

Pulsed Solid State Power Amplifier 108 MHz, 300 kW

- Brief Description -

General

The future operation of the GSI heavy ion linear accelerator UNILAC will focus on providing short, intense beam pulses for injection into the synchrotron SIS18 to deliver high-intensity heavy ion beams for the upcoming FAIR facility. New 108 MHz solid state power amplifiers (SSPA) will replace the old UNILAC RF tube systems to assure reliable operation for FAIR for the coming decades. Modern compact 300 kW solid state amplifiers are planned to drive different accelerator cavities.

The amplifiers have to withstand full reflected power at any phase at any time. Reflections will occur regularly at the rising and falling edges of each RF pulse as well as during other mismatch situations like sparking etc. Thus, suitable proven concepts for amplifier protection against full reflected RF power are required by implementing circulators. In the offer, the bidder has to explain these protection concepts including measurements obtained with amplifiers already built for similar projects or with suitable demonstration units at the requested frequency of 108 MHz. The newest LDMOS transistor type with RF power higher than 3 kW is preferred.

The requested RF pulse power can vary from pulse to pulse for the acceleration of different ion species. This will be controlled by a separate low-level RF (LLRF) system regulating the input power of the solid state amplifier (this LLRF system is not covered by this call for tender and will be provided by GSI). In addition, fast amplitude modulation during each RF pulse for beam loading compensation will be provided by the LLRF system.

Major requirements on the RF systems are also highest reliability and maintainability to minimize downtimes as well as high durability and very long lifetimes. This includes the availability of appropriate spare parts and of individual components or subsystems over the expected lifetime of the amplifiers. The design of the amplifiers must provide options to replace discontinued components by appropriate new parts. In addition, low operational costs including maintenance costs and manpower required for operation will be a major criterion.

Scope

The scope of this call for tender is the design, customization, construction and installation of three water-cooled 300 kW solid state power amplifier systems in compact design (max. 2 cabinets) including local control. The mechanical layout has to fit the existing local surroundings (WxDxH: 2000 x 1400 x 2300mm).

Technical specifications and acceptance tests

The amplifier has to be built to customer specifications. Major parameters and requirements are listed below. **Detailed technical specifications will be provided by GSI.** If questions and open issues will arise during the design phase of the amplifier, they must be discussed and finally agreed by GSI. At the end of the design phase, a written approval by GSI will be required for the production start and for the ordering of components by the contractor.

During ion beam operation, the **pulse parameters** (in particular, amplitude, phase and pulse duration) can vary from pulse to pulse within the specified limits. The amplifier systems shall be able to produce RF pulses with a length up to 2 ms and a repetition rate up to 10 Hz on average. The average duty cycle is 2 %. In any case, a maximum average RF output power of 6 kW will not be exceeded.

Special care has to be taken to **minimize interference effects between this special pulsed RF operation scheme and the switch mode power supplies of the transistor stages.** Additional

buffering of the output of the power supplies should be considered to avoid beats of the output RF amplitude during pulses.

The amplifier must provide an option for **gating of the bias current** by an external signal.

The amplifier has to be equipped with an **independent 2-way directional coupler at the output**, monitoring the forward and reflected power at the load side.

The amplifier has to provide **complete local control** including own **protection circuits** in case of overshoot at the input, reflected output power, power supplies failures, faults at the individual transistor stages and over temperature in general. All error messages, status data and measured values have to be provided to an external monitoring and control system.

The amplifier must provide an **interface for remote control** (Ethernet). A list of signals and commands will be defined in the design phase.

The amplifier has to provide an input for a fast **external interlock** signal to stop immediately operation.

The RF modules and boards must provide a sufficient number of **measurement points**, in particular, for troubleshooting and repair (for instance, to check the forward and reflected RF powers between driver stages and power stages). A complete documentation for troubleshooting and repair as well as for maintenance must be provided, including information about the nominal values and the tolerable range of the measured values at the measurement points.

The contractor must provide full **documentation** of the amplifier, including complete circuit and wiring diagrams, layout information, parts list, circuit descriptions, service instructions, mechanical drawings, etc. as well as all **source codes** of software delivered with the amplifier.

The technical specifications will also include details regarding the **Factory Acceptance Test (FAT)** and the **Site Acceptance Test at GSI (SAT)**. The FAT must include a successful 24 hour test at maximum output power on 50 Ohm dummy load. Besides further tests, arbitrary pulse schemes within the specified boundary values will be tested, including measurements of the RF amplitude variations during the pulses which have to meet the specifications in all cases. The FAT will also include measurements with full reflected power at maximum power level.

The SAT will include additional tests on resonant load (the resonant load will be provided by GSI).

Main parameters (selection)

Center frequency	108.4 MHz
Bandwidth (@ 1 dB)	$\geq \pm 1.0$ MHz
Nominal RF output pulse power	≥ 300 kW
Output impedance	50 Ohm
Output power at 1dB compression	≥ 310 kW
Reflected power	100 % of max. level, any phase
Max. harmonic level @ resistive load at nominal power	< -24 dBc
Max. level of non-harmonic frequencies @ resistive load at nominal power	≤ -60 dBc
Pulse duration	≤ 2 ms @ 300 kW pulse power
Average pulse repetition rate	≤ 10 pulses per second
Duty factor	≤ 2 % @ 300 kW pulse power
Max. average RF output power	≤ 6 kW
Gain linearity 15 % – 90 % of RF power	≤ 1.5 dB
2 % – 15 % of RF power	≤ 3 dB
Max. droop / variation of RF amplitude during pulses	≤ 0.5 dB
Δ Phase over 0 % to 100% Nominal Power	$\leq 40^\circ$
RF output connector	EIA 4 1/2"

RF input power (pulse) at nominal power	≤ 7 dBm
RF input power (pulse) maximum	≤ 10 dBm
Input impedance	50 Ohm
Input VSWR	≤ 1.2
RF input connector	N-type, female

Cooling medium	deionized water (down to $1\mu\text{S}/\text{cm}$) ¹
Cooling water temperature	23 ± 3 °C
Cooling water forward pressure	< 8 bar
Cooling water return pressure	$\approx 1.5\text{--}2.0$ bar
Mechanical size	Width ≤ 2.0 m, depth ≤ 1.4 m Max. height ≤ 2.3 m
Mains supply	3×400 V / 50 Hz
CE certification (required) ²	EN 55011 & other relevant standards ²

¹ Allowed materials for the cooling water circuit: stainless steel, copper, and suitable plastic materials.

² Compliance with RF emission requirements must be certified by an accredited laboratory (EN 55011 Class A, Group 1, or equivalent standards).