EURISOL DS Project
Task 8: SC cavity development

Deliverable D2
RF source development- Three RF source units

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RF power sources are an important part of an accelerator total cost, and they are also the main cause of beam trip or shutdown. Within the EURISOL-DS, it was decided to develop a cost – effective and compact RF source at 352 MHz, based on solid state amplifiers.

A 5 kW unit and then two 10 kW units were fabricated, tested under several conditions, and finally used to supply the RF power to superconducting cavities.

In order to perform the cavity and coupler test at the nominal RF power, RF power amplifiers have been developed by INFN/LNL. The main purpose of this study was to develop and test an unconditionally stable RF amplifier based on transistors (Mosfet), very compact and cost effective. The amplifier uses 300 W solid-state modules (see fig. 1), design at LNL, assembled by means of 8-ways RF combiners and splitters and a high power 4-ways combiner (Figure 2).

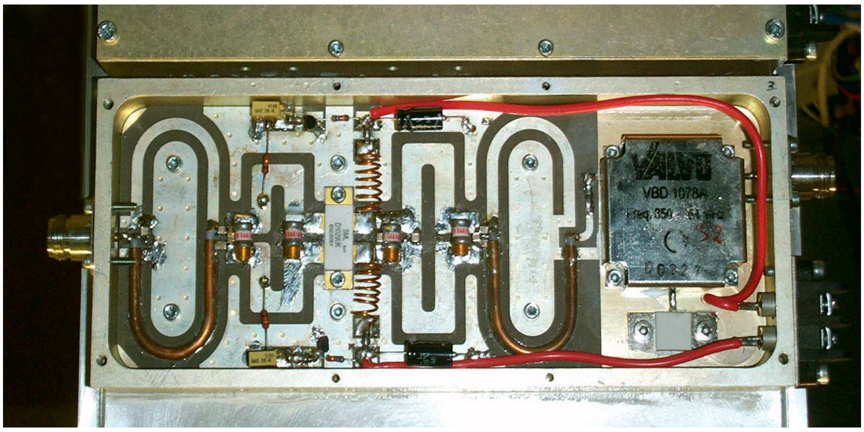

Fig. 1: LNL design of the 300 W module with its RF circulator

The module is based on a Semelab DMD1029A mosfet, a 300 W circulator and a power termination in order to manage the reflected power during transients when there is no beam loading in the superconducting cavities. All modules were assembled in a external broadcasting company. After delivery to LNL, each module was individually measured and tested by a joint LNL / IPN Orsay team.

The control system allows to continuously monitoring the amplifier's status. It is based on a National Instrument Compact Field ¨Point controller with several I/O modules, analog and digitals, and several thermocouple channels (Fig. 3). This device allows quick and easy programming by using the Labview development system. Many parameters like RF power, DC supply currents of all modules and temperatures, as well as digital signals are acquired, measured and used by the control software to generate warnings, alarm indications and safe shutdown procedures in case of failure. The amplifier can be operated from a touch panel computer located in the front panel, or from a remote computer connected through an Ethernet link.

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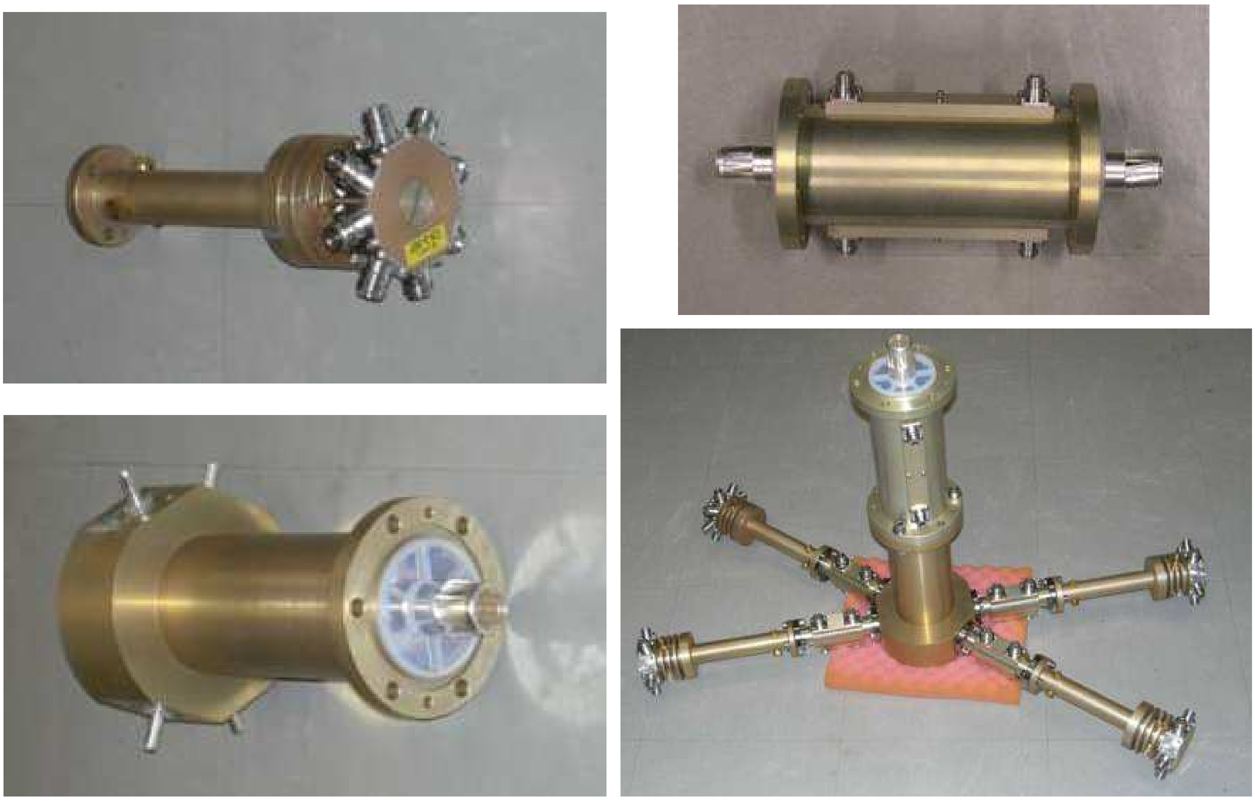

Figure 2: RF components of the amplifier: 2.5 kW 8 way combiner (top left), 10 KW 4-way combiner (bottom left), high power directional coupler (top right) and high power output stage (bottom right).

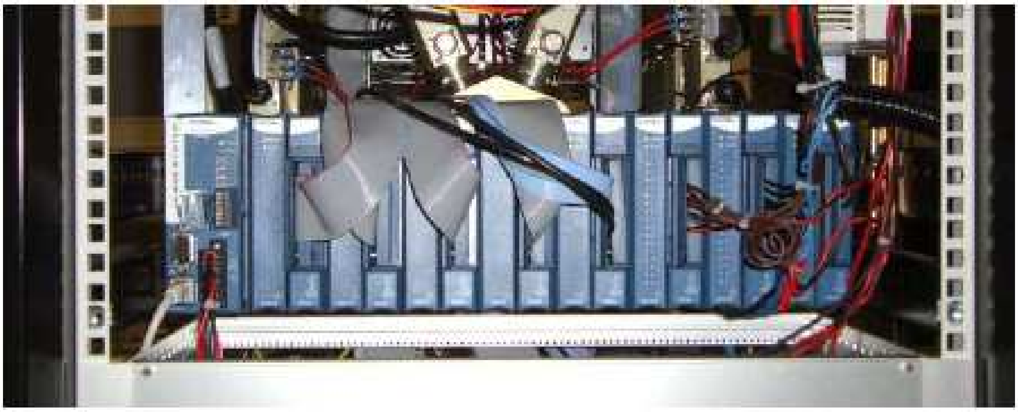

Fig. 3: Embedded controller

The 10 kW amplifier is housed in a 0.6 m wide, 1m deep and 2 m tall rack cabinet. The amplifier integrates the power supplies and the necessary cooling channels and plates to limit the transistors temperature increase. Pictures of the 5 kW unit and of one 10 kW unit is shown in Fig. 4.

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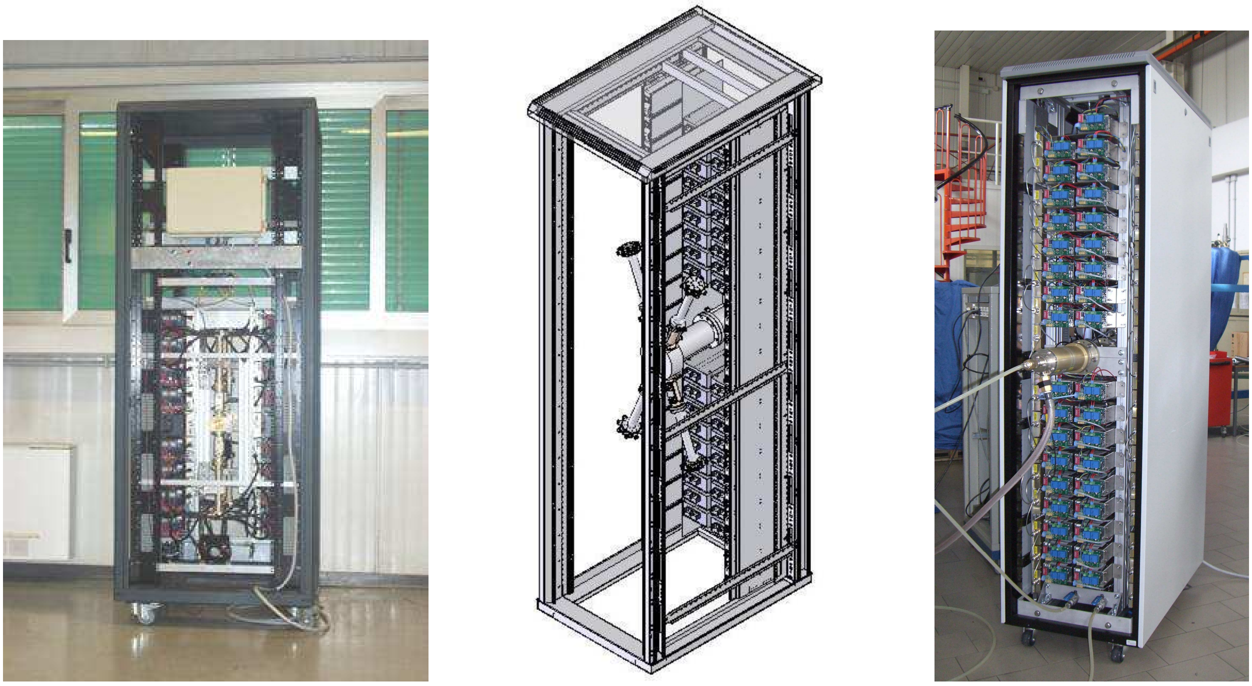

Figure 4: Solid state RF amplifier at 352 MHz: the 5kW unit (left), sketch of the 10 kW unit (centre) and one of the 10 kW unit rear view (right).

An intense test campaign was performed on the 5 kW unit and then the 10 kW in order to fully characterized the amplifier, and also to check the amplifier stability (long run tests) and capability to operate under any condition (with or without reflected power).

The power level of 10 kW has been reached with a moderate gain drop of about 3 dB (see figure 5).

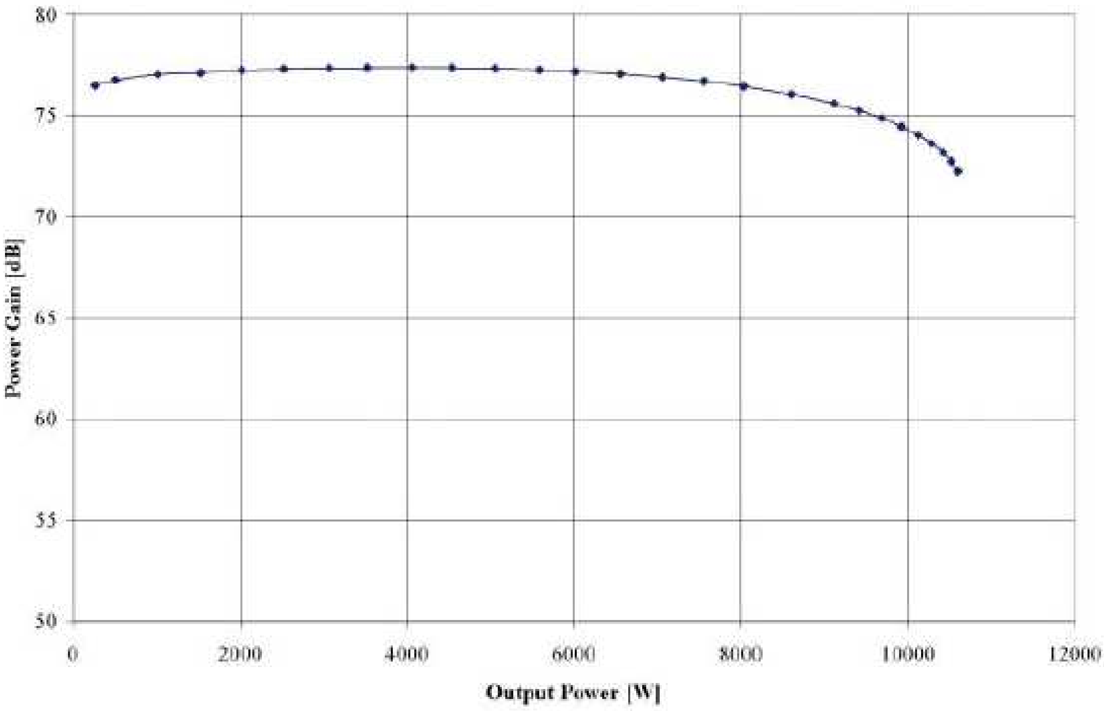

Figure 5: Measurement of the 10 kW RF amplifier gain as a function of the output power.

Above 10 kW, the gain drops much faster, as a consequence of the built-in power limiter. The maximum safe operation point in CW mode has been established to be 8.8 kW in average, while the absolute maximum value (safe only for short time) is 10 kW. These power limits have been established after an analysis of the DC supply currents of all the RF amplifier modules, acquired by the control system and recorded in a remote computer. The histograms of the 64 average DC power supply currents at three output power levels are shown in fig. 6.

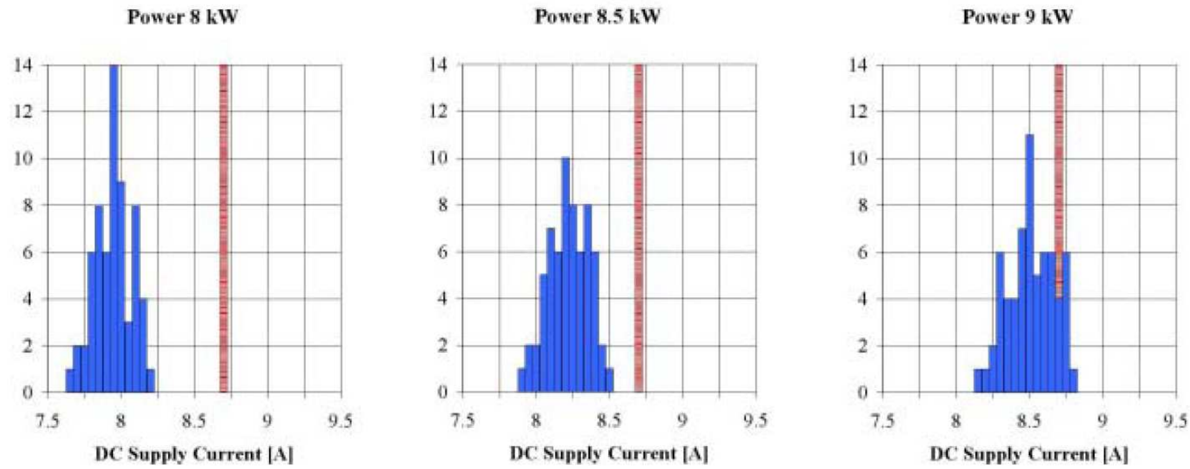

Figure 6: Histogram of the DC supply currents for 3 power levels

A first long test was performed over 14 days at 8 kW in load matching condition. The amplifier was reliable and stable during operation (fig. 7). A small gain degradation appeared at the beginning of the test due to conditioning, and stabilization occurred after 7 days. The gain reduction at the end of the test was 0.4 dB, confirming the need of setting maximum power limits for long term operation.

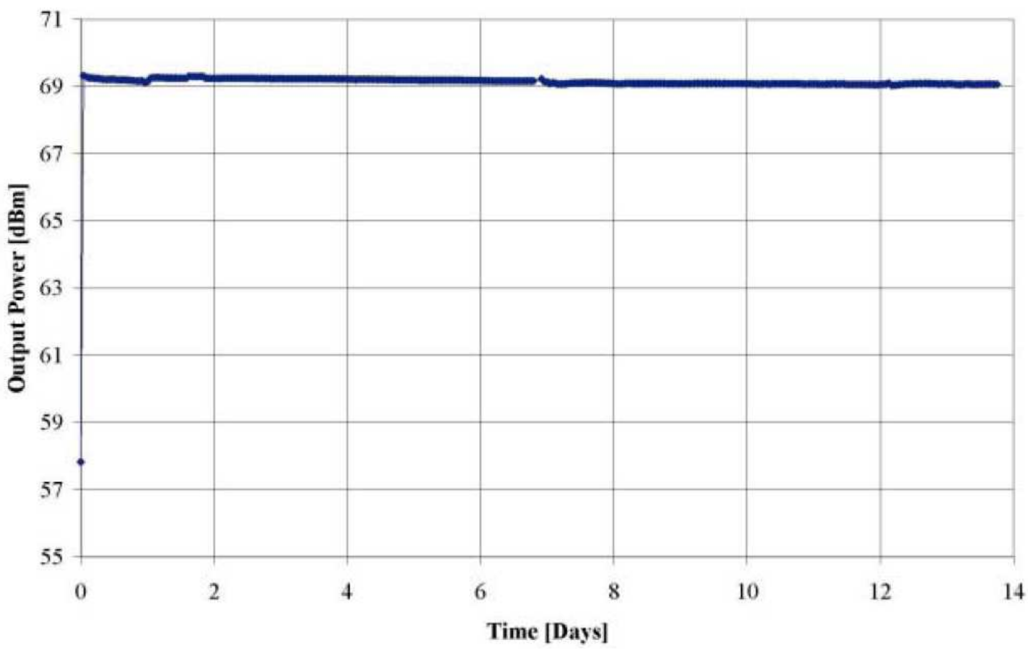

Figure 7: 10 kW unit long test: output power as a function of time

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In order to have the possibility to reach 20 kW of RF power for future tests, a high power combiner was developed. It allows to combine the two 10 kW RF unit in a very efficient way. Calculations performed with CST Microwave Studio showed that the combiner S11 parameter (reflected power coefficient) is only -60 dB (Fig. 8).

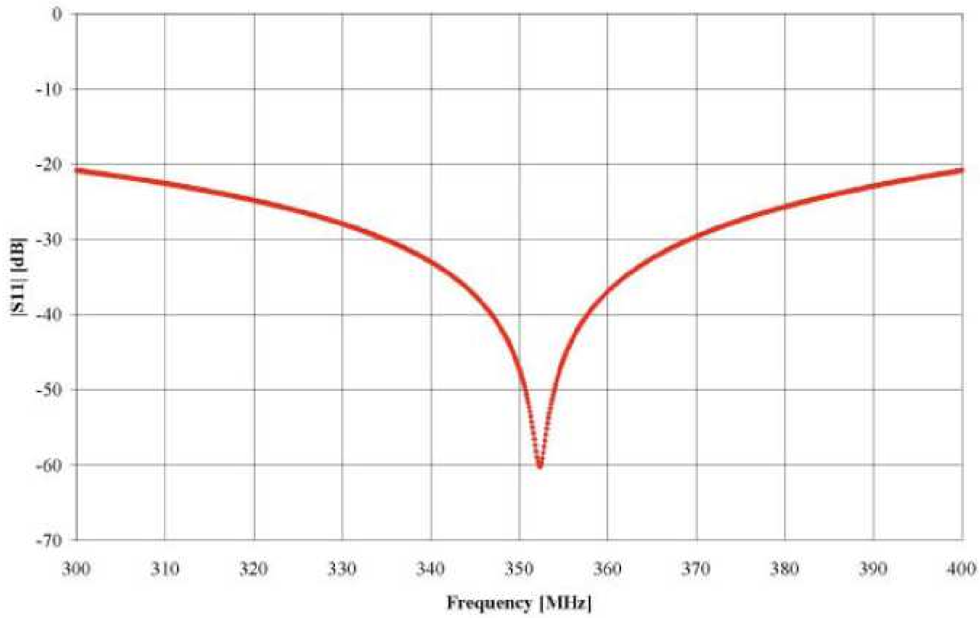

Figure 8: Simulation of the high power combiner frequency bandwith

One 10 kW RF unit was sent to IPN Orsay (Fig. 9) to be used in the power RF bench to conditioned the power coupler and to perform the spoke cavity RF power test in the cryomodule.

Figure 9: One of the 10 kW unit installed at IPN Orsay for the coupler conditioning.

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