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CLIC RF HIGH POWER PRODUCTION TESTING PROGRAM

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Abstract

The CLIC Power Extraction and Transfer Structure (PETS) is a passive microwave device in which bunches of the drive beam interact with the impedance of the periodically loaded waveguide and generate RF power for the main linac accelerating structure. The demands on the high power production (~ 150 MW) and the needs to transport the 100 A drive beam for about 1 km without losses, makes the PETS design rather unique and the operation very challenging. In the coming year, an intense PETS testing program will be implemented. The target is to demonstrate the full performance of the PETS operation. The testing program overview and test results available to date are presented.

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The CLIC Power Extraction and Transfer Structure (PETS) is a passive microwave device in which bunches of the drive beam interact with the impedance of the periodically loaded waveguide and generate RF power for the main linac accelerating structure. The demands on the high power production (~ 150 MW) and the needs to transport the 100 A drive beam for about 1 km without losses, makes the PETS design rather unique and the operation very challenging. In the coming year, an intense PETS testing program will be implemented. The target is to demonstrate the full performance of the PETS operation. The testing program overview and test results available to date are presented.

INTRODUCTION

The CLIC PETS is one of the key components in the CLIC two-beam acceleration scheme [1]. The PETS should deal with high current electron beams and provide extremely stable beam transportation for about one km. In the presence of deceleration, the final energy spread in a drive beam of ~90% is needed in order to achieve high efficiency of the RF power production; therefore, strong damping of any deflecting HOM in the PETS is required to prevent significant beam losses. Each PETS is comprised of eight octants separated by the damping slots, see [2] for more details. Each slot is equipped with HOM damping loads. This arrangement follows the need to provide strong damping of the transverse modes. The upstream end of the PETS is equipped with a special matching cell and the output coupler.

Table 1: The 12 GHz CLIC PETS parameters

Diameter, mm	23
Phase advance/cell, degrees	90
R/Q, Ohm/m	2290
$\beta=V_g/c$	0.453
Q-factor	7200
Active length, m	0.213 (34 cells)
RF pulse length, ns	241
Drive Beam current, A	101
Output RF power, MW	135

Following the design of the current CLIC accelerating structure [3] in the beginning of 2008, the PETS baseline design was finalized (see Table 1). The fabrication and the testing programs were established. In this paper we will present the different aspects and the current status of the PETS testing program to-date.

PETS TESTING PROGRAM

The main objective of the PETS testing program is to demonstrate the reliable production of the nominal CLIC RF power level throughout the deceleration of the drive beam. However, to get the first results as soon as possible and to understand the limiting factors for the PETS ultimate performance, the power generation with drive beam is not the only method. The PETS can be connected to a high power source and tested in a "waveguide" mode, similar to that which is normally done for the accelerating structure testing. This kind of test is now scheduled to be done at SLAC during July-August 2008.

PETS testing at SLAC

The new Accelerating Structure Test Area (ASTA) was recently constructed and commissioned at SLAC [4]. This is a new generation general purpose test stand, which will allow processing various types of high power RF equipment at X-band. The test area is powered by two 50 MW klystrons, whose 1.5 us pulses are combined and compressed using SLED II. The facility can provide a very versatile pulse length and output power: from 100 MW×1500 ns to 530 MW × 64 ns. At a nominal PETS pulse length of 240 ns, the available power is about 300 MW – well above the required PETS RF power level.

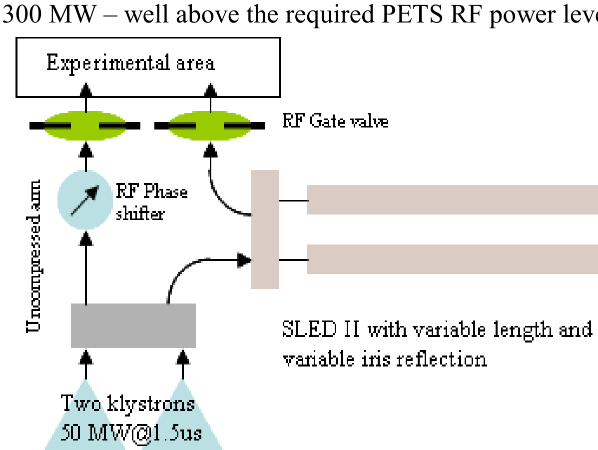

Figure 1: Schematic ASTA layout.

The difference between CLIC frequency - 11.994 GHz and X-band frequency at SLAC – 11.424 GHz required certain modifications in the PETS design. To do these tests, the 11.424 GHz scaled versions of the 12 GHz PETS were designed and fabricated. We consider a number of tests in order to respect the evolution of the PETS configuration. The first structure is equipped with damping slots, but not with damping material. The structure was built and tested at low RF power level (see Fig. 2-4). It will be delivered to SLAC at the beginning of July 2008. The second structure will contain all PETS features, including damping material.

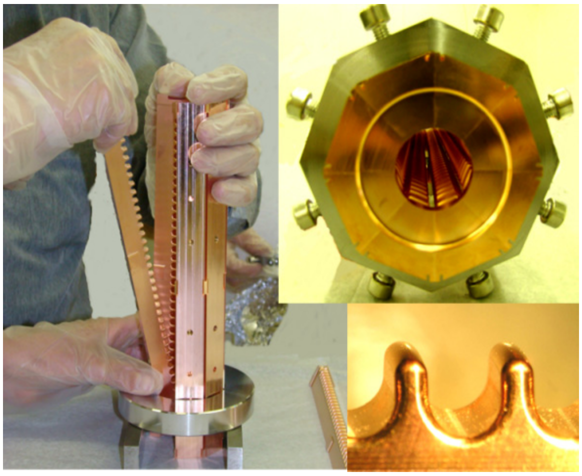

Figure 2: Assembly of the eight PETS bars.

Figure 3: The 11.424 PETS during RF test (left) and before the last EB welding (right).

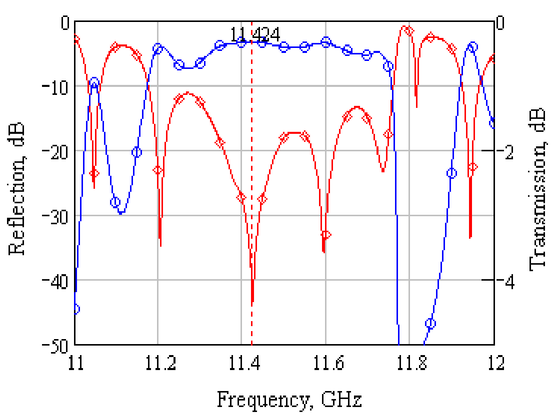

Figure 4: The 11.424 GHz PETS RF measurements: diamonds - reflection, circles – transmission.

PETS testing at CERN

The 12 GHz PETS power production from the drive beam will be demonstrated in the CTF3. The new CLIC experimental area (CLEX) is now under construction as a part of the CTF3 [5]. Upon completion, the CLEX will be equipped with a number of experiments. One of them is the Two Beam Test Stand (TBTS), where the PETS will be installed [6]. As it is shown in Fig. 5, CTF3 will allow for different scenarios of the drive beam generation in terms of the beam current and the pulse length.

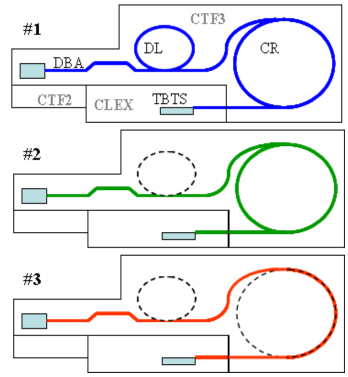

Figure 5: The drive beam generation modes: 1-with full recombination, 2 – with partial recombination, 3 – without recombination.

The drive beam current available in CTF3, even with full recombination, however will be still lower compared to that of the CLIC design; therefore, the TBTS PETS design was evaluated to be able to generate the nominal CLIC RF power. To compensate for the lack of current, the active PETS length was significantly increased: from the original 0.213 m to 1 m. The TBTS PETS power production capability for the different CTF3 modes of operation is summarized in a Table 2.

Table 2: The TBTS PETS power production modes

Operation mode	#1	#2	#3
Current, A	<30	14	4
Pulse length, ns	140	<240	<1200
Bunch Frequency, GHz	12	12	3
PETS power (12 GHz), MW	<280	61	5

Mode 1 of the PETS operation should provide power levels well above CLIC nominal values. Unfortunately, the pulse length of 140 ns is rather short compared to the CLIC nominal pulse of 240 ns. In order to demonstrate the nominal CLIC power level and pulse length, it was decided to implement a different PETS configuration – PETS with external re-circulation, see Fig.6.

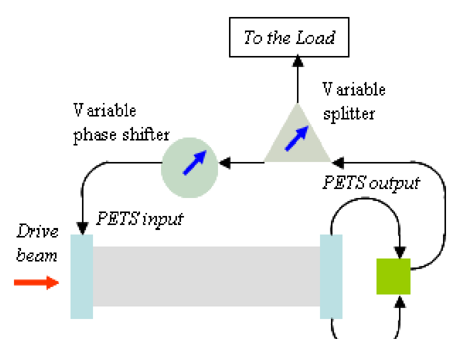

Figure 6: Schematic layout of the PETS with external re-circulation.

In this case, the PETS will operate in the amplification mode, similar to that in the classical resonant rings. The only difference is that now we have a beam as an internal source of the RF power. We have calculated the power production for the CTF3 operation modes 2 and 3. In the calculation, the return loop delay time is 14 ns and the Ohmic efficiency is 75%. The coupling coefficients and pulse lengths were optimized to provide the power level and pulse length comparable to the CLIC nominal values, see Fig. 7. The 3D view of the PETS tank, with all the components integrated is shown in Fig. 8.

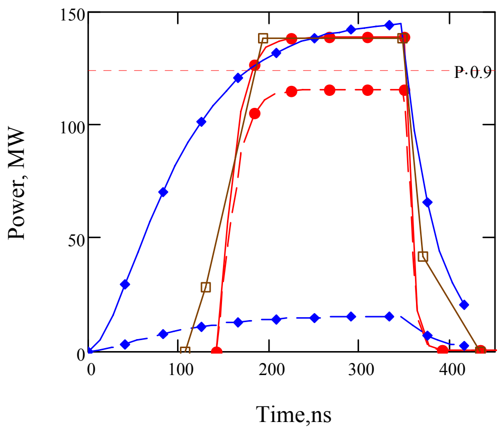

Figure 7: Calculated output RF pulse envelops in PETS with re-circulation. Circles – mode 2 (14 A), diamonds – mode 3 (4 A), boxes – the CLIC pulse by design. Solid line – PETS output, dashed line – to the load.

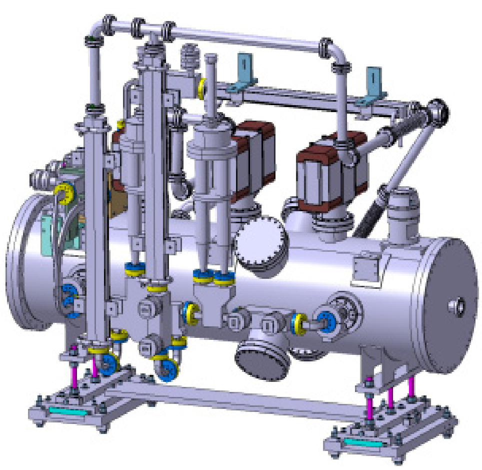

Figure 8: The 3D view of the PETS tank.

Mode 3 of the PETS operation with re-circulation has been fixed now as a starting point for the PETS power production testing program in 2008. It has other advantages: the lower average beam power will potentially allow an increasing repetition rate; it will be much easier to operate the whole CTF3; it gives the leverage to manipulate the power level during conditioning simply by changing the return loop phase or amplitude. Finally, the re-circulation can be terminated by re-directing all the RF power into the load, so that the high current mode can be tested without any waveguide reconnections.

The PETS fabrication and installation program closely follows the CTF3 schedule. All the RF components – variable phase shifter and power splitter, hybrids, directional couplers and loads (see Fig. 10) were designed and ordered from industry, as well as the PETS bars and the PETS couplers (see Fig. 9), vacuum tank, supporting and cooling systems. It is planned that the PETS installation in CLEX will be done in early October 2008 at the time when the drive beam will be available.

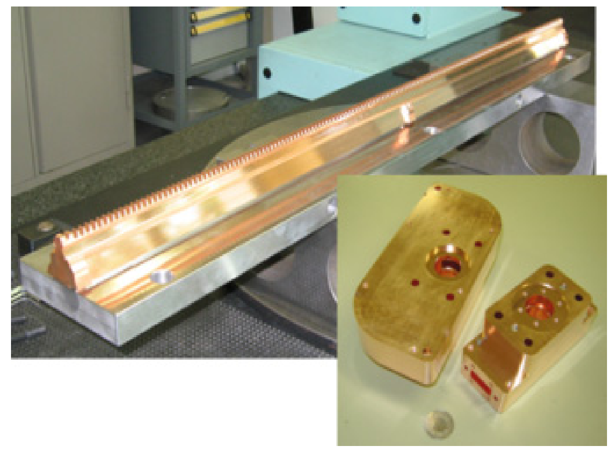

Figure 9: The 12 GHz PETS couplers and 1 m PETS bar on a metrology bench.

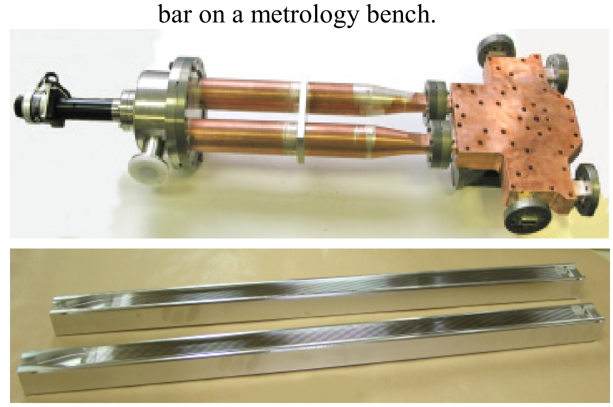

Figure 10: 12 GHz variable RF power splitter (top) and parts of the dry stainless steel high power load (bottom).

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