Construction of the New Amplifiers for the RIKEN-LINAC

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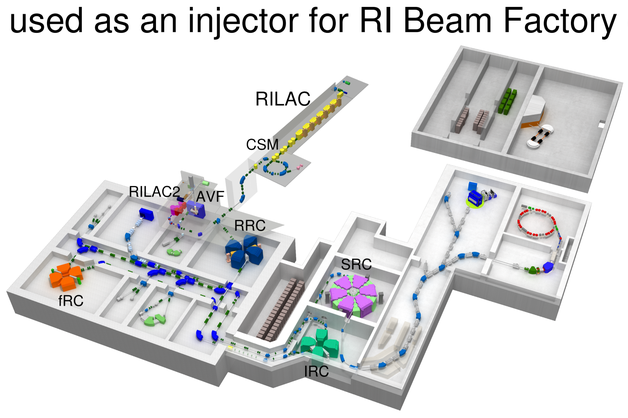
Abstract: New tetrode based amplifiers have been constructed for the RIKEN heavy-ion linac, so called RILAC [1], replacing 36-year-old amplifiers to improve their reliability as a main injector for the RIBF accelerator complex. The RILAC is a DC machine and their frequency are tunable between 18 to 40 MHz so as to be capable of accelerating heavy ions with mass-to-charge (m/q) ratios up to 28. The new rf amplifier is based on a tetrode THALES/SIEMENS RS2042SK coupled with a tetrode THALES/SIEMENS RS2012CJ with a grounded grid circuit. The maximum output power is 150 kW with a frequency ranging from 18 to 40 MHz. The amplifier was originally designed for RIKEN Ring Cyclotron. Since we have many experiences with this type of amplifier, some modification to avoid exciting the parasitic modes which might damage the cavity and/or the amplifier itself. Their construction started in April 2013 and installation was performed in January 2014. After the installation their commissioning has been successfully made. Beam services started in March 2014, and the new amplifiers were operated without any troubles.

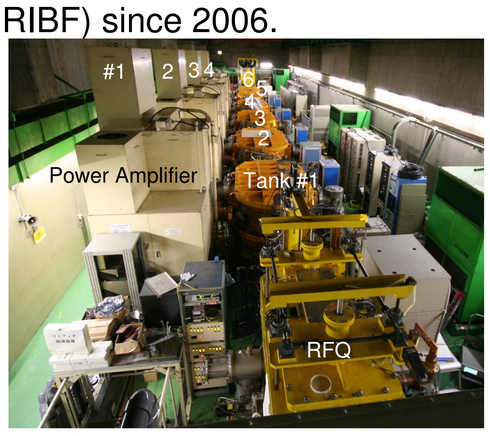
[1] M. Odera et al., Nucl. Instrum. and Methods, 227, 187 (1984).

1. RIKEN heavy-ion Linac (RILAC)

RILAC consists of six variable frequency cavities (tanks) constructed in 1978. It accelerates various kinds of ions up to 4 MeV/u by varying RF frequency from 18 to 40 MHz. Beam service started since 1981. Since 2002, by adding six booster cavities, intense beams up to 6.0 MeV/u are provided for experiments such as super heavy element (SHE) synthesis. RILAC is also used as an injector for RI Beam Factory (RIBF) since 2006.



Layout of RIKEN RI Beam Factory



RILAC tanks and power amplifiers

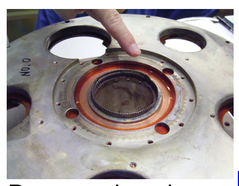
2. Power amplifier for RILAC

- The six amplifiers for RILAC; prototype (#1) was constructed in 1977.
- The others were in 1978.
- #5 and #6 amplifiers were upgraded in 1999 for SHE experiments.
- Three plate DC power supply were upgraded at the same time (one power supply for two amplifiers)
- Several troubles such as cooling water leak deteriorated reliability.

→ #1 and #2 amplifiers were upgraded in FY 2013.

Old type amplifier

Troubles



Damaged socket

Water leak (pin hole)

New amplifier

Schedule of Upgrade

- The project started in April 2013
- Installation January 2014
- Commissioning (dummy load and power test) February 2014
- Beam service March 10 th, 2014 (scheduled)

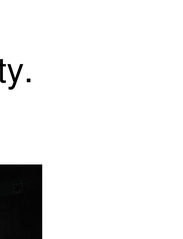
3. Circuit diagram of amplifier

New amplifiers for #1 and #2 are essentially the same as that for #5 and #6, originally designed for RIKEN Ring Cyclotron (RRC).

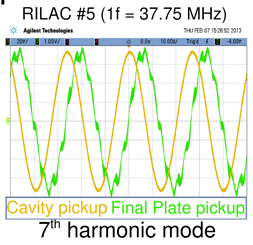
- Tetrode RS2042SK coupled with tetrode RS2012CJ with a grounded grid circuit.
- Frequency range 18— 40 MHz
- Modification from RILAC #5 and #6

50 kW dummy load was installed at STUB to prevent parasitic modes.

Econoload 8776 (water-cooled)



RILAC #5 (1f = 37.75 MHz)



7th harmonic mode w/o dummy load

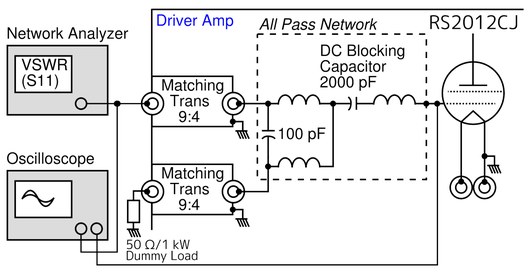
4. Low power test

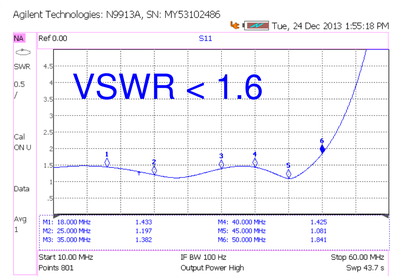
Matching conditions for input and output circuits of driver and final amplifiers were measured and/or tuned at f=18 – 40 MHz.

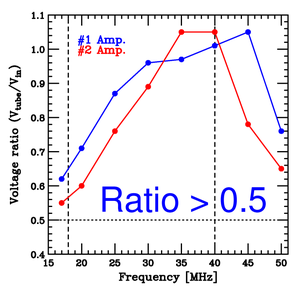
(a) Driver amp.: Input circuit (All Pass Network)

Requirement: Input VSWR < 2 (Return Loss |S11| < -10 dB)

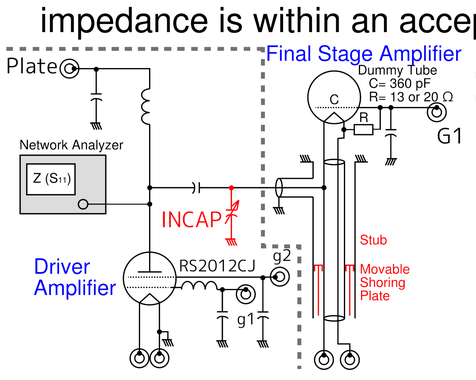
Voltage ratio (V_{tube}/V_{in}) > 0.5

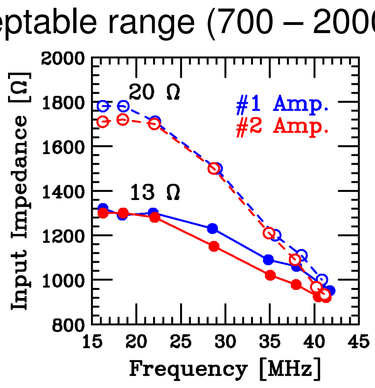


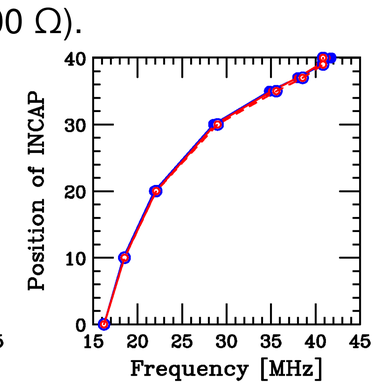




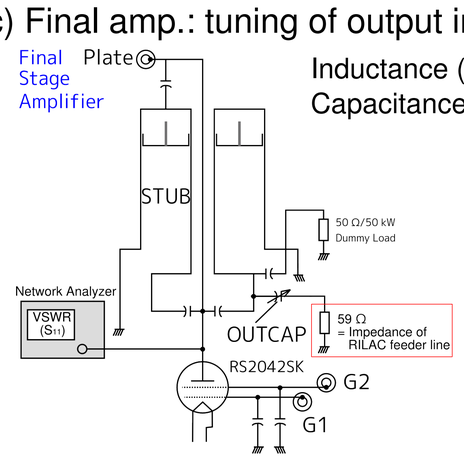
(b) Final amp.: Movable shorting plate of input stub was tuned so that input impedance is within an acceptable range (700 – 2000 Ω).



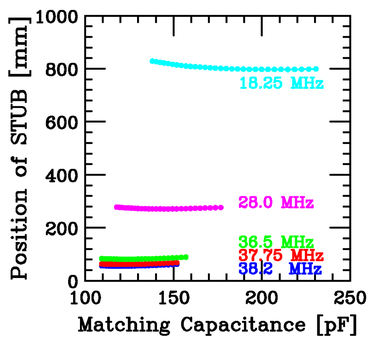


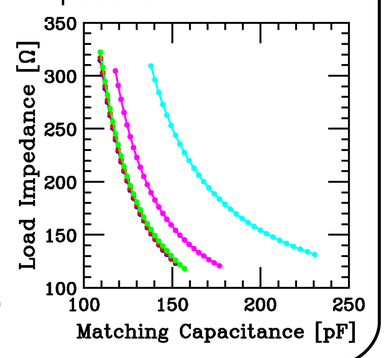


(c) Final amp.: tuning of output impedance



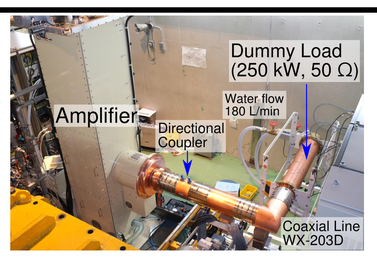
Inductance (STUB) is tuned to cancel the imaginary part of impedance.
Capacitance (OUTCAP) to tune real part of impedance to 59 Ω.



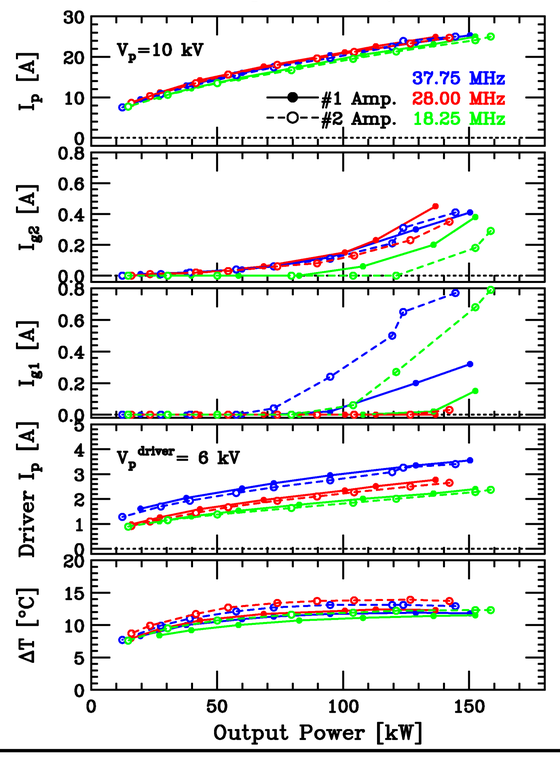


5. Dummy load and power test

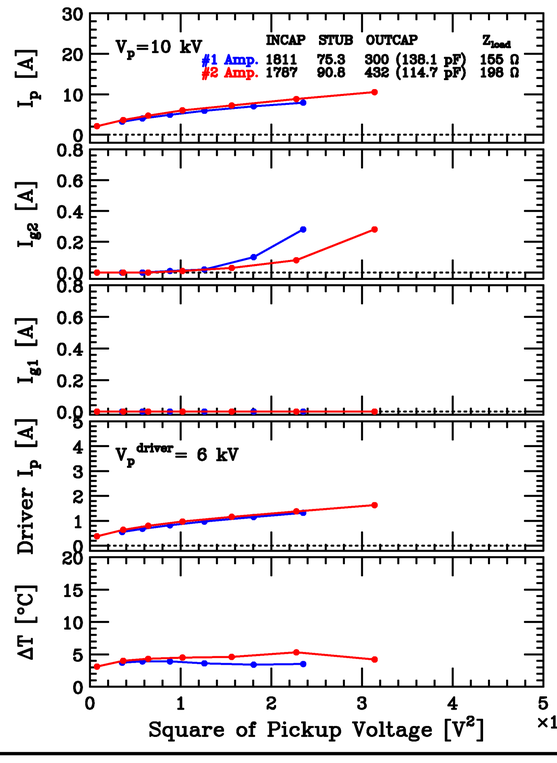
- Output test with a 250 kW dummy load → Successfully achieved to output 150 kW.
- In load test at 36.5 MHz, it succeeded to obtain required accelerating voltages.



RILAC Amplifier Dummy Load Test



RILAC Amplifier Load Test @ 36.5 MHz



6. Beam service

Beam services using the new amplifiers started in March 10th , 2014, on schedule. They operated without any troubles so far at frequencies of 37.75, 36.5, and 28.0 MHz, for seven experiments with eight ions: ^{14}N, ^{15}N, ^{23}Na, ^{27}Al, ^{40}Ar, ^{70}Zn (for RIBF), ^{80}Kr, ^{130}Xe.