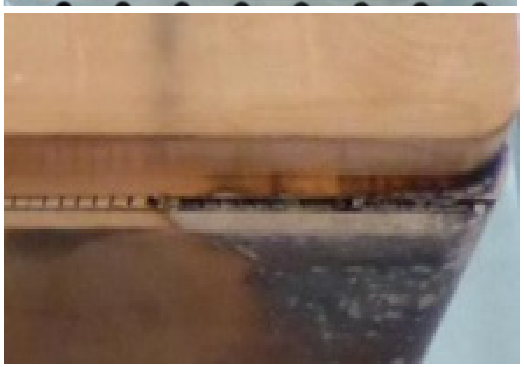
IPHI RFQ at CEA

3 MeV, 100 mA, CW



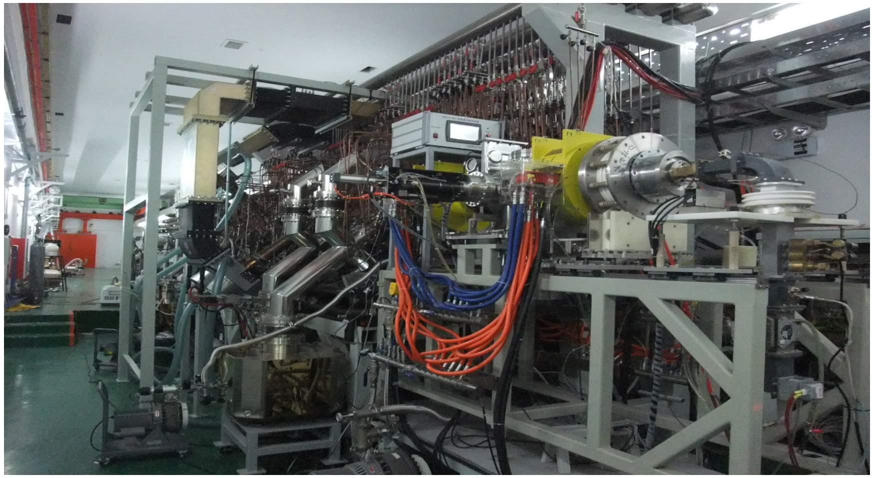
Transmission	Simulated	Experimental
RFQ	98 %	93 %
LHE	100 %	92 %



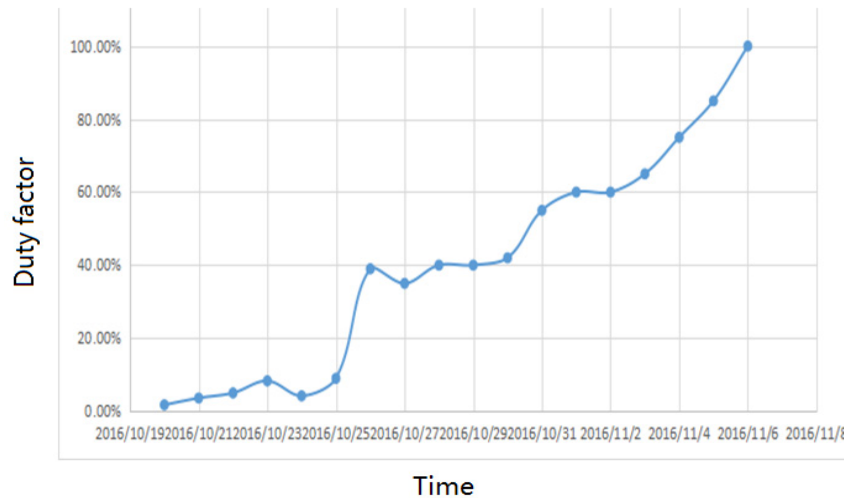


1. Conditioning started in April 2015 the duty factor was limited to 1% due to the cooling system.
2. RF seals had been burned for 2 RF inputs at 900kW peak. Detuning of 50 Hz due to abnormal heating of the 2 RF inputs. New seal and new design of the groove for the 4 RF inputs.
3. Conditioning restarted in Feb. 2016 until 1.2MW with 0.5% duty factor
4. March 2016 , first beam, 68 mA proton, 400 us / 1Hz, pulsed RF @ 400 us / 1s. Transmission of RFQ is 93%, and LHE is 92%.
5. As of March 2017, IPHI has been commissioned up to beam power of 1.5 kW.
6. The commissioning to the design value (300 kW) is foreseen in 2017.

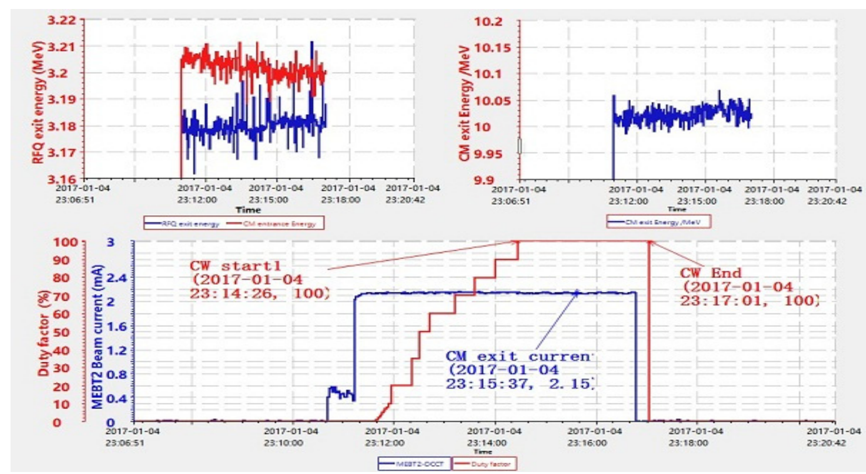
C-ADS Injector I RFQ at IHEP



- May 15, '14, RF conditioning of first RFQ
- Jun. 20, '14, duty factor was 80% wtih RF power 257 kW. The vacuum leakage in the coupling plate due to welding problem. New cooling channel has been designed.
- Aug. 22, '14, CW 194 kW, 30 min, inlet cooling plate pipe of the 2nd coupler leaked.
- Nov. 26, '14, duty factor was 99.97% with 250 kW
- Mar.30 ~Apr.10, '15, CW, RF power is limited to 158 kW. Decided to fabricate the second RFQ.
- Oct. 19 – Nov. 6, '16, the second RFQ conditioned to CW 250 kW (nominal power).
- Jan. 4, '17, the first CW proton beam of 2.1 mA at 10MeV was got in C-ADS injector I.



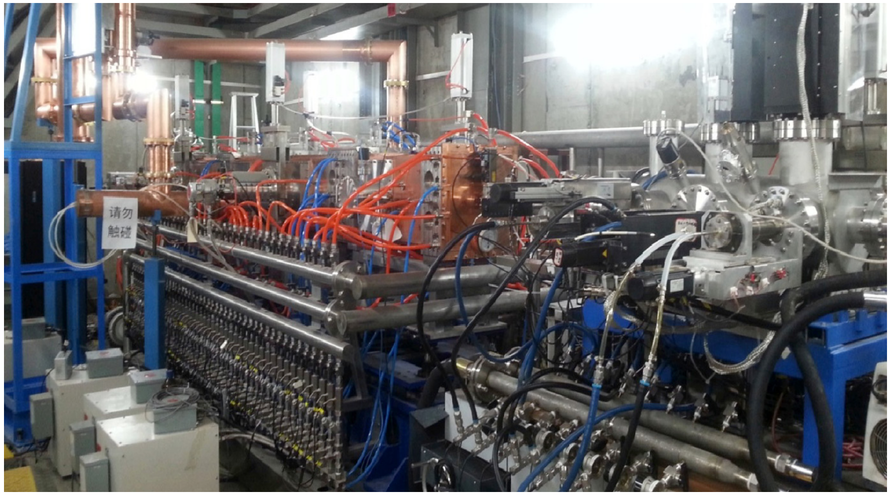
Conditioning record of new RFQ for injector I of C-ADS

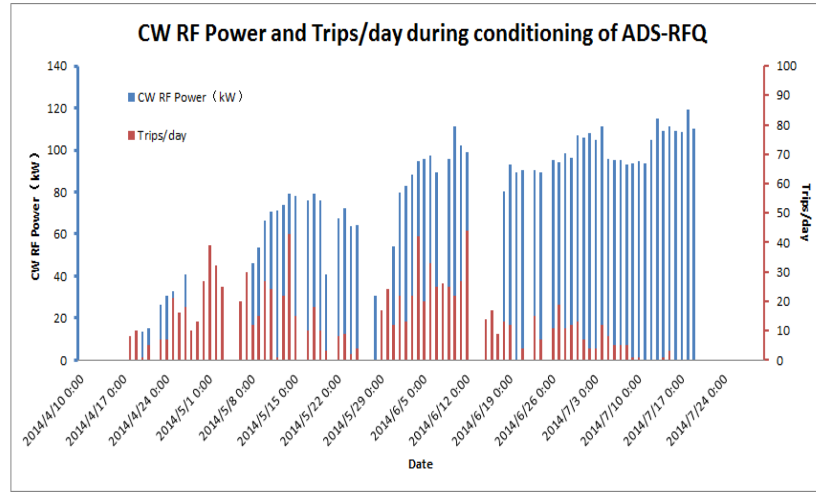


CW be record of injector I for C-ADS with new RFQ

2.1 MeV, 10 mA, CW

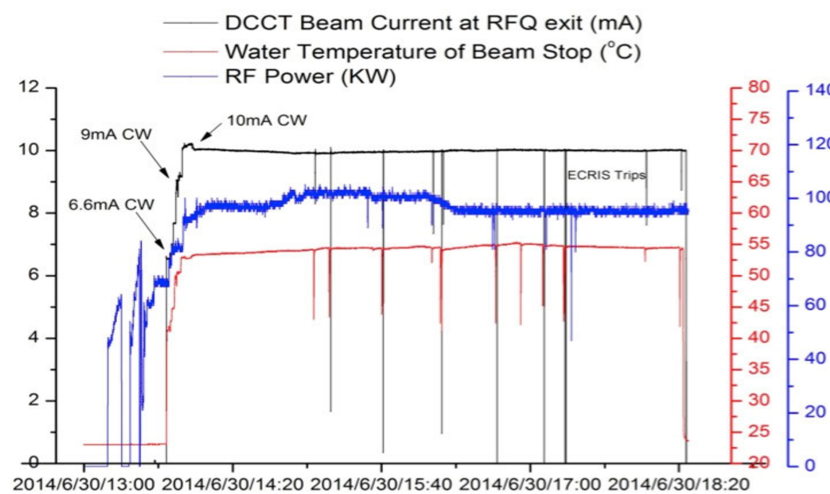
C-ADS Injector II RFQ at IMP





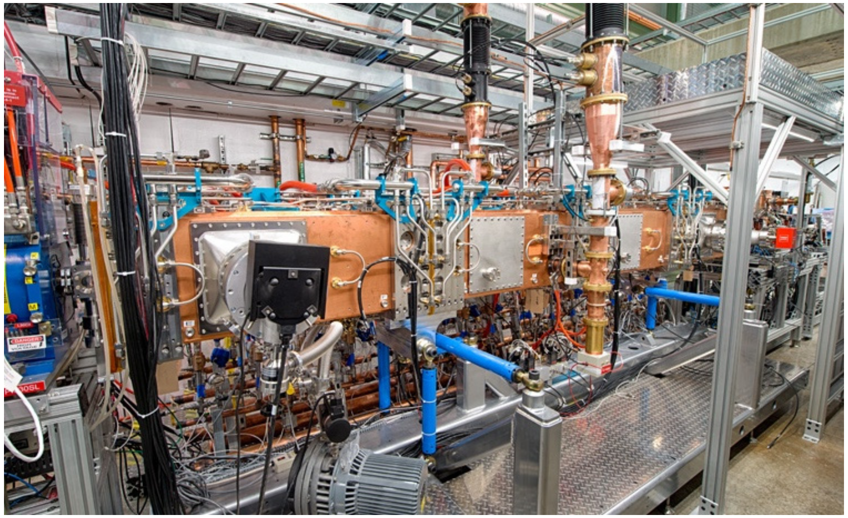
Conditioning procedures

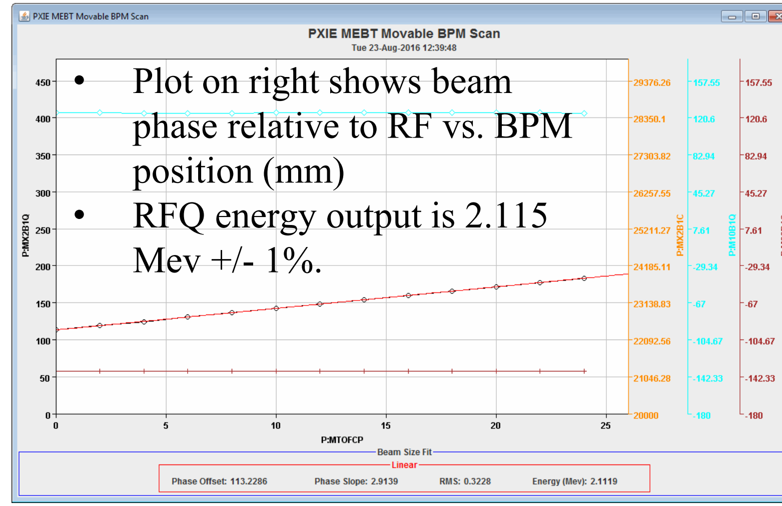
- ‘11-’13, Designed by LBNL and fabricated in IMP.
- Apr. 17 to Jun. 6 ’14, conditioned to 90 kW
- Jun. 6th ‘14, the first pulse beam, 2.1 MeV, trans 97%
- Jun. 21 ‘14, the first CW beam, 2.2 mA
- Jun. 30th, 10 mA, CW, 21 kW beam power, 4.5 hours
- Aug. 7, Sept. 17 ‘15, coupler cracked twice
- Sept. to Dec. ‘15, due to high reflecting power, the tube AMP was broken many times on input/output cavity, socket.
- Apr. ‘16, two SSA were installed.
- Up to date, full power operation 5021 hours, beam time is around 2036 hours, CW beam 77 hours.
- Nov. 2016, 10 MeV, 1.1 ~2.7 mA, CW beam, injector II



Historical record of first 10 mA CW proton bem

PXIE (PIP II) RFQ at FNAL





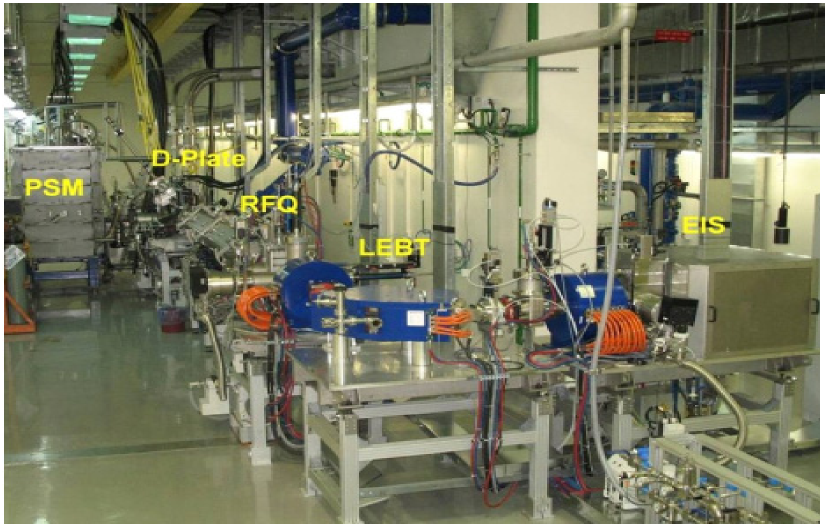
- Plot on right shows beam phase relative to RF vs. BPM position (mm)
- RFQ energy output is 2.115 Mev +/- 1%.

- 4-vane RFQ developed and produced by LBNL
- Commissioned to nominal 60 kV inter-vane voltage in CW
  - > 300 hours of operation in CW (~95 kW)
- Two couplers failed in CW (vacuum leaks)
  - Switched to pulse mode only (5 ms x 10 Hz)
- Frequency tuning is by adjusting of cooling water temperature
  - Successfully tested in CW; works in pulse
  - Issue: the nominal frequency of 162.5 MHz is shifted by ~50 kHz from the middle of the regulation range. Result of unaccounted size change due to atmospheric pressure.

- Sep-Nov 2016: RFQ in CW, tuning, interlocks installation
- 18-Nov-2016 – 5 kW (= 5mA x 2.1 MeV x 60 Hz x 8 ms) – Poor vacuum
- 22-Nov-2016 – run with 2.5 kW beam for 12 hours; melted scraper; hole in bellows
- 1-Dec-2016 – problems with the right RFQ coupler found
- 6-7-Dec-2016 - run with 0.5 kW beam for 33 hrs
- It is now accelerating pulsed beam up to 5ms pulse width at 10Hz repetition rate. CW beam has not been tested.

SARAF RFQ at Sodeq NRC

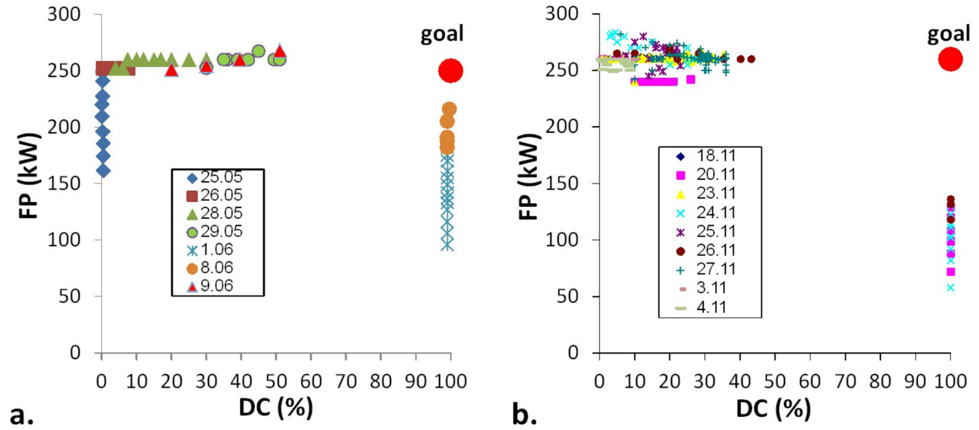
3 MeV, 5 mA, CW



Conditioning Campaigns

May - June in 2014

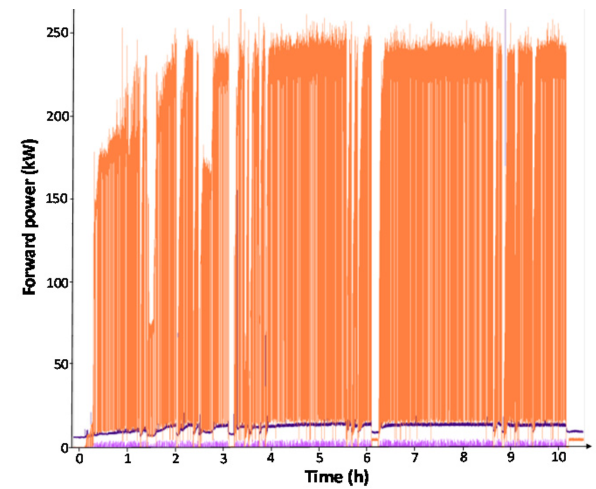
Nov. in 2009



- In the 2014 conditioning campaign, the RFQ reached 200-210 kW CW operation and 50% 250 kW.
- SARAF study revealed that the coupler is the bottle neck that limit the operation at a higher RFQ load.
- Through the updated RF system which coupling power through two new designed coupler, duty cycle 50%~80% at 250 kW have been achieved and 5.5 mA pulsed deuteron beam can be accelerated to 1.5 MeV.

The linac operated with CW/pulsed protons and pulsed deuterons beams.
For CW proton beam :

- 1mA at ~3.7 MeV~ 10 hours/trip
- 2 mA at ~ 2 MeV ~ 5 hours/trip
- 1.6 mA at 3.7 MeV ~ 1 hour/trip

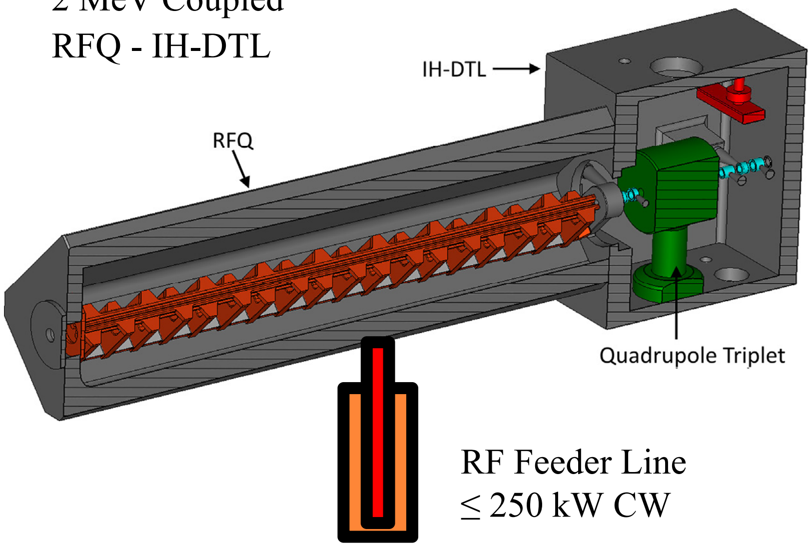


A forward power log of one of the day of April 2017 campaign, RFQ was kept at 240 kW forward power for period more than two hours

FRANZ RFQ at IAP

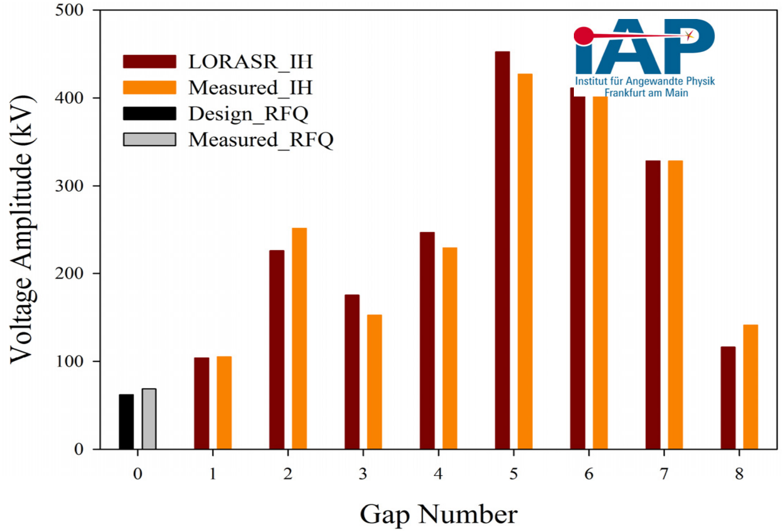
0.7 MeV, 200 mA, CW

2 MeV Coupled
RFQ - IH-DTL



RF Feeder Line
≤ 250 kW CW

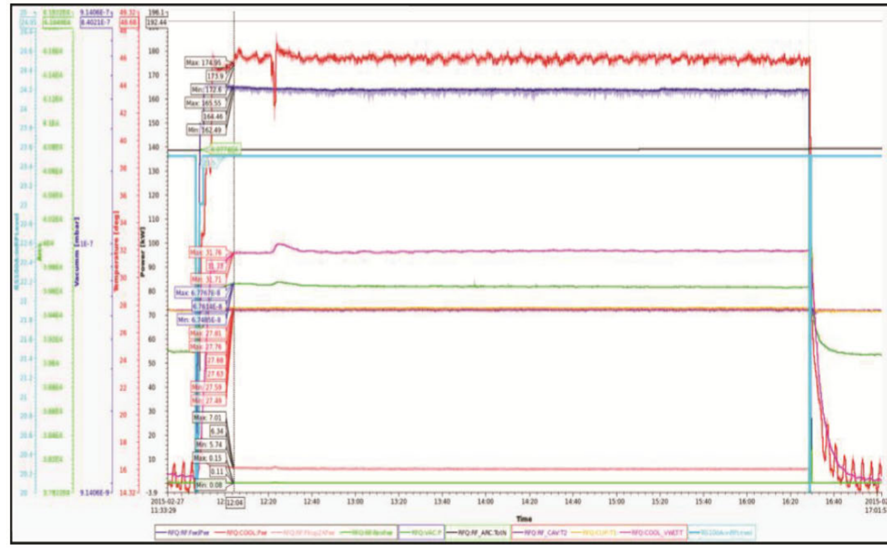

View on Coupling Flanges



Vane-Vane voltage and gap voltages compared to design values

- The RFQ was power tested up to 90 kW in cw operation.
- This is close to nominal power, but some overheat at the exit flange made currently a service necessary.
- Next, the RFQ will be beam tested with investigating the 700 keV beam.
- Afterwards, the rf coupling to the IH-DTL will be performed, followed by 2 MeV beam measurements.
- The schedule is to get these steps during this year

IFMIF RFQ by INFN



- On 27 Feb. '15, the module of RFQ was powered and remained 5 hours at nominal field level.
- In May '16, all modules of RFQ has been assembled and measured by bead pulling.
- The RF system will be expected to be ready in June and conditioning by the end of 2017.

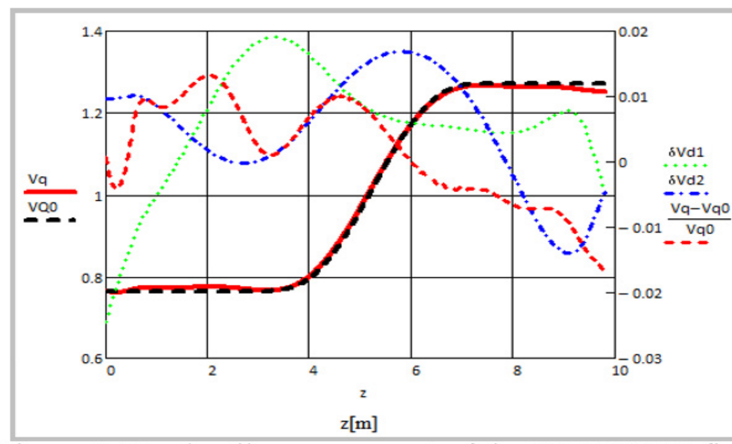
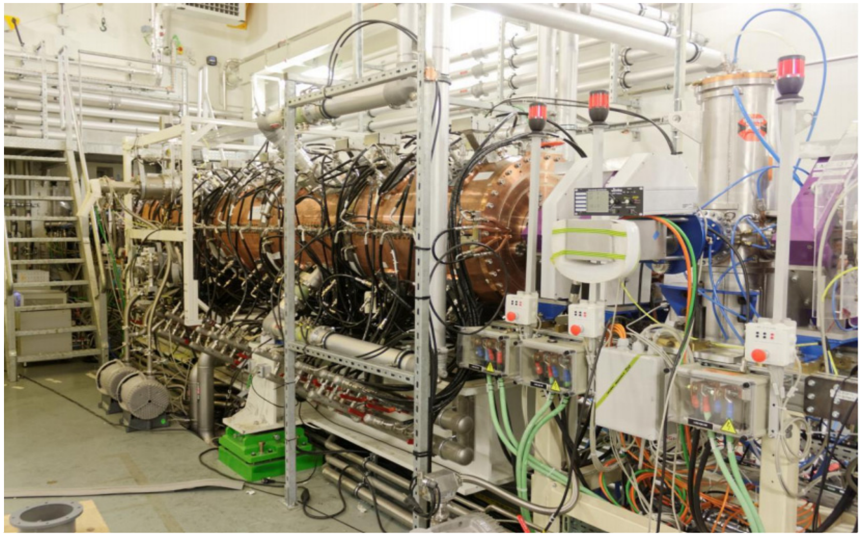
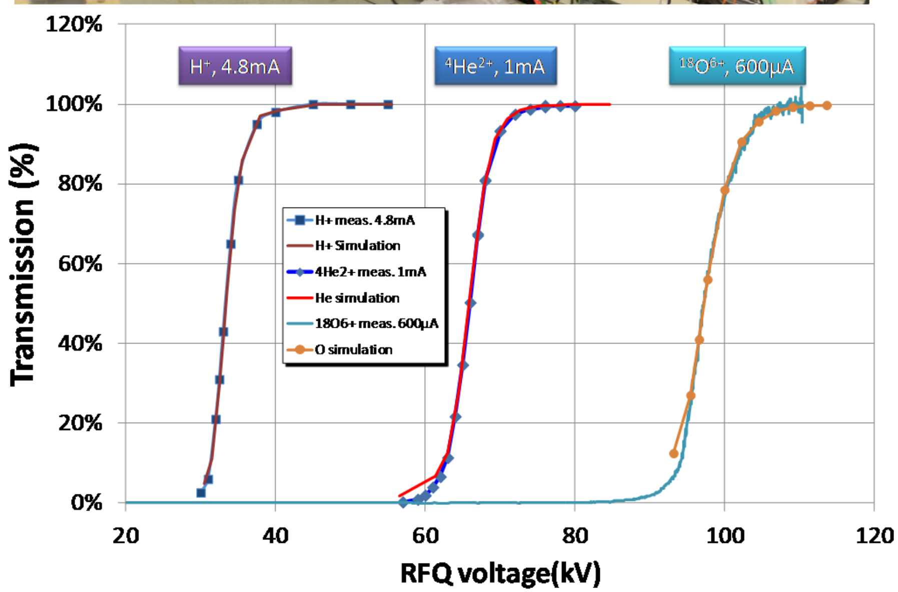


Figure 5: Bead pull measurement of the IFMIF RFQ field. VQ0 is the nominal field, Vq is the measured field (left scale); the dipole components and the relative error on the right.

SPIRAL2 RFQ at GANIL

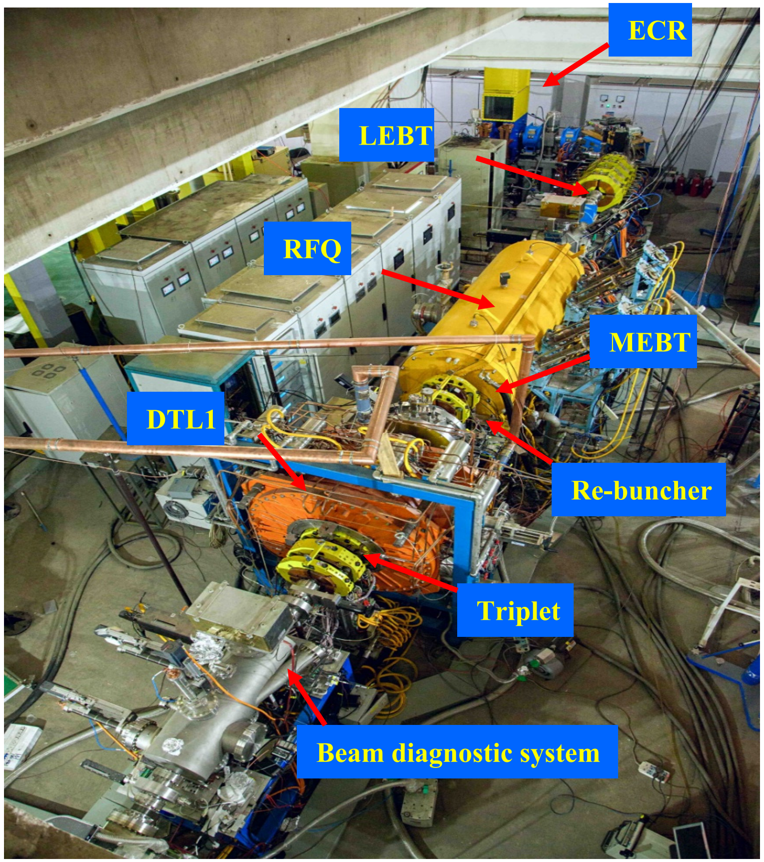


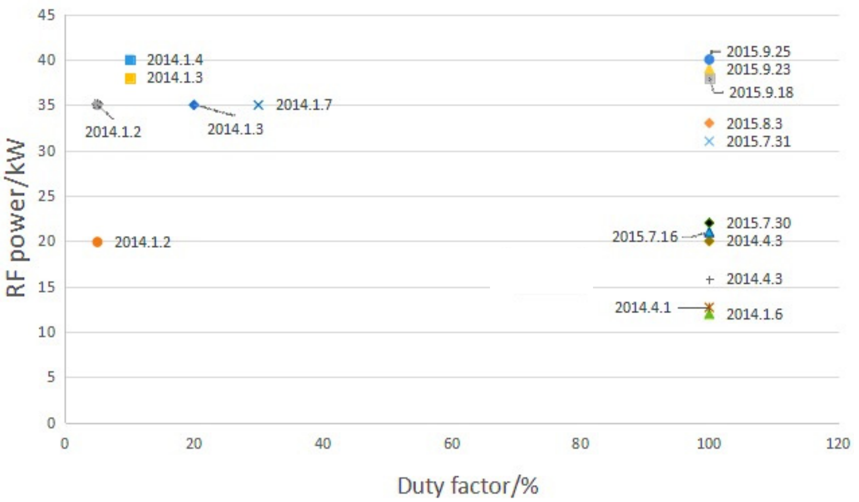


- It is four-vane structure built with solid copper without brazing.
- 4 x 60 kW rf amplifiers (tubes / 3 kW solid state preamplifier)
- Relative errors are less than ±0.8% as the vane voltage is varied from 10 kV to 95 kV, rise to 3.4% at 113.6kV (might be related to a bad cable).
- Commissioned up to 121kV, above the nominal voltage (113.6kV)
  - @nominal : Spark every 45min (mean), record 1.5h.
  - 121kV (one spark every 2min, record 8min)
- RF shows instabilities at high voltage.
  - Investigation of cooling circuits/LLRF/RF amplifiers.

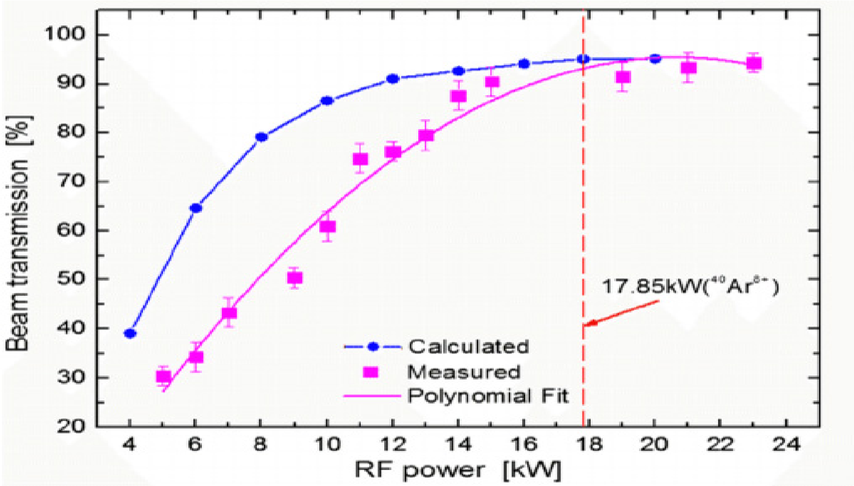
- 5th December '15, first proton beam, 5 mA, 200us/1Hz
- 18th Dec '15, first CW proton beam 2.3 mA
- June '16, He^{2+}, CW beam, voltage = 80 kV, power = 89 kW

SSC-LINAC RFQ at IMP





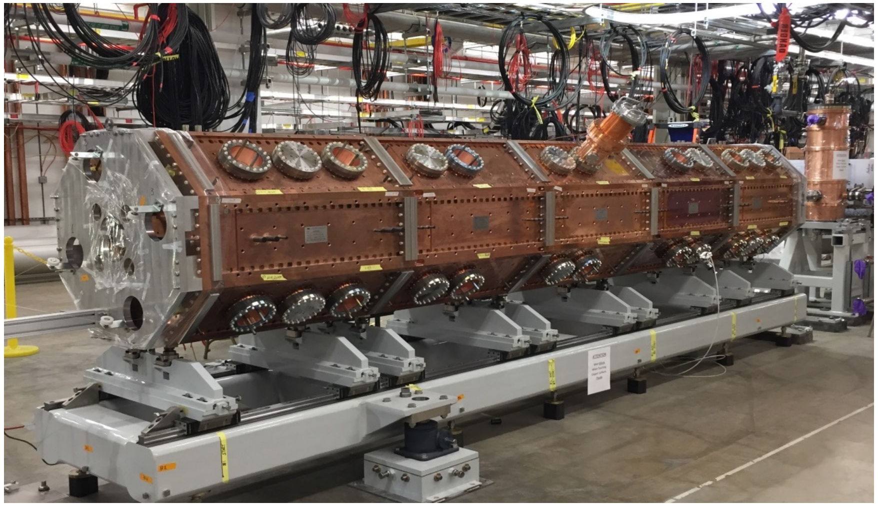
25th Sept 2015, RF power CW 40 kW (nominal 35 kW)

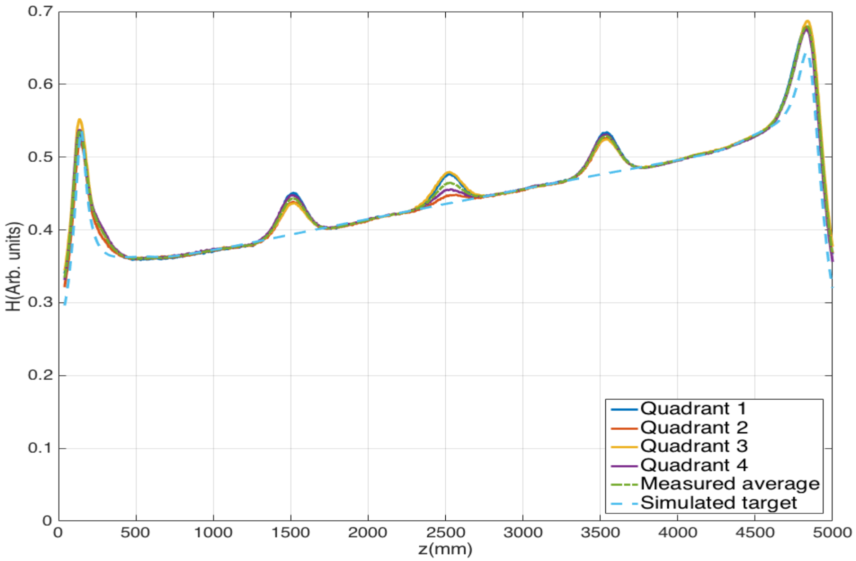


RFQ tranmission 94%@ 17.85 kW

- Collaboration with PKU
- 6th Jan '14, $^{16}O^{5+}$, 170 euA, CW, 10 kW
- 4th Apr '14, $^{40}Ar^{8+}$, 198 euA, CW, 23 kW
- 8th Sept '15, $^{208}Bi^{30+}$, 12 euA, CW, 35 kW

FRIB RFQ at MSU





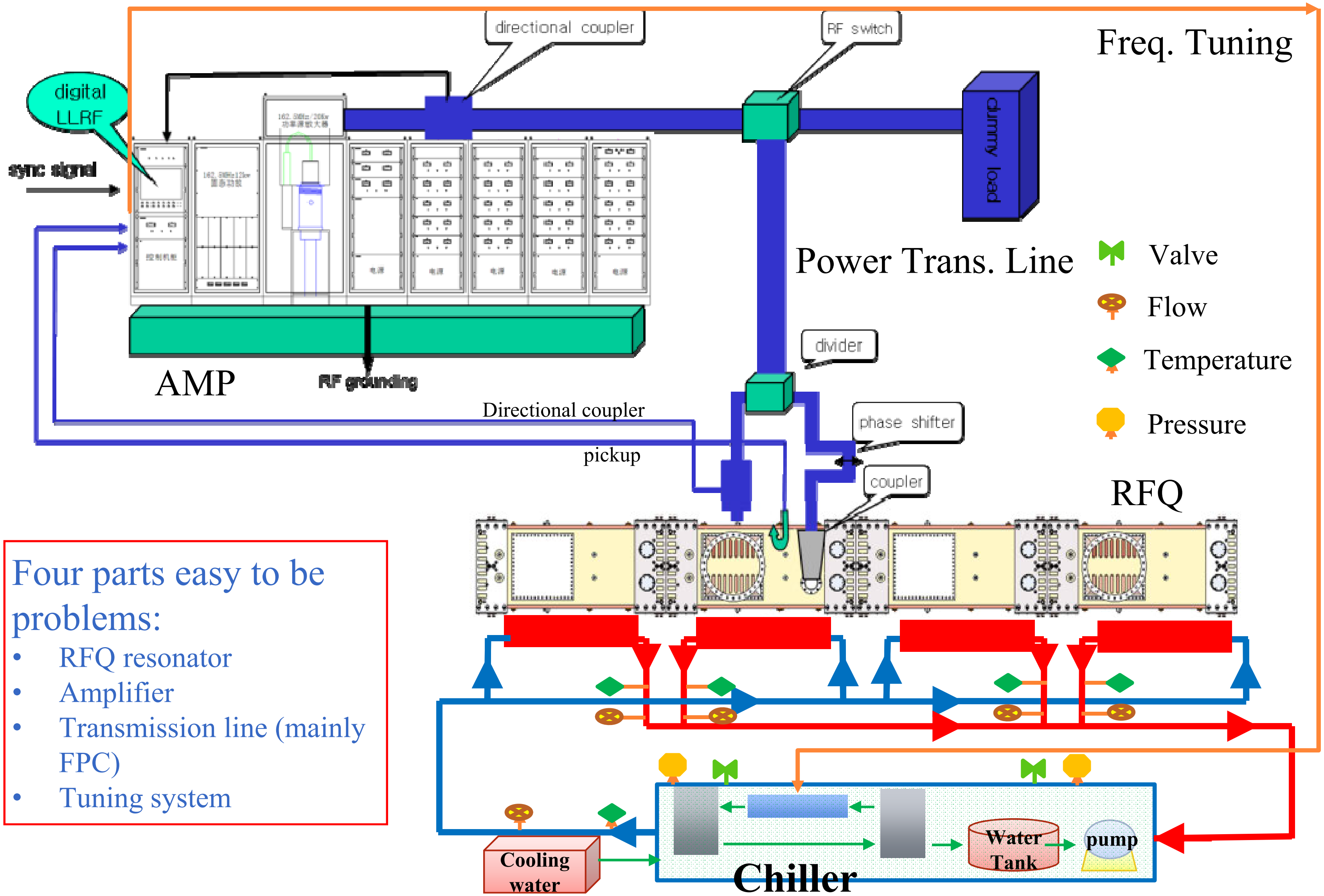
- FRIB RFQ is 80.5 MHz, 5m long, 4-vane fully brazed structure. Consists of five segments.
- The RFQ has been assembled and tuned. Voltage error between segments less than 0.5%.
- The RFQ vacuum pressure is 2e-8Torr.
- RF conditioning expected to start in May 2017.

Parameter	***Measured value***
Q0	*14700*
Faccel (MHz)	*80.503*
Fdipole(MHz)	*77.797 / 82.888*
Vacuum Pressure (Torr)	*2e-8*

Outline

- Introduction of RFQ accelerator
- Recent progress of high intensity RFQs
- Common problems and solutions
- Summary

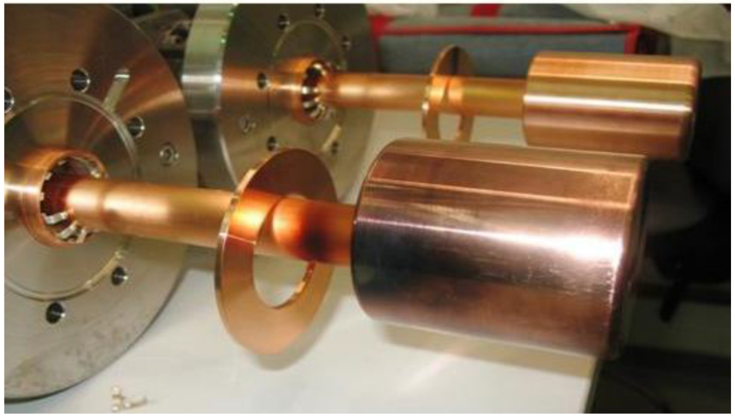
Typical RFQ System



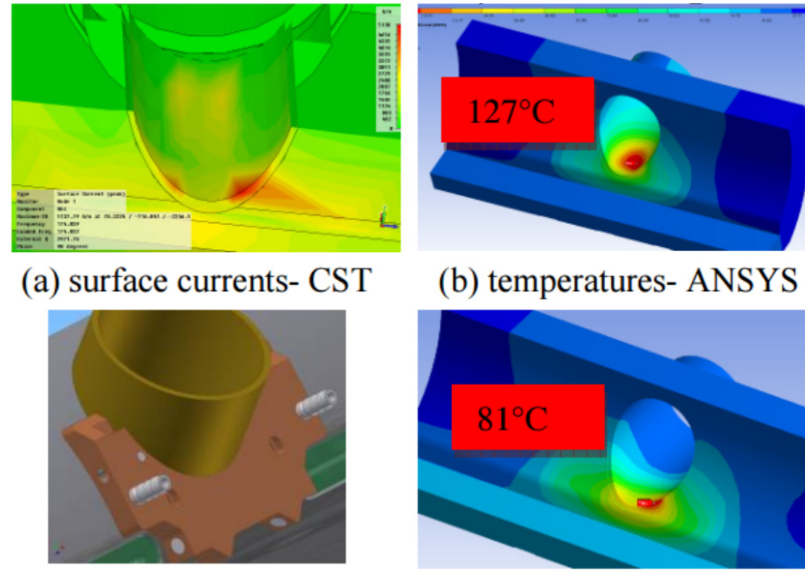
Four parts easy to be problems:

- RFQ resonator
- Amplifier
- Transmission line (mainly FPC)
- Tuning system

Thermal problems of SARAF



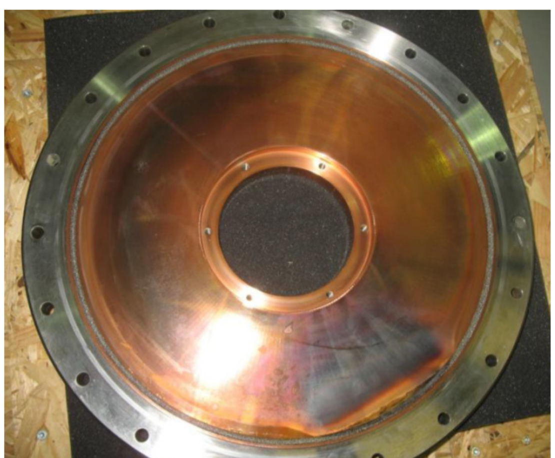
- Broken and deformed RF fingers of the plunger sliding contacts.
- More rigid fingers shafts plated by rhodium to avoid cold welding rigid alignment of the plunger providing uniform contact pressure

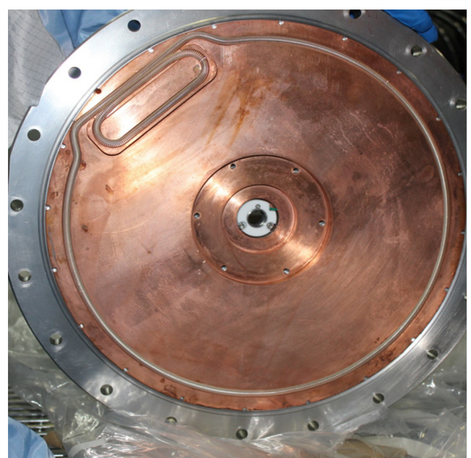


(a) surface currents- CST (b) temperatures- ANSYS

(c) adding cooling plate (d) modified temperatures

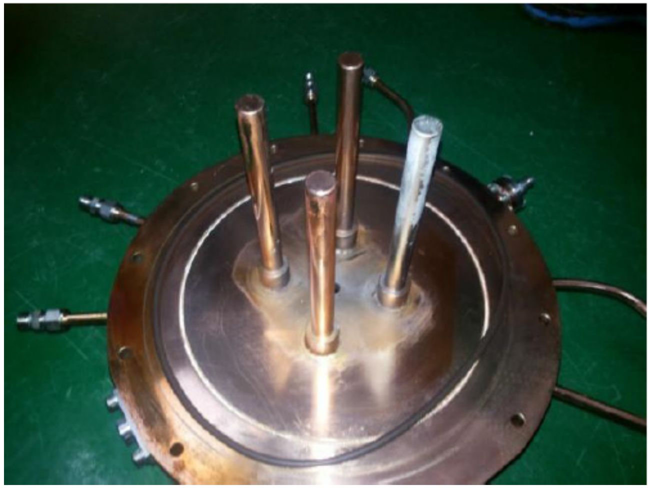
Figure 14: Coupler port thermal analysis at 190 kW.

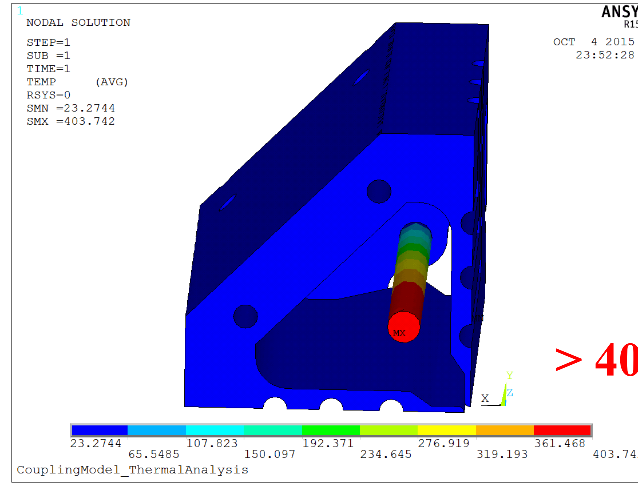




- Heating of RFQ end flanges (not water cooled). Coloration of flanges was observed.
- efficient water cooling and improved RF contact between the flanges and the base plate

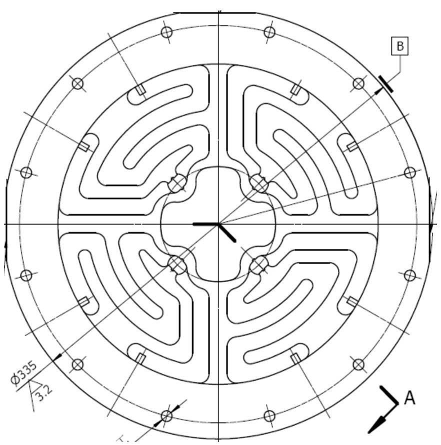
Thermal problem of C-ADS inj. I

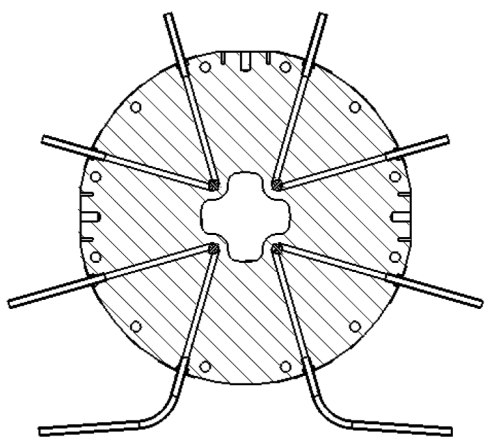




> 400°C

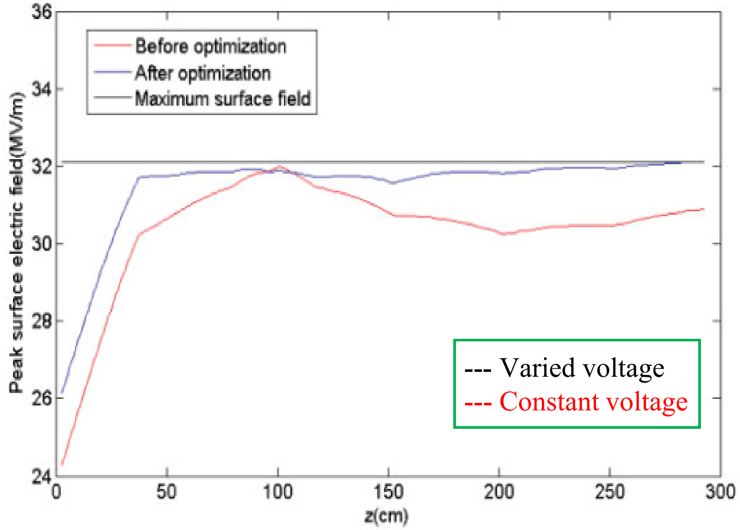
- 71% duty (0.71 ms/1 ms), 250 kW power were achieved, but stopped due to vacuum leakage.
- Reason: very high temperature (> 400°C)

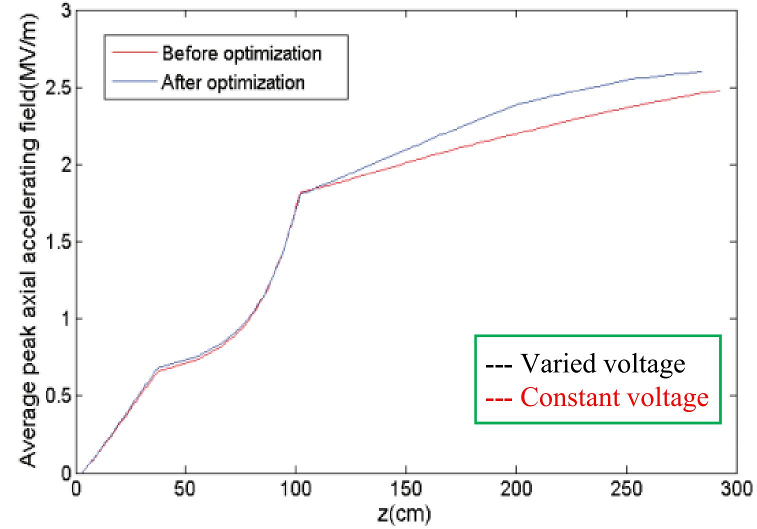


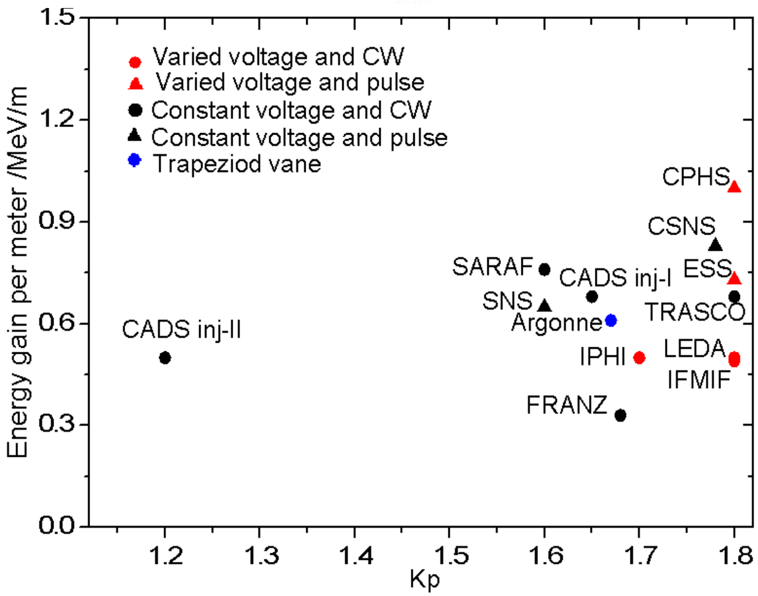


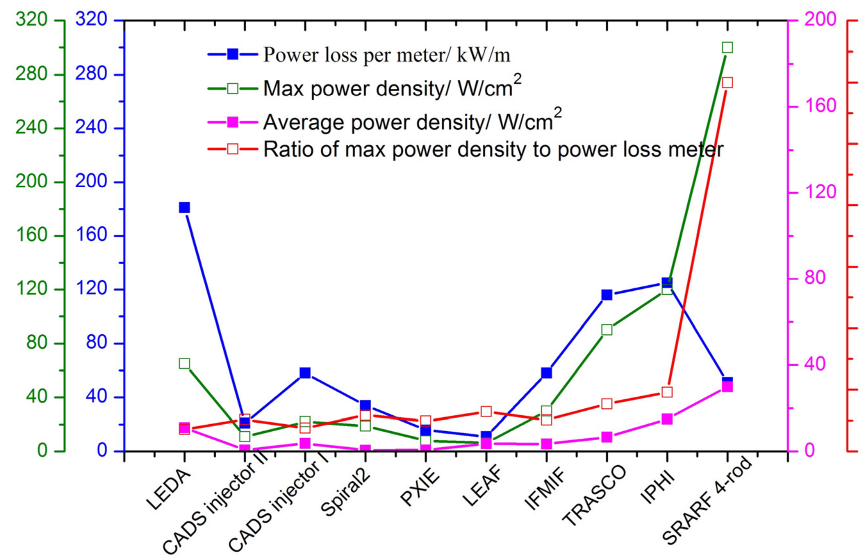
- 80% duty (0.8 ms/1 ms), 257 kW power were obtained, but followed by the vacuum leakage in the coupling plate.
- Reason: welding problem due to the complicated structure of cooling channel and the dipole stabilization rod.
- The new cooling channel has been designed to solve this problem.

Solution: optimize E_{peak} and B_{peak}



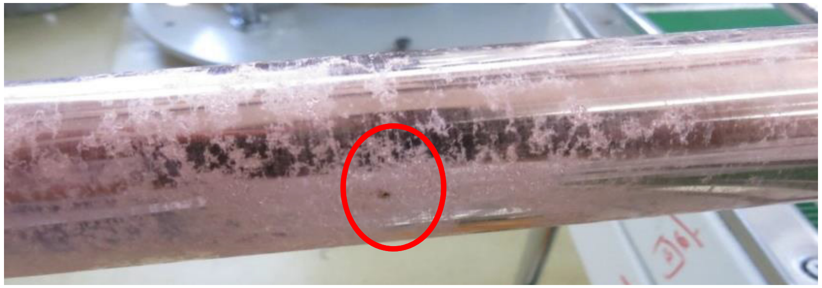




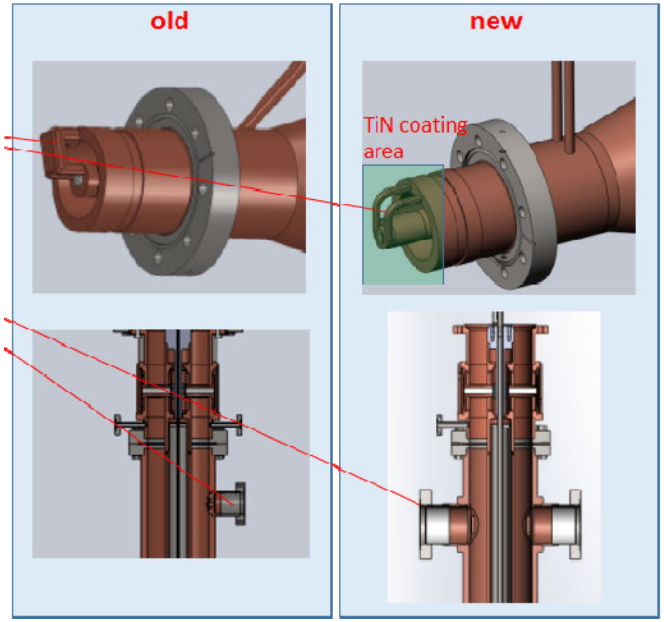


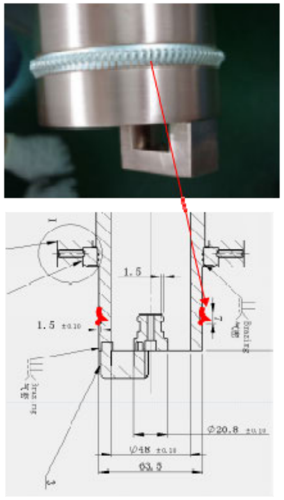
MP problem of C-ADS inj. I

Inner conductor of the coupler



- On Aug. 21, pulse mode, 99.97% duty (12.5 ms/79.975 Hz), 250 kW, but the conditioning couldn't keep very long.
- On Aug. 22, CW mode, 194 kW, keep 30 min, but the inlet cooling pipe of the 2nd coupler leaked for possible strong MP.

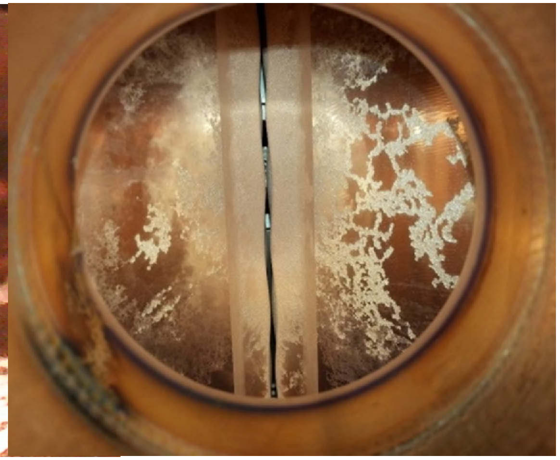




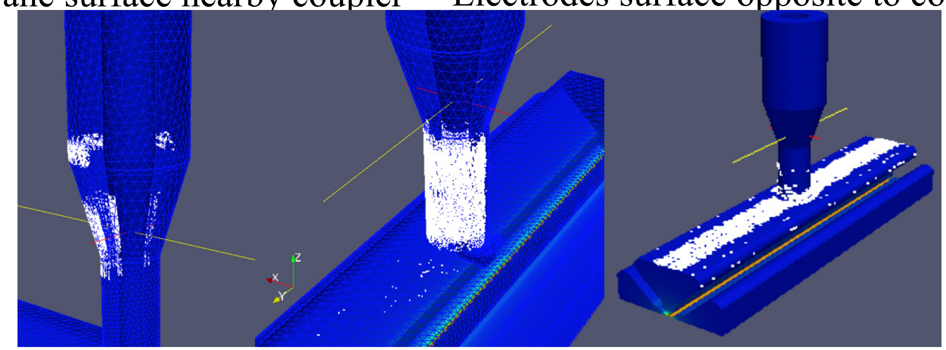
- **Coupling loop:**
  - Structure improvement: larger size, more smooth;
  - TiN coating;
- **The RF contact ring between the coupler and the cavity was canceled:**
  - RF contacted by the copper gasket;
  - Avoided the ring burning successfully.

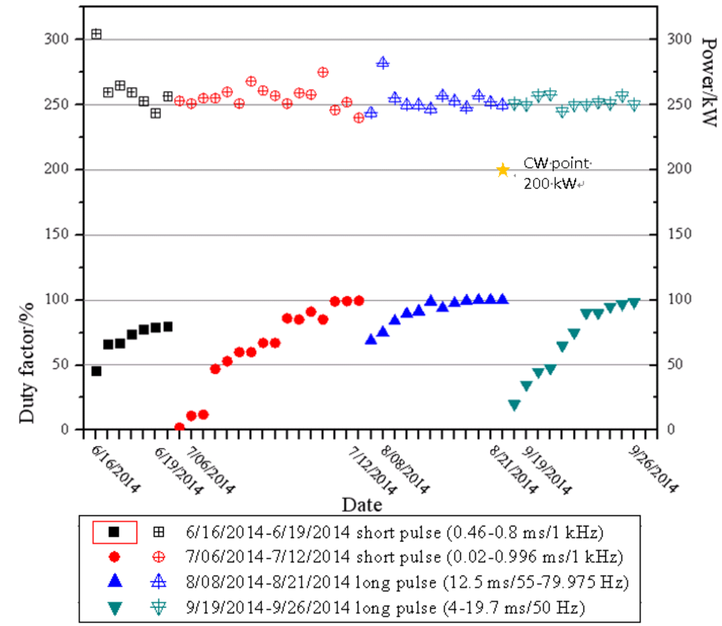
MP problem of C-ADS inj. I

Vane surface nearby coupler



Electrodes surface opposite to coupler



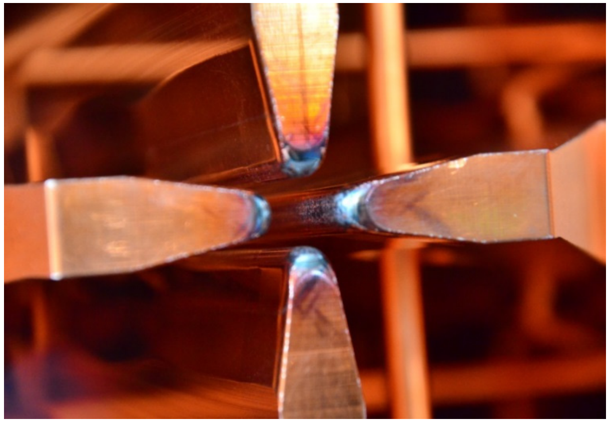


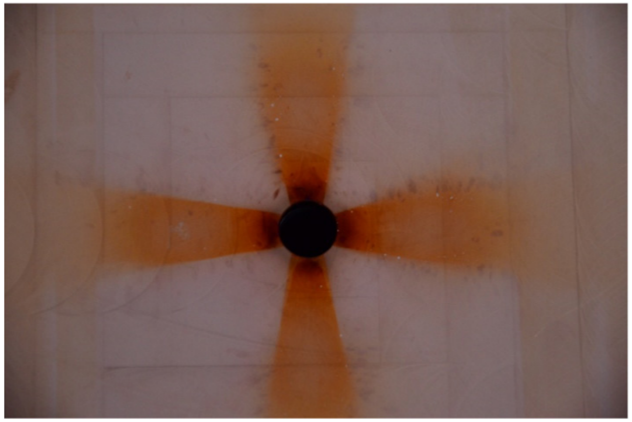
- A 0.6 m long RFQ model is used in the MP analysis, with surface conductivity artificially reduced to achieve beta ~ 1.5 and power reflection 4%.
- Very strong MP pattern is found in the coaxial waveguide (mainly the narrow part) below 60 kW; and strong MP on the RFQ flat wall from ~ 130 kW to 170 kW.

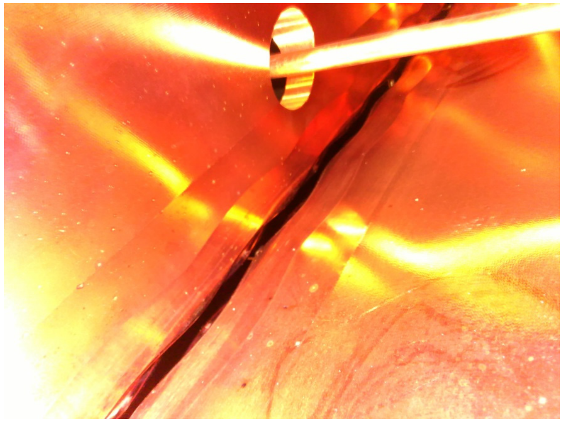
Solutions:

- In the commissioning of the LEDA RFQ, the pulse method with pulses up to 10ms at 100 Hz was always used. RF pulse was always used even when it was nearly CW……
- Improve OFC to reduce electron emission. The second RFQ's OFC was from Luvata.

MP problem of C-ADS inj II and SARAF

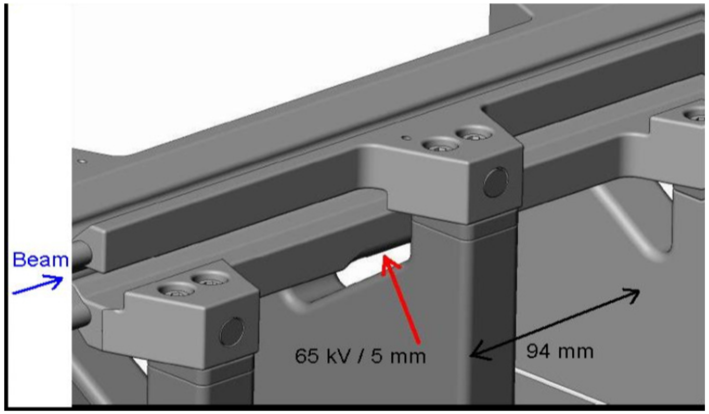






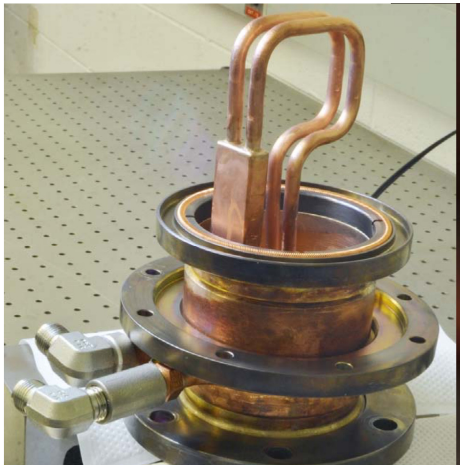
Aug 12, 2014, after conditioning and cw beam commissioning. The blue marks can be seen at the vane tips and end plate. It was assumed as MP. Arc detectors can keep seeing the light. The surface nearby coupler is clean.

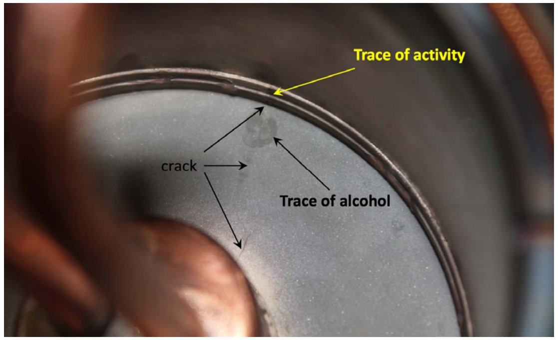
Discharge between back of the rods and stems

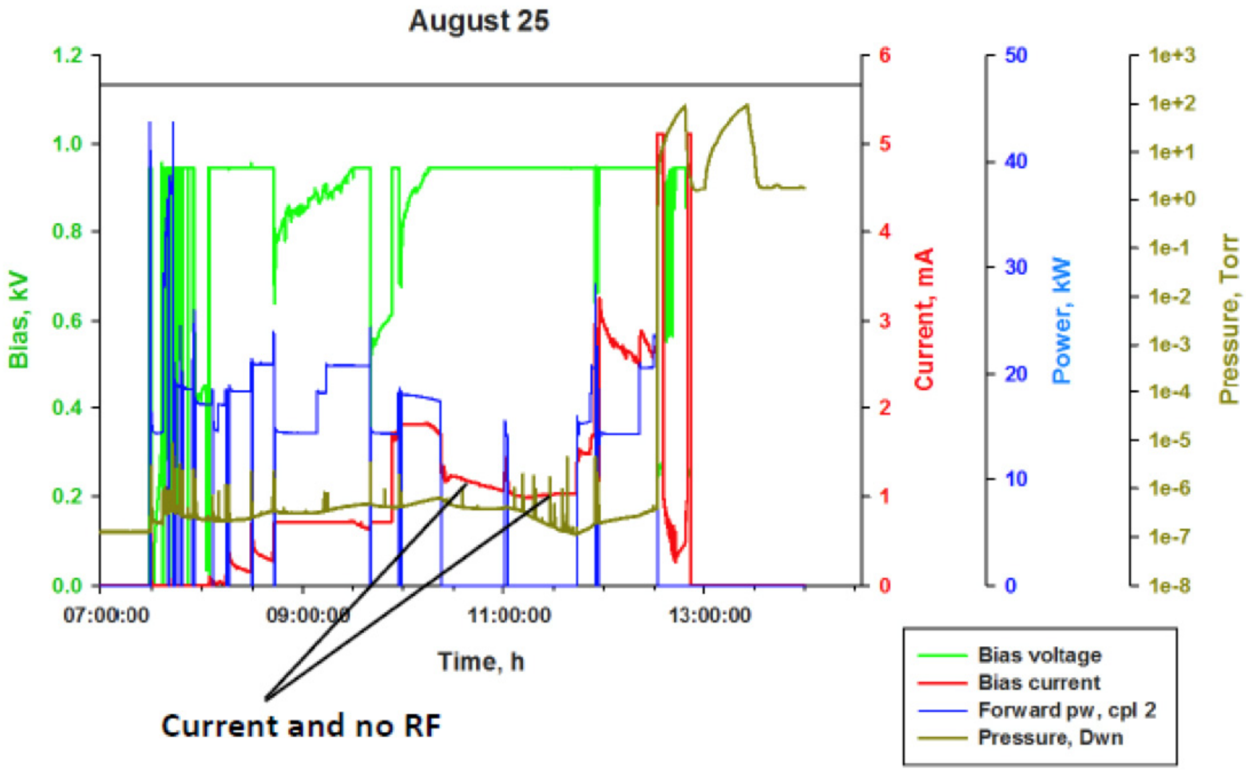


Back side of RFQ rods machined to avoid field emission to opposite voltage stem. Field in machined area is 65 kV per 5 mm. Red arrow marks the machined area.

Problem of coupler of PXIE







Overheating of ceramics because of multipactor (not enough level of bias)?

Surface of ceramics changed the color – grey areas appeared. It indicates that some processes occurred at the surface. The grey areas can be pure Ti as results of decomposition of TiN under electron bombardment.

Another indication - the ceramic surface became conductive. There was several mA DC current under 1 kV voltage bias. Conductivity disappeared at the air. Probably Ti film was partly oxidized in air.

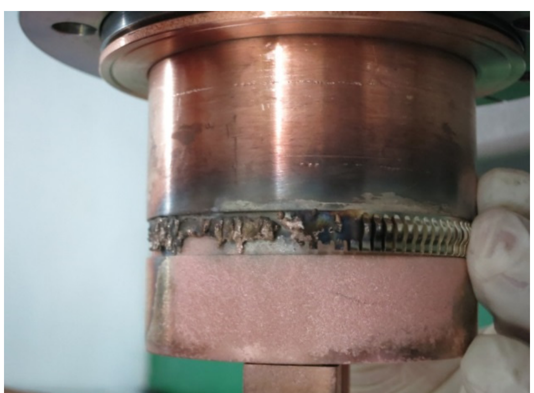
FPC problems of C-ADS RFQs

Injector II

After one year operation, the ceramic window cracked three times in several months.

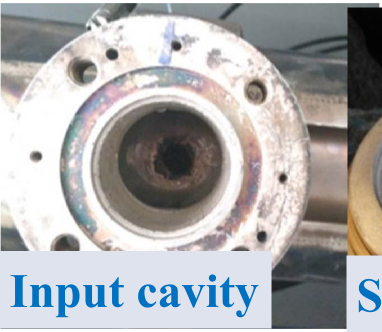
- Mechanical error of cooling channel, the flow in one coupler is much smaller than the other;
- The unbalance power on two couplers is from tuning incorrectly of the phase shifter;
- The RF seal was burned and dropped on the ceramic surface.

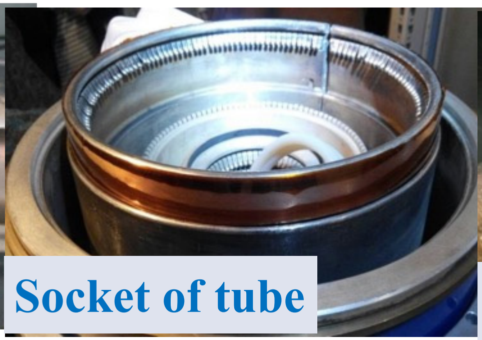
Injector I



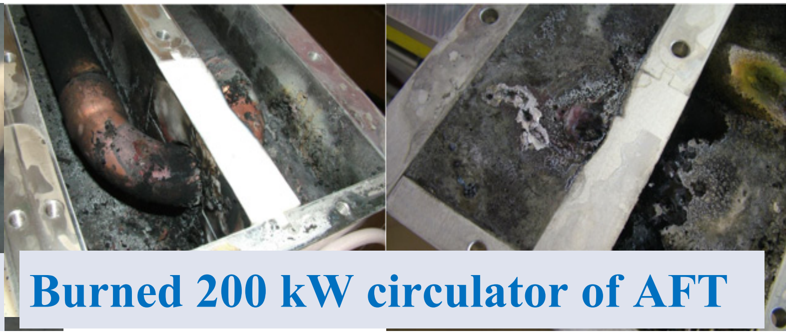
- On July 22nd , 2014, total four coupler ceramic windows were cracked. long pulse, 24 ms/25 ms, 96% duty factor, 229 kW.
- On Aug 22nd , *CW mode, 194 kW, keep 30 min*, However 2nd coupler vacuum leakage happened during the CW conditioning.
- On Sep. 4th , RF contact spring discharging were found on #4 coupler.
- On Sep 14th , the 3rd coupler ceramic window cracked due to the inner and outer conductor shorten by the condensate water.
- Four couplers, unbalanced coupling is the mean reason.

High power AMP problems at C-ADS


Input cavity


Socket of tube


Output cavity


Burned 200 kW circulator of AFT

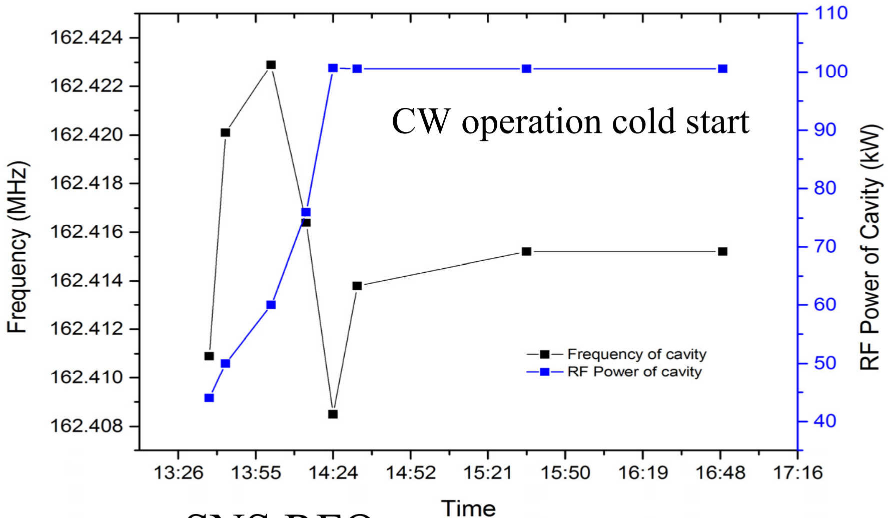
- One 200 kW CW Tetrode AMP with TH571A, and two FPCs. The maximum forward power is 140 kW, max 6% reflection.
- After 15 months operation, AMP started problems: input cavity, socket, and output cavity were burned in series.
- A 200 kW, CW circulator of AFT was destroyed by arc between cooper pipe and cover plate, conditioned up to 50 kW only.
- Jun. 5, ‘14 – Apr. 13 ’16, Tube AMP operated 100 -120 kW 3265 hours, 362 trips.
- Two SSAMP of 80 kW with full power reflection instead.
- Apr. 29, ‘16 – May 14, ‘17, SSAMP operated 50*2 kW 1757 hours, 107 trips.

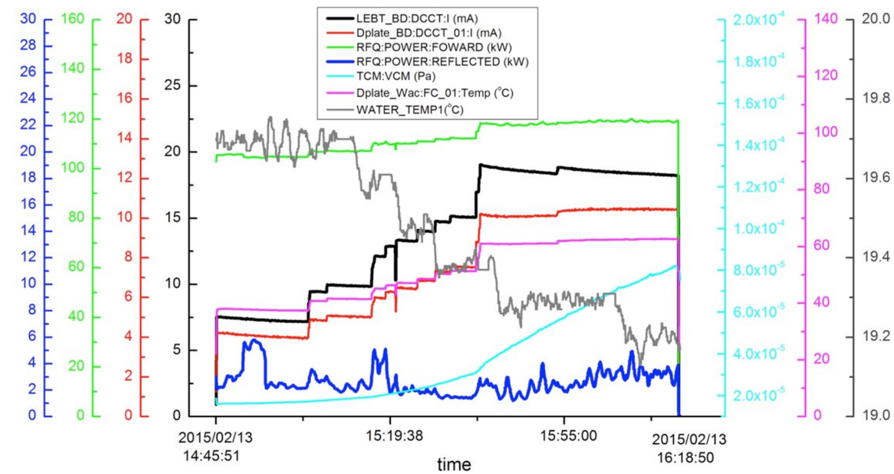

200 kW CW
Tetrode AMP


80 kW CW
Solid State AMP

Detuning of RFQ

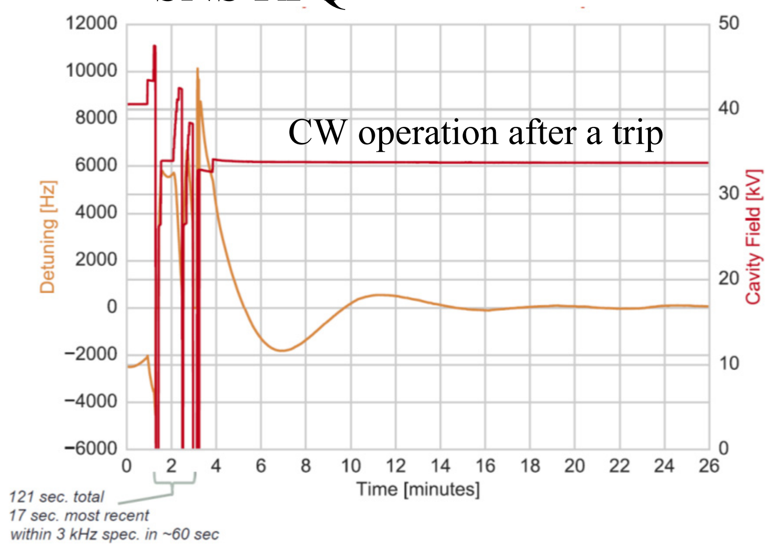
C-ADS inj. II RFQ





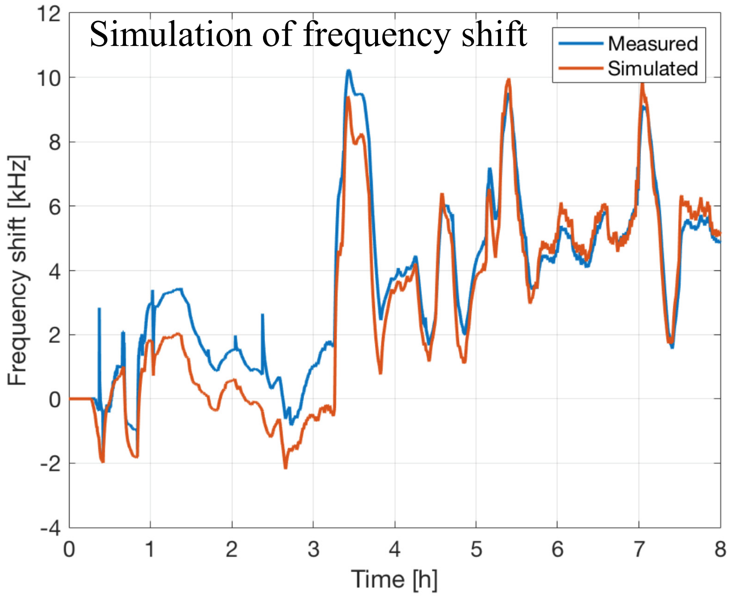
10 mA CW beam loading, -7.8 kHz shift

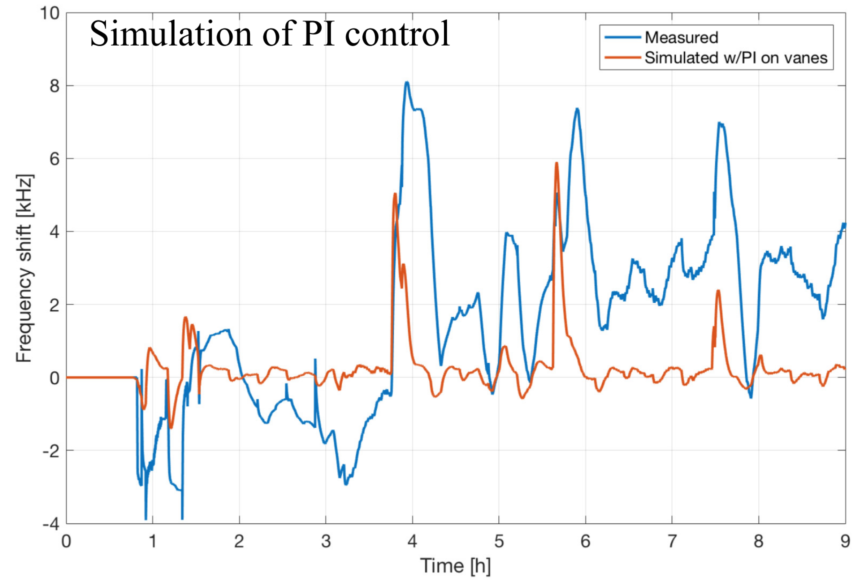
SNS RFQ

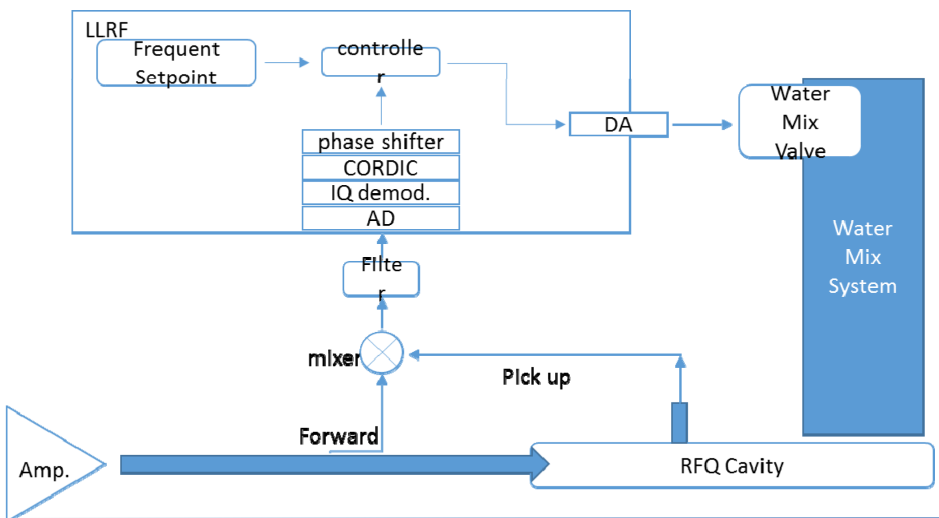


- Detuning due to CW high beam loading, CW RF power, cause instability of operation.
- Optimized feedback and feed-forward to compensate for beam loading.
- Fast tuning hardware and software need to developed to tune the shift.

Solution of Detuning







- PXIE Characterized frequency shift due to perturbation sin the water system and RF system
- Simulation of PI control on the vanes using data gathered during thermal testing
- The results demonstrated a good comparison with simulation

- A water mix system was develop to reduce the response time
- More work on LLRF will be done

Outline

- Introduction of RFQ accelerator
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Summary

- The high intensity RFQs worldwide (incomplete), especially CW RFQs, have a great progress in the past 10 years.
- The progress especially conditioning efforts of each RFQ are introduced.
- The common problems are shown and analyzed. Some of them have solutions.
- It can be concluded that the common problems for a CW RFQs:
  - Sparking at nominal voltage due to high E_{peak} on the surface.
  - Thermal spots at tuner, coupler, dipole mode finger, contact finger, and so on, B_{peak} on the surface is not be optimized.
  - Multipactor at coupler ports, end plate, coupler itself, caused serious problem. It should be simulated in design.
  - Detuning due to beam loading, RF heating, lost beam heating, will lead the instability of system.
- The problems due to high beam power are not included in the presentation.

Acknowledgement

Courtesy of:

SNS	*Michael PLUM*
CSNS	*Huafu OUYANG*
CPHS	*Qingzi XING*
C-ADS injector I	*Hua SHI, Huafu OUYANG*
PXIE	*Jim STEIMEL*
SARAF	*Jacob RODNIZKI*
FRANZ	*Ulrich RATZINGER*
FRIB	*Eduard POZDEYEV*
SSC-LINAC	*Xuejun YIN*
SPIRAl2	*Robin FERDINAND*

Thanks to my colleague:

Weiping DOU, Chenxing LI, Zhijun WANG, Liang LU

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