approach to satisfy the requirements for nearly uniform rate and high-speed scrambling up to 752 krad/s.

In the experiment, six fiber squeezers are arranged as in Fig. 1. The last four squeezers are oriented in the same direction and are driven by the same triangle wave with the amplitude of 60 volts. Because of the rate additive effect, the total phase changing rate is quadrupled and readily to achieve a total rate of 120π krads/s, assuming each squeezer can operate at 30π krad/s. Figure 5(a) shows the measured SOP variation curve using a polarimeter (General Photonics POD-101D), when the frequency and amplitude of the driving triangle signal are set at 7.5 kHz and 60 volts, respectively. As in Fig. 4, dREF is recorded as a function of time. Clearly, a SOP variation rate of 120π krads/s, i.e., 376 krad/s, is achieved. It is noted that the data curve is not as clean as those in Fig. 4, caused by the limited bandwidth of polarimeter's electronics circuit. When taking the data, the first two fiber squeezers are disabled in order not to affect the rate measurement in Fig. 5. When the first two fiber squeezers are enabled, the SOP points immediately fill out the whole Poincare Sphere, and it is difficult to see the SOP evolution as shown in Fig. 3(e). In experiments, we also tried using 15 kHz triangle wave to drive the squeezers and achieved a SOP variation rate of 240π krad/s (752 krad/s), as shown in Fig. 5(b). Although the recorded curves are even more distorted due to the limitations of polarimeter's speed and the electrical amplifier for driving the squeezers, it shows the potential of achieving even higher scrambling speed for the proposed scheme.

Note that that a scrambling rate of 376 krad/s is sufficient to meet the requirements of system tests in general, since the maximum polarization variation rate in a real system is about 280 krad/s [6]. Considering that each PZT actuator in our fiber squeezers has a capacitance of 0.18 uF, the minimum total power consumption is about 20 watts for the scrambler operating at 376 krad/s, and ~40 Watts at 752 krad/s. In practice, 50% more power may be required to account for power consumption overhead by electronic circuit itself. For longtime reliability, we recommend to add more fiber squeezers for scrambling rate higher than 376 krad/s. This will help to lower the driving current or voltage on each PZT actuator and ensure longtime reliability. In addition, one may operate the fiber squeezers at resonant frequencies [22], which can significantly lower the power consumption, while increasing the scrambling rate, although this may compromise the scrambling rate adjustability by the users. Finally, it should be pointed out that fiber squeezer technology for polarization control and scrambling has proven to be commercially reliable with more than 10 years production history. We anticipate similar reliability for scrambling operation at 376 krad/s, especially when we double the number of parallel fiber squeezers in Fig. 1 and thus halve the driving voltage on each fiber squeezer, which allows us to operate each fiber squeezer at a modest driving condition of 30 volts at 7.5 kHz.

4. Conclusion

We propose and demonstrate a new scheme for quasi-uniform rate polarization scrambling for deterministic system performance tests that accommodate both single polarization and polarization multiplexed systems. A scheme to overcome the speed limitations of fiber squeezers is also demonstrated by using rate additive effect of multiple fiber squeezers. By combining both the quasi-uniform rate scrambling scheme and the cascaded multiple fiber squeezer approach, we achieve a 240π krad/s (752 krad/s) quasi-uniform rate polarization scrambler. The proposed scheme is scalable to even higher scrambling rates by adding more fiber squeezers. Furthermore, the schemes described in this paper still work if the fiber squeezers used are replaced with different types of variable phase retarders.

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