A 12 GHZ PULSE COMPRESSOR AND COMPONENTS FOR CLIC TEST STAND

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Abstract

The X-band power test stand needed for preprocessing and testing of key CLIC RF components is being installed in the test facility CTF3. The test stand includes several 12 GHz XL5 klystrons (50 MW, 1.5 μs) and a pulse compressor (PC) of the SLED-I type to obtain over 120 MW peak power at 230 ns pulse length. A compact compressor of this type based on TE_{01}-TE_{02} beating wave in high Q-factor compressor's cavities has been designed, produced, and tested at low power level. For testing accelerating structures and so-called "CLIC recirculation principle" of its operation several -3 dB couplers, tuneable phase shifters, and variable power attenuators were also produced and tested.

DESIGN OF SLED-I PC

In order to provide at 12 GHz an efficient compression of rf pulses with parameters P_{inp}=50 MW, τ_{inp}=1.5μs, aimed to obtain P_{out}=120 MW, τ_{out}=230 ns, it is proposed to use a compact SLED-I pulse compressor [1]. The scheme of the well-known SLED-I is to be modified in order to provide necessary Q-factor of a storage cavity ($Q_l \approx 25\cdot 10^4$, $Q_0 \approx 1.5\cdot 10^5$), because Q-factors of spurious modes in an oversized cavity could be comparable with that for operating mode. The compressor of such modified scheme consists of two identical cavities coupled by -3 dB couplers [2], each cavity is based on TE_{01}-TE_{02} beating wave waveguide which starts from single-mode TE_{01} waveguide and finishes by a waveguide of a big enough radius which is necessary in order to provide the mentioned high Q-factors (Fig. 1). The use of the beating wave due to inserted absorbers allows simple solutions for spurious mode suppression. Indeed, these absorbers made of ceramics are placed out of the operating mode field while spurious mode fields are to penetrate perhaps in these absorbers. The design also naturally solves a problem of pumping ports which also play a role of selective elements and do not spoil Q-factor of the operating TE_{01}-TE_{02} mode (Fig. 2). Similar principle based on beating wave was used in 30 GHz TE_{01} mitre bends produced several years ago for CTF3 [3].

The beating wave (to provide deep modulation of surface field) consists of approximately 80% of the TE_{01} mode and only 20% of the TE_{02} mode. This mode mixture is produced sequentially by TE_{10} – TE_{01} "serpent-like" mode converter [3], and then the resulted TE_{01} mode is converted into the desired mode mixture by specially profiled horn (Fig, 3) which provides excitation level of other than TE_{01} and TE_{02} axisymmetric modes less than -30 dB (Fig. 3a). Mutual phase of the TE_{01} and TE_{02} modes at horn output is zero (this corresponds to flat phase front of a field localized out of waveguide wall) as it is seen in Fig. 3b.

The cavities in each channel are based on ∅100 mm copper waveguides. Length of each cavity corresponds to 3 beating periods (~600 mm).

The mentioned pumping port consists of a ring vacuum vessel which has a set of the 24 circular holes to pump a whole volume of the PC. The mentioned vessel is also partially filled by absorbers.

Fine frequency tuning in each of two channels is organized by means of independent, electric, stepping motors which allowed also manual control.

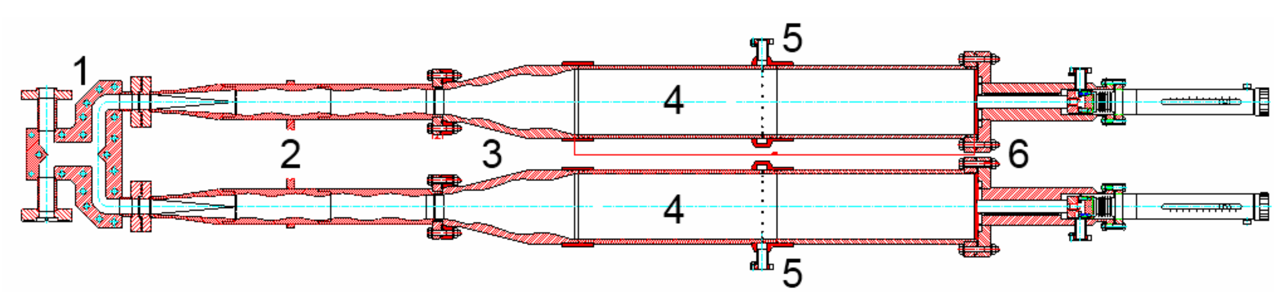

Figure 1: Technical drawing of 12 GHz PC: 1 - -3 dB coupler, 2- TE_{10} rectangular waveguide to TE_{01} of circular waveguide mode converters, 3 - TE_{01} to TE_{01}+TE_{02} mode converters (horns) with coupling irises in the beginning, 4 - circular waveguide cavities, 5- pumping ports, 6- plungers with stepping motors.

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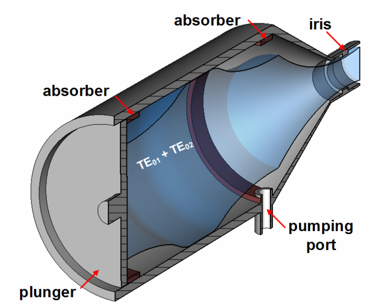
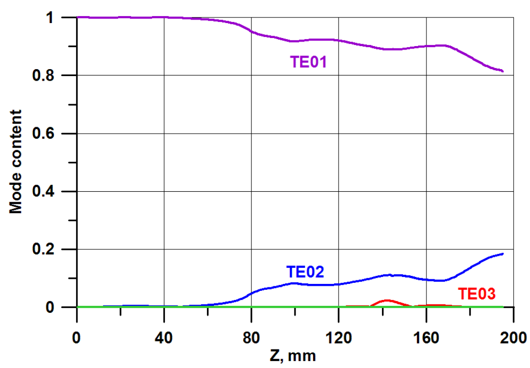
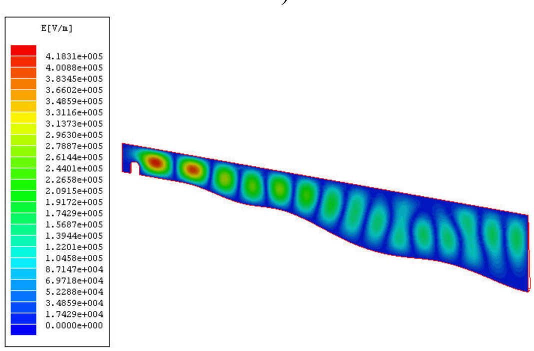


Figure 2: Internal view of PC cavity at TE_{01}-TE_{02} beating wave.



a)



b)

Figure 3: Mode content in TE_{01} – TE_{01}+TE_{02} mode converter along its length (a) and field in storage cavity at horn and coupling iris (b).

PC LOW POWER TESTS

The described 12 GHz PC was produced (Fig. 4) and tested at low power level.

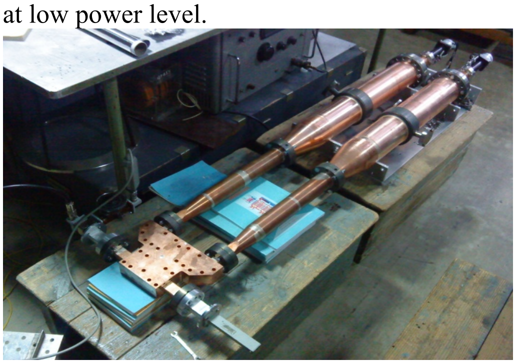


Figure 4: SLED-I type pulse compressor at cold testing.

The measured transmission characteristic S_{12} of the PC is shown in Fig. 5 by red curve. In order to find Q-factors and to simulate pulse compression we decided to fit the obtained measured curve by theoretical curve (blue curve in Fig. 5):

$$S_{12} = B \cdot \left(r - \frac{(1-r^2)\cdot \rho \cdot \exp(i2\pi \cdot n \cdot \Delta f / f_0)}{1 - \rho \cdot r \cdot \exp(i2\pi \cdot n \cdot \Delta f / f_0)} \right) \quad (1)$$

where f_0 =12 GHz is a central frequency, $1\text{-}r^2$ – is a coupling coefficient (transmission through coupling iris), ρ - is an attenuation in a PC cavity, n=80 – is a longitudinal number of variations of the eigen mode, B describes attenuation in waveguide network outside cavity.

The found parameters B, ρ, and r allowed to conclude that in fact the loaded Q-factor was Q_l=$22\cdot10^4$-$25\cdot10^4$. The own Q-factor was $Q_0\approx1.5\cdot10^5$, while the Ohmic Q-factor was estimated as $4\cdot10^5$. This difference is caused by diffraction losses in cavities (due to not perfect axial performance). On a base of the found parameters we also numerically simulated a pulse compression process (Fig. 6).

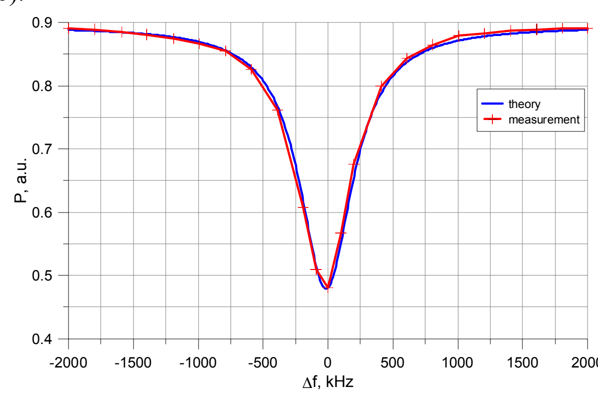


Figure 5: Fitting of the measured S_{12} PC characteristic by theoretical formula.

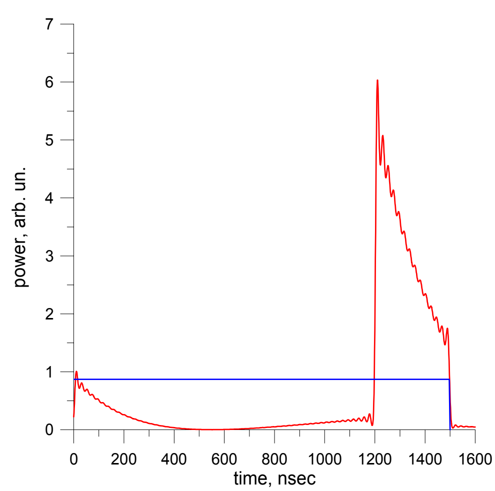
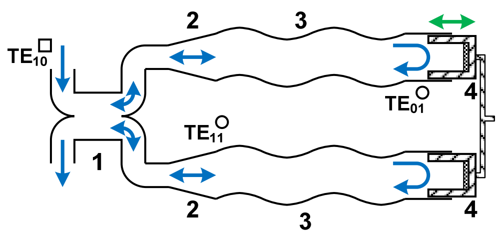


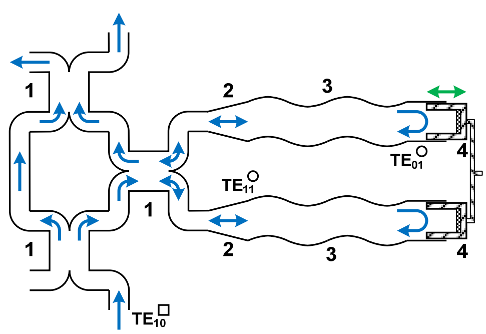
Figure 6: Simulation of pulse compression using the found PC parameters: input pulse (blue) and output compressed pulse (red).

TUNEABLE PHASE SHIFTER AND VARIABLE POWER ATTENUATOR

Schemes of high-power phase shifter and variable power attenuator are shown in Fig. 7a and b correspondingly. Both components are based on so-called -3 dB coupler (phase shifter), or several such couplers (attenuator), and previously described mode converters. These allow to change phase (phase shifter) or to switch powers between output ports (attenuator). In order to provide tune ability, the components have electrically controlled plungers based on cut off waveguides with absorbing ceramics inside for mode selection. The plungers work at TE_{01} mode of a circular waveguide in order to avoid breakdown at high power level which could be caused by inevitable holes between plungers and a waveguide where its move.



a)



b)

Figure 7: Scheme of phase shifter (a) and scheme of attenuator (b). 1 – -3 dB coupler, 2 – transducers of TE_{10} mode in rectangular waveguide to TE_{11} of circular waveguide, 3 – TE_{11} to TE_{01} mode converter, 4 – movable plungers.

Both components were produced of oxygen free copper in vacuum versions and were tested at low power level.

The measured, inserted phase of the phase shifter in dependence on position of the plungers is shown in Fig. 8, where it is seen that this phase can be varied between 0° and 400°. The measured S_{11} parameter was less than -24 dB.

Measurements of the attenuator were aimed to investigate powers as a function of plunger's position in all 4 ports (Fig. 9). One can see that output power can be switched between two output ports in region 1% - 90%. Total losses (Ohmic and diffraction) do not exceed 10%.

High-power experiments are being carried out now.

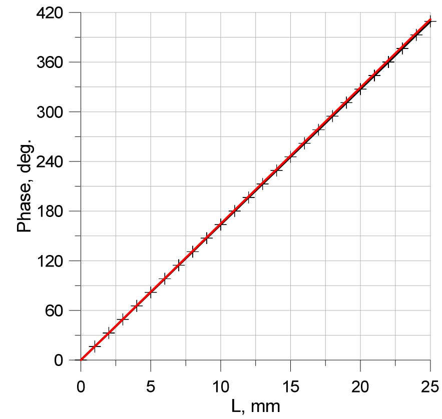


Figure 8: Measured (black crosses) and theoretical (red line) inserted phase by phase shifter.

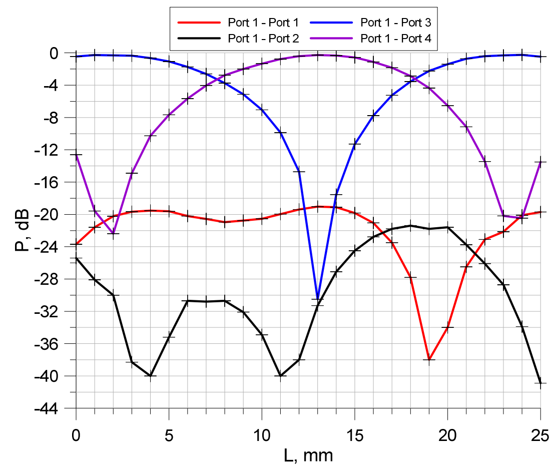


Figure 9: Measured powers in ports of the tested attenuator.

SUMMARY

The produced 12 GHz pulse compressor, phase shifters and variable power attenuators are acceptable for the CLIC high power test program.

REFERENCES

[1] F. Peauger, A. Hamdi, S. Curt, S. Doebert, G. McMonagle, G. Rossat, K.M. Schirm, I. Syratchev, L. Timeo, S. Kuzikov, A.A. Vikharev, A. Haase, D. Sprehn, A. Jensen, E.N. Jongewaard, C.D. Nantista, A. Vlieks, A 12 GHz RF Power Source for the CLIC Study, Proceedings of IPAC'10, Kyoto, Japan, THPEB053, pp. 3990-3992 (2010).

[2] S.V. Kuzikov, Status of CLIC activity at IAP, 2009 CLIC Workshop, (2009); http://indico.cern.ch/contributionDisplay.py?contribId=129&confId=45580

[3] Kuzikov S.V., Denisov G.G., Heikkenen S. et al. Study of Ka-Band High-Power Transmission Lines, AIP Conf. Proc., 7th Workshop on High Energy Density and High Power RF, Ed. by D.K. Abe and G. Nusinovich. Greece, Vol. 807. pp. 424–430, (2006).