Supporting Information

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Dynamic Quarter-Wave Metasurface for Efficient Helicity Inversion of Polarization Beyond the Single-Layer Conversion Limit

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1 Calculated performance of the design in intermediate states

Figure S1 represents the VO$_2$-resistance dependency of the helicity conversion efficiency and circular polarization ratio for the original design. The gradual transition between the off and on states can be observed. Figure S2 shows the corresponding reflection amplitude and phase. The reflection $|\tilde{r}_x|$ remains unchanged as the current barely flows in VO$_2$. On the other hand, $|\tilde{r}_y|$ has dissipation in the intermediate states due to ohmic loss. The transition of the resonant frequency induces a phase jump in $\arg(\tilde{r}_y/\tilde{r}_x)$.

Figure S1: Helicity conversion efficiency and circular polarization ratio when varying the value of VO$_2$ sheet resistance between 10 $\Omega$ to 500 k$\Omega$ with a logarithmic scale in the simulation. The calculation setup is the same as that in Figure 2 in the manuscript.
Figure S2: Amplitude and phase difference of $x$ and $y$ polarizations of reflected waves when the value of VO$_2$ sheet resistance is varied between 10Ω to 500kΩ with a logarithmic scale in the simulation. The calculation setup is the same as that in Figure 2 in the manuscript.
2 Stability of the fabricated device

Figures S3, S4 (used in the manuscript), and S5 show the device characteristics measured at different cycles on three different days. These data certainly confirm the reproducibility of our device. No performance degradation is observed in the cycles. Note that we did not fill the sample box with dry air for the data shown in Figure S3; thus, the data show dips of terahertz absorption by water.

Figure S3: Amplitude and phase difference for \( x \) and \( y \) polarizations based on data measured on March 16, 2021, without dry air. The solid and dashed lines represent the experimental and simulation data, respectively. The gray vertical lines indicate the eigenfrequencies of the structure. The parameters shown in the Experimental section are used in this simulation.
Figure S4: Amplitude and phase difference for $x$ and $y$ polarizations based on data measured on March 17, 2021 (used in the manuscript). The solid and dashed lines represent the experimental and simulation data, respectively. The gray vertical lines indicate the eigenfrequencies of the structure. The parameters shown in the Experimental section are used in this simulation.
Figure S5: Amplitude and phase difference for $x$ and $y$ polarizations based on data measured on March 18, 2021. The solid and dashed lines represent the experimental and simulation data, respectively. The gray vertical lines indicate the eigenfrequencies of the structure. The parameters shown in the Experimental section are used in this simulation.