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30GHz RF Pulse Stretcher

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Abstract RF Pulse stretcher is an antiphrasis of RF pulse compressor. It is used to convert short high power RF pulse to long low power RF pulse. The Power Extraction and Transfer Structure (PETS) in CTF Ⅱ (Compact Linear Collider Test Facility Phase two) can provide 280MW 16ns pulse. It is desirable to use it to get longer pulse to study the pulse length dependence of maximum achievable surface gradient in one of the 30GHz copper accelerating structures. The 30GHz RF pulse stretcher was designed, manufactured, tuned, installed and successfully operated in CTF Ⅱ.

Key words RF pulse stretcher, RF pulse compressor, high power RF pulse, linear collider

1 Introduction

In 2002, CTF Ⅱ[1] was operated mainly as a high gradient test stand for the development of 30GHz accelerating structures. A novel 30-cell structure with so called mode launcher coupler and tungsten irises reached an average gradient of 125MV/m with a peak gradient in the first cell of 150MV/m[2] when powered with 15ns pulses. No damage was found after inspection. This is very close to 150MV/m of the nominal CLIC gradient, but is almost 10 times shorter. Because the achievable gradient is expected to decrease with pulse length, this gradient has to be demonstrated for a longer pulse. So it was decided to build a 30GHz pulse stretcher to lengthen the available RF pulse from 16ns to 32ns.

2 Principle

RF pulse compressors[3,4] have been studied and used for many years. An RF pulse stretcher has the same configurations as. an RF pulse compressor but works for the contrary purposes.

The system setup can be shown in Fig.1(a). The typical output pulse is shown in Fig.1(b).

It is very similar to SLED-Ⅱ[5,6] but several differences exist. First, the reflecting coefficient of the reflecting iris is chosen so that the reflected pulse and the first round trip pulse have the same amplitude. Second, the length of the resonant delay line is tuned to keep the first round trip pulse in phase with the reflected pulse. Third, there is no phase flip in the input pulse.

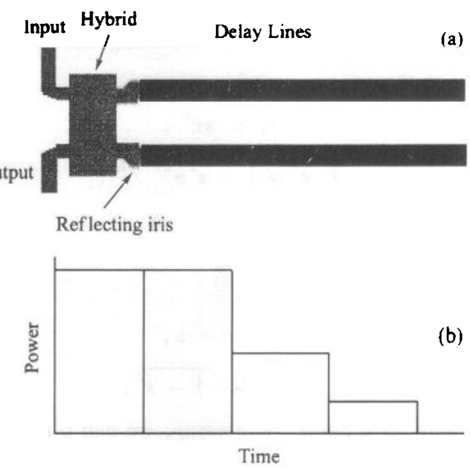

Fig.1. Pulse stretcher.
(a) Pulse stretcher configuration; (b) Typical output pulse.

One part of the input RF power is reflected by the iris and is directed to the load by the hybrid. The left was transmitted to the two delay lines. After the time $t = 2L/v_g$, the RF pulse reaches the iris again. Again, one part is transmitted and directed to the load. The left

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goes back into the delay line. This is repeated after the RF power is attenuated totally in the delay lines. If the length of the delay line is chosen to be $L = v_g \cdot t_{\text{input}}/2$, we can get a reflected pulse followed immediately by several equal-length pulses with the decaying amplitude. We can adjust the reflection coefficient of the reflecting iris to get equal amplitude in the first two bins of the whole pulse series. So we get an RF pulse longer but lower in power level from the input RF pulse. To equalize the amplitudes of the reflected pulse and the first round trip pulse, the relation between the reflection coefficient s and the round trip loss A in the delay lines should be as follows:

$$A = \frac{s}{1 - s^2}, A = e^{-2\alpha L}, \tag{1}$$

where L is the length of the delay line and α is the attenuation coefficient.

To minimize the total cost, it is decided to use the standard rectangular waveguide WR34 (4.32mm × 8.64mm) as delay lines. To provide a delay time of 16ns, the length of a single delay line is 1.97m. Then the value A is 0.825, and s should be 0.56.

As in SLED-Ⅱ, the phase problem can be discussed using a single delay line with reflecting iris. As shown in Fig.2, at the iris

$$R = se^{i\theta}$$
$$T = \sqrt{1 - s^2}e^{i(\theta - \pi/2)}, \tag{2}$$
$$\theta = \frac{\pi}{2} + \sin^{-1}s,$$

At the left reference plane,

$$R' = -s,$$
$$T' = i\sqrt{1 - s^2} \tag{3}$$

When used as a pulse compressor, we can place a short at $L = \frac{N\lambda_g}{2}$ from the right reference plane. The emitted wave traveling left after a round trip is 180 degree out of phase

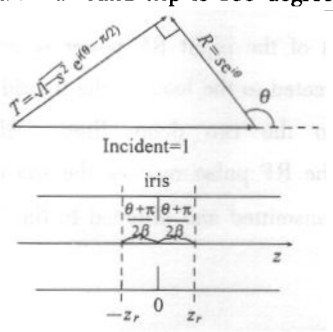

Fig.2. Single delay line with reflective iris.

with the reflected wave. If we add another $\lambda_g/4$, the first emitted wave will be in phase with the reflected wave. This means that we can tune the delay line so that the phase of the extended pulse is the same as the input pulse. This also means that the 32ns pulse can be used with the beam turned on. So the phase length of the delay line should be tuned to be

$$L = \frac{N\lambda_g}{2} + \frac{\lambda_g}{4}. \tag{4}$$

3 30GHz planar hybrid[7]

This is a planar type hybrid. The cross section of the four ports is 4.32mm × 8.64mm, the same as the standard WR34 waveguide. The height of the hybrid is 4.32mm. Port 1 and port 4 are isolation ports. Input power from port 1 is divided equally between port 2 and

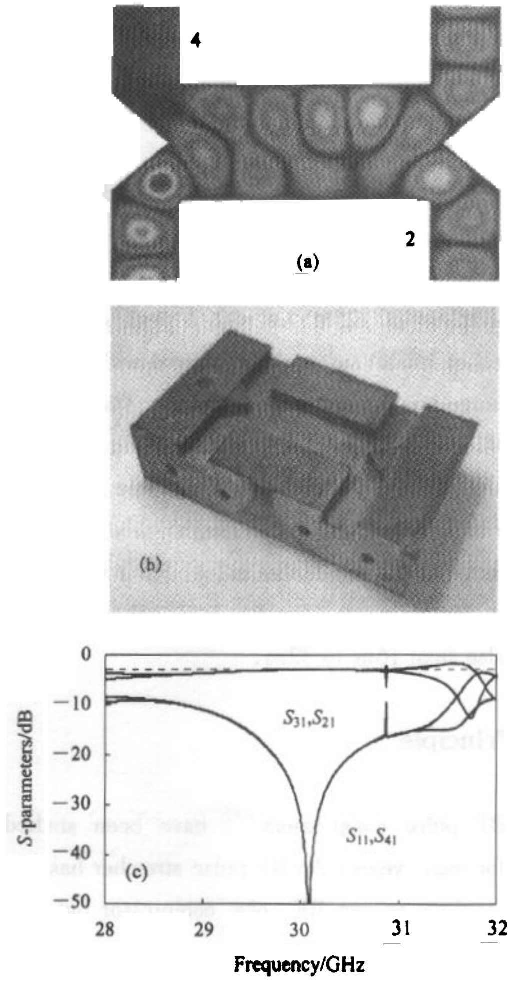

Fig.3. Planar H-hybrid.
(a) Electric field pattern; (b) Real model;
(c) S matrix.

port 3. The phase difference between port 2 and 3 is 90°. The match condition can be reached by tuning the length and width of the connecting wave guide, the depth and angle of the triangular protrusion. The width of the connecting waveguide must allow $TE_{20}^{\square}$ to propagate but must keep $TE_{30}^{\square}$ below the cutoff. It is made from stainless steel by wire cutting. An HFSS was used extensively in the optimization of the hybrid. The electric field pattern, the real model and the S matrix are shown in Fig.3.

4 Pulse stretcher tuning

The pulse stretcher tuning was done in several steps. After measurements of the actual decay (− 2.5 dB) and the delay (16.4ns) of the single line, the reflection coefficient was re-adapted. The new values were: $A^2 = 0.563$ and $s = 0.535$. The hybrid showed a little imbalance (about 0.2 dB), however, the matching remained within an acceptable level, less than − 25 dB. Finally, the lengths of the delay lines were adjusted to provide the synchronous RF phases of the reflected and delayed pulses. This was done by tuning the steady state transmission to a local maximum. Fig.4(a) shows the initial transmission of the pulse stretcher. Fig.4(b) shows the transmission after tuning. It is worth to note that if the device were to be used as a compressor, the tuning would be done to the local minimum.

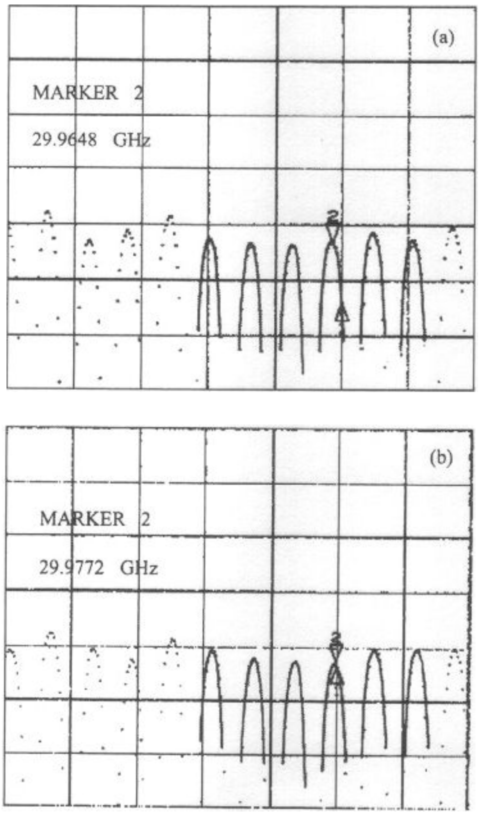

Fig.4. S_{21} before and after tuning.

(a) Before tuning; (b) After tuning.

5 High power test

The pulse stretcher was installed in CTF Ⅱ as shown in Fig. 5. A typical shape of a stretched pulse at high power is shown in Fig.6. It clearly shows that the delay lines were properly tuned and the whole system works well.

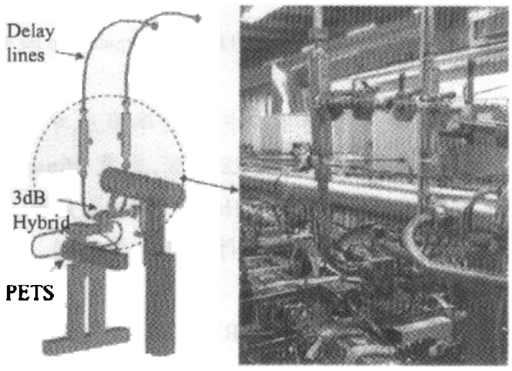

Fig.5. Pulse stretcher in CTF Ⅱ.

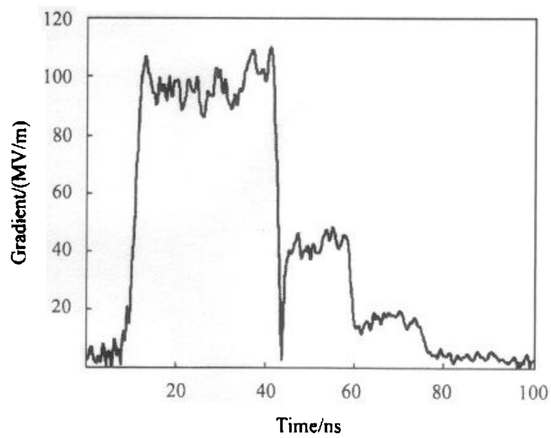

Fig.6. Typical output of pulse stretcher.

6 Conclusion

The principle of RF pulse stretcher has been developed. All the RF components are designed and manufactured. The whole system has been tuned. It has been installed and successfully tested under high power in CTFⅡ.

References

1 Bossart R, Braun H H, Carron G et al. Demonstration of Two-Beam Acceleration in CTFⅡ. XIX International Linac Conference, Chicago, USA, 1998, 85—87
2 Braun H H, Döbert S, Syratchev I et al. CLIC Note 535
3 Nantista C D. Radio Frequency Pulse Compression for Linear Accelerators [D]. UCLA Doctoral Dissertation, 1994
4 GU Peng-Da, PEI Gou-Xi, WANG Shu-Hong. HEP & NP, 2001, **25** (4): 348—353 (in Chinese)
(顾鹏达,裴国玺,王书鸿. 高能物理与核物理,2001,**25**(4): 348—353)
5 Wilson P B, Farkas Z D, Ruth R D. SLAC-PUB-5330, September 1990
6 Fiebig A, Schlieblich C. A. Radio Frequency Pulse Compressor for Square Output Pulse. EPAC88, Rome, Italy, 1988
7 Nantista C D, Tantawi S G. IEEE Microwave and Guided Wave Letters, 2000, **10**(12): 520—522

30GHz RF 脉冲展宽器

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摘要 RF脉冲展宽器用来把高功率窄脉冲变换为较低功率的长脉冲. CLIC实验装置CTFⅡ中的功率提取结构已经可以提供功率达280MW,脉宽16ns的30GHz RF脉冲. 为了用它来研究加速结构的最高表面场强和脉宽的关系,设计了30GHz RF脉冲展宽器. 完成了系统设计,微波部件的设计及加工,系统的调试. 最后安装在CTFⅡ上,并成功进行了高功率实验.

关键词 RF脉冲展宽器 RF脉冲压缩器 高功率微波脉冲 直线对撞机

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