RF PULSE COMPRESSION VIA TE_{01} OPTICALLY CONTROLLED MULTI-MEGAWATT MICROWAVE SWITCH

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Abstract

We present the design and experimental results of an optically controlled high power pulse compression system. The rf parameters of the system are chosen to fit the requirements of the X-band Next Linear Collider design at SLAC. The system is based on the switched resonant delay line theory [1]. The high power microwave switch, required for this system, is realized using optical excitation of an electron-hole plasma layer on the surface of a pure silicon wafer. Previously, we showed that the power handling capability of such a switch is greatly affected by the end effects present at the interface between the silicon wafer and the supporting waveguide[2]. To avoid end effects the switch is designed to operate in the TE_{01} mode in a circular waveguide. We present the theory and design of this novel type of switch, as well as the results of its experimental implementation.

1 INTRODUCTION

During the past few years high power rf pulse compression systems have developed considerably. These systems provide a method for enhancing the peak power capability of high power rf sources. One important application is driving accelerator structures. In particular, future linear colliders, such as the proposed NLC, require peak rf powers that can not be generated by the current state of the art microwave tubes. Pulse compression schemes, available for NLC, are :

- Binary Pulse Compression (BPC) [3], which has a 100% intrinsic efficiency. It uses a large amount of components and copper waveguides. It, also, becomes extremely complicated and large in size for large compression ratios.
- SLED II [4], which uses a small amount of components and copper waveguides. However, it has an intrinsic efficiency which deteriorates with large compression ratios.
- Delay Lines RF Distribution System[5], A variation on the BPC that has a 100% intrinsic efficiency. It uses less copper waveguides than the BPC. It uses more components and copper waveguides than SLED II. It has a complicated topology and is difficult to upgrade

Among all these options SLED II is the simplest and least expensive to implement. To elevate the inherent inefficiency of SLED II at higher pulse compression ratios active pulse compression using switched resonant delay lines was proposed[1]. It is a variation on SLED II which makes it possible to upgrade SLED II to higher compression ratios while improving its intrinsic efficiency. In this paper we will discuss the implementation of such an active pulse compression system.

2 ACTIVE PULSE COMPRESSION USING A SINGLE EVENT SWITCHED RESONANT DELAY LINES

The theory of active pulse compression system is detailed in [1]. Here, we briefly describe the special case of a *single event* switched pulse compression system. The system employs high Q resonant delay lines to store the energy during most of the duration of the incoming pulse. The coupling to the line is optimized so that most of the incoming energy is stored in the line. The round trip time of an rf signal through one of the lines determines the length of the compressed pulse. To discharge the lines, the phase of the incoming pulse is reversed 180° and the coupling to the line is increased. Therefore, the reflected signal from the inputs of the lines and the emitted field from the lines add constructively thus, forming the compressed, high power, pulse. Unlike SLED II, where the phase is reversed but the coupling to the lines remains constant, there is no energy left-over after the output pulse is finished.

Table 1 shows a comparison between SLED II and a single event active pulse compression system.

	SLED II		Discharging just before the last time bin		
C_r	η (%)	R_0	η (%) .	R_0	R_d
4	86.0	0.607	87.0	0.646	0.536
8	64.4	0.733	84.0	0.835	0.386
10	56.2	0.767	83.4	0.869	0.346
16	40.6	0.828	82.7	0.920	0.275
32	23.3	0.893	82.0	0.960	0.195
64	12.6	0.936	81.7	0.980	0.138
128	6.6	0.962	81.6	0.990	0.099

Table 1. Intrinsic Efficiencies of Both SLED II and Active Pulse Compression System

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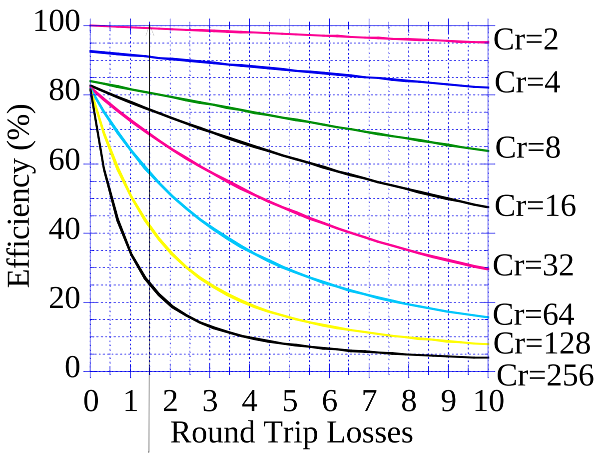
At the last time bin the phase of the incoming signal is flipped and the coupling iris reflection coefficient changes from R_0 to R_d. The table shows, also, the optimum coupling iris reflection coefficient in both cases. As the compression ratio, C_r, increases the efficiency of SLED II decreases dramatically; while that of the active system remains above 81%.



1.51 % round trip losses have already been achieved at SLAC for a 223 nS delay line.

Figure 1. Effect Of Losses On The Active Pulse Compression System.

Furthermore, for reasonably high compression ratios the change in the iris reflection coefficient is relatively small. This simplifies the high power implementation of the active iris. Indeed, the losses in the delay line make the efficiency of the system deteriorates with higher compression ratios. Figure 1 Shows the effect of these losses. Clearly, the active system is advantages at high compression ratios. However, it soon loses its advantage because of delay line losses. Between the compression ratios of 6 and 32 the active system has a significant advantage over SLED II. At the same time the delay line losses does not reduce its efficiency in a significant way.

3 PROOF OF PRINCIPLE EXPERIMENT

Figure 2 shows the schematic diagram of an active pulse compression experiment. A flower petal mode transducer[6] and a long circular waveguide act as the storage delay line. The waveguide is excited at the TE_{01} mode. A magic tee, terminated with a short circuit at the E arm and with a TE_{01} resonant cavity (the switching cavity) at the H arm, acts as an iris. The switching cavity is connected to the magic tee with a special side coupled mode converter.

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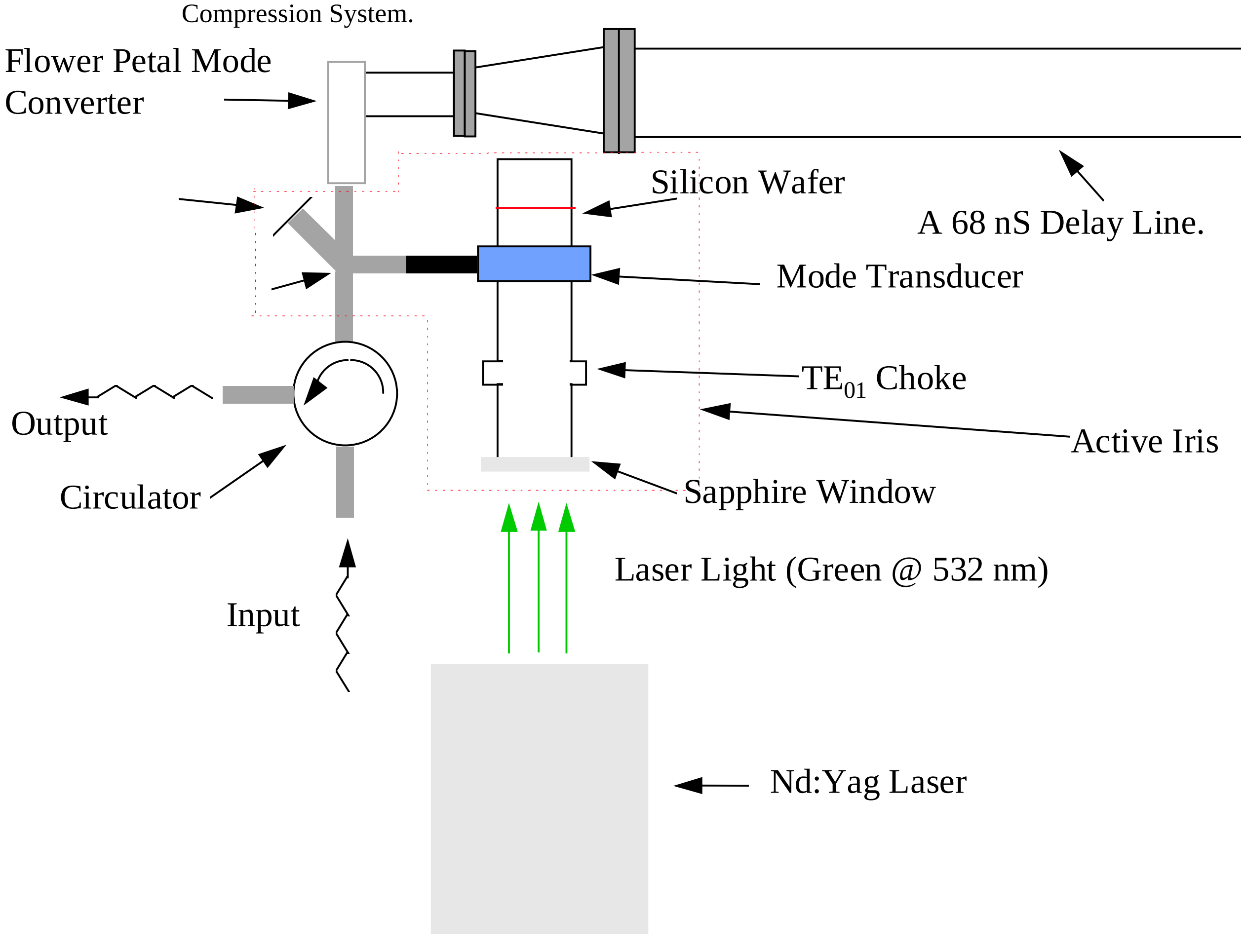

Figure 2 Schematic Diagram Of The Proof Of Principle Experiment.

During the charging time the cavity is out of resonance. Hence, hardly any fields are inside the cavity. At the last time bin the phase of the input signal is shifted by 180 degrees. Also, the laser is fired causing a conducting electron-hole pair plasma layer at the surface of the pure silicon wafer. The distance between the silicon wafer and the TE_{01} choke is adjusted so that the cavity becomes closer to resonance. This has the effect of changing the phase of the reflected signal from the switching cavity back to the magic tee. Hence, the reflection and transmission coefficients, through the magic tee, change, causing the delay line to discharge. For theoretical analysis of this type of microwave controlled devices, the reader is referred to [7]

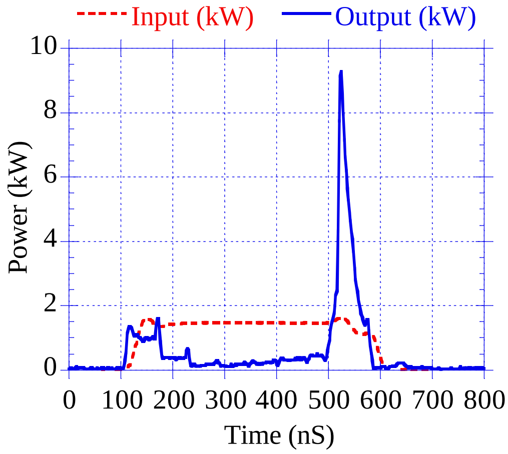

Figure 3. Experimental Output of the Active Pulse Compression System at a Compression Ratio of 8.

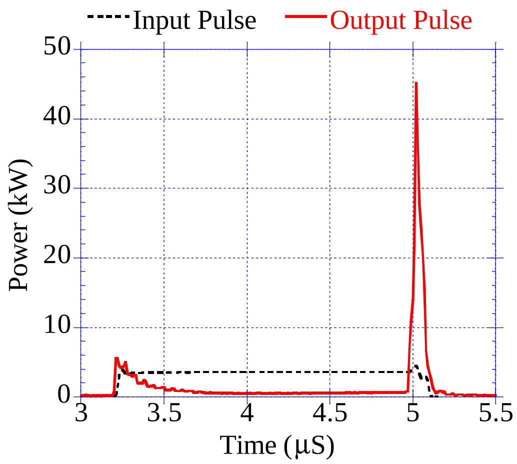

Figure 4. Experimental Output of the Active Pulse Compression System at a Compression Ratio of 32.

Figure 3 shows the output of this system at a compression ratio of 8. The system has a gain of 6. SLED II has a theoretical gain of 5.1, and if one assume similar losses in the delay line SLED II gain would drop to 4.2. Figure 4 shows the output of the system for a compression ratio of 32. The system has a gain of 12. SLED II has a theoretical gain of 7.4, and if one assume similar losses in the delay line SLED II gain would drop to ~5. Indeed, a gain of 12 is much more than the theoretical gain of any passive pulse compression system. These have a maximum gain of 9 as the compression ratio goes to infinity

4 CONCLUSION

We have developed the theory for a single-time-switched resonant delay line pulse-compression system. We gave a design example for an active iris operating at the TE_{01} mode. We, finally, demonstrated the operation of such a switch. The system achieved a power gain of 12 at a compression ratio of 32. This is more than the maximum theoretical gain of SLED II even as the compression ratio goes to infinity.

5 ACKNOWLEDGMENT

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