Progress report on $3\pi/4$ Backward TW Accelerating Module for the ELETTRA 1.5 GeV Electron Injector

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Abstract

The 5 first units of the 6.15 meter $3\pi/4$ backward traveling wave (BTW) structures [1] used for the ELETTRA 1.5 GeV Electron Injector [2] have been measured and brazed. These structures will be fed by a TH 2132 45 MW-4.5 μs coupled to a Thomson CIDR (Compresseur d'impulsion à Double Résonateur) similar to the CERN design of the SLED RF pulse compressor, leading to an expected energy gain value of 33 MeV/m. This paper presents the RF cold tests measurements which have permitted to ascertain the quality factor Q value of the BTW structures and so the acceleration efficiency of these BTW units. It analyses the power tests made at Thomson on the first CIDR which have led to a peak power value at the phase reversal-time equal to 200 MW. It also presents results obtained at the beginning of the BTW unit RF conditioning process.

1. INTRODUCTION

Since electron linac development as injectors for light sources and the availability of several RF pulse compressor systems (SLED, LIPS ...) have renewed the interest for traveling wave accelerating structures, proposals were made to improve acceleration efficiency by using large impedance H-coupled backward TW structures (BTW) at the $4\pi/5$ [3] or $7\pi/8$ [4] modes instead of the classical $2\pi/3$ forward TW units. If energy gain measurements of the 1.27 m $4\pi/5$ BTW installed at *LAL* [5,6], associated to cold tests measurements and simulations, have validated the improvement in energy expected in reference [3], i.e +23% within a 5% margin error, the high power levels reached with a RF pulse compressor have also permitted to expect a good peak field behaviour of a longer unit. Finally, this new kind of BTW structures has been chosen for the ELETTRA Electron Injector [2]. For reasons of efficiency and easy tuning in frequency, the retained accelerating mode has been the $3\pi/4$ one [1]. One of the BTW unit, fed by a TH 2132 45 MW-4.5 μs klystron coupled to a Thomson CIDR, is now under power tests at GE CGR MeV.

In this paper, the RF cold tests measurements of the 5 first BTW structures are presented, and the power tests made at Thomson on the first CIDR RF pulse compressor are analysed as the preliminary power tests of the BTW unit.

2. BTW COLD TESTS MEASUREMENTS

The 6.15 m $3\pi/4$ BTW structure has been already described in detail in reference [1]. One reminds that the choice of RF parameters, as the filling time of the structure, has been optimized for the RF pulse compression mode of operation. The structure consists of two types of cell to optimize the energy gain and to limit the peak field value on copper to 140 MV/m. Five BTW structures have been brazed and two others are in the tuning process. The table 1 presents the section figures obtained from cold tests measurements after brazing on sections S1 to S5 and compares them to expected values.

Table 1: Characteristics of $3\pi/4$ BTW structure.

	expected value	section S1	section S2	section S3	section S4	section S5
Frequency † Mhz	2997.700	2997.740	2997.660	2997.595	2997.595	2997.640
Filling time t_f μs	0.760	0.767	0.777	0.771	0.774	0.770
Attenuation τ Neper	0.573	0.593	0.605	0.600	0.603	0.614
Power attenuation dB	4.98	5.15	5.26	5.22	5.24	5.34
Quality factor Q	12500	12180	12090	12100	12080	11810

† measured in air for surroundind temperature, pressure and relative humidity respectively equal to 19.5^o, 760 Torr and 60%.

The frequency values are found in a bandwith of 145 Khz. One notes that these frequency shifts are due to a non-reproductible frequency variation with the brazure process from a structure to an other one. This effect was expected. These variations will be corrected when structures are under vacuum by regulation temperature values of each unit.

The filling time values are from 1% to 2% greater than the expected one. From the energy gain point of vue, these small differences have no influence with respect to the optimization with the RF pulse compressor. From the CIDR operation point of vue, it means that the phase reversal-time will be adapted on each klystron according to each t_f value.

The average experimental Q value on the 5 BTW units is equal to 12050, i.e a value 3.6% smaller than the theoretical one. This difference decreases the expected energy gain by 1.2%.

3. RF COMPRESSED PULSE MEASUREMENTS

3.1 General design

The RF klystron pulse of 4.5 μs is compressed to 0.77 μs to increase the available power from 45 MW to 170 MW rectangular equivalent (280 MW peak at the phase reversal-time) for CIDR cavities Q factor of 150000. This is done using the CIDR, realized by Thomson and similar to the LIPS [7] (LEP Injector Power Saver) which is the CERN design of the SLED RF pulse compressor used at the SLAC. One just notes that the dimension of the coupling holes have been modified to fit with the optimization of the BTW structures for the RF pulse compression mode of operation.

3.2 Cold tests measurements

The table 2 presents the experimental results for each cavity of the first CIDR, where Q is the quality factor and β is the coupling coefficient.

Table 2: RF Characteristics of the first CIDR.

cavity	frequency † Mhz	Q	β	Q/β
11	2997.110	189800	9.2	20600
22	2996.920	189900	9.2	20600

† measured in air for surrounding temperature equal to 26.1°.

The experimental Q values are 26% greater than the conservative value considered in the original design and equal to 150000. It increases the expected energy gain by 1.4%. Thus, it compensates the slight decrease of 1.2% due to the difference between experimental and theoretical Q values of the BTW units.

The values of β are in very good agreement with the required value (better than 1%). The frequencies of each cavity are not exactly equal. The variations of the RF parameters with the frequency show that this small difference is negligible. At last, one notes that the nearest resonant modes from the operating one are respectively located at −24 Mhz and +15 Mhz.

3.3 Power tests

The power tests of the first CIDR, installed at Thomson, have lasted from August 1991 to December 1991. This large duration is due to the the fact that the RF conditioning process has been slowed down by power limitation on the windows of RF loads which absorbed the RF compressed pulse delivered by the CIDR. After some changes of the experimental setup, 4 TH SF6/water loads have been finally located at the CIDR output through a recombiner and a 3 dB coupler, each load being isolated by a vacuum/SF6 window.

In December 1991, it has been possible to operate with the required klystron pulse length equal to 4.5 μs and a phase reversal-time occuring at 3.7 μs. Then, it has been decided to limit the peak power value at the phase reversal-time to 200 MW in order to preserve the present vacuum/SF6 windows which seemed to be close to their power limitation. It is important to note that no problem on the CIDR itself has been observed for these power values. The figure 1 shows the experimental shape of the RF compressed pulse obtained at the CIDR output.

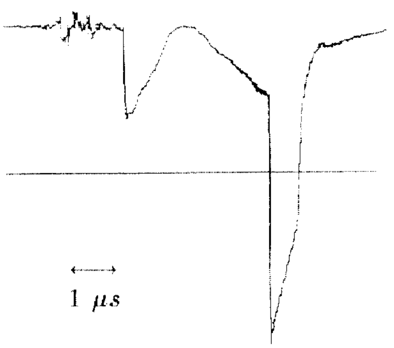

Figure 1: RF compressed pulse at the CIDR output.

For a peak power value of 192 MW, the klystron output power is equal to 37 MW. Considering the losses in the RF system, the amplification factor f_m, defined as being the ratio between the peak power value at the phase reversal-time and the klystron output power value, has been found equal to 5.3, value to compare with the theoretical one equal to 6.4. Simulations, taking into account possible variations of phase and module of the RF signal at the klystron output and an eventual frequency shift between the generator and each cavity, have shown that the decrease of f_m is due to several effects [8] understood and remediable.

For example, the phase switching time, which is estimated equal to 100 ns, can be reduced. The modulator high voltage pulse has a flat part equal only to $3\mu s$ and involves a phase rotation and a module variation of the klystron output signal during 0.9 μs at the beginning of the RF pulse. This problem occurs because the modulator is not devoted to our case but must also produce very long pulses to test other klystrons. It can be solved by a modification of the modulator delay line.

No critical problem has been observed on the CIDR behaviour for the power levels reached. These tests will be obviously completed during the RF conditioning of the BTW unit at GE CGR MeV.

4. BTW POWER TESTS

The first CIDR has been installed at GE CGR MeV and the BTW accelerating module, including a TH 2132 45 MW-4.5 μs klystron, the Thomson CIDR RF pulse compressor and a $3\pi/4$ BTW structure, is now under power tests.

For a klystron pulse length of 2 μs and a phase reversal-time occuring at 1.4 μs, the klystron output power value reached in routine is equal to 22 MW.

For a klystron pulse length of 4 μs and a phase reversal-time occuring at 3.2 μs, the klystron output power value reached in routine is equal to 13 MW. For these operating conditions, the amplification factor f_m has been found equal to 6, i.e a value only 6% smaller than the expected one, though we have not yet the required 4.5 μs pulse length at the klystron output. One notes that the peak power value at the phase reversal-time is equal to 80 MW.

These power values have been obtained after 20 hours of RF conditioning process. Obviously, the goal is to feed the BTW structure with the maximum available power. For the klystron operating nominal point and the CIDR cavities RF parameters given in the table 2, it leads to expect a peak power value at the phase reversal-time, without considering here the losses in the RF system, equal to 290 MW. The amplification factor f_m will also be determinated more precisely at the nominal point.

5. CONCLUSION

The RF cold tests measurements obtained on the 5 first $3\pi/4$ BTW structures and the Thomson CIDR leads to confirm the expected energy gain of the $3\pi/4$ BTW accelerating module. For the BTW and CIDR experimental RF parameter values, the 45 MW-4.5 μs klystron operating point and transmission losses of 7%, the margin with respect to the required energy gain per section equal to 200 MeV varies from 10% to 5% for beam pulse durations from 10 ns to 150 ns.

The CIDR power tests show that no limitation appears for a peak power value at the phase reversal-time equal to 200 MW. But they have to be completed to confirm the good CIDR behaviour for higher peak power levels. In fact, the power tests of the whole $3\pi/4$ BTW accelerating module at GE CGR MeV, which have begun, will permit to ascertain the good CIDR and BTW unit peak field behaviours.

6. REFERENCES

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