

Supplementary Material to the article

"Numerical modeling of the photonic tensor core for hardware acceleration of matrix-vector computation"

S1. Convolution implementation. Due to the unfeasibility of incorporating negative weights into the selected photonic tensor core architecture, the transfer of convolutional filter matrices comprising weights of opposite signs must be performed in accordance with the methodology depicted in Fig. S1. Following the matrix-vector multiplication with these matrices, all output weights must undergo a linear transformation by the eq.3 from the main article to allow negative output weights setup.

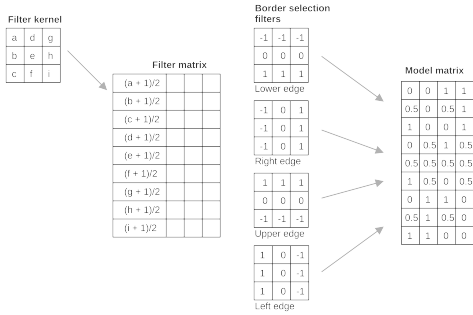


Fig. S1. Transferring principle.

In the main article, we demonstrated the convolution operation of a monochromatic image from the CIFAR-10 dataset. However, our model is also capable of performing the convolution of a colour image. Fig. S2 illustrates an example of this type of convolution.

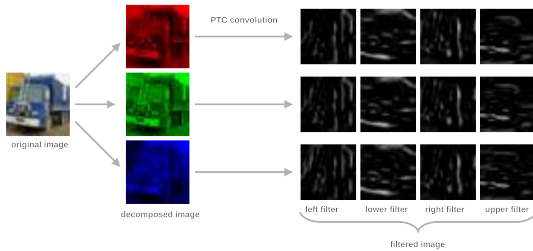


Fig. S2. Convolution of a colored image for CIFAR-10 dataset.

S2. Optical budget. In this simulation, the dependence of three parameters of the photonic tensor core on its size was calculated. The matrices employed in this investigation are enumerated in Fig. S3. In order to obtain the optical budget parameter, the maximum possible matrix and input weights were employed in the developed photonic tensor core. This parameter is employed for the purpose of normalizing the output signal. In order to obtain the minimal useful signal, the maximum possible input signal was employed together with the diagonal weight matrix exhibiting the lowest non-zero weights. The difference between the minimal useful signal and the noise was employed to calculate the maximum possible size of the crossbar array.



Fig. S3. Weight matrices for calculation of the maximum possible array scale.

S3. Matrix-vector multiplication. In order to gain insight into potential errors in the calculation of the matrix-vector product, Table S1 presents an illustrative example of the multiplication of a stochastic input vector and a weight matrix. In addition to detector noise, the primary sources of errors in the photonic tensor core are the quantization of matrix weights and the dispersion of directional couplers.

One of the most crucial parameters influencing the efficiency of multiplication is the bit error rate. In our work, it was employed for the purpose of monitoring the quality of multiplication and to facilitate additional optimization of the electronic binding of the detector, specifically the cutoff frequency of the low-pass filter and the operating resistance of the transimpedance amplifier. The quantitative values of the bit error rate are presented in Fig. S4.

Table S1. Matrix-vector multiplication example.

Input	Matrix				Output	Error
0.971	0.676	0.670	0.347	0.961	1.903	-7.54e-3
0.841	0.026	0.934	0.598	0.772	1.472	-5.77e-3
0.352	0.880	0.496	0.205	0.989	1.935	6.83e-3
0.590	0.493	0.578	0.468	0.329	1.323	-2.55e-3

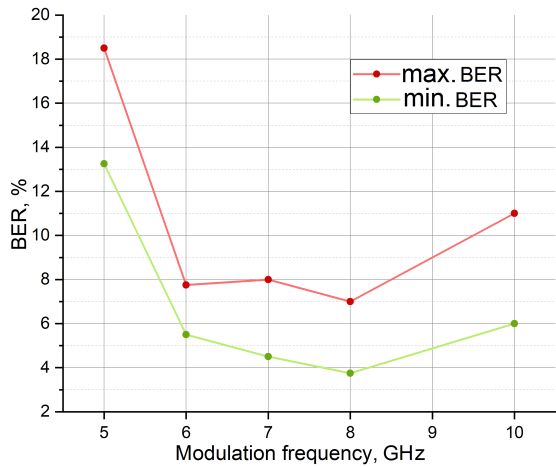
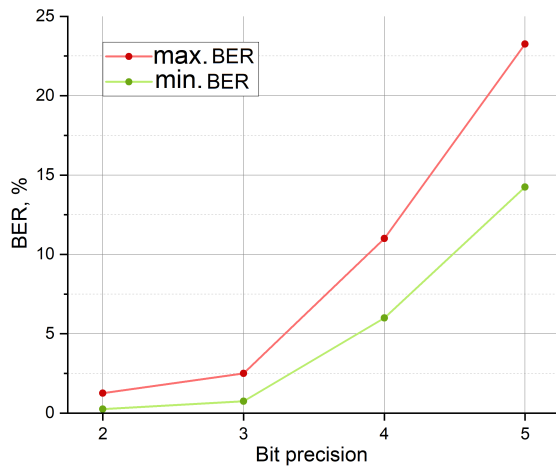


Fig. S4. Bit error rate (BER) depends on the quantization accuracy of the output vector (top) and on the modulation frequency of the input vector (bottom).