X-BAND PULSE COMPRESSION SYSTEM USING ONE CHANNEL CIRCULAR POLARIZED TRAVELING WAVE DELAY LINE

M. Yoshida, S. Fukuda, Y Higashi, T. Higo, N. Kudo, S. Matsumoto, H. Matsushita,
KEK, Ibaraki, Japan
S. Kazakov, Fermilab, Batavia, IL 60510-5011, U.S.A.

Abstract

The X-band pulse compression system has been developed for the high gradient experiment of the accelerating structure in the new X-band test facility (Nextef) [1]. The one channel circular polarized traveling wave delay line was selected to obtain the higher RF compression efficiency under limited delay line length and the easier operation than the cavity chain type. This delay line of the circular waveguide is also frequently used for the C-band feed line from the modulator floor to the accelerator test floor. Thus the delay line is tilted and has the limited length of around 20 m. It is designed to obtain the three times compressed power which has the pulse duration of 150 ns. Further we also proceed to the upgrade plan using the TE_{12} mode to double the pulse duration. In this paper, the design overview of this pulse compression system and the RF components including the mode launcher and the TE_{11}-TE_{12} reflector will be presented.

REQUIREMENTS

The output power of 150 MW is desired for the higher gradient test of the X-band accelerating structure. However the current output power of our PPM klystron is limited around 50 MW for the pulse duration of 0.25 us or 25 MW for the pulse duration of 1.5 us due to its frequent pulse shortening [2]. Thus we considered about many methods of the pulse compression system including the delay line type, the binary compression type [3], the coupled cavity chain and the multi-moded delay line [4]. After many considerations and some experiments of the advanced coupled cavity chain [5], we determined to install a traveling wave delay line type using the circular polarized RF field in one channel.

PULSE COMPRESSION SCHEME

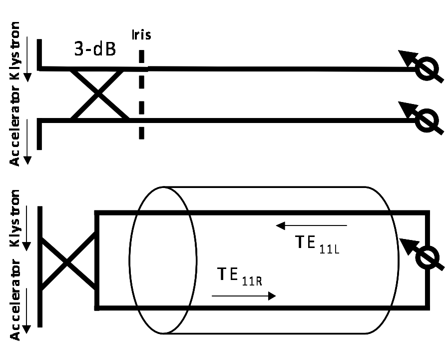

Figure 1: SLED-II and circular polarized traveling wave delay line in one channel.

Figure 1 shows the diagram of the SLED-II [6] and the traveling wave delay line type pulse compression system using the circular polarized RF field in one channel. The reasons why we selected this scheme are as followings:

- The delay line type can easily generate a flat top pulse without modulation of the input RF.
- The total phase length of the traveling wave delay line is adjusted by only one phase shifter.
- A long C-band transmission line was already constructed using same cylindrical waveguide.

At first we determined the cylindrical transmission mode of TE_{11} and TE_{12} mode and the diameter of 80 mm according to the attenuation as shown in Fig. 2. These two modes have approximately same attenuation at this diameter. Further it is possible to make the total delay line length quarter since each mode has the polarization.

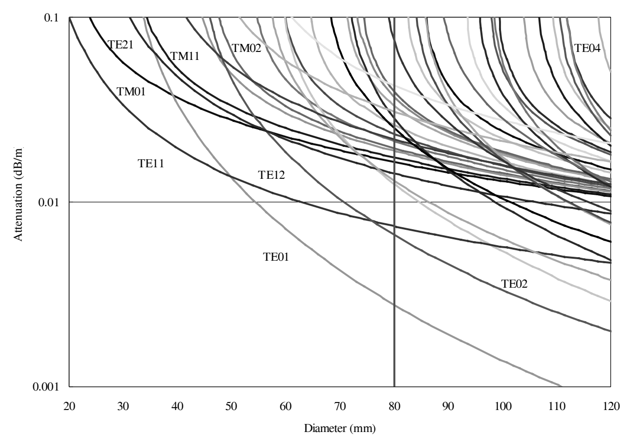

Figure 2: Attenuation vs diameter of the cylindrical waveguide.

Figure 3 shows the schematic diagram of the pulse compressor using the travelling wave resonator [7].

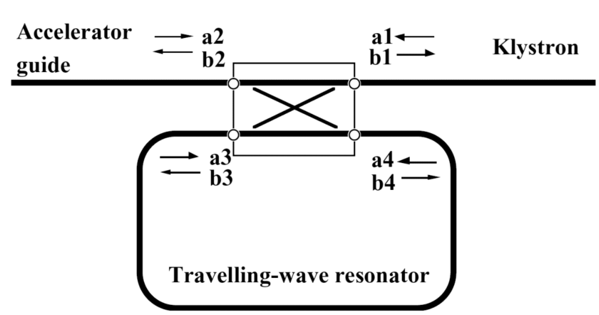

Figure 3: Traveling Wave Pulse Compressor.

The fundamental calculation of the pulse compressor using the traveling wave resonator is described as Eq. 1.

$$\begin{pmatrix} 0 \\ V(b2) \\ V(b3) \\ 0 \end{pmatrix} = \begin{pmatrix} 0 & \sqrt{1-k^2} & jk & 0 \\ \sqrt{1-k^2} & 0 & 0 & jk \\ jk & 0 & 0 & \sqrt{1-k^2} \\ 0 & jk & \sqrt{1-k^2} & 0 \end{pmatrix} \begin{pmatrix} V(a1) \\ 0 \\ 0 \\ V(a4) \end{pmatrix} \quad (1)$$

Figure 4 shows the pulse compression gain according to the coupling coefficient in case using the waveguide length of 43 meter of TE_{11} or TE_{12} mode which has the power attenuation of -0.6 dB per one turn. As the result, enough high gain of 3.3 can be obtained using existing a 3 dB hybrid.

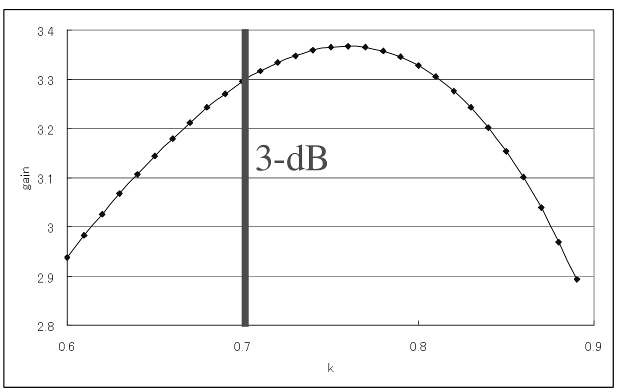

Figure 4: The pulse compression gain vs the coupling coefficient.

LAYOUT IN NEXTEF

As a realistic plan to develop the pulse compression system for the KEK X-Band RF Test Facility (Nextef), we started from the shorter pulse length using only TE_{11} mode as shown in Fig. 5.

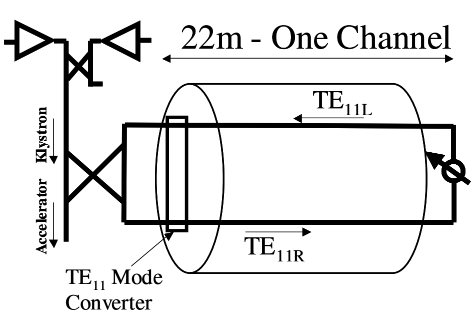

Figure 5: The pulse compression system using TE_{11} mode.

After the fundamental test, the TE_{11} to TE_{12} mode conversion reflector will be installed for longer pulse length as shown in Fig. 6.

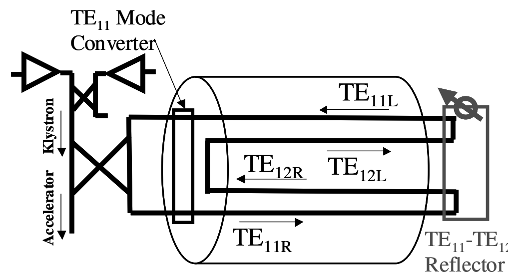

Figure 6: The pulse compression system using TE_{11} and TE_{12} mode.

Figure 7 shows the whole layout of the pulse compression system in Nextef. The delay line was placed with oblique angle because it is commonly used for the C-band transmission line from the C-band RF source which is placed upstairs.

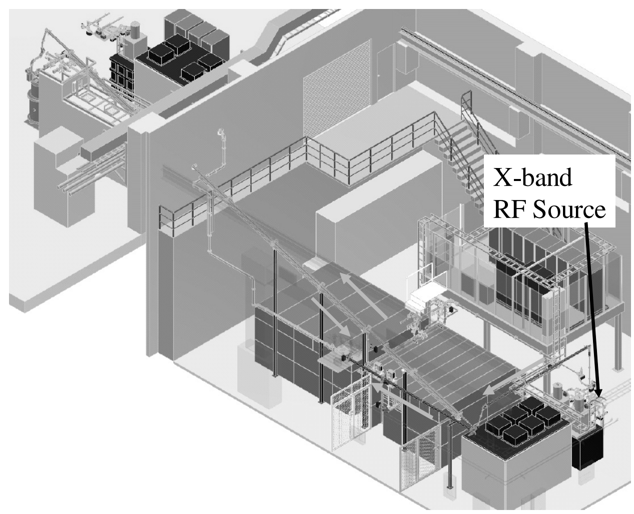

Figure 7: The whole layout in Nextef.

COMPONENTS

The pulse compression system consists of a TE_{11} mode launcher, a TE_{11} horn, a TE_{11} to TE_{12} mode conversion reflector and existing 3 dB hybrid. Figure 8 shows the circular polarized TE_{11} mode launcher and its simulation result.

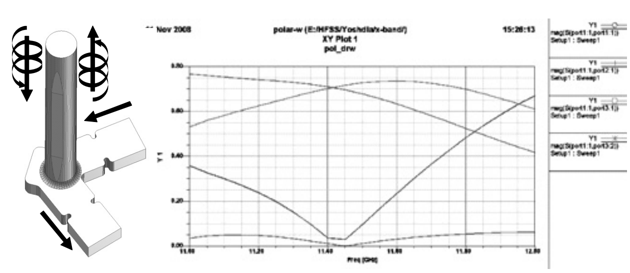

Figure 8: The circular polarized TE11 mode launcher and its simulation result.

Figure 9 shows the photograph of the circular polarized TE_{11} mode launcher.

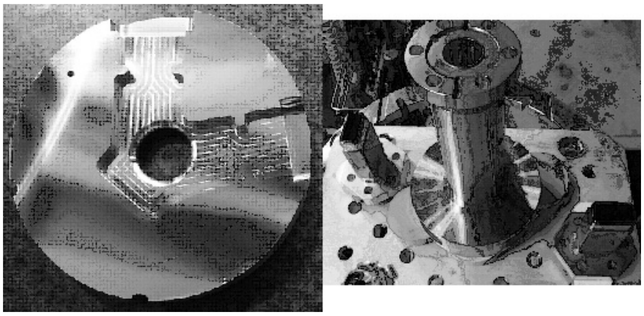

Figure 9: The photograph of the circular polarized TE11 mode launcher.

The length of the TE_{11} horn was determined to reduce the higher mode conversion. As result, the length of 700 mm is chose using the envelope of a cos-shape taper with cutting each 100 mm linear section. Figure 10 shows the photograph of the TE_{11} horn.

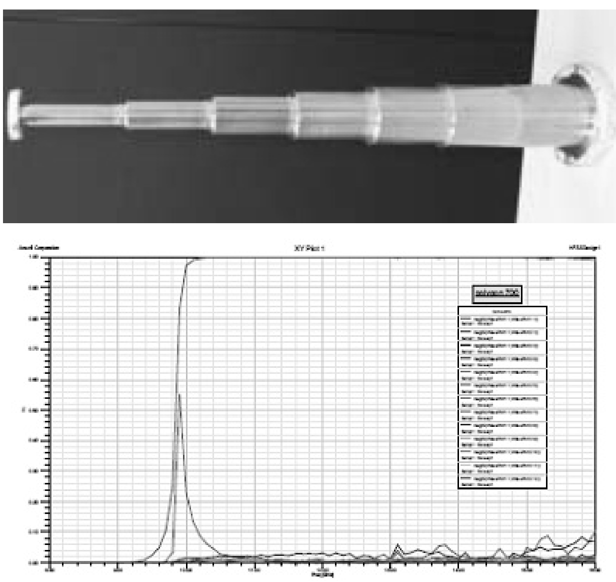

Figure 10: TE_{11} horn and its simulation result.

The 80 mm diameter cylindrical waveguides are connected using MO-type flange [8] which is assembled with the oxygen free copper pipe by using the electron beam welding.

Figure 11 shows the TE_{11} to TE_{12} mode conversion reflector and its simulation result.

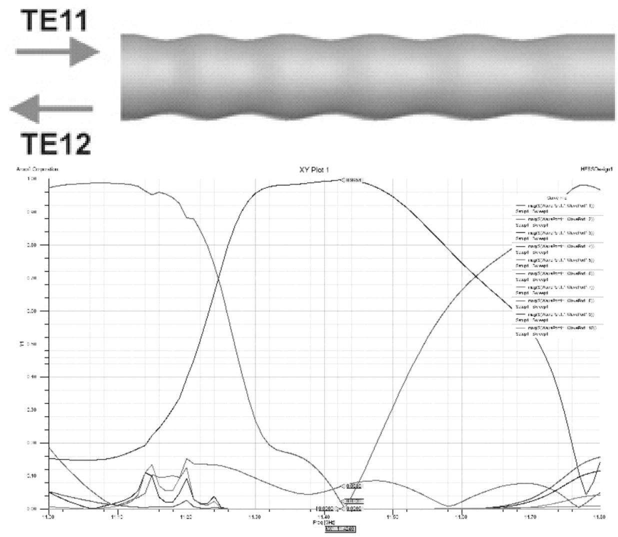

Figure 11: The TE_{11} to TE_{12} mode conversion reflector and its simulation result.

SUMMARY

The pulse compression system using circular polarized traveling wave delay line in one channel is now under construction. The components including mode converters were already assembled and we are measuring its characteristics at the low power test stand.

REFERENCES

[1] S. Matsumoto, et al., “Nextef: 100MW X-Band Test Facility in KEK”, EPAC08, Edinburgh, UK, 2008.

[2] S. Matsumoto, et al., “Study of PPM-Focused X-Band Pulse Klystron”, THP027, Proceedings of Linac 2006, Knoxville, Tennessee, USA, 2006.

[3] Z.D. Farkas, “Binary Peak Power Multiplier and its Application to Linear Accelerator Design,” IEEE Trans. MTT-34, 1986, pp. 1036-1043.

[4] S.G. Tantawi, et al., “A Multimoded RF Delay Line Distribution System for the Next Linear Collider,” submitted to Phys.Rev.ST Accel. Beams, Feb. 2002.

[5] M. Yoshida, "New concept of small delay line type RF pulse compressor using coupled cavities", Proceedings of LINAC 2006, Knoxville, Tennessee USA.

[6] P.B. Wilson, Z.D. Farkas, and R.D. Ruth, “SLED II: A New Method of RF Pulse Compression,” Linear Accel. Conf., Albuquerque, NM, September 1990.

[7] S. Yamaguchi, et al., "DEVELOPMENT OF AN RF PULSE COMPRESSOR USING A TRAVELINGWAVE RESONATOR", Proceedings of 1994 Linac Conference, Aug. 21-26, Tsukuba, Japan, pp. 478-480.

[8] H. Matsumoto, F. Furuta, K. Saito, H. Inoue, N. Sakamoto, K. Ueno and D. Iwai, EPAC2006, Edinburgh, June 2006, p.753 (2006).