ISBN: 978-3-95450-184-7 doi:10.18429/JACoW-IPAC2018-THPML047

DESIGN AND MEASUREMENT OF THE X-BAND PULSE COMPRESSOR FOR TTX*

Yuliang Jiang[1*], Jiaru Shi[1†], Ping Wang[1], Hao Zha[1], Zhihui Wang[1], Xiaowei Wu[1], Huaibi Chen[1], Cheng Cheng[1], Wei Gai,
Department of Engineering Physics, Tsinghua University, Beijing 100084, China
[1]also at Key Laboratory of Particle and Radiation Imaging of Ministry of Education, Tsinghua University, Beijing 100084, China

Abstract

A radio frequency (RF) pulse compressor had been designed for the X-band (11.424 GHz) high power test stands at the Accelerator Laboratory of Tsinghua University. It is a SLED-I type pulse compressor, which uses a high quality factor corrugated circular cavity to store the RF power. An RF polarizer couples two quadrature modes into the cavity so that the pulse compressor needs only one cavity. The cavity implements HE1-1-14 mode, with the Q_0 of 115,000 and the coupling factor (β) of 3.23. The design and the microwave measurement before brazing of this pulse compressor are presented in this paper.

INTRODUCTION

RF pulse compressors enhance the RF peak power at the expense of shortening pulse widths. Passive pulse compressors, rather than active ones, have been widely used due to better stability and easier fabrication. The SLAC energy doubler (SLED-I), the resonant delay line pulse compressor (SLED-II) and the barrel open cavity (BOC) have been proposed and developed as three main types of passive pulse compression systems with different RF components. The SLED-I and SLED-II store the RF pulse in a resonant cavity or a delay line and output a decaying exponential or a flat pulse respectively, while the BOC type houses a whispering galley mode of high unloaded quality factor (Q_0) in a more complicated cavity structure [1-3]. Typical pulse compression systems consist of two identical cavities or delay lines and a 3-dB coupler for isolation. A compact RF pulse compression system with one spherical cavity and an RF polarizer has been designed and tested at SLAC [4].

At Tsinghua University, the Tsinghua Thomson-scattering X-ray Source (TTX) upgrade project plans to add two X-band linacs in the injector and boost the electron beam from the current 50 MeV to 150 MeV, as shown in Fig. 1. To feed these two structures, a SLED-I type pulse compressor is required to compress the pulse width from 1.5 µs to 100 ns and generate more than 250 MW peak power from a 50 MW klystron at the frequency of 11.424 GHz.

RF DESIGN

This SLED-I type pulse compressor at Tsinghua uses a corrugated circular cavity as a new attempt after comparing with the smooth circular cavity and the spherical cavity. A modified RF polarizer was designed to match the cavity and direct the RF power flow [5].

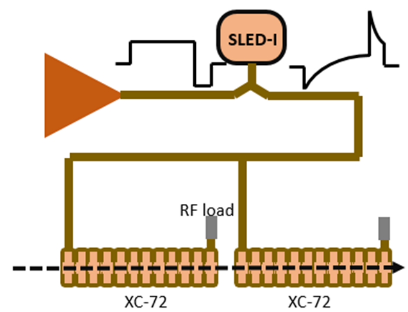

Figure 1: The diagram of the TTX upgrade part, in which a SLED-I type pulse compressor feeds two X-band linacs.

Several minor optimizations has been applied to the last version. This corrugated cavity implements $HE_{1\text{-}1\text{-}14}$ mode with the Q_0 of 115,000 and the coupling factor (β) of 3.23, as shown in Fig. 2. By compressing the pulse as required, the corrugated cavity generates the output pulse with a peak power gain of more than 5. A set of tuned parameters is shown in Table 1.

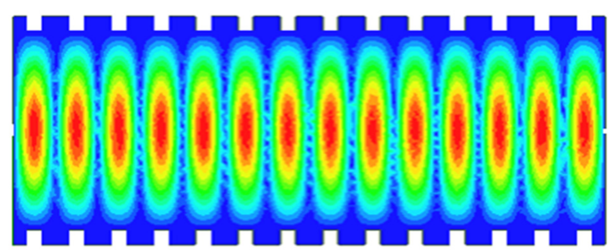

Figure 2: Contour plot of $HE_{1\text{-}1\text{-}14}$ mode in the corrugated circular cavity.

Table 1: Parameters of the Pulse Compression Cavity

Operation frequency	11.424GHz
Mode	$HE_{1\text{-}1\text{-}14}$
Cavity diameter ($2a$)	69.60 mm
Cavity length	191.52 mm
Corrugation depth (d)	6.56 mm
Corrugation distance (h_1)	10.68 mm
Corrugation width (h_2)	3.00 mm
Quality factor (Q_0)	115,000
Iris diameter	8.18 mm
Coupling coefficient (β)	3.23

* jiangyuliang006@163.com
† shij@mail.tsinghua.edu.cn

ISBN: 978-3-95450-184-7 doi:10.18429/JACoW-IPAC2018-THPML047

MECHANICAL DESIGN

The mechanical design of our X-band pulse compression system is shown in Fig. 3. The flanges are made of stainless steel and plated with OFC. The cavity are covered with a stainless-steel water jacket for a constant temperature and two O-rings will be used for watertight.

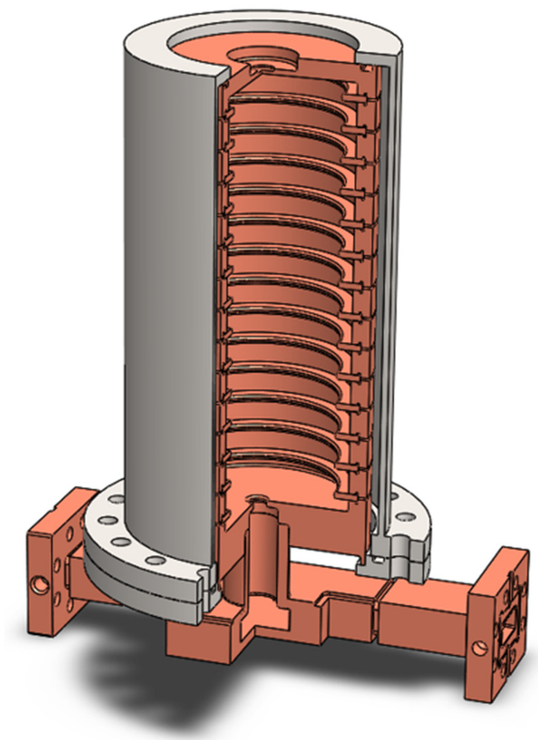

Figure 3: Mechanical design of the pulse compressor.

MEASUREMENTS BEFORE BRAZING

RF Polarizer

As the matched flanges and waveguides for the circular port are currently not available, two RF polarizers were fabricated for measuring the full characteristics [6]. Two polarizers were firstly connected back to back through a circular waveguide, as shown in Fig. 4. One port of each polarizer is connected to the Vector-Network analyzer. Although the other two ports are open rather than matched, minor errors affected the results due to the designed characteristics. We took measurements by placing two polarizers both parallel and vertically in direction to dismiss some fabricated errors, as shown in Fig. 5 and 6. A summary of the measured properties is shown below: (i) The transmission is around -0.35 dB for two back-to-back polarizers, which means a power transmission efficiency of about 92%. (ii) The reflection from the input port is around -20 dB. As the components of the polarizers are not brazed, the results had some fluctuations as well as errors during measurements. These results still show that the two BJ100 ports have good isolation from each other and good transmission to the circular port, which basically satisfies our requirement.

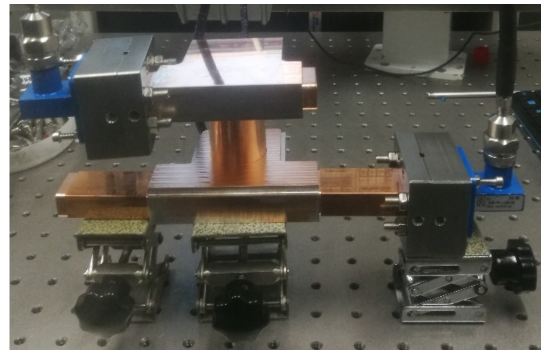

Figure 4: Two polarizers are connected back to back through the circular waveguide. Two ports are connected to the Vector-Network analyser while the other two open.

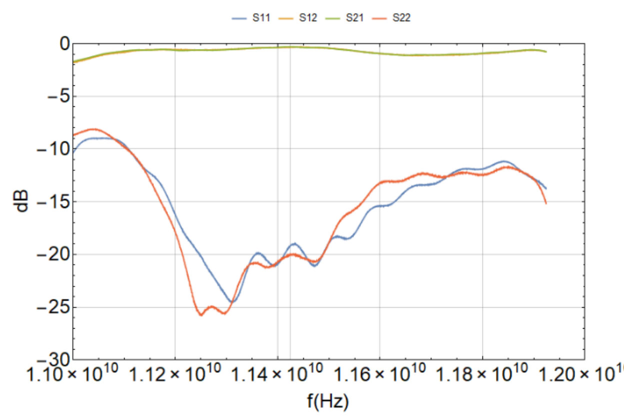

Figure 5: The measurement of S parameters from 11 GHz to 12 GHz with two polarizers placed parallel. At the frequency of 11.424 GHz, S_{11}= -19.18 dB, S_{12}= -0.35 dB, S_{21}= -0.30 dB, S_{22}= -20.01 dB.

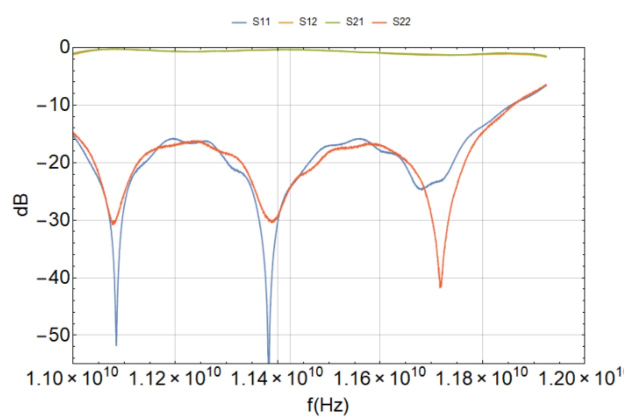

Figure 6: The measurement of S parameters from 11 GHz to 12 GHz with two polarizers placed vertically. At the frequency of 11.424 GHz, S_{11}= -24.26 dB, S_{12}= -0.36 dB, S_{21}= -0.37 dB, S_{22}= -24.30 dB.

RF Polarizer with A Shorting Plate

When the RF polarizer is used in our pulse compressor, the reflected pulse emits from the circular port. To examine the reflection property of the polarizer, especially the top

ISBN: 978-3-95450-184-7 doi:10.18429/JACoW-IPAC2018-THPML047

circular waveguide, a shorting plate was placed at the circular port to reflect the theoretically full power back as shown in Fig. 7.

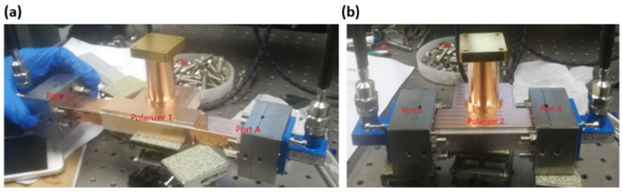

Figure 7: Measurement with a shorting plate at the circular port, (a) for Polarizer 1 and (b) for Polarizer 2.

A simulation for the measurement is shown in Figure 8. The circular waveguide with a shorting plate acts like a small circular cavity during measurements. Therefore, there may be several TE_{11n} modes with different longitudinal periodic numbers while sweeping the frequency from 11 GHz to 12 GHz. Figure 9 and 10 shows the S parameters for the above measurements. Polarizer 1 has an unexpected frequency shift, which increases the reflection and decreases the transmission at the frequency of 11.424 GHz. This frequency shift may results from the position shift of the circular waveguide, and the extended waveguides at two BJ100 ports also influence the results before brazing. Polarizer 2 shows good properties. More accurate measurements are expected to take after brazing.

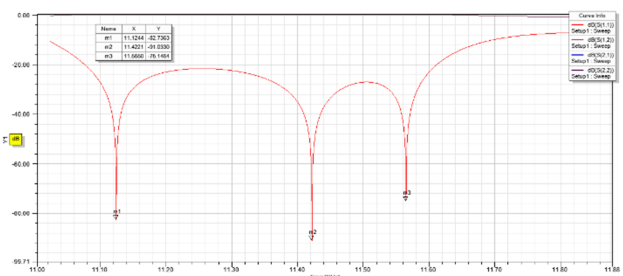

Figure 8: The simulation of S parameters with a shorting plate at the circular port.

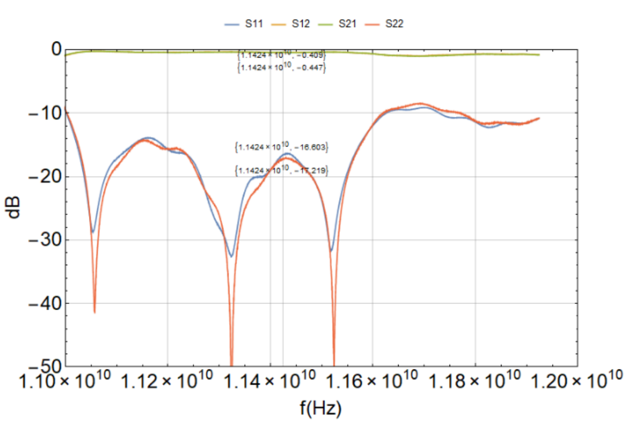

Figure 9: Measurement of S parameters with a shorting plate at the circular port for Polarizer 1. At the frequency of 11.424 GHz, S_{11}= -16.60 dB, S_{12}= -0.40 dB, S_{21}= -0.45 dB, S_{22}= -17.22 dB.

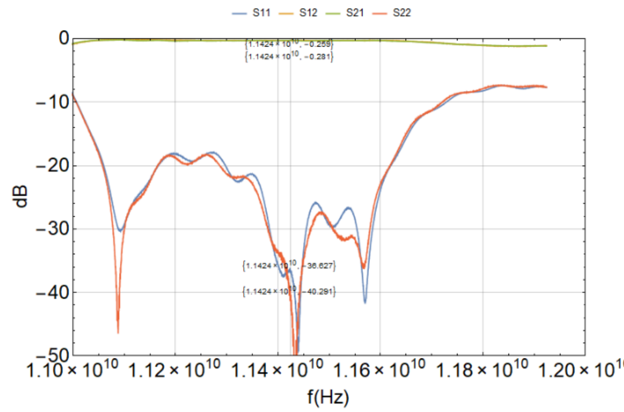

Figure 10: Measurement of S parameters with a shorting plate at the circular port for Polarizer 2. At the frequency of 11.424 GHz, S_{11}= -36.63 dB, S_{12}= -0.26 dB, S_{21}= -0.28 dB, S_{22}= -40.29 dB.

System Test

The whole pulse compressor was connected together for testing the corrugated cavity, as shown in Fig. 11. The transmission and reflection properties agree with the previous measurements. The resonant frequency of $HE_{1\text{-}1\text{-}14}$ mode is 11.414 GHz in atmosphere at 17.8°C. Within a linear approximation, the relationship between the frequencies in vacuum and atmosphere can be expressed as [7]:

$$f(t_0) \approx f'(t_1)\sqrt{\varepsilon_r}[1-\alpha_{Cu}(t_0-t_1) \qquad (1)$$

where f and f' are the frequencies in atmosphere and vacuum respectively, t_0 is the designed working temperature, t_1 is the measured temperature, ε_r is the relative dielectric constant of atmosphere and α_{Cu} is the CLTE.

The calculated frequency in vacuum at 30°C is 11.4147 GHz, and a tuning structure has been designed on the top of the cavity. As the calculated coupling coefficient and Q_0 is not accurate before brazing, the calculated Q_e is 34,971, which matches the designed value of 35,603.

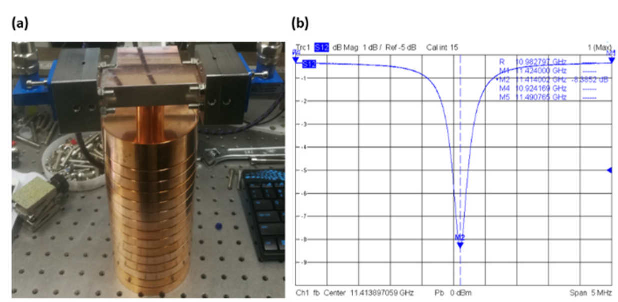

Figure 11: Measurement of the pulse compressor.

CONCLUSION

In this paper, an X-band (11.424 GHz) pulse compression system is designed and measured before brazing for the TTX high-power RF station. This system consists of a corrugated circular cavity using $HE_{1\text{-}1\text{-}14}$ mode and an RF polarizer. Further measurements and high power test will be taken in the future.

ISBN: 978-3-95450-184-7 doi:10.18429/JACoW-IPAC2018-THPML047

REFERENCES

[1] P.B. Wilson, Z.D. Farkas and R.D. Ruth, "SLED II: A New Method of RF Pulse Compression", in *Proc. Linear Accelerator Conf.*, Albuquerque, NM, September 1990; SLAC-PUB-5330.

[2] Z.D. Farkas, H.A. Hogg, G.A. Loew and P.B. Wilson, "SLED: A Method of Doubling SLAC's Energy" in *Proc. 9th Int. Conf. on High Energy Accelerators*, 1976, p.576.

[3] I. V. Syratchev, "The Progress of X-Band "Open" Cavity RF Pulse Compression Systems", in *Proc. EPAC 1994*, London, England.

[4] Matthew Franzi, Juwen Wang, Valery Dolgashev, and Sami Tantawi, "Compact rf polarizer and its application to pulse compression systems" *Phys. Rev. ST Accel. Beams*, vol. 19, p. 062002, 2016.

[5] Yuliang Jiang *et al*, "The X-band pulse compressor for Tsinghua Thomson Scattering X-ray Source" in *Proc. IPAC'17*, Copenhagen, Denmark, May 2017, paper THPIK054, pp. 4214-4217.

[6] Juwen Wang *et al*, "Development for a supercompact X-band pulse compression system and its application at SLAC", *Phys. Rev. ST Accel. Beams*, vol. 20, p. 110401, 2017.

[7] Jiaru Shi, "Studies of RF deflecting crab cavities for beam manipulation and diagnostics", Ph.D. thesis, Dept. of Engi. Phys., Tsinghua University, Beijing, China, 2009.