A SLED type pulse compressor for the CERN X-band test stand

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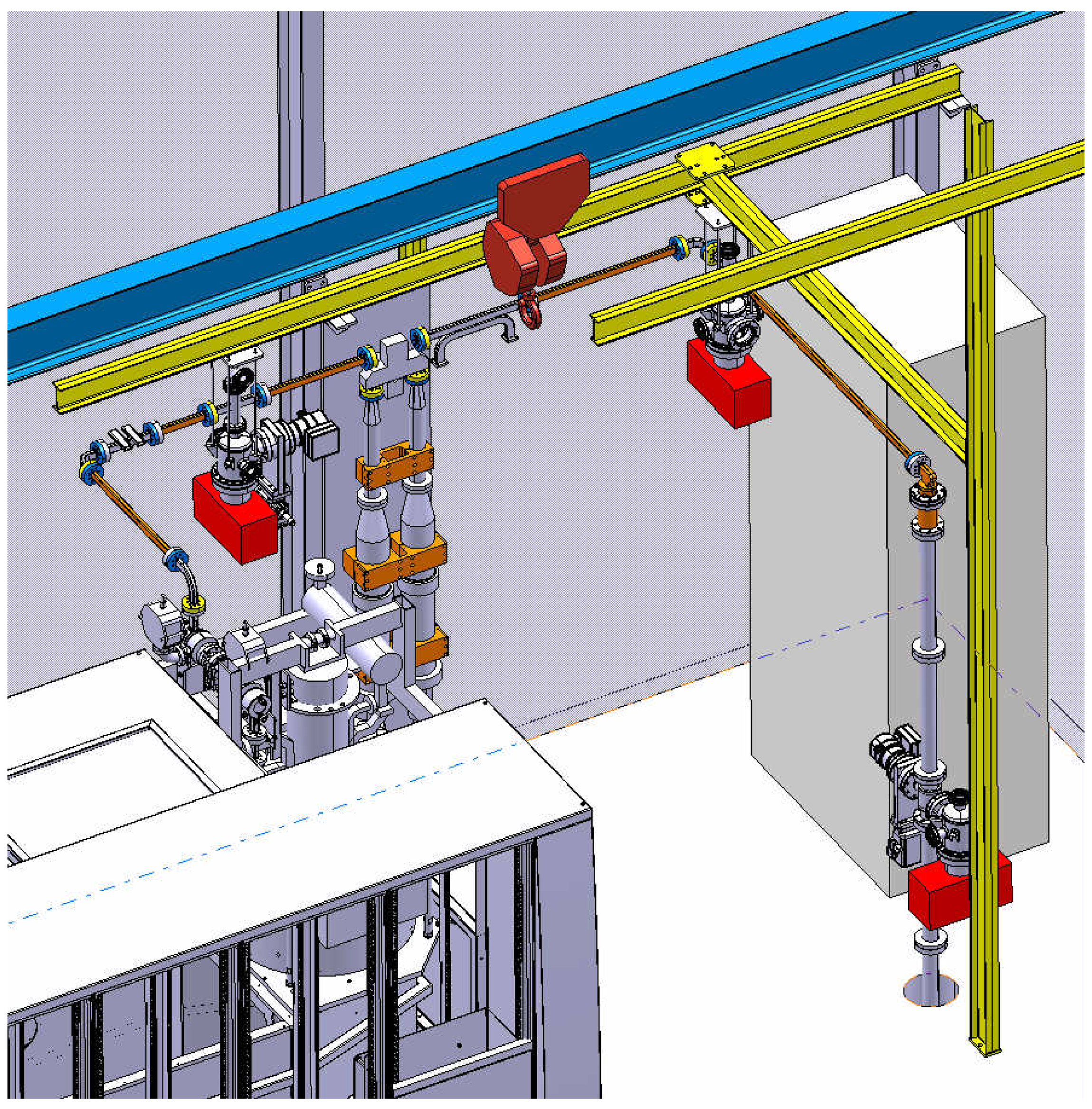
The CERN X-band test stand

The CLIC accelerator requires rf accelerating structures capable of achieving a 100MV/m loaded gradient at a breakdown rate of $4 \cdot 10^{-7}$/pulse at a frequency of 11.99424GHz [1]. The required high-power-rf tests needed to benchmark new structure designs, fabrication and handling techniques are taking place in the existing X-band test facilities at SLAC and KEK, running at 11.424GHz. To gain a higher throughput in the rf structure and rf component test program, and to be able to do testing at the CLIC frequency, CERN has decided to build a dedicated test facility located in the CTF3 building at CERN.

Test stand layout and parameters

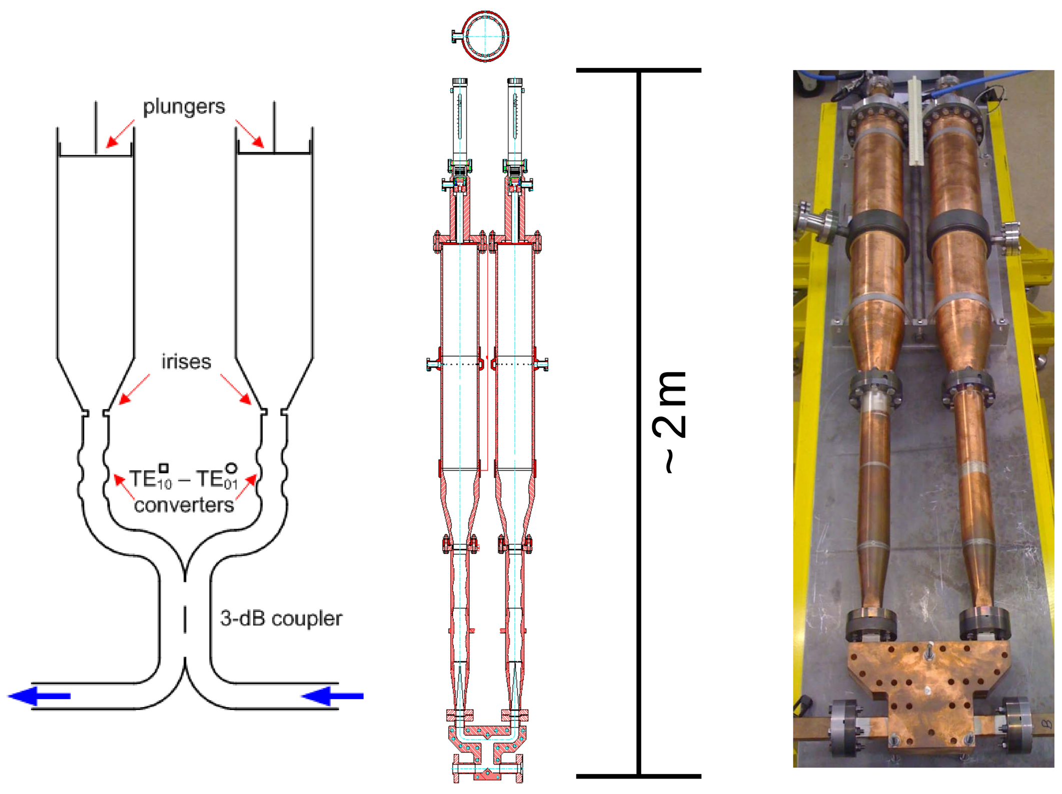
The test stand will consist of a SLAC XL5 12GHz klystron driven by a Scandinova solid state modulator, delivering up to 60MW peak power in 1.5μs long pulses at a repetition rate of 50Hz. In order to arrive at the nominal CLIC rf structure pulse length of 270ns, the klystron output pulse can either be shortened and directly fed into the structure or be compressed using a pulse compressor. In the latter case, the peak power can be increased up to a factor of 2.7. In both cases, about 20% of the rf power is lost in the waveguide network, limiting the available rf power without pulse compression to less than 48MW which would exclude several structures from being tested in this facility. A newly designed compact cavity based pulse compressor is therefore under test at CERN and will be soon implemented in the test stand.



Drawing of the new CERN X-band high-power test stand. Klystron and modulator in the front, pulse compressor, vacuum equipment and mode converters in the waveguide line. The structure under test will be mounted in the CTF2 bunker below, power transmission is done using rectangular and circular (low loss) waveguides. The pulse compressor can be mounted vertically due to its overall length of less than 2m including tuning system and temperature stabilization. Drawing by N.Chritin, CERN.

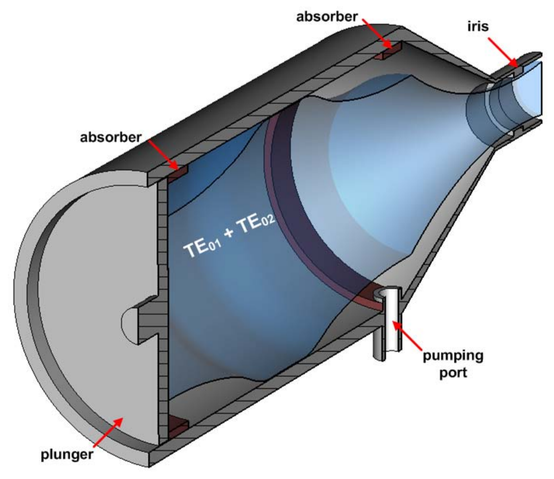
Principle of operation

The compressor consists of two identical high-Q cavities (nominal $Q_{loaded} \approx 25 \cdot 10^4$, $Q_0 \approx 1.5 \cdot 10^5$) coupled by a -3 dB coupler and rectangular to circular mode converters connected to the cavities by coupling irises for frequency tuning.



Schematic and photo of the pulse compressor with plunger-tunable cavities, mode converters and hybrid (left). Mechanical drawing of the full assembly (middle). By S.Kuzikov, GYCOM. Photo of the assembled setup at CERN.

Each cavity is based on TE_{01}-TE_{02} beating wave waveguide which starts from single-mode TE_{01} waveguide and finishes in a waveguide of sufficient radius. The use of beating wave allows the integration of pumping ports without spoiling the Q-factor. Rf absorber material is used to provide mode selectivity. Because the TE_{02} mode in this case is not a spurious mode the design of the matching horn is simplified.

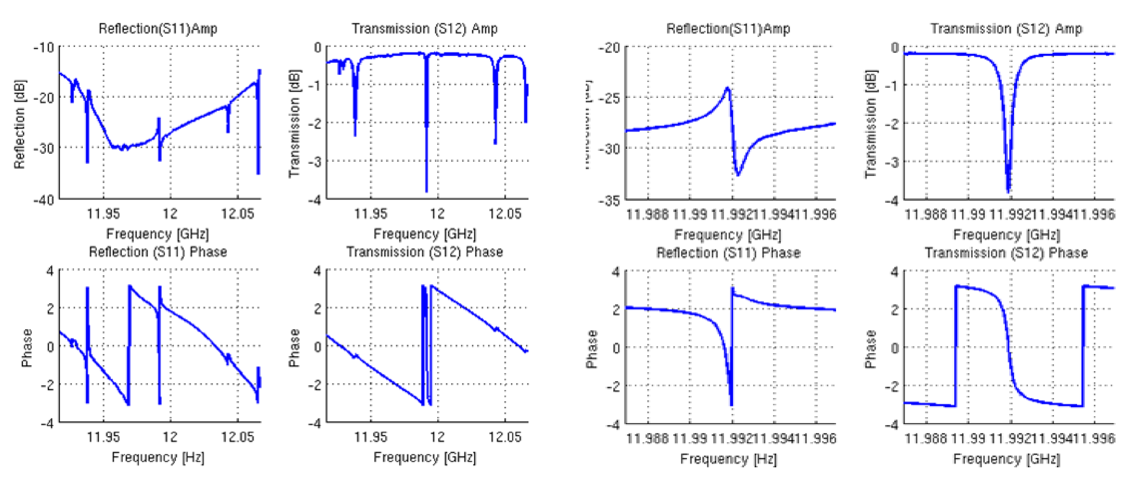


3D drawing of one cavity with indication of the electric field pattern. By S.Kuzikov, GYCOM.

A fully analytical description of the rf behaviour is available.

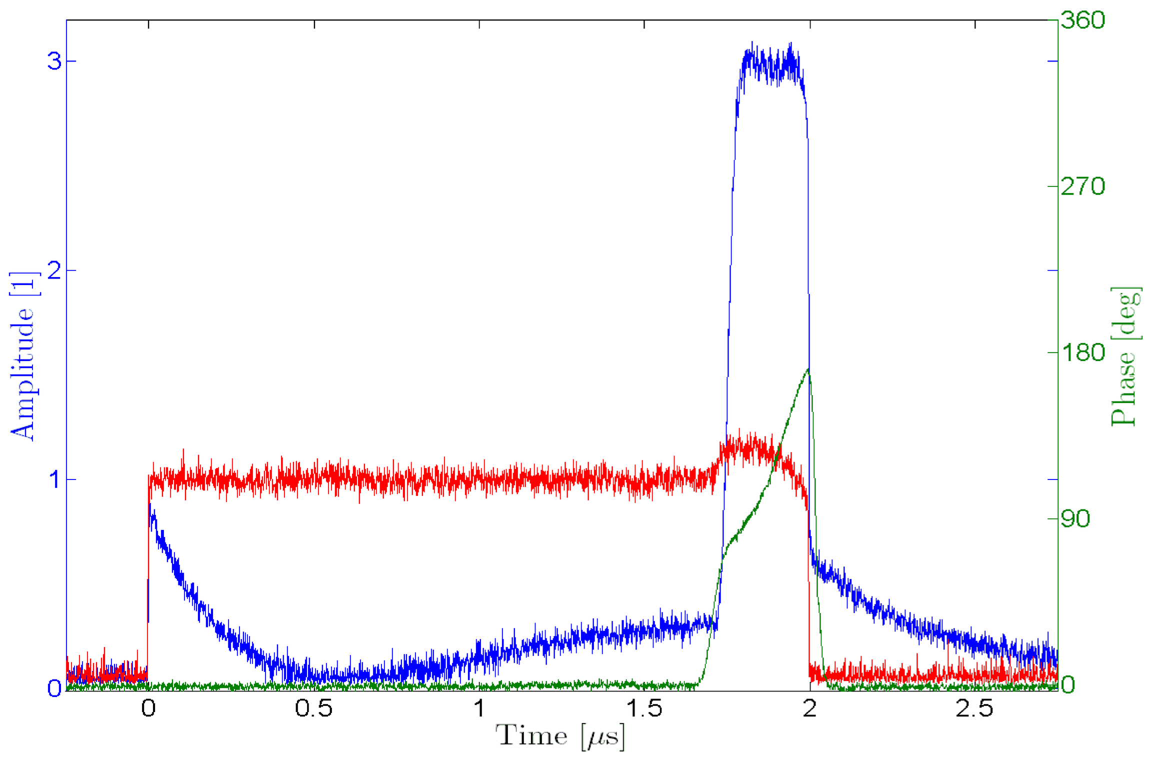
Rf performance

A pulse compressor of the proposed type has been built by GYCOM, Russia and was delivered to CERN in early 2010. First low power measurements showed the proper functioning after necessary realignment of one plunger due

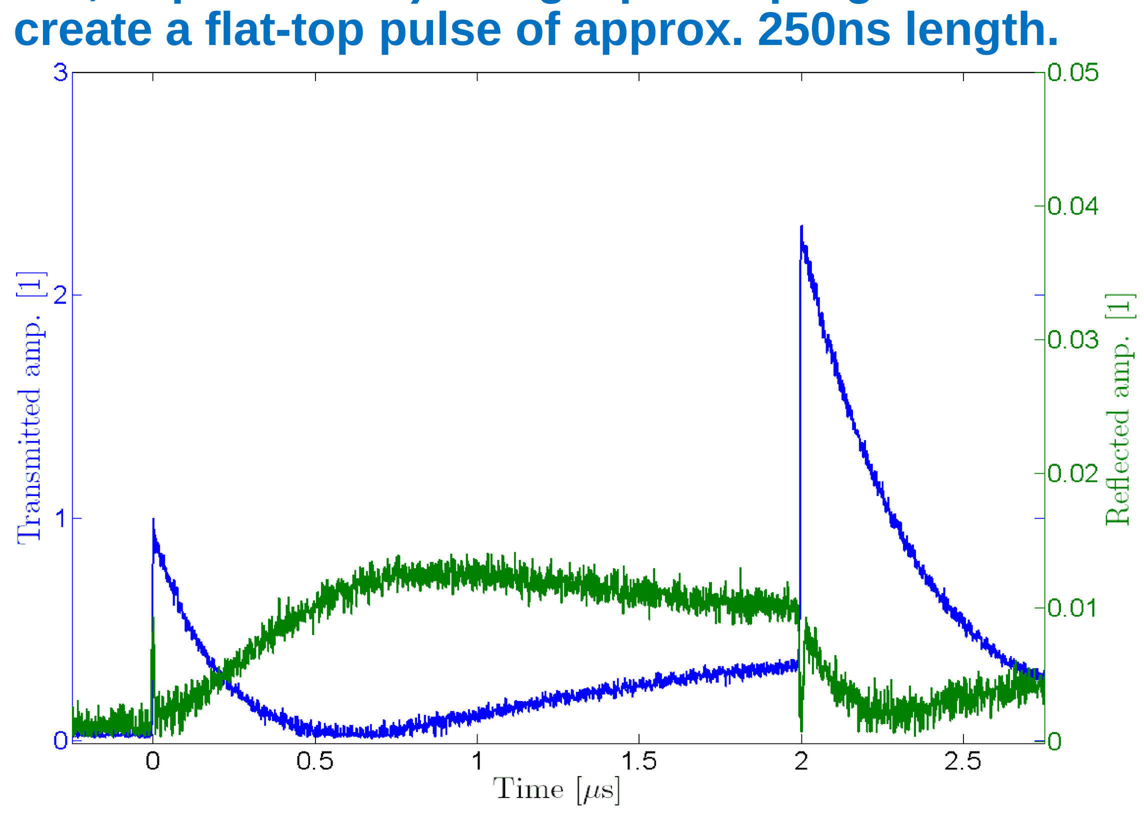


S-parameters of the fully assembled and tuned pulse compressor, overview and detailed zoom.

to transport shocks. The compression factor at an input pulse length of 2μs is about 3 which scales down to 2.5 for 1.5μs pulses.



Compression of a 2μs long input pulse (input in red, ouput in blue) using a phase program to create a flat-top pulse of approx. 250ns length.



The response without phase program was used to calculate Q_{loaded}, Q_0 and the coupling factor β by fitting the response to the analytical model. The values achieved at low power are Q_0 = 90000 to 100000, Q_{loaded} = 26300 and β = 2.4. The power reflected back to the klystron does not exceed -20dB when properly tuned.

Infrastructure requirements

Due to the high Q of the cavities, the pulse compressor is very sensitive to temperature variations, mechanical noise and alignment errors resulting e.g. from misalignment of the plunger during transport. Temperature stabilization to 0.1K is required and can be used for fine-tuning of the resonant frequency. Both cavities have to be thermally coupled. A steep increase in reflection when detuning requires fast interlocks on reflected power to protect the klystron.

Conclusion and outlook

The new SLED design offers a compact alternative to long SLED II type compressors. Even though proper tuning mechanisms and stabilization systems will have to be developed and used, operability in an accelerator environment seems to be feasible. The high-power rf performance will be tested after implementation in the klystron test stand early 2011.

References

[1] A.Grudiev, H.H.Braun, D.Schulte, W.Wuensch: Optimum Frequency and Gradient for the CLIC main linac accelerating structure, CLIC note 771