





RF operation of REX-ISOLDE

Suitbert Ramberger, CERN, BE-RF-LRF

Introduction

- BE-RF Contribution
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- The Team
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- Potential improvements

REX-ISOLDE



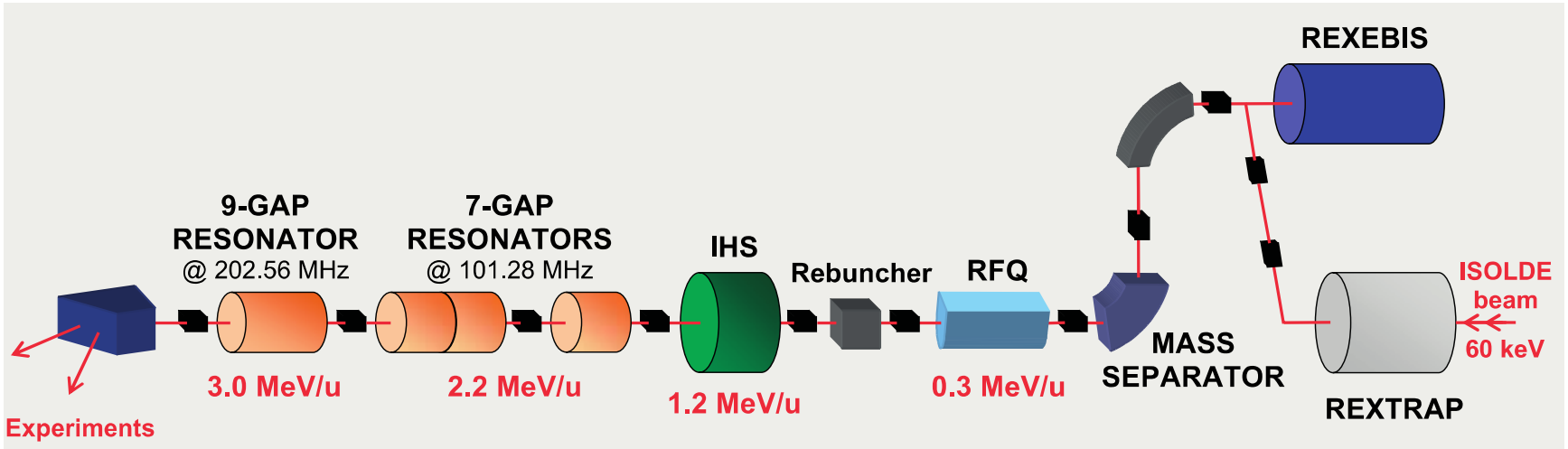
BE-RF Contribution

Responsibility for operation, maintenance, repair (MRO) & upgrade work

- RF power amplifiers
- Control, Interlock & LLRF systems

RF cavity status to be assessed in 2017

Within the **existing limits** of the systems!



General Parameters

Labor intensive machine:

- **Varying parameters** (unlike Linac2, Linac3 or Linac4)
 - repetition rate – up to 100 Hz
 - pulse length – up to 1 ms (50 Hz / 2 ms only w/ hardware modification)
 - power level – up to ~75kW per system (on 90kW amplifiers)
- Manual stepping-up in duty cycle required as **cavities are heating up**
- Tuning too slow to follow heat up at full power
- **Cavity reconditioning** required for demanding RF parameters
- Consecutive RF breakdowns **stop amplifier** → manual restart

BE-RF-LRF

Team of 6 technicians

- ~1 FTE for REX-ISOLDE distributed on the team
- Specialists for tube amplifiers, controls, LLRF
- 1 link person (Luca Timeo)

- Team is also running the RF on L2, L3, RFQD, and some L4 systems
- Call-out service for nights & weekends provided for **L2 & L3 only**
- No off-hours service for REX-ISOLDE

Limitations

Average power

- **Overheating** of cavities may lead to leaks: 2005 and 2009 on 9-gap IH
- Operational **instabilities** of overheated cavities

Peak power

- **Sparking**
- 90kW amplifiers can only provide ~75kW due to LLRF back-off
- **$A/q=4.5$** corresponds to ~80kW on 7-gap cavities → unstable operation at best

Pulse length

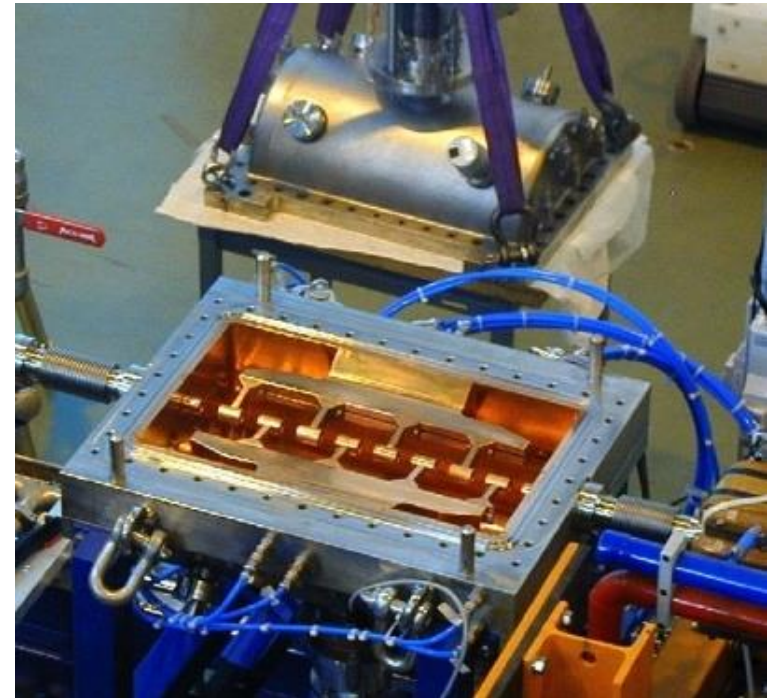
- Amplifiers modified in 2005 from 50 Hz / 2ms to 100 Hz / 1 ms
- New 9-gap with up to 100 Hz or 2 ms, 10% d.c.max

RF Systems

RF systems	Frequency [MHz]	P _{peak} RF (closed loop) [kW]	P _{avg} RF (cavity) [kW]
RFQ	101.28	~45	
Buncher	101.28		
IHS	101.28	~71	
7-gap 1	101.28	~72	
7-gap 2	101.28	~73	
7-gap 3	101.28	~84	
9-gap IH	202.56	~105	2.5

Overheating

- In 2005, the 9-gap cavity was powered up to 4.5 kW average power
- A leak developed on the main seal. Closed by retightening bolts.
- In 2009, the 9-gap cavity accidentally was powered too high again.
- Seal needed to be repaired
- Difficult to get leak tight
- From 2.8 kW thermal runaway
- Limit at 2.5 kW average power



Sparking

- Electric discharge due to field emission at surface defects
- Cavity starts sparking “out of the blue”
- RF power is fully reflected back to amplifier – risk for damages
- In case of persistent sparking, amplifier shuts down for protection

- Restart by technician in open loop, slowly increasing power levels
 - 1/2 hour per amplifier
 - Amplifier restarts every few days undertaken by operators
- Recondition cavity back to operational field levels.
 - Potentially hours to days

$A/q=4.5$

- $A/q=4.5$ is a **design value** of REX-ISOLDE
- The amplifiers had been ordered tight at construction
- $A/q=4.5$ has been used some time ago with optimum settings **but**
 - **Not** in recent years to my knowledge (maximum 4.36)
- The accelerating voltage is proportional to A/q , RF power to $(A/q)^2$
- Going from 4.3 to 4.5 would require **~10% more power**
- Any value above $A/q=4.0$ requires
 - Careful ramping from $A/q=4.0$
 - Tuning and balancing of amplifier power on all cavities
 - Time
 - REX-ISOLDE operation has setup procedures

9-gap Amplifier

In 2016, 90 kW amplifier replaced with 130 kW amplifier

- Previous amplifier ran with insufficient back-off (<20%) for LLRF regulation
- Frequent hardware problems and repairs
- In any case, limited in average RF power to 2.5 kW not to destroy the cavity.

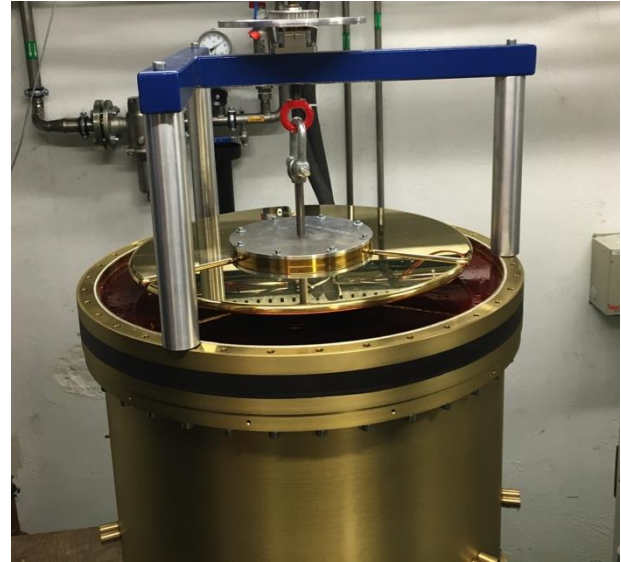
Incident during first months after installation of new amplifier:

- Leak in internal water cooling circuit.
- Repaired on warranty but amplifier required retesting
- Intervention periods at REX-ISOLDE limited due to HIE-ISOLDE installation
- Indirect delays:
 - Some interventions require two RF experts
 - Unforeseen L2 & L3 interventions competing for resources

9-gap Amplifier

Incident on 18 September 2016:

- Short-circuit in the anode capacitor.
 - Warranty Intervention by supplier
 - Correction of breakdown spots
 - Replacement of Kapton insulator
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- Further issue with a control cable detected and repaired at start-up
 - Total down time 8 days.



Potential Improvements

- Will remain on **few kW** level for a **pre-specified duty cycle**
- Correct the RF coupling of the cavities to 50 Ohm for that duty cycle
 - Requires breaking the vacuum of the cavity
 - Major intervention with considerable risk
- Optimize amplifiers for that duty cycle
 - Complete maintenance overhaul
 - Use new tubes
 - Adjust the amplifiers from A-Z on a load
- This is a major effort with dedicated staff and intervention time
- For **which** duty cycle?? – Flexible machine with **varying parameters...**

Conclusions

- HIE-ISOLDE was sold with $A/q=4.5$... - and it **can** do it!
- REX-ISOLDE **cannot** do it reliably.
- **HIE-ISOLDE** was designed with $3 < A/q < 4.5$, not to become the bottleneck.
- RF operation aims at stable operating conditions in the interest of all.
- RF operation is an everyday challenge.
- Improvements on the RF systems will remain limited in power.
- Reliable operation at $A/q=4.5$ calls for **HIE-ISOLDE phase 3**.



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