the numerical results for 8 bits digitization of the ADC.

The quantization error can be decreased by averaging and oversampling the signal if the acquisition is significantly faster than the oscillator's response. Alternatively, it can also be decreased by recording several times the oscillator's response to the same input, and subsequent averaging. As shown in Fig. 6(c), an even lower prediction error (NMSE) of 2% can be found for an improved parameter scan around the best operating range when the signal is detected with five times oversampling and averaging. This error is comparable to the error obtained with a numerical noise-free implementation of standard reservoir computing with 50 nonlinear nodes [22]. Therefore, an excellent performance is obtained despite the finite SNR of the detection apparatus, which is estimated to be equivalent to a 10 bits dynamic range. The 10 bits dynamic range stems from the 8 bits digitization of the ADC, together with the 5:1 oversampling and smooth averaging.

5. Conclusion

Our results show that the performance degradation by noise can be drastically reduced by improving the pre-processing technique. The prediction errors for the time-series prediction task reported in this manuscript are comparable or even better than current state-of-the-art numerical and noise-free approaches [22,24,25]. In particular, the NMSE for the optoelectronic oscillator with feedback in the Santa Fe laser time-series prediction task is lowered to 2% for 10 bits quantization in the output layer, reducing significantly the 12% prediction error previously reported in this system [11]. The reasons for this improvement are twofold. First, the experiments are carried out with optimized conditions with respect to the properties of the nonlinearity, which can be estimated via numerical simulations. Second, we find that the use of a six-valued mask yields prediction errors significantly lower than a two-valued mask for a time-series prediction task in the presence of quantization. A two-valued (binary) mask is, for infinite precision, sufficient to induce the required diversity in the transient responses for a given input. However, we find that, for finite precision, the transients induced by the binary mask cannot be optimally used for information processing. We speculate that some of these transients become indistinguishable due to noise. In the presence of 10 bits quantization noise, a six-valued mask yields better results via inducing significantly different transient responses that can be optimally used for information processing. This approach illustrates and highlights that there is potential to further improve the performance of delay-based photonics RC.

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