

## **Object of the contract:**

### **I. Item of delivery:**

Two identical RF power amplifiers, each capable of delivering of at least 5 kW of RF power.

### **II. Particular requirements for the delivery item:**

#### **1. Power Amplifier parameters**

- a. Working frequency range: 11 MHz to 20 MHz.
- b. Output power: 5 kW minimum, continuous, on a  $50\Omega$  load.
- c. Output connector: coaxial, type N, or other agreed on with the Buyer.
- d. Input signal level at nominal output power:  $1V_{pp}/50\Omega$  maximum.
- e. Input connector: type BNC preferred, or other agreed on with the Buyer.
- f. Input and output impedance: 50 ohm +/- 10% in the working frequency range.
- g. The output power stage: vacuum tube. The tube should be easily obtainable on the European market, and the design of the amplifier should ensure, that the tube can be easily replaced by the user.
- h. Tube cooling: a forced air flow system is preferred. The Buyer allows the deionized water flow cooling if important factors are forcing the Seller to use this form of cooling. Buyer has deionized water cooling system installation.
- i. Amplifier shall include protection circuits to safeguard the tube if an anode's current value threatens the integrity of the power tube. All resonant circuits should be equipped with simple spark gaps.
- j. In order to meet safety requirements, and for proper operation of the amplifier the Seller should implement the following interlocks (at the minimum):
  - against the amplifier cooling medium flow stoppage;
  - against amplifier or HV supply cabinet's door opening;
  - against improper power supplies voltage sequencing during amplifier on and off;
  - against excessive reflected power.
- k. Method of tuning of the power stage is left to the Seller. Tuning each amplifier from the minimum to the maximum working frequency should take no longer than 10 minutes. The Buyer does not expect to change the working frequency more often than once a day.

#### **2. The front panel furnishing of the amplifier**

- a. There should be a front panel to read-out and set parameters, one for each amplifier. Each front panel should display at least the following information:
  - status of each amplifier (on / off, in use / failure etc.);
  - reason of failure, interlock status read-out (including exceeding VSWR and output power setpoint);
  - peak power and/or average power within the RF ON pulse;
  - VSWR, during RF ON pulse, at the output of the amplifier;
  - value of tube's anode voltage and current;
  - value of tube's grid voltage and current.
- b. The front panel should allow the operator to perform the following tasks:
  - fully turn on and turn off the amplifiers (including power supplies);
  - reset alarms;
  - tune the amplifier to the required frequency.
- c. The amplifiers will be connected to cyclotron's SCADA system. The Buyer expects that the above information (control signals from the consoles) will be brought out to terminal blocks.

The Seller may implement a local / remote (SCADA) switch in the console. Detailed signal list of signals for the SCADA system (including description, voltage levels etc.) should be made available to the Buyer no later than **1** month prior to planned shipment of the amplifiers to Warsaw.

### **3. AC Power and cooling systems:**

The Buyer provides in the RF room, designed for installation of the subject of the contract, the following conditions:

- a. AC Mains: 400V  $\pm$  10%, 3 phase + neutral + protective earth, 50 Hz +4% / -6%, phase voltage imbalance  $\pm$  3%, total available power: 500 kW, other parameters of the AC power are in accordance with PN-EN 50160:2002, with further amendments.
- b. Operating temperature: +10°C to +40°C.
- c. Humidity: max. 80%, noncondensing.
- d. In order to cool of the subject of the contract Buyer has deionized water cooling system and forced air system.
  - Forced air flow system can provide at least 3.2 m<sup>3</sup>/sec of air flow to ventilate the RF room.
  - The cooling water system is as follows:
    - conductivity: not more than 20  $\mu$ S / cm,
    - pressure: from 2.5 to 4.5 atm.
    - water flow: at least 2 x 12 dm<sup>3</sup> / min for operating amplifiers,

### **4. Additional requirements:**

- a. If a water cooling system is used by the Seller, then RF system parts having direct contact with cooling water can not be made of brass.  
Only copper, nickel, bronze, Monel, Inconel, stainless steels (304L, 347) or titanium are allowed.
- b. In spaces with high RF power levels the Buyer does not permit components made of polyvinyl chloride (PVC), polyamide (PA), or other materials with high dielectric loss and low softening temperature. Allowed are materials such as polyethylene (PE) or polypropylene (PP).
- c. The object of delivery should include a repair kit, containing nonstandard or made to order components which are subject to wear, and nonstandard, specialized tools needed for ongoing repairs. Nonmetric (ie. imperial) tools the Buyer sees as nonstandard.
- d. Noise and interference of the RF power signals measured at the 4 kW power level with a 50  $\Omega$   $\pm$ 10% resistive load should not exceed the following values:
  - Mains interference: -40 dBc (with respect to carrier frequency);
  - Other noise (wideband): -50 dBc;
  - Other noise in 3 kHz band: -60 dBc (around the output frequency).
- e. The item of delivery has to meet the following requirements:
  - workplace safety: according to PN-EN 60215:2003;
  - environmental impact: the Seller should have the product certified to European standards or have the ability to perform measurements on compliance with those standards (PN-EN 55011:2010 and EN standards, environmental / sanitation);
  - fire safety requirements of the European Union.

### **5. Delivery and installation:**

- a. The Seller will assemble the equipment in the RF room, in the building located at Pasteur 5A Street, Warsaw, Poland. The RF room dimensions are 11.4m x 12.3m x 3.2 m (length x width x height). In some spots, the height in the RF room is limited by ceiling joists by 0,7m. The doors leading into the RF room allow transportation of objects with a maximum height of 2.2 m and a width of 1.45 m. In an agreed by both parties time, at least 3 weeks before the actual installation begins, the Seller will provide documentation regarding the installation of the subject of the contract at the Buyer's site.

- b. The Seller will provide the Buyer with entire technical documentation of the item of delivery, including mechanical, electrical, elektronik etc.

**6. Site Acceptance Tests:**

- a. The Seller, together with the Buyer, shall do Site Acceptance Tests according to previously agreed, by both parties, protocol. The Buyer may, but is not obliged, to take part in the Factory Acceptance Tests.
- b. The Buyer requires, that at least two types of Site Acceptance Test are to be performed: frequency tuning tests (short term) and long term.
  - short term test will consist of tuning procedure of the amplifier to a selected by the Buyer frequency. Then, while connected to the dummy load, the amplifier will work for half an hour. After that, the cyclotron's final RF power stage will be switched in as a load, tuning procedure will be repeated and the test will continue for another half an hour. The test will be carried out with various PWM and power levels. The whole procedure will be repeated for 5 different frequencies.
  - long term test will consist of tuning procedure of the amplifier to a selected by the Buyer frequency. Than the amplifiers will work for 72 hours non-stop with the cyclotron's final RF power stage as a load with various PWM and power levels. The procedure will be repeated for 2 different frequencies.
- c. To pass Site Acceptance Tests both amplifiers will have to operate failure-free, and within technical specifications, during all the above mentioned tests.